

UL 44

ISBN 0-7629-0400-3

Thermoset-Insulated Wires and Cables

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety for Thermoset-Insulated Wires and Cables, UL 44

Fifteenth Edition, Dated March 22, 1999

Revisions: This Standard contains revisions through and including May 13, 2002.

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

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

The revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated December 7, 2001. The bulletin(s) is now obsolete and may be discarded.

The revisions dated April 1, 2002 include a reprinted title page (page1) for this Standard.

Pages 70, 71, and 75 were revised on May 13, 2002 to indicate the revision dates of paragraphs 60.12, 60.16, 60.17, 60.34, 60.36, and 60.38.

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

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

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

UL's Standards for Safety are copyrighted by UL. Neither a printed copy of a Standard, nor the distribution diskette for a Standard-on-Diskette and the file for the Standard on the distribution diskette should be altered in any way. All of UL's Standards and all copyrights, ownerships, and rights regarding those Standards shall remain the sole and exclusive property of UL.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means, electronic, mechanical photocopying, recording, or otherwise without prior permission of UL.

Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

UL provides this Standard "as is" without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

UL will attempt to answer support requests concerning electronic versions of its Standards. However, this support service is offered on a reasonable efforts basis only, and UL may not be able to resolve every support request. UL supports the electronic versions of its Standards only if they are used under the conditions and operating systems for which it is intended. UL's support policies may change from time-to-time without notification.

UL reserves the right to change the format, presentation, file types and formats, delivery methods and formats, and the like of both its printed and electronic Standards without prior notice.

Purchasers of the electronic versions of UL's Standards for Safety agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgement (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing an electronic Standard on the purchaser's computer system.

If a single-user version electronic Standard was purchased, one copy of this Standard may be stored on the hard disk of a single personal computer, or on a single LAN file-server or the permanent storage device of a multiple-user computer in such a manner that this Standard may only be accessed by one user at a time and for which there is no possibility of multiple concurrent access.

If a multiple-user version electronic Standard was purchased, one copy of the Standard may be stored on a single LAN file-server, or on the permanent storage device of a multiple-user computer, or on an Intranet server. The number of concurrent users shall not exceed the number of users authorized.

Electronic Standards are intended for on-line use, such as for viewing the requirements of a Standard, conducting a word search, and the like. Only one copy of the Standard may be printed from each single-user version of an electronic Standard. Only one copy of the Standard may be printed for each authorized user of a multiple-user version of an electronic Standard. Because of differences in the computer/software/printer setup used by UL and those of electronic Standards purchasers, the printed copy obtained by a purchaser may not look exactly like the on-line screen view or the printed Standard.

An employee of an organization purchasing a UL Standard can make a copy of the page or pages being viewed for their own fair and/or practical internal use.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

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.

Copyright © 2002 Underwriters Laboratories Inc.

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

Page	Date
1-2.....	April 1, 2002
3.....	July 13, 2000
4.....	April 1, 2002
5.....	May 18, 2000
6.....	April 1, 2002
7.....	May 18, 2000
8.....	November 1, 2001
8A.....	April 1, 2002
8B-9.....	July 13, 2000
10.....	March 22, 1999
11.....	April 1, 2002
12-13.....	July 13, 2000
14.....	April 1, 2002
15.....	July 13, 2000
16-18.....	April 1, 2002
19.....	November 1, 2001
20-21.....	April 1, 2002
22-22B.....	July 13, 2000
23.....	March 22, 1999
24-27.....	April 1, 2002
28-31.....	March 22, 1999
32-34B.....	May 18, 2000
35.....	March 22, 1999
36-36B.....	April 1, 2002
37-38.....	March 22, 1999
39.....	April 1, 2002
40.....	July 13, 2000
41.....	March 22, 1999
42-43.....	April 1, 2002
44.....	March 22, 1999
45.....	April 1, 2002
46-47.....	July 13, 2000
48-50D.....	April 1, 2002
51.....	July 13, 2000
52.....	May 18, 2000
53-57.....	March 22, 1999
58-59.....	July 13, 2000
60.....	March 22, 1999
61.....	April 1, 2002
62-63.....	March 22, 1999
64-68.....	April 1, 2002
69.....	March 22, 1999
70-71.....	May 13, 2002
72-74.....	April 1, 2002
75.....	May 13, 2002
76-78.....	April 1, 2002

No Text on This Page

MARCH 22, 1999
(Title Page Reprinted: April 1, 2002)



1

UL 44

Standard for Thermoset-Insulated Wires and Cables

The First through Fifth editions were titled Rubber-Covered Wires and Cables. The Sixth through Thirteenth editions were titled Rubber-Insulated Wires and Cables.

First Edition – November, 1917
Second Edition – March, 1932
Third Edition – March, 1939
Fourth Edition – June, 1940
Fifth Edition – April, 1956
Sixth Edition – May, 1961
Seventh Edition – July, 1968
Eighth Edition – June, 1975
Ninth Edition – December, 1976
Tenth Edition – December, 1977
Eleventh Edition – February, 1983
Twelfth Edition – August, 1983
Thirteenth Edition – October, 1991
Fourteenth Edition – January, 1997

Fifteenth Edition

March 22, 1999

UL maintains this standard under the ANSI continuous maintenance procedure, resulting in each revision being designated as ANSI approved upon completion of the process. The Fifteenth Edition of UL 44, including revisions published through April 1, 2002, was designated as the American National Standard ANSI/UL 44 on March 1, 2002.

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

Approved as ANSI/UL 44 – 2002, March 1, 2002

The Department of Defense (DoD) has adopted UL 44 on April 5, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

Comments on this standard should be made in writing to the UL-Melville Standards Department at 1285 Walt Whitman Road, Melville, New York 11747–3081.

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.

ISBN 0-7629-0400-3

COPYRIGHT © 1975, 2002 UNDERWRITERS LABORATORIES INC.

CONTENTS

FOREWORD	8
-----------------------	---

INTRODUCTION

1 Scope	.8A
2 Units of Measurement	.8A
3 References	.8B
4 Materials	.8B
5 Index Table	.8B

CONDUCTOR(S)

6 Metal	16
7 Size, Temper, and Assembly	16
8 Conductor Diameter and Cross-Sectional Area	18
9 Metal Coating	18
10 Joints	18
11 Resistance	19
12 Stranding	19
13 Separator	22

INSULATION

14 Material and Application	22
15 Thicknesses of Insulation	22A
15.1 General	22A
16 Centering	26

NONMETALLIC COVERINGS AND FILLERS

17 General	26
18 Number of Coverings	27
19 Fillers	27
20 Tapes	27
21 Cotton Braids	28
21.1 General	28
21.2 Coverage	28
22 All-Glass and Glass/Cotton Braids	34
23 Cotton Wraps and Servings	35
23.1 General	35
23.2 Coverage	36
24 Glass Wraps	38
25 Spun-Rayon Braids and Wraps	38
26 Saturation of Fibrous Coverings Other Than Tapes	38
27 Finish	38
28 Thicknesses of Jacket	39
29 Lubrication	40

METAL COVERINGS

30 General	41
31 Lead Sheath	41
32 Aluminum Sheath	41

LAY OF CABLED CONDUCTORS

33 General	41
------------------	----

ASSEMBLIES THAT INCLUDE SINGLE-CONDUCTOR THERMOSET-INSULATED WIRES

34 General	42
------------------	----

CABLE FOR DEEP-WELL SUBMERSIBLE WATER PUMPS

35 General	42
------------------	----

PERFORMANCE**DIELECTRIC VOLTAGE-WITHSTAND TEST IN WATER**

36 General	45
------------------	----

TEST FOR INSULATION RESISTANCE AT 60.0°F (15.6°C)

37 General	46
38 Temperature Factor	50C

TEST FOR INSULATION RESISTANCE IN WATER AT RATED TEMPERATURE

39 General	53
39.1 Minimum value	53
39.2 Maximum rate of decrease	56
39.3 Test method	56

TEST FOR INSULATION RESISTANCE IN AIR AT 97.0°C (206.6°F)

40 General	57
40.1 Minimum value	57
40.2 Maximum rate of decrease	60
40.3 Test method	60

ALTERNATIVE SPARK TESTING

41 General	61
------------------	----

CAPACITANCE AND RELATIVE-PERMITTIVITY TESTS

42 General	62
------------------	----

TEST FOR STABILITY FACTOR

43 General	.62
------------------	-----

TEST FOR GLASS CONTENT OF BRAID ON TYPE SA WIRE

44 General	.63
------------------	-----

TEST FOR FALLING PARTICLES AND DRIPPING FROM FIBROUS-COVERED WIRE AND CABLE

45 General	.63
------------------	-----

TEST FOR MOISTURE ABSORPTION BY FIBROUS COVERINGS OTHER THAN TAPE

46 General	.63
------------------	-----

COLD-BEND TEST

47 General	.63
------------------	-----

COLD-IMPACT TEST

48 General	.64
------------------	-----

DEFORMATION TEST

49 General	.64
------------------	-----

CRUSHING TEST (TYPES XHHW-2, XHHW, AND XHH)

50 General	.65
------------------	-----

TEST FOR DIELECTRIC BREAKDOWN AFTER GLANCING IMPACT (TYPES XHHW-2, XHHW, AND XHH)

51 General	.65
------------------	-----

TEST FOR DIELECTRIC BREAKDOWN AFTER SCORING (TYPES XHHW-2, XHHW, AND XHH)

52 General	.65
------------------	-----

HORIZONTAL-SPECIMEN FLAME TEST

53 General	.66
------------------	-----

VW-1 (VERTICAL-SPECIMEN) FLAME TEST

54 General	.66
------------------	-----

VERTICAL-TRAY FLAME TEST

55 General	.66
------------------	-----

SUNLIGHT-RESISTANCE TEST

56 General	.67
------------------	-----

LIMITED SMOKE

57 General	.68
------------------	-----

TESTS FOR OIL-RESISTANCE

58 General	.68
------------------	-----

TESTS FOR GASOLINE- AND OIL-RESISTANCE

59 General	.68
------------------	-----

MARKINGS

60 Details	.69
------------------	-----

No Text on This Page

FOREWORD

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

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

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

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

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

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

INTRODUCTION

1 Scope

1.1 These requirements cover 14 – 4/0 AWG and 213 – 2000 kcmil sizes of Type XHHW-2, XHHW, XHH, RHW-2, RHH, RHW, SIS, and SA wires and cables for use in accordance with Article 310 and other applicable parts of National Electrical Code. Deep-well pump cables and other multiple-conductor assemblies to which a type-letter designation is not assigned are included in these requirements.

1.1 revised April 1, 2002

1.2 These requirements do not cover wires or cables for use at potentials higher than 2000 V.

1.3 Although these requirements cover parallel and cabled assemblies of two or more insulated conductors, they do not cover complete armored (AC series), metal-clad (Type MC), medium-voltage (Type MV), or service-entrance (Types SE and USE) cables. These cables are covered in separate requirements.

1.4 *Deleted November 1, 2001*

2 Units of Measurement

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

2.1 revised April 1, 2002

3 References

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

4 Materials

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

5 Index Table

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

No Text on This Page

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

Table 5.1
Index to requirements^a for XHHW-2, XHHW, XHH, RHH, RHW-2, and RHW
 Table 5.1 revised April 1, 2002

Type-letter designation	XHHW-2	XHHW	XHH	RHH	RHW-2	RHW
Maximum Temperature	90°C (194°F) wet or dry	75°C (167°F) wet 90°C (194°F) dry	90°C (194°F) dry	90°C (194°F) dry	90°C (194°F) wet or dry	75°C (167°F) wet or dry
Maximum Voltage	600					
Conductor Size	14 AWG – 2000 kcmil (Table 7.1)					
Number of Conductors	One, 2 parallel, 2 or more cabled					
Conductor Metal	14 and 13 AWG – soft-annealed copper, 12 AWG – 2000 kcmil – aluminum, copper-clad aluminum, or soft-annealed copper (6.1)					
Conductor Dimensions	See 8.1 – 8.3 for diameter and cross-sectional area					
Conductor – General	Metal coating (9.1 and 9.2) Splices (10.1 and 10.2) Separator (13.1 and 13.2)					
Conductor Resistance	(11.1)					
Conductor Stranding	(12.1 – 12.7)					
Insulation Material(s) ^b	XL EPCV SBR/IIR/NR CP CPE EPCV EP XL Silicone rubber (RHH only)					
Insulation – General	Application (14.1), Joints (14.2), Other materials (14.3), Centering (16.1)					
Thickness of Insulation – Average	(15.1)					
Thickness of Insulation – Minimum at Any Point	(15.1)					

Table 5.1 Continued on Next Page

Table 5.1 Continued

Type-letter designation	XHHW-2	XHHW	XHH	RHH	RHW-2	RHW
Nonmetallic Coverings and Fillers	(17.1 and 17.2)			General (17.1 and 17.2) Number of Coverings (18.1 – 18.4) Fillers (19.1) Tapes (20.1 – 20.4) Cotton Braids (21.1 – 21.2.7) All-Glass and Glass/Cotton Braids (22.1 – 22.4) Aramid Braid (22.5) Cotton Wraps and Servings (23.1.1 – 23.2.4) Glass Wraps (24.1 and 24.2) Spun-Rayon Braids and Wraps (25.1) Saturation of Fibrous Coverings (26.1– 26.4) Finish (27.1) CP CPE Neoprene (RHW, RHH, RHW-2) NBR/PVC (RH, RHW) Thickness of Jacket (28.1) Lubrication (29.1)		
				(33.1)		
				(34.1)		
	Pump Cable	General	(1.1, 19.1, 29.1, 33.1, 35.1, 60.6, 60.7, and 60.32)	none	(1.1, 19.1, 29.1, 33.1, 35.1, 60.6, 60.7, and 60.32)	
		Thickness of Jacket	(35.1)	none	(35.1)	
Physical Properties of Insulation ^b	Physical Properties of Jacket	(35.1)	none	(35.1)		
	Unaged	XL EPCV		SBR/IIR/NR CP CPE EPCV EP XL Silicone rubber (RHH only)		
After Aging						
Physical Properties of Jacket ^b	Unaged	none		CP CPE Neoprene NBR/PVC		
	After Aging					
Dielectric Voltage-Withstand				(36.1 – 36.3)		
Insulation Resistance at 60.0°F (15.6°C)				(37.1 and 38.1)		
Insulation Resistance in Water at Rated Temperature	(39.1.1 – 39.3.1)		none	(39.1.1– 39.3.1)		
Insulation Resistance in Air at 97.0°C (206.6°F)	none	(40.1.1 – 40.3.2)		none		
Alternative Spark Testing				(41.1)		
Continuity				[pars. 900.13 – 900.17 of UL 1581]		

Table 5.1 Continued on Next Page

Table 5.1 Continued

Type-letter designation	XHHW-2	XHHW	XHH	RHH	RHW-2	RHW
Capacitance and Relative Permittivity	(42.1)			none		(42.1)
Stability Factor	(43.1)			none		(43.1)
Glass Content		none			(22.1)	
Falling Particles and Dripping from Fibrous Coverings		none			(45.1)	
Moisture Absorption by Fibrous Coverings Other Than Tape		none			(46.1)	
Cold Bend			(47.1)			
Cold Impact			(48.1)			
Deformation			(49.1)			
Crushing	(50.1 and 50.2)				none	
Glancing Impact	(51.1)				none	
Scoring	(52.1)				none	
Horizontal Flame			(53.1)			
VW-1 Flame			(54.1)			
Vertical-Tray Flame	Single- and multiple-conductor (55.1 – 55.4)					
Tray Cables Sunlight Resistance	Single- and jacketed multiple-conductor (56.1 – 56.4)					
Sunlight Resistance for Messenger Use	Single- and jacketed multiple-conductor (56.1–56.4)	Messenger use not applicable	Single- and jacketed multiple-conductor (56.1 – 56.4)	Messenger use not applicable	Single- and jacketed multiple-conductor (56.1 – 56.4)	Messenger use not applicable
Oil Resistance	(57.1 and 57.2)					
Gasoline- and Oil-Resistance	(58.1)					
Markings	(60.1– 60.44)					
a See 5.2.						
b The physical properties requirements for individual material are in UL 1581. See also 40.2 in UL 1581.						

Table 5.2
Index to requirements^a for Types SA and SIS
 Table 5.2 revised April 1, 2002

Type-letter designation	SA	SIS
Maximum Temperature	90°C (194°F) dry 200°C (392°F) special dry	90°C (194°F) dry
Maximum Voltage	600	
Conductor Size	14 AWG – 2000 kcmil (6.1, 8.1)	14 – 4/0 AWG (6.1, 8.1)
Number of Conductors	One, 2 parallel, 2 or more cabled	
Conductor Metal	Soft-annealed copper	14, 13 AWG soft-annealed copper, 12 – 4/0 AWG – aluminum, copper-clad aluminum, or soft-annealed copper (6.1)
Conductor Dimensions	See 8.1– 8.3 for diameter and cross-sectional area	
Conductor – General	Metal coating (9.1 and 9.2) Splices (10.1 and 10.2) Separator (13.1 and 13.2)	
Conductor Resistance	(11.1)	
Conductor Stranding	(12.1 – 12.7)	
Insulation Material(s) ^b	200°C silicone	CP CPE EPCV XL
Insulation – General	Application (14.1) Joints (14.2) Other material (14.3) Centering (16.1)	
Thickness of Insulation– Average	(15.1)	
Thickness of Insulation – Minimum at Any Point	(15.1)	
Nonmetallic Coverings and Fillers	General (17.1 and 17.2) Number of Coverings (18.1– 18.4) Fillers (19.1) Tapes (20.1 – 20.4) Glass Braids (22.1 – 22.4) Aramid Braids (22.5) Saturation of Fibrous Coverings (26.1– 26.4) Finish (27.1) Lubrication (29.1)	none
Lay of Cabled Conductors	(33.1)	
Assemblies That Include Single- Conductor Rubber- Insulated Wires	(34.1)	
Physical Properties of Insulation ^b	200°C silicone	EPCV, XL CP, CPE
	Unaged After Aging	

Table 5.2 Continued on Next Page

Table 5.2 Continued

Type-letter designation	SA	SIS
Dielectric Voltage-Withstand	(36.1 – 36.3)	
Insulation Resistance at 60.0°F (15.6°C)	(37.1 and 38.1)	
Alternative Spark Testing	(41.1)	
Continuity	[pars. 900.13 – 900.17 of UL 1581]	
Glass Content	(44.1)	none
Cold Bend	(47.1)	
Cold Impact	(48.1)	
Deformation	none	(49.1)
Horizontal Flame Test	(53.1)	
VW-1 Flame Test	(54.1)	
Vertical-Tray Flame Test	(55.1 – 55.4)	
Markings	(60.1 – 60.41)	
^a See 5.2.		
^b The physical properties requirements for individual material are in UL 1581. See also 40.2 of UL 1581.		

CONDUCTOR(S)

6 Metal

6.1 Only soft-annealed copper, copper-clad aluminum, or an aluminum alloy shall be used for the conductor or conductors in a wire or cable. Soft-annealed copper shall comply with ASTM B 3-01. Each 27 – 36 AWG (14.2 – 5.0 mils or 0.361 – 0.127 mm) strand in wire rated for 200°C (392°F) shall be protected against oxidation by a coating of nickel complying with ASTM B 355-95, a coating of silver complying with ASTM B 298-99, or a coating of another metal or alloy (evaluation required – lead, tin/lead, and tin coatings are not acceptable). Uncoated or tin/lead-coated or tin-coated solid conductors and uncoated or tin/lead-coated or tin-coated strands whose diameter is at least 0.015 inch or 0.38 mm are acceptable in wire rated for 200°C (392°F). Solid aluminum conductors in size 12 – 8 AWG shall comply with the requirements for aluminum-wire stock (aluminum-alloy conductor material). All other aluminum conductors shall comply with the requirements for semi-annealed 8000 series aluminum conductors in Requirements for Aluminum Conductors of an 8000 Series Alloy, Section 10 of UL 1581. Copper-clad aluminum conductors shall comply with the requirements in Requirements for Copper-Clad Aluminum Conductors, Section 11 of UL 1581.

6.1 revised April 1, 2002

7 Size, Temper, and Assembly

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

Table 7.1
Conductors

Table 7.1 revised April 1, 2002

Types of wire	Sizes and metal (See Tables 5.1 and 5.2)	Temper	Assembly
XHHW-2, XHHW, XHH, RHH, RHW, RHW-2, SIS ^a , SA	14 – 4/0 AWG copper	Soft-annealed	Solid
	2 – 4/0 AWG copper	Soft-annealed	Compact stranding ^{b,f}
	14 AWG – 2000 kcmil copper	Soft-annealed	Compressed stranding and every other type of stranding ^b covered in Table 210.1 of UL 1581 other than compact stranding
XHHW-2, XHHW, XHH, RHH, RHW, RHW-2, RHH, RHW, SIS ^a	12 – 8 AWG aluminum	^c	Solid
	6 – 4/0 AWG aluminum	Semi-annealed ^d	Solid
	12 AWG – 2000 kcmil aluminum	Semi-annealed ^d	Compressed stranding and every other type of stranding ^b covered in Table 210.2 of UL 1581 other than compact stranding
	12 AWG – 1000 kcmil aluminum	Semi-annealed ^d	Compact stranding ^b
	12 – 4/0 AWG copper-clad aluminum	^d	Solid
	12 AWG – 2000 kcmil copper-clad aluminum	^d	Any type of stranding ^b covered in Table 210.2 of UL 1581 other than compact and compressed stranding

^a Type SIS is limited to 14 – 4/0 AWG copper and 12 – 4/0 AWG aluminum and copper-clad aluminum.

^b See 12.1 – 12.7.

^c Aluminum-wire stock (aluminum-alloy conductor material).

^d See 6.1.

^e Deleted.

^f See 60.39.

8 Conductor Diameter and Cross-Sectional Area

8.1 The nominal, maximum (1.01 x nominal), and minimum (0.98 x nominal) diameters of solid and stranded conductors are shown in Tables 20.1, 20.2, 20.3, 20.3.1, 20.4, 20.5, and 20.6 of UL 1581. Conductor diameter is to be measured using the method shown in Conductor Diameter, Section 200 of UL 1581.

8.1 revised March 22, 1999

8.2 Compressed unilay copper conductors that are smaller in diameter than the requirement (0.98 x nominal as indicated in Table 20.3 of UL 1581) for compressed concentric-lay conductors shall be marked the same as compact conductors in accordance with 60.39.

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

9 Metal Coating

9.1 Where the insulation adjacent to a copper or copper-clad aluminum conductor is of a material that corrodes unprotected copper in the test in Conductor Corrosion, Section 500 of UL 1581, and where a protective separator is not provided, the solid conductor and each of the individual strands of a stranded conductor shall be separately covered with a coating of tin complying with ASTM B 33-00, of a tin/lead alloy complying with ASTM B 189-95, of nickel complying with ASTM B 355-95, of silver complying with ASTM B 298-99, or of another metal or alloy (evaluation required).

9.1 revised April 1, 2002

9.2 The use of a metal coating, when not required for corrosion protection, is still appropriate for use on solid or individual wires (strands) or selected wires, such as the outer layer of wires of a stranded conductor. The metal coating when used shall comply with 9.1

9.2 revised March 22, 1999

10 Joints

10.1 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner and shall not change the diameter of the solid conductor, the individual wire strand, or the overall stranded conductor. A joint shall not be made in a stranded conductor as a whole. A joint in a stranded conductor shall be made by separately joining each individual wire. A joint shall be made only before any coverings are applied to an insulated conductor and before a conductor is assembled into a cable. The insulation applied to such joints shall be equivalent to that removed and shall comply with the requirements in this Standard. A joint in a compact- or compressed-stranded conductor shall be made before compacting or compressing.

10.1 revised March 22, 1999

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

10.2 revised March 22, 1999

11 Resistance

11.1 The direct-current resistance of any length of conductor in ohms per thousand conductor feet or in ohms per conductor kilometer shall not be higher than the maximum (nominal x 1.02) resistance indicated in the applicable table in D-C Conductor Resistance, Section 30 of UL 1581 at 20°C (68°F) or at 25°C (77°F) when measured as described in D-C Conductor Resistance, Section 220 of UL 1581. The d-c resistance of each conductor in a finished Type XHHW-2M, XHHWM, XHHM, RHW-2M, RHHM, RHWM, RHM, SISM, or SAM cable shall not exceed the value tabulated in the applicable one of the tables in Section 30 of UL 1581 for a single conductor multiplied by whichever of the following factors is applicable:

Construction	Multiplier
Cabled in one layer	1.02
Cabled in more than one layer	1.03
Cabled as one pair	1.04
Cabled as an assembly of pairs or other precabled units.	1.04

11.1 revised March 22, 1999

12 Stranding

12.1 A stranded conductor shall have the number of strands indicated in Table 12.1.

Table 12.1
Conductor stranding

Table 12.1 revised November 1, 2001

Size of wire	Number of strands in combination unilay	Minimum number of strands ^b	
		Compact stranded	All others
AWG			
14, 13	19 ^a	—	7
12 – 9	19 ^a	7	7
8	19 ^a	7	7
7 – 2	19	7	7
1 – 4/0	19	18	19
kcmil			
213 – 500	—	35	37
501 – 1000	—	58	61
1001 – 1500	—	—	91
1501 – 2000	—	—	127

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

12.2 The individual wires used in making up a stranded conductor are usually drawn to the same diameter which is not required to be the diameter of any AWG or other standard gauge number.

12.2 revised March 22, 1999

12.3 Copper strands smaller than 36 AWG and aluminum and copper-clad aluminum strands smaller than 22 AWG shall not be used.

12.3 revised April 1, 2002

12.4 A 19-wire combination round-wire unilay-stranded conductor of soft-annealed copper, or an aluminum alloy as indicated in 6.1, shall be round and shall consist of a straight central wire, an inner layer of six wires of the same diameter as the central wire with the six wires having identical lengths of lay and an outer layer consisting of six wires of the same diameter as the central wire alternated with six smaller wires having a diameter of 0.732 times the diameter of the central wire and with all twelve wires of the outer layer having the same length of lay and direction of lay as the six wires of the inner layer. No particular assembly of the individual wires of any other stranded conductor is required. However, simple bunching (untwisted strands) shall not be used for the entire conductor or any part thereof. The length of lay of the strands in a single-bunch bunch-stranded conductor shall not be greater than indicated in Table 12.2. The direction of lay of the strands in a single-bunch bunch-stranded conductor shall be left-hand. Any type of stranding in Table 210.2 of UL 1581 other than compact stranding or single-bunch bunch-stranding shall comply with 12.6 or 12.7 as applicable. The direction of lay of the outer layer shall be left-hand in all cases.

Table 12.2
Length of lay of strands in a single-bunch bunch-stranded conductor^a

Table 12.2 revised May 14, 2001

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

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

12.5 A compact-stranded conductor shall be a round conductor consisting of a central core (one or more strands) surrounded by one or more layers of helically laid strands. A compact-stranded copper conductor shall consist of uncoated strands. A compact-stranded aluminum conductor shall have all layers with the same direction of lay (left-hand unidirectional). A compact-stranded copper conductor is to be left-hand unidirectional or have the direction of lay reversed in adjacent layers (concentric-lay-stranded with the outer layer left-handed) and with each layer rolled, drawn, or otherwise compressively formed to change the originally round or partially preshaped strands to various close-fitting shapes that achieve almost complete filling of the spaces originally present between the strands. Each layer shall be compacted before the next layer is applied, and each compacted layer – including the outermost layer – shall have a smooth, round outer surface. The length of lay of the strands in the outer layer of a 1 AWG – 1000 kcmil conductor shall be 8 – 16 times the overall diameter of that layer. The length of lay of the strands in the outer layer of a 12 – 2 AWG conductor shall be 8.0 – 17.5 times the overall diameter of that layer. A compact-stranded conductor shall not be segmented.

12.5 revised November 1, 2001

12.6 A compressed-stranded conductor shall be a round conductor consisting of a central core (one or more strands) surrounded by one or more layers of helically laid strands with either the direction of lay reversed in successive layers, or of unilay or unidirectional lay. The direction of lay of the outer layer shall be left-hand in all cases. The strands of one or more layers may be compressed by rolling, drawing, or other means to change the originally round strands to various shapes that achieve filling of some of the spaces originally present between the strands.

12.6 revised November 1, 2001

12.7 Every stranded conductor covered in Table 210.2 of UL 1581 other than a compact-stranded conductor or a single-bunch bunch-stranded conductor shall comply with the following:

- a) The direction of lay of the strands, members, or ropes in a 6 AWG – 2000 kcmil conductor other than a combination unilay or compressed unilay or compressed unidirectional lay conductor shall be reversed in successive layers. Rope-bunched lay and rope-concentric lay conductors shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.
- b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.
- c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.
- d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded or compressed stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of the conductor.
- e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded or compressed stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.
- f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

12.7 revised April 1, 2002

13 Separator

13.1 The insulation shall be kept by the manufacturing process or a separator from penetrating between the strands of a conductor (see Insulation Fall-In Test, Section 520 of UL 1581). A separator is not required between the conductor and the insulation of a solid or stranded wire or cable. When used a separator shall be electrically nonconductive (an insulation grade is not required) and shall not be counted as part of the required insulation.

13.1 revised March 22, 1999

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

13.2 revised March 22, 1999

INSULATION

14 Material and Application

14.1 A single-conductor wire or cable and each conductor of a multiple-conductor cable shall be insulated for its entire length with one of the insulations specified for the construction in Table 5.1 or 5.2. The insulation shall be applied directly to the surface of the conductor or to any separator and shall cover the conductor or any separator completely. The insulation shall fit tightly to the conductor and shall not adhere. For the case of an insulated conductor for use in a pump cable, see tag marking required in 60.34(g). The insulation shall not have any defects visible with normal or corrected vision without magnification.

14.1 revised March 22, 1999

14.2 Any repair or joint in the insulation shall be made in a workmanlike manner resulting in all parts affected in the process complying with the same electrical tests as the remainder of the insulation. The thickness of insulation at the repaired part or joint shall comply with the requirements in 15.1.1.

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

- a) Material generically different from any insulation or jacket material that is named in Table 5.1 or 5.2 for the construction (new material).
- b) Material that is named in Table 5.1 or 5.2 yet does not comply with the short-term tests specified for the material in Specific Materials, Section 50 of UL 1581.

The temperature rating of materials (a) and (b) shall be as required for the specific thermoset-insulated wire or cable type. The thickness of insulation and/or jacket using materials (a) and/or (b) shall be as required for the specific type. Investigation of the electrical, mechanical, and physical characteristics of the wire or cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to an insulation or jacket material named in Table 5.1 or 5.2 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand, or other tests as appropriate.

14.3 revised July 13, 2000

15 Thicknesses of Insulation

15.1 General

15.1.1 The average thickness of the insulation and the minimum thickness at any point of the insulation on an individual conductor shall not be less than indicated in Table 15.1, 15.2, 15.3, 15.4, 15.5, or 15.6 as applicable to the particular type, size, and voltage rating of the wire when determined as described in Thickness of Insulation and Jacket, Section 240 of UL 1581. In addition, when two layers of XL and/or EPCV insulation are used, the insulation compounds shall be those that individually comply with the requirements for Type RHW or RHH when applied in a single layer of the thicknesses indicated in Table 15.4 (600-volt rating) or 15.5 (2000-volt rating). The total thicknesses shall not be less than indicated in Table 15.4 or 15.5 for a single layer and neither layer shall be less than 10 mils or 0.25 mm thick.

15.1.1.1 revised March 22, 1999