

UL 66

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Fixture Wire

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

Until the new edition of UL 62 is published, the Fixture Wire portion of UL 62 should be ignored.

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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.

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

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

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FOREWORD

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

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

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

D. A product 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 This standard states basic construction, test, and marking requirements for fixture wires. Fixture wires are single conductor and are of the following types:

600 volt Types: PTF, PTFP, KF-2, KFF-2, PF, PFF, PGF, PGFF, SF-2, SFF-2, ZF, ZFF, ZHF, TF, TFF, TFN, TFFN, RFH-2, FFH-2, RFHH-2, and RFHH-3

300 volt Types: KF-1, KFF-1, SF-1, SFF-1, XF, and XFF

These types are for use as specified in Article 402 and other applicable parts of the National Electrical Code (NEC), ANSI / NFPA 70-1999. These types are as described individually in index Tables 4.1 – 4.8 of this standard.

2 Units of Measurement

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

3 References

3.1 Whenever 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.

4 Index Tables

4.1 Tables 4.1 – 4.8 each serve as an index to the requirements for construction details, test performance, and marking of the wire types described in the particular table. Each vertical column summarizes and references the requirements that apply to the particular wire whose type letters appear at the top of the column. The applicable paragraphs and tables in this standard (UL 66) are indicated in parenthesis. Square brackets [...] indicate the applicable parts of UL 1581.

Table 4.1
PTFE insulated Types PTF and PTFF^a

Type-letter designation		PTF	PTFF
Maximum temperature		250°C (482°F)	150°C (302°F)
Maximum voltage		600	
CONDUCTOR	Sizes	18, 16, and 14 AWG	
	Metal	Nickel-base alloy or nickel-coated copper (6.1.2)	Nickel-coated copper or silver-coated copper (6.1.2)
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)	Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)
	Size verification	(6.4.1, 6.4.2, and 6.4.3)	(6.4.1 and 6.4.3)
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)	(Table 6.2)
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)	
INSULATION	Material	PTFE [Table 50.219 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, and 8.2.2.4)	
	Minimum average thickness	20.0 mils or 0.51 mm (8.3.1)	
	Minimum thickness at any point	18.0 mils or 0.46 mm (Table 8.1)	
Covering over the insulation		No covering	
TESTS ON FINISHED WIRE	Physical properties tests of insulation	PTFE [Table 50.219 of UL 1581] (8.2.2.1 and 8.2.2.4)	
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)	
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)	
	D-C resistance test of conductor	(12.1 – 12.3)	
	Spark test	(13.1)	
	Deformation test	Not applicable	
	Cold bend test	(15.1 – 15.7)	
	Test for insulation resistance at 60°F	(16.1 and 16.2)	
	Flame tests for VW-1 wire (elective)	(17.1)	
	Vertical flame test (required)	(18.1)	
	Durability test of ink printing	(20.1)	
	MARKINGS	Polarity ID	(21.1)
Legibility of printing		(22.1)	
Sequence of printed markings		No sequence is specified (23.1)	
Responsible organization and factory IDs		(24.1 – 24.3 and 24.5)	
Temperature ID		(25.1 and 25.2)	
ID of VW-1 wire		(27.1)	
Tag, reel, and carton markings		(28.1)	
Current designation		Prohibited (29.1)	
Date of manufacture	(30.1)		

^a Index tables are explained in 4.1.

Table 4.2
Polyimide tape insulated Types KF-1, KF-2, KFF-1, and KFF-2^a

Type-letter designation		KF-1	KF-2	KFF-1	KFF-2
Maximum temperature		200°C (392°F)			
Maximum voltage		300	600	300	600
CONDUCTOR	Sizes	18, 16, 14, 12, and 10 AWG			
	Metal	Nickel-base alloy or nickel- or silver-coated copper (6.1.2)			
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)		Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)	
	Size verification	(6.4.1, 6.4.2, and 6.4.3)		(6.4.1 and 6.4.3)	
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)		(Table 6.2)	
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)			
INSULATION	Material	Polyimide tape			
	Minimum average thickness	KF-1 and KFF-1: 5.5 mils or 0.14 mm KF-2 and KFF-2: 8.4 mils or 0.21 mm (8.3.1)			
	Minimum thickness at any point	KF-1 and KFF-1: 5.0 mils or 0.13 mm KF-2 and KFF-2: 7.6 mils or 0.19 mm (Table 8.1)			
Covering over the insulation		No covering			
TESTS ON FINISHED WIRE	Flexing test of insulation after conditioning	(8.2.1.1 – 8.2.1.6)			
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)			
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)			
	D-C resistance test of conductor	(12.1 – 12.3)			
	Spark test	(13.1)			
	Deformation test	Not applicable			
	Cold bend test	(15.1 – 15.7)			
	Test for insulation resistance at 60°F	(16.1 and 16.2)			
	Flame tests for VW-1 wire (elective)	(17.1)			
	Vertical flame test (required)	(18.1)			
	Durability test of ink printing	(20.1)			

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Table 4.2 Continued

Type-letter designation		KF-1	KF-2	KFF-1	KFF-2
MARKINGS	Polarity ID	(21.1)			
	Legibility of printing	(22.1)			
	Sequence of printed markings	No sequence is specified (23.1)			
	Responsible organization and factory IDs	(24.1 – 24.3 and 24.5)			
	Temperature ID	(25.1 and 25.2)			
	ID of VW-1 wire	(27.1)			
	Tag, reel, and carton markings	(28.1)			
	Current designation	Prohibited (29.1)			
	Date of manufacture	(30.1)			
^a Index tables are explained in 4.1.					

Table 4.3
FEP insulated Types PF, PGF, PFF, and PGFF^a

Type-letter designation		PF	PGF	PFF	PGFF
Maximum temperature		200°C (392°F)		150°C (302°F)	
Maximum voltage		600			
CONDUCTOR	Sizes	18, 16, and 14 AWG			
	Metal	Nickel-base alloy or nickel- or silver-coated copper (6.1.2)		Nickel-base alloy or uncoated or coated copper (6.1.1 and 6.1.2)	
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)		Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)	
	Size verification	(6.4.1, 6.4.2, and 6.4.3)		(6.4.1 and 6.4.3)	
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)		(Table 6.2)	
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)			
INSULATION	Material	FEP [Table 50.73 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, and 8.2.2.4)			
	Minimum average thickness	PF and PFF: 20.0 mils or 0.51 mm PGF and PGFF: 14.0 mils or 0.36 mm (8.3.1)			
	Minimum thickness at any point	PF and PFF: 18.0 mils or 0.46 mm PGF and PGFF: 12.6 mils or 0.32 mm (Table 8.1)			
Covering over the insulation: Elective on Types PF and PFF Required on Types PGF and PGFF		Saturated glass or aramid-fiber braid (10.2.1, 10.2.2, and 10.2.4) Other covering (10.2.5)			
TESTS ON FINISHED WIRE	Physical properties tests of insulation	FEP [Table 50.73 of UL 1581] (8.2.2.1 and 8.2.2.4)			
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)			
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)			
	D-C resistance test of conductor	(12.1 – 12.3)			
	Spark test	(13.1)			
	Deformation test	(14.1 – 14.3)			
	Cold bend test	(15.1 – 15.7)			

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Table 4.3 Continued

Type-letter designation		PF	PGF	PFF	PGFF
	Test for insulation resistance at 60°F	(16.1 and 16.2)			
	Flame tests for VW-1 wire (elective)	(17.1)			
	Vertical flame test (required)	(18.1)			
	Flexing test of covering	(10.2.4 and 10.2.5)			
	Durability test of ink printing	Not applicable			
MARKINGS	Polarity ID	(21.2 and 21.3)			
	Legibility of printing	(22.1)			
	Sequence of printed markings	No sequence is specified (23.1)			
	Responsible organization and factory IDs	(24.1, 24.3, and 24.4)			
	Temperature ID	(25.1 and 25.2)			
	ID of VW-1 wire	(27.1)			
	Tag, reel, and carton markings	(28.1)			
	Current designation	Prohibited (29.1)			
	Date of manufacture	(30.1)			

^a Index tables are explained in 4.1.

Table 4.4
Silicone rubber insulated Types SF-1, SFF-1, SF-2, and SFF-2^a

Type-letter designation		SF-1	SF-2	SFF-1	SFF-2
Maximum temperature		200°C (392°F)		150°C (302°F)	
Maximum voltage		300	600	300	600
CONDUCTOR	Sizes	18 AWG	18, 16, 14, 12, and 10 AWG	18 AWG	18, 16, 14, 12, and 10 AWG
	Metal	Nickel-base alloy or copper coated with nickel or silver (6.1.1 and 6.1.2)		Nickel-base alloy or coated copper (6.1.1 and 6.1.2)	
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)		Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)	
	Size verification	(6.4.1 – 6.4.3)		(6.4.1 and 6.4.3)	
	Maximum length of lay of strands	48 x strand dia (6.3.2)		(Table 6.2)	
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)			
INSULATION	Material	Silicone rubber [Table 50.210 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, 8.2.2.4)			
	Minimum average thickness	SF-1, SFF-1: 15.0 mils or 0.38 mm SF-2, SFF-2: 18, 16, and 14 AWG – 30.0 mils or 0.76 mm 12 and 10 AWG – 45.0 mils or 1.14 mm (8.3.1)			
	Minimum thickness at any point	SF-1, SFF-1: 13.0 mils or 0.33 mm SF-2, SFF-2: 18, 16, and 14 AWG – 27.0 mils or 0.69 mm 12 and 10 AWG – 40.0 mils or 1.02 mm (Table 8.1)			

Table 4.4 Continued on Next Page

Table 4.4 Continued

Type-letter designation		SF-1	SF-2	SFF-1	SFF-2
Covering over the insulation		Lacquered or saturated glass or aramid-fiber braid (10.2.1 – 10.2.4) Other covering (10.2.5)			
TESTS ON FINISHED WIRE	Physical properties tests of insulation	Silicone rubber [Table 50.210 of UL 1581] (8.2.2.1 and 8.2.2.4)			
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)			
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)			
	D-C resistance test of conductor	(12.1 – 12.3)			
	Spark test	(13.1)			
	Deformation test	Not applicable			
	Cold bend test	(15.1 – 15.7)			
	Test for insulation resistance at 60°F	(16.1 and 16.2)			
	Flame tests for VW-1 wire (elective)	(17.1)			
	Vertical flame test (required)	(18.1)			
	Flexing test of covering	(10.2.4 and 10.2.5)			
	Durability test of ink printing	Not applicable			
	MARKINGS	Polarity ID	(21.2 and 21.3)		
Legibility of printing		(22.1)			
Sequence of printed markings		No sequence is specified (23.1)			
Responsible organization and factory IDs		(24.1, 24.3, and 24.4)			
Temperature ID		(25.1 and 25.2)			
ID of VW-1 wire		(27.1)			
Tag, reel, and carton markings		(28.1)			
Current designation		Prohibited (29.1)			
Date of manufacture		(30.1)			

^a Index tables are explained in 4.1.

Table 4.5
ETFE insulated Types ZHF, ZF, and ZFF

Type-letter designation		ZHF	ZF	ZFF
Maximum temperature		200°C (392°F)	150°C (302°F)	
Maximum voltage		600		
CONDUCTOR	Sizes	18, 16, and 14 AWG		
	Metal	Nickel-base alloy or nickel- or silver-coated copper (6.1.2)	Nickel-base alloy or uncoated or coated copper (6.1.1 and 6.1.2)	
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)		Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)
	Size verification	(6.4.1, 6.4.2, and 6.4.3)		(6.4.1 and 6.4.3)
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)		(Table 6.2)
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)		
INSULATION	Material	ETFE [Table 50.64 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, and 8.2.2.4)		
	Minimum average thickness	15.0 mils or 0.38 mm (8.3.1)		
	Minimum thickness at any point	13.0 mils or 0.33 mm (Table 8.1)		
Covering over the insulation		No covering		
TESTS ON FINISHED WIRE	Physical properties tests of insulation	ETFE [Table 50.64 of UL 1581] (8.2.2.1, 8.2.2.3, and 8.2.2.4)		
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)		
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)		
	D-C resistance test of conductor	(12.1 – 12.3)		
	Spark test	(13.1)		
	Deformation test	Not applicable		
	Cold bend test	(15.1 – 15.7)		
	Test for insulation resistance at 60°F	(16.1 and 16.2)		
	Flame tests for VW-1 wire (elective)	(17.1)		
	Vertical flame test (required)	(18.1)		
	Durability test of ink printing	(20.1)		
MARKINGS	Polarity ID	(21.1)		
	Legibility of printing	(22.1)		
	Sequence of printed markings	No sequence is specified (23.1)		
	Responsible organization and factory IDs	(24.1 – 24.3 and 24.5)		
	Temperature ID	(25.1 and 25.2)		
	ID of VW-1 wire	(27.1)		
	Tag, reel, and carton markings	(28.1)		
	Current designation	Prohibited (29.1)		
Date of manufacture	(30.1)			

^a Index tables are explained in 4.1.

Table 4.6
XLPO insulated Types XF and XFF^a

Type-letter designation		XF	XFF
Maximum temperature		150°C (302°F)	
Maximum voltage		300	
CONDUCTOR	Sizes	18, 16, 14, 12, and 10 AWG	
	Metal	Nickel-base alloy or nickel- or silver-coated copper (6.1.2)	Nickel-base alloy or uncoated or coated copper (6.1.1 and 6.1.2)
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)	Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)
	Size verification	(6.4.1, 6.4.2, and 6.4.3)	(6.4.1, and 6.4.3)
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)	(Table 6.2)
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)	
INSULATION	Material	XLPO [Table 50.232 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, and 8.2.2.4)	
	Minimum average thickness	18, 16, and 14 AWG: 30.0 mils or 0.76 mm 12 and 10 AWG: 45.0 mils or 1.14 mm (8.3.1)	
	Minimum thickness at any point	18, 16, and 14 AWG: 27.0 mils or 0.69 mm 12 and 10 AWG: 40.0 or 1.02 mm (Table 8.1)	
Covering over the insulation		No covering	
TESTS ON FINISHED WIRE	Physical properties tests of insulation	XLPO [Table 50.232 of UL 1581] (8.2.2.1 and 8.2.2.4)	
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)	
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)	
	D-C resistance test of conductor	(12.1 – 12.3)	
	Spark test	(13.1 and 13.2)	
	Deformation test	(14.1 – 14.3)	
	Cold bend test	(15.1 – 15.7)	
	Test for insulation resistance at 60°F	(16.1 and 16.2)	
	Flame tests for VW-1 wire (elective)	(17.1)	
	Vertical flame test (required)	(18.1)	
	Durability test of ink printing	(20.1)	
MARKINGS	Polarity ID	(21.1)	
	Legibility of printing	(22.1)	
	Sequence of printed markings	No sequence is specified (23.1)	
	Responsible organization and factory IDs	(24.1 – 24.3 and 24.5)	
	Temperature ID	(25.1 and 25.2)	
	ID of VW-1 wire	(27.1)	
	Tag, reel, and carton markings	(28.1)	
	Current designation	Prohibited (29.1)	
Date of manufacture	(30.1)		

^a Index tables are explained in 4.1.

Table 4.7
PVC insulated Types TF, TFN, TFF, and TFFN^a

Type-letter designation		TF	TFN	TFF	TFFN
Maximum temperature		60°C (140°F)	90°C (194°F)	60°C (140°F)	90°C (194°F)
Maximum voltage		600			
CONDUCTOR	Sizes	18 and 16 AWG			
	Metal	Uncoated or coated copper (6.1.1)			
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)		Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)	
	Size verification	(6.4.1, 6.4.2, and 6.4.3)		(6.4.1, and 6.4.3)	
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)		(Table 6.2)	
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)			
INSULATION	Material	TF and TFF: 60°C PVC [Table 50.183 of UL 1581] TFN and TFFN: 90°C PVC [Table 50.155 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1, 8.2.2.2, and 8.2.2.4)			
	Minimum average thickness	TF and TFF: 30.0 mils or 0.76 mm TFN and TFFN: 15.0 mils or 0.38 mm (8.3.1)			
	Minimum thickness at any point	TF and TFF: 27.0 mils or 0.69 mm TFN and TFFN: 13.0 mils or 0.33 mm (Table 8.1)			
Covering over the insulation		TF and TFF: elective saturated braid (10.1.1 – 10.1.4) TFN and TFFN: nylon jacket (9.1)			
TESTS ON FINISHED WIRE	Physical properties tests of insulation	TF and TFF: 60°C PVC [Table 50.183 of UL 1581] TFN and TFFN: 90°C PVC [Table 50.155 of UL 1581] 8.2.2.1, 8.2.2.2, and 8.2.2.4)			
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)			
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)			
	D-C resistance test of conductor	(12.1 – 12.3)			
	Spark test	(13.1)			
	Deformation test	(14.1 – 14.3)			
	Cold bend test	(15.1 – 15.7)			
	Test for insulation resistance at 60°F	(16.1 and 16.2)			
	Flame tests for VW-1 wire (elective)	(17.1)			
	Vertical flame test (required)	(18.1)			
	Flexing test of covering	Braid: (10.1.4) Nylon jacket: (19.1)			
	Durability test of ink printing	(20.1)			
	MARKINGS	Polarity ID	(21.1 and 21.2)		
Legibility of printing		(22.1)			
Sequence of printed markings		No sequence is specified (23.1)			
Responsible organization and factory IDs		(24.1 – 24.5)			
Temperature ID		(25.1 and 25.2)			
ID of gasoline and oil resistance		TF and TFF: not applicable TFN and TFFN: (26.1)			

Table 4.7 Continued on Next Page

Table 4.7 Continued

Type-letter designation		TF	TFN	TFF	TFFN
	ID of VW-1 wire	(27.1)			
	Tag, reel, and carton markings	(28.1)			
	Current designation	Prohibited (29.1)			
	Date of manufacture	(30.1)			
^a Index tables are explained in 4.1.					

Table 4.8

XL insulated Types RFHH-2 and RFHH-3 and XL or rubber insulated Types RFH-2 and FFH-2^a

Type-letter designation		RFHH-2	RFHH-3	RFH-2	FFH-2
Maximum temperature		90°C (194°F)		75°C (167°F)	
Maximum voltage		600			
CONDUCTOR	Sizes	18 and 16 AWG			
	Metal	Uncoated or coated copper (6.1.1)			
	Stranding	Solid or 7-strand (6.1.1, 6.2.2, and 6.3.1)			Flexible-stranded (6.1.1, 6.2.2, and 6.3.1)
	Size verification	(6.4.1, 6.4.2, and 6.4.3)			(6.4.1, and 6.4.3)
	Maximum length of lay of strands	48 x individual strand diameter (6.3.2)			(Table 6.2)
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)			
INSULATION	Material	RFHH-2 and RFHH-3: 90°C XL [Table 50.231 of UL 1581] RFH-2 and FFH-2: 75°C XL [Table 50.241 of UL 1581] or 75°C EPDM or SBR/NR rubber [Table 50.54 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1 and 8.2.2.4)			
	Minimum average thickness	RFHH-2, RFH-2, and FFH-2: 30.0 mils or 0.76 mm RFHH-3: 45.0 mils or 1.14 mm (8.3.1)			
	Minimum thickness at any point	RFHH-2, RFH-2, and FFH-2: 27.0 mils or 0.69 mm RFHH-3: 40.0 mils or 1.02 mm (Table 8.1)			
Covering over the insulation		RFHH-2, RFHH-3, XL-insulated RFH-2 and FFH-2: elective saturated braid (10.1.1 – 10.1.4) Rubber-insulated RFH-2 and FFH-2: saturated braid or wrap or an extruded covering (10.3.1.1 – 10.3.5.4)			
TESTS ON FINISHED WIRE	Physical properties tests of insulation	RFHH-2 and RFHH-3: 90°C XL [Table 50.231 of UL 1581] RFH-2 and FFH-2: 75°C XL [Table 50.241 of UL 1581] or 75°C EPDM or SBR/NR rubber [Table 50.54 of UL 1581] (8.2.2.1 and 8.2.2.4)			
	Conductor corrosion test	[500.1 of UL 1581] (6.7.1)			
	Continuity test of conductor	(6.5.1, 11.1, and 11.2)			
	D-C resistance test of conductor	(12.1 – 12.3)			
	Spark test	(13.1)			
	Deformation test	Not applicable			
	Cold bend test	(15.1 – 15.7)			
	Test for insulation resistance at 60°F	(16.1 and 16.2)			

Table 4.8 Continued on Next Page

Table 4.8 Continued

Type-letter designation		RFHH-2	RFHH-3	RFH-2	FFH-2
	Flame tests for VW-1 wire (elective)	(17.1)			
	Vertical flame test	RFHH-2 and RFHH-3: required		RFH-2 and FFH-2: not applicable (18.1)	
	Flexing test of covering	Glass braid (10.3.3) Wrap: (10.3.5.3)		Other braid: (10.3.4.4) Extruded covering: (10.3.2.1)	
	Durability test of ink printing	(20.1)			
MARKINGS	Polarity ID	(21.1 and 21.2)			
	Legibility of printing	(22.1)			
	Sequence of printed markings	No sequence is specified (23.1)			
	Responsible organization and factory IDs	(24.1 – 24.5)			
	Temperature ID	(25.1 and 25.2)			
	ID of VW-1 wire	(27.1)			
	Tag, reel, and carton markings	(28.1)			
	Current designation	Prohibited (29.1)			
	Date of manufacture	(30.1)			
^a Index tables are explained in 4.1.					

CONSTRUCTION

5 Materials

5.1 Each material used in a fixture wire shall be applicable for the use and shall be compatible with all of the other materials used in the wire.

6 Conductor

6.1 Metal

6.1.1 Except as noted in 6.1.2, all conductors shall be of soft-annealed copper complying with the American Society for Testing and Materials Standard Specification for Soft or Annealed Copper Wire, ASTM B 3-01. Copper strands that are smaller in diameter than 0.015 inch or 0.38 mm and are uncoated or have a coating of tin complying with the Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes, ASTM B 33-00, or a tin/lead alloy coating complying with the Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, ASTM B 189-95, are for products whose temperature rating does not exceed 150°C (302°F). Uncoated or tin/lead alloy coated or tin-coated solid copper conductors and uncoated or tin/lead alloy coated or tin-coated copper strands whose diameter is at least 0.015 inch or 0.38 mm are for products whose temperature rating does not exceed 200°C (392°F).

6.1.2 Type PTF, KF-1, KF-2, KFF-1, KFF-2, ZHF, SF-1, SF-2, SFF-1, and SFF-2 wires not employing copper shall be of a nickel-base alloy complying with the American Society for Testing and Materials Standard Specification for Nickel Rod and Bar, ASTM B 160-99, and having a tensile strength of 65,000 \pm 15,000 lbf/in² or 448 \pm 103 MN/m² or 44,816 \pm 10,342 N/cm² or 45.7 \pm 10.5 kgf/mm², an elongation of at least 35 percent, and a nominal volume resistivity of 66 ohm \times cmil/ft at 20°C (68°F) or 0.110 ohm \times mm²/m at 20°C (68°F). Where smaller in diameter than 0.015 inch or 0.38 mm, the individual copper strands of the conductor in Type PTF wire and the individual strands of a copper conductor in Type KF-1, KF-2, KFF-1, KFF-2, ZHF, SF-1, and SF-2 wires shall have a nickel coating complying with the Standard Specification for Nickel-Coated Soft or Annealed Copper Wire, ASTM B 355-95, or a silver coating complying with the Standard Specification for Silver-Coated Soft or Annealed Copper Wire, ASTM B 298-99. The conductor in Type ZF, ZFF, XF, XFF, PF, PFF, PGF, and PGFF wires shall be of uncoated copper; of nickel-, silver-, or tin-coated copper; or of a nickel-base alloy – complying as stated in this paragraph and in 6.1.1. A copper conductor in Type PTF wire shall have a nickel coating complying with ASTM B 355-95.

6.2 Sizes

6.2.1 The conductor of a fixture wire shall be of an even-numbered AWG size and shall not be smaller than 18 AWG.

6.2.2 The individual wires used in making up a stranded conductor shall be drawn to an AWG or other specific diameter. The wires in a stranded conductor are not required to be of a single diameter.

6.3 Stranding

6.3.1 The conductor in a fixture wire shall be solid, 7-strand, or flexible-stranded as specified for the type in Table 6.1. The nominal dimensions of the strands are shown in Table 20.5 of UL 1581. The direction of lay of the strands shall be left-hand.

Table 6.1
Conductor stranding

Wire type	Conductor construction (see 6.1.1 and 6.2.2)
Types PF, PGF, RFH-2, RFHH-2, RFHH-3, TF, SF-1, SF-2, TFN, XF, KF-1, KF-2, PTF, ZF, and ZHF	SOLID OR 7-STRAND
Types FFH-2, TFF, TFFN, PFF, PGFF, PTF, SFF-1, SFF-2, XFF, KFF-1, KFF-2, and ZFF	FLEXIBLE STRANDED Smallest AWG strand size: 36 Largest AWG strand size: 26

6.3.2 The length of lay of the strands of a flexible-stranded conductor shall not be longer than specified in Table 6.2. The length of lay of the strands of a 7-strand conductor shall not be more than 48 times the diameter of an individual strand.

Table 6.2
Maximum length of lay of the strands in a flexible-stranded conductor

Conductor size	Types SFF-1, SFF-2, PFF, PGFF, and PTFP		Types FFH-2, TFF, TFFN, KFF-1, KFF-2, ZFF, and XFF	
	1.00 inch	25 mm	2.00 inches	51 mm
18 AWG	1.25	32	2.00	51
16	1.62	41	2.00	51
14	2.00	51	2.00	51
12	2.50	64	2.50	64
10				

6.4 Size verification

6.4.1 Each solid and stranded conductor shall be identified as a particular AWG size in the markings [see 28.1(b)] on or in the wire and on the tag, reel, or carton. The size of a solid conductor shall be verified either by determination of the d-c resistance or by determination of the cross-sectional area by measuring the average diameter as described in 6.4.2. The size of a stranded conductor shall be verified either by determination of the d-c resistance or by determination of the cross-sectional area as described in 6.4.3. Determination of the conductor size by measurement of the direct-current resistance as described in D-C Resistance Test, Section 12, is the referee method in all cases. The size(s) of each type of wire are specified in the index table (Tables 4.1 – 4.8) for the wire type.

6.4.2 Where measured as the means of size verification by cross-sectional area (see 6.4.1), the average diameter of a round solid conductor shall not be smaller than the minimum diameter indicated as 0.99 x nominal for the size in Table 20.1 of UL 1581. The average diameter of the conductor is to be determined and compared with the minimum in Table 20.1 in the following manner:

- a) Measurements of the diameter of a round solid conductor are to be made over the metal-coated or uncoated conductor by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle. The measurements are to be made at a single point on the conductor. The micrometer is to be calibrated to read directly to at least 0.001 inch or 0.01 mm, with each division of a width that facilitates estimation of each measurement to at least 0.001 inch or 0.001 mm. The maximum and minimum diameters at that point are each to be recorded to the nearest 0.0001 inch or 0.001 mm, added together, and divided by 2 without any rounding of the sum or resulting average
- b) Each minimum indicated in Table 20.1 of UL 1581 is absolute. The unrounded average of the two diameter readings is therefore to be compared directly with the minimum indicated as 0.99 x nominal in the table. Where the average diameter is smaller than the minimum in the table, the cross-sectional area of the round solid conductor does not comply as being of the marked AWG size.

6.4.3 Where measured as the means of size verification (see 6.4.1), the cross-sectional area of a stranded conductor shall not be smaller than the minimum area indicated as 0.98 x nominal for the size in Table 20.1 of UL 1581. The cross-sectional area of a stranded conductor is to be determined as the sum of the areas of its component round strands. However, where the sum of the strand areas does not comply, the conductor area is to be determined by the weight method outlined in conductor Cross-Sectional Area by the Weight Method, Section 210 of UL 1581.

6.5 Continuity

6.5.1 The conductor of a fixture wire shall be continuous throughout the entire length of the finished wire as determined by the Conductor Continuity Test, Section 11.

6.6 Joints

6.6.1 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be smooth and shall not have any sharp projections. 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 (strand). A joint shall not reduce or increase the diameter of the conductor or the individual wire (strand). Joints in a stranded conductor shall not be any closer together than two lay lengths. A joint made after insulating shall be made prior to further processing and shall be insulated by applying the original or investigated equivalent insulation material by means of a bonded patch or molding. The insulation applied to a joint shall comply with the requirements in this standard.

6.7 Metal coating

6.7.1 Where the insulation adjacent to a copper conductor is of a material that corrodes unprotected copper in the test described in 500.1 of UL 1581 and a protective separator is not used, the solid conductor and each of the individual strands of a stranded conductor shall separately be covered with a coating of tin complying with the American Society for Testing and Materials Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes, ASTM B 33-00, a coating of a tin/lead alloy complying with the Standard Specification for Lead-Coated or Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, ASTM B 189-95, or a coating of another metal or alloy which shall be investigated. In Type SF-1, SF-2, SFF-1, and SFF-2 silicone-rubber-insulated wires, the solid conductor or each individual strand of a stranded conductor shall be metal-coated as described in this paragraph regardless of whether a separator (not required) is or is not used.

6.7.2 Where the insulation adjacent to a conductor is not of a material that corrodes unprotected copper in the test described in 500.1 of UL 1581, and regardless of whether a separator is used, the solid conductor or the strands of a stranded conductor are not required to be metal-coated. Where a metal coating is used, it shall comply with 6.5.1 in all respects.

7 Separator

7.1 Where insulation is adjacent to an uncoated copper conductor and the insulation is of a material that corrodes the unprotected copper in the test described in 500.1 of UL 1581, a protective separator shall be used between the conductor and the insulation. The separator shall be of an electrically nonconductive material (an insulation grade is not required). The separator shall cover the conductor completely and shall consist of a braid or wrap of fibrous yarn or a longitudinal paper or polyester wrap. The construction details are not specified.

7.2 A separator shall be of a color or colors contrasting with that of the conductor on which it is used. A separator shall not be clear, green, or green and yellow.

7.3 A separator is not required for any purpose other than to protect uncoated copper from corrosion. A separator used where not required shall comply with 7.1 and 7.2 except that it is not required to cover the conductor completely.

8 Insulation

8.1 Material and application

8.1.1 The conductor shall be insulated for its entire length with insulation material specified for the wire type in the applicable index table (Tables 4.1 – 4.8) or investigated as described in 8.1.3 and 8.1.4. The insulation shall be solid, not expanded (foamed). The insulation shall be applied directly to the surface of the conductor or any separator used. The insulation shall cover the conductor or separator completely and shall not have any defects that are visible with normal or corrected vision without magnification.

8.1.2 The insulation shall be applied in a single layer or simultaneously in more than one layer with no layer separable from any other and with each layer of the same base material of the same color or differing only in color. The thickness of the individual layers is not specified.

8.1.3 Each insulation material that fits one of the following descriptions shall be investigated for use in a specific fixture wire type and for the temperature rating required for the type.

a) **NEW MATERIAL** – Material that is generically different from any insulation material named in UL 1581 or for the wire type in the applicable UL 66 index table (Tables 4.1 – 4.8). Investigation of a new material for the requested temperature rating shall be as described in Long-Term Aging, Section 481 of UL 1581. The applicability of the insulation using the new material shall be verified by the investigation outlined in 8.1.4.

b) **NONCOMPLYING UL 1581 MATERIAL THAT IS NAMED IN THE APPLICABLE UL 66 INDEX TABLE** – Material that is named for the wire type in the applicable UL 66 index table (Tables 4.1 – 4.8) yet does not comply with the short-term tests specified for the material in Specific Materials, Section 50 of UL 1581. Investigation of a noncomplying material for the requested temperature rating shall be as described in Long-Term Aging, Section 481 of UL 1581. The thicknesses of the insulation shall be as specified for the wire type in UL 66.

c) **COMPLYING UL 1581 MATERIAL THAT IS NOT NAMED IN THE APPLICABLE UL 66 INDEX TABLE** – Material that is not named for the wire type in the applicable UL 66 index table (Tables 4.1 – 4.8) yet complies with the short-term test requirements tabulated for the requested temperature rating under Specific Materials, Section 50 of UL 1581. Long-term air-oven aging is not required. The applicability of the insulation shall be verified by the investigation outlined in 8.1.4.

8.1.4 Investigation of the electrical, mechanical, and physical characteristics of the wire using a material described in 8.1.3 shall show the material to be comparable in performance to an insulation of material that is named for the wire type in the applicable UL 66 index table (Tables 4.1 – 4.8) and has both the required temperature rating specified in UL 66. The investigation shall include tests such as crushing, abrasion, deformation, heat shock, and dielectric-voltage withstand.

8.2 Properties

8.2.1 Flexing test of polyimide tape insulation

8.2.1.1 Finished Type K-1, K-2, KFF-1, and KFF-2 wires shall be capable, after conditioning, of being wound onto a mandrel without cracking of the inside or outside surface of the insulation. The test is to be conducted as described in 8.2.1.2 – 8.2.1.6.

8.2.1.2 Specimens of the finished insulated conductor are to be conditioned in a full-draft circulating-air oven that complies with 420.9 of UL 1581. The conditioning is to be for 168 h at $232.0 \pm 2.0^{\circ}\text{C}$ ($449.6 \pm 3.6^{\circ}\text{F}$).

8.2.1.3 After removal from the oven, the conditioned specimens are to rest in still air at a room temperature of $23.0 \pm 5.0^{\circ}\text{C}$ ($73.4 \pm 9.0^{\circ}\text{F}$) for 16 – 96 h before being wound onto the mandrel specified in 8.2.1.4.

8.2.1.4 The conditioned and rested specimens are to be wound for six complete turns (adjacent turns touching) onto a round mandrel having a diameter twice that of the diameter measured over the wire insulation.

8.2.1.5 Each specimen is to be unwound before its exterior surface is examined. Each specimen is then to be disassembled before its interior surface is examined.

8.2.1.6 Cracking on the inside surface is to be determined by direct visual examination of the inside surface because both cracking and yield marks (locally strong points) show as circumferential depressions in the outer surface of the polyimide material. Yield marks are not cause for rejection. The examinations are to be made with normal or corrected vision without magnification.

8.2.2 Tensile strength and ultimate elongation tests

8.2.2.1 GENERAL – Insulation other than polyimide tape shall be capable of exhibiting values of tensile strength and ultimate elongation that comply with the limits for unaged and aged specimens shown in the UL 1581 table of physical properties referenced for the material in the index table (Tables 4.1 – 4.8) for the wire type. The insulation from which the test specimens are prepared is to be taken from the finished wire. The specimens are to be prepared and the testing is to be conducted as specified in 8.2.2.2 – 8.2.2.4.

8.2.2.2 TESTS OF TYPES TFN AND TFFN MARKED AS RESISTANT TO OIL OR OIL AND GASOLINE – The PVC insulation in finished Type TFN and TFFN wires that are marked as designated in Table 26.1 for use where exposed to oil or oil and gasoline shall be capable of complying with the applicable tensile strength and elongation limits in Tables 50.150, 50.155, and 50.156 of UL 1581 when conditioned and unconditioned specimens of the insulation from finished wire are tested as specified in 8.2.2.4.

8.2.2.3 BAND MARKINGS – Band-marking inks are to be removed from ETFE insulations prior to the aging of specimens unless the wire manufacturer specifies that the inks are to remain in place.

8.2.2.4 METHOD – The methods of preparation, of selection and conditioning of specimens, and of making the measurements and calculations for tensile strength and ultimate elongation are to be as indicated (beginning with 400.1) under the heading PHYSICAL PROPERTIES OF INSULATION AND JACKET in UL 1581.

8.3 Thicknesses

8.3.1 The average thickness of the insulation on the conductor shall not be less than specified for the particular wire type and size in the applicable index table (Tables 4.1 – 4.8).

8.3.2 The thickness at any point of the insulation on the conductor, corresponding to the average thickness specified for the type and size in the applicable index table (Tables 4.1 – 4.8), shall not be less than indicated in Table 8.1 when measured as described in Thicknesses of Insulation on Flexible Cord and on Fixture Wire, Section 250 of UL 1581.

Table 8.1
Minimum point thickness of insulation

Minimum average thickness specified in index table	Minimum thickness at any point	Minimum average thickness specified in index table	Minimum thickness at any point
5.5 mils	5.0 mils	0.14 mm	0.13 mm
8.4	7.6	0.21	0.19
14.0	12.6	0.36	0.32
15.0	13.0	0.38	0.33
20.0	18.0	0.51	0.46
23.0	21.0	0.58	0.53
30.0	27.0	0.76	0.69
45.0	40.0	1.14	1.02
60.0	54.0	1.52	1.37

9 Jacket on Types TFN and TFFN

9.1 A nylon jacket shall be applied directly over the PVC insulation of wire Types TFN and TFFN. The thickness at any point of the nylon jacket shall not be less than 4 mils or 0.10 mm. Measurements are to be made as described in 280.1 – 280.3 of UL 1581. The finished wire shall be capable of complying with the flexing test described in 19.1.

10 Covering on Other Wire Types

10.1 Elective braid on Types TF, TFF, RFHH-2, and RFHH-3 and on XL-insulated Types RFH-2 and FFH-2

10.1.1 Where employed on wire Types TF, TFF, RFHH-2, and RFHH-3 and on XL-insulated wire Types RFH-2 and FFH-2, a braid shall consist of 150-1/0 or larger fibered-glass yarn in both directions or shall consist of cotton, spun rayon, or silk yarn in both directions or one of these materials in one direction and another of these materials in the other direction. A braid using other textile yarn shall be shown by investigation to be applicable for the particular use – that is, it shall be demonstrated that critical characteristics such as flexibility, temperature rating, and moisture resistance result in a braid comparable to a braid of the named yarn materials.

10.1.2 The braid shall be applied directly to the PVC or XL insulation (percent coverage not specified). The braid shall be fabricated on a machine having the same number of ends per carrier throughout. Each end of glass shall consist of the same size and ply of yarn. Each end of other yarn shall consist of the same kind (soft or glazed), size, and ply of yarn. The angle of weave with reference to the axis of the conductor (lay angle) is not specified.

10.1.3 A glass braid shall be saturated with a moisture-resistant compound (no moisture test, color not specified) or shall be coated with lacquer or varnish. A braid of other than glass shall be saturated with a moisture-resistant compound (no moisture test, color not specified). A finishing compound applied to the surface of a saturated braid shall be wiped to remove any excess.

10.1.4 The finished wire shall be capable of being wrapped tightly around itself for six complete turns (adjacent turns touching) at room temperature without rupture of the threads in the braid.

10.2 Braid or other covering on Types PF, PFF, PGF, PGFF, SF-1, SF-2, SFF-1, and SFF-2

10.2.1 BRAID – Index Table 4.3 indicates that a saturated glass or aramid-fiber braid is elective on wire Types PF and PFF and required on wire Types PGF and PGFF. Index Table 4.4 indicates that a lacquered or saturated glass or aramid-fiber braid is required on wire Types SF-1, SF-2, SFF-1, and SFF-2. A braid on these wires shall consist of 150-1/0 or larger fibered-glass yarn in both directions or of aramid-fiber yarn in both directions, with the aramid-fiber yarn having a diameter not less than 0.0225 inch or 0.57 mm. The diameter of 150-1/0 glass yarn is 0.00750 inch or 0.1905 mm. See 10.2.5.

10.2.2 The braid shall be applied directly to the insulation (percent coverage not specified). The braid shall be fabricated on a machine having the same number of ends per carrier throughout. Each end shall consist of the same size and ply of yarn. The angle of weave with reference to the axis of the conductor (lay angle) is not specified.

10.2.3 The braid shall be lacquered or saturated.

10.2.4 The finished wire shall be capable of being wrapped tightly around itself for six complete turns (adjacent turns touching) at room temperature without rupture of the threads in the braid.

10.2.5 OTHER COVERING – Index Tables 4.3 and 4.4 indicate that a covering other than a braid as described in 10.2.1 – 10.2.4 is an alternate to the elective or required covering on these wire types. Such a covering shall be shown by investigation to be applicable for the particular use – that is, it shall be demonstrated that critical characteristics such as thickness (where applicable), flexibility, and temperature rating result in a covering comparable to a braid that complies with 10.2.1 – 10.2.4.

10.3 Braid, wrap, or extruded covering on rubber-insulated Types RFH-2 and FFH-2

10.3.1 General

10.3.1.1 A fibrous or extruded covering is required over EPDM or SBR/NR rubber insulation on wire Types RFH-2 and FFH-2. These wires shall be covered by the following form of fibrous covering or by an extruded covering complying with 10.3.2.1

- a) SOLID OR 7-STRAND CONDUCTOR – The fibrous covering shall be a braid of textile yarn complying with 10.3.4.1 – 10.3.4.10, a cotton wrap of textile yarn complying with 10.3.5.1 – 10.3.5.5, or a glass braid complying with 10.3.3.1 – 10.3.3.3.
- b) FLEXIBLE-STRANDED CONDUCTOR – A wrap shall not be used. The fibrous covering shall be a braid of textile yarn complying with 10.3.4.1 – 10.3.4.10 or a glass braid complying with 10.3.3.1 – 10.3.3.3.

10.3.2 Extruded covering

10.3.2.1 An extruded covering shall be of nylon or another material (see 21.1, 24.5, and 27.1 regarding visibility of colors and legibility of ink printing through the covering) and shall be shown by investigation to be applicable for the particular use – that is, it shall be demonstrated that critical characteristics such as flexibility, temperature rating, and thickness result in a covering comparable to the braid or wrap specified in 10.3.1.1. The finished wire shall be capable of complying with a flexing test in which the extruded covering does not crack when the wire is wound for six complete turns around a mandrel at room temperature after specimens of the finished wire are aged in a full-draft circulating-air oven. The aging and the flexing are to be conducted as described in 1540.1 of UL 1581.

10.3.3 Glass braid

10.3.3.1 A glass braid shall consist of 150-1/0 or larger fibered-glass yarn in both directions. The braid shall be applied directly to the rubber insulation before or after the rubber is vulcanized. The braid shall be fabricated on a machine having the same number of ends per carrier throughout. Each end shall consist of the same size and ply of yarn. The diameter of 150-1/0 glass yarn is 0.00750 inch or 0.1905 mm. The angle of weave with respect to the longitudinal axis of the wire (lay angle) shall be at least 35° and the coverage in each direction shall be at least 40 percent.

10.3.3.2 The braid shall be saturated with a moisture-resistant compound (no moisture test, color not specified) or shall be coated with lacquer or varnish. A finishing compound applied to the surface of a saturated braid shall be wiped to remove any excess.

10.3.3.3 The finished wire shall be capable of being wound tightly around itself for six complete turns (adjacent turns touching) at room temperature without rupture of the threads in the braid.

10.3.4 Braid of other than glass

10.3.4.1 A braid not of glass shall consist of cotton, spun rayon, or silk yarn in both directions or one of these materials in one direction and another of these materials in the other direction. A braid using other textile yarn shall be shown by investigation to be applicable for the particular use – that is, it shall be demonstrated that critical characteristics such as flexibility, temperature rating, and moisture resistance result in a braid comparable to a braid of the named yarn materials.

10.3.4.2 The braid shall be applied directly to the rubber insulation before or after the rubber is vulcanized. The braid shall be fabricated on a machine having the same number of ends per carrier throughout. Each end shall consist of the same kind (soft or glazed), size, and ply of yarn. Braid measurements and calculations on the finished wire as described in 10.3.4.5 – 10.3.4.7 shall show that the angle of weave with respect to the longitudinal axis of the wire (lay angle) is at least 50° ($\tan \geq 1.1918$) and that the coverage in each direction is at least 76 percent.

10.3.4.3 The braid shall be saturated with a moisture-resistant compound (no moisture test, color not specified) or shall be coated with lacquer. A finishing compound applied to the surface of a saturated braid shall be wiped to remove any excess.

10.3.4.4 The finished wire shall be capable of being wound tightly around itself for six complete turns (adjacent turns touching) at room temperature without rupture of the threads in the braid.

10.3.4.5 The lay angle A is to be determined by calculation using the following formula:

$$\text{Using dimensions in inches: } A = \arctan [\pi N (2 T + D)] / K$$

$$\text{Using metric dimensions: } A = \arctan [\pi N (2 T + D)] / (25.4 K)$$

in which:

N is the number of picks per inch or per centimeter measured as described in 10.3.4.7,

T is the diameter of one end of yarn in inches or millimeters from Table 10.1,

D is the nominal diameter in inches or millimeters from Table 10.2, and

K is the number of carriers in one direction.

10.3.4.6 The percent coverage Q in each direction is to be determined by calculation using the following formula:

$$\text{Using dimensions in inches: } Q = (100 N E T) / (\sin A)$$

$$\text{Using metric dimensions: } Q = (100 N E T) / (25.4 \sin A)$$

in which:

Q is the percent coverage in one direction,

N is the average number of picks per inch or per centimeter determined as described in 10.3.4.7,

E is the number of ends per pick,

T is the diameter of one end of yarn in inches or millimeters from Table 10.1, and

A is the lay angle in degrees determined as described in 10.3.4.5.

10.3.4.7 The outer surface of a specimen having a saturated and finished braid is to be wiped with cloth wet with an organic solvent. The number *N* of picks per inch or per centimeter is then to be measured by means of a standard braid counter at three places that are at least 2 inches or 50 mm apart in any 12-inch or 300-mm section in the center 3 feet or 1 meter of a 5-ft or 1500-mm specimen of the finished braid-covered wire. The average of the three determinations is to be calculated to one decimal place. This average is to be taken as the number of picks per inch or per centimeter for that specimen for use in the calculations described in 10.3.4.5 and 10.3.4.6.

Table 10.1
Diameter of cotton yarn

Size and ply of yarn	Yarn diameter T	
12/1 or 25/2 or 26/2	0.01074 inch	0.2728 mm
14/1 or 30/2	0.00986	0.2504
36/2	0.00875	0.2223
20/1 or 40/2	0.00830	0.2108
25/1 or 26/1 or 50/2	0.00725	0.1842
30/1 or 60/2	0.00673	0.1709
36/1	0.00619	0.1572

Table 10.2
Nominal diameter D calculated over the insulation of Types RFH-2 and FFH-2

Insulated conductor	Nominal D	
18 AWG solid (dia = 0.040 inch) with 30 mils or 0.76 mm of insulation	0.100	2.54
18 AWG 7 strands (dia = 0.046 inch) with 30 mils or 0.76 mm of insulation	0.106	2.69
18 AWG flexible stranding (dia = 0.048 inch) with 30 mils or 0.76 mm of insulation	0.108	2.74
16 AWG solid (dia = 0.051 inch) with 30 mils or 0.76 mm of insulation	0.111	2.82
16 AWG 7 strands (dia = 0.058 inch) with 30 mils or 0.76 mm of insulation	0.118	3.00
16 AWG flexible stranding (dia = 0.060 inch) with 30 mils or 0.76 mm of insulation	0.120	3.05

10.3.4.8 The minimum number of picks per unit width for the most commonly used braids that are woven on a 16-carrier braider is specified in Tables 10.3 (picks per inch) and 10.4 (picks per centimeter) for 18 AWG conductors and in Tables 10.5 (picks per inch) and 10.6 (picks per centimeter) for 16 AWG

conductors. A braid complying with these tables has coverage and a braid angle that comply with 10.3.4.2. Braids are not limited to those covered in the tables. Other braids are required to comply with 10.3.4.1 – 10.3.4.7.

10.3.4.9 The minimum number N of picks per unit width in Tables 10.3 and 10.5 were calculated by means of the following formula except that, in cases in which N from the following formula resulted in a braid angle less than the minimum of 50° specified in 10.3.4.2, the minimum N for the tables was recalculated using the formula in 10.3.4.10:

$$\text{Using dimensions in inches: } N = [Q^2 / (100 E T)^2 - K^2 / \pi^2 (2 T + D)^2]^{1/2}$$

$$\text{Using metric dimensions: } N = 25.4 [Q^2 / (100 E T)^2 - K^2 / \pi^2 (2 T + D)^2]^{1/2}$$

in which:

N is the minimum number of picks per inch or per centimeter,

$Q = 76$, the minimum percent coverage specified in 10.3.4.2,

E is the number of ends per pick,

T is the diameter of one end of yarn in inches or millimeters from Table 10.1,

D is the nominal diameter in inches or millimeters from Table 10.2,

$K = 8$, the number of carriers in one direction from 10.3.4.8.

10.3.4.10 Where the formula in 10.3.4.9 gave a value of N that resulted in the calculation in 10.3.4.5 yielding a lay angle less than the minimum of 50° specified in 10.3.4.2, N was recalculated for Tables 10.3 and 10.5 using the following formula:

$$\text{Using dimensions in inches: } N = (K \tan A) / \pi (2 T + D)$$

$$\text{Using metric dimensions: } N = (25.4 K \tan A) / \pi (2 T + D)$$

in which:

$\tan A = 1.1918$ for the minimum lay angle of 50° , and

N , K , T , and D are as indicated in 10.3.4.9.

Table 10.3
Minimum picks per inch N in commonly used 16-carrier braids over the insulation on 18 AWG
Types RFH-2 and FFH-2

Size/ply	Yarn Number of ends per pick	Minimum <i>N</i>		
		Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	28.5	29.2	29.4
14/1 or 30/2	2 3	32.1 25.3	32.8 24.1	33.0 23.8
36/2	3	19.2	20.2	20.6
20/1 or 40/2	3	26.0	24.8	24.4
25/1 or 26/1 or 50/2	3	26.9	27.8	28.1
30/1 or 60/2	3 4	30.2 26.7	31.0 25.4	31.3 25.0
36/1	4	27.0	25.6	25.2

Table 10.4
Minimum picks per centimeter N in commonly used 16-carrier braids over the insulation on 18
AWG Types RFH-2 and FFH-2

Size/ply	Yarn Number of ends per pick	Minimum <i>N</i>		
		Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	11.2	11.5	11.6
14/1 or 30/2	2 3	12.6 10.0	12.9 9.5	13.0 9.4
36/2	3	7.6	8.0	8.1
20/1 or 40/2	3	10.2	9.8	9.6
25/1 or 26/1 or 50/2	3	10.6	10.9	11.1
30/1 or 60/2	3 4	11.9 10.5	12.2 10.0	12.3 9.8
36/1	4	10.6	10.1	9.9

Table 10.5
Minimum picks per inch N in commonly used 16-carrier braids over the insulation on 16 AWG
Types RFH-2 and FFH-2

Size/ply	Yarn Number of ends per pick	Minimum <i>N</i>		
		Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	29.7	30.3	30.5
14/1 or 30/2	2 3	33.3 23.2	37.6 22.0	34.0 21.7
36/2	3	23.6	22.4	22.2
20/1 or 40/2	3	23.8	24.0	24.2
25/1 or 26/1 or 50/2	3	28.4	29.2	29.4
30/1 or 60/2	3 4	31.6 24.4	32.3 23.1	32.5 22.7
36/1	4	23.1	23.7	23.9

Table 10.6
Minimum picks per centimeter N in commonly used 16-carrier braids over the insulation on 16
AWG Types RFH-2 and FFH-2

Size/ply	Yarn Number of ends per pick	Minimum <i>N</i>		
		Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	11.7	11.9	12.0
14/1 or 30/2	2 3	13.1 9.1	14.8 8.7	13.4 8.5
36/2	3	9.3	8.8	8.7
20/1 or 40/2	3	9.4	9.4	9.5
25/1 or 26/1 or 50/2	3	11.2	11.5	11.6
30/1 or 60/2	3 4	12.4 9.6	12.7 9.1	12.8 8.9
36/1	4	9.1	9.3	9.4

10.3.5 Cotton wrap

10.3.5.1 The cotton wrap specified in 10.3.1.1(a) shall be of 14/1, 30/2, or heavier cotton yarn and shall be closely laid directly onto the rubber insulation before or after the rubber is vulcanized. Binder threads of a fibrous material shall be applied helically in the direction opposite that of the lay of the yarn in the wrap and shall be uniformly spaced. Wrap measurements and calculations on the finished wire as described in 10.3.5.4 and 10.3.5.5 shall show that the angle between the yarn and the longitudinal axis of the wire (lay angle) is at least 33° ($\tan \geq 0.6494$) and that the coverage is at least 80 percent.

10.3.5.2 The wrap shall be saturated with a moisture-resistant compound (no moisture test, color not specified). A finishing compound applied to the surface of the saturated wrap shall be wiped to remove any excess.

10.3.5.3 The finished wire shall be capable of being wound tightly around itself for six complete turns (adjacent turns touching) at room temperature without rupture of the yarn or binder threads in the wrap.

10.3.5.4 The lay angle A is to be determined by calculation using the following formula:

$$A = \arctan [\pi (T - D) / L]$$

in which:

0.00986 inch or 0.2504 mm, the diameter of 14/1 or 30/2 cotton yarn from Table 10.1,

D is the nominal diameter over the insulation (diameter under the wrap) from Table 10.2, and

L is the length of lay in inches or millimeters measured using a specimen of the finished wire at least 20 inches or 500 mm long.

10.3.5.5 The size, number of ends, and length of lay of the yarn used in a wrap shall result in at least the coverage specified in 10.3.5.1 when the coverage is determined by calculation using the following formula:

$$C = (100 E T) / (L \sin A)$$

in which:

C is the percent coverage,

E is the number of ends of yarn in the ribbon,

T is the yarn constant as stated in 10.3.5.4,

L is the length of lay measured as described in 10.3.5.4, and

A is the angle between the yarn and the axis of the wire, calculated as described in 10.3.5.4.

PERFORMANCE

11 Continuity Test of Conductor

11.1 The finished wire shall be tested for continuity of the conductor. The continuity test is to be conducted concurrent with or preceding the Spark Test, Section 13. The continuity test is to be conducted as described in 900.13 – 900.17 of UL 1581 on 100 percent of production by the wire manufacturer at the wire factory.

11.2 The finished wire is to be tested on each master reel before the final rewind operation, or each individual shipping length is to be tested after the final rewind operation. A master reel is any reel containing a single length of finished wire that is intended to be cut into shorter lengths for shipping.

12 D-C Resistance Test of Conductor

12.1 Where measured as the means of size verification (see 6.4.1), the direct-current resistance of any length of conductor in ohms based on 1000 conductor feet or in ohms based on 1000 conductor meters shall not be higher than the following maximum value for the marked size of the solid or stranded construction:

- a) SOLID OR STRANDED COPPER CONDUCTORS THAT ARE UNCOATED OR ARE COATED WITH TIN OR A TIN/LEAD ALLOY – See the maximum value in Table 12.1, 12.2, 12.3, or 12.4 as applicable.
- b) SOLID OR STRANDED COPPER CONDUCTORS THAT ARE COATED WITH SILVER OR NICKEL FOR USE AS STATED IN 6.1.2 – Calculate the maximum value as described in 12.2
- c) CONDUCTORS OF THE NICKEL-BASE ALLOY STATED IN 6.1.2 – Calculate the maximum value as described in 12.2.

See 12.3 regarding measurements at other temperatures. All resistance measurements are to be conducted as described in D-C Conductor Resistance, Section 220 of UL 1581.

12.2 For the silver-coated, nickel-coated, and nickel-base-alloy conductors referenced in 12.1 (b) and (c), the maximum resistance for the marked size of the solid or stranded construction is to be determined by multiplying the maximum resistance for uncoated copper of the same size and construction by the ratio of 100 percent IACS (International Annealed Copper Standard) to the percent conductivity of the conductor under consideration. For example, to determine the maximum resistance R at 25°C (77°F) of a solid 18 AWG conductor with a nickel coating of a thickness equal to 10 percent of the diameter over the conductor, note that Table 12.4 assigns a value of 6.66 ohms per 1000 conductor feet or 21.84 ohms per 100 conductor meters to the uncoated solid copper conductor and that ASTM B 355-95 assigns a conductivity of 88.0 percent to the Class 10 nickel-coated conductor:

$$R_{\max \text{ at } 25^{\circ}\text{C}} = 66.6 \times 100 / 88 = 7.57 \text{ ohms per 1000 conductor feet.}$$

$$R_{\max \text{ at } 25^{\circ}\text{C}} = 21.84 \times 100 / 88 = 24.82 \text{ ohms per 1000 conductor meters.}$$

12.3 A conductor complies without temperature adjustment of the resistance values read where readings at a temperature higher than 20 or 25°C are below the value in the applicable table for 20 or 25°C. All other resistance readings at temperatures higher or lower than 20 or 25°C are to be adjusted to the resistance at 20 or 25°C by means of the applicable multiplying factor from Table 220.1 of UL 1581.

Table 12.1
Maximum direct-current resistance of flexible-stranded copper conductors at 20°C (68°F)

AWG conductor size (single bunch)	Uncoated	Tin / lead coated or tin coated	
		36 – 30 AWG strands	29 – 26 AWG strands
Ohms per 1000 conductor feet			
18	6.66	7.15	7.07
16	4.18	4.49	4.44
14	2.62	2.82	2.79
12	1.65	1.77	1.75
10	1.04	1.12	1.10
Ohms per 1000 conductor meters			
18	21.8	23.4	23.2
16	13.7	14.7	14.6
14	8.59	9.24	9.15
12	5.41	5.82	5.75
10	3.41	3.66	3.62

Table 12.2
Maximum direct-current resistance of flexible-stranded copper conductors at 25°C (77°F)

AWG conductor size (single bunch)	Uncoated	Tin / lead coated or tin coated	
		36 – 30 AWG strands	29 – 26 AWG strands
Ohms per 1000 conductor feet			
18	6.79	7.29	7.21
16	4.26	4.58	4.53
14	2.67	2.87	2.84
12	1.68	1.81	1.79
10	1.06	1.14	1.13
Ohms per 1000 conductor meters			
18	22.3	23.9	23.7
16	14.0	15.0	14.9
14	8.76	9.42	9.33
12	5.52	5.93	5.87
10	3.48	3.73	3.69

Table 12.3
Maximum direct-current resistance of solid and 7-strand copper conductors at 20°C (68°F)

AWG conductor size	Solid		7 Strands	
	Uncoated	Tin / lead coated or tin coated	Uncoated	Tin / lead coated or tin coated
Ohms per 1000 conductor feet				
18	6.53	6.79	6.66	7.07
16	4.10	4.26	4.18	4.44
14	2.57	2.68	2.62	2.73
12	1.62	1.68	1.65	1.72
10	—	—	1.04	1.08
Ohms per 1000 conductor meters				
18	21.42	22.27	21.84	23.20
16	13.45	13.99	13.71	14.57
14	8.44	8.78	8.59	8.95
12	5.31	5.53	5.41	5.64
10	—	—	3.41	3.55

Table 12.4
Maximum direct-current resistance of solid and 7-strand copper conductors at 25°C (77°F)

AWG conductor size	Solid		7 Strands	
	Uncoated	Tin / lead coated or tin coated	Uncoated	Tin / lead coated or tin coated
Ohms per 1000 conductor feet				
18	6.66	6.92	6.79	7.21
16	4.18	4.35	4.26	4.53
14	2.62	2.73	2.67	2.78
12	1.65	1.72	1.68	1.75
10	—	—	1.06	1.10
Ohms per 1000 conductor meters				
18	21.84	22.71	22.27	23.66
16	13.71	14.26	13.98	14.86
14	8.61	8.95	8.76	9.13
12	5.42	5.63	5.52	5.75
10	—	—	3.48	3.62

13 Spark Test

13.1 The insulation on finished fixture wire of every type and size shall withstand without breakdown the application of the 50 – 4000 Hz near sinusoidal rms test potential specified in Table 13.1. The test is to be conducted with the spark-testing equipment described in Method, Section 900 of UL 1581, with 13.2 substituted for 900.12 of UL 1581. The spark test is to be conducted on 100 percent of production by the wire manufacturer at the wire factory. The spark test is to be conducted concurrent with or after the Continuity Test of Conductor, Section 11.

Table 13.1
Spark-test potential

Wire	RMS test potential
Types KF-1, KFF-1, SF-1, SFF-1, XF, and XFF	3000 volts
Types KF-2, KFF-2, RFH-2, FFH-2, RFHH-2, RFHH-3, SF-2, SFF-2, TF, TFF, PF, PFF, PGF, PGFF, PTF, PTFF, TFN, TFFN, ZF, ZFF, and ZHF	6000 volts

13.2 The conductor of the wire shall be earth-grounded during the spark test. Where the conductor coming from the pay-off reel is bare, the conductor shall be earth-grounded at the pay-off reel or at another point at which continuous contact with the bare conductor, prior to the insulating process, is maintained, in which case, testing for continuity or earth-grounding at the take-up reel is not required. Where the conductor coming from the pay-off reel is insulated, an earth-ground connection shall be made at both the pay-off and take-up reels except that, for wire that is tested for continuity with the conductor found to be of one integral length, the earth-ground connection is required to be made at only one point – at either the take-up or pay-off reel. In any case, each earth-ground connection shall be bonded directly to the earth ground in the spark tester.

14 Deformation Test

14.1 The FEP, PVC, and XLPO insulations on finished Type PF, PFF, PGF, PGFF, TFN, TFFN, TF, TFF, XF, and XFF wires shall be capable of decreasing no more in thickness than the percentage specified in Table 14.1 when specimens as described in 14.2 are subjected to the temperature and load specified in Table 14.1. The test is to be conducted and the measurements and calculations are to be made as described under Deformation Test, Section 560 of UL 1581, and in 14.2 and 14.3.

14.2 The specimens in each case are to be 1-inch or 25-mm lengths of the finished wire having a solid conductor. Specimens with stranded conductors are not to be tested. D1 and d are to be measured and T1 is to be calculated as described in 560.1 of UL 1581. The nylon is to be in place on Types TFN and TFFN and all measurements are to be made over the nylon

14.3 An entire diameter of the foot end of the test rod is to be in contact with each specimen during the second hour of heating.

Table 14.1
Deformation test specifications

Material, oven ^a temperature maximum percent decrease	Specimens	Load ^b	
		gf	N
FEP on Types PF, PFF, PGF, and PGFF 121.0 ±1.0°C (249.8 ±1.8°F) 25 percent	Insulation on conductor 18 AWG 16 AWG 14 AWG	500 500 500	4.90 4.90 4.90
PVC on Types TFN and TFFN 136.0 ±1.0°C (276.8 ±1.8°F) 25 percent	Insulation on conductor with nylon in place 18 AWG 16 AWG	300 400	2.94 3.92
PVC on Types TF and TFF 121.0 ±1.0°C (249.8 ±1.8°F) 50 percent	Insulation on conductor 18 AWG 16 AWG	300 400	2.94 3.93
XLPO on Types XF and XFF 121.0 ±1.0°C (249.8 ±1.8°F) 50 percent	Insulation on conductor: 18 AWG 16 AWG 14 – 10 AWG	300 400 500	2.94 3.93 4.90
<p>^a As stated in 560.6 of UL 1581, a full-draft circulating-air oven, a dead-air oven, or an internal-fan oven is to be used in this test.</p> <p>^b The specified load is not the weight to be added to each rod in the test apparatus. The specified load is the total of the weight added and the weight of the individual rod. Because the weight of the rod varies from one apparatus to another and from one rod to another, specifying the exact weight to be added to a rod to achieve the specified load is impractical in all cases except for an individual apparatus and rod.</p>			

15 Cold Bend Test

15.1 The finished wire shall be capable of being wound onto a mandrel at low temperature without cracking of the inside or outside surface of the insulation. The test is to be conducted as described in 15.2 – 15.7.

15.2 Round metal mandrels are to be used in this test. The diameter of mandrel for each diameter (measured) of finished wire, with the nylon jacket in place in the case of Types TFN and TFFN, is to be as specified in Table 15.1. For each winding, the mandrel used is to be securely mounted in a position that facilitates the winding.

15.3 The mandrels and lengths of the finished wire are to be conditioned for 4 h in circulating air that is precooled to and maintained at the following temperature:

- a) WIRE MARKED "50C" OR "MINUS 50C": $-50.0 \pm 2.0^{\circ}\text{C}$ ($-58.0 \pm 3.6^{\circ}\text{F}$).
- b) TYPE PF, PFF, PGF, OR PGFF: $-35.0 \pm 2.0^{\circ}\text{C}$ ($-31.0 \pm 3.6^{\circ}\text{F}$).
- c) ALL OTHER TYPES: $-20.0 \pm 2.0^{\circ}\text{C}$ ($-4.0 \pm 3.6^{\circ}\text{F}$).

15.4 At the end of the fourth hour, the cold specimens are to be wound individually, and in quick succession, onto the specified mandrel for the following number of turns:

- a) SIX COMPLETE TURNS around mandrels 0.250 – 1.250 inch or 6.5 – 31.8 mm in diameter.
- b) ONE COMPLETE TURN around larger mandrels.

15.5 Adjacent turns are to touch one another. The winding is to be at a uniform rate that results in 18 ± 3 seconds for six turns. The winding is to be completed in the cold chamber where space and mounting means are available in the chamber. Where this is not practical, one specimen at a time plus its mandrel are to be removed from the cold chamber and the winding is to be completed outside the chamber. Whether it is done in or out of the chamber, the winding is to be completed within 30 s of the time that the cold chamber is opened for that specimen. Insulating gloves are to be worn by the person performing the test. Where the same diameter of mandrel is used for a succession of specimens tested outside the cold chamber, either a separate mandrel is to be cold conditioned for each specimen or the mandrel used is to be returned to the cold chamber for at least 15 min between tests of successive specimens.

15.6 With a minimum of handling and while still in the coiled form, each specimen is to be slid from its mandrel and placed on a horizontal surface. The specimens are to rest in the coiled form on that surface undisturbed for at least 60 min in still air to warm to a room temperature of $23.0 \pm 5.0^{\circ}\text{C}$ ($73.4 \pm 9.0^{\circ}\text{F}$). Each specimen is then to be examined for cracks on the inside and outside surfaces of the insulation.

15.7 Cracking on the inside surface of nonfluoropolymer insulation is detectable as circumferential depressions in the outer surface of the insulation. Cracking on the inside surface of fluoropolymer insulation is to be determined by direct visual examination of the inside surface because both cracking and yield marks (locally strong points) show as circumferential depressions in the outer surface of the fluoropolymer material. Yield marks are not cause for rejection. The examinations are to be made with normal or corrected vision without magnification.

Table 15.1
Mandrel diameter for the cold-bend test

Measured diameter of the finished wire		Mandrel diameter
inches		
Over	But not	
...	over ...	
0	0.125	0.250
0.125	0.250	0.500
0.250	0.375	0.750
0.375	0.500	1.000
0.500	0.625	1.250
0.625	0.750	1.500
0.750	0.875	1.750
0.875	1.000	2.000
1.000	1.125	2.250
mm		
Over	But not	
...	over ...	
0	3.18	6.5
3.18	6.35	12.7
6.35	9.52	19.0
9.52	12.70	25.4
12.70	15.88	31.8
15.88	19.05	38.0
19.05	22.22	44.5
22.22	25.40	50.8
25.40	28.58	57.1

16 Test for Insulation Resistance at 60.0°F (15.6°C)

16.1 The insulation on the conductor shall be such that the finished wire is capable of exhibiting a value of insulation resistance no lower than indicated in Table 16.1 when measurements are taken on coils of the wire immersed for at least 6 h in tap water at room temperature. The test is to be conducted as described in Insulation-Resistance Test in Water, Section 920 of UL 1581.

16.2 The temperature of the water in which a coil of wire is immersed has a marked effect on the resistance of the insulation. Each insulation-resistance reading taken at a temperature other than 60.0°F (15.6°C) is to be adjusted to what the reading would be at 60.0°F (15.6°C). Adjustment is to be made by means of a multiplying factor M for the insulation material at the reading temperature. M is to be as specified in the Table 16.1 note for the insulation material.

Table 16.1
Minimum insulation resistance

Insulation	Minimum IR	
	Megohms based on 1000 conductor feet	Megohms based on 1000 conductor meters
PVC ^a	2.5	0.762
ETFE ^b	1000	305
Polyimide tape insulation ^b	1000	305
FEP ^b PTFE ^b	1000	305
XLPO ^a XL ^a EPDM ^a SBR/NR ^a	2500	762
Silicone rubber ^c	100	30.5

^a For PVC, XLPO, XL, EPDM, and SBR/NR insulations, the Table 16.2 columns of default M values are to be used or the method described in Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 919 of UL 1581, is to be used to establish a column of M values to use for the particular PVC or thermoset compound.

^b For ETFE, FEP, PTFE, and polyimide tape insulations, M is 1.00 for any room temperature.

^c For silicone rubber insulation, M is 1.00 at any room temperature and the temperature of the water during the final hour of immersion is to be 60.0 ±1.8°F (15.6 ±1.0°C).

Table 16.2
Default columns of multiplying factors M for adjusting insulation-resistance readings to 60.0°F (15.6°C) from another room temperature

Temperature		Default M values	
°F	°C	XLPO, XL, EPDM, or SBR/NR	PVC
50	10.0	0.73	0.79
51	10.6	0.76	0.81
52	11.1	0.78	0.82
53	11.7	0.80	0.84
54	12.2	0.83	0.86
55	12.8	0.86	0.88
56	13.3	0.88	0.90
57	13.9	0.91	0.92
58	14.4	0.94	0.95
59	15.0	0.97	0.97
60	15.6	1.00	1.00
61	16.1	1.03	1.03
62	16.7	1.07	1.06
63	17.2	1.10	1.10
64	17.8	1.13	1.14

Table 16.2 Continued on Next Page

Table 16.2 Continued

Temperature		Default <i>M</i> values	
°F	°C	XLPO, XL, EPDM, or SBR/NR	PVC
65	18.3	1.17	1.19
66	18.9	1.20	1.23
67	19.4	1.24	1.27
68	20.0	1.28	1.38
69	20.6	1.32	1.39
70	21.1	1.36	1.46
71	21.7	1.40	1.56
72	22.2	1.45	1.67
73	22.8	1.50	1.78
74	23.3	1.55	1.91
75	23.9	1.59	2.06
76	24.4	1.64	2.23
77	25.0	1.69	2.39
78	25.6	1.75	2.56
79	26.1	1.80	3.03
80	26.7	1.86	3.21
81	27.2	1.90	3.40
82	27.8	1.97	3.60
83	28.3	2.02	3.82
84	28.9	2.10	4.05
85	29.4	2.15	4.30

17 Flame Tests for VW-1 Wire

17.1 Finished fixture wire that is marked "VW-1" as described in marking 27.1 shall be capable of complying with the VW-1 (Vertical-Specimen) Flame Test, Section 1080 of UL 1581, and shall also be capable of complying with the Horizontal-Specimen / FT2 Flame Test, Section 1100 of UL 1581. Finished wire that is marked "VW-1" and has a nylon jacket or other overall covering that is not required is to be VW-1 and horizontal flame tested both with and without the nylon or other covering.

18 Vertical Flame Test

18.1 Finished fixture wire Types RFHH-2, RFHH-3, KF-1, KF-2, KFF-1, KFF-2, XF, XFF, TF, TFF, TFN, TFFN, PTF, PTFP, PF, PFF, PGF, PGFF, ZF, ZFF, ZHF, SF-1, SF-2, SFF-1, and SFF-2 shall be capable of complying with the Vertical Flame Test, Section 1060 of UL 1581. Types RFH-2 and FFH-2 are not required to comply with any flame test.

19 Flexing Test of Nylon Jacket on Types TFN and TFFN

19.1 Finished fixture wire Types TFN and TFFN shall be capable of having the nylon jacket not crack when specimens of the finished wire are aged and wound onto a mandrel as described in Cracking of Nylon Covering on Coaxial-Cable Members of Elevator Cables or of Nylon Jacket on Types TFN, TFFN, and SPT-1 and of Insulated Conductors in Service Cords, Test, Section 1540 of UL 1581.

20 Durability Test of Ink Printing

20.1 Where the wire markings required in this standard are ink printed on the insulation, jacket, or covering, the printing shall be capable of complying with the test described in Durability of Indelible-Ink Printing, Section 1690 of UL 1581.

MARKINGS

21 Polarity Identification

21.1 Where a wire intended as a grounded circuit conductor has a transparent or translucent nylon jacket or extruded covering over the insulation, or has no covering over the insulation, the wire shall be identified by one of the following color means throughout the entire length of the finished wire. The means used is to show through the nylon jacket or extruded covering. Ridges, grooves, and ink or indent or raised printing of words, numbers, and symbols shall not be used for polarity identification.

- a) The insulation shall be grey or white throughout.
- b) A surface coating on the insulation shall show the color white or grey throughout the entire circumference of the wire.
- c) Three continuous (unbroken) white stripes shall be applied straight or helically on insulation whose surface is not green. Straight stripes shall be applied a nominal 120° apart. The stripes shall be of even or varying width and shall occupy a total of 15 – 70 percent of the calculated circumference of the outer surface of the insulation. An individual stripe shall occupy no less than 5 percent of the indicated circumference, with the width measured perpendicular to the stripe.

21.2 A braid-covered wire intended as a grounded circuit conductor shall be identified as such by one of the following color means throughout the entire length of the finished wire:

- a) The braid shall be finished to show the color white throughout the entire circumference of the wire
- b) The braid shall show a white tracer. The tracer shall be no more than two carriers wide. Where two carriers are used, all ends comprising the tracer shall be applied from adjacent carriers

21.3 The outer surface of a wire intended as an ungrounded circuit conductor shall show a color or combination of colors other than and in contrast with white, grey, green, and green and yellow throughout the entire length of the finished wire.

22 Legibility of Printing

22.1 All forms of printing (ink, indent, embossing) on the wire, anywhere in the wire (including marker tapes), and on tags, reels, and cartons shall be readily legible.

23 Sequence of Printed Markings

23.1 The sequence of printing markings is not specified.

24 Responsible Organization and Factory Identification

24.1 The finished wire shall have a durable, distinctive marking throughout its entire length by means of which the wire is readily identifiable as the product of the organization responsible for the wire. Where the organization responsible for the wire is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by coding such as trade name, trademark, or the assigned electrical reference number. The meaning of any coded identification shall be made available by the organization responsible for the wire. The means of identifying a private labeler is not specified.

24.2 Where ink printing of the organization identification required in 24.1 is not tested on a surface-printed wire, the ink printing shall be supplemented by a thread or threads whose color or combination of colors is assigned to the responsible organization. Where a glass-fiber thread or threads are used, the length of lay of the filaments in each basic strand shall not be longer than 1/3 inch or 8.5 mm. Marker threads are to be located between any braid and the insulation, immediately under the insulation, or under any separator.

24.3 Where the organization responsible for the wire produces fixture wire in more than one factory, the marking in 24.1 shall include an identification of the factory. Where a colored thread or threads are used to supplement ink printing as stated in 24.2, the ply or 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 shall make available the meaning of the different plies and materials. Where there is more than one factory, the absence of a factory identification is a means of identifying one factory.

24.4 For a braid-covered wire, the responsible organization and factory markings shall consist of one of the following:

- a) MARKER TAPE – The name of the actual wire manufacturer, the actual manufacturer's trade name for the wire, or both, or another distinctive designation by means of which the organization responsible for the wire is readily identifiable and, where required in 24.3, identification of the factory. Where the organization responsible for the wire is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by coding such as trade name, trademark, or the assigned electrical reference number. This information shall be durably and legibly printed at intervals no longer than 12 inches or 305 mm on a tape located between the braid and the insulation, immediately under the insulation, or under any separator. For Types SF-1, SF-2, SFF-1, and SFF-2 wires, this information shall be on the tape as described or shall be legibly printed at intervals no longer than 12 inches or 305 mm on the surface of the silicone-rubber insulation (under the

braid). The printing on the silicone insulation is durable where unreeling and straightening a length of the finished wire and then removing the glass braid does not decrease the legibility of the printing.

b) MARKER THREAD(S) – The responsible organization's assigned identifying colored marker thread or threads located between the braid and the insulation, immediately under the insulation, or under any separator.

24.5 For a wire that has a nylon jacket or an extruded covering over the insulation or has no covering over the insulation, the responsible organization and factory markings shall consist of one of the following:

a) PRINTING – The name of the actual manufacturer, the actual manufacturer's trade name for the wire, or both, or another distinctive designation by means of which the organization responsible for the wire is readily identifiable and, where required in 24.3, identification of the factory. Where the organization responsible for the wire is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by coding such as trade name, trademark, or the assigned electrical reference number. This information shall be applied in one of the following forms:

1) ON SURFACE – Durable and legible ink printing, indent printing (the thickness of any nylon jacket shall not be reduced below the required minimum), or embossing on the insulation or nylon jacket or extruded covering at intervals no longer than 12 inches or 305 mm or, where the nylon or extruded covering is transparent, legible ink printing at the same intervals on the insulation under the nylon jacket or extruded covering.

2) ON MARKER TAPE – Durable and legible printing at intervals no longer than 12 inches or 305 mm on a tape located immediately under the insulation or under any separator.

b) MARKER THREAD(S) – The responsible organization's assigned identifying colored marker thread or threads located immediately under the insulation or under any separator. Marker thread(s) shall be used where supplementing ink printing as specified in 24.2 or where there is no covering over insulation that is not printable.

25 Temperature Identification

25.1 Wire of any type that complies with the Cold-Bend Test, Section 15, conducted at -50°C (-58°F) shall be durably and legibly surface marked with the designation " -50C " or "minus 50C" by means of indent, embossed, or ink printing at intervals no longer than 24 inches or 610 mm.

25.2 Unless the type letters are marked on the wire durably and legibly at intervals no longer than 24 inches or 610 mm, the finished wire shall have colored temperature-identification marker threads located immediately under the insulation or under any separator. Temperature marker threads shall not be located between the insulation and any braid, wrap, extruded covering, or nylon jacket. The quantity and color of the threads shall be as specified in Table 25.1.

Table 25.1
Temperature marker threads

Wire type	Temperature limit	Quantity and color of threads
PTF	250°C (482°F)	two black
SF-1 ^a , SF-2 ^a , PF, PGF ZHF, KF-1, KF-2, KFF-1, KFF-2	200°C (392°F)	one black
XF, XFF, SFF-1 ^a , SFF-2 ^a , PFF, PGFF, PTF, ZF, ZFF	150°C (302°F)	one orange
TFN, TFFN, RFHH-2, RFHH-3	90°C (194°F)	one red
RFH-2, FFH-2	75°C (167°F)	one green
TF, TFF	60°C, 140°F)	none

^a The temperature marker thread is not required in silicone-insulated wires in which the wire type letters are durably and legibly printed at intervals no longer than 12 inches or 305 mm on the surface of the insulation.

26 Identification of Types TFN and TFFN That Are Resistant to Oil or Oil and Gasoline

26.1 Type TFN and TFFN wire that comply with the requirements for resistance to oil or oil and gasoline referenced in 8.2.2.2 shall be marked as specified in Table 26.1.

Table 26.1
Markings for oil and gasoline resistance of Types TFN and TFFN

Exposure to be indicated by the marking	Compliance is required with UL 1581 Table 50.155 and also with the UL 1581 tables indicated in this column	Marking required on the nylon jacket or on the surface of the insulation and legible through the nylon jacket ^a
Oil resistant at 75°C (167°F) ^b	Table 50.156	"Oil resistant II"
Oil resistant at 60°C (140°F) ^b	Table 50.156	"Oil resistant I"
Oil resistant at 75°C (167°F) and gasoline resistant ^c	Tables 50.156 and 50.150	"Gasoline and oil resistant II"
Oil resistant at 60°C (140°F) ^c	Tables 50.156 and 50.150	"Gasoline and oil resistant I"

^a The specified marking shall be repeated at intervals no longer than 24 inches or 610 mm.

^b Oil resistance of Types TFN and TFFN is described as resistance to mineral oil at temperatures up to and including the indicated 60 or 75°C limit. The UL 1581 testing specified for establishing oil resistance at 60°C covers resistance to machine-tool cutting oil coolants as well as resistance to mineral oil. Gasoline resistance is separate.

^c Gasoline resistance of Types TFN and TFFN is described as resistance to gasoline vapors at temperatures up to and including the 90°C limit for the wire. Gasoline resistance does not include resistance to immersion in or wetting by gasoline at any temperature. Gasoline resistance does not include resistance to any solvent. Oil resistance is separate.

27 Identification of VW-1 Wire

27.1 Finished wire of any type that complies with the VW-1 and horizontal flame tests referenced in 8.2.1.1 shall be durably and legibly marked as follows:

- a) WIRE WITH NO COVERING OVER THE INSULATION – “VW-1” shall be legibly ink printed at intervals no longer than 24 inches or 610 mm on the outer surface of the insulation.
- b) WIRE HAVING A NYLON JACKET OR EXTRUDED COVERING – “VW-1” shall be legibly and durably ink printed at intervals no longer than 24 inches or 610 mm on the outer surface of the nylon jacket or extruded covering or, where the nylon or extruded covering is transparent (not translucent), shall be legibly ink printed at the indicated intervals on the surface of the insulation under the nylon jacket or extruded covering.
- c) WIRE HAVING A BRAID OR WRAP – “VW-1” shall be durably and legibly ink printed at intervals no longer than 24 inches or 610 mm on the surface of the braid or wrap or at intervals no longer than 12 inches or 305 mm on the surface of the insulation under the braid or wrap. Printing on the insulation is durable when unreeling and straightening a length of the finished wire followed by removal of the braid or wrap does not decrease the legibility of the printing.

28 Tag, Reel, and Carton Markings

28.1 The following information shall be indicated plainly with every shipping length of finished wire (see 30.1 for date marking). The sequence of the items is not specified. Other information, where added, shall not confuse or mislead and shall not conflict with the requirements in this standard. Where the wire is wound on a reel or coiled in a carton, the information is to be printed or stenciled directly onto the reel or carton or the information is to be on a tag tied to the wire or tied, glued, stapled, or otherwise attached to the reel or carton. In the absence of a reel or carton, the information is to be on a tag tied to the wire.

- a) The type-letter designation for the wire.
- b) The AWG size of the wire.
- c) The maximum voltage rating for the particular wire type:

“600 V” or “600 volts” “300 V” or “300 volts”

- d) The name of the actual wire manufacturer, the actual manufacturer’s trade name for the wire, or both, the actual manufacturer’s assigned colored marker thread or combination of colored marker threads where used in the wire, or another distinctive marking by means of which the organization responsible for the wire is readily identifiable. Where the organization responsible for the wire is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by coding such as trade name, trademark, or the assigned electrical reference number. Colored marker thread(s) shall be used in the wire to supplement ink printing as described in 24.2 or where there is no covering over insulation that is not printable. The meaning of any coded identification shall be made available by the organization responsible for the wire. The means of identifying a private labeler is not specified.

29 Current Designation

29.1 No ampacity or other current designation shall appear on or in the finished wire or on the tag, reel, or carton for the wire. A part, specification, catalog, or other number or designation that is not required yet is used in addition to the required wire and tag, reel, or carton markings shall not result in the completed legend containing any statement construable as a current designation.

30 Date of Manufacture

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