UL 1309

STANDARD FOR SAFETY

Marine Shipboard Cable

UL Standard for Safety for Marine Shipboard Cable, UL 1309

Third Edition, Dated April 21, 2017

Summary of Topics

This new edition of ANSI/UL 1309 is being issued to incorporate the following changes in requirements:

1. Updates to the Standard for Safety for Marine Shipboard Cable, UL 1309 to Coordinate with the Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities, IEEE 1580, Revised Table 4.2 and Table 38.1;

2. Definition of Spacing Between Cable Holes, Revised 29.2;

3. Correction to Test Temperature in 29.3;

4. Clarification of Reference to Test, Revised 5.4.2.1;

5. Clarification to Constructions Subject to Requirement, Revised 14.1.2, 14.1.3, 14.2.1; and

6. Updated IEC Standard Number, Revised 40.1(j).

The revised requirements are substantially in accordance with Proposal(s) on this subject dated September 16, 2016 and March 10, 2017.

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UL 1309

Standard for Marine Shipboard Cable

First Edition – July, 1995
Second Edition – April, 2011

Third Edition

April 21, 2017

This ANSI/UL Standard for Safety consists of the Third edition.

The most recent designation of ANSI/UL 1309 as an American National Standard (ANSI) occurred on April 21, 2017. 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 UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 This Standard specifies the requirements for distribution (power) cables, and control and signal cables for installation aboard marine vessels, fixed and floating offshore petroleum facilities, and mobile offshore drilling units (MODUs), in accordance with industry installation standards and the regulations of the authorities having jurisdiction. The cables are single or multi-conductor, with or without metal armor and/or jacket, and are rated 300 V – 35 kV.

1.2 These cables are not intended for use in accordance with the National Electrical Code (NEC), ANSI/NFPA 70. Cables that also meet the requirements for use with the NEC may be additionally marked with the appropriate ″Type″ designation from the NEC.

2 Units of Measurement

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

3 References

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

4 Copper Conductors

4.1 General

4.1.1 All conductors shall be of soft annealed stranded copper wire. The conductors may be tinned or alloy coated where necessary to ensure compatibility with primary insulation. Conductor sizes and resistances shall comply, within allowable tolerances, with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

4.2 Composition

4.2.1 Stranded conductors shall comply with the requirements of the Standard Specification for Soft or Annealed Copper Wire, ASTM B3; the Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft, ASTM B8; the Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes, ASTM B33; the Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, ASTM B172; the Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors, ASTM B173; the Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors, ASTM B174; the Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, ASTM B189; the Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors, ASTM B496; or the Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation, ASTM B787; as applicable. Metric sizes complying with Conductors of Insulated Cables, IEC 60228 are acceptable.

4.3 Stranding

4.3.1 Except as specified in 4.3.2 – 4.3.5, the conductors shall be stranded Class B concentric conductors, as specified in the Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft, ASTM B8. See Table 4.1.

Table 4.1
Construction and resistance of standard Class B concentric conductors

Conductor size		Class B stranding			Maximum dc resistance (Ω/km at 20°C)	
Area in circular mils	AWG or kcmil	Number of wires	Diameter of strand wire mm (mils)	Conductor diameter mm (in)	Uncoated	Alloy coated or tinned
640	22	7	0.240 (9.6)	0.7 (0.0288)	55.4	59.4
1 020	20	7	0.310 (12.1)	0.9 (0.0363)	34.6	36.7
1 620	18	7	0.386 (15.2)	1.2 (0.0456)	21.8	23.2
2 580	16	7	0.488 (19.2)	1.5 (0.0576)	13.7	14.6
4 110	14	7	0.615 (24.2)	1.8 (0.0726)	8.62	8.96
6 530	12	7	0.755 (30.5)	2.3 (0.0915)	5.43	5.64
10 380	10	7	0.987 (38.5)	2.9 (0.116)	3.41	3.55
16 510	8	7	1.234 (48.6)	3.7 (0.146)	2.14	2.23
20 820	7	7	1.384 (54.5)	4.2 (0.164)	1.70	1.77
26 240	6	7	1.554 (61.2)	4.8 (0.184)	1.35	1.40
33 090	5	7	1.748 (68.8)	5.2 (0.206)	1.07	1.11
41 740	4	7	1.961 (77.2)	5.9 (0.232)	0.848	0.882
52 620	3	7	2.202 (86.7)	6.6 (0.260)	0.673	0.700
66 360	2	7	2.474 (97.4)	7.4 (0.292)	0.534	0.555
83 690	1	19	1.687 (66.4)	8.4 (0.332)	0.423	0.440
105 600	1/0	19	1.892 (74.5)	9.5 (0.373)	0.335	0.349
133 100	2/0	19	2.126 (83.7)	10.6 (0.419)	0.266	0.277
167 800	3/0	19	2.386 (94.0)	11.9 (0.470)	0.211	0.219
211 600	4/0	19	2.680 (105.5)	13.4 (0.528)	0.167	0.172
250 000	250	37	2.088 (82.2)	14.6 (0.575)	0.142	0.147
300 000	300	37	2.286 (90.0)	16.0 (0.630)	0.118	0.123

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Table 4.1 Continued

Conductor size		Class B stranding			Maximum dc resistance (Ω/km at 20°C)	
Area in circular mils	AWG or kcmil	Number of wires	Diameter of strand wire mm (mils)	Conductor diameter mm (in)	Uncoated	Alloy coated or tinned
350 000	350	37	2.471 (97.3)	17.3 (0.681)	0.101	0.105
400 000	400	37	2.642 (104.0)	18.5 (0.728)	0.0885	0.0911
500 000	500	37	2.951 (116.2)	20.7 (0.813)	0.0708	0.0729
600 000	600	61	2.520 (99.2)	22.7 (0.893)	0.0590	0.0614
750 000	750	61	2.817 (110.9)	25.3 (0.998)	0.0472	0.0486
1 000 000	1000	61	3.251 (128.0)	29.2 (1.152)	0.0354	0.0364
1 250 000	1250	91	2.977 (117.2)	32.7 (1.289)	0.0283	0.0292
1 500 000	1500	91	3.261 (128.4)	37.0 (1.459)	0.0236	0.0243
2 000 000	2000	127	3.187 (125.5)	41.5 (1.632)	0.0177	0.0182

4.3.2 Class B stranded conductors, compressed to a reduction in diameter of 3 percent maximum of concentric stranded conductors, shall also be permitted.

4.3.3 Unilay stranded conductors complying with the Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation, ASTM B787 shall also be permitted.

4.3.4 Flexible rope lay stranded conductors may be substituted for concentric conductors. Bunch-stranded conductors in sizes 6 AWG and smaller may be substituted for concentric stranded conductor. See Table 4.2.

Table 4.2
Construction and resistance of flexible stranded conductors

AWG or Kcmil	Conductor area in circular mils	Nominal mm²	Nominal stranding: Number of wires	Individual wire diameter: inch	Individual wire diameter: mm	Max. cond diameter: inch	Max. cond diameter: mm	Maximum DC resistance, Ohms per 1000-ft at 25°C: Bare	Ohms per 1000-ft at 25°C: Coated	Ohms per km at 25°C: Bare	Ohms per km at 25°C: Coated
22	754	0.38	19	0.0063	0.160	0.0315	0.80	17.19	18.46	56.4	60.6
20	1216	0.62	19	0.0080	0.203	0.0400	1.02	10.83	11.62	35.5	38.1
18	1900	0.96	19	0.0100	0.254	0.052	1.32	5.91	6.342	19.4	20.8
16	2601	1.32	19	0.0117	0.297	0.062	1.56	4.26	4.527	14.0	14.9
or 16	2426	1.23	19	0.0113	0.287	0.060	1.51	4.63	4.915	15.2	16.1
14	4106	2.08	19	0.0147	0.373	0.076	1.92	2.67	2.835	8.76	9.30
or 14	3831	1.94	19	0.0142	0.361	0.073	1.85	2.93	3.110	9.61	10.2
12	6503	3.29	19	0.0185	0.470	0.095	2.40	1.68	1.784	5.51	5.85
or 12	6088	3.08	19	0.0179	0.455	0.092	2.32	1.84	1.958	6.05	6.42
10	10908	5.53	27	0.0201	0.511	0.128	3.25	1.048	1.101	3.44	3.61
or 10	10319	5.23	37	0.0167	0.424	0.117	2.97	1.045	1.110	3.43	3.64
8	16564	8.4	41	0.0201	0.511	0.147	3.73	0.659	0.692	2.16	2.27
or 8	14948	7.6	37	0.0201	0.511	0.147	3.73	0.728	0.765	2.39	2.51
6	26261	13.3	65	0.0201	0.511	0.207	5.26	0.423	0.445	1.39	1.46
or 6	24645	12.5	61	0.0201	0.511	0.207	5.26	0.455	0.478	1.49	1.57

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Table 4.2 Continued

AWG or Kcmil	Conductor area in circular mils	Nominal mm^2	Nominal stranding			Max. cond diameter		Maximum DC resistance			
			Number of wires	Individual wire diameter				Ohms per 1000-ft at 25°C		Ohms per km at 25°C	
				inch	mm	inch	mm	Bare	Coated	Bare	Coated
5	36765	18.6	91	0.0201	0.511	0.244	6.20	0.336	0.353	1.10	1.16
4	41668	21.1	133	0.0177	0.450	0.258	6.55	0.269	0.286	0.88	0.94
or 4	42421	21.5	105	0.0201	0.511	0.264	6.71	0.266	0.279	0.87	0.92
3	53733	27.2	133	0.0201	0.511	0.295	7.49	0.211	0.221	0.69	0.73
or 3	50501	25.6	125	0.0201	0.511	0.295	7.37	0.220	0.231	0.72	0.76
2	66140	33.5	133	0.0223	0.566	0.324	8.23	0.183	0.193	0.60	0.63
or 2	60602	30.7	150	0.0201	0.511	0.325	8.23	0.183	0.193	0.60	0.63
or 2	65046	33.0	161	0.0201	0.511	0.325	8.26	0.167	0.175	0.55	0.58
1	84438	42.8	209	0.0201	0.511	0.361	9.17	0.133	0.140	0.44	0.46
or 1	90902	46.1	225	0.0201	0.511	0.390	9.91	0.122	0.128	0.40	0.42
1/0	107467	54.5	266	0.0201	0.511	0.407	10.34	0.1058	0.111	0.35	0.37
or 1/0	111103	56.3	275	0.0201	0.511	0.440	11.18	0.1009	0.106	0.33	0.35
2/0	131303	66.5	325	0.0201	0.511	0.477	12.12	0.0854	0.090	0.28	0.29
or 2/0	138171	70.0	342	0.0201	0.511	0.461	11.71	0.0842	0.0885	0.28	0.29
3/0	168876	85.6	418	0.0201	0.511	0.510	12.95	0.0669	0.0703	0.22	0.23
or 3/0	181805	92.1	450	0.0201	0.511	0.565	14.35	0.0615	0.0646	0.20	0.23
4/0	214933	109	532	0.0201	0.511	0.575	14.61	0.0530	0.0557	0.17	0.183
or 4/0	222206	113	550	0.0201	0.511	0.620	15.75	0.0505	0.0530	0.17	0.174
262	262607	133	650	0.0201	0.511	0.660	16.76	0.0437	0.0459	0.14	0.151
313	313108	159	775	0.0201	0.511	0.725	18.42	0.0365	0.0383	0.12	0.126
373	373709	189	925	0.0201	0.511	0.795	20.19	0.0304	0.0319	0.10	0.105
444	444411	225	1100	0.0201	0.511	0.870	22.10	0.0256	0.0269	0.08	0.088
535	535313	271	1325	0.0201	0.511	0.970	24.64	0.0213	0.0223	0.07	0.073
597	597935	303	1480	0.0201	0.511	1.020	25.91	0.0207	0.0217	0.07	0.071
646	646416	328	1600	0.0201	0.511	1.060	26.92	0.0177	0.0186	0.06	0.061
777	777719	394	1925	0.0201	0.511	1.130	28.70	0.0147	0.0154	0.05	0.051
1111	1111028	563	2750	0.0201	0.511	1.340	34.04	0.0105	0.0110	0.03	0.036

Note 1 – The total number of wires should be as specified ±1 percent providing that the maximum conductor diameter and conductor resistance does not exceed the values indicated.

Note 2 – The resistance values of 22 AWG and 20 AWG have been increased to account for stretching of the conductor during the insulating operations in accordance with the Standard Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment , ASTM B286.

Tolerance for maximum resistance:[a]

Single Conductor:	R_{max} = value from Table 4.2
Multi-Conductor	
One layer of conductor:	R_{max} = value from Table 4.2 X 1.02
More than one layer of conductors:	R_{max} = value from Table 4.2 X 1.03
Pairs or other precabled units:	R_{max} = value from Table 4.2 X 1.04
More than one layer of pairs or other precabled units:	R_{max} = value from Table 4.2 X 1.05

4.3.5 Compact round concentric lay stranded copper conductors complying with the Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors, ASTM B496 shall also be permitted. See Table 4.3.

Table 4.3
Construction and resistance of stranded compact concentric conductors

Conductor size		Compact stranding		Maximum dc resistance Ω/km at 20°C	
Area in circular mils	AWG or kcmil	Number of wires	Conductor diameter mm (in)	Uncoated	Alloy coated or tinned
16 510	8	7	3.4 (0.134)	2.14	2.23
26 240	6	7	4.3 (0.169)	1.35	1.40
41 740	4	7	5.4 (0.213)	0.848	0.881
66 360	2	7	6.8 (0.268)	0.533	0.554
83 690	1	19[a]	7.6 (0.299)	0.423	0.440
105 600	1/0	19[a]	8.5 (0.336)	0.335	0.348
133 100	2/0	19[a]	9.6 (0.376)	0.266	0.276
167 800	3/0	19[a]	10.7 (0.423)	0.211	0.219
211 600	4/0	19[a]	12.1 (0.475)	0.167	0.172
250 000	250	37[b]	13.2 (0.520)	0.142	0.147
300 000	300	37[b]	14.5 (0.570)	0.118	0.123
350 000	350	37[b]	15.7 (0.616)	0.101	0.105
400 000	400	37[b]	16.7 (0.659)	0.0884	0.0910
500 000	500	37[b]	18.7 (0.736)	0.0708	0.0728
600 000	600	61[c]	20.7 (0.813)	0.0590	0.0613
750 000	750	61[c]	23.1 (0.908)	0.0472	0.0486
1 000 000	1000	61[c]	26.9 (1.060)	0.0354	0.0364

[a] 18 wires minimum.
[b] 35 wires minimum.
[c] 58 wires minimum.
To convert from kg/km to lb/1000 ft multiply number × 0.672.
To convert from Ω/km to Ω/1000 ft multiply number × 0.3048.

4.4 Joints

4.4.1 Joints in the individual wires of a stranded conductor shall neither increase the diameter nor substantially decrease the strength of the conductor or the individual wire. Joints in stranded conductors larger than 16 AWG shall only be permitted in the individual wires of the strand. The distance between brazes or welds in individual strand wires shall be not less than 0.3 m (1 ft) of conductor.

4.4.2 For rope-lay stranded conductors, a stranded member (primary group) may be jointed as a unit; these joints shall not be closer than two lay lengths.

4.4.3 Joints in stranded conductors 16 AWG and smaller may be made in the whole conductor, provided that the solid section of the braze or weld does not exceed 13 mm (0.5 in) in length and the distance between brazes or welds is greater than 1000 m (3280 ft).

4.5 Conductor stress control layer (for cables rated above 2 kV)

4.5.1 The conductor stress control layer shall be an extruded semiconducting material of a thickness as shown in the Standard for Medium-Voltage Power Cables, UL 1072. This layer shall be applied over the surface of the conductor and bonded to the inner surface of the insulation. The conductor stress control layer material shall be compatible with all materials into which it comes in contact.

4.5.2 The contact surface between the conductor stress control layer and the insulation shall be cylindrical and free from protrusions and irregularities that extend more than 0.13 mm (0.005 in) into the insulation or more than 0.25 mm (0.01 in) into the conductor stress control layer.

4.5.3 The conductor stress control layer shall have a maximum volume resistivity of 1000 Ω·m at 90 ±1 °C (194 ±1.8°F), and other physical properties in accordance with the Standard for Medium-Voltage Power Cables, UL 1072.

4.5.4 The extruded conductor stress control layer may be supplemented by a semiconducting tape applied directly over the conductor. The maximum dc resistance of the semiconducting tape at room temperature shall be 10 000 Ω per unit square, when determined in accordance with the Standard Test Method for D-C Rated Resistance or Conductance of Moderately Conductive Materials, ASTM D4496.

4.5.5 The extruded conductor stress control layer material shall have a brittleness temperature not warmer than –25°C (–13°F) when tested in accordance with the Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact, ASTM D746.

4.5.6 The conductor stress control layer shall be easily removable from the conductor when terminating or splicing.

5 Insulation

5.1 General

5.1.1 The insulation shall be one of the following types:

Marking code symbol	Material	Maximum conductor operating temperature °C
T75	Polyvinyl chloride	75
TPE90	Thermoplastic elastomer	90
T/N90	Polyvinyl chloride/nylon	90
E90	Ethylene propylene rubber	90
X90	Cross-linked/polyolefin	90
X100	Cross-linked/polyolefin	100
X110	Cross-linked/polyolefin	110
X100P	Cross-linked/polyolefin for special applications	100
X110P	Cross-linked/polyolefin for special applications	110
S100	Silicone rubber	100
Note – The maximum short circuit temperature of all thermoplastic materials is 150°C, and of the thermoset materials is 250°C.		

5.2 Separator

5.2.1 Where required to ensure free stripping, a suitable opaque separator tape may be applied to the conductor of a cable rated 2 kV or less.

5.3 Thickness of extruded insulation

5.3.1 The average thickness of the insulation shall not be less than the values given in Table 5.1.

5.3.2 The minimum thickness of the insulation at any point shall not be less than 90 percent of the average value shown in Table 5.1.

5.3.3 For silicone insulated conductor sizes larger than 8 AWG, refer to the General Specification for Cable and Cord, Electrical, Low Smoke, for Shipboard Use, MIL-C-24643 for construction details using silicone impregnated tape insulation.

Table 5.1
Thickness of extruded insulations for distribution, control, and signal cables

		Average insulation thickness, mm (mils)			
Rated voltage phase to phase (V)	**Conductor size (AWG or kcmil)**	**Types X90, X100, X100P, X110, X110P, E90**	**Type S100 Silicone rubber**	**Types T75 PVC, TPE90 Thermoplastic Elastomer**	**Types T/N90 PVC/ Nylon**
0 – 300	22 – 19	0.28 (15)	0.87 (35)	0.50 (20)	0.37/0.10 (15/4)
	18 – 16	0.50 (20)	0.87 (35)	0.50 (20)	0.37/0.10 (15/4)
0 – 600/1000	18 – 11	0.76 (30)	1.14 (45)	1.14 (45)	0.37/0.10 (15/4)
	10 – 9	0.76 (30)	1.14 (45)	1.14 (45)	0.50/0.10 (20/4)
	8 – 5	1.14 (45)	1.50 (60)	1.50 (60)	0.76/0.13 (30/5)
	4 – 2	1.14 (45)	1.50 (60)	1.50 (60)	1.00/0.15 (40/6)
	1 – 4/0	1.37 (55)	2.00 (80)	2.00 (80)	1.25/0.18 (50/7)
	225 – 500	1.62 (65)	2.37 (95)	2.37 (95)	1.50/0.20 (60/8)
	525 – 1000	2.00 (80)	2.75 (110)	2.75 (110)	1.75/0.23 (70/9)
	1100 – 2000	2.37 (95)	–	–	–
1001 – 2000	14 – 9	1.14 (45)			
	8 – 2	1.37 (55)			
	1 – 4/0	1.62 (65)			
	225 – 500	1.87 (75)			
	525 – 1000	2.25 (90)			
	1100 – 2000	2.75 (110)			
2400 (unshielded)	8 – 1000	2.25 (90)			
5 kV – 35 kV shielded	See the Standard for Medium-Voltage Power Cables, UL 1072 for dimensions.				

5.4 Properties of insulation

5.4.1 General

5.4.1.1 The insulation resistance at 15.5°C shall meet the requirements of Table 5.2 when tested in accordance with Section 920 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

5.4.2 Long-term insulation resistance

5.4.2.1 The long term insulation resistance in water at 75°C shall meet the requirements of Table 5.2 when tested in accordance with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

5.4.3 Heat deformation

5.4.3.1 The heat deformation shall meet the requirements of Table 5.2 when tested in accordance with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

5.4.4 Hot creep

5.4.4.1 The hot creep shall meet the requirements of Table 5.2 when tested in accordance with Hot Creep Tests, Section 65 of the Standard for Medium-Voltage Power Cables, UL 1072.

5.4.5 Physical properties of insulation

5.4.5.1 The physical properties of the insulation shall meet the requirements of Table 5.2 when tested in accordance with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

5.4.6 Cold bend

5.4.6.1 The cold bend shall meet the requirements of Table 5.2 when tested in accordance with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

5.4.7 Conductor corrosion

5.4.7.1 The conductor corrosion shall be determined as follows:

a) A copper conductor removed from unaged specimens of the finished wire or cable and from specimens aged at elevated temperature, as described in Table 5.2, for the particular insulation being employed shall not show any evidence of corrosion (normal oxidation or discoloration of the copper not caused by the insulation or any separator is to be disregarded) when subjected to a visual examination.

b) The examination shall be made with normal or corrected vision without magnification.

5.4.8 Accelerated water absorption

5.4.8.1 The accelerated water absorption (electrical method) shall meet the requirements of Table 5.2 when tested in accordance with the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

Table 5.2
Electrical and physical requirements of insulation Types E90, X90, X100, X100P, X110, X110P, S100, T75, TPE90, and T/N90

Insulation material	**Ethylene propylene rubber**		**Cross-linked polyolefin**		**Cross-linked polyolefin for special applications**	**Silicone rubber**	**Polyvinyl chloride**	**Polyvinyl chloride/ nylon**	**Thermoplastic elastomer**
Insulation-type designation	**E90**	**E90**	**X90, X100, X110**	**X90**	**X100P, X110P**	**S100**	**T75**	**T/N90[a]**	**TPE90**
Voltage rating	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/1000 V**
Electrical Requirements: Insulation Resistance Constant MΩ-1000 ft at 15.5°C, min	10 000	20 000	10 000	20 000	10 000	4 000	2 000	2 000	2 000
Accelerated Water Absorption @ 75°C as per UL 1581 **Electrical Method:**									
Dielectric constant after 1 day, max	6.0	4.0	6.0	3.5	6.0	6.0	10.0	10.0	10.0
Increase in capacitance, max, 1 to 14 days	5.0	3.5	4.0	3.0	4.0	10.0	4.0	4.0	4.0
7 to 14 days	3.0	1.5	2.0	1.5	2.0	3.0	2.0	2.0	2.0
Stability factor after 14 days, max	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Long Term Insulation Resistance @75°C as per UL 44 or UL 83, using 14 AWG, 600 V	UL 44 pass	Not applicable	UL 44 pass	Not applicable	UL 44 pass	Not applicable	UL 83 pass	UL 83 pass	UL 83 pass
Heat deformation 1 h, per 5.4.3									
Test temperature °C (°F),	–	–	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	–	121 ±1 (250 ±1.8)	136 ±1 (277 ±1.8)	121 ±1 (250 ±1.8)
% of unaged value 4/0 AWG and smaller	–	–	30	25	30	–	25	25	25
Larger than 4/0	–	–	15	15	15	–	25	25	25
Hot Creep per UL 1072									
Test temperature °C (°F)	–	150 ±1 (302 ±1.8)	150 ±1 (302 ±1.8)	150 ±1 (302 ±1.8)	175 ±2 (347 ±3.6)	–	–	–	–

Table 5.2 Continued on Next Page

Table 5.2 Continued

Insulation material	Ethylene propylene rubber		Cross-linked polyolefin		Cross-linked polyolefin for special applications	Silicone rubber	Polyvinyl chloride	Polyvinyl chloride/ nylon	Thermoplastic elastomer
Insulation-type designation	**E90**	**E90**	**X90, X100, X110**	**X90**	**X100P, X110P**	**S100**	**T75**	**T/N90[a]**	**TPE90**
Voltage rating	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/1000 V**
Hot creep elongation, max., %	–	50	100	175	25	–	–	–	–
Hot creep set, max., %	–	5	10	10	5	–	–	–	–
Physical Requirements: Unaged									
Tensile strength, min, MPa (psi)	8.3 (1200)	4.8 (700)	12.4 (1800)	12.4 (1800)	12.4 (1800)	5.5 (800)	13.8 (2000)	13.8 (2000)	5.5 (800)
Elongation at rupture, min, percent	150	200	150	150	250	250	150	150	200
Aging Requirements – 75°C Rated:									
After air oven at °C (°F)	–	–	–	–	–	–	121 ±1 (250 ±1.8)	–	–
Hours	–	–	–	–	–	–	168	–	–
Tensile strength, % retention of unaged, min	–	–	–	–	–	–	75	–	–
Elongation at rupture, % retention of unaged, min	–	–	–	–	–	–	65[b]	–	–
Aging Requirements – 90°C Rated:					–				
After air oven at °C (°F)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	–	–	–	136 ±1 (277 ±1.8)	121 ±1 (250 ±1.8)
Hours	168	168	168	168	–	–	–	168	168
Tensile strength, % retention of unaged, min	75	75	85	75	–	–	–	75	75
Elongation at rupture, retention of unaged, min	75	75	60	75		–	–	65[b]	75
Aging Requirements – 100°C Rated:									
After air oven at °C (°F)	–	–	130 ±1 (266 ±1.8)	130 ±1 (266 ±1.8)	130 ±1 (266 ±1.8)	158 ±1 (316 ±1.8)	–	–	–
Hours	–	–	168	168	168	168	–	–	–
Tensile strength, % retention of unaged, min	–	–	75	75	90	65	–	–	–

Table 5.2 Continued on Next Page

Table 5.2 Continued

Insulation material	Ethylene propylene rubber		Cross-linked polyolefin		Cross-linked polyolefin for special applications	Silicone rubber	Polyvinyl chloride	Polyvinyl chloride/ nylon	Thermoplastic elastomer
Insulation-type designation	**E90**	**E90**	**X90, X100, X110**	**X90**	**X100P, X110P**	**S100**	**T75**	**T/N90[a]**	**TPE90**
Voltage rating	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**2001 – 35 kV**	**0 – 2000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/ 1000 V**	**0 – 600/1000 V**
Elongation at rupture, retention of unaged, min	–	–	75	75	50	50	–	–	–
Aging Requirements – 110°C Rated:									
After air oven at °C (°F)	–	–	141 ±1 (286 ±1.8)	141 ±1 (286 ±1.8)	158 ±1 (316 ±1.8)	–	–	–	–
Hours	–	–	168	168	168	–	–	–	–
Tensile strength, % retention of unaged, min	–	–	75	75	90	–	–	–	–
Elongation at rupture, retention of unaged, min	–	–	75	75	50	–	–	–	–
Cold Bend After 4 h at –30 ±1°C insulation shall not crack after being bent 180° around a mandrel 8 times the diameter of the insulation.	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Conductor Corrosion	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

[a] The nylon jacket shall be removed prior to aging.

[b] For 6 AWG and larger, buffed samples, value is 50 percent.

[c] For 6 AWG and larger, buffed samples, value is 45 percent.

5.4.10 Evaluation of alternate materials

5.4.10.1 Materials named in Table 5.2 that do not meet all of the physical property requirements may be evaluated using the long-term aging test in Section 481 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

6 Insulation Shield

6.1 The use of an insulation shield is mandatory for 5 to 35 kV cables. Where an insulation shield is used, both the metallic and non-metallic components shall comply with the requirements of the Standard for Medium-Voltage Power Cables, UL 1072.

7 Binder or Separator

7.1 An insulating binder or separator tape(s) is not required but is acceptable over an individual insulated conductor, over one or several groups of conductors, or over the entire cable assembly. Several binders may be used in a given cable.

8 Braids

8.1 Extruded silicone rubber insulated conductors shall be covered with a glass braid in accordance with the Standard for Thermoset-Insulated Wires and Cables, UL 44.

9 Conductor Identification

9.1 Where conductor color coding is specified, the identification may be made either by colored conductor insulation or separate tapes. Conductor identification of distribution cables, when colored conductors are used, shall be as follows:

a) Two conductors – black, and white or red;

b) Three conductors – black, white or blue, and red;

c) Four conductors – either black, white or blue, red, and orange or green; or black, red, blue, and orange or white.

Alternate conductor identification methods such as numbers are acceptable. Note that green or green with yellow stripes is accepted only for the grounding (or bonding) conductor of a distribution system.

9.2 The insulated conductors of control and signal cables shall be distinctly color coded. See Appendix A for a recommended practice for color code for control and signal cables.

9.3 Recommended color coding for pairs in signal cables is one black and one white conductor with the pair number printed on each conductor. Recommended color coding for triads in signal cables is one black, one white, and one red conductor with the triad number printed on each conductor.

10 Shielding

10.1 When required, signal cable shall contain shielded components that may consist of shielding over single conductors, pairs, triads, groups, and/or the complete cable.

11 Individually Shielded Components and Overall Shielding

11.1 The shielding shall consist of either a polyester/aluminum tape applied helically, aluminum side inward for an individual conductor shield and either inward or outward for an overall cable shield, or a copper tape, all with a minimum overlap of 25 percent or 6.4 mm (0.25 in), whichever is smaller, or a copper braid. Where a tape shield is used, a tinned copper, stranded drain wire shall be applied under the shield and shall be in contact with the aluminum side. The size of the drain wire shall be no smaller than two gauge sizes less than the signal circuit conductor size. Where a braided copper shield is used, it shall be constructed in accordance with Section 15. The wires in the braid shall be a minimum of 38 AWG copper.

11.2 Cables with individual and overall shielding shall be identified as such in accordance with Sections 40 – 42.

12 Cabling

12.1 Conductors, pairs, triads, or groups shall be cabled in concentric layers.

12.2 In multi-layer cables, the direction of lay for adjacent layers shall be reversed or unidirectional.

12.3 For cables employing lay reversal cabling, the transition zone shall not be less than 1.8 times the lay length.

12.4 The maximum length of lay shall be as noted in Table 12.1.

Table 12.1
Maximum length of lay

Number of conductors in cable	Maximum length of lay
2	30 × single conductor diameter
3	35 × single conductor diameter
4	40 × single conductor diameter
5 or more	15 × cable core diameter

12.5 Individual conductors that are paired or triplexed in signal cables shall have a maximum lay length the same as that shown for a cable in 12.4.

13 Fillers

13.1 Fillers shall be compatible with other cable components, moisture resistant, and maximize the filling of all voids. Fillers shall be used as required to give the completed cable a substantially circular cross section.

14 Cable Jackets

14.1 General

14.1.1 Except for single conductors described in 14.1.2 or 14.2.1, a cable jacket shall be provided and shall be one of the following types:

Marking code symbol	Material	Temperature rating, °C
TPO	Thermoplastic polyolefin	60 or 75
T	Polyvinyl chloride	60, 75, or 90
TPE	Thermoplastic elastomer	60, 75 or 90
N	Thermosetting neoprene	75 or 90
CP	Thermosetting chlorosulfonated polyethylene	75 or 90
CPE	Thermosetting chlorinated polyethylene	75 or 90
XP	Cross-linked polyolefin	90

14.1.2 Single conductors that are not part of a multi-conductor cable, 18 AWG and larger, rated 2 kV or less and insulated in accordance with Section 5, that are intended for use within equipment or an enclosure shall not be required to be jacketed.

14.1.3 The temperature rating of a jacket applied over the insulation may be less than that of the insulation with the difference in temperature ratings not exceeding 20°C.

14.1.4 The physical properties of the jacket shall meet the requirements of Table 14.1 when tested in accordance with Section 400 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

Table 14.1
Jacket properties Types T, CP, N, CPE, XP, TPE, and TPO

Jacket material	Polyvinyl chloride	Thermosetting chlor-sulfonated polyethylene	Thermo-setting neoprene	Thermosetting chlorinated polyethylene	Thermo-setting crosslinked polyolefin	Thermo-plastic elastomer	Thermo-plastic polyolefin
Jacket-type designation	T	CP	N	CPE	XP	TPE	TPO
Physical Requirements Unaged:							
Tensile strength, min, MPa (psi)	10.3 (1500)	12.4 (1800)	12.4 (1800)	12.4 (1800)	10.3 (1500)	10.3 (1500)	8.3 (1400)
Elongation at rupture, min, percent	150	300	300	300	150	150	100
Tension set, max, percent	–	30	20	30	–	–	–

Table 14.1 Continued on Next Page

Table 14.1 Continued

Jacket material	Polyvinyl chloride	Thermosetting chlor-sulfonated polyethylene	Thermo-setting neoprene	Thermosetting chlorinated polyethylene	Thermo-setting crosslinked polyolefin	Thermo-plastic elastomer	Thermo-plastic polyolefin
Aging Requirements – 60°C Rated Jacket:							
After air oven at °C	100 ±1 (212 ±1.8)	100±1 (212 ±1.8)	100 ±1 (212 ±1.8)	100 ±1 (212 ±1.8)	100 ±1 (212 ±1.8)	100 ±1 (212 ±1.8)	100 ±1 (212 ±1.8)
Hours	240	168	168	168	168	168	168
Tensile strength, % retention of unaged, min	85	85	50	85	70	75	75
Elongation at rupture, % retention of unaged, min	60	65	50	60	70	75	60
Aging Requirements – 75°C Rated Jacket:							
After air oven at °C	100 ±1 (212 ±1.8)	113 ±1 (236 ±1.8)	100 ±1 (212 ±1.8)	113 ±1 (236 ±1.8)	113 ±1 (236 ±1.8)	100 ±1 (212 ±1.8)	100 ±1 (212 ±1.8)
hours	240	168	240	168	168	240	240
Tensile strength, % retention of unaged, min	85	85	50	85	70	75	75
Elongation at rupture, % retention of unaged, min	60	50	50	50	70	75	60
Aging Requirements – 90°C Rated Jacket:							
After air oven at °C	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	–
Hours	168	168	240	168	168	168	–
Tensile strength, % retention of unaged, min	85	85	–	85	70	75	–
Elongation at rupture, % retention of unaged, min	60	50	–	60	70	75	–
Tensile strength, min, MPa (psi)	–	–	6.2 (900)	–	–	–	–
Elongation at rupture, min, %	–	–	50	–	–	–	–
Oil Exposure Resistance							
After oil immersion at °C	70 ±1 (158 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	121 ±1 (250 ±1.8)	100 ±2 (212 ±3.6)	70 ±1 (158 ±1.8)	70 ±1 (158 ±1.8)
Hours	4	18	18	18	96	4	4

Table 14.1 Continued on Next Page

Table 14.1 Continued

Jacket material	Polyvinyl chloride	Thermosetting chlor-sulfonated polyethylene	Thermo-setting neoprene	Thermosetting chlorinated polyethylene	Thermo-setting crosslinked polyolefin	Thermo-plastic elastomer	Thermo-plastic polyolefin
Tensile strength, % retention of unaged, min	80	60	80	60	50	80	50
Elongation at rupture, % retention of unaged, min	60	60	60	60	50	60	50
Heat Deformation, at 121°C ± 1°C max, percent of unaged value	50	–	–	15	15	30	–

14.1.5 Materials named in Table 14.1 that do not meet the aging test requirements may be evaluated using the long-term aging tests in Section 481 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

14.2 Integral insulation/jacket

14.2.1 Single conductor cables rated 2 kV only, with conductor sizes equal to or larger than 4/0 AWG, may use an increased insulation thickness in lieu of using a separate cable jacket.

14.2.2 The minimum average thickness of insulation shall be 2.67 mm (105 mils) for conductor sizes 4/0 AWG to 450 kcmil and 3.05 mm (120 mils) for conductor sizes 500 kcmil and larger.

14.2.3 When insulation is used as an integral insulation and jacket, the material shall comply with the requirements of Section 24.

14.2.4 When the thicker insulation value permitted in 14.2.1 is used, the cable markings shall be augmented by a suffix as specified in Section 40.

14.3 Jacket thickness

14.3.1 The minimum average thickness of the cable jacket shall be in accordance with Table 14.2. The minimum thickness at any point shall not be less than 80% of the minimum average values shown.

Table 14.2
Thickness of jacket

Calculated diameter of cable under jacket, mm	Minimum average jacket thickness, mm	Calculated diameter of cable under jacket, in	Minimum average jacket thickness, in
0 – 10.8	1.14	0 – 0.425	0.045
10.9 – 17.8	1.52	0.426 – 0.700	0.060
17.9 – 38.1	2.03	0.701 – 1.500	0.080
38.2 – 63.5	2.79	1.501 – 2.500	0.110
63.6 and larger	3.56	2.501 and larger	0.140

15 Metal Wire Armor (Optional)

15.1 General

15.1.1 The armor shall consist of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be 0.32 ±0.01 mm (0.0126 ±0.0005 in) in diameter. The wire shall be free from cracks, splits, or other flaws. The wire shall be commercial bronze, aluminum, or copper. The weave shall be the ″one over-one under″ or the ″two over-two under″ type. The selection of the number of ends per carrier and the number of carriers per braider shall be such as to produce a basket weave with a braid angle and coverage within the following limits:

Diameter under jacket		Percent braid coverage		Angle (°)	
mm	(in)	Min	Max	Min	Max
up to 15.2	up to 0.600	88	94	30	60
15.3 to 25.4	0.601 to 1.000	88	94	35	60
25.5 to 38.1	1.001 to 1.500	88	94	40	70
38.2 to 50.8	1.501 to 2.000	88	94	45	70
50.9 and over	2.001 and over	88	94	50	80

where the percent coverage = $(2F - F^2) \times 100$

in which:

$$F = \frac{NPd}{\sin a}; \ (0 \leq F \leq 1)$$

a = angle of braid with axis of cable and

$$\operatorname{Tan} a = \frac{2 \pi DP}{C}$$

d = diameter of individual braid wire in mm (in)

C = number of carriers

D = diameter of cable under armor, in mm (in)

N = number of wires per carrier

P = picks per mm (in) of cable length

The maximum number of ends per carrier shall conform to the following table:

Cable diameter under armor mm	(in)	Maximum number of ends per carrier	
		″one over-one under″	″two over-two under″
0 to 10.1	0 to 0.400	8	5
10.2 to 20.3	0.401 to 0.800	12	8
20.4 to 38.1	0.801 to 1.500	15	10
38.2 and larger	1.501 and larger	20	10

15.2 Aluminum armor

15.2.1 Aluminum armor braid shall be aluminum alloy 5154 or an equivalent alloy having a minimum tensile strength of 345 MPa (50 000 psi) and a minimum elongation of 2 percent in 254 mm (10 in).

15.3 Commercial bronze armor

15.3.1 Commercial bronze armor braid shall be annealed 90-10 bronze, Copper Development Association (CDA) alloy number 220.

15.4 Copper armor

15.4.1 Uncoated copper armor braid shall meet the requirements of ASTM B3. Coated copper armor braid shall meet the requirements of ASTM B33.

16 Corrugated Aluminum Sheath (Optional)

16.1 The sheath shall consist of either an extruded or a seam welded and corrugated aluminum tube that is applied directly over the cable assembly or over the cable jacket. The sheath shall meet the requirements of the Standard for Metal-Clad Cables, UL 1569. An overall jacket meeting the requirements of Section 14 shall be provided. The minimum average thickness of the jacket shall be in accordance with Table 16.1. The minimum thickness at any point shall not be less than 80 percent of the minimum average values shown.

Table 16.1
Thickness of jacket over armor or corrugated aluminum sheath

Calculated diameter under jacket		Minimum acceptable average jacket thickness	
mm	in	mm	in
0 – 10.80	0 – 0.425	1.02	0.040
Over 10.80 but not over 38.10	Over 0.425 but not over 1.500	1.27	0.050
Over 38.10 but not over 57.15	Over 1.500 but not over 2.250	1.52	0.060
Over 57.15 but not over 76.20	Over 2.250 but not over 3.000	1.91	0.075
Over 76.20	Over 3.000	2.16	0.085

17 Paint

17.1 Cables shall not be painted, except that 5 kV types may be painted yellow. The overall jacket of a cable may be of a color denoting the voltage rating of the cable as follows: a yellow-colored jacket for cable rated 5 kV, a red-colored jacket for cable rated 15 kV, or an orange-colored jacket for cable rated 35 kV.

18 Jacket Over Armor

18.1 A jacket over the armor is optional on cables with aluminum or bronze metal braid armor. A jacket over the armor is required on cables with copper braid armor. The jacket material shall be in accordance with the requirements for cable jackets as specified in Section 14. The minimum average thickness of the jacket shall be in accordance with Table 16.1. The minimum thickness at any point shall not be less than 80% of the minimum average values shown.

19 Equipment Grounding Conductors

19.1 Cables are manufactured with or without a bare or insulated equipment grounding (or bonding) conductor. When insulated equipment grounding (or bonding) conductors are provided, the color of the insulation shall be green or green with yellow stripes. For cables rated 2 kV or less, the insulation shall be of the same material and have the same voltage rating as the circuit conductor. The minimum size of the grounding conductor shall be in accordance with Table 19.1.

Table 19.1
Minimum grounding conductor size

AWG or kcmil	mm^2	Circular mils	Two-conductor cable				Three-conductor cable			
			Minimum conductor size, AWG							
			75°C	90°C	100°C	110°C	75°C	90°C	100°C	110°C
20	0.52	1020	20	20	20	20	20	20	20	20
18	0.82	1620	18	18	18	18	18	18	18	18
16	1.31	2580	16	16	16	16	16	16	16	16
14	2.08	4110	14	14	14	14	14	14	14	14
12	3.31	6530	12	12	12	12	12	12	12	12
10	5.26	10380	10	10	10	10	10	10	10	10
8	8.37	16510	10	10	8	8	10	10	10	10
7	10.55	20820	8	8	8	8	10	10	8	8
6	13.30	26240	8	8	8	8	8	8	8	8
5	16.77	33090	8	8	6	6	8	8	8	8
4	21.15	41740	8	6	6	6	8	8	8	8
3	26.66	52620	6	6	6	6	8	8	6	6
2	33.62	66360	6	6	6	6	8	6	6	6
1	44.21	83690	6	6	6	6	6	6	6	6
1/0	53.50	105600	6	6	6	4	6	6	6	6
2/0	67.44	137100	6	4	4	4	6	6	6	6
3/0	85.02	167800	4	4	4	4	6	4	4	4
4/0	107.2	211600	4	4	3	3	6	4	4	4
250	126.7	250000	4	3	3	3	4	4	4	4
263	133.1	262600	4	3	3	3	4	4	4	3
313	158.6	313100	3	3	3	2	4	4	3	3
350	177.3	350000	3	3	2	2	4	3	3	3
373	189.3	373700	3	2	2	2	4	3	3	3

Table 19.1 Continued on Next Page

Table 19.1 Continued

AWG or kcmil	mm²	Circular mils	Two-conductor cable				Three-conductor cable			
			Minimum conductor size, AWG							
			75°C	90°C	100°C	110°C	75°C	90°C	100°C	110°C
444	225.2	444400	3	2	1	1	3	3	2	2
500	253.3	500000	2	2	1	1	3	3	2	2
535	271.2	535300	2	2	1	1	3	2	2	2
646	327.5	646400	2	1	1/0	1/0	3	2	1	1
750	380.0	750000	1	1/0	1/0	1/0	2	2	1	1
777	394.0	777700	1	1/0	1/0	1/0	2	1	1	1
1000	506.7	1000000	–	–	–	–	–	–	–	–
1111	563.1	1111000	–	–	–	–	–	–	–	–
1250	633.3	1250000	–	–	–	–	–	–	–	–
1500	760.0	1500000	–	–	–	–	–	–	–	–
2000	1013.3	2000000	–	–	–	–	–	–	–	–

20 System Ground

20.1 The system ground conductor shall be the same size as the phase conductor size. The color of the system ground conductor shall not be green or green with yellow stripes.

PERFORMANCE

21 General

21.1 Cables manufactured to this Standard shall comply with the performance requirements in Sections 22 – 36.

21.2 Shielded cables rated 5 kV and above additionally shall comply with all the electrical tests specified in the Standard for Medium-Voltage Power Cables, UL 1072.

22 Low Temperature Bend Test

22.1 Neither the insulation nor the jacket of any specimens of finished cable shall exhibit cracks or ruptures when examined under normal or corrected-to-normal vision when bent 180° around a mandrel equal to eight times the overall diameter of the cable after the specimen and the mandrel have been conditioned for 4 h at the test temperature shown in the table below. Compliance shall be determined in accordance with the cold bend test specified in Section 580 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

Cable marking	Conditioning test temperature
none	–25 ±1°C
–35°C	–35 ±1°C
–40°C	–40 ±1°C
–55°C	–55 ±1°C

23 Low Temperature Impact Test

23.1 Neither the insulation nor the jacket of at least eight out of ten specimens of finished cable shall exhibit cracks or ruptures when examined under normal or corrected-to-normal vision when tested in accordance with Section 593 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581 after conditioning for 4 h at the test temperature shown in the following table:

Cable marking	Conditioning test temperature
none	no test
–35°C	–35 ± 1°C
–40°C	–40 ± 1°C
–55°C	–55 ± 1°C

24 Sunlight/Weather Resistance Test

24.1 Jacket specimens from finished cables shall be subjected to 720 h of carbon or xenon arc conditioning in accordance with Section 1200 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

24.2 The cable shall not be acceptable for sunlight/weather-resistant use if the retention of the original tensile strength and elongation at break of the specimen after aging is less than 80 percent.

25 Flame Test

25.1 All cable constructions except those limited to use within equipment or enclosures shall exhibit flame spread characteristics as specified in 25.2. The following constructions shall be tested:

a) Distribution cables: (600 V, 2 kV) – one single conductor, 6 AWG, or 3 conductor, 6 AWG cable; for cables rated 5 kV and above, the sample sizes specified in the Standard for Medium-Voltage Power Cables, UL 1072, shall be used

b) Control cables: 7 conductor, 12 AWG, or 7 conductor, 14 AWG; and

c) Signal and/or instrumentation cables: 7 pairs, 18 AWG.

25.2 These cable constructions shall be subjected to the FT4/IEEE 1202 Vertical-Tray flame test in accordance with the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. The cable shall be considered to comply if the damage to the cable does not exceed 1.5 m (4 ft, 11 in) above the point of flame impingement on the cable sample. The smoke release requirements in UL 1685 do not apply.

25.3 Although the fire type testing is performed on these selected sample sizes, the manufacturer shall ensure that the complete product range also complies with the requirements of FT4/IEEE 1202 flame test in accordance with the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

25.4 Single conductor cables as described in 14.1.2 shall meet the requirements of the VW-1 flame tests in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Compliance shall be determined by testing a 14 AWG conductor.

26 Ease of Stripping Test

26.1 When subjected to the procedures described in 26.2, the cable shall comply with the following requirements:

a) The cable core shall not be damaged when the jacket is removed; and

b) There shall not be any evidence of insulating compound beneath the outer layer of conductor strands.

26.2 A specimen of multiple conductor cable approximately 380 mm (15 in) in length shall have its jacket and filler material cut using a razor blade or similar instrument. The cut shall be made longitudinally and vertically down to the insulation for approximately 150 mm (6 in). A second cut around the circumference of the cable shall be made at the end of the first cut. The resulting jacket piece shall then be removed by pulling at right angles away from the cable. Observation shall be made as to whether or not the jacket and filler material can be removed without damage to the conductor insulation or other internal conductor coverings. Particles which can be removed by light brushing are acceptable. In addition, the insulation shall be prevented by the manufacturing process or by an acceptable separator from penetrating between the strands of the conductor. A 75-mm (3-in) length of the insulation shall be stripped from a sample length of the finished stranded conductor and the outer layer of strands shall be opened and observation made as to whether or not the insulation is found beneath the outer layer.

27 Salt Water Immersion Test

27.1 Cables shall comply with the following requirements after being subjected to salt water immersion in accordance with the procedure described in 27.2:

a) The cable shall comply with the dielectric withstand test described in 38.1 of this Standard;

b) The mechanical properties of the jacket or insulation shall not degrade to the point where the jacket or insulation will crack when the cable is wound around a mandrel having a diameter equal to nine times the sample overall diameter; and

c) The insulation and jacket shall not degrade to the point where either will crack or separate from the cable during the conditioning or during the testing described in (a) or (b) above.

27.2 Three 1-m (39-in) lengths of cable shall be immersed in a 20 percent (by weight) solution of common salt (sodium chloride) at 60 ±1°C (140 ±1.8°F) for 240 h. The cable shall be immersed in a ″U″ bend such that each end of the ″U″ bend of the cable is 300 mm (1 ft) above the surface of the water.

28 Oil Compatibility Test

28.1 Cables shall comply with the following requirements after being subjected to oil immersion in accordance with 28.2:

a) The cable shall comply with the dielectric withstand test described in 38.1 of this Standard;

b) The mechanical properties of the jacket or insulation shall not degrade to the point where the jacket or insulation will crack when the cable is wound around a mandrel having a diameter equal to nine times the sample overall diameter; and

c) The insulation and jacket shall not degrade to the point where either will crack or separate from the cable during the conditioning or during the testing described in (a) or (b) above.

28.2 Three 1-m (39-in) lengths of cable shall be immersed in IRM 902 oil at 100 ±1°C (212 ±1.8°F) for 96 h or, at the manufacturer's option, 60 ±1°C (140 ±1.8°F) for 60 days. The cable shall be immersed in the oil in a ″U″ bend such that each end of the ″U″ bend is 300 mm (1 ft) above the surface of the oil.

29 Pulling Through Metal Plates Test

29.1 There shall not be any damage to the overall covering or jacket to the extent that the parts of the cable underlying the covering or jacket are exposed to view after completion of the pull through test as specified in 29.2 and 29.3.

29.2 The metal plates for the test set-up in Figure 29.1 shall consist of four 150-mm (6-in) or longer lengths of 13 × 100 mm (1/2 × 4 in) cold rolled steel. Both ends of each length shall be cut perpendicular to the long surfaces. Three holes of the size specified in the following table shall be bored through the broad faces of each plate as shown in Figure 29.1. The longitudinal axes of the holes shall be parallel and at an angle of 15° to the horizontal as shown in the end view and 38 mm (1.5 in) apart on center. In cases where the nominal diameter of the hole is 38.1 mm (1.5 in) or greater, the holes shall be separated by 6 mm (0.25 in). The edges of the hole shall be reamed sufficiently to remove burrs and rough edges caused by the drilling.

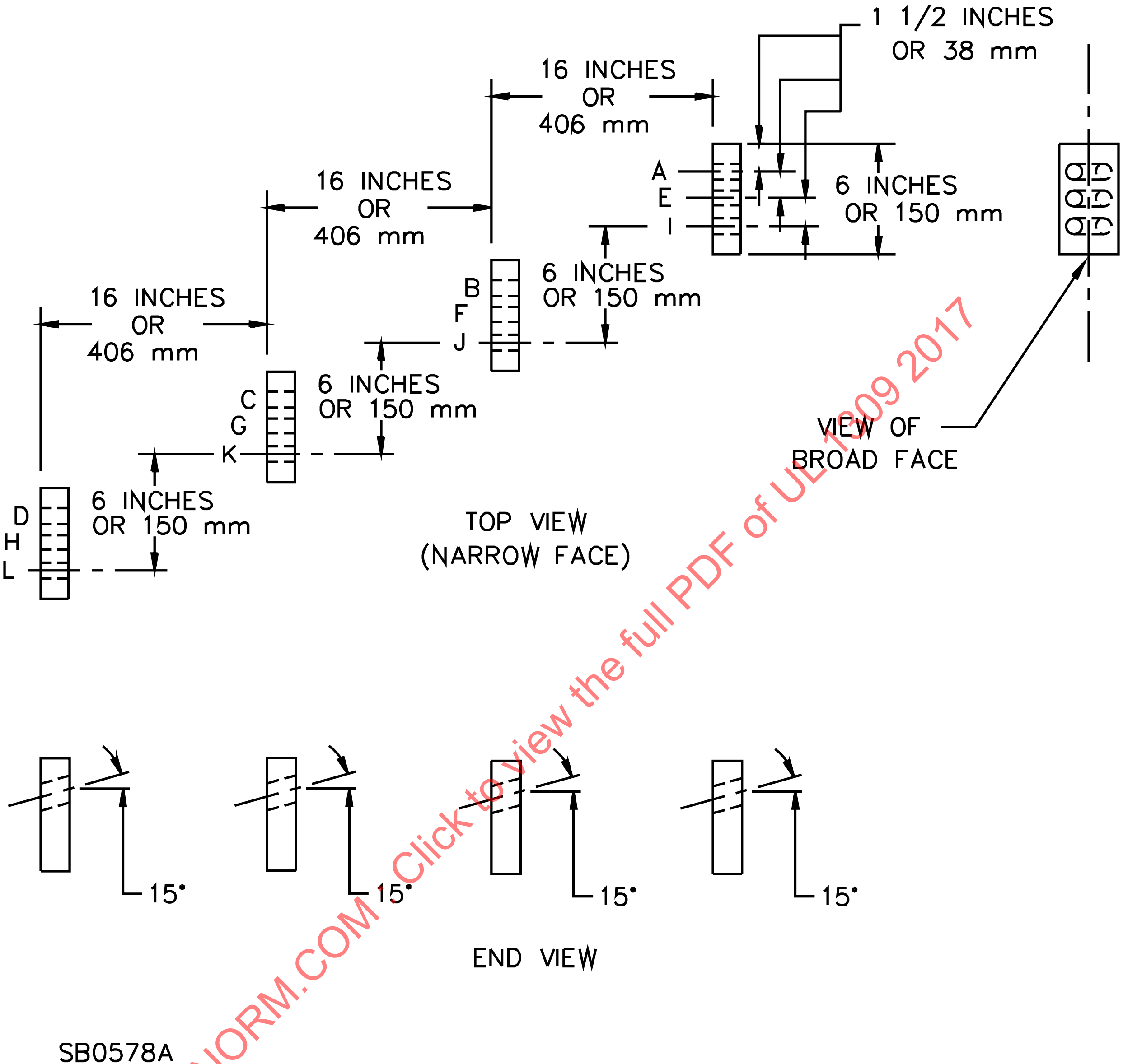
Size of hole			
Calculated diameter over finished round cable or length of major axis of finished flat cable		Nominal diameter of each hole	
mm	(in)	mm	(in)
0.0 – 17.8	0 – 0.700	28.6	1.125
17.9 – 20.3	0.701 – 0.800	31.8	1.250
20.4 – 22.2	0.801 – 0.874	34.9	1.375
22.3 – 24.1	0.875 – 0.949	38.1	1.500
24.1 – 26.0	0.950 – 1.024	41.3	1.625
≥ 26.1	≥ 1.025	1.5 × cable OD	
Note – An open, rigid, metal frame shall be provided on which four of the plates are supported on edge (broad faces vertical) approximately 2.13 m (7 ft) above the inside floor of a cold chamber with their centerlines 400 mm (16 in) apart and parallel to one another in a horizontal direction (longitudinal axes of holes parallel). The four end views in Figure 29.1 shall be noted and a horizontal distance of 150 mm (6 in) shall be progressively offset as also shown in Figure 29.1, which is a view looking down from above the plates.			

29.3 A reel containing 45 m (150 ft) in length of finished cable shall be mounted on a stand, and placed on the floor so that the distance between the bottom of the cable reel and a line perpendicular to the center of the plates is 2.03 m (80 in). The cable shall be cooled in air at minus 10 ±1°C (14 ±1.8°F) for 24 h. The distance between the first plate and a line tangent to the coil at the point where the cable comes off the coil shall be 460 mm (18 in). Upon completion of the period of cooling, the following procedures shall be carried out immediately.

29.4 One end of the sample shall be threaded in succession through the holes labelled A, B, C, and D in Figure 29.1. As soon as the first part of the sample has been threaded through the four holes, the end of the sample emerging from hole D (head end) shall be grasped securely by one or two persons standing on the floor in a position such that the cable emerges from hole D at an angle of about 45 degrees to the vertical. While maintaining this angle, 15 m (50 ft) of the sample shall be pulled (hand-over-hand whenever possible) entirely through the holes until the end of this sample (tail end) emerges from hole D. The sample shall be pulled through rapidly, and no effort shall be made to straighten or adjust the sample except to remove kinks that would prevent the sample from being pulled completely through the four holes. All of the pulling shall be done from beyond hole D, not from between plates.

29.5 As soon as the tail end of the sample emerges from hole D, the sample shall be cut to provide a 15-m (50-ft) length, and the head end of this sample shall be threaded in succession through holes E, F, G, and H. The entire length of the sample shall be pulled through in the manner indicated in the preceding paragraph. As soon as the tail end of the sample emerges from hole H, the head end of the sample shall be threaded in succession through holes I, J, K, and L, and the entire length of the sample shall be pulled through in the manner indicated. Immediately thereafter, the overall sample shall be examined visually to determine if the cable is damaged and the degree of damage.

Figure 29.1
Test setup for pull through metal plates test



30 Bending Endurance Test

30.1 There shall not be any evidence of the cable insulation or jacket cracking as a result of the bending test described in 30.2 and the subsequent dielectric withstand test of 38.1.

30.2 Samples shall be conditioned for 4 h in a cold chamber at a temperature of –25 ±1°C (–13 ±1.8°F). While still at that temperature, each sample shall be tightly wound for 1/4 turn around a mandrel having a diameter equal to 12 times the overall diameter of the specimen. The specimen shall then be straightened to its original position and then bent for 1/4 turn in the opposite direction and then straightened. This procedure shall be repeated 9 more times for a total of 10 times. The specimens shall then be subjected to the dielectric withstand test described in 38.1.

31 Long-Term Insulation Resistance

31.1 Types X and E insulation materials shall meet the applicable long-term insulation resistance requirements for a 75°C XHHW or RHW wet location insulation material as outlined in the Standard for Thermoset-Insulated Wires and Cables, UL 44.

31.2 Types T and TPE insulation material shall meet the applicable long-term insulation resistance requirements for a 75°C THW wet location insulation material as outlined in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

31.3 Types T/N insulation materials shall meet the applicable long-term insulation resistance requirements for a 75°C THWN wet location insulation material as outlined in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

32 Heat Deformation Test

32.1 The heat deformation test on Types X, T75, T/N90, and TPE90 insulation shall be conducted in accordance with Section 560 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581 except that the temperature and requirements are found in Table 5.2 and the following specimen loading is used:

Table 32.1
Deformation load requirements

Size of conductor, AWG	Minimum load exerted on specimen by the foot of the rod	
	Grams	Newtons
22 – 16	400	3.92
14 – 7	500	4.90
6 – 1	750	7.35
1/0 – 4/0	1000	9.81
213 – 2000 kcmil	2000	19.61

32.2 The heat deformation test on Types T, CPE, XP, and TPE jackets shall be conducted in accordance with Section 560 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581 except using a load of 2000 grams (19.61 N) on the specimen and the requirements specified in Table 14.1.

33 Heat Shock Test of Jacket

33.1 Types T and TPE jackets shall not show any cracks either on the surface or internally after a specimen of the complete, finished cable is wound around a mandrel and is then subjected to a temperature of 121 ±1°C (249.8 ±1.8°F) for 1 h. The test shall be conducted in accordance with 33.2.

33.2 A metal right-circular mandrel shall be used for this test. The mandrel shall have a diameter that is 3 times the outside diameter of finished cable that is 0 – 19.05 mm (0 – 0.750 in) in calculated overall diameter, 8 times the outside diameter of finished cable that is 19.08 – 38.10 mm (0.751 – 1.500 in) in calculated overall diameter, and 12 times the outside diameter of finished cable that is over 38.10 mm (1.500 in) in calculated overall diameter. Four sample lengths of the complete cable shall be used. The diameter of the cable shall be measured by means of a diameter tape. One sample shall be bent for not less than 180° around the mandrel, with the cable in contact with the mandrel throughout the bend. The ends of the cable shall be securely held in place by a means such as friction tape. The assembly of cable and mandrel shall be heated in a full-draft circulating-air oven to 121 ±1°C (249.8 ±1.8°F) for 1 h. The assembly shall be removed from the oven and, while still hot and on the mandrel, the cable shall be examined for cracking of the inner and outer surfaces of the jacket. Cracking of the inner surface can be detected from circumferential depressions in the outer surface of the jacket. The overall jacket shall be acceptable if, for the first sample, there is no evidence of cracking. If the first sample shows any cracking, the test shall be repeated on each of the three remaining samples. The overall jacket shall not be acceptable if there is evidence of cracking in any of the three additional samples.

34 Tension Set of Jacket

34.1 The tension set of Types CP, N, and CPE jackets shall comply with Table 14.1 when tested in accordance with Set of Non-Conductive Thermoset Jackets, Section 36 of the Standard for Medium-Voltage Power Cables, UL 1072.

35 Hot Oil Resistance

35.1 The insulated conductor diameter increase (swell) for X100P and X110P insulation materials shall not exceed values shown below, after the center 30.5-cm (1-ft) section of a 61-cm (2-ft) length of insulated 12 AWG conductor, with ends stripped of 61 cm (2 in) of insulation, is exposed for 100 h in the following fluids:

Fluid	Temperature, °C (°F)	Allowable swell, percent
IRM 902	150 (302)	60
Diesel (fuel) oil	60 (140)	60

Swelling shall be evaluated no sooner than 24 h and no later than 48 h after immersion. The specimens shall additionally show no cracks in insulation following immersion.

35.2 The insulation shall withstand an AC rms potential of 3.5 kV for 5 min conducted between conductor and aluminum foil wrapped around insulation.

36 Vertical-Tray Fire and Smoke-Release Test for Cables with "ST1" Marking

36.1 Each cable that is surface marked ″ST1″ in accordance with Item m of 40.1 shall comply with the limits for smoke release and cable damage height stated in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685 when sets of specimens as described in 36.2 are tested in accordance with the FT4/IEEE 1202 flame exposures described in UL 1685 with smoke measurements included.

36.2 The test specimens shall be of the complete, finished cable. The test specimens shall be representative of the entire size range that the manufacturer intends to produce in each construction made. Specimens for a UL 1685 fire test typically consist of the smallest, largest, and an intermediate diameter that the manufacturer intends to produce in each construction made. Where the UL 1685 limits are exceeded by the smoke released and/or cable damage height for any set of specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer.

MANUFACTURING AND PRODUCTION LINE TESTS

37 Spark Test (0 – 2 kV Unshielded Cables)

37.1 Each individual insulated conductor, before assembly, shall withstand without breakdown the application of the ac spark test voltage given in Table 37.1.

37.2 Compliance with the spark test in 37.1 shall be determined with the apparatus in, and in accordance with, the method described in Section 900 of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

Table 37.1
AC spark test voltage

Conductor size, AWG or kcmil	Cable voltage rating (V)		
	300	600/1000	2000
	AC Spark test voltage, kV		
22 – 20	1.75	–	–
18 – 16	1.75	7.5	–
14 – 10	1.75	7.5	10.0
8	–	10.0	12.5
6 – 2	–	10.0	12.5
1 – 4/0	–	12.5	15.0
250 – 500	–	15.0	17.5
600 – 1000	–	17.5	20.0
1250 – 2000	–	20.0	22.5

38 Dielectric Withstand Test on Finished Cable (0 – 2.4 kV Cables)

38.1 Each reel of finished cable shall be tested and shall successfully withstand for a period of 5 min the high voltage ac test potential given in Table 38.1. The ac potential shall be applied between the conductor (or conductors) and the metallic sheath, metallic shield, metallic armor, or water (for those cables without a metallic sheath, metallic shield, or metallic armor). Single conductor cables rated 0 – 2 kV manufactured without shield or armor are not required to be tested.

38.2 The reel of single conductor unshielded cable shall be immersed in a water tank for at least 6 h and the ac test potential shall be applied between the insulated conductor and the metal water tank or other electrode immersed in the water in the tank if the tank is nonmetallic.

38.3 For cables having from 2 to 5 conductors, with or without metal sheath or armor, the dielectric withstand test shall be applied in turn between each conductor and all other conductors connected together and to the metal covering, if any.

38.4 For cables having more than 5 conductors, the dielectric withstand test shall be applied as follows:

a) Between all conductors of uneven number in all layers and all conductors of even number in all layers;

b) Between all conductors of even layers and all conductors of uneven layers; and

c) If necessary, between the first and the last conductor of each layer having an uneven number of conductors.

Table 38.1
High-voltage ac test potentials for Types E90, S100, X90, X100, X100P, X110, X110P, T75, T/N90, and TPE90 insulation (0 – 2.4 kV cables)

Cable voltage rating, V	300	600/1000V	2000	2400 (unshielded)
Conductor size, AWG or kcmil	Test potentials, kV			
22 – 19	1.5	1.5	–	–
18 – 15	1.5	1.5	–	–
14 to 9	–	3.5	5.5	–
8 to 2	–	5.5	7.0	13.0
1 to 4/0	–	7.0	8.0	13.0
250 to 450	–	8.0	9.5	13.0
500 to 525	–	8.0	11.5	13.0
535 to 1 000	–	10.0	11.5	13.0
over 1 000	–	10.0	11.5	–

38.5 Compliance with the dielectric withstand test shall be determined with the apparatus in, and in accordance with, the method described in the Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members, UL 1277.

39 Insulation Resistance Test on Finished Cable (0 – 2.4 kV Cables)

39.1 Each reel of finished cable shall have the insulation resistance measured between each conductor and metallic sheath, metallic shield, metallic armor, or water (for those cables without a metallic sheath, metallic shield, or metallic armor) as described in 38.2 – 38.4. The insulation resistance shall not be less than the values given in Table 39.1. Single conductor cables rated 0 – 2.4 kV manufactured without shield or armor are not required to be tested.

39.2 Compliance with the insulation resistance test in 39.1 shall be determined with the apparatus and in accordance with the method described in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

39.3 The current shall be measured after a 1 min electrification with a continuous direct-current potential of not less than 100 V or more than 500 V, the conductor being negative to ground. If the test is made at a temperature different from 15.5°C, the measured value shall be multiplied by the proper correction factor as specified in Table 39.2.