UL 66

STANDARD FOR SAFETY

Fixture Wire

UL Standard for Safety for Fixture Wire, UL 66

Third Edition, Dated January 18, 2023

Summary of Topics:

This revision of ANSI/UL 66 dated July 17, 2024 includes changes for Gasoline Resistance Rating, revising Table 27.1.

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated June 14, 2024.

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ANSI/UL 66-2024

UL 66

Standard for Fixture Wire

First Edition – April, 2002
Second Edition – June, 2018

Third Edition

January 18, 2023

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through July 17, 2024.

The most recent designation of ANSI/UL 66 as an American National Standard (ANSI) occurred on July 17, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

MARKINGS

ANNEX A (normative) – U.S. GOVERNMENT REQUIREMENTS AND ORDERING INSTRUCTIONS FOR ACQUISITION OF FIXTURE WIRE

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, PTFF, PAF, PAFF, KF-2, KFF-2, PF, PFF, PGF, PGFF, SF-2, SFF-2, ZF, ZFF, ZHF, TF, TFF, TFN, TFFN, RFH-2, FFH-2, FFHH-2, HF, HFF, RFHH-2, and RFHH-3
300 volt Types:	KF-1, KFF-1, SF-1, SFF-1, RFH-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. These types are as described individually in index Table 4.1 – Table 4.10 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. Whenever the designation UL 2556 is used, reference is to be made to the designated sections of UL 2556, the Standard for Wire and Cable Test Methods.

4 Index Tables

4.1 Table 4.1 – Table 4.10 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)	
	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	(22.1)	
	Legibility of printing	(23.1)	
	Sequence of printed markings	No sequence is specified (24.1)	
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)	
	Temperature ID	(26.1 and 26.2)	
	ID of VW-1 wire	(28.1)	
	Tag, reel, and carton markings	(29.1)	
	Current designation	Prohibited (30.1)	
	Date of manufacture	(31.1)	

[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)			
	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	(22.1)			
	Legibility of printing	(23.1)			
	Sequence of printed markings	No sequence is specified (24.1)			
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)			
	Temperature ID	(26.1 and 26.2)			
	ID of VW-1 wire	(28.1)			
	Tag, reel, and carton markings	(29.1)			
	Current designation	Prohibited (30.1)			
	Date of manufacture	(31.1)			

[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 (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 (uncoated copper only)	Not applicable		(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	(10.2.4 and 10.2.5)			
	Durability test of ink printing	Not applicable			
MARKINGS	Polarity ID	(22.2 and 22.3)			
	Legibility of printing	(23.1)			
	Sequence of printed markings	No sequence is specified (24.1)			
	Responsible organization and factory IDs	(25.1, 25.3, and 25.4)			
	Temperature ID	(26.1 and 26.2)			

Table 4.3 Continued on Next Page

Table 4.3 Continued

Type-letter designation		PF	PGF	PFF	PGFF
	ID of VW-1 wire	(28.1)			
	Tag, reel, and carton markings	(29.1)			
	Current designation	Prohibited (30.1)			
	Date of manufacture	(31.1)			
[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 tin, nickel, or silver (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, 14, and 12 AWG – 30.0 mils or 0.76 mm 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, 14, and 12 AWG – 27.0 mils or 0.69 mm 10 AWG – 40.0 mils or 1.02 mm (Table 8.1)			
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)			
	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			
	Flexibility of finished wire	[1560.1 of UL 1581]			
	Test for insulation resistance at 60 °F	(16.1 and 16.2)			

Table 4.4 Continued on Next Page

Table 4.4 Continued

Type-letter designation		SF-1	SF-2	SFF-1	SFF-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	(22.2 and 22.3)			
	Legibility of printing	(23.1)			
	Sequence of printed markings	No sequence is specified (24.1)			
	Responsible organization and factory IDs	(25.1, 25.3, and 25.4)			
	Temperature ID	(26.1 and 26.2)			
	ID of VW-1 wire	(28.1)			
	Tag, reel, and carton markings	(29.1)			
	Current designation	Prohibited (30.1)			
	Date of manufacture	(31.1)			

[a] Index tables are explained in 4.1.

Table 4.5
ETFE insulated Types ZHF, ZF, and ZFF[a]

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 (8.2.2.16.3.2)		(Table 6.2)
	General	Continuity, joints, metal coating, and separator (6.5.1 – 7.3)		
INSULATION	Material	ETFE [Tables 50.64 (200 °C), 50.63 (150 °C) of UL 1581] (8.1.1 – 8.1.4, , 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 [Tables 50.64 (200 °C), 50.63 (150 °C) of UL 1581] (8.2.2.1, 8.2.2.3, and 8.2.2.4)		

Table 4.5 Continued on Next Page

Table 4.5 Continued

Type-letter designation		ZHF	ZF	ZFF
	Conductor corrosion test (uncoated copper only)	Not applicable	(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	(22.1)		
	Legibility of printing	(23.1)		
	Sequence of printed markings	No sequence is specified (24.1)		
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)		
	Temperature ID	(26.1 and 26.2)		
	ID of VW-1 wire	(28.1)		
	Tag, reel, and carton markings	(29.1)		
	Current designation	Prohibited (30.1)		
	Date of manufacture	(31.1)		

[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	

Table 4.6 Continued on Next Page

Table 4.6 Continued

Type-letter designation		XF	XFF
		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 (uncoated copper only)	Not applicable	(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	(22.1)	
	Legibility of printing	(23.1)	
	Sequence of printed markings	No sequence is specified (24.1)	
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)	
	Temperature ID	(26.1 and 26.2)	
	ID of VW-1 wire	(28.1)	
	Tag, reel, and carton markings	(29.1)	
	Current designation	Prohibited (30.1)	
	Date of manufacture	(31.1)	

[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)	

Table 4.7 Continued on Next Page

Table 4.7 Continued

Type-letter designation		**TF**	**TFN**	**TFF**	**TFFN**
	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 50.182 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 – 21.1) TFN and TFFN: nylon jacket (9.1)			
TESTS ON FINISHED WIRE	Physical properties tests of insulation	TF and TFF: 60 °C PVC [Table 50.182 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 (uncoated copper only)	(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: (21.1) Nylon jacket: (19.1)			
	Durability test of ink printing	(20.1)			
	Rupture of braid	(21.1)			
MARKINGS	Polarity ID	(22.1 and 22.2)			
	Legibility of printing	(23.1)			
	Sequence of printed markings	No sequence is specified (24.1)			
	Responsible organization and factory IDs	(25.1 – 25.5)			
	Temperature ID	(26.1 and 26.2)			
	ID of gasoline and oil resistance	TF and TFF: not applicable TFN and TFFN: (27.1)			

Table 4.7 Continued on Next Page

Table 4.7 Continued

Type-letter designation		TF	TFN	TFF	TFFN
	ID of VW-1 wire	(28.1)			
	Tag, reel, and carton markings	(29.1)			
	Current designation	Prohibited (30.1)			
	Date of manufacture	(31.1)			
[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-1, RFH-2, FFH-2 and FFHH-2[a]

Type-letter designation		RFHH-2	RFHH-3	RFH-1	RFH-2	FFH-2	FFHH-2
Maximum temperature		90 °C (194 °F)		75 °C (167 °F)			90 °C (194 °F)
Maximum voltage		600		300	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-3: 90 °C XL [Table 50.231 of UL 1581] or silicone rubber [Table 50.206 of UL 1581] RFHH-2: 90 °C XL [Table 50.231 of UL 1581] RFH-1, 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] FFHH-2: 90 °C XL [Table 50.237 of UL 1581] (8.1.1 – 8.1.4, 8.2.2.1 and 8.2.2.4)					
	Minimum average thickness	RFH-1: 15 mils or 0.38 mm RFHH-2, RFH-2, FFH-2 and FFHH-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	RFH-1: 13 mils or 0.33 mm RFHH-2, RFH-2, FFH-2 and FFHH-2: 27.0 mils or 0.69 mm RFHH-3: 40.0 mils or 1.02 mm (Table 8.1)					
Covering over the insulation		Silicone-insulated RFHH-3: extruded covering (10.3.1.1 and 10.3.2.1) RFHH-2 and XL-insulated RFHH-3, RFH-1, RFH-2, FFH-2 and FFHH-2: elective saturated braid (10.1.1 – 21.1) Rubber-insulated RFH-1, RFH-2, FFH-2 and FFHH-2: saturated braid or wrap or an extruded covering (10.3.1.1 – 10.3.5.4)					

Table 4.8 Continued on Next Page

Table 4.8 Continued

Type-letter designation		RFHH-2	RFHH-3	RFH-1	RFH-2	FFH-2	FFHH-2
TESTS ON FINISHED WIRE	Physical properties tests of insulation	RFHH-3: 90 °C XL [Table 50.231 of UL 1581] or silicone rubber [Table 50.206 of UL 1581] RFHH-2: 90 °C XL [Table 50.231 of UL 1581] RFH-1, 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] FFHH-2: 90 °C XL [Table 50.237 of UL 1581] (8.2.2.1 and 8.2.2.4)					
	Conductor corrosion test (uncoated copper only)	(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	RFHH-2 and RFHH-3: required RFH-1, RFH-2, FFH-2, and FFHH-2: not applicable (18.1)					
	Flexing test of covering	Glass braid: (10.3.3) Other braid: (10.3.4.4) Wrap: (10.3.5.3) Extruded covering: (10.3.2.1)					
	Durability test of ink printing	(20.1)					
	Rupture of Braid	(21.1)					
MARKINGS	Polarity ID	(22.1 and 22.2)					
	Legibility of printing	(23.1)					
	Sequence of printed markings	No sequence is specified (24.1)					
	Responsible organization and factory IDs	(25.1 – 25.5)					
	Temperature ID	(26.1 and 26.2)					
	ID of VW-1 wire	(28.1)					
	Tag, reel, and carton markings	(29.1)					
	Current designation	Prohibited (30.1)					
	Date of manufacture	(31.1)					

[a] Index tables are explained in 4.1.

Table 4.9
PTFE insulated Types PAF and PAFF[a]

Type-letter designation		PAF	PAFF
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 (6.1.1, 6.2.2, and 6.3.1)	Nickel-coated copper or silver-coated copper (6.1.1, 6.1.2, and 6.3.1)
	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	ECTFE [Table 50.63 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: 15.0 mils or 0.38 mm	
	Minimum thickness at any point	18, 16, and 14 AWG: 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	ECTFE [Table 50.63 of UL 1581] (8.2.2.1 and 8.2.2.4)	
	Conductor corrosion test (uncoated copper only)	(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	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 (optional)	(17.1)	
	Vertical flame test (required)	(18.1)	
	Durability test of ink printing	(20.1)	
MARKINGS	Polarity ID	(22.1)	
	Legibility of printing	(23.1)	
	Sequence of printed markings	No sequence is specified (24.1)	
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)	
	Temperature ID	(26.1 and 26.2)	
	ID of VW-1 wire	(28.1)	
	Tag, reel, and carton markings	(29.1)	
	Current designation	Prohibited (30.1)	
	Date of manufacture	(31.1)	

[a] Index tables are explained in 4.1.

[b] Table 50.137 specifies aging 200 °C material for 96 hours at 260 °C. This aging applies to the insulation on Type PAFF.

Table 4.10
ECTFE insulated Types HF and HFF[a]

Type-letter designation		HF	HFF
Maximum temperature		150 °C (302 °F)	
Maximum voltage		600	
CONDUCTOR	Sizes	18, 16, and 14 AWG	
	Metal	Nickel-based alloy or tin, nickel or silver coated or uncoated 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	ECTFE [Table 50.63 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: 15.0 mils or 0.38 mm	
	Minimum thickness at any point	18, 16, and 14 AWG: 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	ECTFE [Table 50.63 of UL 1581] (8.2.2.1 and 8.2.2.4)	
	Conductor corrosion test (uncoated copper only)	(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	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 (optional)	(17.1)	
	Vertical flame test	(18.1)	
	Durability test of ink printing	(20.1)	
MARKINGS	Polarity ID	(22.1)	
	Legibility of printing	(23.1)	
	Sequence of printed markings	No sequence is specified (24.1)	
	Responsible organization and factory IDs	(25.1 – 25.3 and 25.5)	
	Temperature ID	(26.1 and 26.2)	
	ID of VW-1 wire	(28.1)	
	Tag, reel, and carton markings	(29.1)	
	Current designation	Prohibited (30.1)	
	Date of manufacture	(31.1)	

[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 Types PTF, PAF, 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 ±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 %, and a nominal volume resistivity of 66 ohm×cmil/ft at 20 °C (68 °F) or 0.110 $ohm×mm^2/m$ 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 PTFF and PAFF wires 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, HF, HFF, 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 and PAF wires 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-1, RFH-2, RFHH-2, RFHH-3, TF, SF-1, SF-2, TFN, XF, KF-1, KF-2, PTF, PAF, ZF, HF, and ZHF	SOLID OR 7-STRAND
Types FFH-2, FFHH-2, TFF, TFFN, PFF, PGFF, PTFF, PAFF, SFF-1, SFF-2, XFF, KFF-1, KFF-2, HFF, 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, PTFF, and PAFF		Types FFH-2, FFHH-2, TFF, TFFN, KFF-1, KFF-2, ZFF, HFF, and XFF	
18 AWG	1.00 inch	25 mm	2.00 inches	51 mm
16	1.25	32	2.00	51
14	1.62	41	2.00	51
12	2.00	51	2.00	51
10	2.50	64	2.50	64

6.4 Size verification

6.4.1 Each solid and stranded conductor shall be identified as a particular AWG size in the markings [see 29.1(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 (Table 4.1 – Table 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 mass (weight) Method, in UL 2556.

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 Copper corrosion, in UL 2556 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 Copper corrosion, in UL 2556, 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 Copper corrosion, in UL 2556, 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 (Table 4.1 – Table 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 the tables in Section 50 of UL 1581 or for the wire type in the applicable UL 66 index table (Table 4.1 – Table 4.8). Investigation of a new material for the requested temperature rating shall be as described in test, Dry temperature rating of new materials (long-term aging test), in UL 2556. 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 (Table 4.1 – Table 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 test, Dry temperature rating of new materials (long-term aging test), in UL 2556. 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 (Table 4.1 – Table 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 (Table 4.1 – Table 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 forced air-circulating oven that complies with the requirements described in the test Physical properties (ultimate elongation and tensile strength) in UL 2556. The conditioning is to be for 168 h at 232.0 ±2.0 °C (449.6 ±3.6 °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 ±5.0 °C (73.4 ±9.0 °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 (Table 4.1 – Table 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 27.1 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 shall be determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556. IRM 902 oil is to be used in the testing for oil resistance.

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 (Table 4.1 – Table 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 (Table 4.1 – Table 4.8), shall not be less than indicated in Table 8.1 when measured in accordance with the test, Thickness, as described in UL 2556.

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 in accordance with the test, Thickness, as described in UL 2556. 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, and RFHH-2 and on XL-insulated Types RFHH-3, RFH-1, RFH-2, FFH-2, and FFHH-2

10.1.1 Where employed on wire Types TF, TFF, and RFHH-2 and on XL-insulated wire Types RFHH-3, RFH-1, RFH-2, FFH-2, and FFHH-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.

10.2 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 Table 4.3 and Table 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 Extruded covering on silicone-insulated Type RFHH-3 and braid, wrap, or extruded covering on rubber-insulated Types RFH-1, RFH-2, FFH-2, and FFHH-2

10.3.1 General

10.3.1.1 An extruded covering complying with 10.3.2.1 is required over silicone rubber insulation on wire Type RFHH-3. A fibrous or extruded covering is required over EPDM or SBR/NR rubber insulation on wire Types RFH-1, RFH-2, FFH-2, and FFHH-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 22.1, 25.5, and 28.1 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 for the same time and temperature as is required for the Physical Properties Test. The test shall be conducted in accordance with the test Bend Test on Nylon Covered Conductors after aging as described in UL 2556.

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 %.

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 ≥ 1.1918) and that the coverage in each direction is at least 76 %.

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:

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

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

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:

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

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-1, RFH-2, FFH-2, and FFHH-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 Table 10.3 (picks per inch) and Table 10.4 (picks per centimeter) for 18 AWG conductors and in Table 10.5 (picks per inch) and Table 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 Table 10.3 and Table 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:

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

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 Table 10.3 and Table 10.5 using the following formula:

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

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-1, RFH-2, FFH-2, and FFHH-2

Yarn		Minimum *N*		
Size/ply	Number of ends per pick	Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	28.5	29.2	29.4
14/1 or	2	32.1	32.8	33.0
30/2	3	25.3	24.1	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	3	30.2	31.0	31.3
60/2	4	26.7	25.4	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-1, RFH-2, FFH-2, and FFHH-2

Yarn		Minimum *N*		
Size/ply	Number of ends per pick	Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	11.2	11.5	11.6
14/1 or	2	12.6	12.9	13.0
30/2	3	10.0	9.5	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	3	11.9	12.2	12.3
60/2	4	10.5	10.0	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-1, RFH-2, FFH-2, and FFHH-2

Yarn		Minimum *N*		
Size/ply	Number of ends per pick	Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	29.7	30.3	30.5
14/1 or	2	33.3	37.6	34.0
30/2	3	23.2	22.0	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	3	31.6	32.3	32.5
60/2	4	24.4	23.1	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-1, RFH-2, FFH-2, and FFHH-2

Yarn		Minimum *N*		
Size/ply	Number of ends per pick	Solid	7 Strands	Flexible stranding
12/1 or 25/2 or 26/2	2	11.7	11.9	12.0
14/1 or	2	13.1	14.8	13.4
30/2	3	9.1	8.7	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	3	12.4	12.7	12.8
60/2	4	9.6	9.1	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 ≥ 0.6494) and that the coverage is at least 80 %.

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 accordance with the test, Continuity, Method 1 (general) or Method 2 (eddy current), in UL 2556 on 100 % 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, Table 12.2, Table 12.3, or Table 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 in accordance with the test, DC Resistance, in UL 2556.

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 % 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 % 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 % to the Class 10 nickel-coated conductor:

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

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

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 the table titled ‘Adjustment factors for dc resistance of conductors’ in UL 2556.

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

Table 12.1 Continued on Next Page

Table 12.1 Continued

AWG conductor size (single bunch)	Uncoated	Tin / lead coated or tin coated	
		36 – 30 AWG strands	29 – 26 AWG strands
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

Table 12.3 Continued on Next Page

Table 12.3 Continued

AWG conductor size	Solid		7 Strands	
	Uncoated	Tin / lead coated or tin coated	Uncoated	Tin / lead coated or tin coated
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 in accordance with the test, Spark, in UL 2556, with 13.2 superseding the requirements in UL 2556. The spark test is to be conducted on 100 % 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-1, RFH-2, FFH-2, FFHH-2, RFHH-2, RFHH-3, SF-2, SFF-2, TF, TFF, PF, PFF, PGF, PGFF, PTF, PTFF, PAF, PAFF, TFN, TFFN, HF, HFF, 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 in accordance with the test, Deformation, described in UL 2556, 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. Testing of a solid conductor represents identical constructions using a stranded conductor. 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 %	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 %	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 %	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 %	Insulation on conductor: 18 AWG 16 AWG 14 – 10 AWG	 300 400 500	 2.94 3.93 4.90

Table 14.1 Continued on Next Page

Table 14.1 Continued

Material, oven[a] temperature maximum percent decrease	Specimens	Load[b]	
		gf	N

[a] A forced air-circulating oven, a dead-air oven, or an internal-fan oven may be used in this test.

[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.

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 ±2.0 °C (−58.0 ±3.6 °F).

b) TYPE PF, PFF, PGF, OR PGFF: −35.0 ±2.0 °C (−31.0 ±3.6 °F).

c) ALL OTHER TYPES: −20.0 ±2.0 °C (−4.0 ±3.6 °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 ±5.0 °C (73.4 ±9.0 °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, Method 1 (15 °C in water), in UL 2556.

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] PFA[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, PFA, ECTFE 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