UL 83

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Thermoplastic-Insulated Wires and Cables

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
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UL Standard for Safety for Thermoplastic-Insulated Wires and Cables, UL 83

Twelfth Edition, Dated September 29, 1998

Revisions: This Standard contains revisions through and including November 1, 2001.

Announcement Bulletin(s): This Standard contains the announcement bulletin(s) dated August 25, 1997 and October 30, 1997. The announcement bulletin is located at the end of the Standard (after the adoption bulletin(s)).

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

The revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated July 10, 2001. The bulletin(s) is now obsolete and may be discarded.

The revisions dated November 1, 2001 include a reprinted title page (page1) for this Standard.

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

As indicated on the title page (page1), this UL Standard for Safety has been adopted by the Department of Defense.

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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 Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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

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SEPTEMBER 29, 1998 **ANSI/UL 83-1999**
(Title Page Reprinted: November 1, 2001)

1

UL 83

Thermoplastic-Insulated Wires and Cables

The First edition was titled Synthetic-Insulated Wires. The Second through Seventh editions were titled Thermoplastic-Insulated Wires.

First Edition – October, 1942
Second Edition – March, 1945
Third Edition – April, 1948
Fourth Edition — April, 1963
Fifth Edition — October, 1971
Sixth Edition — December, 1975
Seventh Edition — July, 1979
Eight Edition — October, 1980
Ninth Edition — September, 1983
Tenth Edition — September, 1991
Eleventh Edition — October, 1996

Twelfth Edition

September 29, 1998

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated September 29, 1998. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

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

Approved as ANSI/C33.80-1971, October 18, 1971
Approved as ANSI/UL 83-1985, January 8, 1985
Approved as ANSI/UL 83-1991, May 23, 1991
Approved as ANSI/UL 83-1999, April 23, 1999

The Department of Defense (DoD) has adopted UL 83 on February 27, 1984. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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MARKINGS

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FOREWORD

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

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

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

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

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

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

INTRODUCTION

1 Scope

1.1 These requirements cover 14 – 4/0 AWG and 250 – 2000 kcmil sizes of 600-V, single-conductor, thermoplastic-insulated wires and cables for use in accordance with the National Electrical Code. Single conductors for use in armored cable and nonmetallic-sheathed cable, deep-well pump cables, and other multiple-conductor assemblies to which no type-letter designations are assigned are included in these requirements.

1.1 revised November 1, 2001

1.2 These requirements do not cover thermoplastic-insulated flexible cords or fixture wires, which are covered in a separate standard.

1.3 Deleted November 1, 2001

2 Units of Measurement

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

3 References and Terms

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

3.2 *Deleted September 29, 1998*

CONSTRUCTION

GENERAL

4 Materials

4.1 Each material used in a thermoplastic-insulated wire and cable shall be compatible with all of the other materials in the wire or cable.

5 Index Tables

5.1 A thermoplastic-insulated wire or cable shall be as specified in Table 5.1, 5.2, or 5.3 and shall comply in all respects with the requirements for the construction details and test performance that are applicable.

5.2 Tables 5.1, 5.2, and 5.3 serve as an index to the requirements for construction details and test performance. Each vertical column serves as an index to the requirements that apply to the particular wire or cable whose type letters appear at the top of the column. The figures in parentheses are the numbers of the paragraphs in the text of this Standard to which reference should always be made. References in square brackets are to UL 1581.

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Table 5.1
Index to requirements for 60 and 75°C wires[a]

Table 5.1 revised September 9, 1999

Type-letter designation		TW	THW	Insulated conductors for Type ACTH cable	THWN
Maximum temperature		60°C (140°F) dry or wet	75°C (167°F) dry or wet	75°C (167°F) dry	75°C (167°F) dry or wet
Conductor size		14 AWG – 2000 kcmil (7.1)		14 – 1 AWG (7.1)	14 AWG – 1000 kcmil (7.1)
Conductor metal		Soft-annealed copper for Nos. 14 and 13 AWG; aluminum, copper-clad aluminum, or soft-annealed copper for other sizes (6.3 and 7.1)			
Conductor dimensions		Diameter and cross-sectional area (8.1 and 8.2)			
Conductor – general		Metal coating (9.1 and 9.2)	Splices (11.1 and 11.2)		Separator (10.1 and 10.2)
Conductor resistance		(12.1)			
Conductor stranding		(13.1 – 13.6)			
Insulation – material[c]		PVC	PVC in one or two layers		PVC[b,d]
Insulation – general		Application (14.1)	Joints (14.2)	Other material (14.3)	Centering (16.1)
Thickness of insulation – average		(15.1)			
Thickness of insulation – minimum at any point		(15.1)			
Physical properties of insulation[c]		PVC			
Nylon jacket		None			(15.1 and 22.1)
Assemblies that include single-conductor thermoplastic-insulated wires		(24.1)			
Pump Cable	General	(25.1)			
	Thickness of jacket	(22.1)			
	Physical properties of PVC jacket[c]	PVC			
Wrap test		None			(26.1)
Dielectric voltage-withstand		(27.1 and 27.2)			
Insulation resistance (short-time)		(30.1)			
Insulation resistance temperature factor		(30.2)			

Table 5.1 Continued on Next Page

Table 5.1 Continued

Type-letter designation	TW	THW	Insulated conductors for Type ACTH cable	THWN
Insulation resistance in water at rated temperature	(30.1.1 – 31.3.1)			
Insulation resistance in air at 97.0°C (206.6°F)	None			
Insulation Resistance in air at 82.0°C (179.6°F)	None		(33.1.1 – 33.3.2)	None
Alternative spark testing	(34.1)			
Continuity	[pars. 900.13 – 900.17 of UL 1581]			
Relative permittivity	(36.1)		None	(36.1)
Room-temperature flexibility	(37.1)			
Heat shock	(38.1)			
Cold bend	(39.1 and 39.2)			
Deformation	(40.1)			
VW-1 Flame Text	(41.1)			
Horizontal Flame Test	(42.1)			
Vertical Flame Test	(43.1)			
Vertical-Tray Flame Test	(44.1 and 44.2)		None	(44.1 and 44.2)
Tray-Cables Sunlight-Resistance Test	(45.1 and 45.2)		None	(45.1 and 45.2)
Sunlight-Resistance Test for messenger use	(45.1 and 45.2)		Messenger use not applicable	(45.1 and 45.2)
Oil-resistant wires	(46.1 and 46.2)			
Gasoline resistant and oil-resistant wires		None	(47.1)	
Abrasion Test	None			(49.1)
Crushing Test	None			(50.1)
Impact Test	None			(51.1)
Color Coating	(52.1)			
Markings	(53.1 – 72.1)			

[a] See 5.2.

[b] Type THWN wire is required to have over the insulation a jacket of nylon whose minimum thickness at any point is as specified in Table 15.5 (see also 14.1).

[c] The physical properties requirements for individual materials are in UL 1581. See 47.1 and index Table 47.1 in UL 1581. See also 40.2 of UL 1581.

[d] Type THWN wire shall employ insulation of PVC or a thermoplastic material other than PVC. See 23.1.

Table 5.2
Index to requirements for 90°C wires[a]

Table 5.2 revised September 9, 1999

Type-letter designation	**THW-2**	**THHW**	**THWN-2**	**THHN**	**Insulated conductors without a nylon jacket for Type ACTHH, NM-B, and NMC-B cables**	**Insulated conductors without a nylon jacket for Type UF-B cable**
Maximum temperature	90°C (194°F) dry or wet	90°C (194°F) dry 75°C (167°F) wet	90°C (194°F) dry or wet	90°C (194°F) dry		90°C (194°F) dry 60°C (140°F) wet
Conductor size	14 AWG – 2000 kcmil (7.1)	14 AWG – 1000 kcmil			14 – 1 AWG (7.1)	14 – 6 AWG (7.1)
Conductor metal	Soft-annealed copper for Nos.14 and 13 AWG; aluminum, copper-clad aluminum, or soft-annealed copper for other sizes (6.3 and 7.1)					
Conductor dimensions	Diameter and cross-sectional area (8.1 and 8.2)					
Conductor – general	Metal coating (9.1 and 9.2)		Splices (11.1 and 11.2)		Separator (10.1 and 10.2)	
Conductor resistance	(12.1)					
Conductor stranding	(13.1 – 13.6)					
Insulation – material[c]	PVC in one or two layers	PVC	PVC[b,d]		PVC[d]	PVC
Insulation – general	Application (14.1)	Joints (14.2)	Other material (14.3)		Centering (16.1)	
Thickness of insulation – average	(15.1)					
Thickness of insulation – minimum at any point	(15.1)					
Physical properties of insulation[c]	PVC					
Nylon jacket	None		(15.1 and 22.1)		None	
Assemblies that include single-conductor thermoplastic-insulated wires	(24.1)					

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Table 5.2 Continued

Type-letter designation		THW-2	THHW	THWN-2	THHN	Insulated conductors without a nylon jacket for Type ACTHH, NM-B, and NMC-B cables	Insulated conductors without a nylon jacket for Type UF-B cable
Pump cable	General	(25.1)			None		
	Thickness of jacket	(22.1)			None		
	Physical properties of PVC jacket[c]	PVC			None		
Wrap Test		None		(26.1)		None	
Dielectric voltage-withstand		(27.1 and 27.2)					
Insulation resistance (short-time)		(30.1)					
Insulation resistance temperature factor		(30.2)					
Insulation resistance in water at rated temperature		(31.1.1 – 31.3.1)			None		(31.1.1 – 31.3.1)
Insulation resistance in air at 97.0°C (206.6°F)		None			(32.1.1 – 32.3.2)		
Insulation resistance in air at 82.0°C (179.6°F)		None	(33.1.1 – 33.3.2)	None			
Alternative spark testing		(34.1)					
Continuity		[900.13 – 900.17 of UL 1581]					
Relative permittivity		(36.1)			None		(36.1)
Room-temperature flexibility		(37.1)					
Heat shock		(38.1)					
Cold bend		(39.1 and 39.2)					
Deformation		(40.1)					
VW-1 Flame Test		(41.1)			None		
Horizontal Flame Test		(42.1)			None		
Vertical Flame Test		(43.1)					

Table 5.2 Continued on Next Page

Table 5.2 Continued

Type-letter designation	THW-2	THHW	THWN-2	THHN	Insulated conductors without a nylon jacket for Type ACTHH, NM-B, and NMC-B cables	Insulated conductors without a nylon jacket for Type UF-B cable
Vertical-Tray Flame Test	(44.1 and 44.2)				None	
Tray-Cables Sunlight-Resistance Test	(45.1 and 45.2)				None	
Sunlight-Resistance Test for messenger use	(45.1 and 45.2)			Messenger use not applicable		
Oil-resistant wires	(46.1 and 46.2)				None	
Gasoline-resistant and Oil-resistant wires	None	(47.1)		None		
Abrasion Test	None		(49.1)		None	
Crushing Test	None		(50.1)		None	
Impact Test	None		(51.1)		None	
Color coating	(52.1)					
Markings	(53.1 – 72.1)					

[a] See 5.2.

[b] Type THHN and THWN-2 wires are required to have over the insulation a jacket of nylon whose minimum thickness at any point is as specified in Table 15.5 (see also 14.1).

[c] The physical properties requirements for individual materials are in UL 1581. See 40.2, 47.1, and index Table 47.1 of UL 1581.

[d] Type THHN and THWN-2 wires, and insulated conductors for Type ACTHH, NM-B, and NMC-B shall employ insulation of PVC or a thermoplastic material other than PVC. See 23.1.

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Table 5.3
Index to requirements for switchboard and other wires[a]

Table 5.3 revised September 9, 1999

Type-letter designation	TBS	FEP	FEPB	PFA	TFE	PFAH	Z	ZW
Maximum temperature	90°C (194°F) dry	90°C (194°F) dry[b]			250°C (482°F) dry		90°C (194°F) dry[d]	90°C (194°F) dry[d] 75°C (161°F) wet
Conductor size	14 – 4/0 AWG (7.1)	14 – 2 AWG (7.1)	14 – 2 AWG (7.1)	14 – 4/0 AWG (7.1)				14 – 2 AWG (7.1)
Conductor metal	Soft-annealed copper for Nos. 14 and 13 AWG Aluminum, copper-clad aluminum, or soft-annealed copper for other sizes (6.3)	Soft-annealed copper (6.1)			Nickel-coated copper or nickel-base alloy (6.2)		Soft-annealed copper (6.1)	
Conductor dimensions	Diameter and cross-sectional area (8.1 and 8.2)							
Conductor – general	Metal coating (9.1 and 9.2)			Splices (11.1 and 11.2)			Separator (10.1 and 10.2)	
Conductor resistance	(12.1)							
Conductor stranding	(13.1 – 13.6)							
Insulation – material	PVC	FEP		PFA	PTFE	PFA	ETFE	
Insulation – general	Application (14.1)		Joints (14.2)		Other material (14.3)		Centering (16.1)	
Thickness of insulation – average	(15.1)							
Thickness of insulation – minimum at any point	(15.1)							
Nonmetallic coverings and fillers	General (17.1) Cotton braid (19.1) Glass or Aramid braid (20.1) Saturation and coating of braids (21.1)	None	General (17.1) Glass or Aramid braid (20.1) Saturation and coating of braids (21.1)	None				

Table 5.3 Continued on Next Page

Table 5.3 Continued

Type-letter designation	TBS	FEP	FEPB	PFA	TFE	PFAH	Z	ZW
Assemblies that include single-conductor thermoplastic-insulated wires	None	(24.1)						
Physical properties of insulation[c]	PVC	FEP		PFA	PTFE	PFA	ETFE	
Dielectric voltage-withstand	(28.1.1 and 28.2.1	(27.1 and 27.2)						
Leakage resistance	(29.1)	None						
Insulation resistance (short-time)	None	(30.1)						
Insulation resistance (temperature factor)	None	(30.2)						
Alternative spark testing	(35.1)	(34.1)						
Insulation resistance in water at rated temperature	None							(33.1.1 – 33.3.2)
Continuity	[pars. 900.13 – 900.17 of UL 1581]							
Room-temperature flexibility	(37.1)							
Heat shock	(38.1)	None						
Cold bend	(39.1 and 39.2)							
Deformation	(40.1)			None				
VW-1 Flame Test	(41.1)							
Horizontal Flame Test	(42.1)							
Vertical Flame Test	(43.1)							
Color coating	(52.1)							
Markings	(53.1 – 72.1)							

[a] See 5.2.

[b] The temperature limit is 90°C (194°F) for general use and 200°C (392°F) for special applications, except that a limit of 150°C (302°F) applies for special applications where Nos. 27 – 36 AWG (14.2 – 5.0 mils) strands are used without an individual protective metal coating.

[c] The physical properties requirements for individual materials are in UL 1581. See 40.2, 47.1, and index Table 47.1 of UL 1581.

[d] The temperature limit is 90°C (194°F) for general use and 150°C (302°F) for special applications.

CONDUCTOR(S)

6 Metal

6.1 Types FEP, FEPB, PFA, Z, and ZW

6.1.1 The conductor wires shall be of soft-annealed copper complying with ASTM B 3-95. Each 27 – 36 AWG (14.2 – 5.0 mils or 0.361 – 0.127 mm) strand in wire rated for 200°C (392°F) shall be protected against oxidation by a coating of nickel complying with ASTM B 355-95, a coating of silver complying with ASTM B 298-94, or a coating of another metal or alloy (evaluation required – lead, tin/lead, and tin coatings are not to be used). Size 27 – 36 AWG (14.2 – 5.0 mils or 0.36 – 0.127 mm) strands that are uncoated or have a coating of tin complying with ASTM B 33-94 or a tin/lead coating complying with ASTM B 189-95 are appropriate for use in wire rated for 150°C (302°F). Uncoated or tin/lead-coated or tin-coated solid conductors and uncoated or tin/lead-coated or tin-coated strands whose diameter is at least 0.015 inch or 0.38 mm are appropriate for use in wire rated for 200°C (392°F).

6.1.1 revised November 1, 2001

6.2 Types TFE and PFAH

6.2.1 The conductor shall be of nickel-base alloy complying with ASTM B 160-93 and having a tensile strength of 65,000 ±15,000 lbf/in^{2}or 448 ±103 MN/m^2 or 44,816 ±10,342 N/cm^{2}or 45.7 ±10.5 kgf/mm^2, an elongation of at least 35 percent, and a nominal volume resistivity of 66 ohm·cmil/ft at 20°C (68°F) or 0.110 ohm·m^2/m at 20°C (68°F) or shall be of soft-annealed copper complying with ASTM B 3-95. A solid copper conductor and each strand in a stranded copper conductor shall be protected against oxidation by a coating of nickel complying with ASTM B 355-95.

6.2.1 revised November 1, 2001

6.3 Types TW, THW, THWN, THHN, and TBS and insulated conductors for armored cable Types ACHT and ACTHH and for cable Types UF-B, NM-B, and NMC-B

6.3.1 The conductor shall be of soft-annealed copper, copper-clad aluminum, or an aluminum alloy. Soft-annealed copper shall comply with ASTM B 3-95. A metal coating that is provided on soft-annealed copper or on copper-clad aluminum in compliance with Metal Coating, Section 9, shall be of tin complying with ASTM B 33-94, of a tin/lead alloy complying with ASTM B 189-95, of nickel complying with ASTM B 355-95, of silver complying with ASTM B 298-94, or of another metal or alloy (evaluation required). Solid aluminum conductors in size 12 – 8 AWG shall comply with the requirements for aluminum-wire stock (aluminum-alloy conductor material). All other aluminum conductors shall comply with the requirements for semi-annealed 8000 series aluminum conductors in Requirements for Aluminum Conductors of an 8000 Series Alloy, Section 10 of UL 1581. Copper-clad aluminum conductors shall comply with the requirements in Requirements for Copper-Clad Aluminum Conductors, Section 11 of UL 1581.

6.3.1 revised November 1, 2001

7 Size, Temper, and Assembly

7.1 Conductors shall be of the size, temper, and assembly indicated for the finished wire type in Table 7.1.

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Table 7.1
Conductors

Table 7.1 revised September 29, 1998

Wire type	Sizes (see Tables 5.1 and 5.2) and metal	Temper	Assembly
THW-2, THWN-2, THHW, TW, THW, THWN, THHN, TBS and Insulated Conductors for Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables	14 – 4/0 AWG copper	Soft-annealed	Solid
	2 – 4/0 AWG copper	Soft-annealed	Compact-stranding[a,d]
	14 AWG – 2000 kcmil copper	Soft-annealed	Compressed stranding and every other type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding
	12 – 8 AWG aluminum	b	Solid
	7 – 4/0 AWG aluminum	Semi-annealed[c]	Solid
	12 AWG – 2000 kcmil aluminum	Semi-annealed[c]	Compressed stranding and every other type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding
	12 AWG – 1000 kcmil aluminum	Semi-annealed[a]	Compact-stranding[a]
	12 – 4/0 AWG copper-clad aluminum	c	Solid
	12 AWG – 2000 kcmil copper-clad aluminum	c	Any type of stranding[a] covered in Table 210.2 of UL 1581 other than compact and compressed stranding
TFE and PFAH	14 – 4/0 AWG copper	Soft-annealed	Solid or any type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding
	14 – 4/0 AWG nickel-base alloy	See 6.2.1	
FEP and ZW	14 – 2 AWG copper	Soft-annealed	Solid or any type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding
FEPB	14 – 2 AWG copper	Soft-annealed	Solid or any type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding
PFA and Z	14 – 4/0 AWG copper	Soft-annealed	Solid or any type of stranding[a] covered in Table 210.2 of UL 1581 other than compact stranding

[a] See 13.1 – 13.6.

[b] Aluminum-wire stock (aluminum-alloy conductor material).

[c] See 6.3.1.

[d] See 71.1.

8 Conductor Diameter and Cross-Sectional Area

8.1 The nominal, maximum (1.01 x nominal), and minimum (0.98 x nominal) diameters of solid and stranded conductors are shown in Tables 20.1, 20.2, 20.3, 20.3.1, 20.4, and 20.6 of UL 1581. Conductor diameter is to be measured using the method shown in Section 200 of UL 1581.

8.1 revised September 9, 1999

8.2 Compressed unilay copper conductors that are smaller in diameter than the requirement (0.98 x nominal in Table 20.3) for compressed concentric lay conductors shall be marked the same as compact conductors in accordance with 71.1.

8.3 The nominal cross-sectional area of a conductor is indicated in Table 20.1 of UL 1581 (not a requirement).

9 Metal Coating

9.1 When the insulation adjacent to a copper or copper-clad aluminum conductor is of a material that corrodes unprotected copper 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 6.1, 6.2, or 6.3 as applicable to the finished wire type.

9.2 The use of a metal coating, when not required for corrosion protection is still appropriate for use on solid or individual wires(strands) or selected wires, such as the outer layer of wires of a stranded conductor. The metal coating when used shall comply with 6.1, 6.2, or 6.3 as applicable to the finished wire type.

9.2 revised September 29, 1998

10 Separator

10.1 A separator is not required between the conductor and the insulation of a solid or stranded wire or cable. When used, a separator shall be electrically nonconductive (an insulating grade is not required) and shall not be counted as part of the required insulation.

10.2 A separator used between a conductor and insulation shall be colored or shall be opaque to make the separator clearly distinguishable from the conductor once the insulation is removed. The color shall be other than copper, silver, green or green and yellow and shall be solid, striped, or in some other pattern.

10.2 revised September 29, 1998

11 Joints

11.1 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner and shall not change the diameter of the solid conductor, the individual wire strand, or the overall stranded conductor. A joint shall not be made in a stranded conductor as a whole. A joint in a stranded conductor shall be made by separately joining each individual wire. A joint shall be made only before any coverings are applied to an insulated conductor and before a conductor is assembled into a cable. 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.

11.1 revised September 29, 1998

11.2 In a rope-lay stranded conductor, which consists of a central core surrounded by one or more layers of stranded members (primary groups), splices of the members as individual units shall not be closer together than two lay lengths.

12 Resistance

12.1 The direct-current resistance of any length of conductor in ohms per thousand conductor feet or in ohms per conductor kilometer shall not be higher than the maximum (nominal x 1.02) resistance indicated in the applicable table in D-C Conductor Resistance, in Section 30 of UL 1581 at 20°C (68°F) or at 25°C (77°F) when measured as described in D-C Conductor Resistance, Section 220 of UL 1581.

13 Stranding

13.1 A stranded wire or cable shall have the number of strands indicated in Table 13.1. Copper strands smaller than 36 AWG and aluminum or copper-clad aluminum strands smaller than 22 AWG shall not be used. A compact-stranded conductor shall not be segmented.

13.1 revised November 1, 2001

Table 13.1
Conductor stranding

Table 13.1 revised November 1, 2001

Size of wire	Number of strands in combination unilay	Minimum number of strands[b]	
		Compact stranded	All others
14, 13 AWG	19[a]	–	7
12 – 8	19[a]	7	7
7 – 2	19	7	7
1 – 4/0	19	18	19
213 – 500 kcmil	–	35	37
501 – 1000	–	58	61
1001 – 1500	–	–	91
1501 – 2000	–	–	127

[a] Copper only

[b] Conductors with a lesser number of strands shall be permitted based on the results of an investigation which shall include testing for connectability and bending.

13.2 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.

13.3 A 19-wire combination round-wire unilay-stranded conductor of soft-annealed copper or an aluminum alloy indicated in 6.3.1 shall be round and shall consist of a straight central wire, an inner layer of six wires of the same diameter as the central wire with the six wires having identical lengths of lay, and 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 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 13.2. The direction of lay of the strands in a single-bunch bunch-stranded

conductor shall be left-hand. Any type of stranding in Table 210.2 of UL 1581 other than compact stranding or single-bunch bunch-stranding shall comply with 13.5 or 13.6 as applicable. The direction of lay of the outer layer shall be left-hand in all cases.

Table 13.2
Length of lay of strands in a single-bunch bunch-stranded conductor[a]

Table 13.2 revised May 4, 2001

AWG size of conductor	Maximum length of lay	
	Inches	mm
14 AWG	1-5/8	41
13	1-5/8	41
12	2	51
11	2	51
10	2-1/2	64
9	2-1/2	64
8	2-3/4	70
7	3	76
6	3-3/8	86
5 AWG – 2000 kcmil	16 times the diameter of the conductor	

[a] Includes the constructions in note [a] to Table 210.2 of UL 1581.

13.4 A compact-stranded conductor shall be a round conductor consisting of a central core (one or more strands) surrounded by one or more layers of helically laid strands. A compact-stranded copper conductor shall consist of uncoated strands. A compact-stranded aluminum conductor shall have all layers with the same direction of lay (left-hand unidirectional). A compact-stranded copper conductor shall be either left-hand unidirectional or have the direction of lay reversed in adjacent layers (concentric-lay-stranded with the outer layer left-handed) and with each layer rolled, drawn, or otherwise compressively formed to distort the originally round or partially preshaped strands to various close-fitting shapes that achieve almost complete filling of the spaces originally present between the strands. Each layer shall be compacted before the next layer is applied, and each compacted layer – including the outermost layer – shall have an essentially smooth, round outer surface. The length of lay of the strands in the outer layer of a 1 AWG – 1000 kcmil conductor shall be 8 – 16 times the overall diameter of that layer. The length of lay of the strands in the outer layer of a 12 – 2 AWG conductor shall be 8.0 – 17.5 times the overall diameter of that layer.

13.4 revised November 1, 2001

13.5 A compressed-stranded conductor shall be a round conductor consisting of a central core (one or more strands) surrounded by one or more layers of helically laid strands 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 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.

13.5 revised November 1, 2001

13.6 Every stranded conductor covered in 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 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 8 – 16 times the outside diameter of that conductor.

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 the conductor.

f) The length 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.

13.6 revised November 1, 2001

INSULATION

14 Material and Application

14.1 A wire or cable shall be insulated for its entire length with the insulation specified for the construction in Table 5.1, 5.2, or 5.3 as applicable. The insulation shall be applied directly to the surface of the conductor or to any separator, shall cover the conductor or any separator completely, and shall not have any defects visible with normal or corrected vision without magnification. The PVC insulation on Type THW-2 and THW wires is to be applied in one layer or two distinct and inseparable layers (different compounds). PVC insulation that is applied in up to 3 integral layers of differing colors (same compound) to facilitate color changeovers is to be treated as a single layer. Type THWN-2, THHN, and THWN wires shall each have, in addition, a nylon jacket (see note [b] to Tables 5.1 and 5.2) applied directly to the surface of the insulation.

14.1 revised November 1, 2001

14.2 Any repair or joint made in the insulation shall be made in a workmanlike manner resulting in all parts affected in the process complying with the same electrical tests as the remainder of the insulation. The thickness of insulation at the repaired part or joint shall comply with the requirements in 15.1.

14.3 Either of the following materials that the manufacturer wishes to use as insulation or a jacket shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of UL 1581:

a) Material generically different from any insulation or jacket material that is named in 23.1 or in Table 5.1, 5.2, or 5.3 for the construction (new material).

b) Material that is named in 23.1 or in Table 5.1, 5.2, or 5.3 yet does not comply with the short-term tests specified for the material in Specific Materials, Section 50 of UL 1581.

The temperature rating of materials (a) and (b) shall be as required for the specific thermoplastic-insulated wire or cable type. The thicknesses of insulation and/or jacket using materials (a) and/or (b) shall be as required for the specific type. Investigation of the electrical, mechanical, and physical characteristics of the wire or cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to an insulation or jacket material named in 23.1 or in Table 5.1, 5.2, or 5.3 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand. The program for insulation of a thermoplastic material that is other than PVC and is intended for use in a Type THHN, THWN, or THWN-2 wire is specified in 23.1.

14.3 revised November 1, 2001

15 Thicknesses of Insulation and Nylon

15.1 General

15.1.1 The overall average thickness of the insulation and the minimum overall thickness at any point of the insulation and of any nylon jacket on an individual conductor shall not be less than indicated in Tables 15.1 – 15.8 as applicable to the particular construction and size of the wire when determined as described in Thicknesses of Insulation on Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 240 of UL 1581.

Table 15.1
Thicknesses of insulation on Type FEP and FEPB wires

Table 15.1 revised September 29, 1998

Wire type	Conductor size	Minimum thicknesses			
		Average		At any point	
		mils	mm	mils	mm
FEP	14 – 10 AWG	20	0.51	18	0.46
	9 – 2	30	0.76	27	0.69
FEPB	14 – 2 AWG	14[a]	0.36	13[a]	0.33

[a] A lacquer-coated glass braid (see 17.1) is required over the insulation.

Table 15.2
Thicknesses of insulation on Type TFE, PFA, and PFAH wires

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 10 AWG	20	0.51	18	0.46
9 – 2	30	0.78	27	0.89
1 – 4/0	45	1.14	40	1.02

Table 15.3
Thicknesses of insulation on Type Z wire

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 12 AWG	15	0.38	13	0.33
10	20	0.51	18	0.46
9 – 4	25	0.63	22	0.56
3 – 1	35	0.89	31	0.79
1/0 – 4/0	45	1.14	40	1.02

Table 15.4
Thicknesses of insulation on Type ZW wire

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 10 AWG	30	0.78	27	0.69
9 – 2	45	1.14	40	1.02

Table 15.5
Thicknesses of insulation on Type TW, THW, THW-2, THHW, and TBS wires and on insulated circuit and grounding conductors for use in Type ACTH and ACTHH armored cables and in Type UF-B, NM-B, and NMC-B cables

Table 15.5 revised September 9, 1999

Conductor size[a]	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 10	30	0.76	27	0.69
9, 8	45	1.14	40	1.02
7 – 2	60	1.52	54	1.37
1 – 4/0	80	2.03	72	1.83
213 – 500 kcmil	95	2.41	86	2.18
501 – 1000	110	2.79	99	2.51
1001 – 2000	125	3.18	112	2.84

[a] Size range is limited to: 14 AWG – 2000 kcmil for Types TW, THW, and THW– 2; 14 AWG – 1000 kcmil for Type THHW; 14 – 4/0 AWG for Type TBS; 14 – 6 AWG for insulated conductors for use in Type UF-B; 14 – 1 AWG for insulated conductors for use in Type ACTH and ACTHH armored cables and for use in Type NM-B and NMC-B cables.

Table 15.6
Thicknesses of single layer insulation on Type THW-2, THW, and THHW wires

Table 15.6 deleted September 29, 1998

Table 15.7
Thicknesses of double-layer insulation on Type THHW, THW-2, and THW wires and on insulated circuit and grounding conductors for use in Type ACTH[d] armored cables

Table 15.7 revised September 29, 1998

Conductor size	Minimum average thickness overall[a] A	Minimum thickness at any point overall[a] B	Minimum thickness at any point of the inner layer[b] C = 0.50 x A	Maximum thickness at any point of the inner layer[b] D= 0.75 x A
	mils			
14 – 10 AWG	30	27	15.0	22.5
9, 8	45	40	22.5	33.8
7 – 2	60	54	30.0	45.0
1 – 4/0	80	72	40.0	60.0
213 – 500 kcmil	95	86	47.5	71.9
501 – 1000	110	99	55.0	82.5
1001 – 2000[c]	125	112	62.5	93.8
	mm			
14 – 10 AWG	0.76	0.69	0.381	0.572
9, 8	1.14	1.02	0.572	0.859
7 – 2	1.52	1.37	0.762	1.143
1 – 4/0	2.03	1.83	1.016	1.524
213 – 500 kcmil	2.41	2.18	1.206	1.826
501 – 1000	2.79	2.51	1.397	2.096
1001 – 2000[c]	3.18	2.84	1.588	2.383

[a] The average overall thickness and the minimum overall thickness at any point are to be determined as described in Thicknesses of Insulation on Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 240 of UL 1581.

[b] The conductor and any separator are to be removed from a sample length of the finished wire. A specimen is to be prepared by cutting a short length from the center of the empty tube of the double-layer insulation, with both cuts made clean and perpendicular to the longitudinal axis of the tube. An optical instrument that is calibrated to at least 0.0001 inch or 0.001 mm is to be used to view one end of the specimen to locate the thinnest and thickest points of the inner layer of the insulation. The thickness of the inner layer at each of these points is to be measured, recorded to the nearest 0.0001 inch or 0.001 mm, and then compared with the minimum and maximum thicknesses at any point of the inner layer stated in columns C and D of the table.

[c] 1001 – 2000 kcmil applies to Types THW and THW-2 only.

[d] 14 – 1 AWG for insulated conductors for use in Type ACTH armored cables.

Table 15.8
Thicknesses of insulation and jacket on Type THWN-2, THHN, and THWN wires

Table 15.8 revised September 29, 1998

	Minimum thicknesses					
	PVC insulation				At any point of nylon jacket	
	Average		At any point			
Conductor size	mils	mm	mils	mm	mils	mm
14 – 12 AWG	15	0.38	13	0.33	4	0.10
11, 10	20	0.51	18	0.46	4	0.10
9 – 5	30	0.76	27	0.69	5	0.13
4 – 2	40	1.02	36	0.91	6	0.15
1 – 4/0	50	1.27	45	1.14	7	0.18
213 – 500 kcmil	60	1.52	54	1.37	8	0.20
501 – 1000	70	1.78	63	1.60	9	0.23

16 Centering

16.1 Within the limits specified in 15.1, the insulation shall have a circular cross section, shall be applied concentrically about the conductor (so that the conductor is well centered in the insulation), and shall fit tightly thereto. Double-layer (composite) insulation on Type THW-2 and THW wires shall be in two distinct and inseparable layers (different compounds). For insulation applied in more than one layer, the adjacent layers shall form an integral mass (same compound). The integral or composite mass shall be taken as a whole for all measurements and tests except as noted (layers tested separately) in 40.1 for the Deformation Test and in note b to Table 50.145 of UL 1581 for Physical Properties Tests.

NONMETALLIC COVERINGS AND FILLERS

17 Braids in General

17.1 A Type TBS wire shall have an impregnated overall braid applied to the outer surface of the insulation. The braid shall be one of the following: entirely of cotton, entirely of spun rayon, entirely of glass, a combination of 50 percent glass and 50 percent spun rayon, or a combination of 50 percent glass and 50 percent cotton (see Rupture Test in 28.2.1). Type FEPB wire in size Nos. 14 – 2 AWG shall be provided with a lacquer-coated glass braid applied over the insulation.

17.1 revised September 29, 1998

18 Fillers

18.1 Fillers, though not required, are appropriate for use in a pump cable or in a multiple-conductor assembly.

19 Cotton Braids

19.1 A cotton braid shall be of a close-weave, shall completely cover the insulation over which it is applied, and shall be fabricated on a machine having the same number of ends per carrier throughout. Each end shall consist of the same kind (that is, soft or glazed), size, and ply of yarn.

20 Glass Braids

20.1 A glass braid and a combination glass-and-cotton or glass-and-spun-rayon braid shall comply with the requirement in 19.1, and shall employ a glass yarn not smaller than No. 150-1/0. Aramid-fiber yarn when used to replace glass yarn shall have a minimum diameter of 0.0225 inch or 0.57 mm.

20.1 revised September 29, 1998

21 Saturation and Coating of Braids

21.1 The braid on Type TBS wire shall be saturated and finished to make the completed wire capable of complying with the applicable flame testing required in this Standard. The lacquer coating on the glass braid on size Nos. 14 – 2 AWG Type FEPB wires shall not reduce the ability of the finished wires to comply with the applicable flame test(s) in this Standard.

21.1 revised September 29, 1998

22 Thicknesses of Jacket

22.1 The average and minimum thicknesses of the overall jacket used on deep-well submersible-pump cable, and the minimum thickness of the nylon jacket used on Type THWN-2, THHN, and THWN wires, and on gasoline-and-oil-resistant Type TW wire, shall not be less than indicated in the applicable Table 15.3, 15.6, or 25.5, when determined as indicated in Thicknesses of Jacket on Thermoplastic- and Rubber-Insulated Wires and Cables, Section 260 or Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable, Section 280 of UL 1581.

TYPE THHN, THWN, AND THWN-2 WIRES AND INSULATED CONDUCTORS FOR TYPES ACTHH, NM-B, AND NMC-B HAVING THERMOPLASTIC INSULATION OTHER THAN PVC

23 General

23.1 The physical properties of a thermoplastic insulation material other than PVC removed from finished Type THHN, THWN-2, THWN wires and from finished insulated conductors for use in Type ACTHH, NM-B, and NMC-B shall comply with the after-aging requirements specified in Table 50.144 of UL 1581 and shall also be shown appropriate for the applicable temperature rating when evaluated as specified in Long-Term Aging, Section 481 of UL 1581. Requirements for material removed from the finished wire and tested unaged are to be established based on the properties of the new material. The finished wires shall be electrically equivalent to their PVC-insulated counterparts as demonstrated by compliance with all of the applicable tests referenced in Table 5.1 or 5.2. The finished wires shall also be mechanically equivalent to their PVC-insulated counterparts as demonstrated by the results of tests such as the crushing, impact, and abrasion tests referenced in Sections 49 – 51.

23.1 revised September 29, 1998

ASSEMBLIES THAT INCLUDE SINGLE-CONDUCTOR THERMOPLASTIC-INSULATED WIRES

24 General

24.1 All single-conductor wires, except Type TBS, that individually comply with the requirements in this Standard, with or without including other single-conductor wires or cables, are eligible to be cabled (length and direction of lay not specified) into assemblies (assemblies are not cables) without overall coverings except for an open, skeleton tape or wrap obviously intended only to hold the assembly together. A bare or covered aluminum or copper-clad aluminum conductor shall not be part of an assembly. A bare copper conductor – size is not specified – that is coated with tin, lead, a lead-base alloy, or other metal is appropriate in an assembly. A bare, coated copper conductor is not to be covered. The completed assembly shall meet the following requirements:

a) Assemblies in which a bare, coated copper conductor is included are to be tank tested (dielectric voltage-withstand) as indicated in 27.1 after immersion in water for at least 1 h.

b) Each assembly in which a bare conductor is not included is either to be tank tested (1-h or longer immersion) as indicated in 27.1 or spark tested as indicated in 33.1.1 (each layer in a multiple-layer assembly is to be sparked separately).

c) Each No. 14 – 7 AWG conductor in an assembly is to be individually tested for continuity after the assembly is completed.

CABLE FOR DEEP-WELL SUBMERSIBLE WATER PUMPS

25 General

25.1 Cable for use within well casings for wiring deep-well submersible water pumps shall consist of solid or stranded No. 14 – 2 AWG copper, solid or stranded No. 12 – 2 AWG aluminum or copper-clad aluminum, or stranded No. 1 AWG – 500 kcmil copper or aluminum or copper-clad aluminum circuit conductors. A grounding conductor is not required. Where used, a grounding conductor shall consist of a fully insulated solid or stranded conductor that is of the same construction, is of a size that is not smaller than indicated in Table 25.3 or 25.4 for the largest size circuit conductor used, and is identified as indicated in 59.1. See 14.3 for the long-term evaluation of an insulation or jacket material not named in this Standard or not complying with the short-term tests specified for the material in Specific Materials, Section 50 of UL 1581. The circuit and grounding conductors shall be assembled in one of the following ways:

a) TWISTED WITH JACKET – Two through six insulated circuit conductors plus any insulated grounding conductor that comply with the requirements for one of the five constructions detailed in Table 25.1 (mils) or 25.2 (millimeters) and are cabled (length of lay not specified) with an overall covering. The overall covering shall consist of a PVC jacket complying with the requirements in this Standard, including the jacket thicknesses in Table 25.5 for the largest size circuit conductor used, and the physical properties in Table 50.175 of UL 1581.

b) TWISTED WITHOUT JACKET – Two through six insulated circuit conductors plus any insulated grounding conductor that comply with the requirements for one of the five constructions detailed in Table 25.1 (mils) or 25.2 (millimeters) and are cabled (length of lay not specified) without an overall covering.

c) PARALLEL WITH INTEGRAL WEB – Two or three PVC-insulated circuit conductors plus any PVC-insulated grounding conductor that comply with the requirements for either the A or C construction detailed in Table 25.1 (mils) or 25.2 (millimeters) and are laid flat and parallel to one another with an interconnecting web between adjacent conductors extruded simultaneously with the insulation and with polarity identification of each circuit conductor consisting of ridges, surface striping, or word printing. The minimum thickness of insulation at any point on each circuit conductor and any grounding conductor after separation shall not be less than the minimum thickness at any point that is indicated in Table 25.1 (mils) or 25.2 (millimeters) for the applicable construction A or C.

d) PARALLEL WITH JACKET INTEGRAL WITH FILLERS OR WEB – Two or three insulated circuit conductors plus any insulated grounding conductor that comply with the requirements for one of the five constructions detailed in Table 25.1 (mils) or 25.2 (millimeters) and are laid flat and parallel to one another with a nonintegral, overall PVC jacket complying with the requirements in this Standard, including the jacket thicknesses in Table 25.5 and the physical properties in Table 50.175 of UL 1581. Either the jacket shall come down to an interconnecting web of unspecified thickness between the conductors, or fillers that are integral with the jacket are to be used. The degree to which the integral fillers fill the valleys between the conductors is not specified except that the fill shall maintain the stability of the flat construction.

25.1 revised September 9, 1999

Table 25.1
Constructions of insulated conductors used in submersible-water-pump cable – dimensions in mils

Table 25.1 revised September 9, 1999

Size of conductor	Minimum thicknesses											
	Construction A		Construction B			Construction C		Construction D			Construction E	
	Type TW insulation		Type TW insulation		At any point of nylon jacket	Type THW, THW-2, and THHW insulation		Type THWN and THWN-2 insulation		At any point of nylon jacket	Type ZW	
	Average	At any point	Average	At any point		Average	At any point	Average	At any point		Average	At any point
14[a] – 11 AWG	30	27	30	27	5	45	40	15	13	4	30	27
10	45	40	30	27	5	45	40	20	18	4	30	27
9	45	40	30	27	5	45	40	20	18	4	45	40
8, 7	45	40	30	27	5	60	54	30	27	5	45	40
6, 5	60	54	45	40	5	60	54	30	27	5	45	40
4 – 2	60	54	45	40	5	60	54	40	36	6	45	40
1 – 4/0	80	72	65	59	7	80	72	50	45	7	–	–
213 – 500 kcmil	95	86	80	72	7	95	86	60	54	8	–	–

[a] Nos. 12, 11 AWG for aluminum or copper-clad aluminum conductors.

Table 25.2
Constructions of insulated conductors used in submersible-water-pump cable – dimensions in millimeters

Table 25.2 revised September 9, 1999

Size of conductor	Minimum thicknesses											
	Construction A		Construction B			Construction C		Construction D			Construction E	
	Type TW insulation		Type TW insulation		At any point of nylon jacket	Type THW, THW-2, and THHW insulation		Type THWN and THWN-2 insulation		At any point of nylon jacket	Type ZW	
	Average	At any point	Average	At any point		Average	At any point	Average	At any point		Average	At any point
14[a] – 11 AWG	0.70	0.69	0.76	0.69	0.13	1.14	1.02	0.38	0.33	0.10	0.78	0.69
10	1.14	1.02	0.76	0.69	0.13	1.14	1.02	0.51	0.46	0.10	0.78	0.69
9	1.14	1.02	0.76	0.69	0.13	1.14	1.02	0.51	0.46	0.10	1.14	1.02
8, 7	1.14	1.02	0.76	0.69	0.13	1.52	1.37	0.76	0.69	0.13	1.14	1.02
6, 5	1.52	1.37	1.14	1.04	0.13	1.52	1.37	0.76	0.69	0.13	1.14	1.02
4 – 2	1.52	1.37	1.14	1.04	0.13	1.52	1.37	1.02	0.91	0.15	1.14	1.02
1 – 4/0	2.03	1.83	1.65	1.50	0.18	2.03	1.83	1.27	1.14	0.18	–	–
213 – 500 kcmil	2.41	2.18	2.03	1.83	0.18	2.41	2.18	1.52	1.37	0.20	–	–

[a] Nos. 12, 11 AWG for aluminum or copper-clad aluminum conductors.

Table 25.3
Smallest size of grounding conductor where used in deep-well submersible-water-pump cable with all conductors of copper

Table 25.3 revised September 29, 1998

Size of circuit conductors	Smallest AWG size of grounding conductor		
	Type THW-2 or THWN-2	Type THW, THWN, THHW, or ZW	Type TW
14 AWG	14	14	14
13	13	13	13
12	12	12	12
11	11	11	11
10 – 8	10	10	10
7, 6	8	8	10
5, 4	8	8	8
3	6	8	8
2	6	6	8
1 – 2/0	6	6	6
3/0	4	6	6
4/0	4	4	6
213 – 250 kcmil	4	4	4
251 – 300	3	4	4
301 – 400	3	3	4
401 – 500	2	3	3

Table 25.4
Smallest size of grounding conductor where used in deep-well submersible-water-pump cable with all conductors of aluminum or copper-clad aluminum

Table 25.4 revised September 29, 1998

Size of circuit conductors	Smallest AWG size of grounding conductor		
	Type THW-2 or THWN-2	Type THW, THWN, THHW	Type TW
12 AWG	12	12	12
11	11	11	11
10	10	10	10
9	9	9	9
8 – 6	8	8	8
5	6	8	8
4	6	6	8
3, 2	6	6	6
1	4	6	6
1/0	4	4	6
2/0, 3/0	4	4	4
4/0	2	4	4
213 – 300 kcmil	2	2	4
301 – 350	2	2	2
351 – 400	1	2	2
401 – 500	1	1	2

Table 25.5
Thicknesses of nonintegral PVC jacket on multiple-conductor pump cable

Table 25.5 revised September 29, 1998

Size of circuit conductors	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 9 AWG	15	0.38	12	0.30
8 – 2	30	0.76	24	0.61
1 – 4/0	45	1.14	36	0.91
213 – 500 kcmil	65	1.65	52	1.32

PERFORMANCE

NYLON JACKET

26 Mandrel Test

26.1 The nylon jacket on a Type THWN-2, THWN, or THHN wire shall not crack when wrapped around a mandrel as described in 1590.1 of UL 1581.

DIELECTRIC VOLTAGE-WITHSTAND TESTS

27 Type THW-2, THWN-2, THHW, TW, THW, THHN, THWN, Z, ZW, PFA, PFAH, FEP, FEPB, and TFE and insulated conductors for use in Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables

27.1 The insulation of Type THW-2, THWN-2, THHW, TW, THW, THHN, THWN, Z, ZW, PFA, PFAH, FEP, FEPB, and TFE wires, the insulated conductors for use in Type ACTH, and ACTHH armored cables, and the insulated conductors without a nylon jacket for use in Types UF-B, NM-B, and NMC-B cables shall make the finished wire capable of withstanding for 60 s without breakdown the application of the sinusoidal or nearly sinusoidal rms test potential indicated in Table 27.1 under the following conditions. The wire shall be immersed in water at room temperature for not less than 6 h, following which it shall be subjected to the voltage test while still immersed. The dielectric voltage-withstand test shall be conducted before the insulation-resistance test. The test is to be made as described in Dielectric Voltage-Withstand Test of Coils and Reels in Water, Section 820 of UL 1581. See also 34.1.

27.1 revised September 29, 1998

Table 27.1
RMS dielectric test potential in volts

Table 27.1 revised September 29, 1998

Conductor size	Types THW-2, THWN-2, THHW, TW, THW, THHN, and THWN and insulated conductors for Types ACTH, ACTHH, UF-B, NM-B, and NMC-B	Types ZW, FEP, and FEPB	Types Z, ZW, PFA, PFAH, and TFE
14 – 9 AWG	1500[a]	2000	2000
8 – 2	2000	2000	2000
1 – 4/0	2500	–	2000
213 – 500 kcmil	3000	–	–
501 – 1000	3500	–	–
1001 – 2000	4000	–	–

[a] 1500 V for Type TW. 2000 V for all others.

27.2 The individual conductors of a jacketed multiple-conductor cable are to be tested in tap water before assembly as described in 27.1 or the individual conductors are to be a-c spark tested in 34.1. After assembly, the test potential is to be applied between each conductor and all of the adjacent conductors connected together.

28 TYPE TBS

28.1 Initial test

28.1.1 The insulation of finished Type TBS wire shall be capable of withstanding for 5 min without breakdown the application of the sinusoidal or nearly sinusoidal rms test potential indicated in Table 28.1. The test is to be made as described in Dielectric Voltage-Withstand Test of Straight Foil-Wrapped Specimens, Section 760 of UL 1581.

Table 28.1
RMS dielectric test potential in volts

AWG size of conductor	Test potential
14 – 7	3000
6 – 2	4000
1 – 4/0	5000

28.2 Test after bending

28.2.1 The insulation of finished Type TBS wire in the Nos. 14 – 8 AWG sizes shall be capable of withstanding for 60 s without breakdown the application of a sinusoidal or nearly sinusoidal rms test potential of 5000 V after the wire is bent. The test is to be made as described in Dielectric Voltage-Withstand Test of Foil-Wrapped U-Bend Specimens, Section 780 of UL 1581.

LEAKAGE RESISTANCE

29 General

29.1 The surface leakage resistance of finished Type TBS wire, after exposure for 18 h to a saturated moist atmosphere at a temperature of 23.0 ±1.0°C (73.4 ±1.8°F), shall not be less than 1.0 megohm as determined in accordance with Test of Type TBS for Surface Leakage Resistance, Section 1300 of UL 1581.

SHORT-TIME INSULATION RESISTANCE IN WATER

30 General

30.1 The insulation on conductors without a nylon jacket for Type UF-B, NM-B, and NMC-B cables; on conductors for Type ACTH, and ACTHH cables; and on Type THWN-2, THW-2, THHW, TW, THW, THWN, and THHN wires shall result in the finished wire having an insulation resistance at 60.0°F (15.6°C) and at rated temperature (60°C or 140°F for Types TW and conductors for Type UF-B cables, 75°C or 167°F for Types THHW, THW, and THWN, 90°C or 194°F for Types THWN-2 and THW-2; Type THHN and conductors for Type ACTH, ACTHH, NM-B, and NMC-B cables not tested in water at rated temperature), of not less than the number of megohms, based on 1000 conductor feet, or not less than the number of megohms, based on a conductor kilometer as indicated in Table 30.1 for the test at room temperature, or as indicated in Table 31.1 for the test at elevated temperature. The insulation of Type ZW, Z, PFA, PFAH, FEP, FEPB, and TFE wires shall result in the full range of sizes of finished wire having an insulation resistance of not less than 1000 megohms based on 1000 conductor feet or 304 megohms based on a conductor kilometer. The wire shall be immersed in tap water at the specified temperature for 6 h or more, and shall then be tested for insulation resistance while still immersed. The test at room temperature – but not the test at 60°C (140°F), 75°C (167°F), or 90°C (194°F) – is to be conducted immediately following the dielectric voltage-withstand test but, in any case, the coil or coils shall be earth-grounded and completely discharged previous to the measurement of insulation resistance. The test is to be made as described in Insulation-Resistance Test in Water, Section 920 of UL 1581.

30.1 revised September 29, 1998

30.2 The temperature of the water in which a coil is immersed has a marked effect upon the insulation resistance. When the temperature at which the readings are taken (see 920.2 of UL 1581) is other than 60.0°F (15.6°C), the readings are to be multiplied by the applicable multiplying factor from Table 30.2. One of the four columns in the table is assigned to every PVC compound covered in Table 5.1 or 5.2 except when one of these compounds cannot be made to fit into any of the four patterns (columns); in that case, applicable multiplying factors are to be determined. A multiplying factor of 1.00 shall apply for any room-temperature test conducted on Type ZW, Z, PFA, PFAH, FEP, FEPB, or TFE wire. The multiplying factor for a thermoplastic compound other than PVC employed in Type THW-2, THWN-2, THW, TW, THHN, and THWN wires and in insulated conductors for Type ACTHH, NM-B, and NMC-B is to be determined by means of an investigation.

30.2 revised September 29, 1998

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Table 30.1
Minimum insulation resistance at 60.0°F (15.6°C) in water

Table 30.1 revised September 29, 1998

Size of conductor	Megohms based on 1000 conductor feet			Megohms based on a conductor kilometer		
	Type TW	Types THW-2, THHW, and THW and insulated conductors for Type ACTH cable (see note[a])	Types THWN-2, THWN, and THHN and insulated conductors for Types ACTHH, NM-B, NMC-B, and UF-B cables	Type TW	Types THW-2, THHW, THW, and insulated conductors for Type ACTH cable (see note[a])	Types THWN-2, THWN, and THHN and insulated conductors for Types ACTHH, NM-B, NMC-B, and UF-B cables
14 AWG	140	570	665	45	175	205
13	130	530	605	45	165	190
12	120	485	560	40	150	175
11	110	440	635	35	135	195
10	100	405	580	35	125	180
9	125	505	735	40	155	225
8	105	415	595	35	130	185
7	115	475	545	40	145	170
6	105	435	495	35	135	155
5	95	395	440	30	125	135
4	90	360	505	20	115	155
3	80	325	465	25	110	145
2	75	295	415	25	95	130
1	85	340	455	30	105	140
1/0	75	310	415	25	95	130
2/0	70	280	370	25	85	115
3/0	60	250	330	20	80	105
4/0	55	225	300	20	70	95
250 kcmil	60	245	330	20	80	105
300	55	225	300	20	70	95
350	50	210	285	20	65	90
400	50	200	255	15	65	80
450	45	190	255	15	60	80
500	45	180	240	15	55	75

Table 30.1 Continued on Next Page

Table 30.1 Continued

Size of conductor	Megohms based on 1000 conductor feet			Megohms based on a conductor kilometer		
	Type TW	Types THW-2, THHW, and THW and insulated conductors for Type ACTH cable (see note[a])	Types THWN-2, THWN, and THHN and insulated conductors for Types ACTHH, NM-B, NMC-B, and UF-B cables	Type TW	Types THW-2, THHW, THW, and insulated conductors for Type ACTH cable (see note[a])	Types THWN-2, THWN, and THHN and insulated conductors for Types ACTHH, NM-B, NMC-B, and UF-B cables
550	50	200	255	15	65	80
600	45	190	255	15	60	80
650	45	185	240	15	60	75
700	45	180	225	15	55	70
750	40	170	225	15	55	70
800	40	165	225	15	55	70
900	40	155	210	15	50	65
1000	35	150	195	15	50	60
1100	35	140	–	15	45	–
1200	30	135	–	10	45	–
1250	30	135	–	10	45	–
1300	30	135	–	10	45	–
1400	30	125	–	10	40	–
1500	30	125	–	10	40	–
1600	30	120	–	10	40	–
1700	30	120	–	10	40	–
1750	25	110	–	10	35	–
1800	25	110	–	10	35	–
1900	25	110	–	10	35	–
2000	25	105	–	10	35	–

[a] The values in this column apply to Type THHW, THW-2, and THW wires and insulated conductors for Type ACTH cable that have a single or double layer of insulation.

Table 30.2
Multiplying factors for changing insulation resistance to 60.0°F (15.6°C) for PVC compounds covered in Table 5.1

Table 30.2 revised September 29, 1998

Temperature[a]		Multiplying factor			
°F	°C	I	II	III	IV
50	10.0	0.35	0.42	0.46	0.56
51	10.6	0.39	0.46	0.50	0.59
52	11.1	0.43	0.50	0.54	0.63
53	11.7	0.48	0.55	0.58	0.67
54	12.2	0.54	0.60	0.63	0.70
55	12.8	0.60	0.65	0.68	0.75
56	13.3	0.66	0.71	0.74	0.79
57	13.9	0.73	0.78	0.80	0.84
58	14.4	0.82	0.85	0.86	0.90
59	15.0	0.90	0.92	0.93	0.95
60	15.6	1.00	1.00	1.00	1.00
61	16.1	1.11	1.09	1.08	1.06
62	16.7	1.24	1.19	1.17	1.13
63	17.2	1.38	1.30	1.26	1.19
64	17.8	1.53	1.41	1.36	1.26
65	18.3	1.70	1.54	1.47	1.34
66	18.9	1.88	1.69	1.59	1.42
67	19.4	2.09	1.84	1.72	1.51
68	20.0	2.31	1.99	1.85	1.60
69	20.6	2.57	2.18	2.00	1.69
70	21.1	2.85	2.38	2.17	1.79

Table 30.2 Continued on Next Page

Table 30.2 Continued

Temperature[a]		Multiplying factor			
°F	°C	I	II	III	IV
71	21.7	3.17	2.59	2.34	1.90
72	22.2	3.52	2.82	2.53	2.02
73	22.8	3.90	3.08	2.72	2.14
74	23.3	4.31	3.35	2.94	2.27
75	23.9	4.78	3.65	3.18	2.40
76	24.4	5.30	3.98	3.43	2.54
77	25.0	5.88	4.34	3.70	2.70
78	25.6	6.51	4.73	4.00	2.86
79	26.1	7.27	5.16	4.33	3.03
80	26.7	8.07	5.61	4.67	3.21
81	27.2	8.98	6.12	5.04	3.40
82	27.8	9.92	6.69	5.45	3.60
83	28.3	11.0	7.28	5.89	3.82
84	28.9	12.2	7.92	6.35	4.05
85	29.4	13.5	8.67	6.84	4.30

[a] The temperature of the water in which the coil or coils are immersed at the time that the insulation-resistance readings are taken is the basis for selection of the multiplying factor. When, because of hot or cold weather or local conditions, the temperature of the insulation to be tested differs by more than 5.0°F (2.8°C) from the temperature of the water in which the insulation is to be immersed, the test results after a 6-h immersion are not accurate unless one of the following is accomplished before insulation-resistance readings are taken:

A. The wire is to be in the water for whatever time is required for the conductor, insulation, and all other parts of the complete wire to attain the same temperature as the water. The water and the wire immersed in it are to be considered to be at the same temperature when three successive measurements of the d-c resistance of the conductor made at 30-min intervals by means of the equipment indicated in 220.1 of UL 1581 show no change.

B. The water is to be heated or cooled, as required, to within 5.0°F (2.8°C) of the temperature of the wire before the wire is immersed for at least 6 h.

LONG-TIME INSULATION RESISTANCE IN WATER

31 General

31.1 Minimum value

31.1.1 The insulation on Type THW-2, THWN-2, THHW, TW, THW, and THWN wires and on conductors for Type UF-B cable shall result in the finished wire (without the nylon jacket in the case of Types THWN, THWN-2, and nylon-jacketed conductors for Type UF-B cable) having an insulation resistance in tap water at 50°C (122°F) for Type TW wire and the insulated conductors for Type UF-B cables, and at 75°C (167°F) for Types THHW, THW and THWN, and at 90°C (194°F) for Types THW-2 and THWN-2, that is not less than the number of megohms based on 1000 conductor feet, or the number of megohms based on a conductor kilometer specified in Table 31.1, at any time during immersion. The insulation on Type ZW wire shall result in the full range of sizes of finished wire having an insulation resistance in tap water at 90°C (194°F) of not less than 100 megohms based on 1000 conductor feet or 30.4 megohms based on a conductor kilometer. The period of immersion shall be 12 weeks or more when the insulation resistance throughout the last 6 weeks of the period is higher than 10 megohms based on 1000 conductor feet or is higher than 3 megohms based on a conductor kilometer. The period of immersion shall be 24 – 36 weeks when the insulation resistance is less than 10 megohms based on 1000 conductor feet or 3 megohms based on a conductor kilometer but equals or exceeds the value indicated in Table 31.1. A sinusoidal or nearly sinusoidal rms potential of 600 V at 48 – 62 Hz shall be applied to the insulation at all times other than while readings of insulation resistance are being taken. See also 31.2.1 for the requirement covering the maximum rate of decrease of the insulation resistance.

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Table 31.1
Minimum insulation resistance at elevated temperature in water

Table 31.1 revised September 9, 1999

Conductor size	Megohms based on 1000 conductor feet			Megohms based on a conductor kilometer		
	Type TW and insulated conductors for Type UF-B cable (50 or 60°C test)[b]	Type THW[a] and THHW (75°C Test) or THW-2 (90°C test)	Type THWN (75°C test) or THWN-2 (90°C test)	Type TW and insulated conductors for Type UF-B cable (50 or 60°C test)[a]	Type THW[a] and THHW (75°C test) or THW-2 (90°C test)	Type THWN (75°C test) or THWN-2 (90°C test)
14 AWG	0.095	0.380	0.115	0.030	0.120	0.035
13	0.085	0.350	0.105	0.030	0.110	0.035
12	0.080	0.320	0.095	0.025	0.100	0.030
11	0.070	0.290	0.110	0.025	0.090	0.035
10	0.065	0.265	0.100	0.025	0.085	0.035
9	0.080	0.335	0.125	0.030	0.105	0.040
8	0.070	0.270	0.100	0.025	0.085	0.035
7	0.075	0.315	0.095	0.025	0.100	0.030
6	0.070	0.285	0.085	0.025	0.090	0.030
5	0.065	0.260	0.075	0.020	0.080	0.025
4	0.060	0.240	0.085	0.020	0.075	0.030
3	0.050	0.215	0.080	0.020	0.070	0.025
2	0.050	0.195	0.070	0.015	0.060	0.025
1	0.055	0.225	0.075	0.020	0.070	0.025
1/0	0.050	0.205	0.070	0.020	0.065	0.025
2/0	0.045	0.185	0.065	0.015	0.060	0.020
3/0	0.040	0.165	0.055	0.015	0.055	0.020
4/0	0.035	0.150	0.050	0.015	0.050	0.020
250 kcmil	0.040	0.160	0.055	0.015	0.050	0.020
300	0.035	0.150	0.050	0.015	0.050	0.020
350	0.035	0.140	0.050	0.015	0.045	0.015

Table 31.1 Continued on Next Page

Table 31.1 Continued

Conductor size	Megohms based on 1000 conductor feet			Megohms based on a conductor kilometer		
	Type TW and insulated conductors for Type UF-B cable (50 or 60°C test)[b]	Type THW[a] and THHW (75°C Test) or THW-2 (90°C test)	Type THWN (75°C test) or THWN-2 (90°C test)	Type TW and insulated conductors for Type UF-B cable (50 or 60°C test)[a]	Type THW[a] and THHW (75°C test) or THW-2 (90°C test)	Type THWN (75°C test) or THWN-2 (90°C test)
550	0.030	0.130	0.045	0.010	0.040	0.015
600	0.030	0.125	0.045	0.010	0.040	0.015
650	0.030	0.120	0.040	0.010	0.040	0.015
700	0.030	0.115	0.040	0.010	0.040	0.015
750	0.025	0.115	0.040	0.010	0.035	0.015
800	0.025	0.110	0.040	0.010	0.035	0.015
900	0.025	0.105	0.035	0.010	0.035	0.010
1000	0.025	0.100	0.030	0.010	0.030	0.010
1100	0.020	0.095	–	0.010	0.030	–
1200	0.020	0.090	–	0.010	0.030	–
1250	0.020	0.090	–	0.010	0.030	–
1300	0.020	0.080	–	0.010	0.030	–
1400	0.020	0.085	–	0.010	0.030	–
1500	0.020	0.085	–	0.010	0.030	–
1600	0.020	0.085	–	0.010	0.025	–
1700	0.020	0.080	–	0.010	0.025	–
1750	0.015	0.075	–	0.010	0.025	–
1800	0.015	0.075	–	0.010	0.025	–
1900	0.015	0.075	–	0.010	0.025	–
2000	0.015	0.075	–	0.005	0.025	–

[a] The values in this column apply to Type THW or THHW or THW-2 wires with a single or double layer of insulation.

[b] The 60°C test refers to Short-Time Insulation Resistance in Water, Section 30.

31.1.2 The extended immersion tests at 50°C (122°F) or 75°C (167°F) or 90°C (194°F) are to be considered accelerated tests for Types THW-2, THWN-2, THWN, THHW, TW, and THW wires and for the insulated conductors for Type UF-B cable. Although these wires and insulated conductors are rated for such exposure to water, it is not expected that during service they are exposed simultaneously to a temperature of 60°C (140°F) or 75°C (167°F) or 90°C (194°F) and to water for long periods of time.

31.1.2 revised September 29, 1998

3.1.3 The values in Table 31.1 apply only to conductors with the insulation thicknesses indicated in Table 15.5 (Type TW, THW, THW-2, THHW, and UF-B singles), or 15.7 (Type THHW, THW-2, or THW), and 15.8 (Type THWN-2 or THWN). For other thicknesses of the same materials, the insulation-resistance values are to be calculated by means of whichever of the following formulas is applicable

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

$$IR_{\substack{75°C \\ THW}} = K_{15.6°C} \times 6.63 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{75°C \\ THHW}} = K_{15.6°C} \times 6.63 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{75°C \\ THWN}} = K_{15.6°C} \times 1.74 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{90°C \\ THWN-2}} = K_{15.6°C} \times 1.74 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{90°C \\ THW-2}} = K_{15.6°C} \times 6.63 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

IR at 50°C (122°F) or 75°C (167°F) or 90°C (194°F) is the insulation resistance in megohms based on 1000 conductor feet at 50°C (122°F) or 75°C (167°F) or 90°C (194°F),

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

6.63×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) to the value it would have at 50°C (122°F) for Type TW and UF-B singles or 75°C (167°F) for Type THHW and THW wires or 90°C (194°F) for Type THW-2 wire,

1.74×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) to the value it would have at 75°C (167°F) for Type THWN wire or 90°C (194°F) for Type THWN-2 wire,

D is the diameter over the insulation in inches, and

d is the diameter of the metal conductor in inches; or

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

$$IR_{\substack{75°C \\ THW}} = K_{15.6°C} \times 2.02 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{75°C \\ THHW}} = K_{15.6°C} \times 2.02 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{75°C \\ THWN}} = K_{15.6°C} \times 5.30 \times 10^{-5} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{90°C \\ THWN-2}} = K_{15.6°C} \times 5.30 \times 10^{-5} \times \log_{10} \frac{D}{d}$$

$$IR_{\substack{90°C \\ THW-2}} = K_{15.6°C} \times 2.02 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

IR at 50°C (122°F) or 75°C (167°F) or 90°C (194°F) is the insulation resistance in megohms based on a conductor kilometer at 50°C (122°F) or 75°C (167°F) or 90°C 194°C),

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

2.02×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) in megohms based on 1000 conductor feet to the value it would have based on a conductor kilometer at 50°C (122°F) for Type TW and UF-B singles or 75°C (167°F) for Type THHW and THW wires or at 90°C (194°F) for Type THW-2 wire,

5.30×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) in megohms based on 1000 conductor feet to the value it would have based on a conductor kilometer at 75°C (167°F) for Type THWN wire or 90°C (194°F) for Type THWN-2 wire,

D is the diameter over the insulation in millimeters, and

d is the diameter of the metal conductor in millimeters.

For example, the insulation resistance of a No. 8 AWG Type TW wire with ASTM Class B stranding and a 0.050 inch or 1.27 mm average thickness of insulation would be:

In nonmetric terms –

For a Class B No. 8 AWG conductor, d = 0.146 inch

D = d + 2 (insulation thickness) = 0.146 + 2(0.050) = 0.246 inch

$IR_{50°C} = K_{15.6°C} \times 6.63 \times 10^{-4} \times \log_{10}(D/d)$

$= 500 \times 6.63 \times 10^{-4} \times \log_{10}(0.246/0.146)$

= 0.076 megohm based on 1000 conductor feet. This value rounded down to 0.075 megohm based on 1000 conductor feet would be the requirement for insulation resistance at 50°C (122°F)

In metric terms –

For a Class B No. 8 AWG conductor, d = 3.70 mm

D = d + 2 (insulation thickness) = 3.79 + 2(1.27) = 6.24 mm

$IR_{50°C} = K_{15.6°C} \times 2.02 \times 10^{-4} \times \log_{10}(D/d)$

$= 500 \times 2.02 \times 10^{-4} \times \log_{10}(6.24/3.70)$

= 0.023 megohm based on a conductor kilometer. This value rounded up to 0.025 megohm based on a conductor kilometer would be the requirement for insulation resistance at 50°C (122°F)

31.1.3 revised September 29, 1998

31.2 Maximum rate of decrease

31.2.1 The insulation indicated in 31.1.1 shall also have the effect that, during the extended immersion of Type TW wire or UF-B singles at 50°C (122°F), Type ZW, THHW, THW, or THWN wire at 75°C (167°F), or Type THW-2 or THWN-2 wires at 90°C (194°F), the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the latter half of the specified immersion time, is not more than 4 percent when and while the insulation resistance on the basis of 1000 conductor feet is 10 megohms or more (3 megohms or more based on a conductor kilometer); and is not more than 2 percent when and while the insulation resistance is less than 10 megohms based on 1000 conductor feet, or 3 megohms based on a conductor kilometer, and more than the value indicated in Table 31.1.

31.3 Test method

31.3.1 To determine whether the insulation complies with the requirements in 31.1.1 and 31.2.1, it is to be tested with the apparatus and according to the methods described in Insulation-Resistance Test in Water, Section 920 of UL 1581. Type THWN-2 and THWN wires are to be tested without the nylon jacket in place. The ends of the specimen are to be brought well away from the tank, and the temperature of the water is to be maintained at 50.0 ±1.0°C (122.0 ±1.8°F) or 75.0 ±1.0°C (167.0 ±1.8°F) or 90.0 ±1.0°C (197.0 ±1.8°F). A coil that shows a greater percent decrease in insulation resistance during the extended immersion than that specified in 31.2.1 shall be tested for additional 1-week immersion periods and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks of immersion, provided that the final insulation resistance is not less than specified in Table 31.1.

LONG-TIME INSULATION RESISTANCE IN AIR AT 97.0°C (206.6°F)

32 General

32.1 Minimum value

32.1.1 The insulation on Type THHN wire and on the insulated conductors for Type ACTHH NM-B, NMC-B, and UF-B cables shall have the effect that the wire, without the nylon jacket in place, in the case of Type THHN wire, and tested in graphite as the electrode or provided with a snug-fitting close-weave outer braid of copper, has an insulation resistance in air at 97.0 ±1.0°C (206.6 ±1.8°F) that is not less than indicated in Table 32.1 at any time during an extended period in a full-draft circulating-air oven complying with 420.9 of UL 1581 under the following conditions. The period in the oven shall be 12 weeks or more when the insulation resistance throughout the last 6 weeks of the period is higher than 10 megohms based on 1000 conductor feet or is higher than 3 megohms based on a conductor kilometer. The period in the oven shall be 24 – 36 weeks when the insulation resistance is less than 10 megohms based on 100 conductor feet, or is less than 3 megohms based on a conductor kilometer, and equals or exceeds the value indicated in Table 32.1. A 48 – 62 Hz sinusoidal or nearly sinusoidal potential of 600 V shall be applied to the insulation at all times other than while readings of insulation resistance are being taken. See also 32.2.1 for the requirement covering the maximum rate of decrease of the insulation resistance.

32.1.1 revised September 29, 1998

Table 32.1
Minimum long-time insulation resistance of Type THHN wire and of the insulated conductors for Type ACTHH, NM-B, NMC-B, and UF-B cables at 97.0°C (206.6°F) in air

Table 32.1 revised September 29, 1998

Size of conductor	Megohms based on 1000 conductor feet	Megohms based on a conductor kilometer
14 AWG	0.260	0.080
13	0.240	0.075
12	0.220	0.070
11	0.250	0.080
10	0.230	0.070
9	0.290	0.090
8	0.235	0.075
7	0.215	0.070
6	0.195	0.060
5	0.170	0.055
4	0.200	0.065
3	0.185	0.060
2	0.160	0.050
1	0.180	0.055
1/0	0.160	0.050
2/0	0.145	0.045
3/0	0.130	0.040
4/0	0.115	0.040
250 kcmil	0.130	0.040
300	0.115	0.040
350	0.110	0.035
400	0.100	0.035
450	0.100	0.035
500	0.095	0.030
550	0.100	0.035
600	0.100	0.035
650	0.095	0.030
700	0.090	0.030
750	0.090	0.030
800	0.090	0.030
900	0.080	0.030
1000	0.075	0.025

32.1.2 The values in Table 32.1 apply only to Type THHN wire and singles for Type NM-B, NMC-B, and UF-B cables with insulation thicknesses that are indicated in Table 15.8. For other thicknesses of the same materials, the insulation resistance values are to be calculated by means of whichever of the following formulas is applicable. See the end of 31.1.3 for sample nonmetric and metric calculations.

$$IR_{\substack{97°C \\ THHN}} = K_{15.6°C} \times 3.94 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

$IR_{97°C}$ is the insulation resistance in megohms based on 1000 conductor feet at 102 percent of the absolute dry-locations rated temperature of the wire,

K is the constant for the insulation material at 60.0°F (15.6°C) in megohms based on 1000 conductor feet, 3.94×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) to the value it would have at 97.0°C (206.6°F),

D is the diameter over the insulation in inches, and

d is the diameter of the metal conductor in inches; or

$$IR_{\substack{97°C \\ THHN}} = K_{15.6°C} \times 1.20 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

$IR_{97°C}$ is the insulation resistance in megohms based on a conductor kilometer at 102 percent of the absolute dry-locations rated temperature of the wire,

K is the constant for the insulation material at 60.0°F (15.6°C) in megohms based on 1000 conductor feet, 1.20×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) in megohms based on 1000 conductor feet to the value it would have at 97.0°C (206.6°F) in megohms based on a conductor kilometer,

D is the diameter over the insulation in millimeters, and

d is the diameter of the metal conductor in millimeters.

32.1.2 revised September 29, 1998

32.2 Maximum rate of decrease

32.2.1 The insulation mentioned in 32.1.1 shall also have the effect that, during the extended period in the oven of Type THHN wire and singles for Type ACTHH, NM-B, NMC-B, and UF-B cables at 97.0 ±1.0°C (206.6 ±1.8°F), the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the latter half of the specified period of time in the oven is not more than 4 percent when the insulation resistance on the basis of 1000 conductor feet is 10 megohms or more (3 megohms or more based on a conductor kilometer), and is not more than 2 percent when and while the insulation resistance is less than 10 megohms based on 1000 conductor feet, or 3 megohms based on a conductor kilometer, and more than the value indicated in Table 32.1.

32.2.1 revised September 29, 1998

32.3 Test method

32.3.1 The test to determine whether or not the insulation complies with the requirements in 32.1.1 and 32.2.1 is to be made on three or more 50-ft or 20-m coils of unaged Type THHN wire without the nylon jacket and unaged singles for Type ACTHH, NM-B, NMC-B, and UF-B cables provided with a snug-fitting close-weave outer braid of copper. Except for the use of a large full-draft circulating-air oven complying with 420.9 of UL 1581 and having provision for bringing out the necessary wire leads, and except that no tank and water are involved because this is a dry test in heated air, the test is to be made with the equipment and according to the method described in Insulation-Resistance Test in Water, Section 920 of UL 1581. Before the test voltage is applied to wire provided with a copper braid, the copper braid is to be removed from each end of each coil for a distance of 6 – 8 inches or 150 – 200 mm. For wire tested in graphite, each end of each coil is to extend a distance of 6 – 8 inches or 100 – 200 mm out of the graphite.

32.3.1 revised September 29, 1998

32.3.2 Any coil that shows a greater percent decrease in insulation resistance during the extended period of time in the oven than specified in 32.2.1 shall be tested for additional 1-week periods in the oven and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks in the oven, provided that the final insulation resistance is not less than specified in the applicable column of Table 32.1.

LONG-TIME INSULATION RESISTANCE IN AIR AT 82.0°C (179.6°F)

33 General

33.1 Minimum value

33.1.1 The insulation on the insulated conductors for Type ACTH cable shall have the effect that the insulated conductor provided with a snug-fitting close-weave outer braid of copper has an insulation resistance in air at 82.0 ±1.0°C (179.6 ±1.8°F) that is not less than indicated in Table 33.1 at any time during an extended period in a full-draft circulating-air oven under the following conditions [this test is waived when the insulated conductors for Type ACTH cable consist of standard Type THW conductors (single or double layer of insulation) that are not surface marked ″THW″ and are surface marked ″for ACTH″]. The period in the oven shall be twelve weeks or more when the insulation resistance throughout the last 6 weeks of the period is higher than 10 megohms based on 1000 conductor feet or is higher than 3 megohms based on a conductor kilometer. The period in the oven shall be 24 – 36 weeks when the insulation resistance is less than 10 megohms based on 1000 conductor feet, or is less

than 3 megohms based on a conductor kilometer, and equals or exceeds the value indicated in Table 33.1. A sinusoidal or nearly sinusoidal rms potential of 600 V at 48 – 62 Hz shall be applied to the insulation at all times other than while readings of insulation resistance are being taken. See also 33.2.1 for the requirement covering the maximum rate of decrease of the insulation resistance.

Table 33.1
Minimum long-time insulation resistance of the insulated conductors for Type ACTH cable at 82.0°C (179.6°F) in air

Table 33.1 revised September 29, 1998

Size of conductor	Megohms based on 1000 conductor feet	Megohms based on a conductor kilometer
14 AWG	0.955	0.295
13	0.885	0.275
12	0.810	0.250
11	0.740	0.230
10	0.675	0.210
9	0.850	0.260
8	0.695	0.215
7	0.795	0.245
6	0.725	0.225
5	0.665	0.205
4	0.605	0.185
3	0.550	0.170
2	0.495	0.155
1	0.570	0.175

33.1.2 The values in Table 33.1 apply only to conductors with insulation thicknesses that are indicated in Table 15.5 or 15.7. For other thicknesses of the same materials, the insulation resistance values are to be calculated by means of whichever of the following formulas is applicable. See the end of 31.1.3 for sample nonmetric and metric calculations.

$$IR_{\substack{82°C \\ ACTH}} = K_{15.6°C} \times 1.67 \times 10^{-3} \times \log_{10} \frac{D}{d}$$

in which:

$IR_{82°C}$ is the insulation resistance in megohms based on 1000 conductor feet at 102 percent of the absolute dry-locations rated temperature of the insulated conductor,

K is the constant for the insulation material at 60.0°F (15.6°C) in megohms based on 1000 conductor feet, 1.67×10^{-3} is the multiplier necessary for reducing K at 60.0°F (15.6°C) to the value it would have at 82.0°C (179.6°F),

D is the diameter over the insulation in inches, and

d is the diameter of the metal conductor in inches; or

$$IR_{\substack{82°C \\ ACTH}} = K_{15.6°C} \times 5.09 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

$IR_{82°C}$ is the insulation resistance in megohms based on a conductor kilometer at 102 percent of the absolute dry-locations rated temperature of the wire,

K is the constant for the insulation material at 60.0°F (15.6°C) in megohms based on 1000 conductor feet, 5.09×10^{-4} is the multiplier necessary for reducing K at 60.0°F (15.6°C) in megohms based on 1000 conductor feet to the value it would have at 82.0°C (179.6°F) in megohms based on a conductor kilometer,

D is the diameter over the insulation in millimeters, and

d is the diameter of the metal conductor in millimeters.

33.1.2 revised September 29, 1998

33.2 Maximum rate of decrease

33.2.1 The insulation indicated in 33.1.1 shall also have the effect that, during the extended period of time that the insulated conductors for Type ACTH cable are in the oven at 82.0 ±1.0°C (179.6 ±1.8°F), the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the latter half of the specified period of time in the oven is not more than 4 percent when and while the insulation resistance on the basis of 1000 conductor feet is 10 megohms or more (3 megohms or more based on a conductor kilometer), and is not more than 2 percent when and while the insulation resistance is less than 10 megohms based on 1000 conductor feet, or 3 megohms based on a conductor kilometer, and is more than the value indicated in Table 33.1.

33.3 Test method

33.3.1 The test to determine whether or not the insulation complies with the requirements in 33.1.1 and 33.2.1 is to be made on three or more 51-ft or 15.5-m coils of unaged insulated conductor provided with a snug-fitting close-weave outer braid of copper. Except for the use of a large full-draft circulating-air oven complying with 420.9 of UL 1581 and having provision for bringing out the necessary wire leads, and except that no tank and water are involved because this is a dry test in heated air, the test is to be made with the equipment and according to the method described in Insulation-Resistance Test in Water, Section 920 of UL 1581. Before the test voltage is applied, the copper braid is to be removed from each end of each coil for a distance of 6 – 8 inches or 150 – 200 mm.

33.3.2 Any coil that shows a greater percent decrease in insulation resistance during the extended period of time in the oven than specified in 33.2.1 shall be tested for additional 1-week periods in the oven and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks in the oven, where the final insulation resistance is not less than specified in the applicable column of Table 33.1.

ALTERNATIVE SPARK TESTING

34 Types THW-2, THWN-2, THHW, TW, THW, THHN, THWN, Z, ZW, PFA, PFAH, FEP, FEPB, and TFE and conductors for Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables

34.1 To expedite the factory production testing of conductors for Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables and of Type THW-2, THWN-2, THHW, TW, THW, THHN, THWN, Z, ZW, PFA, PFAH, FEP, FEPB, and TFE wires, the a-c spark test described in Spark Test Method, Section 900 of UL 1581, is an alternative to the Dielectric Voltage-Withstand Test in 27.1 and 27.2 and the 60.0°F (15.6°C) Insulation-Resistance Test in 30.1 and 30.2. The alternative chosen for a given type and size of wire at a given factory is to be applied to 100 percent of production of that type and size at that factory. Within a factory, it is appropriate to choose different alternatives for different sizes of the same type of wire. The test potential shall be as indicated in Table 35.1.

34.1 revised September 29, 1998

35 Type TBS

35.1 The factory production testing of Type TBS wire shall include an a-c spark test on 100 percent production of the finished wire in accordance with Spark Test Method, Section 900 of UL 1581. The test potential shall be as indicated in Table 35.1.

Table 35.1
Spark-test potential

Wire size	RMS test potential in kilovolts
14 – 9 AWG	7.5
8, 7	10.0
6 – 2	10.0
1 – 4/0	12.5
213 – 500 kcmil	15.0
550 – 1000	17.5
1100 – 2000	20.0

CAPACITANCE AND RELATIVE PERMITTIVITY

36 General

36.1 The insulation on Type ZW, TW, THHW, THWN, and THWN-2 wires; on Type THW and THW-2 wires (single or double layer of insulation); and on the insulated conductors for Type UF-B cable shall have the effect that specimens of the finished wire that are tested in accordance with the Capacitance and Relative Permittivity Test, Section 1020 of UL 1581 comply with each of the following:

a) The relative permittivity (dielectric constant) determined after immersion for 24 h shall not be more than 4.00 for Type ZW, shall not be more than 8.00 for Type TW wire and for the insulated conductors for Type UF-B cable, and shall not be more than 10.0 for Type THW and THW-2 (single or double layer of insulation) and for Type THWN-2, THHW, and THWN wires.

b) The capacitance determined for all insulations after immersion for 14 d shall not be more than 10.0 percent higher than the capacitance after the 24-h immersion.

c) The capacitance determined for all insulations after the 14-d immersion shall not be more than 5.0 percent higher than the capacitance determined after immersion for 7 d.

ROOM-TEMPERATURE FLEXIBILITY TEST

37 General

37.1 Within 16 – 96 h after oven treatment under the conditions specified in the applicable table of physical properties in Specific Materials, Section 50 of UL 1581, the insulation and nylon jacket from finished Type THW-2, THWN-2, THHW, TW, THW, THWN, THHN, TBS, FEP, FEPB, PFA, PFAH, ZW, Z, and TFE wires and from finished conductors for Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables shall not show any cracks either on the surface or internally when wound on a mandrel at room temperature using the method described in 39.1 and 39.2. In addition to the test on oven-treated specimens, unaged specimens of Type TBS wire shall also be subjected to this test. The mandrel diameter for all tests shall be as specified in column B of Table 38.1.

37.1 revised September 29, 1998

HEAT SHOCK TEST

38 General

38.1 Insulation from Type TW, THHW, THWN, THWN-2, THHN, and TBS wires; from Type THW and THW-2 wires (single or double layer of insulation); and from finished conductors for Type ACTH (single or double layer of insulation), ACTHH, UF-B, NM-B, and NMC-B cables shall not show any cracks on the inside or outside surface after a specimen of finished wire is wound in accordance with 540.2 of UL 1581 around a mandrel having a diameter as specified in column A of Table 38.1 and is then subjected to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) in an oven for 1 h.

38.1 revised September 29, 1998

Table 38.1
Mandrel diameters

Size of conductor	A (Heat shock)		B (Room temperature and cold bend)	
	inches	mm	inches	mm
14 AWG	0.133	3	0.313	8
13	0.139	4	0.350	9
12	0.148	4	0.375	9
11	0.157	4	0.415	11
10	0.168	4	0.563	14
9	0.182	5	0.585	15
8	0.228	6	0.688	17
7	0.246	6	0.740	19
6	0.646	16	1.250	32
5	0.672	17	1.305	33
4	0.744	19	1.375	35
3	0.802	20	1.458	37
2	0.866	22	1.563	40
1	1.016	26	2.688	68
1/0	1.098	28	2.875	73
2/0	1.190	30	3.000	76
3/0	1.294	33	3.250	83
4/0	1.410	36	3.500	89

Table 38.1 Continued on Next Page

Table 38.1 Continued

Size of conductor	A (Heat shock)		B (Room temperature and cold bend)	
	inches	mm	inches	mm
250 kcmil	3.940	100	6.304	160
300	4.215	107	6.744	171
350	4.475	114	7.160	182
400	4.710	120	7.563	191
450	4.935	125	7.904	201
500	5.145	131	8.232	209
550	5.515	140	11.030	280
600	5.715	145	11.430	290
650	5.895	150	11.790	299
700	6.070	154	12.140	308
750	6.245	159	12.490	317
800	6.410	163	12.820	326
900	6.725	171	13.450	342
1000	7.020	178	14.040	357
1100	7.465	190	14.930	379
1200	7.745	197	15.490	393
1250	7.885	200	15.770	401
1300	8.025	204	16.050	408
1400	8.270	210	16.540	420
1500	8.510	216	17.020	432
1600	8.745	222	17.490	444
1700	8.970	228	17.940	456
1750	9.085	231	18.170	462
1800	9.190	233	18.380	467
1900	9.400	239	18.800	478
2000	9.610	244	19.220	488

COLD-BEND TEST

39 General

39.1 Insulation from Type TW, THHW, THWN, THWN-2, THHN, TBS, FEP, FEPB, PFA, PFAH, ZW, and Z wires; on Type THW-2 and THW (single or double layer of insulation); and from conductors for Type ACTH, ACTHH, UF-B, NM-B, and NMC-B cables shall not show any cracks on the inside or outside surface after a specimen of finished wire that has been subjected to a temperature of -25.0 ±2.0°C (-13.0 ±3.6°F) for 4 h is wound around a mandrel while at the test temperature, in accordance with 39.2. The mandrel diameter shall be as specified in column B of Table 38.1. The winding shall be done at a uniform rate at or near 4 seconds per turn so that the time taken for winding 4 turns is 16 seconds.

39.1 revised September 29, 1998

39.2 In the case of a No. 3/0 AWG or smaller conductor, 4 adjacent turns are to be tightly wound around the mandrel. In the case of a No. 4/0 AWG or larger conductor, a U bend is to be made with the specimen in contact with the mandrel for not less than 180°.

DEFORMATION

40 General

40.1 The thickness of thermoplastic insulation shall not decrease more than 50 percent for Type TW and TBS wires and for conductors for Type UF-B, NM-B, and NMC-B cables, and for Type THW, THW-2 and THHW (single or double layer of insulation), and for conductors for Type ACTH (single or double layer of insulation) cable; and 30 percent for Type THWN wires; and 25 percent for Type THWN-2, THHN, FEP, PFA, PFAH, ZW, Z, and FEPB wires and for conductors for Type ACTHH cable when specimens of insulation from finished wire are subjected to the load indicated in Table 40.1 while being maintained at a temperature of 136.0 ±1.0°C (276.8 ±1.8°F) for Type THWN-2 and THHN wires, and 121.0 ±1.0°C (249.8 ±1.8°F) for all other types of wire. The test shall be made as described in Deformation Test, Section 560 of UL 1581, with each layer in rectangular specimens of double-layer insulation tested separately. The load used in the test of Type FEP, PFA, PFAH, ZW, Z, and FEPB wires shall be twice the load specified in Table 40.1. The nylon jacket is to be in place on Type THWN-2, THHN, and THWN wires, and the measurements are to be made over the nylon.

40.1 revised September 9, 1999

Table 40.1
Specimen loading

Table 40.1 revised September 29, 1998

Size of conductor	Minimum load[a] exerted on a specimen by the foot of the rod	
	gf	N
14 – 7 AWG	500	4.90
6 – 1	750	7.35
1/0 – 4/0	1000	9.81
213 – 2000 kcmil	2000	19.61

[a] The specified load is not the weight to be added to each rod in the test apparatus. It is the total of the weight added and the weight of the rod. Because the weight of the rod varies from one apparatus to another, specifying the exact weight to be added to a rod to achieve the specified load on a specimen is impractical in all cases except for an individual apparatus.

FLAME

41 VW-1 (Vertical-Specimen) Flame Test

41.1 For a given size and construction (materials, thickness, and so forth) of a finished Type THW-2, THWN-2, THHW, TW, THW, THHN, THWN, TBS, FEP, FEPB, PFA, PFAH, ZW, Z, or TFE insulated conductor to be eligible to be marked VW-1, that size and the 14 AWG size for wire with a copper conductor or that size and the 12 AWG size for wire with an aluminum conductor of that construction shall be capable of complying with the horizontal flame test referenced in 42.1 and shall also be capable of complying with the VW-1 (Vertical-Specimen) Flame Test, Section 1080 of UL 1581. A nylon-jacketed wire or cable is to be tested with the nylon in place. A finished wire or cable with a color overcoating or other extra overall coating is to be tested with the coating. See VW-1 marking provision in 57.1.

Revised 14.1 and heading effective December 19, 1999

41.2 *Deleted effective December 19, 1999*

42 Horizontal-Specimen / FT2 Flame Test

42.1 The horizontal flame test referenced in 41.1 shall be conducted in accordance with Horizontal-Specimen / FT2 Flame Test, Section 1100 of UL 1581.

Revised 42.1 effective December 19, 1999

42.2 *Deleted effective December 19, 1999*

43 Vertical Flame Test

43.1 A vertical specimen of finished single-conductor wire that is of any of the NEC types covered in this Standard or is for use in Type ACTH armored cable, Type UF-B underground feeder cable, or for use in Type NM-B or NMC-B nonmetallic-sheathed cable shall comply with the Vertical Flame Test, Section 1060 of UL 1581. A nylon-jacketed wire is to be tested with the nylon in place. A finished wire with a color overcoating or other extra overall coating is to be tested with the coating. A wire that complies with the VW-1 flame test referenced in 41.1 also complies with the vertical flame test.

Revised 43.1 and heading effective December 19, 1999

44 Vertical-Tray Flame Test

44.1 No. 4 – 1 AWG Type TW, THW, THW-2, THHN, THHW, THWN, THWN-2, PFA, PFAH, and Z insulated equipment-grounding conductors that are colored green in accordance with 59.1, and all No. 1/0 AWG and larger circuit and grounding conductors of the same types, are eligible to be marked (see 63.1 – 63.3) to indicate use in cable trays when the insulation or the insulation and jacket do not exhibit cable damage that reaches the limit for any specimen after two sets of specimens of the specific wire type are tested in accordance with the UL Flame Exposure, Sections 4 – 11 of Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables of UL 1685, or the FT4/IEEE 1202 Type of Flame Exposure, Sections 12 – 19 of UL 1685. Smoke measurements are not applicable.

44.1 revised September 29, 1998

44.2 The results of this test using No. 1/0 AWG conductors are representative of the performance of the specific wire Type for all No. 1/0 AWG and larger sizes. The results of this test using No. 4 AWG conductors are representative of performance of the specific wire Type for all No. 4 AWG and larger size insulated equipment-grounding conductors and all No. 1/0 AWG and larger circuit and grounding conductors.

44.2 revised September 29, 1998

SUNLIGHT-RESISTANCE TEST

45 General

45.1 A wire or cable marked for the sunlight-resistance application indicated in 63.1 (tray use) or 63.3 (messenger use) shall comply with the Carbon-Arc and Xenon-Arc Tests, Section 1200 of UL 1581, using 720 h of either carbon-arc exposure or xenon-arc exposure.

45.1 revised September 29, 1998

45.2 The results of this test using No. 1/0 AWG specimens are to be considered representative of the performance of the finished cable in the range of sizes No. 1/0 AWG and larger.

45A Limited-Smoke Test

45A.1 Multiple-conductor and single-conductor wires and cables of Type THW-2, THW, THHN, THHW, THWN-2, THWN, PFA, PFAH, or Z are eligible to be marked (see 63A.1) to indicate limited smoke (-LS) after sets of specimens as described in 45A.2 are tested in accordance with the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685, and comply with the smoke release and cable damage requirements therein.

45A.1 added September 9, 1999

45A.2 Specimens for Flame-Propagation and Smoke-Release (-LS) testing shall consist of the smallest, largest, and an intermediate size of each construction indicated in 45A.1 plus any other size(s) in each construction that is appropriate because of the cable geometry and/or materials. Only finished cable is to be tested.

45A.2 added September 9, 1999

OIL- AND GASOLINE-RESISTANT WIRES

46 Oil-Resistant Wires

46.1 A thermoplastic-insulated wire is oil-resistant at 60°C (140°F) when the retention of tensile strength and ultimate elongation of the insulation is not less than 50 percent after immersion of the finished wire in oil for 96 h at 100.0 ±1.0°C (212.0 ±1.8°F) as described in 480.6 of UL 1581. The nylon jacket on Type THWN-2, THWN, and THHN is to be intact on the wire during immersion and is to be removed prior to the tensile-strength and ultimate-elongation determinations.

46.2 A wire is oil-resistant at 75°C (167°F) when the retention of tensile strength and ultimate elongation of the insulation is not less than 65 percent after immersion of the finished wire in oil for 60 d at a temperature of 75.0 ±1.0°C (167.0 ±1.8°F) as described in 480.6 of UL 1581. The nylon jacket on Type THWN-2, THWN, and THHN is to be intact on the wire during the immersion and removed prior to the tensile-strength and ultimate-elongation determinations.

No Text on This Page

47 Gasoline-Resistant and Oil-Resistant Type THWN-2 and THWN Wires

47.1 Type THWN-2 or THWN wires in the No. 14 AWG – 1000 kcmil sizes are gasoline-resistant and oil-resistant when the following conditions are met:

a) Type THWN-2 or THWN wire is to comply with all of the requirements applicable to Type THWN-2 or THWN wire, including oil-immersion aging.

b) The percentage of tensile strength and ultimate elongation retained by the insulation after 30 d immersion of the finished wire, as indicated in 480.10 of UL 1581, in water-saturated ASTM Reference Fuel C (see 480.11 of UL 1581 and ASTM D 471-95) at 23.0 ±1.0°C (73.4 ±1.8°F) is not to be less than indicated in Table 50.150 of UL 1581. The nylon jacket is to be intact on the wire during the immersion and removed prior to the tensile strength and ultimate elongation tests. The nylon jacket is to be removed prior to determining the unaged tensile strength and ultimate elongation.

47.1 revised September 29, 1998

48 Reagent Resistant Type TW and ZW Wires

Section 48 deleted September 29, 1998

MECHANICAL TESTS

49 Abrasion Resistance

49.1 The insulation on solid No. 14 AWG conductors for use in Type ACTHH, NM-B, and NMC-B cables and the insulation and nylon jacket on solid No. 14 AWG Type THWN-2, THHN, and THWN wires shall not wear through to expose the conductor on any of six specimens when the specimens are subjected to 800 cycles of the abrasion procedure described in Abrasion Test, Section 1510 of UL 1581.

49.1 revised September 29, 1998

50 Crushing Resistance

50.1 An average of no less than 225 lbf or 1000 N or 102 kgf shall be required to crush solid No. 14 AWG Type THWN-2, THHN, and THWN wires and solid No. 14 AWG insulated conductors for use in Type ACTHH, NM-B, and NMC-B cables until contact is established between the conductor and the earth-grounded flat steel plate or steel rod when ten specimens of the finished wire are subjected to the crushing procedure described in Crushing Resistance Test, Section 595 of UL 1581.

50.1 revised September 29, 1998

51 Impact Resistance

51.1 The insulation and nylon jacket on solid No. 14 AWG Type THWN-2, THHN, and THWN wires and the insulation on solid No. 14 AWG insulated conductors for use in Type ACTHH, NM-B, and NMC-B cables shall keep a free-falling steel weight that impacts the wire or insulated conductor with an energy of 2 ft-lbf or 2.7 J or 0.277 kgf-m from exposing the conductor to view or causing the lamp to light when specimens are subjected to the impact procedure described in Impact Resistance Test, Section 1400 of UL 1581.

51.1 revised September 29, 1998

COLOR COATING

52 General

52.1 When color coding of the thermoplastic-insulated wire is accomplished by means of a surface coating, the coating shall comply with each of the following requirements:

a) The surface-coated thermoplastic-insulated conductor shall comply with the tensile strength and ultimate elongation requirements before and after the 168-h air-oven aging applicable to the insulation.

b) The coating shall not flake off the surface of the insulation when samples of the wire are flexed at room temperature in the manner described in 37.1, 39.1, and 39.2 both before and after the 168-h air-oven aging applicable to the insulation.

c) The surface coating shall not migrate when tested as follows. Two specimens of any convenient length and in contrasting colors, one having the surface color coating and the other uncoated, are to be twisted together for six or more turns having a length of lay not exceeding 20 times the measured overall diameter of one specimen. The twisted conductors are then to be suspended in a full-draft circulating-air oven and conditioned for 7 h at a temperature of 70.0 ±1.0°C (158 ±1.8°F). The specimens are then to be removed from the oven and kept in still air to cool to room temperature for 1 h after which they are to be untwisted and examined. When the coating from the colored specimen has transferred in an amount greater than 15 mils or 0.38 mm in width and/or length to the uncoated specimen, the coating does not comply.

MARKINGS

53 Intervals

53.1 All printing on the outer surface of a wire or cable or anywhere within a wire or cable shall be repeated at the following intervals throughout the length of the wire or cable:

a) Markings on the outer surface of the wire or cable:

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

2) The marking in 70.2 for identification of copper-clad aluminum shall be repeated at intervals that are not longer than 6 inches or 150 mm.

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

b) Size and all other information on a marker tape shall be repeated at intervals that are not longer than a nominal 24 inches or 610 mm (maximum 25 inches or 635 mm).

53.1 revised September 9, 1999

54 Responsible-Organization Identification

54.1 Except as noted in 54.5, each thermoplastic-insulated wire and cable shall have a permanent distinctive marking throughout its entire length to readily identify the wire or cable as the product of the organization that is responsible for the wire or cable. The marking shall consist of one of the following (see also 59.7 for tracer threads in the overall braid) with or without the addition of the colored thread or threads assigned to the organization responsible for the wire or cable (Type FEPB wire is eligible to have the information durably printed on a tape located under the braid and over the insulation). Additional information added shall not confuse or mislead.

a) Readily legible embossing, indelible-ink printing that complies with 55.1, or indent printing that does not reduce the thickness of the insulation below the minimum stated in this Standard.

b) Indent stamping of the metal of a solid conductor in a manner that does not embrittle the conductor metal.

54.2 When the organization responsible for the wire or cable produces thermoplastic-insulated wires in more than one factory, the marking mentioned in 54.1 shall include an identification of the factory. In the case of a colored thread or threads, the ply of the material of one or more of the threads used at each factory shall be different from the ply or material of the same color thread or threads used at every other factory. The organization responsible for the wire or cable shall make available the meaning of the different plies and materials.

54.3 When a glass-fiber thread or threads are employed as the identifying marker, the length of lay of the filaments in each basic strand shall not be longer than 1/3 inch or 8.5 mm.

54.4 The identification of the organization responsible for the wire or cable that is required in 53.1 and provided by means of ink printing, indent printing, stamping, embossing, or a printed tape shall consist of the name of the wire or cable manufacturer, that manufacturer's trade name for the product, or both, or any other appropriate distinctive marking by means of which the organization responsible for the wire or cable is readily identified. When the organization that is responsible for the wire or cable is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by appropriate coding such as by trade name, trademark, the assigned electrical reference number, or the assigned combination of colored marker threads. The meaning of any coded identification shall be made available. It is appropriate also to identify a private labeler; the means is not specified.

54.5 The marking identifying the responsible organization and factory is not required in the case of a wire or cable that is intended for further processing as a component of a cable in another category. In that case, both the component wire or cable and the finished cable shall be produced in the same factory.

55 Indelible-Ink-Printing Test

55.1 Printing of the responsible organization and factory identification required in 54.1 and 54.2 on the outer surface of the thermoplastic insulation, or nylon jacket when a jacket is used, complies when the printing on specimens remains legible after being rubbed repeatedly with a felt-faced weight as described in Durability of Indelible-Ink Printing Test, Section 1690 of UL 1581.

56 Type Letters

56.1 Except as noted in 56.3, a thermoplastic-insulated wire shall have a durable, readily legible surface marking to indicate the type-letter designation for the wire or cable. In the case of a nylon-jacketed wire or cable, the marking shall be on the outside surface of the nylon or on the surface of the insulation and clearly legible through the nylon. In the case of a wire or cable whose outer surface is of PVC, PFA, ETFE, or FEP, the marking shall be on the PVC, PFA, ETFE, or FEP.

56.2 The use of the word ″TYPE″ preceding the type-letter designation is not required. For example, any of the following markings comply: ″TYPE THWN or TYPE THHN″, ″TYPE THHN″, or ″THWN or THHN″.

56.3 The marking to indicate the type-letter designation is not required in the case of a braid-covered wire – that is, from Types TBS and FEPB. Wire intended for use in a cable shall be marked as indicated in Table 56.1.

Table 56.1
Marking of wire intended for use in a cable

Table 56.1 revised September 29, 1998

Cable type	Construction of wire	Designation to be marked on wire
ACTH	Type THW thicknesses using a single or double layer of 75°C (167°F) dry-locations PVC, 82.0°C (179.6°F) dry IR required	″for ACTH″ or none.
	Type THHW	Wire shall not be marked ″THHW″
ACTHH	Type THHN	″THHN″ or none. ″-B″ shall not be used.
	Type TW thicknesses using a PVC for Type THHN	″for ACTHH″ or none. ″-B″ shall not be used
NM-B, NMC-B	Type THHN	Wire shall not be marked ″THHN″ or ″-B″
	Type TW thicknesses using a PVC for Type THHN	″-B″ or none
Multiple-conductor UF-B	Type THWN-2, THWN, or THHN	Wire shall not be marked ″THWN-2, ″THWN″, ″THHN″, ″THWN″ or ″THHN″, or ″-B″
	Type TW thicknesses using a PVC for Type THHN, 50°C (122°F) wet IR required	″-B″ or none.
Multiple-conductor UF	Type TW	″TW″ or none.

57 VW-1 Flame Marking

57.1 NEC types of wire and cable that are marked ″VW-1″ shall comply with the VW-1 flame test in Section 41 and with the horizontal-specimen flame test in Section 42.

Revised 57.1 effective December 19, 1999

58 Size

58.1 All thermoplastic-insulated wires and cables marked with an NEC type-letter designation other than the braided types (TBS and FEPB) shall be legibly marked on the outer surface in durable printing to indicate the AWG or kcmil or MCM size. This marking is not required on a wire or cable intended for further processing. The nominal metric cross-sectional area in square millimeters as shown in UL 1581, Table 20.1, when added, is to be before or after the required size designation, with either the required or metric size in parentheses – for example, ″8 AWG (8.367 mm2)″ or ″8.367 mm2 (8 AWG)″. The abbreviation ″sq mm″ , ″SQ MM″, or ″mm2″ is to be used. Rounding of the metric size is to be in accordance with ASTM E 29-93a to at least three significant figures.

59 Surface Color

59.1 An insulated conductor intended for use as an equipment-grounding conductor shall be finished to show the color green throughout the entire length and circumference of its outer surface with or without one or more straight or helical, broken (non-continuous) or unbroken yellow stripes. See 59.3A for details on stripes. Where there is more than one grounding conductor in an assembly, each must be distinguishable from the other(s) such as, one striped and one not striped. In the case of a flat cable [see 25.1(c)] that includes an insulated equipment-grounding conductor, the grounding conductor shall be identified as such either as indicated above in this paragraph or by means of readily legible, durable ink printing of ″grounding only″ or an equivalent wording on the outer surface of the finished conductor.

59.1 revised May 4, 2001

59.2 An insulated conductor intended for use as a grounded circuit conductor shall be finished to show the color white or natural grey throughout the entire length and circumference of its outer surface, or shall be identified by three continuous straight or helical, unbroken white stripes on other than green insulation, along its entire length. See 59.3A for details on stripes. Straight stripes are to be placed a nominal 120° apart. Where multiple grounded circuit conductors are used in a cable, no more than one shall employ white stripes. A white or natural grey conductor intended for use where different systems are installed in the same raceway, box, gutter, or other wiring enclosure also complies with the intent of this requirement where it has a raised tracer or one or more broken (non-continuous) or unbroken straight or helical stripes that are of a contrasting color other than green or green and yellow (see 59.3A).

59.2 revised May 4, 2001

59.3 An insulated conductor intended for use as an ungrounded insulated circuit conductor shall be finished to show a color or combination of colors other than and in contrast with white, natural grey, or green. The outer surface so colored also complies with the intent of this requirement where it contains any one of the following throughout the length of the wire or cable in a color or combination of colors other than and in contrast with white, natural grey, or green.

a) One or more broken or unbroken straight or helical stripes.

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

c) Numerals, letters, and/or words that comply with this Standard.

See 59.3A for details on stripes.

The markings covered in this paragraph shall not conflict with or be confusable with any of the other markings required or otherwise covered in this Standard.

59.3 revised May 4, 2001

59.3A Stripes as specified in 59.1 – 59.3 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor in the case of a yellow stripe(s) or a total of 15 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor in the case of white stripes, with no individual width less than 5 percent of that same circumference. The width shall be measured perpendicular to each stripe. Where broken stripes are appropriate, they shall consist of a series of identical marks and spaces, the length of each mark shall be at least 1/8 inch or 3 mm and the linear spacing between marks shall not be greater than 3/4 inch or 19 mm.

59.3A added May 4, 2001

59.4 Deleted May 4, 2001

59.5 Deleted May 4, 2001

59.6 Deleted May 4, 2001

59.7 Type TBS or FEPB wire is eligible to have tracer threads in the overall braid as the responsible organization's identifying marker required in 54.1; however, a conductor finished to show a solid color other than white or natural grey shall not have any white or natural grey as a stripe or tracer marking, or otherwise.

60 Oil Resistance

60.1 Wires and cables that comply with the requirements for oil resistance in this Standard are eligible to be durably surface-marked to so indicate. The oil resistance is at the temperature rating of the wire or the cable unless the marking on the wire or the cable specifically designates a different temperature for the oil resistance. See Table 62.1 for the required markings.

61 Type THHN or THWN

61.1 Any Type THHN wire that complies with the requirements in this Standard for Type THWN wire as well as the requirements for Type THHN wire is eligible to be dual marked ″THHN or THWN″.

62 Gasoline and Oil Resistance

62.1 Type THWN-2 and THWN wires that comply with the requirements for gasoline-resistance and oil-resistance in 47.1 are eligible to be durably surface marked as indicated in Table 62.1.

62.1 revised September 29, 1998

Table 62.1
Markings for gasoline- and oil-resistant wires and cable

Table 62.1 revised September 29, 1998

Type Letters	Gasoline-resistant	Oil-resistant		Corresponding surface markings
		60°C (140°F)	75° (167°F)	
TW	–	X	–	Oil resistant I
THW	–	X	–	Oil resistant I
THW	–	–	X	Oil resistant II
THW-2	–	X	–	Oil resistant I
THW-2	–	–	X	Oil resistant II
THWN	–	X	–	Oil resistant I
THWN	–	–	X	Oil resistant II
THWN	X	X	–	Gasoline and oil resistant I
THWN	X	–	X	Gasoline and oil resistant II
THWN-2	–	X	–	Oil resistant I
THWN-2	–	–	X	Oil resistant II
THWN-2	X	X	–	Gasoline and oil resistant I
THWN-2	X	–	X	Gasoline and oil resistant II
THHN	–	X	–	Oil resistant I
THHN	–	–	X	Oil resistant II
THHN or THWN	–	X	–	Oil resistant I
THHN or THWN	–	–	X	Oil resistant II
THHN or THWN	X	X	–	Gasoline and oil resistant I
THHN or THWN	X	–	X	Gasoline and oil resistant II
THHW	–	X	–	Oil resistant I
THHW	–	–	X	Oil resistant II

X indicates that the wire or cable complies with the applicable requirements.

63 Use in Cable Trays

63.1 The designation ″sunlight-resistant, for CT use″ or ″sunlight-resistant, for use in cable trays″ is eligible to be marked on No. 4 – 1 AWG Type TW, THW-2, THW, THHN, THHW, THWN, THWN-2, PFA, PFAH, and Z insulated equipment-grounding conductors that are colored green in accordance with 59.1 and on all No. 1/0 AWG and larger circuit and grounding conductors of the same type when the requirements in Sections 44 and 45 are complied with. These cables are eligible for the additional designation ″FT4/IEEE 1202″ or ″FT4″ where they comply with the FT4/IEEE 1202 test in 44.1 and 44.2.

63.1 revised September 9, 1999

63.2 The designation ″CT use″ or ″for use in cable trays″ is eligible to be marked on No. 4 – 1 AWG Type TW, THW-2, THW, THHN, THHW, THWN, THWN-2, PFA, PFAH, and Z insulated equipment-grounding conductors that are colored green in accordance with 59.1 and on all No. 1/0 AWG and larger circuit and grounding conductors of the same type when the requirements in Vertical-Tray Flame Test, Section 44, are complied with. These cables are eligible for the additional designation ″FT4/IEEE 1202″ or ″FT4″ where they comply with the FT4/IEEE 1202 test in 44.1 and 44.2.

63.2 revised September 9, 1999

63.3 Any size of Type THWN-2, THWN, THHW, THW-2, THW, or TW wire that complies with the sunlight-resistance requirements in 45.1 and is intended for use as messenger-supported wiring that is exposed to the weather is eligible to be marked with the designation ″sun res″ or ″sunlight resistant″.

63.3 revised September 29, 1998

63.4 *Deleted September 29, 1998*

63A Limited-Smoke Markings

63A.1 Multiple-conductor and single-conductor wires and cables of Type THW-2, THW, THHN, THHW, THWN-2, THWN, PFA, PFAH, or Z that comply with the flame-propagation and smoke-release requirements indicated in 45A.1 and 45A.2 are eligible to be marked on the outer surface with the designation ″-LS″. Where used, the ″-LS″ designation shall be added as a suffix immediately following the type letters.

63A.1 and heading added September 9, 1999

64 Extra Markings

64.1 AUTHORIZED SURFACE MARKING – An authorized Canadian Standards Association (CSA) type designation that includes numbers indicative of a temperature rating is eligible to be surface marked on a wire or cable in addition to the markings required in this Standard. The CSA designation shall be clearly associated with CSA and clearly separated by ″or″, a dash, or a wide space from the legend required in this Standard.

64.2 TAG, REEL, OR CARTON MARKING NOT TO BE USED – Any designation that is other than as described in 64.1 and is not completely indicative of the meaning of the National Electrical Code type letters for a wire or cable shall not be marked in words on or in the wire or cable or on any tag, reel, or carton for the wire or cable. For example, the temperature rating ″75C″, the current rating ″40 amps″, and the wording ″heat resistant″ are precluded from a No. 10 AWG copper Type THW wire because, although they are suggestive of the meaning of the H in the type letters, these designations taken alone or together do not account for the type of circuit, the number of conductors, the ambient temperature, and other influences whose consideration is required for determining the correct maximum current for the wire in a particular installation. Such determination can be made only by using the factors found for the wire type in the National Electrical Code.

64.3 AUTHORIZED TEMPERATURE THREAD AND TAG, REEL, OR CARTON MARKING – A temperature marker thread is appropriate for use in a wire or cable of a National Electrical Code type that is additionally authorized for use(s) not covered by the National Electrical Code. Where the non-NEC temperature rating(s) is used in the tag, carton, or reel marking, the marking shall clearly:

a) Tie the rating to the specific non-NEC use to which it applies, and

b) Separate the rating from any NEC type.

For example, a marking such as ″NEC Type ___ ___C AWM CSA Type ___ ___ C″ is not to be used. ″NEC Type ___ for use as appliance-wiring material rated ___C. CSA Type ___ rated ___C.″ is to be used.

65 Other Authorized Extra Markings

65.1 A designation that is not required in this Standard (a part, specification, or catalog designation or a trade name or the like) is authorized in addition to the required markings when the completed legend containing such designation cannot be read as providing the information prohibited in 64.2 and is in no way confusing or misleading.

66 Pump Cable

66.1 Each wire in a cable intended to be used as submersible water-pump cable is eligible to be durably and legibly marked ″pump cable″. In a pump cable without an overall covering, each circuit conductor shall be durably and legibly marked with the conductor type letters. The marking shall be on the outside surface of the nylon or, where the marking is clearly legible through the nylon, on the surface of the insulation.

66.1 revised September 29, 1998

66.2 The outer surface of the overall covering on a pump cable of any of the constructions detailed in 25.1 (a), (c) and (d) shall be durably and legibly marked ″submersible pump cable″. When each circuit conductor is not surface-marked with its type-letter designation, the marking on the outer surface of the pump cable shall include the conductor type letters.

67 Voltage

67.1 Except for the braided types (TBS and FEPB), the surface of a wire not intended for further processing shall be durably and legibly marked ″600 V″ or ″600 volts″.

68 Tag, Reel, or Carton Markings

68.1 A tag on which the following information is indicated plainly (the sequence of the items is not specified) shall be tied to every shipping length of finished wire or cable. However, where the wire or cable is wound on a reel or coiled in a carton, it is appropriate for the tag to be glued, tied, stapled, or otherwise attached to the reel or carton instead of to the wire or cable or, for the tag to be eliminated, and the information printed or stenciled directly onto the reel or carton. Other information, where added, shall not confuse or mislead and shall not conflict with these requirements. See 72.1 for date marking.

a) The maximum voltage for which the wire or cable is rated: ″600 volts″ or ″600 V″.

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

c) *Deleted September 9, 1999*

d) The AWG or kcmil or MCM size of the wire or cable. The nominal metric cross-sectional area, where added, shall be as described in 58.1.

e) The type-letter designation for the wire or cable.

f) The colored-thread marker assigned to identify the organization responsible for the wire or cable where the thread(s) are used in the wire or cable.

g) For submersible water-pump cable:

> ″For use within the well casing for wiring deep-well water-pumps where the cable is not subject to repetitive handling caused by frequent servicing of the pump units.″

68.1 revised September 9, 1999

69 Color Coating

69.1 When color coding of a thermoplastic-insulated wire or cable is accomplished by means of a surface coating, the coating shall comply with the requirements in 52.1.

70 Aluminum and Copper-Clad Aluminum Conductors

70.1 When the conductor of a wire or cable is of aluminum, the AWG or kcmil or MCM size of the conductor – wherever it appears (on tags, reels, cartons, or on or in the wire or cable) – shall be followed by the word ″aluminum″ or the letters ″AL″.

70.2 The outer surface of the insulation or covering over the insulation on each copper-clad aluminum conductor shall be durably and legibly ink printed, indent printed, or embossed at 6-inches or 150-mm or shorter intervals throughout the entire length of the wire or cable with one of the designations ″AL (CU-CLAD)″, ″ALUMINUM (COPPER-CLAD)″, ″CU-CLAD AL″, or ″COPPER-CLAD ALUMINUM″.

70.3 When a copper-clad aluminum conductor is used, the AWG or kcmil or MCM size of the conductor, wherever the size appears (on the tag, reel, or carton, or on or in the wire or cable), shall be followed by one of the designations ″AL (CU-CLAD)″, ″ALUMINUM (COPPER-CLAD)″, ″CU-CLAD AL″, or ″COPPER-CLAD ALUMINUM″. Tags, reels, and cartons for copper-clad aluminum wire and cable shall have the following markings:

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

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

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

71 Compact-Stranded Copper Conductors

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

72 Date of Manufacture

72.1 The date of manufacture by month and year (or in the sequence month, day, and year) shall be included among the tag, reel, or carton markings described in 68.1, or shall be included among the product markings described in this Standard where legible on or through the outer surface of the wire or cable. The date shall be shown in plain language, not in code.

72.1 and heading added September 9, 1999

No Text on This Page

Subjects83(4, 13, 44, 444, 493, 719, 805, 854, 1063, 1072, 1277, 1309, 1424, 1425, 1569, 1651, 1655, 1690, 2250)

1285 Walt Whitman Road
Melville, L.I., NY 11747
August 25, 1997

TO: **Electrical Council of Underwriters Laboratories Inc.**
Industry Advisory Conference of UL for Armored Cable and Cords
Industry Advisory Conference of UL for NM and UF Cables
Industry Advisory Group of UL for Marine Shipboard Cable
Technical Advisory Panel of UL for Power Wires and Cables
Technical Advisory Panel of UL for Communications and Power-Limited Wire and Cable
Subscribers to UL's Listing Services for
Thermoplastic-Insulated Wires
Armored Cable
Power Limited Circuit Cable
Rubber-Insulated Wires
Communications Cable
Underground Feeder and Branch Circuit Cable
Nonmetallic-Sheathed Cable
Miscellaneous Wire
Service Entrance Cable
Machine-Tool Wires
Medium-Voltage Cable
Power and Control Tray Cable
Shipboard Cable, Marine
Power Limited Fire-Alarm Cable
Non-Power-Limited Fire-Alarm Cable
Metal-Clad Cable
Optical Fiber Cable
Community Antenna Television Cable
Data-Processing Cable
Instrumentation Tray Cable

SUBJECT: **Optional Surface Marking for Wire Products Complying with the IEC 332-3 Flame Test**

At the request of wire manufacturers, UL has subjected Listed wires and cables to the flame test described in IEC 332-3, which is the International Electrotechnical Commission Technical Report ″Tests on Electric Cables Under Fire Conditions, Part 3: Tests on Bunched Wires or Cables″. The IEC test method and sampling are different from the UL and FT4/IEEE 1202 vertical-tray flame tests. The results of the IEC test are independent of any required UL flame test.

UL Listed wires and cables that individually comply with the IEC test conducted at UL Northbrook may be surface marked ″IEC 332-3″ at the wire manufacturer's option. Procedure authorization is necessary. This marking is to be placed at the end of the surface legend. ″Complies with IEC 332-3 flame test conducted by Underwriters Laboratories Inc.″ or an equivalent tag marking is required. The IEC test is not required for the basic UL Listing of the wire product.

Wires and cables with the IEC marking will be IEC 332-3 tested in periodic Follow-Up at UL Northbrook.

Manufacturers needing specific details of the IEC 332-3 test should contact Tom Ebert (Extension 43086) or Rick Wadecki (Extension 42276) at UL's Northbrook IL office (847-272-8800).

Manufacturers interested in obtaining authorization in the Follow-Up Service Procedure for the optional IEC tray flame marking on specific wire products should contact Brett Milau at UL's Melville NY office (516-271-6200 Extension 22592) for communications and power-limited cable types, Austin Wetherell at UL's Melville NY office (516-271-6200 Extension 22818) for other wire and cable types, Carl Huang at UL's Santa Clara CA office (408-985-2400 Extension 32810) for wires and cables Listed through UL Santa Clara, or Roger Herb at UL's Camas WA office (360-817-5500 Extension 55657) for wires and cables Listed through UL Camas. Testing is required.

UNDERWRITERS LABORATORIES INC.

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83BUL.W01;WHH;mc

Subjects 44, 62, 83, and 1263

1285 Walt Whitman Road
Melville, L.I., NY 11747
October 30, 1997

TO: Subscribers to UL's Listing Service for Irrigation Cable OFFY

SUBJECT: List of Compounds Acceptable for Irrigation-Cable Jackets

This bulletin supersedes the Underwriters Laboratories Inc. bulletin of July 12, 1994 on the same subject.

The following is a list of commercially available thermoplastic polyethylene (PE) compounds that UL has found to comply with the requirements for the environmental exposure tests described in the revised Outline of Proposed Investigation of Irrigation cables issued under Subjects 514 and 1263 as a bulletin dated April 23, 1980. They have all exhibited 80 percent of original tensile strength and elongation after the exposures. These compounds may be used interchangeably, without submittal to UL's Engineering Services, with the PE compounds covered in the Type L Follow-Up Service Procedure for Irrigation Cable. Acceptability in any cable construction necessitates compliance with the applicable performance requirements for that cable.

PVC compounds, included in previous bulletins under this subject, are now covered in the QMTT2 category, Polymeric Materials For Use on Wire and Cable.

Any manufacturer interested in obtaining Listing for Irrigation Cable, or in having a particular jacketing compound investigated for use on Irrigation Cable, should contact the UL engineering office to which the manufacturer normally makes submittals.

UNDERWRITERS LABORATORIES INC.

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PE (POLYETHYLENE) COMPOUNDS FOR USE AS IRRIGATION CABLE JACKETS

Compound Supplier	Compound Designation	Color	Generic Class
BP Chemicals Americas Inc. 620 Fifth Avenue New York, NY 10020 Mr. Colin D. Garside	DFDG 0588 Black 21	Black	PE
E. I. Du Pont De Nemours & Co., Inc. Polymer Products Department, ELD Div. Barley Mill Plaza Kirk Mill Building Wilmington, DE 19898 Electrical Industry Group (302) 999-4849	Alathon 1250	Black	PE
Union Carbide Corp. Old Ridgebury Road Danbury, CT 06817 Mr. Luke C. Du 203-794-3046	DFDB 0588 DFDD 6059 DGDJ 3479	Black	PE PE PE