UL 1581

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Reference Standard for Electrical Wires, Cables, and Flexible Cords

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Electrical Wires, Cables, and Flexible Cords, UL 1581

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

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.

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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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.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, Recognition, and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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

Page	Date
1-214	October 31, 2001

UL 1581

Reference Standard for Electrical Wires, Cables, and Flexible Cords

First Edition – August, 1983
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An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

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

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FOREWORD

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

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

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

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

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

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

INTRODUCTION

1 Scope

1.1 This standard contains specific details of the conductors, of the insulation, of the jackets and other coverings, and of the methods of sample preparation, of specimen selection and conditioning, and of measurement and calculation that are required in the Standards for Thermoset-Insulated Wires and Cables (UL 44), Thermoplastic-Insulated Wires and Cables (UL 83), Flexible Cord and Fixture Wire (UL 62), and Service-Entrance Cables (UL 854). Elements of this standard are referenced in other requirements as well.

1.2 The requirements for the particular materials, construction, performance, and marking of an individual type of wire, cable, or flexible cord are stated in the standard covering the finished type. They are not part of this reference standard.

1.3 In each case in which an element of this standard does not apply, the standard covering the finished type so states and specifies what does apply.

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.

3 References and Terms

3.1 The term ″wire standard″ as used in this standard means any standard that covers finished electrical wires, cables, or flexible cords and in which reference is made to this reference standard (UL 1581).

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CONDUCTORS

10 Requirements for Aluminum Conductors of an 8000 Series Alloy

10.1 These requirements cover aluminum wire in annealed and intermediate tempers using 8000 series electrical-conductor-grade aluminum alloys. These alloys are for use in solid conductors in the 6 – 4/0 AWG sizes and in round-strand and compressed- and compact-stranded conductors in the 12 AWG – 2000 kcmil sizes.

10.2 The wire shall be of a registered 8000 series electrical-conductor-grade aluminum alloy complying with ASTM B 800-00. The conductor diameter and cross-sectional area shall comply with Conductor Diameter and Cross-Sectional Area, Section 20. The d-c resistance of the conductors shall comply with D-C Conductor Resistance, Section 30.

10.3 The temper of the wire of the finished conductor shall be annealed (-0) or intermediate (-H1X) or (-H2X). The tensile strength and elongation (see note [b] to Table 10.1) of the finished stranded conductor tested as a unit or of the individual strands removed from the finished conductor or of the finished solid conductor shall comply with Table 10.1 when specimens are tested at a speed of 1 in/min or 25 mm/min using the equipment and procedure described in ASTM B 557-94.

Table 10.1
Mechanical properties[a] of solid and stranded conductors of an 8000 series aluminum alloy

Temper	Tensile strength	Elongation[b] in 10 inches or 250 mm
Annealed (-0)	All specimens: 11,250 ±2,750 lbf/in^2 or 78 ±19 MPa (MN/m^2) or 7,757 ±1,896 N/cm^2 or 7.91 ±1.93 kgf/mm^2	Solid conductor: 10.0 percent minimum Stranded conductor: 10.0 percent minimum
Semi-annealed: (-H1X) and (-H2X)	Wires (strands) removed from the finished stranded conductor: 18,675 ±4,425 lbf/in^2 or 129 ±30 MPa (MN/m^2) or 12,876 ±3,050 N/cm^2 or 13 ±3 kgf/mm^2	Solid conductor: 10.0 percent minimum Stranded conductor: 10.0 percent minimum
	All other specimens: 18,500 ±3,500 lbf/in^2 or 128 ±24 MPa (MN/m^2) or 12,755 ±2,413 N/cm^2 or 13.01 ±2.46 kgf/mm^2	Solid conductor: 10.0 percent minimum Stranded conductor: 10.0 percent minimum

[a] For the purpose of determining compliance with the tabulated limits, test results are to be rounded as follows after specimens are tested at a speed of 1 in/min or 25 mm/min using the equipment and procedure described in ASTM B 557-94:

1) Each calculated value of tensile strength is to be rounded to the nearest 100 lbf/in^2 or 1 MPa (MN/m^2) or 69 N/cm^2 or 0.07 kgf/mm^2.

2) Each value of elongation is to be rounded to the nearest 0.5 percent as described in the rounding method in ASTM E 29-93a(R1999).

[b] Compliance with the elongation requirement for stranded conductors is to be determined on wires taken prior to stranding into conductors, on wires taken from a stranded conductor, or on the stranded conductor as a whole.

11 Requirements for Copper-Clad Aluminum Conductors

11.1 The requirements in this section (11.1) cover copper-clad aluminum conductors. Copper-clad aluminum conductors shall be drawn from copper-clad aluminum rod. The copper shall be metallurgically bonded to the aluminum core, shall occupy 10 percent or more of the cross section of a solid conductor and of each wire (strand) of a stranded conductor, and shall be concentric with the aluminum. The thickness of the copper shall not be less than 2.56 percent of the diameter of the solid conductor or wire (strand) as determined by microscopic examination of a polished right cross section of the round strand or round solid conductor. The tensile strength of a finished copper-clad aluminum conductor tested as a unit or of the wires (strands) from a finished stranded copper-clad aluminum conductor and of a finished solid copper-clad aluminum conductor shall not exceed 20,000 lbf/in^2 or 138 MPa (MN/m^2) or 13,800 N/cm^2 or 14 kgf/mm^2 when specimens are tested at the speed and using the equipment and procedure indicated in ASTM B 566-93(R1998). The elongation of the same specimens shall not be less than 15 percent in 10 inches or 250 mm.

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20 Conductor Diameter and Cross-Sectional Area

Table 20.1
Conductor dimensions

	Diameter of solid conductor								Cross-sectional area of conductor					
									Nominal		Minimum			
	Nominal		Minimum[c]		Maximum[c]		Minimum[d]				0.98 × Nominal[a]		0.97 × Nominal[b]	
Size of con-ductor	mils	mm	mils (0.98 x nominal)	mm	mils (1.01 x nominal)	mm	mils (0.99 x nominal)	mm	cmil	mm^2	cmil	mm^2	cmil	mm^2
30 AWG	10.0	0.254	9.8	0.249	10.1	0.257	9.9	0.251	100	0.0507	98	0.0497	–	–
29	11.3	0.287	11.1	0.282	11.4	0.290	11.2	0.284	128	0.0647	125	0.0633	–	–
28	12.6	0.320	12.3	0.312	12.7	0.323	12.5	0.318	159	0.0804	156	0.0790	–	–
27	14.2	0.361	13.9	0.353	14.3	0.363	14.1	0.358	202	0.102	198	0.100	–	–
26	15.9	0.404	15.6	0.396	16.1	0.409	15.7	0.399	253	0.128	248	0.126	–	–
25	17.9	0.455	17.5	0.444	18.1	0.460	17.7	0.450	320	0.162	314	0.159	–	–
24	20.1	0.511	19.7	0.500	20.3	0.516	19.9	0.506	404	0.205	396	0.201	392	0.199
23	22.6	0.574	22.1	0.561	22.8	0.579	22.4	0.568	511	0.259	501	0.254	496	0.251
22	25.3	0.643	24.8	0.630	25.6	0.650	25.0	0.635	640	0.324	627	0.318	621	0.314
21	28.5	0.724	27.9	0.709	28.8	0.732	28.2	0.717	812	0.412	796	0.404	788	0.400
20	32.0	0.813	31.4	0.798	32.3	0.820	31.7	0.805	1020	0.519	1000	0.509	989	0.503
19	35.9	0.912	35.2	0.894	36.3	0.922	35.5	0.902	1290	0.653	1264	0.641	1251	0.633
18	40.3	1.02	39.5	1.00	40.7	1.03	39.9	1.01	1620	0.823	1588	0.807	1571	0.798
17	45.3	1.15	44.4	1.13	45.8	1.16	44.8	1.14	2050	1.04	2009	1.02	1989	1.01
16	50.8	1.29	49.8	1.26	51.3	1.30	50.3	1.28	2580	1.31	2528	1.28	2503	1.27
15	57.1	1.45	56.0	1.42	57.7	1.47	56.5	1.44	3260	1.65	3195	1.62	3162	1.60
14	64.1	1.63	62.8	1.60	64.7	1.64	63.5	1.61	4110	2.08	4028	2.04	3987	2.02

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Table 20.1 Continued

Size of con-ductor	Diameter of solid conductor								Cross-sectional area of conductor					
	Nominal		Minimum[c]		Maximum[c]		Minimum[d]		Nominal		Minimum			
											0.98 × Nominal[a]		0.97 × Nominal[b]	
	mils	mm	mils (0.98 x nominal)	mm	mils (1.01 x nominal)	mm	mils (0.99 x nominal)	mm	cmil	mm^2	cmil	mm^2	cmil	mm^2
13 AWG	72.0	1.83	70.6	1.79	72.7	1.85	71.3	1.81	5180	2.63	5076	2.58	5025	2.55
12	80.8	2.05	79.2	2.01	81.6	2.07	80.0	2.03	6530	3.31	6399	3.24	6334	3.21
11	90.7	2.30	88.9	2.26	91.6	2.33	89.8	2.28	8230	4.17	8065	4.09	7983	4.04
10	101.9	2.588	99.9	2.537	102.9	2.614	100.9	2.563	10380	5.261	10172	5.16	10069	5.103
9	114.4	2.906	112.1	2.847	115.5	2.934	113.3	2.878	13090	6.631	12828	6.50	–	–
8	128.5	3.264	125.9	3.198	129.8	3.297	1.272	3.231	16510	8.367	16180	8.20	–	–
7	144.3	3.665	141.4	3.592	145.7	3.701	142.9	3.630	20820	10.55	20404	10.34	–	–
6	162.0	4.115	158.8	4.034	163.6	4.155	160.4	4.074	26240	13.30	25715	13.03	–	–
5	181.9	4.620	178.3	4.529	183.7	4.666	180.1	4.575	33090	16.77	32428	16.43	–	–
4	204.3	5.189	200.2	5.085	206.3	5.240	202.3	5.138	41740	21.15	40905	20.73	–	–
3	229.4	5.827	224.8	5.710	231.7	5.885	227.1	5.768	52620	26.67	51568	26.14	–	–
2	257.6	6.543	252.4	6.411	260.2	6.609	255.0	6.477	66360	33.62	65033	32.95	–	–
1	289.3	7.348	283.5	7.201	292.2	7.422	286.4	7.275	83690	42.41	82016	41.56	–	–
1/0	324.9	8.252	318.4	8.087	328.1	8.334	321.7	8.171	105600	53.49	103488	52.42	–	–
2/0	364.8	9.266	357.5	9.080	368.4	9.357	361.2	9.174	133100	67.43	130438	66.08	–	–
3/0	409.6	10.40	401.4	10.20	413.7	10.51	405.5	10.30	167800	85.01	164444	83.31	–	–
4/0	460.0	11.68	450.8	11.45	464.6	11.80	455.4	11.57	211600	107.2	207368	105.1	–	–
250 kcmil	–	–	–	–	–	–	–	–	250	127	245	124.1	–	–
300	–	–	–	–	–	–	–	–	300	152	294	149.0	–	–
350	–	–	–	–	–	–	–	–	350	177	343	173.8	–	–
400	–	–	–	–	–	–	–	–	400	203	392	198.6	–	–
450	–	–	–	–	–	–	–	–	450	228	441	223.5	–	–
500	–	–	–	–	–	–	–	–	500	253	490	248.3	–	–
550	–	–	–	–	–	–	–	–	550	279	539	273.1	–	–
600	–	–	–	–	–	–	–	–	600	304	588	297.9	–	–
650	–	–	–	–	–	–	–	–	650	329	637	322.8	–	–
700	–	–	–	–	–	–	–	–	700	355	686	347.6	–	–
750	–	–	–	–	–	–	–	–	750	380	735	372.4	–	–
800	–	–	–	–	–	–	–	–	800	405	784	397.2	–	–
900	–	–	–	–	–	–	–	–	900	456	882	446.9	–	–

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Table 20.1 Continued

Size of conductor	Diameter of solid conductor: Nominal mils	Nominal mm	Minimum[c] mils (0.98 x nominal)	Minimum[c] mm	Maximum[c] mils (1.01 x nominal)	Maximum[c] mm	Minimum[d] mils (0.99 x nominal)	Minimum[d] mm	Cross-sectional area of conductor: Nominal cmil	Nominal mm²	Minimum 0.98 × Nominal[a] cmil	0.98 × Nominal[a] mm²	Minimum 0.97 × Nominal[b] cmil	0.97 × Nominal[b] mm²
1000 kcmil	–	–	–	–	–	–	–	–	1000	507	980	496.6	–	–
1100	–	–	–	–	–	–	–	–	1100	557	1078	546.2	–	–
1200	–	–	–	–	–	–	–	–	1200	608	1176	595.9	–	–
1250	–	–	–	–	–	–	–	–	1250	633	1225	620.7	–	–
1300	–	–	–	–	–	–	–	–	1300	659	1274	645.5	–	–
1400	–	–	–	–	–	–	–	–	1400	709	1372	695.2	–	–
1500	–	–	–	–	–	–	–	–	1500	760	1470	744.9	–	–
1600	–	–	–	–	–	–	–	–	1600	811	1568	794.5	–	–
1700	–	–	–	–	–	–	–	–	1700	861	1666	844.2	–	–
1750	–	–	–	–	–	–	–	–	1750	887	1715	869.0	–	–
1800	–	–	–	–	–	–	–	–	1800	912	1764	893.8	–	–
1900	–	–	–	–	–	–	–	–	1900	963	1862	943.5	–	–
2000	–	–	–	–	–	–	–	–	2000	1013	1960	993.1	–	–

[a] The minimums in this column apply to flexible cord and fixture wire conductors composed of 29 – 20 AWG strands. Except where specified otherwise in the wire standard, the minimums in this column also apply to solid and stranded wires and cables (regardless of strand size).

[b] For conductors in flexible cords and fixture wires in which the conductors are composed of 36 – 30 AWG strands, the minimums in this column apply.

[c] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameters for the conductor.

[d] The values in this column apply where the wire standard specifies only a minimum diameter for the conductor.

Table 20.2
Diameters over round compact-stranded conductors

Conductor size	Nominal		Minimum[a]		Maximum[a]	
	inch	mm	inches (0.98 x nominal)	mm	inches (1.01 x nominal)	mm
12 AWG	0.085	2.16	0.083	2.11	0.086	2.18
11	0.095	2.41	0.093	2.36	0.096	2.44
10	0.107	2.72	0.105	2.67	0.108	2.74
9	0.120	3.05	0.118	3.00	0.121	3.07
8	0.134	3.40	0.131	3.23	0.135	3.43
7	0.152	3.86	0.149	3.78	0.154	3.91
6	0.169	4.29	0.166	4.22	0.171	4.34
5	0.191	4.85	0.187	4.75	0.193	4.90
4	0.213	5.41	0.209	5.31	0.215	5.46
3	0.238	6.02	0.233	5.92	0.240	6.10
2	0.268	6.81	0.263	6.68	0.271	6.88
1	0.299	7.59	0.293	7.44	0.302	7.67
1/0	0.336	8.53	0.329	8.36	0.339	8.61
2/0	0.376	9.55	0.368	9.35	0.380	9.65
3/0	0.423	10.74	0.415	10.54	0.415	10.54
4/0	0.475	12.07	0.466	11.84	0.480	12.19
250 kcmil	0.520	13.21	0.510	12.95	0.525	13.34
300	0.570	14.48	0.559	14.20	0.576	14.63
350	0.616	15.65	0.604	15.34	0.622	15.80
400	0.659	16.74	0.646	16.41	0.666	16.92
450	0.700	17.78	0.686	17.42	0.707	17.96
500	0.736	18.69	0.721	18.31	0.743	18.87
550	0.775	19.69	0.760	19.30	0.783	19.89
600	0.813	20.65	0.797	20.24	0.821	20.85
650	0.845	21.46	0.828	21.03	0.853	21.67
700	0.877	22.28	0.859	21.82	0.886	22.50
750	0.908	23.06	0.890	22.61	0.917	23.29
800	0.938	23.83	0.919	23.34	0.947	24.05
900	0.999	25.37	0.979	24.87	1.009	25.63
1000	1.060	26.92	1.039	26.39	1.071	27.20

[a] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameters for the conductor.

Table 20.3
Diameters over round compressed concentric-lay-stranded ASTM Classes B, C, and D aluminum, uncoated copper, and coated copper conductors

	Nominal[b]		Minimum[c]		Maximum[c]	
Conductor size	inch	mm	inches (0.98 x nominal)	mm	inches (1.01 x nominal)	mm
14 AWG	0.071[a]	1.80[a]	0.070	1.79	0.072	1.83
13	0.080[a]	2.03[a]	0.078	1.98	0.081	2.06
12	0.089	2.26	0.087	2.21	0.090	2.29
11	0.100	2.54	0.098	2.49	0.101	2.57
10	0.113	2.87	0.111	2.82	0.114	2.90
9	0.126	3.20	0.123	3.12	0.127	3.23
8	0.142	3.61	0.139	3.53	0.143	3.63
7	0.159	4.04	0.156	3.96	0.161	4.09
6	0.178	4.52	0.174	4.42	0.180	4.57
5	0.200	5.08	0.196	4.98	0.202	5.13
4	0.225	5.72	0.221	5.61	0.227	5.77
3	0.252	6.40	0.247	6.27	0.255	6.48
2	0.283	7.19	0.277	7.04	0.286	7.26
1	0.322	8.18	0.316	8.03	0.325	8.26
1/0	0.362	9.19	0.355	9.02	0.366	9.30
2/0	0.405	10.3	0.397	10.08	0.409	10.39
3/0	0.456	11.6	0.447	11.35	0.461	11.71
4/0	0.512	13.0	0.502	12.75	0.517	13.13
250 kcmil	0.558	14.2	0.547	13.89	0.564	14.33
300	0.611	15.5	0.599	15.21	0.617	15.67
350	0.661	16.8	0.648	16.46	0.668	19.97
400	0.706	17.9	0.692	17.58	0.713	18.11
450	0.749	19.0	0.734	18.64	0.756	19.20
500	0.789	20.0	0.773	19.63	0.797	20.24
550	0.829	21.1	0.812	20.62	0.837	21.26
600	0.866	22.0	0.849	21.56	0.875	22.23
650	0.901	22.9	0.883	22.43	0.910	23.11
700	0.935	23.7	0.916	23.27	0.944	23.98
750	0.968	24.6	0.949	24.10	0.978	24.84
800	1.000	25.4	0.980	24.89	1.010	25.65
900	1.060	26.9	1.039	26.39	1.071	27.20
1000	1.117	28.4	1.095	27.81	1.128	28.65
1100	1.173	29.8	1.150	29.21	1.185	30.10

Table 20.3 Continued on Next Page

Table 20.3 Continued

Conductor size	Nominal[b] inch	Nominal[b] mm	Minimum[c] inches (0.98 x nominal)	Minimum[c] mm	Maximum[c] inches (1.01 x nominal)	Maximum[c] mm
1200 kcmil	1.225	31.1	1.200	30.48	1.237	31.42
1250	1.250	31.8	1.225	31.12	1.262	32.05
1300	1.275	32.4	1.250	31.75	1.288	32.72
1400	1.323	33.6	1.297	32.94	1.336	33.93
1500	1.370	34.8	1.343	34.11	1.384	35.15
1600	1.415	35.9	1.387	35.23	1.429	36.30
1700	1.459	37.1	1.430	36.32	1.474	37.44
1750	1.480	37.6	1.450	36.83	1.495	37.97
1800	1.502	38.2	1.472	37.39	1.517	38.53
1900	1.542	39.2	1.511	38.38	1.557	39.55
2000	1.583	40.2	1.551	39.40	1.599	40.61

[a] Aluminum is for use in the 12 AWG – 2000 kcmil sizes, not in the 14 and 13 AWG sizes.

[b] In no case is the diameter of a compressed-stranded conductor to be more than 3 percent smaller than the diameter of the conductor determined after the conductor is assembled and before it is compressed.

[c] The values in these two columns apply where the wire standard (power principally) specifies maximum and minimum diameters for the conductor.

Table 20.3.1
Diameters over round compressed unilay-stranded ASTM Class B aluminum, uncoated copper, and coated copper conductors

Conductor size	Nominal inches	Nominal mm	Minimum[a] inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] inches (1.01 x nominal)	Maximum[a] mm
1 AWG	0.313	7.95	0.307	7.80	0.316	8.03
1/0	0.352	8.94	0.345	8.76	0.356	9.04
2/0	0.395	10.03	0.387	9.83	0.399	10.13
3/0	0.443	11.25	0.434	11.02	0.447	11.35
4/0	0.498	12.65	0.488	12.40	0.503	12.78
250 kcmil	0.542	13.77	0.531	13.49	0.547	13.89
300	0.594	15.09	0.582	14.78	0.600	15.24
350	0.641	16.28	0.628	15.95	0.647	16.43
400	0.685	17.40	0.671	17.04	0.692	17.58
450	0.727	18.47	0.712	18.08	0.734	18.64
500	0.766	19.46	0.751	19.08	0.774	19.66
550	0.804	20.42	0.788	20.02	0.812	20.62
600	0.840	21.34	0.823	20.90	0.848	21.54

Table 20.3.1 Continued on Next Page

Table 20.3.1 Continued

Conductor size	Nominal inches	Nominal mm	Minimum[a] inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] inches (1.01 x nominal)	Maximum[a] mm
650 kcmil	0.874	22.20	0.857	21.77	0.883	22.43
700	0.907	23.04	0.889	22.58	0.916	23.27
750	0.939	23.85	0.920	23.37	0.948	24.08
800	0.969	24.61	0.950	24.13	0.979	24.87
900	1.028	26.11	1.007	25.58	1.038	26.37
1000	1.084	27.53	1.062	26.97	1.095	27.81
1100	1.137	28.88	1.114	28.30	1.148	29.16
1200	1.187	30.15	1.163	29.54	1.199	30.45
1250	1.212	30.78	1.188	30.18	1.224	31.09
1300	1.236	31.39	1.211	30.76	1.248	31.70
1400	1.282	32.56	1.256	31.90	1.295	32.89
1500	1.327	33.71	1.300	33.02	1.340	34.04
1600	1.371	34.82	1.344	34.14	1.385	35.18
1700	1.413	35.89	1.385	35.18	1.427	36.25
1750	1.434	36.42	1.405	35.69	1.448	36.78
1800	1.454	36.93	1.425	36.20	1.469	37.31
1900	1.494	37.95	1.464	37.19	1.509	38.33
2000	1.533	38.94	1.502	38.15	1.548	39.32

[a] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameteers for the conductor. Otherwise, in no case is the diameter of a compressed-stranded conductor to be more than 3 percent smaller than the diameter of the conductor determined after the conductor is assembled and before it is compressed.

Table 20.4
Diameters over ASTM Class B round concentric-lay-stranded conductors

Conductor size	Nominal inches	Nominal mm	Minimum[a] inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] inches (1.01 x nominal)	Maximum[a] mm
30 AWG	0.0113	0.287	0.0111	0.282	0.0114	0.290
29	0.0128	0.325	0.0125	0.318	0.0129	0.328
28	0.0143	0.363	0.0140	0.356	0.0144	0.356
27	0.0161	0.409	0.0158	0.401	0.0163	0.414
26	0.0180	0.457	0.0176	0.447	0.0182	0.462
25	0.0203	0.516	0.0199	0.505	0.0205	0.521
24	0.0228	0.579	0.0223	0.566	0.0230	0.584
23	0.0256	0.650	0.0251	0.638	0.0259	0.658

Table 20.4 Continued on Next Page

Table 20.4 Continued

Conductor size	Nominal		Minimum[a]		Maximum[a]	
	inches	mm	inches (0.98 x nominal)	mm	inches (1.01 x nominal)	mm
22 AWG	0.0287	0.729	0.0281	0.714	0.0290	0.737
21	0.0323	0.820	0.0317	0.805	0.0326	0.828
20	0.0362	0.919	0.0355	0.902	0.0366	0.930
19	0.0407	1.03	0.0399	1.013	0.0411	1.044
18	0.0456	1.16	0.0447	1.135	0.0461	1.171
17	0.0513	1.30	0.0502	1.275	0.0518	1.315
16	0.0576	1.46	0.0564	1.433	0.0582	1.478
15	0.0647	1.64	0.0635	1.613	0.0653	1.659
14	0.0727	1.85	0.0712	1.81	0.0734	1.86
13	0.0816	2.07	0.0800	2.03	0.0824	2.09
12	0.0915	2.32	0.0897	2.28	0.0924	2.35
11	0.103	2.62	0.101	2.57	0.104	2.64
10	0.116	2.95	0.114	2.90	0.117	2.97
9	0.130	3.30	0.127	3.23	0.131	3.33
8	0.146	3.71	0.143	3.63	0.147	3.73
7	0.164	4.17	0.161	4.09	0.166	4.22
6	0.184	4.67	0.180	4.57	0.186	4.72
5	0.206	5.23	0.201	5.11	0.208	5.28
4	0.232	5.89	0.227	5.77	0.234	5.94
3	0.260	6.60	0.255	6.48	0.263	6.68
2	0.292	7.42	0.286	7.26	0.295	7.49
1	0.332	8.43	0.325	8.26	0.335	8.51
1/0	0.372	9.45	0.365	9.27	0.376	9.55
2/0	0.418	10.62	0.410	10.41	0.422	10.72
3/0	0.470	11.94	0.461	11.71	0.475	12.07
4/0	0.528	13.41	0.517	13.13	0.533	13.54
250 kcmil	0.575	14.61	0.564	14.33	0.581	14.76
300	0.630	16.00	0.617	15.67	0.636	16.15
350	0.681	17.30	0.667	16.94	0.688	17.48
400	0.728	18.49	0.713	18.11	0.735	18.67
450	0.772	19.61	0.757	19.23	0.780	19.81
500	0.813	20.65	0.797	20.24	0.821	20.85
550	0.855	21.72	0.838	21.29	0.864	21.95
600	0.893	22.68	0.875	22.23	0.902	22.91

Table 20.4 Continued on Next Page

Table 20.4 Continued

Conductor size	Nominal inches	Nominal mm	Minimum[a] inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] inches (1.01 x nominal)	Maximum[a] mm
650 kcmil	0.929	23.60	0.910	22.86	0.938	23.83
700	0.964	24.49	0.945	24.00	0.974	24.74
750	0.998	25.35	0.978	24.84	1.008	25.60
800	1.030	26.16	1.009	25.63	1.040	26.42
900	1.094	27.79	10.72	27.23	1.105	28.07
1000	1.152	29.26	1.129	28.68	1.164	29.57
1100	1.209	30.71	1.185	30.10	1.221	31.01
1200	1.263	32.08	1.238	31.45	1.276	32.41
1250	1.289	32.74	1.263	32.08	1.302	33.07
1300	1.314	33.38	1.288	32.72	1.327	33.71
1400	1.365	34.67	1.338	33.99	1.379	35.03
1500	1.412	35.86	1.384	35.15	1.426	36.22
1600	1.459	37.06	1.430	36.32	1.474	37.44
1700	1.504	38.20	1.474	37.44	1.519	38.58
1750	1.526	38.76	1.495	37.97	1.541	39.14
1800	1.548	39.32	1.517	38.53	1.563	39.70
1900	1.590	40.39	1.558	39.57	1.606	40.79
2000	1.632	41.45	1.599	40.61	1.648	41.86

[a] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameters for the conductor.

Table 20.4.1
Diameters over ASTM Class C round concentric-lay-stranded conductors

Conductor size	Nominal Inches	Nominal mm	Minimum[a] Inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] Inches (1.01 x nominal)	Maximum[a] mm
30 AWG	0.0115	0.292	0.0113	0.338	0.0116	0.295
29	0.0130	0.330	0.0127	0.323	0.0131	0.333
28	0.0145	0.368	0.0142	0.361	0.0146	0.371
27	0.0163	0.414	0.0160	0.406	0.0165	0.419
26	0.0182	0.465	0.0178	0.452	0.0184	0.467
25	0.0205	0.521	0.0201	0.511	0.0207	0.526
24	0.0230	0.584	0.0225	0.572	0.0232	0.589
23	0.0259	0.658	0.0254	0.645	0.0262	0.665
22	0.0290	0.737	0.0284	0.721	0.0293	0.744

Table 20.4.1 Continued on Next Page

Table 20.4.1 Continued

Conductor size	Nominal Inches	Nominal mm	Minimum[a] Inches (0.98 x nominal)	Minimum[a] mm	Maximum[a] Inches (1.01 x nominal)	Maximum[a] mm
21 AWG	0.0327	0.830	0.0320	0.813	0.0330	0.838
20	0.0365	0.927	0.0358	0.909	0.0369	0.937
19	0.0412	1.046	0.0404	1.026	0.0416	1.057
18	0.0460	1.168	0.0451	1.146	0.0465	1.181
17	0.0519	1.318	0.0509	1.293	0.0524	1.331
16	0.0585	1.486	0.0573	1.455	0.0591	1.501
15	0.0655	1.664	0.0642	1.631	0.0662	1.681
14	0.0735	1.867	0.0720	1.829	0.0743	1.887
13	0.0825	2.096	0.0850	2.159	0.0833	2.116
12	0.0925	2.350	0.0907	2.304	0.0934	2.372
11 AWG – 2000 kcmil	b	b	b	b	b	b

[a] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameters for the conductor.

[b] Use Table 20.4.

Table 20.5
Nominal dimensions of round strands

AWG size of strand	Diameter Mils	Diameter mm	Cross-sectional area cmil	Cross-sectional area mm²
40	3.1	0.079	9.61	0.00487
39	3.5	0.089	12.2	0.00621
38	4.0	0.102	16.0	0.00811
37	4.5	0.144	20.2	0.0103
36	5.0	0.127	25.0	0.0127
35	5.6	0.142	31.4	0.0159
34	6.3	0.160	39.7	0.0201
33	7.1	0.180	50.4	0.0255
32	8.0	0.203	64.0	0.0324
31	8.9	0.226	79.2	0.0401
30	10.0	0.254	100	0.0507
29	11.3	0.287	128	0.0647
28	12.6	0.320	159	0.0804
27	14.2	0.361	202	0.102
26	15.9	0.404	253	0.128
25	17.9	0.455	320	0.162

Table 20.5 Continued on Next Page

Table 20.5 Continued

AWG size of strand	Diameter		Cross-sectional area	
	Mils	mm	cmil	mm^2
24	20.1	0.511	404	0.205
23	22.6	0.574	511	0.259
22	25.3	0.643	640	0.324
21	28.5	0.724	812	0.412
20	32.0	0.813	1020	0.519

Table 20.6
Nominal strand and conductor dimensions for 19-wire combination round-wire unilay-stranded copper or aluminum conductors

AWG conductor size	Nominal strand dimensions								Conductor diameter					
	Large strand				Small strand									
	A Diameter		B Cross-sectional area		C Diameter		D Cross-sectional area		E = 3A + 2C Nominal		F = 0.98 x E Minimum[a]		G = 1.01 x E Maximum[a]	
	inch	mm	cmil	mm²	inch	mm	cmil	mm²	inch	mm	inch	mm	inch	mm
14	0.0159	0.4	253	0.128	0.0117	0.3	137	0.069	0.071	1.80	0.70	1.78	0.72	1.83
12	0.0201	0.5	404	0.205	0.0147	0.4	216	0.109	0.090	2.29	0.88	2.24	0.091	2.31
10	0.0253	0.6	640	0.324	0.0185	0.5	342	0.173	0.113	2.87	1.11	2.87	0.114	2.90
9	0.0284	0.7	807	0.408	0.0208	0.5	433	0.219	0.127	3.23	0.127	3.14	0.128	3.25
8	0.0319	0.8	1018	0.515	0.0234	0.6	548	0.277	0.143	3.63	1.40	3.56	0.144	3.66
7	0.0358	0.9	1282	0.649	0.0262	0.67	686	0.347	0.160	4.06	0.157	3.99	0.162	4.11
6	0.0402	1.0	1616	0.818	0.0294	0.7	864	0.437	0.179	4.55	0.175	4.45	0.181	4.60
5	0.0452	1.1	2043	1.034	0.0331	0.8	1096	0.555	0.202	5.13	0.198	5.03	0.204	5.18
4	0.0507	1.3	2570	1.301	0.0371	0.9	1376	0.696	0.226	5.74	0.221	5.61	0.228	5.79
3	0.0570	1.4	3249	1.644	0.0417	1.1	1739	0.880	0.254	6.45	0.249	6.32	0.257	6.53
2	0.0640	1.6	4096	2.073	0.0468	1.2	2190	1.108	0.286	7.26	0.280	7.11	0.289	7.34
1	0.0718	1.8	5155	2.609	0.0526	1.3	2767	1.400	0.321	8.15	0.316	8.03	0.324	8.23
1/0	0.0807	2.1	6512	3.296	0.0591	1.5	3493	1.768	0.360	9.14	0.353	8.97	0.364	9.25
2/0	0.0906	2.3	8208	4.154	0.0663	1.7	4396	2.225	0.404	10.26	0.396	10.06	0.408	10.36
3/0	0.1017	2.6	10343	5.234	0.0745	1.9	5550	2.809	0.454	11.53	0.445	11.30	0.459	11.66
4/0	0.1142	2.9	13042	6.600	0.0836	2.1	6989	3.537	0.510	12.95	0.500	12.70	0.515	13.08

[a] The values in these two columns apply where the wire standard (power cables principally) specifies maximum and minimum diameters for the conductor.

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30 D-C Conductor Resistance

Table 30.1
Maximum direct-current resistance of solid conductors of aluminum, copper-clad aluminum, and uncoated copper

AWG size of conductor	20°C				25°C			
	Aluminum and copper-clad aluminum		Uncoated copper		Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
30	–	–	106	347	–	–	108	354
29	–	–	82.8	271	–	–	84.5	277
28	109	358	66.6	218	111	364	67.9	223
27	85.9	282	52.4	172	87.6	287	53.4	175
26	68.6	225	41.8	138	70.0	230	42.6	140
25	54.1	178	33.0	108	55.3	181	33.7	110
24	43.0	141	26.2	85.9	43.8	144	26.7	87.6
23	33.9	111	20.7	67.9	34.6	114	21.1	69.3
22	27.1	88.9	16.5	54.3	27.6	90.6	16.8	55.3
21	21.5	70.5	13.1	42.7	21.8	71.5	13.3	43.6
20	16.9	55.4	10.3	33.9	17.2	56.6	10.5	34.6
19	13.5	44.2	8.21	26.9	13.7	45.0	8.37	27.4
18	10.7	35.1	6.52	21.4	10.9	35.7	6.64	21.8
17	8.45	27.7	5.15	16.9	8.61	28.2	5.25	17.2
16	6.72	22.0	4.10	13.5	6.85	22.5	4.18	13.7
15	5.31	17.4	3.24	10.6	5.41	17.8	3.30	10.8
14	–	–	2.57	8.45	–	–	2.62	8.61
13	–	–	2.04	6.69	–	–	2.08	6.82
12	2.65	8.71	1.62	5.31	2.71	8.89	1.65	5.42
11	2.11	6.92	1.29	4.22	2.15	7.06	1.32	4.30
10	1.670	5.479	1.019	3.343	1.703	5.590	1.038	3.408
9	1.325	4.347	0.8084	2.652	1.352	4.435	0.8242	2.704
8	1.051	3.446	0.6407	2.102	1.071	3.515	0.6532	2.143
7	0.8328	2.733	0.5081	1.667	0.8497	2.788	0.5181	1.699
6	0.6609	2.168	0.4031	1.323	0.6741	2.211	0.4110	1.348
5	0.5242	1.720	0.3197	1.049	0.5361	1.754	0.3260	1.070
4	0.4155	1.363	0.2535	0.8315	0.4239	1.390	0.2585	0.8478
3	0.3296	1.081	0.2010	0.6595	0.3362	1.103	0.2050	0.6725
2	0.2613	0.8574	0.1594	0.5231	0.2666	0.8747	0.1626	0.5333

Table 30.1 Continued on Next Page

Table 30.1 Continued

AWG size of conductor	20°C				25°C			
	Aluminum and copper-clad aluminum		Uncoated copper		Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
1	0.2073	0.6798	0.1264	0.4146	0.2113	0.6935	0.1289	0.4228
1/0	0.1643	0.5390	0.1002	0.3287	0.1676	0.5499	0.1022	0.3353
2/0	0.1304	0.4275	0.07949	0.2608	0.1329	0.4362	0.08105	0.2659
3/0	0.1033	0.3392	0.06306	0.2069	0.1055	0.3460	0.06429	0.2109
4/0	0.08196	0.2689	0.04999	0.1640	0.08361	0.2743	0.05098	0.1673

Table 30.2
Maximum direct-current resistance of solid copper conductors coated with tin or a tin/lead alloy

AWG Size of Conductor	20°C		25°C	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
30	110	361	112	368
29	86.1	282	87.8	289
28	69.3	227	70.6	232
27	54.5	179	55.6	182
26	43.5	143	44.3	145
25	34.4	112	35.0	115
24	27.3	89.3	27.8	91.1
23	21.5	70.6	22.0	72.0
22	17.2	56.4	17.5	57.5
21	13.6	44.4	13.8	45.3
20	10.7	35.2	10.9	36.0
19	8.54	28.0	8.70	28.6
18	6.77	22.2	6.91	22.7
17	5.37	17.6	5.47	17.9
16	4.26	14.0	4.35	14.2
15	3.38	11.1	3.44	11.2
14	2.68	8.78	2.72	8.96
13	2.12	6.97	2.16	7.10
12	1.68	5.53	1.71	5.64
11	1.34	4.39	1.37	4.48
10	1.060	3.476	1.080	3.545
9	0.8319	2.730	0.8483	2.784
8	0.6594	2.163	0.6724	2.206
7	0.5229	1.716	0.5332	1.749

Table 30.2 Continued on Next Page

Table 30.2 Continued

AWG Size of Conductor	20°C		25°C	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
6	0.4148	1.361	0.4230	1.388
5	0.3291	1.079	0.3356	1.101
4	0.2608	0.8559	0.2660	0.8727
3	0.2069	0.6788	0.2109	0.6922
2	0.1641	0.5384	0.1673	0.5489
1	0.1300	0.4268	0.1326	0.4352
1/0	0.1026	0.3367	0.1047	0.3433
2/0	0.08140	0.2670	0.08300	0.2723
3/0	0.06457	0.2119	0.06583	0.2160
4/0	0.05119	0.1680	0.05219	0.1713

Table 30.3
Maximum direct-current resistance of aluminum, copper-clad aluminum, and compact-stranded aluminum conductors and uncoated copper conductors: concentric-stranded ASTM Classes B, C, and D, compact-stranded, and compressed-stranded

Size of conductor	20°C				25°C			
	Aluminum and copper-clad aluminum		Uncoated copper		Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
30 AWG	–	–	108	354	–	–	110	361
29	–	–	84.3	277	–	–	86.0	282
28	111	364	67.9	223	113	371	69.2	227
27	87.6	287	53.4	175	89.4	293	54.5	179
26	70.0	230	42.7	140	71.3	234	43.5	143
25	55.3	181	33.7	111	56.4	185	34.4	113
24	43.8	144	26.7	87.6	44.6	146	27.2	89.2
23	34.6	114	21.1	69.2	35.3	116	21.5	70.5
22	27.7	90.9	16.9	55.4	28.2	92.5	17.2	56.4
21	21.8	71.5	13.3	43.6	22.1	72.5	13.5	44.3
20	17.4	57.1	10.6	34.6	17.7	58.1	10.8	35.3
19	13.7	44.9	8.36	27.4	14.0	45.9	8.53	28.0
18	10.9	35.8	6.66	21.8	11.1	36.4	6.79	22.2
17	8.68	28.5	5.27	17.3	8.86	29.1	5.37	17.6
16	6.87	22.5	4.18	13.7	7.00	23.0	4.26	14.0
15	5.41	17.8	3.31	10.9	5.53	18.1	3.37	11.1
14	–	–	2.62	8.62	–	–	2.68	8.78

Table 30.3 Continued on Next Page

Table 30.3 Continued

Size of conductor	20°C Aluminum and copper-clad aluminum Ohms per 1000 feet	20°C Aluminum and copper-clad aluminum Ohms per 1000 m	20°C Uncoated copper Ohms per 1000 feet	20°C Uncoated copper Ohms per 1000 m	25°C Aluminum and copper-clad aluminum Ohms per 1000 feet	25°C Aluminum and copper-clad aluminum Ohms per 1000 m	25°C Uncoated copper Ohms per 1000 feet	25°C Uncoated copper Ohms per 1000 m
13 AWG	–	–	2.08	6.82	–	–	2.12	6.97
12	2.71	8.88	1.65	5.43	2.76	9.07	1.68	5.53
11	2.15	7.07	1.32	4.30	2.19	7.20	1.34	4.39
10	1.70	5.589	1.039	3.409	1.738	5.702	1.060	3.476
9	1.35	4.434	0.8245	2.705	1.379	4.524	0.8407	2.758
8	1.07	3.515	0.6535	2.144	1.092	3.585	0.6663	2.186
7	0.8495	2.787	0.5182	1.700	0.8666	2.844	0.5284	1.734
6	0.6740	2.211	0.4112	1.348	0.6876	2.256	0.4192	1.375
5	0.5346	1.754	0.3261	1.070	0.5454	1.789	0.3325	1.091
4	0.4238	1.390	0.2585	0.8481	0.4324	1.419	0.2636	0.8649
3	0.3361	1.103	0.2050	0.6727	0.3429	1.125	0.2091	0.6860
2	0.2665	0.8745	0.1626	0.5335	0.2719	0.8922	0.1659	0.5440
1	0.2113	0.6934	0.1289	0.4230	0.2156	0.7074	0.1315	0.4313
1/0	0.1676	0.5498	0.1022	0.3354	0.1710	0.5609	0.1042	0.3419
2/0	0.1329	0.4361	0.08108	0.2660	0.1356	0.4450	0.08267	0.2712
3/0	0.1055	0.3459	0.06431	0.2110	0.1075	0.3529	0.06558	0.2151
4/0	0.08360	0.2743	0.05099	0.1673	0.08528	0.2798	0.05200	0.1705
250 kcmil	0.07076	0.2322	0.04316	0.1416	0.07219	0.2368	0.04401	0.1444
300	0.05897	0.1935	0.03597	0.1180	0.06015	0.1974	0.03667	0.1204
350	0.05054	0.1659	0.03082	0.1011	0.05156	0.1691	0.03144	0.1031
400	0.04423	0.1450	0.02698	0.08851	0.04511	0.1480	0.02751	0.09024
450	0.03931	0.1289	0.02398	0.07867	0.04010	0.1316	0.02445	0.08021
500	0.03537	0.1161	0.02158	0.07080	0.03609	0.1184	0.02200	0.07220
550	0.03216	0.1055	0.01961	0.06436	0.03281	0.1076	0.02000	0.06563
600	0.02948	0.09673	0.01798	0.05900	0.03008	0.09867	0.01834	0.06016
650	0.02721	0.08928	0.01660	0.05447	0.02776	0.09109	0.01692	0.05553
700	0.02527	0.08291	0.01541	0.05057	0.02578	0.08458	0.01572	0.05157
750	0.02358	0.07738	0.01438	0.04721	0.02406	0.07894	0.01467	0.04812
800	0.02211	0.07254	0.01348	0.04425	0.02255	0.07400	0.01375	0.04512
900	0.01966	0.06448	0.01199	0.03933	0.02005	0.06578	0.01222	0.04011
1000	0.01769	0.05804	0.01079	0.03540	0.01804	0.05920	0.01101	0.03610
1100	0.01609	0.05275	0.009809	0.03218	0.01640	0.05383	0.01000	0.03281
1200	0.01474	0.04836	0.008992	0.02950	0.01503	0.04934	0.009169	0.03008

Table 30.3 Continued on Next Page

Table 30.3 Continued

Size of conductor	20°C				25°C			
	Aluminum and copper-clad aluminum		Uncoated copper		Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
1250 kcmil	0.01415	0.04643	0.008632	0.02833	0.01443	0.04736	0.008802	0.02888
1300	0.01357	0.04465	0.008230	0.02723	0.01388	0.04554	0.008463	0.02776
1400	0.01264	0.04145	0.007707	0.02529	0.01289	0.04229	0.007859	0.02579
1500	0.01179	0.03869	0.007193	0.02360	0.01203	0.03947	0.007335	0.02406
1600	0.01106	0.03627	0.006744	0.02212	0.01128	0.03701	0.006877	0.02256
1700	0.01040	0.03414	0.006347	0.02083	0.01062	0.03482	0.006472	0.02124
1750	0.01011	0.03316	0.006166	0.02023	0.01031	0.03383	0.006287	0.02062
1800	0.009827	0.03224	0.005995	0.01967	0.01003	0.03290	0.006112	0.02005
1900	0.009310	0.03055	0.005679	0.01864	0.009497	0.03116	0.005791	0.01900
2000	0.008844	0.02902	0.005395	0.01770	0.009023	0.02960	0.005501	0.01804

Table 30.4
Maximum direct-current resistance of copper conductors, concentric-stranded ASTM Class B with each strand coated with tin or a tin/lead alloy and compressed-stranded ASTM Class B with each strand coated

Size of Conductor	20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
30 AWG	116	381	118	387
29	90.5	297	92.3	303
28	72.8	239	74.3	244
27	57.3	188	58.5	192
26	45.8	150	46.7	153
25	36.2	199	36.9	121
24	28.7	94.2	29.2	95.8
23	22.7	74.5	23.1	75.8
22	18.1	59.4	18.5	60.7
21	14.3	46.9	14.5	47.6
20	11.2	36.7	11.4	37.4
19	8.88	29.1	9.06	29.7
18	7.06	23.2	7.19	23.6
17	5.59	18.3	5.70	18.7
16	4.45	14.6	4.53	14.9
15	3.44	11.3	3.51	11.5
14	2.73	8.96	2.78	9.14

Table 30.4 Continued on Next Page

Table 30.4 Continued

Size of Conductor	20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
13 AWG	2.16	7.10	2.20	7.24
12	1.72	5.64	1.75	5.75
11	1.37	4.48	1.39	4.56
10	1.080	3.546	1.102	3.615
9	0.8574	2.813	0.8742	2.868
8	0.6795	2.230	0.6929	2.274
7	0.5389	1.768	0.5495	1.802
6	0.4276	1.403	0.4359	1.430
5	0.3392	1.113	0.3458	1.134
4	0.2689	0.8820	0.2742	0.8993
3	0.2132	0.6996	0.2175	0.7133
2	0.1691	0.5548	0.1724	0.5657
1	0.1340	0.4398	0.1367	0.4485
1/0	0.1063	0.3487	0.1084	0.3556
2/0	0.08432	0.2766	0.08598	0.2820
3/0	0.06688	0.2194	0.06820	0.2238
4/0	0.05248	0.1722	0.05352	0.1755
250 kcmil	0.04488	0.1473	0.04577	0.1501
300	0.03740	0.1227	0.03814	0.1252
350	0.03206	0.1052	0.03270	0.1072
400	0.02776	0.09109	0.02831	0.09288
450	0.02467	0.08097	0.02516	0.08256
500	0.02222	0.07287	0.02264	0.07431
550	0.02040	0.06693	0.02080	0.06825
600	0.01871	0.06135	0.01907	0.06257
650	0.01709	0.05606	0.01742	0.05715
700	0.01586	0.05205	0.01618	0.05307
750	0.01481	0.04858	0.01510	0.04953
800	0.01388	0.04554	0.01416	0.04644
900	0.01234	0.04048	0.01259	0.04128
1000	0.01111	0.03643	0.01132	0.03715
1100	0.01010	0.03312	0.01029	0.03377
1200	0.009254	0.03037	0.009436	0.03096
1250	0.008884	0.02915	0.009059	0.02972
1300	0.008543	0.02803	0.008711	0.02858

Table 30.4 Continued on Next Page

Table 30.4 Continued

Size of Conductor	20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
1400 kcmil	0.007933	0.02602	0.008089	0.02654
1500	0.007403	0.02429	0.007549	0.02477
1600	0.006941	0.02278	0.007078	0.02322
1700	0.006533	0.02143	0.006661	0.02186
1750	0.006346	0.02082	0.006471	0.02123
1800	0.006171	0.02024	0.006291	0.02063
1900	0.005845	0.01918	0.005960	0.01955
2000	0.005552	0.01822	0.005662	0.01857

Table 30.5
Maximum direct-current resistance of copper conductors, concentric-stranded ASTM Classes C and D with each strand coated with tin or a tin/lead alloy and compressed-stranded ASTM Classes C and D with each strand coated

Size of conductor	Class C				Class D			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
30 AWG	116	381	118	387	116	381	118	387
29	90.5	297	92.3	303	90.5	297	92.3	303
28	72.8	239	74.3	244	72.8	239	74.3	244
27	57.3	188	58.5	192	57.3	188	58.5	192
26	45.8	150	46.7	153	45.8	150	46.7	153
25	36.2	119	36.9	121	36.2	119	36.9	121
24	28.7	94.2	29.2	95.8	28.7	94.2	29.2	95.8
23	22.7	74.5	23.1	75.8	22.7	74.5	23.1	75.8
22	18.1	59.4	18.5	60.7	18.1	59.4	18.5	60.7
21	14.3	46.9	14.5	47.6	14.3	46.9	14.5	47.6
20	11.4	37.4	11.6	38.1	11.4	37.4	11.6	38.1
19	8.98	29.5	9.16	30.1	8.98	29.5	9.16	30.1
18	7.15	23.5	7.29	23.9	7.15	23.5	7.29	23.9
17	5.65	18.5	5.76	18.9	5.65	18.5	5.76	18.9
16	4.44	14.6	4.53	14.9	4.49	14.7	4.58	15.0
15	3.52	11.5	3.58	11.7	3.55	11.6	3.62	11.9
14	2.78	9.15	2.85	9.32	2.82	9.25	2.89	9.42
13	2.21	7.26	2.25	7.41	2.21	7.26	2.25	7.41
12	1.75	5.75	1.78	5.88	1.75	5.75	1.78	5.88
11	1.37	4.48	1.39	4.56	1.40	4.57	1.42	4.66

Table 30.5 Continued on Next Page

Table 30.5 Continued

Size of conductor	Class C 20°C Ohms per 1000 feet	Class C 20°C Ohms per 1000 m	Class C 25°C Ohms per 1000 feet	Class C 25°C Ohms per 1000 m	Class D 20°C Ohms per 1000 feet	Class D 20°C Ohms per 1000 m	Class D 25°C Ohms per 1000 feet	Class D 25°C Ohms per 1000 m
10 AWG	1.08	3.55	1.10	3.62	1.10	3.62	1.12	3.69
9	0.857	2.82	0.874	2.87	0.875	2.88	0.892	2.93
8	0.679	2.23	0.692	2.27	0.679	2.23	0.693	2.27
7	0.539	1.76	0.550	1.81	0.539	1.76	0.550	1.81
6	0.427	1.41	0.436	1.43	0.427	1.41	0.436	1.43
5	0.339	1.11	0.346	1.13	0.339	1.11	0.346	1.13
4	0.269	0.882	0.274	0.900	0.269	0.882	0.274	0.900
3	0.213	0.700	0.217	0.713	0.213	0.700	0.217	0.713
2	0.169	0.555	0.172	0.566	0.169	0.555	0.172	0.566
1	0.134	0.440	0.137	0.449	0.134	0.440	0.137	0.449
1/0	0.106	0.349	0.108	0.355	0.106	0.349	0.108	0.355
2/0	0.0844	0.276	0.0860	0.282	0.0844	0.276	0.0860	0.282
3/0	0.0669	0.219	0.0681	0.223	0.0669	0.219	0.0681	0.223
4/0	0.0530	0.174	0.0541	0.177	0.0530	0.174	0.0541	0.177
250 kcmil	0.0449	0.147	0.0458	0.150	0.0449	0.147	0.0458	0.150
300	0.0374	0.122	0.0381	0.125	0.0374	0.122	0.0381	0.125
350	0.0320	0.105	0.0326	0.107	0.0320	0.105	0.0326	0.107
400	0.0280	0.0920	0.0286	0.0938	0.0280	0.0920	0.0286	0.0938
450	0.0249	0.0818	0.0254	0.0834	0.0249	0.0818	0.0254	0.0834
500	0.0224	0.0736	0.0228	0.0751	0.0224	0.0736	0.0228	0.0751
550	0.0204	0.0669	0.0208	0.0682	0.0204	0.0669	0.0208	0.0682
600	0.0187	0.0614	0.0191	0.0625	0.0187	0.0614	0.0191	0.0625
650	0.0172	0.0566	0.0176	0.0577	0.0172	0.0566	0.0176	0.0577
700	0.0160	0.0526	0.0163	0.0537	0.0160	0.0526	0.0163	0.0537
750	0.0150	0.0491	0.0153	0.0501	0.0150	0.0491	0.0153	0.0501
800	0.0141	0.0460	0.0143	0.0469	0.0141	0.0460	0.0143	0.0469
900	0.0124	0.0409	0.0128	0.0417	0.0124	0.0409	0.0128	0.0417
1000	0.0111	0.0364	0.0113	0.0371	0.0112	0.0368	0.0114	0.0375
1100	0.0102	0.0335	0.0104	0.0342	0.0102	0.0335	0.0104	0.0342
1200	0.00935	0.0307	0.00954	0.0313	0.00935	0.0307	0.00954	0.0313
1250	0.00898	0.0295	0.00915	0.0300	0.00898	0.0295	0.00915	0.0300
1300	0.00863	0.0284	0.00880	0.0289	0.00863	0.0284	0.00880	0.0289
1400	0.00794	0.0260	0.00809	0.0265	0.00802	0.0263	0.00817	0.0268
1500	0.00741	0.0243	0.00755	0.0248	0.00748	0.0246	0.00763	0.0250

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Table 30.5 Continued

Size of conductor	Class C				Class D			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
1600 kcmil	0.00702	0.0231	0.00715	0.0235	0.00702	0.0231	0.00715	0.0235
1700	0.00660	0.0216	0.00673	0.0220	0.00660	0.0216	0.00673	0.0220
1750	0.00642	0.0210	0.00654	0.0214	0.00642	0.0210	0.00654	0.0214
1800	0.00617	0.0202	0.00629	0.0206	0.00623	0.0205	0.00635	0.0208
1900	0.00584	0.0192	0.00596	0.0196	0.00591	0.0194	0.00602	0.0198
2000	0.00555	0.0183	0.00566	0.0186	0.00561	0.0184	0.00572	0.0188

Table 30.6
Maximum direct-current resistance of 19-wire combination round-wire unilay-stranded copper conductors

Metal coating of strands	AWG size of conductors	20°C		25°C	
		Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
	14	2.78	9.15	2.85	9.32
	13	2.21	7.26	2.25	7.41
Each	12	1.75	5.75	1.78	5.88
	11	1.37	4.48	1.39	4.56
	10	1.08	3.55	1.10	3.62
	9	0.857	2.82	0.874	2.87
	8	0.679	2.23	0.692	2.27
Strand	7	0.539	1.76	0.550	1.81
	6	0.427	1.41	0.436	1.43
	5	0.339	1.11	0.346	1.13
	4	0.269	0.882	0.274	0.900
	3	0.213	0.700	0.217	0.713
Coated	2	0.169	0.555	0.172	0.566
	1	0.1340	0.4398	0.1367	0.4485
	1/0	0.1063	0.3487	0.1084	0.3556
	2/0	0.08432	0.2766	0.08598	0.2820
	3/0	0.06688	0.2194	0.06820	0.2238
	4/0	0.05248	0.1722	0.05352	0.1755
	14	2.62	8.62	2.68	8.78
	13	2.08	6.82	2.12	6.97
Each	12	1.65	5.43	1.68	5.53

Table 30.6 Continued on Next Page

Table 30.6 Continued

Metal coating of strands	AWG size of conductors	20°C		25°C	
		Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
	11	1.32	4.30	1.34	4.39
	10	1.039	3.409	1.060	3.476
	9	0.8245	2.705	0.8407	2.758
	8	0.6535	2.144	0.6663	2.186
Strand	7	0.5182	1.700	0.5284	1.734
	6	0.4122	1.348	0.4192	1.375
	5	0.3261	1.070	0.3225	1.091
	4	0.2585	0.8481	0.2636	0.8649
	3	0.2050	0.6727	0.2091	0.6860
Uncoated	2	0.1626	0.5335	0.1659	0.5440
	1	0.1289	0.4230	0.1315	0.4313
	1/0	0.1022	0.3354	0.1042	0.3419
	2/0	0.08108	0.2660	0.08267	0.2712
	3/0	0.06431	0.2110	0.06558	0.2151
	4/0	0.05099	0.1673	0.05200	0.1705

Table 30.6A
Maximum direct-current resistance of 19-wire combination round-wire unilay-stranded aluminum conductors

AWG size of conductor	20°C		25°	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
6	0.6716	2.204	0.6852	2.248
5	0.5326	1.748	0.5436	1.784
4	0.4224	1.386	0.4309	1.414
3	0.3351	1.100	0.3418	1.121
2	0.2656	0.8714	0.2710	0.8892
1	0.2107	0.6913	0.2149	0.7051
1/0	0.1671	0.5483	0.1705	0.5594
2/0	0.1325	0.4347	0.1351	0.4433
3/0	0.1051	0.3448	0.1072	0.3517
4/0	0.08332	0.2734	0.08501	0.2789

Table 30.7
Maximum direct-current resistance of ASTM Class G stranded conductors

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
14 AWG	2.65	8.70	2.70	8.86	2.82	9.24	2.87	9.41	–	–	–	–
13	2.10	6.90	2.14	7.03	2.23	7.33	2.28	7.47	–	–	–	–
12	1.67	5.48	1.70	5.58	1.77	5.81	1.81	5.93	–	–	–	–
11	1.32	4.35	1.35	4.42	1.40	4.61	1.43	4.70	–	–	–	–
10	1.05	3.45	1.07	3.51	1.11	3.66	1.13	3.73	–	–	–	–
9	0.832	2.73	0.849	2.78	0.884	2.90	0.902	2.96	–	–	–	–
8	0.660	2.16	0.673	2.20	0.701	2.30	0.715	2.35	–	–	–	–
7	0.523	1.71	0.533	1.75	0.545	1.79	0.555	1.82	0.858	2.82	0.875	2.88
6	0.415	1.37	0.423	1.39	0.431	1.42	0.441	1.45	0.680	2.23	0.695	2.27
5	0.329	1.08	0.336	1.10	0.343	1.12	0.349	1.14	0.540	1.77	0.551	1.81
4	0.261	0.857	0.266	0.873	0.271	0.890	0.276	0.908	0.428	1.41	0.437	1.43
3	0.207	0.679	0.211	0.693	0.215	0.707	0.219	0.720	0.340	1.11	0.347	1.13
2	0.164	0.539	0.167	0.550	0.170	0.560	0.174	0.571	0.369	0.883	0.274	0.901
1	0.132	0.431	0.134	0.440	0.137	0.449	0.140	0.457	0.215	0.707	0.220	0.721
1/0	0.104	0.342	0.106	0.349	0.108	0.355	0.110	0.362	0.170	0.560	0.174	0.571
2/0	0.0826	0.271	0.0843	0.276	0.0860	0.282	0.0876	0.288	0.136	0.445	0.139	0.454
3/0	0.0656	0.215	0.0668	0.219	0.0681	0.223	0.0696	0.228	0.107	0.353	0.109	0.360
4/0	0.0520	0.170	0.0530	0.174	0.0541	0.177	0.0552	0.181	0.0853	0.279	0.0869	0.286
250 kcmil	0.0443	0.145	0.0451	0.148	0.0460	0.151	0.0469	0.154	0.0725	0.238	0.0740	0.243
300	0.0368	0.121	0.0375	0.123	0.0384	0.125	0.0391	0.129	0.0604	0.198	0.0616	0.202
350	0.0316	0.104	0.0322	0.106	0.0328	0.108	0.0335	0.110	0.0518	0.170	0.0528	0.173
400	0.0276	0.0917	0.0282	0.0924	0.0288	0.0942	0.0293	0.0962	0.0453	0.149	0.0462	0.152
450	0.0246	0.0806	0.0251	0.0822	0.0255	0.0838	0.0260	0.0855	0.0403	0.132	0.0411	0.135
500	0.0221	0.0725	0.0225	0.0704	0.0230	0.0755	0.0235	0.0769	0.0362	0.119	0.0370	0.121

Table 30.7 Continued on Next Page

Table 30.7 Continued

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
550 kcmil	0.0202	0.0663	0.0206	0.0675	0.0210	0.0690	0.0214	0.0703	0.0332	0.108	0.0338	0.111
600	0.0186	0.0607	0.0189	0.0619	0.0193	0.0631	0.0196	0.0644	0.0304	0.0996	0.0310	0.102
650	0.0171	0.0561	0.0174	0.0571	0.0177	0.0583	0.0182	0.0595	0.0280	0.0919	0.0286	0.0937
700	0.0159	0.0520	0.0162	0.0530	0.0165	0.0542	0.0168	0.0552	0.0260	0.0834	0.0265	0.0871
750	0.0148	0.0486	0.0151	0.0496	0.0154	0.0505	0.0157	0.0515	0.0243	0.0797	0.0248	0.0813
800	0.0139	0.0456	0.0142	0.0464	0.0145	0.0473	0.0147	0.0483	0.0227	0.0747	0.0233	0.0762
900	0.0123	0.0405	0.0125	0.0413	0.0129	0.0421	0.0131	0.0429	0.0202	0.0664	0.0206	0.0677
1000	0.0111	0.0364	0.0113	0.0371	0.0115	0.0379	0.0117	0.0387	0.0183	0.0598	0.0186	0.0610
1100	0.0101	0.0332	0.0103	0.0338	0.0105	0.0345	0.0107	0.0351	0.0165	0.0543	0.0169	0.0554
1200	0.00926	0.0304	0.00944	0.0310	0.00963	0.0316	0.00981	0.0322	0.0152	0.0498	0.0155	0.0508
1250	0.00888	0.0292	0.00906	0.0297	0.00924	0.0303	0.00942	0.0309	0.0146	0.0478	0.0149	0.0488
1300	0.00855	0.0280	0.00871	0.0286	0.00888	0.0292	0.00906	0.0297	0.0140	0.0460	0.0143	0.0469
1400	0.00794	0.0260	0.00809	0.0265	0.00825	0.0270	0.00842	0.0276	0.0131	0.0426	0.0133	0.0436
1500	0.00741	0.0243	0.00755	0.0248	0.00770	0.0253	0.00785	0.0258	0.0121	0.0398	0.0123	0.0406
1600	0.00701	0.0230	0.00715	0.0235	0.00729	0.0239	0.00744	0.0244	0.0115	0.0377	0.0117	0.0385
1700	0.00660	0.0216	0.00672	0.0220	0.00686	0.0225	0.00700	0.0230	0.0108	0.0355	0.0110	0.0362
1750	0.00641	0.0210	0.00654	0.0214	0.00666	0.0218	0.00679	0.0223	0.0105	0.0345	0.0107	0.0352
1800	0.00623	0.0204	0.00635	0.0208	0.00648	0.0212	0.00661	0.0216	0.0102	0.0335	0.0104	0.0342
1900	0.00591	0.0194	0.00602	0.0198	0.00614	0.0201	0.00626	0.0205	0.00968	0.0317	0.00987	0.0323
2000	0.00561	0.0184	0.00572	0.0188	0.00583	0.0192	0.00595	0.0195	0.00919	0.0302	0.00937	0.0308

Table 30.8
Maximum direct-current resistance of ASTM Class H stranded conductors

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
8 AWG	0.666	2.18	0.679	2.23	0.708	2.33	0.722	2.37	–	–	–	–
7	0.528	1.73	0.539	1.76	0.561	1.85	0.572	1.88	–	–	–	–
6	0.419	1.38	0.427	1.41	0.446	1.46	0.454	1.49	–	–	–	–
5	0.333	1.09	0.339	1.11	0.353	1.16	0.360	1.18	–	–	–	–
4	0.263	0.865	0.268	0.881	0.279	0.918	0.286	0.936	–	–	–	–
(wires)												
3	0.209	0.686	0.213	0.700	0.222	0.728	0.226	0.743	–	–	–	–
2 (133)	0.166	0.544	0.169	0.555	0.172	0.566	0.175	0.576	0.271	0.891	0.277	0.910
2 (259)	0.166	0.547	0.170	0.557	0.176	0.580	0.181	0.592	–	–	–	–
1	0.133	0.434	0.135	0.442	0.141	0.460	0.143	0.469	–	–	–	–
1/0	0.105	0.344	0.107	0.350	0.109	0.357	0.111	0.364	0.171	0.563	0.175	0.574
2/0	0.0830	0.272	0.0847	0.277	0.0864	0.284	0.0880	0.289	0.136	0.447	0.139	0.456
3/0 (259)	0.0659	0.216	0.0672	0.220	0.0685	0.224	0.0699	0.230	0.108	0.354	0.110	0.361
3/0 (427)	0.0662	0.217	0.0675	0.221	0.0703	0.231	0.0717	0.236	–	–	–	–
4/0 (259)	0.0522	0.171	0.0532	0.174	0.0544	0.179	0.0554	0.182	0.0857	0.280	0.0874	0.287
4/0 (427)	0.0525	0.172	0.0536	0.175	0.0546	0.180	0.0557	0.183	0.0861	0.283	0.0878	0.288
250 kcmil	0.0445	0.146	0.0453	0.149	0.0462	0.152	0.0471	0.155	0.0728	0.239	0.0743	0.244
300	0.0370	0.121	0.0377	0.123	0.0386	0.126	0.0393	0.129	0.0607	0.199	0.0619	0.203
350	0.0317	0.104	0.0323	0.106	0.0330	0.108	0.0337	0.110	0.0520	0.170	0.0530	0.174
400	0.0277	0.0911	0.0284	0.0929	0.0289	0.0948	0.0295	0.0966	0.0455	0.149	0.0464	0.152
450	0.0247	0.0810	0.0252	0.0826	0.0257	0.0843	0.0262	0.0859	0.0405	0.133	0.0413	0.136
500	0.0222	0.0729	0.0226	0.0744	0.0232	0.0758	0.0236	0.0773	0.0364	0.119	0.0371	0.122
550	0.0204	0.0669	0.0208	0.0682	0.0212	0.0696	0.0216	0.0709	0.0335	0.110	0.0341	0.112
600	0.0187	0.0613	0.0191	0.0625	0.0195	0.0638	0.0198	0.0650	0.0306	0.100	0.0312	0.103
650	0.0172	0.0566	0.0175	0.0577	0.0180	0.0589	0.0183	0.0600	0.0283	0.0928	0.0289	0.0947
700	0.0160	0.0525	0.0163	0.0536	0.0166	0.0547	0.0170	0.0557	0.0262	0.0862	0.0268	0.0879

Table 30.8 Continued on Next Page

Table 30.8 Continued

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
750 kcmil	0.0150	0.0491	0.0152	0.0500	0.0155	0.0510	0.0158	0.0520	0.0245	0.0804	0.0250	0.0820
800	0.0140	0.0460	0.0143	0.0470	0.0146	0.0478	0.0149	0.0488	0.0230	0.0754	0.0235	0.0769
900	0.0124	0.0409	0.0128	0.0417	0.0130	0.0425	0.0133	0.0434	0.0204	0.0670	0.0208	0.0683
1000	0.0112	0.0368	0.0114	0.0375	0.0116	0.0382	0.0119	0.0390	0.0184	0.0603	0.0188	0.0615
1100	0.0102	0.0335	0.0104	0.0341	0.0106	0.0348	0.0108	0.0354	0.0167	0.0549	0.0170	0.0559
1200	0.00934	0.0307	0.00953	0.0312	0.00972	0.0319	0.00990	0.0325	0.0153	0.0503	0.0156	0.0513
1250	0.00897	0.0295	0.00915	0.0300	0.00933	0.0306	0.00952	0.0312	0.0147	0.0482	0.0150	0.0493
1300	0.00863	0.0283	0.00879	0.0289	0.00897	0.0295	0.00915	0.0300	0.0142	0.0464	0.0144	0.0473
1400	0.00801	0.0263	0.00817	0.0268	0.00833	0.0273	0.00850	0.0278	0.0132	0.0430	0.0134	0.0439
1500	0.00748	0.0245	0.00762	0.0250	0.00777	0.0255	0.00793	0.0260	0.0122	0.0402	0.0125	0.0410
1600	0.00701	0.0230	0.00715	0.0235	0.00729	0.0239	0.00744	0.0244	0.0115	0.0377	0.0117	0.0385
1700	0.00660	0.0216	0.00672	0.0220	0.00686	0.0225	0.00700	0.0230	0.0108	0.0355	0.0110	0.0362
1750	0.00641	0.0210	0.00654	0.0214	0.00666	0.0218	0.00679	0.0223	0.0105	0.0345	0.0107	0.0352
1800	0.00623	0.0204	0.00635	0.0208	0.00648	0.0212	0.00661	0.0216	0.0102	0.0335	0.0104	0.0342
1900	0.00591	0.0194	0.00602	0.0198	0.00614	0.0201	0.00626	0.0205	0.00968	0.0317	0.00987	0.0323
2000	0.00561	0.0184	0.00572	0.0188	0.00583	0.0192	0.00595	0.0195	0.00919	0.0302	0.00937	0.0308

Table 30.9
Maximum direct-current resistance of ASTM Class I stranded conductors

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
10 AWG	1.04	3.41	1.06	3.48	1.08	3.55	1.10	3.62	–	–	–	–
9	0.824	2.70	0.840	2.75	0.857	2.82	0.874	2.87	–	–	–	–
8	0.654	2.14	0.666	2.18	0.679	2.23	0.693	2.27	1.07	3.52	1.09	3.59
7	0.518	1.70	0.528	1.73	0.538	1.76	0.550	1.81	0.850	2.78	0.867	2.85
6	0.419	1.38	0.427	1.41	0.436	1.43	0.445	1.46	0.687	2.25	0.701	2.31
5	0.333	1.09	0.339	1.11	0.346	1.13	0.353	1.15	0.545	1.79	0.556	1.83
4	0.263	0.865	0.268	0.881	0.274	0.900	0.279	0.917	0.432	1.42	0.441	1.45
3	0.209	0.686	0.213	0.700	0.217	0.713	0.221	0.727	0.343	1.12	0.350	1.14
2	0.166	0.544	0.169	0.555	0.172	0.566	0.175	0.576	0.271	0.891	0.277	0.910
1	0.132	0.431	0.134	0.440	0.137	0.449	0.140	0.457	0.215	0.707	0.220	0.721
1/0	0.105	0.345	0.107	0.352	0.109	0.359	0.111	0.366	0.172	0.566	0.175	0.577
2/0	0.0834	0.273	0.0851	0.279	0.0868	0.285	0.0885	0.291	0.137	0.449	0.140	0.458
3/0	0.0662	0.217	0.0675	0.221	0.0689	0.225	0.0702	0.231	0.108	0.356	0.111	0.363
4/0	0.0525	0.172	0.0536	0.175	0.0546	0.180	0.0557	0.183	0.0861	0.283	0.0878	0.288
250 kcmil	0.0449	0.147	0.0457	0.150	0.0466	0.153	0.0475	0.156	0.0735	0.242	0.0750	0.246
300	0.0373	0.122	0.0381	0.125	0.0389	0.128	0.0397	0.130	0.0613	0.201	0.0625	0.205
350	0.0320	0.105	0.0326	0.107	0.0334	0.109	0.0340	0.111	0.0525	0.172	0.0536	0.175
400	0.0280	0.0920	0.0286	0.0937	0.0292	0.0957	0.0297	0.0975	0.0460	0.151	0.0469	0.154
450	0.0249	0.0817	0.0254	0.0833	0.0259	0.0850	0.0264	0.0867	0.0408	0.134	0.0417	0.137
500	0.0224	0.0735	0.0228	0.0751	0.0234	0.0765	0.0238	0.0780	0.0367	0.120	0.0375	0.123
550	0.0204	0.0669	0.0208	0.0682	0.0212	0.0696	0.0216	0.0709	0.0335	0.110	0.0341	0.112
600	0.0187	0.0613	0.0191	0.0625	0.0195	0.0638	0.0198	0.0650	0.0306	0.100	0.0312	0.103
650	0.0174	0.0571	0.0177	0.0582	0.0182	0.0594	0.0185	0.0606	0.0286	0.0936	0.0292	0.0956
700	0.0162	0.0530	0.0165	0.0541	0.0168	0.0552	0.0171	0.0563	0.0265	0.0870	0.0270	0.0887

Table 30.9 Continued on Next Page

Table 30.9 Continued

Size of Conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
750 kcmil	0.0151	0.0495	0.0154	0.0505	0.0157	0.0515	0.0160	0.0525	0.0248	0.0812	0.0252	0.0828
800	0.0142	0.0464	0.0144	0.0473	0.0147	0.0482	0.0150	0.0493	0.0232	0.0761	0.0237	0.0776
900	0.0125	0.0413	0.0129	0.0420	0.0131	0.0429	0.0134	0.0438	0.0206	0.0676	0.0210	0.0691
1000	0.0113	0.0371	0.0115	0.0378	0.0117	0.0387	0.0120	0.0394	0.0186	0.0610	0.0190	0.0621
1100	0.0103	0.0338	0.0105	0.0344	0.0107	0.0351	0.0109	0.0358	0.0168	0.0554	0.0172	0.0565
1200	0.00944	0.0310	0.00962	0.0315	0.00981	0.0322	0.0101	0.0328	0.0155	0.0507	0.0158	0.0517
1250	0.00906	0.0297	0.00923	0.0303	0.00941	0.0310	0.00960	0.0315	0.0149	0.0487	0.0151	0.0497
1300	0.00871	0.0286	0.00887	0.0292	0.00906	0.0297	0.00923	0.0303	0.0143	0.0468	0.0146	0.0477
1400	0.00809	0.0265	0.00824	0.0270	0.00840	0.0275	0.00858	0.0282	0.0133	0.0435	0.0136	0.0444
1500	0.00755	0.0248	0.00769	0.0252	0.00784	0.0257	0.00801	0.0262	0.0123	0.0406	0.0126	0.0414
1600	0.00708	0.0233	0.00721	0.0237	0.00735	0.0242	0.00750	0.0246	0.0116	0.0380	0.0118	0.0389
1700	0.00666	0.0218	0.00679	0.0222	0.00693	0.0227	0.00706	0.0232	0.0109	0.0358	0.0111	0.0365
1750	0.00647	0.0212	0.00660	0.0216	0.00672	0.0220	0.00685	0.0225	0.0106	0.0348	0.0108	0.0355
1800	0.00629	0.0206	0.00642	0.0210	0.00654	0.0214	0.00667	0.0218	0.0103	0.0339	0.0105	0.0345
1900	0.00596	0.0196	0.00608	0.0199	0.00619	0.0203	0.00631	0.0207	0.00977	0.0320	0.00997	0.0326
2000	0.00566	0.0186	0.00577	0.0190	0.00589	0.0193	0.00600	0.0197	0.00928	0.0304	0.00947	0.0310

Table 30.10
Maximum direct-current resistance of ASTM Class K stranded conductors

Size of conductor	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
14 AWG	2.62	8.61	2.67	8.78	2.82	9.25	2.88	9.42
13	2.08	6.84	2.12	6.97	2.23	7.34	2.28	7.48
12	1.65	5.43	1.68	5.53	1.77	5.82	1.81	5.94
11	1.31	4.30	1.33	4.39	1.40	4.61	1.44	4.71
10	1.04	3.41	1.06	3.48	1.11	3.66	1.14	3.73
9	0.840	2.75	0.857	2.82	0.903	2.96	0.920	3.02
8	0.666	2.18	0.679	2.23	0.715	2.35	0.729	2.40
7	0.528	1.73	0.539	1.76	0.567	1.87	0.578	1.90
6	0.419	1.38	0.427	1.41	0.450	1.48	0.459	1.51
5	0.333	1.09	0.339	1.11	0.357	1.17	0.364	1.19
4	0.263	0.865	0.268	0.881	0.283	0.928	0.289	0.947
3	0.211	0.693	0.215	0.706	0.226	0.744	0.232	0.758
2	0.167	0.549	0.170	0.560	0.180	0.590	0.184	0.601
1	0.133	0.436	0.136	0.444	0.143	0.467	0.145	0.476
1/0	0.105	0.345	0.107	0.352	0.113	0.370	0.115	0.377
2/0	0.0843	0.276	0.0859	0.282	0.0904	0.297	0.0922	0.303
3/0	0.0668	0.219	0.0681	0.223	0.0717	0.236	0.0731	0.240
4/0	0.0530	0.173	0.0541	0.177	0.0569	0.187	0.0580	0.191
250 kcmil	0.0449	0.147	0.0457	0.150	0.0481	0.158	0.0491	0.161
300	0.0373	0.122	0.0381	0.125	0.0401	0.132	0.0409	0.135
350	0.0323	0.106	0.0329	0.108	0.0347	0.114	0.0354	0.116
400	0.0283	0.0928	0.0289	0.0947	0.0304	0.0997	0.0310	0.102
450	0.0252	0.0825	0.0256	0.0842	0.0270	0.0886	0.0275	0.0904
500	0.0226	0.0743	0.0231	0.0757	0.0243	0.0798	0.0248	0.0813
550	0.0206	0.0675	0.0210	0.0688	0.0221	0.0725	0.0225	0.0740
600	0.0189	0.0619	0.0193	0.0631	0.0203	0.0664	0.0207	0.0677
650	0.0174	0.0571	0.0177	0.0582	0.0187	0.0613	0.0191	0.0625
700	0.0162	0.0530	0.0165	0.0541	0.0173	0.0569	0.0177	0.0580
750	0.0151	0.0495	0.0154	0.0505	0.0162	0.0531	0.0165	0.0542
800	0.0142	0.0464	0.0144	0.0473	0.0152	0.0499	0.0155	0.0508
900	0.0125	0.0413	0.0129	0.0420	0.0135	0.0443	0.0138	0.0452
1000	0.0113	0.0371	0.0115	0.0378	0.0121	0.0399	0.0124	0.0407

Table 30.11
Maximum direct-current resistance of ASTM Class M stranded conductors

	Uncoated copper				Coated copper (each strand coated with tin or a tin/lead alloy)			
	20°C		25°C		20°C		25°C	
Size of conductor	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m	Ohms per 1000 feet	Ohms per 1000 m
14 AWG	2.62	8.61	2.67	8.78	2.82	9.25	2.88	9.42
13	2.10	6.89	2.13	7.03	2.26	7.40	2.31	7.54
12	1.68	5.53	1.71	5.64	1.81	5.94	1.85	6.05
11	1.33	4.39	1.36	4.47	1.44	4.71	1.46	4.79
10	1.06	3.48	1.08	3.55	1.14	3.73	1.16	3.80
9	0.840	2.75	0.857	2.82	0.898	2.96	0.920	3.02
8	0.666	2.18	0.679	2.23	0.715	2.35	0.729	2.40
7	0.533	1.75	0.544	1.78	0.572	1.88	0.584	1.92
6	0.423	1.39	0.431	1.42	0.455	1.49	0.463	1.52
5	0.336	1.10	0.343	1.12	0.360	1.18	0.367	1.20
4	0.266	0.873	0.271	0.887	0.286	0.937	0.292	0.956
3	0.213	0.699	0.217	0.704	0.226	0.744	0.232	0.758
2	0.169	0.554	0.172	0.565	0.182	0.595	0.185	0.607
1	0.134	0.440	0.137	0.448	0.144	0.472	0.147	0.481
1/0	0.106	0.349	0.108	0.355	0.114	0.374	0.116	0.381
2/0	0.0851	0.276	0.0867	0.282	0.0913	0.300	0.0931	0.305
3/0	0.0674	0.221	0.0687	0.225	0.0724	0.238	0.0738	0.242
4/0	0.0534	0.175	0.0546	0.179	0.0574	0.189	0.0585	0.192
250 kcmil	0.0453	0.149	0.0462	0.151	0.0487	0.159	0.0496	0.162
300	0.0377	0.123	0.0385	0.125	0.0405	0.133	0.0413	0.136
350	0.0323	0.106	0.0329	0.108	0.0347	0.114	0.0354	0.116
400l	0.0283	0.0928	0.0289	0.0947	0.0304	0.0997	0.0310	0.102
450	0.0252	0.0825	0.0256	0.0842	0.0261	0.0858	0.0267	0.0875
500	0.0226	0.0743	0.0231	0.0757	0.0243	0.0798	0.0248	0.0813
550	0.0206	0.0675	0.0210	0.0688	0.0221	0.0725	0.0225	0.0740
600	0.0189	0.0619	0.0193	0.0631	0.0203	0.0664	0.0206	0.0677
650	0.0174	0.0571	0.0177	0.0582	0.0187	0.0613	0.0191	0.0625
700	0.0162	0.0530	0.0165	0.0541	0.0173	0.0569	0.0177	0.0580
750	0.0151	0.0495	0.0154	0.0505	0.0162	0.0531	0.0165	0.0542
800	0.0142	0.0464	0.0144	0.0473	0.0152	0.0499	0.0155	0.0508
900	0.0125	0.0413	0.0129	0.0420	0.0135	0.0443	0.0138	0.0452
1000	0.0113	0.0371	0.0115	0.0378	0.0121	0.0399	0.0123	0.0407

31 – 39 *Reserved for Future Use*

INSULATION AND JACKET MATERIALS

40 General

40.1 The chemical composition of an insulating or jacketing material is not specified.

40.2 The methods of preparation of samples, of selection and conditioning of specimens, and of making the measurements and calculations for ultimate elongation and tensile strength are indicated under the heading Physical Properties Tests of Insulation and Jacket in this standard (see Sections 400 – 481).

41 – 46 *Reserved for Future Use*

47 Index Table

47.1 Table 47.1 is an index to all of the materials that are for use as insulation and jackets in the various types of wire, cable, and flexible cord. The materials are grouped alphabetically by their generic designations. Physical properties requirements are given in the indicated tables(s) or paragraphs in Specific Materials, Section 50 of this standard, either for the particular insulation or jacket material from an individual type as specified in the applicable wire standard, or for the class of insulation or jacket material specified in the applicable wire standard.

47.2 Table 47.1 is an index to the location in UL 1581 of the physical properties requirements for the insulating and jacketing materials specified in the applicable wire standards for all types of wire and cable, including fixture wire, but not including decorative-lighting cords and wire, other flexible cords, elevator cable, or hoistway cable. In Table 47.1, the materials are grouped alphabetically by their generic names or letter designations, and reference is made to particular paragraphs or a particular table in Specific Materials, Section 50, for the physical properties requirements.

47.3 Requirements for the physical properties of materials used in decorative-lighting cords and wire, in other flexible cords, in elevator cable, and in hoistway cable are tabulated in the UL 62 standard (covering flexible cords) under the decimal class numbers 2.x for insulating materials and 1.x for jacketing materials. UL 62 no longer specifies UL 1581 insulating and jacketing materials; however, for use where specified for applications outside UL 62, these materials continue to be indexed in Table 47.1, with physical properties requirements tabulated in Specific Materials, Section 50.

Table 47.1
Index to insulation and jacket materials

Table 47.1 revised October 31, 2001

Material	Applicable table(s) or paragraphs in this standard
CP	
Insulations and jackets from Type USE-2 and USE cable; power-limited circuit cable; cable for power-limited fire-alarm circuits; other cables; and from Type SIS, RHW-2, RHW, and RHH wires; jacket from CATV cables	Table 50.1
Jacket from cable for deep-well submersible water pumps	Table 50.10
Class 24 insulation and jacket	Table 50.20
Class 26 jacket	Table 50.21
Class 32 insulation and jacket	Table 50.22
Class 42 insulation and jacket	Table 50.23
Class 46 jacket	Table 50.24
CPE	
Thermoplastic jacket from CATV cables, power-limited circuit cable, and cable for power-limited fire-alarm circuits, and other cables	Table 50.28
Thermoset jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, Type USE and USE-2 cables, other cables, and from Type RHH and RHW-2 wires	Table 50.29
Thermoset jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, Type USE cable, other cables, and from Type RHW wires	Table 50.30
Jacket from cable for deep-well submersible water pumps	Table 50.31
Class 37 insulation	Table 50.32
Class 42 insulation and jacket	Table 50.23
Class 47 thermoset insulation and jacket	Table 50.33
ECTFE and ETFE	
ETFE insulation from Type Z and ZW wires and from 150°C Type ZF and ZFF wires and insulation and jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables; and jacket from CATV cables	Table 50.63
ETFE from Type ZHF wire	Table 50.64
EP	
Insulation from Types RHW-2, RHH, and RHW	Table 50.42
Class 28 EPDM insulation and jacket	Table 50.52
Class 35 insulation	Table 50.53
Class 44 EPDM insulation	Table 50.54
Class 45 insulation	Table 50.55
Class 46 EPDM insulation and jacket	Table 50.24
EPCV	
Insulation from Types SIS, RHW-2, RHH, and RHW	Table 50.62
FEP	
Insulation and jacket from power-limited circuit-cable, cable for power-limited fire-alarm circuits, and other cables; and insulation from Types FEP and FEPB; jacket from CATV cables	Table 50.70

Table 47.1 Continued on Next Page

Table 47.1 Continued

Material	Applicable table(s) or paragraphs in this standard
Class 12A insulation	Table 50.73
FRPE (HDFRPE and LDFRPE)	
Insulation from power-limited circuit cable and cable for power-limited fire-alarm circuits; jacket from CATV cables	Table 50.133
NBR/PVC	
Jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, other cables, and Type RHW	Table 50.80
Jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, other cables, and Type RHW-2 and RHH	Table 50.83
Jacket from cable for deep-well submersible water pumps	Table 50.87
Class 23 jacket	Table 50.96
Class 25 insulation and jacket	Table 50.97
Class 41 jacket	Table 50.125
90°C (194°F) jacket from Type USE-2 and USE cables	Table 50.99
75°C (167°F) jacket from Type USE cable	Table 50.100
Class 42 insulation and jacket	Table 50.23
Class 46 insulation and jacket	Table 50.24
Neoprene	
90°C (194°F) jacket from Type USE and USE-2 cables	Table 50.99
75°C (167°F) jacket Type USE cable	Table 50.100
Jacket from Type RHW	Table 50.105
Jacket from Types RHW-2 and RHH	Table 50.108
Jacket from cable for deep-well submersible water pumps	Table 50.112
Class 13 insulation	Table 50.120
Class 14 insulation	Table 50.121
Class 15 jacket	Table 50.122
Class 16 jacket and jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables	Table 50.123
Class 17 insulation and jacket and jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables	Table 50.124
Class 41 insulation and jacket	Table 50.125
Class 46 insulation and jacket	Table 50.24
PE [75°C (167°F) thermoplastic HDPE and LDPE]	
HDPE insulation from single-conductor Type USE cable	Table 50.135
Class 30 PE insulation (LDPE), HDPE insulation from power-limited circuit cable, LDPE insulation from power-limited circuit cable and from cable for power-limited fire-alarm circuits	Table 50.136
PFA	
Insulation from Type PFA and PFAH wires, jacket from CATV cables, and insulation and jacket from other wires and cables	Table 50.137
PP and FRPP	
Insulation from power-limited circuit cable	Table 50.139

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Table 47.1 Continued

Material	Applicable table(s) or paragraphs in this standard
and cable for power-limited fire-alarm circuits; jacket from CATV cables	
PVC	
Insulation from Type TW	Table 50.140
Insulation from Types THWN and THW	Table 50.145
Insulation from gasoline-resistant Types TFN, TFFN, THWN-2, and THWN	Table 50.150
Insulation from Types THW-2, THWN-2, THHW, and THHN	Table 50.155
Insulation from Type TBS	Table 50.160
Class 11 insulation	Table 50.165
Class 11 insulation and jacket	Table 50.166
Class 11 jacket	Table 50.167
Class 11 insulation and jacket	Table 50.169
Class 11 jacket	Table 50.172
Jacket from cable for deep-well submersible water pumps	Table 50.175
Class 12 75°C (167°F) insulation and jacket	Table 50.179
Class 12 90°C (194°F) insulation and jacket	Table 50.180
Class 12 105°C (221°F) insulation and jacket	Table 50.181
Class 12B insulation	Table 50.155
Oil-resistant Class 12B insulation	Table 50.156
Class 43 insulation and jacket;	Table 50.182
insulation and jacket from power-limited circuit cable and cable from power-limited fire-alarm circuits, and from other cables; jacket from CATV cables	
Thermoplastic insulation other than PVC	Table 50.144
from Type THHN and THWN wires	
SRPVC (semirigid PVC)	
Insulation and jacket from power-limited	Table 50.183
circuit cable, cable for power-limited fire-alarm circuits, and from other cables	
PTFE (TFE)	
Class 12C PTFE insulation, PTFE insulation from	Table 50.219
Type TFE, PTF, and PTFF wires and PTFE (TFE) insulation from power-limited circuit cable and cable for power-limited fire-alarm circuits	
PVDF and PVDF copolymer	
Jackets from CATV cables and insulation and jacket from power-limited circuit cable and cable for power-limited fire-alarm circuits	Table 50.185
Rubber	
SBR/IIR/NR insulation from Types RHW-2, RHH, and RHW	Table 50.189
Class 2 insulation	Table 50.193
Class 3 insulation	Table 50.194
Class 4 insulation	Table 50.195
Class 6 jacket	Table 50.196
Class 7 insulation	Table 50.197
Class 8 insulation	Table 50.198
Class 10 insulation	Table 50.199

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Table 47.1 Continued

Material	Applicable table(s) or paragraphs in this standard
Class 40 SBR/NR insulation	Table 50.200
Class 44 SBR/NR insulation	Table 50.54
Class 46 SBR/NR insulation and jacket	Table 50.24
SBR/IIR/NR – see ″Rubber″	
Silicone rubber	
Insulation from Type SA	Table 50.205
Insulation from jacketed/fibrous-covered Type RHH wire	Table 50.206
Class 22 insulation and insulation from power-limited circuit cable, cable for power-limited fire-alarm circuits, from other cables, and jackets for CATV cables	Table 50.210
TFE	
Class 12C PTFE insulation and PTFE insulation from power-limited circuit cable, from cable for power-limited fire-alarm circuits, from other cables, and from Type TFE wire	Table 50.219
TPE	
105°C (221°F) insulation and jacket from power-limited circuit cable and from cable for power-limited fire-alarm circuits, and from other cables; and 105°C (221°F) Class 36 insulation and jacket, and 105°C (221°F) jacket from CATV cables	Table 50.223
90°C (194°F) insulation and jacket from power-limited circuit cable and from cable for power-limited fire-alarm circuits, and from other cables; and 90°C (194°F) Class 36 insulation and jacket; 90°C (194°F) jacket from CATV cables	Table 50.224
XL	
90°C (194°F) jacket from Type USE-2 and USE cables	Table 50.228
75°C (167°F) jacket from Type USE cable	Table 50.229
Jacket from cable for deep-well submersible water pumps	Table 50.230
XL insulation from Type RFHH-2, RFHH-3, XHHW-2, XHHW, SIS, RHH, RHW-2, and RHW and power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables; jackets from CATV cables	Table 50.231
Class 29 [90°C (194°F)]	Table 50.237
Class 31 [75°C (167°F)]	Table 50.241
Class 33 [105°C (221°F)]	Table 50.245
XLPO insulation	
Class 38 [150°C (302°F)]	Table 50.232
105°C (221°F) insulation or jacket from power-limited circuit-cable, cable for power-limited fire-alarm circuits, and other cables	Table 50.233

48 and 49 *Reserved for Future Use*

50 Specific Materials

Table 50.1
Physical properties of 90°C (194°F) and 75°C (167°F) CP[a] jackets from CATV cables and insulations and jackets from Type USE and USE-2 cables; power-limited circuit cable; cable for power-limited fire-alarm circuits; other cables; and Type RHW-2, RHH, RH, and SIS wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h:		
At 121.0 ±1.0°C (249.8 ±1.8°F) for specimens of 90°C (194°F) insulation or jacket from power-limited circuit cable, Type USE-2 cable, or from Type RHW-2, RHH, and SIS wires	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
At 113.0 ±1.0°C (235.4 ±1.8°F) for specimens of 75°C (167°F) insulation or jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, or from Type RHW and RH wires, or Type USE cable	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene. CP rated 90°C (194°F) is for use as conductor insulation on Type RHW-2, RHH, and SIS wires without any covering over the insulation. CP rated 75°C (167°F) is for use as conductor insulation on Type RHW and RH wires without any covering over the insulation.

Table 50.10
Physical properties of CP[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

Table 50.20
Physical properties of Class 24 90°C (194°F) CP[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	100 percent (1 inch or 25 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket:		
Aged in oil for 18 h at 121 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 24 CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

Table 50.21
Physical properties of Class 26 60°C (140°F) CP[a] jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3-inches or 75-mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.2 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 26 CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

Table 50.22
Physical properties of Class 32 105°C (221°F) CP[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	100 percent (1 inch or 25 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket:		
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 32 CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

Table 50.23
Physical properties of Class 42 90°C (194°F) CP[a], CPE[b], and NBR/PVC[c] insulations and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	100 percent (1 inch or 25 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket:		
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 42 CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

[b] Class 42 CPE designates a thermoset compound whose characteristic constituent is chlorinated polyethylene.

[c] Class 42 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.24
Physical properties of Class 46 60°C (140°F) and 75°C (167°F) CP[a], EPDM[b], NBR/PVC[c], neoprene[d], and SBR/NR[e] insulations and jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength	
	60°C (140°F) compound	75°C (167°F) compound	60°C (140°F) compound	75°C (167°F) compound
Unaged	200 percent (2 inches or 50 mm)		1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2	
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	65 percent of the result with unaged specimens where the sum of the tensile and elongation percentages is at least 140. Otherwise, 70 percent of the result with unaged specimens	Not measured	65 percent of the result with unaged specimens where the sum of the tensile and elongation percentages is at least 140. Otherwise, 70 percent of the result with unaged specimens	Not measured
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0±1.8°F)	Not measured	50 percent of the result with unaged specimens	Not measured	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket: Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens			

[a] Class 46 CP designates a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

[b] Class 46 EPDM designates a thermoset compound whose characteristic constituent is a terpolymer of ethylene, propylene, and small amount of nonconjugated diene.

[c] Class 46 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

[d] Class 46 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

[e] Class 46 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.28
Physical properties of 90°C (194°F) thermoplastic CPE[a] jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 38 mm)	1400 lbf/in^2 or 9.65 MPa (MN/m^2) or 965 N/cm^2 or 0.984 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens

[a] CPE designates a thermoplastic compound whose characteristic constituent is chlorinated polyethylene.

Table 50.29
Physical properties of 90°C (194°F) thermoset CPE[a] jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, Type USE-2 cables, other cables, and Type RHW-2 and RHH wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 1.8°F)	60 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Thermoset CPE designates a thermoset compound whose characteristic constituent is chlorinated polyethylene.

Table 50.30
Physical properties of 75°C (167°F) thermoset CPE[a] jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, Type USE cable, other cables, and Type RHW and RH wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2-1/2 inches or 62.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	60 percent of the result with unaged specimens	85 percent of the result with unaged specimens

Table 50.30 Continued on Next Page

Table 50.30 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Thermoset CPE is described in note [a] to Table 50.29.

Table 50.31
Physical properties of thermoset CPE[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2-1/2 inches or 62.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	60 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Thermoset CPE is described in note [a] to Table 50.29.

Table 50.32
Physical properties of Class 37 90°C (194°F) thermoset CPE[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	100 percent (1 inch or 25 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket: Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 37 thermoset CPE designates a thermoset compound whose characteristic constituent is chlorinated polyethylene.

Table 50.33
Physical properties of Class 47 105°C (221°F) thermoset CPE[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	50 percent of the result with unaged specimens	80 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:		
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 47 thermoset CPE designates a thermoset compound whose characteristic constituent is chlorinated polyethylene.

Table 50.34
Physical properties of 90°C (194°F) and 75°C (167°F) thermoset CPE[a] insulations from Type USE and USE–2 cables and Type RHW–2, RHW, RHH, and SIS wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1–inch or 25–mm bench marks)	Minimum tensile strength
Unaged	200 percent	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h:		
At 121.0 ±1.0°C (249.8 ±1.8°F) for specimens of 90°C (194°F) insulation or jacket from power-limited circuit cable, Type USE–2 cable, or from Type RHW–2, RHH, and SIS wires	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
At 113.0 ±1.0°C (235.4 ±1.8°F) for specimens of 75°C (167°F) insulation or jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, or from Type RHW wire, or Type USE cable	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Thermoset CPE designates a thermoset compound whose characteristic constituent is chlorinated polyethylene. Thermoset CPE rated 90°C (194°F) is for use as conductor insulation on Type RHW–2, RHH, and SIS wires without any covering over the insulation. Thermoset CPE rated 75°C (167°F) is for use as conductor insulation on Type RHW wire without any covering over the insulation.

Table 50.42
Physical properties of EP[a] insulation from Type RHW-2, RH, RHW, and RHH wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 50 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] EP designates a thermoset compound whose characteristic constituent is a copolymer (EPM) of ethylene and propylene; a terpolymer (EDPM) of ethylene, propylene, and a small amount of nonconjugated diene; or a blend of EPM and EPDM. EP is for use where subjected to 75°C (167°F) and lower temperatures as insulation under a CP, NBR/PVC, or neoprene jacket or a fibrous covering on Type RH wire; where subjected to 90°C (194°F) and lower temperatures as insulation under a CP, NBR/PVC, or neoprene jacket or a fibrous covering on Type RHH and RHW-2 wires or as the underlayer of composite insulation consisting of CP over EP without a covering over the CP on Type RHH wire; and where subjected to 75°C (167°F) and lower temperatures as insulation under a CP, NBR/PVC, or neoprene jacket or a fibrous covering on Type RHW wire.

Table 50.52
Physical properties of Class 28 75°C (167°F) and 90°C (194°F) EPDM[a] insulations and jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)			Minimum tensile strength		
	Insulation		Jacket	Insulation		Jacket
	75°C (167°F)	90°C (194°F)	75°C (167°F)	75°C (167°F)	90°C (194°F)	75°C (167°F)
Unaged	250 percent (2-1/2 inches or 62.5 mm)	250 percent (2-1/2 inches or 62.5 mm)	300 percent (3 inches or 75 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens	Not measured	70 percent of the result with unaged specimens
Aged in a full-draft circulating-air oven for 240 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	50 percent of the with unaged specimens	Not measured	Not measured	50 percent of the result with unaged specimens	Not measured

[a] Class 28 EPDM designates a thermoset compound whose characteristic constituent is a terpolymer of ethylene, propylene, and a small amount of nonconjugated diene.

Table 50.53
Physical properties of Class 35 105°C (221°F) EP[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	50 percent of the result with unaged specimens	50 percent of the result with unaged specimens

[a] Class 35 EP designates a thermoset compound whose characteristic constituent is a copolymer (EPM) of ethylene and propylene; a terpolymer (EPDM) of ethylene, propylene, and a small amount of nonconjugated diene; or a blend of EPM and EPDM.

Table 50.54
Physical properties of Class 44 75°C (167°F) EPDM[a] and SBR/NR[b] insulations and jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	600 lbf/in^2 or 4.14 MPa (MN/m^2) or 414 N/cm^2 or 0.422 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 44 EPDM designates a thermoset compound whose characteristic constituent is a terpolymer of ethylene, propylene, and a small amount of nonconjugated diene.

[b] Class 44 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.55
Physical properties of Class 45 90°C (194°F) and 105°C (221°F) EP[a] insulations

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2
Aged in a full-draft circulating-air oven for the specified time at the specified temperature[b]	50 percent of the result with unaged specimens	50 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation:		
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

Table 50.55 Continued on Next Page

Table 50.55 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength

[a] Class 45 EP designates a thermoset compound whose characteristic constituent is a copolymer (EPM) of ethylene and propylene; a terpolymer (EPDM) of ethylene, propylene, and a small amount of nonconjugated diene; or a blend of EPM and EPDM.

[b] The oven time and temperature are to be as follows:

Temperature rating of insulation	Specified oven time and temperature: h	Specified oven time and temperature: Temperature
90°C (194°F)	240	121.0 ±1.0°C (294.8 ±1.8°F)
105°C (221°F)	168	136.0 ±1.0°C (276.8 ±1.8°F)

Table 50.62
Physical properties of EPCV[a] insulation from Type RHW-2, RH, RHW, RHH, and SIS wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	225 percent (2-1/4 inches or 56.2 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] EPCV designates a thermoset compound whose characteristic constituent is a covulcanizate of ethylene and propylene (EP) with a polyethylene (PE). EPCV is for use where subjected to 75°C (167°F) and lower temperatures as insulation on Type RH and RHW wires without any outer covering and where subjected to 90°C (194°F) and lower temperatures as insulation on Type RHW-2, RHH, and SIS wires without any covering over the insulation.

Table 50.63
Physical properties of ETFE[a] insulation from Type Z and ZW wires and from 150°C (302°F) Type ZF and ZFF wires; ECTFE[a] and ETFE[a] insulation or jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, and other cables; and ECTFE[a] and ETFE[a] jackets from CATV cables

Table 50.63 revised October 31, 2001

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b,c]	Minimum tensile strength[b,c]
Unaged	100 percent (1 inch or 25 mm)	5000 lbf/in^2 or 34.5 MPa (MN/m^2) or 3447 N/cm^2 or 35.2 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 180.0 ±1.0°C (356.0 ±1.8°F)	75 percent of the result with unaged specimens	85 percent of the result with unaged specimens or 5000 lbf/in^2 or 34.5 MN/m^2 or 3447 N/cm^2 or

Table 50.63 Continued on Next Page

Table 50.63 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b,c]	Minimum tensile strength[b,c]
		35.2 kgf/mm^2

[a] ECTFE and ETFE designate thermoplastic materials whose characteristic constituent is either a copolymer of ethylene and tetrafluoroethylene (ETFE) or a copolymer of ethylene and chlorotrifluoroethylene (ECTFE). The material is uncompounded ECTFE or ETFE to which a small amount of pigment, lubricant, or both, is or is not added.

[b] ECTFE and ETFE are to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min.

[c] With band-marking inks in place or removed prior to the aging of specimens.

Table 50.64
Physical properties of 200°C (382°F) ETFE[a] insulation

Table 50.64 added October 31, 2001

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b,c]	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 232.0 ±2.0°C (449.6 ±3.6°F)	85 percent of the result with unaged specimens	80 percent of the result with unaged specimens

[a] ETFE designates a thermoplastic material whose characteristic constituent is a copolymer of ethylene and tetrafluoroethylene. The material is uncompounded ETFE to which a small amount of pigment, lubricant, or both, is or is not added.

[b] ETFE is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min.

[c] With band-marking inks in place or removed prior to the aging of specimens.

Table 50.70
Physical properties of 200°C (392°F) FEP[a] jacket from CATV cables, jacket or insulation from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or other cables; and insulation from Type FEP and FEPB wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	200 percent (2 inches or 50 mm)	2500 lbf/in^2 or 17.2 MPa (MN/m^2) or 1724 N/cm^2 or 1.76 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 232.0 ±1.0°C (449.6 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] FEP designates a thermoplastic material whose characteristic constituent is a copolymer of tetrafluoroethylene and hexafluoropropylene. The material is uncompounded FEP to which it is appropriate to add a small amount of pigment, lubricant, or both.

[b] FEP is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.73
Physical properties of Class 12A FEP[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	2500 lbf/in^2 or 17.2 MPa (MN/m^2) or 1724 N/cm^2 or 1.76 kgf/mm^2
Aged in a full-draft circulating-air oven for 96 h at 232.0 ±1.0°C (449.6 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] FEP designates a thermoplastic material whose characteristic constituent is a copolymer of tetrafluoroethylene and hexafluoropropylene. The material is uncompounded FEP to which it is appropriate to add a small amount of pigment, lubricant, or both.

[b] FEP is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.80
Physical properties of 75°C (167°F) NBR/PVC[a] thermoset jacket from power-limited circuit cable, cable for power-limited fire-alarm circuits, other cables, and Type RH and RHW wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm Bench Marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1500 lbf/in^a or 10.3 MPa (MN/m^a) or 1034 N/cm^a or 1.05 kgf/mm^a
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.83
Physical properties of 90°C (194°F) NBR/PVC[a] thermoset jacket from CATV cables, power-limited circuit cable, cables for power-limited fire-alarm circuits, other cables, and Type RHW-2 and RHH wires

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	31.25 percent (5/16 inch or 7.8 mm)	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating air oven for 240 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 or 6.21 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.87
Physical properties of NBR/PVC[a] thermoset jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	31 percent (5/16 inch or 7.8 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] NBR/PVC thermoset is described in note [a] to Table 50.83.

Table 50.96
Physical properties of Class 23 60°C (140°F) NBR/PVC[a] thermoset jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	31 percent (5/16 inch or 7.8 mm)	300 percent (3 inches or 75 mm)	Jackets from 8 AWG and larger Type SO cables: 1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mn^2 Other jackets: 1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 23 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylontrile butadiene rubber and polyvinyl chloride.

Table 50.97
Physical properties of Class 25 90°C (194°F) and 75°C (167°F) NBR/PVC[a] thermoset insulations and jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength	
	75°C (167°F) compound	90°C (194°) compound	75°C (167°F) compound	90°C (194°F) compound
Unaged	200 percent (2 inches or 50 mm)		1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2	
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	Not measured	70 percent of the result with unaged specimens	Not measured
Aged in a full-draft circulating air oven for 168 h at	Not measured	100 percent (1 inch or 25 mm)	Not measured	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or

Table 50.97 Continued on Next Page

Table 50.97 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength	
	75°C (167°F) compound	90°C (194°) compound	75°C (167°F) compound	90°C (194°F) compound
121.0 ±1.0°C (249.8 ±1.8°F)				827 N/cm^2 or 0.844 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket:				
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	60 percent of the result with unaged specimens		60 percent of the result with unaged specimens	

[a] Class 25 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.98
Physical properties of Class 27 90°C (194°F) NBR/PVC[a] thermoset jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	31.25 percent (5/16 inch or 7.8 mm)	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 or 6.21 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
60°C (140°F) oil-resistant jacket:			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 27 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylontrile butadiene rubber and polyvinyl chloride.

Table 50.99
Physical properties of 90°C (194°F) neoprene[a] and NBR/PVC[b] jackets from Type USE-2 and USE cables

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 or 6.2 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

[b] NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.100
Physical properties of 75°C (167°F) neoprene[a] or NBR/PVC[b] jacket from Type USE cable

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

[b] NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.105
Physical properties of neoprene[a] jacket from Type RH and RHW wires

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	Jackets 15 mils or 0.38 mm thick: 1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2 Thicker jacket: 1800 lbf/in^2 or 12.4 MPa (MN//m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Neoprene designates a thermoset compound whose characteristic constituent is polychloroprene. Neoprene is for use where subjected to 75°C (167°F) and lower temperatures as a jacket on Type RH or RHW wire insulated with SBR/IIR/NR rubber or EP thermoset.

Table 50.108
Physical properties of neoprene[a] jacket from Type RHW-2 and RHH wires

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	Jacket 15 mils or 0.38 mm thick: 1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2 Thicker jacket: 1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2
Aged in a full-draft circulating-air for 240 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 or 6.2 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

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Table 50.108 Continued

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
[a] Neoprene designates a thermoset compound whose characteristic constituent is polychloroprene. Neoprene is for use where subjected to 90°C (194°F) and lower temperatures as a jacket on Type RHH and RHW-2 wires insulated with SBR/IIR/NR rubber or EP thermoset.			

Table 50.112
Physical properties of neoprene[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens
[a] Neoprene thermoset is described in note [a] to Table 50.120.			

Table 50.120
Physical properties of Class 13 60°C (140°F) neoprene[a] insulation

Conditions of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating- air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens
[a] Class 13 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.			

Table 50.121
Physical properties of Class 14 60°C (140°F) neoprene[a] insulation

Conditions of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens where the sum of the tensile plus elongation percentages is at least 140. Otherwise, 70 percent of the result with unaged specimens.	
60°C (140°F) oil-resistant insulation			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 13 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

Table 50.122
Physical properties of Class 15 60°C (140°F) neoprene[a] jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to (3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	Jackets from 8 AWG and larger Type SOW and SO cables: 2800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2 Other jackets: 1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 15 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

Table 50.123
Physical properties of 75°C (167°F) neoprene[a] jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, other cables, and from applications specifying a Class 16 jacket

Conditions of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 16 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

Table 50.124
Physical properties of 90°C (194°F) neoprene[a] jacket from CATV cables, power-limited circuit cable, cable for power-limited fire-alarm circuits, other cables, and from cable for applications specifying a Class 17 insulation or jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 8.27 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 or 6.21 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
60°C (140°F) oil-resistant Class 17 insulation or jacket:			
Aged in oil for 18 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 17 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

Table 50.125
Physical properties of Class 41 90°C (194°F) neoprene[a] and NBR/PVC[b] insulations and jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 121.0±1.0°C (249.8 ±1.8°F)	50 percent (1/2 inch or 12.5 mm)	900 lbf/in^2 6.21 MPa (MN/m^2) or 621 N/cm^2 or 0.633 kgf/mm^2
60°C (140°F) oil-resistant insulation or jacket: Aged in oil for 18 h at 121.0 ±1.0°C (249.8±1.8°F)	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 41 neoprene designates a thermoset compound whose characteristic constituent is polychloroprene.

[b] Class 41 NBR/PVC designates a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Table 50.133
Physical properties of 75°C (167°F) LDFRPE[a] and HDFRPE[b] jackets from CATV cables and insulations from power-limited circuit cable and cable for power-limited fire-alarm circuits

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[c]	Minimum tensile strength[c]
Unaged	100 percent (1 inch or 25 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2
Aged in a full-draft circulating-air oven for 48 h at 100.0 ±1.0°C (212.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] LDFRPE designates a compound whose characteristic constituent is thermoplastic polyethylene, with the base resin (uncolored material) having a nominal density in the range of 0.910 – 0.925 g/m^3 (resin identified as Type I in ASTM D 1248-00) and a high molecular weight.

[b] HDFRPE designates high-density polyethylene, a compound whose characteristic constituent is thermoplastic polyethylene, with a base resin (uncolored material) having a nominal density in the range of 0.941 – 0.959 g/cm^3 (resin identified as Type III in ASTM D 1248-00) and a high molecular weight.

[c] FRPE is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min, and specimens are to be prepared after aging.

Table 50.135
Physical properties of 75°C (167°F) thermoplastic HDPE[a] insulation from single-conductor Type USE cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	300 percent (3 inches or 75 mm)	2000 lbf/in^2 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	60 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] HDPE designates a high-density-polyethylene compound whose characteristic constituent is thermoplastic polyethylene, with the base resin (uncolored, unfilled material) having a nominal density in the range 0.941– 0.959 g/cm^3 (resin identified as Type III in ASTM D 1248-00) and a high molecular weight.

[b] HDPE is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min. Specimens are to be prepared after aging.

Table 50.136
Physical properties of 75°C (167°F) LDPE[a] insulation from power-limited circuit cable, from cable for power-limited fire-alarm circuit cables, and from applications specifying Class 30 insulation; and physical properties of 75°C (167°F) HDPE[b] insulation from power-limited circuit cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[c]	Minimum tensile strength[c]
Unaged solid LDPE insulation	LDPE tube from air-gap coaxial member: 300 percent (3 inches or 75 mm) All other solid LDPE insulation: 350 percent (3-1/2 inches or 87.5 mm)	All solid LPDE insulation: 1400 lbf/in^2 or 9.65 MPa (MN/m^2) or 965 N/cm^2 or 0.984 kgf/mm^2
Unaged solid HDPE insulation	300 percent (3 inches or 75 mm)	2400 lbf/in^2 or 16.5 MPa (MN/m^2) or 1665 N/cm^2 or 1.69 kgf/mm^2
All solid LDPE and HDPE insulation: Aged in a full-draft circulating-air over for 48 h at 100.0 ±1.0°C (212.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] LDPE designates a compound whose characteristic constituent is thermoplastic polyethylene, with the base resin (uncolored, unfilled material) having a nominal density in the range of 0.910 – 0.925 g/m^3 (resin identified as Type I in ASTM D 1248-00) and a high molecular weight.

[b] HDPE designates a high-density-polyethylene compound whose characteristic constituent is thermoplastic polyethylene, with the base resin (uncolored, unfilled material) having a nominal density in the range of 0.941 – 0.959 g/cm^3 (resin identified as Type III in ASTM D 1248-00) and a high molecular weight.

[c] PE with a density of 0.93 g/cm^3 (930 kg/m^3) or higher is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min and specimens are to be prepared after aging. PE with a density lower than 0.93 g/cm^3 (930 kg/m^3) is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min. A quick, rough check of whether the density of a given piece of unfilled PE is below 0.93 g/cm^3 (930 kg/m^3) is to immerse the insulation in olive, cottonseed, or coconut oil while the oil and PE are at room temperature (25°C or 77°F maximum). Unfilled material with a density lower than 0.93 g/cm^3 (930 kg/m^3) rises to the surface and floats within a minute or so.

Table 50.137
Physical properties of PFA[a] jacket from CATV cables, PFA[a] insulation from Type PFA and PFAH wires, and PFA[a] insulation or jacket from other wires and cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	200 percent (2 inches or 50 mm)	2500 lbf/in^2 or 17.2 MPa (MN/m^2) 1724 N/cm^2 or 1.76 kgf/mm^2
200°C insulation from Type PFA wire and insulation or jacket from CATV cables and other wires and cables		
Aged in a full-draft circulating-air oven for 96 h at 260.0 ±1.0°C (500.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
250°C insulation from Type PFAH wire and other wires and cables		
Aged in a full-draft circulating-air oven for 168 h at 287.0 ±1.0°C (548.6 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens

[a] PFA designates a thermoplastic material whose characteristic constituent is the fluoropolymer resin perfluoralkoxy. The material is uncompounded PFA to which it is appropriate to add a small amount of pigment, lubricant, or both.

[b] PFA is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.139
Physical properties of 75°C (167°F) and 60°C (140°F) PP[a] (polypropylene) insulation from power-limited circuit cable and from cable for power-limited fire-alarm circuits; and 75°C (167°F) PP[a] jacket from CATV cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	150 percent (1-1/2 inches or 38 mm)	3000 lbf/in^2 or 20.7 MPa (MN/m^2) or 2068 N/cm^2 or 2.11 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h (75°C or 167°F insulation) or for 168 h (60°C or 140°F insulation) at 100.0 ±1.0°C (212.0 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] PP designates a thermoplastic compound whose characteristic constituent is polypropylene, the crystalline copolymer of ethylene and propylene.

[b] PP is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min.

Table 50.140
Physical properties of PVC[a] insulation from Type TW wire

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	Die-cut specimens: 65 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens

[a] PVC is described in note [a] to Table 50.155.

Table 50.142
Physical properties of PVC[a] insulations and jackets from medium- and low-power broadband cables rated for 105, 90, 75, and 60°C

Condition of specimens at time of measurement	Minimum ultimate elongation (1–inch or 25–mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
105°C (221°F) insulations and jackets:	Die-cut and other specimens:	Die-cut and other specimens:
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
90°C (194°F) insulations and jackets:	Die-cut and other speciments:	Die-cut and other specimens:
Aged in a full-draft circulating air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
75°C (167°F) insulations and jackets:	Die-cut and other specimens:	Die-cut and other specimens:
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) insulations and jackets:	Die-cut and other specimens:	Die-cut and other specimens:
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	75 percent of the result with unaged specimens

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Table 50.142 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1–inch or 25–mm bench marks)	Minimum tensile strength
[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.		

Table 50.144
Physical properties of insulation of thermoplastic other than PVC from Type THWN-2, THHN, and THWN wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength
Unaged	Values as established for the particular commercial or proprietary compound used		
Insulation from conductors of ACTHH, NM-B, and NMC-B cables and Type THHN and THWN-2 wires (nylon removed before aging):	Die-cut specimens:	Other specimens:	All specimens:
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	45 percent of the result with unaged specimens	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens
Insulation from Type THWN wire (nylon removed before aging):	Die-cut specimens:	Other specimens:	All specimens:
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	45 percent of the result with unaged specimens	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens

Table 50.145
Physical properties of PVC[a] insulation from Type THW and THWN wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength
	Type THWN	Type THW[b]	Types THWN and THW[b]
Unaged	150 percent (1-1/2 inches or 38 mm)	150 percent (1-1/2 inches or 38 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens	Die-cut specimens: 35 percent of the result with unaged specimens	All specimens: 75 percent of the result with unaged specimens
	Other specimens: 65 percent of the result with unaged specimens	Other specimens: 50 percent of the result with unaged specimens	
[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.			

Table 50.145 Continued on Next Page

Table 50.145 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength
	Type THWN	Type THW[b]	Types THWN and THW[b]

[b] For Type THW wire in which the PVC insulation is in two layers:

1) For the 14 – 7 AWG sizes, tubular specimens are to be tested as a whole.

2) For the 6 AWG and larger sizes, die-cut specimens prepared from each layer are to be tested separately. In each case, the layer not being tested is to be buffed away or otherwise removed before die-cut specimens are prepared for the layer being tested.

Table 50.150
Physical properties of PVC[a] insulation from gasoline- and oil-resistant Type TFN, TFFN, THWN-2, and THWN wires

Table 50.150 revised October 31, 2001

Condition of PVC specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged (nylon removed)	150 percent (1-1/2 inches or 38 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Conditioned by immersion in water-saturated ASTM Reference Fuel C for 30 d at 23.0 ±1.0°C (73.4 ±1.8°F) with nylon intact during immersion and removed prior to testing	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Table 50.155
Physical properties of PVC[a] insulation from Type THW-2[b], THWN-2, THHW, and THHN wires and of Class 12B 90°C (194°F) PVC[a] insulation from Type TFN and TFFN fixture wires

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength
	Types THHN, TFN, TFFN, and THWN-2	Types THW-2[b] and THHW	Types THWN-2, THW-2[b], THHW, THHN, TFN, and TFFN
Unaged	150 percent (1-1/2 inches or 37.5 mm)		2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F) with nylon jacket removed before aging	Die-cut specimens:	Die-cut specimens:	All specimens:

Table 50.155 Continued on Next Page

Table 50.155 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)		Minimum tensile strength
	Types THHN, TFN, TFFN, and THWN-2	Types THW-2[b] and THHW	Types THWN-2, THW-2[b], THHW, THHN, TFN, and TFFN
	45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	35 percent of the result with unaged specimens Other specimens: 50 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

[b] For Type THW-2 wire in which the PVC insulation is in two layers:

1) For the 14 – 7 AWG sizes, tubular specimens are to be tested as a whole.

2) For the 6 AWG and larger sizes, die-cut specimens prepared from each layer are to be tested separately. In each case, the layer not being tested is to be buffed away or otherwise removed before die-cut specimens are prepared for the layer being tested.

Table 50.156
Physical properties of oil-resistant Class 12B 90°C (194°F) PVC[a] insulation

Oil-resistant rating of wire	Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
75°C (167°F)	Aged in oil for 60 d at 75.0 ±1.0°C (167.0 ±1.8°F)	65 percent of the result with unaged specimens	
60°C (140°F)	Aged in oil for 96 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	

[a] PVC is described in note [a] to Table 50.155.

Table 50.160
Physical properties of PVC insulation from Type TBS wire

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F) with all materials over the thermoplastic insulation removed before aging	Die-cut specimens: 45 percent of result with unaged specimens	Die-cut specimens: 70 percent of the result with unaged specimens
	Other specimens: 65 percent of result with unaged specimens	Other specimens: 70 percent of the result with unaged specimens

[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Table 50.165
Physical properties of Class 11 60°C (140°F) PVC[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1600 lbf/in^2 or 11.0 MPa (MN/m^2) or 1103 N/cm^2 or 1.12 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 60 days at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 11 PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Table 50.166
Physical properties of Class 11 60°C (140°F) PVC[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1600 lbf/in^2 or 11.0 MPa (MN/m^2) or 1103 N/cm^2 or 1.12 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 100.0 ±1.0°C (212.0 ±1.8°F)	60 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 11 PVC is described in note [a] to Table 50.165.

Table 50.167
Physical properties of Class 11 60°C (140°F) PVC[a] jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	225 percent (2-1/4 inches or 56.3 mm)	1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 100.0 ±1.0°C (212.0 ±1.8°F)	60 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 11 PVC is described in note [a] to Table 50.165.

Table 50.169
Physical properties of Class 11 60°C (140°F) PVC[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1600 lbf/in^2 or 11.0 MPa (MN/m^2) or 1103 N/cm^2 or 1.12 kgf/mm^2
Aged in a full-draft circulating-air oven at 100.0±1.0°C (212.0 ±1.8°F)	Die-cut specimens of insulation: 45 percent of the result with unaged specimens Other specimens: 60 percent of the result with unaged specimens	Die-cut specimens: 85 percent of the result with unaged specimens Other specimens: 85 percent of the result with unaged specimens

[a] Class 11 PVC is described in note [a] to Table 50.165.

Table 50.172
Physical properties of Class 11 60°C (140°F) PVC[a] jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1600 lbf/in^2 or 11.0 MPa (MN/m^2) or 1103 N/cm^2 or 1.12 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 100.0 ±1.0°C (212.0 ±1.8°F)	45 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket: Aged in for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 11 PVC is described in note [a] to Table 50.165.

Table 50.175
Physical properties of PVC[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	Die-cut Specimens: 65 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens

[a] PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Table 50.179
Physical properties of Class 12 75°C (167°F) PVC[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged for 240 h in a full-draft circulating-air oven at 100.0 ±1.0°C (212.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	Die-cut specimens: 70 percent of the result with unaged specimens Other specimens: 70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket: Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation: Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 60 d at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 12 PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Table 50.180
Physical properties of Class 12 90°C (194°F) PVC[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 121.0 ±1.0°C (249.8 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	Die-cut specimens: 70 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
60°C (140°F) oil-resistant insulation:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 60 d at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 12 PVC is described in note [a] to Table 50.179.

Table 50.181
Physical properties of Class 12 105°C (221°F) PVC[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged for 168 h in a full-draft circulating-air oven at 136.0 ±1.0°C (276.8 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	Die-cut specimens: 70 percent of the result with unaged specimens Other specimens: 70 percent of the result with unaged specimens
60°C (140°F) oil-resistant jacket:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

Table 50.181 Continued on Next Page

Table 50.181 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
60°C (140°F) oil-resistant insulation:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Aged in oil for 60 d at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
[a] Class 12 PVC is described in note [a] to Table 50.179.		

Table 50.182
Physical properties of 60°C (140°F), 75°C (167°F), 90°C (194°F), and 105°C (221°F) PVC[a] jackets from CATV cables, and insulations and jackets from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or from other cables and from applications specifying a Class 43 insulation or jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for the specified time at the specified temperature[b]	Die-cut specimens:	Die-cut specimens:
	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens
	Other specimens:	Other specimens:
	65 percent of the result with unaged specimens	70 percent of the result with unaged specimens
60°C (140°F) oil-resistant Class 43 jacket:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
60°C (140°F) oil-resistant Class 43 insulation:		
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens
60°C (140°F) oil-resistant uses other than in flexible cords and elevator cables:		
Aged in oil for 60 d at 60.0 ±1.0°C (140 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

Table 50.182 Continued on Next Page

Table 50.182 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength

[a] Class 43 PVC designates a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

[b] The oven time and temperature are to be as follows:

Temperature rating of insulation	Specified oven time and temperature h	°C (°F)
60°C (140°F)	168	100.0 ±1.0°C (212.0±1.8°F)
75°C (167°F)	240	100.0 ±1.0°C (212.0 ±1.8°F)
90°C (194°F)	168	121.0 ±1.0°C (249.8 ±1.8°F)
105°C (221°F)	168	136.0 ±1.0°C (276.8±1.8°F)

Table 50.183
Physical properties of 105°C (221°F), 90°C (194°F), 75°C (167°F), and 60°C (140°F) semirigid PVC[a] insulations and 75°C (167°F) and 60°C (140°F) jackets from CATV cables, from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	100 percent (1 inch or 25 mm)	3000 lbf/in^2 or 20.7 MPa (MN/m^2) or 2068 N/cm^2 or 2.11 kgf/mm^2
Aged in a full-draft circulating-air oven for the specified time[c] at the specified temperature[c]	70 percent of the result with unaged specimens[d]	70 percent of the result with unaged specimens[d]

[a] Semirigid PVC (SRPVC) designates a partially plasticized thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

[b] Semirigid PVC is to be tested at a speed of 2.0 ±0.2 in/min or 50 ±5 mm/min.

[c] The oven time and temperature are to be as follows:

Temperature rating of insulation or jacket	Specified oven time and temperature h	°C (°F)
105°C (221°F)	168	136.0 ±1.0°C (276.8±1.8°F)
90°C (194°F)	168	121.0 ±1.0°C (249.8 ±1.8°F)
75°C (167°F)	168	113.0 ±1.0°C (235.4 ±1.8°F)
60°C (140°F)	168	100.0 ±1.0°C (212.0 ±1.8°F)

[d] As an alternative to testing for retention of tensile strength and elongation, it is appropriate to wind aged specimens of the 60°C (140°F) insulation in place on the conductor onto a mandrel as described under ″Flexibility″ in the applicable wire Standard. Unaged specimens are to be tested for tensile strength and elongation. Where aged specimens that are tested for retention of tensile strength and elongation show results that do not comply, it is appropriate to use the flexibility procedure described under ″Flexibility″ as a referee test.

Table 50.185
Physical properties of 150°C (302°F) and 125°C (257°F) PVDF[a] and PVDF copolymer[b] jackets from CATV cables; and insulations and jackets from power-limited circuit cable and from cable for power-limited fire-alarm circuits

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[c]	Minimum tensile strength[c]
Unaged	100 percent (1 inch or 25 mm)	3500 lbf/in^2 or 24.1 MPa (MN/m^2) or 2413 N/cm^2 or 2.46 kgf/mm^2
Specimens of 150°C (302°F) material:		
Aged in a full-draft circulating-air oven for 60 d at 158.0 ±1.0°C (316.4 ±1.8°F)	50 percent of the result with unaged specimens	50 percent of the result with unaged specimens
Specimens of 125°C (257°F) material:		
Aged in a full-draft circulating-air oven for 168 h at 158.0 ±1.0°C (316.4 ±1.8°F)	See note[d]	See note[d]
or		
as an option for PVDF copolymer only: aged in a full-draft circulating-air oven for 30 d at 136.0 ±1.0°C (276.8 ±1.8°F)	See note[d]	See note[d]

[a] PVDF designates a thermoplastic compound whose characteristic constituent is the homopolymer resin polyvinylidene fluoride. The material is uncompounded PVDF to which it is appropriate to add a small amount of pigment, lubricant, or both.

[b] PVDF copolymer designates a thermoplastic material whose characteristic constituent is a copolymer of polyvinylidene fluoride and hexafluoropropylene. The material is the uncompounded polymer to which it is appropriate to add a small amount of pigment, lubricant, or both.

[c] PVDF and PVDF copolymer are to be tested at a speed of 2.0±0.2 in/min or 50 ±5 mm/min.

[d] Aged specimens of the jacket, of the foamed insulation in place on the conductor, or the solid insulation in place on the conductor are to be wound onto a mandrel as described under ″Flexibility″ in the applicable wire Standard. Unaged specimens of the jacket and of the solid insulation are to be tested for tensile strength and elongation. Jacket damage after aging caused by outgassing of lower-temperature insulated conductors within the cable does not constitute noncomplying performance.

Table 50.189
Physical properties of SBR/IIR/NR[a] insulation from Type RH, RHW-2, RHW, and RHH wires

Condition of specimens at time of measurement	Maximum set for 75°C (167°F) compounds – inapplicable for 90°C (194°F) compounds (1-inch or 25-mm bench marks stretched to 2-1/2 inches or 62.5 mm)	Maximum set for 90°C (194°F) compounds – inapplicable for 75°C (167°F) compounds (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	25 percent (1/4 inch or 6.2 mm)	300 percent (3 inches or 75 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2
75°C (167°F) compounds aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	–	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens
90°C (194°F) compounds aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	–	Not measured	60 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] SBR/IIR/NR designates a thermoset compound whose characteristic constituent is SBR, IIR (butyl rubber), blends of SBR and IIR, or blends of SBR and/or IIR with NR (natural rubber). These thermosets are for use where subjected to 75°C (167°F) and lower temperatures as insulation on NBR/PVC-, CP-, or neoprene-jacketed or fibrous-covered Type RHW and RH wires and where subjected to 90°C (194°F) and lower temperatures as insulation on CP- or neoprene-jacketed or fibrous-covered Type RHW-2 and RHH wires.

Table 50.193
Physical properties of Class 2 60°C (140°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 2-1/2 inches or 62.5 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength (test not required for insulation less than 30 mils or 0.76 mm thick)
Unaged	25 percent (1/4 inch or 6.2 mm)	200 percent (3 inches or 75 mm)	500 lbf/in^2 or 3.45 MPa (MN/m^2) or 345 N/cm^2 or 0.352 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Class 2 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.194
Physical properties of Class 3 60°C (140°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 2-1/2 inches or 62.5 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength (test not required for insulation less than 30 mils or 0.76 mm thick)
Unaged	25 percent (1/4 inch or 6.2 mm)	250 percent (2-1/2 inches or 62.5 mm)	600 lbf/in^2 or 4.14 MPa (MN/m^2) or 414 N/cm^2 or 0.422 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens where the sum of tensile plus elongation percentages is at least 140 percent. Otherwise, 70 percent of the result with unaged specimens.	

[a] Class 3 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.195
Physical properties of Class 4 60°C (140°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	350 percent (3-1/2 inches or 87.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens where the sum of tensile plus elongation percentages is at least 140 percent. Otherwise, 70 percent of the result with unaged specimens.	

[a] Class 4 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.196
Physical properties of Class 6 60°C (140°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 3 inches or 75 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	Jackets from 8 AWG and larger Type S cords: 1800 lbf/in^2 or 12.4 MPa (MN/m^2) or 1240 N/cm^2 or 1.27 kgf/mm^2 Other jackets: 1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	Not measured	65 percent of the result with unaged specimens where the sum of tensile plus elongation percentages is at least 140 percent. Otherwise, 70 percent of the result with unaged specimens.	

[a] Class 6 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.197
Physical properties of Class 7 75°C (167°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	300 percent (3 inches or 75 mm)	700 lbf/in^2 or 4.83 MPa (MN/m^2) or 483 N/cm^2 or 0.492 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 7 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.198
Physical properties of Class 8 75°C (167°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 2-1/2 inches or 62.5 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	25 percent (1/4 inch or 6.2 mm)	250 percent (2-1/2 inches or 62.5 mm)	600 lbf/in^2 or 4.14 MPa (MN/m^2) or 414 N/cm^2 or 0.422 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 8 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.199
Physical properties of Class 10 75°C (167°F) SBR/NR[a] jacket

Condition of specimens at time of measurement	Maximum set in recovery test (1-inch or 25-mm bench marks stretched to 2-1/2 inches or 62.5 mm)	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	19 percent (3/16 inch or 4.8 mm)	300 percent (3 inches or 75 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Not measured	50 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 10 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.200
Physical properties of Class 40 60°C (140°F) SBR/NR[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength (test not required for insulation less than 30 mils or 0.76 mm thick)
Unaged	200 percent (2 inches or 50 mm)	500 lbf/in^2 or 3.45 MPa (MN/m^2) or 345 N/cm^2 or 0.352 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 70.0 ±1.0°C (158.0 ±1.8°F)	65 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Class 40 SBR/NR designates a thermoset compound whose characteristic constituent is SBR, NR (natural rubber), or a blend of the two.

Table 50.205
Physical properties 200°C (392°F) silicone rubber[a] insulation from Type SA wire

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0,562 kgf/mm^2
Aged in a full-draft circulating-air oven for 60 d at 210.0 ±1.0°C (410.0 ±1.8°F)	25 percent of the result with unaged specimens	60 percent of the result with unaged specimens

[a] Silicone rubber designates a thermoset compound whose characteristic constituent is poly-organo-siloxane.

Table 50.206
Physical properties of silicone rubber[a] insulation from Type RHH wire

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0.562 kgf/mm^2
Aged in a full-draft circulating-air oven for 60 d at 136.0 ±1.0°C (276.8 ±1.8°F)	65 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] Silicone rubber designates a thermoset compound whose characteristic constituent is poly-organo-siloxane.

Table 50.210
Physical properties 200°C (392°F) and 150°C (302°F) silicone rubber[a] jackets from CATV cables and insulations from power-limited circuit cable, from cable for power-limited fire-alarm circuits, from other cables, and from applications specifying Class 22 insulation

Temperature rating of insulation	Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
150°C (302°F) or 200°C (392°F)	Unaged	100 percent (1 inch or 25 mm)	500 lbf/in^2 or 3.45 MPa (MN/m^2) or 345 N/cm^2 or 0.352 kgf/mm^2
150°C (302°F)	Aged in a full-draft circulating-air oven for 60 d at 158.0 ±1.0°C (316.4 ±1.8°F)	50 percent (1/2 inch or 12.5) or 25 percent of the result with unaged specimens	500 lbf/in^2 or 3.45 MPa (MN/m^2) or 345 N/cm^2 or 0.352 kgf/mm^2 or 60 percent of the result with unaged specimens
200°C (392°F)	Aged in a full-draft circulating-air oven for 60 d at 210.0 ±1.0°C (410.0 ±1.8°F)	50 percent (1/2 inch or 12.5 mm) or 25 percent of the result with unaged specimens	500 lbf/in^2 or 3.45 MPa (MN/m^2) or 345 N/cm^2 or 0.352 kgf/mm^2 or 60 percent of the result with unaged specimens

[a] Silicone rubber designates a thermoset compound whose characteristic constituent is poly-organo-siloxane.

Table 50.219
Physical properties of 250°C (482°F) PTFE[a] (TFE[a]) jacket from CATV cables and insulations from power-limited circuit cable, from cable for power-limited fire-alarm circuits, from other cables, and from Type PTF, PTFF, and TFE wires; and of Class 12C PTFE[a] insulation

Table 50.219 revised October 31, 2001

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	175 percent (1-3/4 inches or 43.8 mm)	4000 lbf/in^2 or 27.6 MPa (MN/m^2) or 2758 N/cm^2 or 2.81 kgf/mm^2
Aged in a full-draft circulating-air oven for 60 d at 260.0 ±1.0°C (500.0 ±1.8°F)	85 percent of the result with unaged specimens	85 percent of the result with unaged specimens

[a] PTFE (TFE) designates a thermoplastic material whose characteristic constituent is either the homopolymer tetrafluoroethylene (TFE) or a copolymer of TFE with no more than 1 percent by weight of another fluoropolymer. The material is uncompounded PTFE (TFE) to which a small amount of pigment, lubricant, or both is or is not added.

[b] PTFE (TFE) is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.223
Physical properties of 105°C (221°F) TPE[a] jacket from CATV cables; insulations and jackets from power-limited circuit cable, from cable for power-limited fire-alarm circuits; and of 105°C (221°F) Class 36 TPE[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength		Maximum deformation (see Section 560 for method, see Table 57.1 of UL 62 for specimen loading)
		Insulation	Jacket	
Unaged	200 percent (2 inches or 50 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0.562 kgf/mm^2	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2	–
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	–
60°C (140°F) oil-resistant jacket or insulation:				–
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	
Heated in an oven at 150.0 ±1.0°C (302.0 ±1.8°F)	–	–	–	50 percent

[a] Class 36 TPE designates an extensible compound whose characteristic constituent is a thermoplastic elastomer.

Table 50.224
Physical properties of 90°C (194°F) TPE[a] jacket form CATV cables; insulations and jackets from power-limited circuit cable, from cable for power-limited fire-alarm circuits; and from other cables; and of 90°C (194°F) Class 36 TPE[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength		Maximum deformation (see Section 560 for method, see Table 57.1 of UL 62 for specimen loading)
		Insulation	Jacket	
Unaged	200 percent (2 inches or 50 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0.562 kgf/mm^2	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2	–

Table 50.224 Continued on Next Page

Table 50.224 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength		Maximum deformation (see Section 560 for method, see Table 57.1 of UL 62 for specimen loading)
		Insulation	Jacket	
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	–
60°C (140°F) oil-resistant jacket or insulation:				–
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	
Heated in an oven at 150.0 ±1.0°C (302.0 ±1.8°F)	–	–	–	50 percent

[a] Class 36 TPE designates an extensible compound whose characteristic constituent is a thermoplastic elastomer.

Table 50.228
Physical properties of 90°C (194°F) XL[a] jacket from Type USE-2 and USE cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.229
Physical properties of 75°C (167°F) XL[a] jacket from Type USE cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.230
Physical properties of XL[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.231
Physical properties of 90°C (194°F) and 75°C (167°F) XL[a] jackets from CATV cables and insulations and jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables; and XL[a] insulation from Type RFHH-2, RFHH-3, XHHW-2, XHHW, XHH, RHW-2, RHH, RHW, and SIS wires

Table 50.231 revised October 31, 2001

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h:		

Table 50.231 Continued on Next Page

Table 50.231 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
At 121.0 ±1.0°C (249.8 ±1.8°F) for specimens of 90°C (194°F) insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or of 90°C (194°F) insulation from Type XHHW-2, XHHW, XHH, RHW-2, RHH, and SIS wires	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
At 113.0 ±1.0°C (235.4 ±1.8°F) for specimens of 75°C (167°F) insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or of 75°C (167°F) insulation from Type RHW wire	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross-linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof, with the cross-linking achieved either chemically or by irradiation. XL rated 90°C (194°F) is for use as conductor insulation on Type XHHW-2, XHHW, XHH, RHW-2, RHH, and SIS wires without any covering over the insulation. XL rated 75°C (167°F) is for use as conductor insulation on Type RHW wire without any covering over the insulation.

Table 50.232
Physical properties of Class 38 150°C (302°F) XLPO[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	300 percent (3 inches or 75 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 180.0 ±1.0°C (356.0 ±1.8°F)	80 percent of the result with unaged specimens	80 percent of the result with unaged specimens

[a] XL designates a thermoset polyolefin compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLEVA (cross-linked ethylene vinyl acetate), or a blend of the two. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.233
Physical properties of 105°C (221°F) XLPO[a] insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength[b]
Unaged	150 percent (1-1/2 inches or 37.5 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	70 percent of the result with unaged specimens	85 percent of the result with unaged specimens

[a] XLPO designates a thermoset polyolefin compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLEVA (cross-linked ethylene vinyl acetate), or a blend of the two. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

[b] XLPO is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.237
Physical properties of Class 29 90°C (194°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 29 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

Table 50.241
Physical properties of Class 31 75°C (167°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 31 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

Table 50.245
Physical properties of Class 33 105°C (221°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 33 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

51 – 199 *Reserved for Future Use*

METHODS

CONDUCTOR DIMENSIONS AND RESISTANCE

200 Conductor Diameter

200.1 Regardless of whether any tin or other metal coating is employed, measurements of the diameter of a solid conductor are to be made over such coating by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.001 mm. The maximum and minimum diameters at a given point on the conductor are each to be recorded to the nearest 0.0001 inch or 0.001 mm, added together, and divided by 2 without any rounding of the sum or resulting average.

200.2 Each minimum and maximum diameter in Tables 20.1, 20.2, 20.3, 20.3.1, 20.4, and 20.6 is an absolute minimum or maximum. For the purpose of determining whether the conductor does or does not comply with the diameter requirement(s), the unrounded average of the two micrometer readings is to be compared directly with whichever of the following applies:

a) Both the 0.98 x nominal minimum and the 1.01 x nominal maximum where the wire standard specifies these diameter limits for the solid or stranded conductor.

b) The 0.99 x nominal minimum in Table 20.1 where the wire standard specifies only a minimum diameter for a solid conductor.

201 – 209 *Reserved for Future Use*

210 Conductor Cross-Sectional Area by the Weight Method

210.1 For determining the cross-sectional area of a stranded conductor by the weight method, the test specimen is to consist of a straight length of a single conductor cut from a sample of the finished wire, cable, or cord. The specimen is to be at any convenient room temperature, is to have both of its ends perpendicular to the longitudinal axis of the conductor, and is to have any insulation, separator, and other coverings removed. For an 8 AWG or smaller conductor (8.367 mm^2 or smaller), the specimen is to be at least 48 inches or 1220 mm long. For a conductor larger than 8 AWG (larger than 8.367 mm^2), the specimen is to be at least 24 inches or 610 mm long. The length of the specimen is to be measured to the nearest 1/32 inch or 1 mm. The specimen is to be weighed by means of a precision balance to within 0.1 percent of the weight of the specimen. For example, a 4-ft or 1220-mm specimen of a 12 AWG aluminum conductor having seven round strands (Class B) weighs about 0.02 lb or 11 g. One tenth of 1 percent of these figures is, respectively, 0.00002 lb and 0.009 g, which means that the weight of a 12 AWG aluminum conductor must be determined to the fifth decimal place when in pounds and to the nearest 10 mg when in grams.

210.2 The conductor cross-sectional area in circular mils is to be calculated by whichever of the following formulas applies to the conductor material (as a convenience for the strandings that are common in wiring, it is appropriate to compare the specimen weight directly with the weight in Table 210.1 instead of calculating the cross-sectional area):

For a copper conductor that has each of its strands uncoated or coated with tin or a tin/lead alloy –

$$A_{cmil} = \frac{33.036 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

For a copper-clad aluminum conductor –

$$A_{cmil} = \frac{88.417 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

For an aluminum conductor –

$$A_{cmil} = \frac{108.654 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

in which:

A_{cmil} is the cross-sectional area in circular mils,

W_{lb} is the weight of the specimen in pounds (see the last sentence of this paragraph),

L_{ft} is the length of the specimen in feet, and

k is the percentage increase in weight applicable to the type of stranding used from Table 210.2.

For a copper conductor that has each of its strands coated with nickel or silver or another metal other than tin or a tin/lead alloy and for a conductor of a copper-base alloy or a nickel-base alloy –

$$A_{cmil} = \frac{100{,}000 \times W_{lb}}{(100 + k) \times L_{ft} \times f}$$

in which:

A_{cmil}, W_{lb}, k, and L_{ft} are as noted above and

f is the weight factor in lb·cmil/1000 ft applicable to the alloy used or to the thickness and the metal of the coating used.

It is appropriate to weigh a specimen in grams W_g instead of pounds, in which case,

$W_g/453.5924$ is to be substituted for W_{lb} in the formula.

210.3 The conductor cross-sectional area in square millimeters is to be calculated by whichever of the following formulas applies to the conductor material (as a convenience for the strandings that are common in wiring, it is appropriate to compare the specimen weight directly with the weight in Table 210.1 instead of calculating the cross-sectional area):

For a copper conductor that has each of its strands uncoated or coated with tin or a tin/lead alloy –

$$A_{mm^2} = \frac{11248 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

For a copper-clad aluminum conductor –

$$A_{mm^2} = \frac{30105 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

For an aluminum conductor –

$$A_{mm^2} = \frac{36996 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

in which:

$A_{mm}2$ is the cross-sectional area in square millimeters,

W_g is the weight of the specimen in grams,

L_{mm} is the length of the specimen in millimeters, and

k is the percentage increase in weight applicable to the type of stranding used from Table 210.2.

For a copper conductor that has each of its strands coated with nickel or silver or another metal other than tin or a tin/lead alloy and for a conductor of a copper-base alloy or a nickel-base alloy –

$$A_{mm^2} = \frac{45.154222 \times W_g}{(100 + k) \times L_{mm} \times f}$$

in which:

$A_{mm}2$, W_g, k, and L_{mm} are as noted above and

f is the weight factor in (kg·mm^2)/km applicable to the alloy used or to the thickness and the metal of the coating used.

Table 210.1
Minimum weight of specimens of stranded conductors for which k is 2[a,b]

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g
48 inches or 1220 mm	14 AWG	0.04975	22.57	0.01859	8.43	0.01513	6.86
	13	0.06269	28.44	0.02342	10.62	0.01906	8.64
	12	0.07903	35.85	0.02952	13.39	0.02403[c]	10.90[c]
	11	0.09960	45.18	0.03721	16.88	0.03028[c]	13.74[c]
	10	0.1256	56.97	0.04693	21.29	0.03820[c]	17.33[c]
	9	0.1584	71.85	0.05920	26.85	0.04817[c]	21.85[c]
	8	0.1998	90.63	0.07465	33.86	0.06076[c]	27.56[c]
24 inches or 610 mm	7 AWG	0.1260	57.15	0.04707	21.35	0.03832[c]	17.78[c]
	6	0.1588	72.03	0.05932	26.91	0.04829[c]	21.90[c]
	5	0.2002	90.81	0.07481	33.93	0.06090[c]	27.62[c]
	4	0.2526	114.6	0.09437	42.81	0.07682[c]	34.85[c]
	3	0.3184	144.4	0.1190	53.98	0.09684[c]	43.93[c]
	2	0.4016[d]	182.2[d]	0.1500	68.04	0.1221[c]	55.38[c]
	1	0.5064[d]	229.7[d]	0.1892	85.82	0.1540[c]	69.85[c]
	1/0	0.6390[d]	289.8[d]	0.2387	108.3	0.1944[c]	88.18[c]
	2/0	0.8055[d]	365.4[d]	0.3009	136.5	0.2450[c]	111.1[c]
	3/0	1.015[d]	460.4[d]	0.3794	172.1	0.3088[c]	140.1[c]
	4/0	1.280[d]	580.6[d]	0.4784	217.0	0.3894[c]	176.6[c]

Table 210.1 Continued on Next Page

Table 210.1 Continued

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/ lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g
24 inches or 610 mm	250 kcmil	1.513	686.3	0.5652	256.4	0.4601[c]	208.7[c]
	300	1.815	823.3	0.6783	307.7	0.5521[c]	250.4[c]
	350	2.118	960.7	0.7913	358.9	0.6442[c]	292.2[c]
	400 kcmil	2.421	1098	0.9043	410.2	0.7362[c]	333.9[c]
	450	2.723	1235	1.017	461.3	0.8282[c]	375.7[c]
	500	3.026	1373	1.130	512.6	0.9202[c]	417.4[c]
	550	3.328	1510	1.243	563.8	1.012[c]	459.0[c]
	600	3.631	1647	1.357	615.5	1.104[c]	500.8[c]
	650	3.933	1784	1.470	666.8	1.196[c]	542.5[c]
	700	4.236	1921	1.583	718.0	1.288[c]	584.2[c]
	750	4.539	2059	1.696	769.3	1.380[c]	626.0[c]
	800	4.841	2196	1.809	820.5	1.472[c]	667.7[c]
	900	5.446	2470	2.035	923.1	1.656[c]	751.1[c]
	1000	6.052	2745	2.261	1026	1.840[c]	834.6[c]
	1100	6.657	3020	2.487	1128	2.024	918.1
	1200	7.262	3294	2.713	1231	2.209	1002
	1250	7.564	3431	2.826	1282	2.301	1044
	1300	7.867	3568	2.939	1333	2.393	1085
	1400	8.472	3843	3.165	1436	2.577	1169
	1500	9.077	4120	3.391	1538	2.761	1252
	1600	9.682	4392	3.617	1641	2.945	1336
	1700	0.29	4667	3.843	1743	3.129	1419
	1750	0.59	4804	3.957	1795	3.221	1461
	1800	0.89	4940	4.070	1846	3.313	1503
24 inches or	1900 kcmil	1.50	5216	4.296	1949	3.497	1586
610 mm	2000	2.10	5488	4.522	2051	3.681	1670

[a] k is 2 for many of the bunch-stranded (single bunch of round strands); concentric-lay (round strands) Classes B, C, and D; 19-wire combination round-lay unilay-stranded copper or aluminum; compact-stranded; and compressed-stranded conductor constructions produced. For these conductor constructions having a k other than 2 and for rope-lay constructions, the minimum cross-sectional area is to be calculated as described in 210.2 – 210.4.

Table 210.1 Continued on Next Page

Table 210.1 Continued

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g

[b] Weights for copper conductors with each strand coated with nickel or silver are not included because a different value of f (weight factor) applies to each conductor with a different thickness of nickel or silver coating. Where f is known for a particular coated conductor, the minimum cross-sectional area is to be calculated from the specimen weight and the applicable k using the last area formula either in 210.2 (circular mils) or in 210.3 (square millimeters).

[c] For a compact-stranded aluminum conductor, sizes are limited to No. 12 AWG – 1000 kcmil.

[d] For a compact-stranded copper conductor, sizes are limited to Nos. 2 – 4/0 AWG.

Table 210.2
Percentage increase (k) in weight for type of strands

Construction of Conductor	k
Bunch-stranded (single bunch of round strands)[a]	2[b]
Concentric-lay Classes B, C, and D (round strands)	2[b]
Compact- or compressed-stranded	2[b]
19-wire combination round-wire unilay-stranded copper or aluminum	2[b]
Rope-lay (constructed of concentric-lay members composed of round strands) Classes G and H:	
49 wires	3
133 wires	4
259 wires	4, 5
427 wires	5
more than 427 wires	6
Rope-lay (constructed of bunch-stranded members composed of round strands) Classes I, K, and M:	
7 ropes with each rope consisting of a single bunch	4
19, 37, or 61 ropes with each rope consisting of a single bunch	5
7 ropes with each rope constructed of 7 bunch-stranded members	6
19, 37, or 61 ropes with each rope constructed of 7 bunch-stranded members	7

[a] Includes the following single-bunch constructions included in ICEA requirements (not in ASTM B 172-01) under Classes I, K, and M:

AWG size	Number of strands in single bunch: Class I	Class K	Class M
14		41	104
13		52	
12		65	
11		83	
10	26	104	
9	33		

Table 210.2 Continued on Next Page

Table 210.2 Continued

Construction of Conductor		k
8	41	
7	52	
6	65	

[b] Values other than 2 percent are used. See 210.4 for the method of calculation.

210.4 It is appropriate, in any case, to calculate the percentage increase k in weight due to stranding by means of the formula

$$k = 100(M - 1)$$

in which:

the ratio increase (conductor lay factor) M is as indicated in one of the following items:

a) For a concentric component or conductor, $M = M_{conc}$

$$M_{conc} = \frac{1 + (p_2)x(m_2) + (p_3)x(m_3) + \ldots + (p_y)x(m_y)}{\text{total number of strands}}$$

in which:

y is the number of layers (including the central wire or central concentric component as the first layer),

p is the number of strands or concentric components in the layer, and

m is the ratio increase (layer lay factor) for the layer as determined from the formula

$$m = \sqrt{1 + \pi^2/n^2}$$

which, for n equal to or greater than 10, is

$$m = 1 + \pi^2/(2n^2) = 1 + \frac{4.9348}{n^2}$$

in which:

n is the lay ratio for the layer determined from

$$n = \frac{\text{length of lay of the strands or components in the layer}}{d}$$

in which:

d is the diameter of the helical path of one strand or component of the layer (pitch diameter) determined from whichever of the following formulas is applicable and convenient (all give the same result).

For round strands or components:

d = diameter under the layer + diameter of one strand or component

or

d = diameter over the layer – diameter of one strand or component

For strands or components of any shape, including round:

$$d = \frac{\text{diameter over the layer} + \text{diameter under the layer}}{2}$$

b) For a bunched component or single-bunch conductor, $M = M_{bunch}$

$$M_{bunch} = \sqrt{1 + \left[\frac{\pi (D - d)}{\sqrt{2}\ LEN}\right]^2}$$

in which:

D is the diameter over the bunched component or single-bunch conductor,

d is the diameter of one strand, and

LEN is the length of lay of the bunched component or of the strands in the single bunch.

c) For a rope-stranded conductor with 1 roping operation,

$$M = M_{single\ rope}$$

$$M_{single\ rope} = M_{unit} \times M_{conc}$$

or

$$M_{single\ rope} = M_{unit} \times M_{bunch}$$

in which:

M_{conc} or M_{bunch} is calculated for one concentric or bunched component as indicated in (a) or (b)

and

M_{unit} is calculated for the single-roped assembly in the same way as M_{conc} or M_{bunch} treating each concentric or bunched component as solid.

d) For a multiple rope-stranded conductor with 2 roping operations, $M = M_{double\ rope}$

$$M_{double\ rope} = M_{mult} \times M_{unit} \times M_{conc}$$

or

$$M_{double\ rope} = M_{mult} \times M_{unit} \times M_{bunch}$$

in which:

$M_{unit} \times M_{conc} \times M_{bunch}$ is calculated as indicated in (a), (b), or (c) for a single rope and

M_{mult} is calculated for the double-roped assembly in the same way as $M_{unit} \times M_{conc}$ or $M_{unit} \times M_{bunch}$ treating each single-rope component as solid.

e) The first formula in (a) expresses the effect of the individual wires based on the weight of each wire. While the wires are identical in (a), six of them are smaller (0.732 x D) in a 19-wire combination round-wire unilay-stranded conductor, which modifies the formula to the following. It is to be understood that this variety of unilay conductor consists of a straight central wire of diameter D, an inner layer of six wires of diameter D with each wire having a length of lay designated as LOL, and an outer layer consisting of six wires of diameter D alternated with six smaller wires having a diameter of 0.732 x D and with all twelve wires of the outer layer having the same length of lay LOL and direction of lay as the six wires of the inner layer.

$$M_{combo.\ unilay} = \frac{1 + 6m_2 + 6m_3 + (6 \times 0.732^2) \times m_4}{1 + 6 + 6 + (6 \times 0.732^2)}$$

in which:

m_2 is the ratio increase (layer lay factor) for the inner layer,

m_3 is the ratio increase for the wires of diameter D in the outer layer, and

m_4 is the ratio increase for the wires of diameter 0.732 × D in the outer layer.

As in (a),

$$m = \sqrt{1 + \pi^2/n^2}$$

in which:

n is the lay ratio determined as follows:

For the central wire of diameter D, n_1 = infinity.

For the 6 wires of diameter D in the inner layer,

$$n_2 = \frac{LOL}{2D}$$

For the 6 wires of diameter D in the outer layer,

$$n_3 = \frac{LOL}{3.464D}$$

For the 6 wires of diameter 0.732 × D in the outer layer,

$$n_4 = \frac{LOL}{3.732D}$$

When n_2 and n_3 and n_4 each equal or exceed 10, an estimate of

$$m = \sqrt{1 + \pi^2/n^2}$$

is

$$m = 1 + \pi^2/(2n^2) = 1 + \frac{4.9348}{n^2}$$

Then,

$$m_2 = 1 + 19.7392 \times \frac{D^2}{(LOL)^2}$$

$$m_3 = 1 + 59.2141 \times \frac{D^2}{(LOL)^2}$$

$$m_4 = 1 + 68.7310 \times \frac{D^2}{(LOL)^2}$$

and

$$M_{combo.\ unilay} = 1 + 42.8423 \times \frac{D^2}{(LOL)^2}$$

and

$$k = 4284 \times \frac{D^2}{(LOL)^2}$$

(applies only where each n equals or exceeds 10).

211 – 219 *Reserved for Future Use*

220 D-C Conductor Resistance

220.1 The direct-current resistance of any length of conductor in ohms per thousand conductor feet or in ohms per conductor kilometer is to be measured to an accuracy of 2 percent or better by means of a Kelvin-bridge ohmmeter or its equivalent – see 220.2 concerning measurement at temperatures other than 25°C (77°F) and 20°C (68°F). Tables 30.1– 30.11 do not cover nickel-coated copper, silver-coated copper, or nickel-base-alloy conductors because the thickness of the nickel or silver and the composition of the nickel-base alloy vary in practice thereby varying the conductor resistance (the maximum conductor resistance is to be determined individually in such cases). Where the results of any measurement do not comply, the results of measurements made under the conditions outlined in 220.3 – 220.9 are to be taken as conclusive.

220.2 The resistance of a conductor measured at a temperature other than 25°C (77°F) or 20°C (68°F) is to be adjusted to the resistance at 25°C (77°F) or 20°C (68°F) by means of the applicable multiplying factor from Table 220.1.

220.3 A referee determination of the direct-current resistance of a conductor is to be made to an accuracy of 0.2 percent or better by means of a general-purpose Kelvin bridge or its equivalent using a straight specimen of the conductor that is 24 – 48 inches or 610 – 1220 mm long.

220.4 Each general-purpose Kelvin-bridge current electrode is to be attached to a stranded specimen in a way – adjacent strands in mutual contact, each strand of the outer layer in full-length contact with the electrode, no strands damaged or bent, uniform pressure by the electrode at all points of strand contact, and so forth – that results in a uniform or nearly uniform distribution of current among the strands.

220.5 The distance between each general-purpose Kelvin-bridge potential electrode and its corresponding current electrode is to equal or exceed 1.5 times the circumference of the conductor specimen. The resistance of the Kelvin-bridge yoke between the reference standard and the specimen is not to be more than 0.1 percent of the resistance of the reference standard or the specimen, whichever is less, unless compensation is made for the potential leads or the coil and lead ratios are balanced.

220.6 Each general-purpose Kelvin-bridge potential electrode shall contact the conductor specimen with a surface that is a sharp knife edge (see 220.9). The length of the conductor specimen between the knife edges is to be measured to the nearest 0.01 inch or 0.2 mm.

220.7 When using the general-purpose Kelvin bridge, the conductor specimen, all equipment, and the surrounding air are to be in thermal equilibrium with one another at one temperature in the range of 15 – 30°C (59 – 86°F). All of the referee resistance measurements are to be made at that one temperature. See 220.2 and note [a] to Table 220.1.

220.8 Because the general-purpose Kelvin-bridge measuring current raises the temperature of the specimen, the magnitude of the current is to be low and the time of its use is to be brief. Too much current, too much time, or both are being used for a measurement where any change in resistance is detected with the galvanometer in two successive readings.

220.9 The contact surfaces of the general-purpose Kelvin-bridge current electrodes, the surface of the conductor specimen, and the knife edges of the general-purpose Kelvin-bridge potential electrodes are to be clean and undamaged. Contact-potential error is to be eliminated by taking four readings in direct succession: the first with the current flowing in one direction, the second with the current flowing in the other direction, then – after the specimen has been turned end for end – the third with the current flowing in one direction, and the fourth with the current flowing in the other direction. Contact-potential imbalance is to be minimized by having the potential electrodes made of the same material.

Table 220.1
Factors for adjusting d-c resistance of conductors[a]

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
0	32.0	1.107	1.110	1.085	1.088
1	33.8	1.102	1.105	1.081	1.083
2	35.6	1.098	1.100	1.076	1.078
3	37.4	1.093	1.095	1.072	1.074
4	39.2	1.089	1.090	1.067	1.069
5	41.0	1.084	1.085	1.063	1.064
6	42.8	1.079	1.081	1.059	1.060
7	44.6	1.075	1.076	1.054	1.055
8	46.4	1.070	1.072	1.050	1.051
9	48.2	1.066	1.067	1.045	1.046
10	50.0	1.061	1.063	1.041	1.042
11	51.8	1.057	1.059	1.037	1.038

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
12	53.6	1.053	1.054	1.033	1.033
13	55.4	1.048	1.050	1.028	1.029
14	57.2	1.044	1.045	1.024	1.024
15	59.0	1.040	1.041	1.020	1.020
16	60.8	1.036	1.037	1.016	1.016
17	62.6	1.032	1.033	1.012	1.012
18	64.4	1.028	1.028	1.008	1.008
19	66.2	1.024	1.024	1.004	1.004
20	68.0	1.020	1.020	1.000	1.000
21	69.8	1.016	1.016	0.996	0.996
22	71.6	1.012	1.012	0.992	0.992
23	73.4	1.008	1.008	0.989	0.988
24	75.2	1.004	1.004	0.985	0.984
25	77.0	1.000	1.000	0.981	0.980
26	78.8	0.996	0.996	0.977	0.976
27	80.6	0.992	0.992	0.973	0.972
28	82.4	0.989	0.989	0.970	0.969
29	84.2	0.985	0.985	0.966	0.965
30	86.0	0.981	0.981	0.962	0.961
31	87.8	0.977	0.977	0.958	0.957
32	89.6	0.974	0.973	0.955	0.954
33	91.4	0.970	0.970	0.951	0.950
34	93.2	0.967	0.966	0.948	0.947
35	95.0	0.963	0.962	0.944	0.943
36	96.8	0.959	0.958	0.941	0.939
37	98.6	0.956	0.955	0.937	0.936
38	100.4	0.952	0.951	0.934	0.932
39	102.2	0.949	0.948	0.930	0.929
40	104.0	0.945	0.944	0.927	0.925
41	105.8	0.942	0.941	0.924	0.922
42	107.6	0.938	0.937	0.921	0.918
43	109.4	0.935	0.934	0.917	0.915
44	111.2	0.931	0.930	0.914	0.911

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
45	113.0	0.928	0.927	0.911	0.908
46	114.8	0.925	0.924	0.908	0.905
47	116.6	0.922	0.920	0.905	0.902
48	118.4	0.918	0.917	0.901	0.898
49	120.2	0.915	0.913	0.898	0.895
50	122.0	0.912	0.910	0.895	0.892
51	123.8	0.909	0.907	0.892	0.889
52	125.6	0.906	0.904	0.889	0.886
53	127.4	0.902	0.900	0.885	0.882
54	129.2	0.889	0.897	0.882	0.879
55	131.0	0.896	0.894	0.879	0.876
56	132.8	0.893	0.891	0.876	0.873
57	134.6	0.890	0.888	0.873	0.870
58	136.4	0.887	0.884	0.870	0.867
59	138.2	0.884	0.881	0.867	0.864
60	140.0	0.881	0.878	0.864	0.861
61	141.8	0.878	0.875	0.861	0.858
62	143.6	0.875	0.872	0.858	0.855
63	145.4	0.872	0.869	0.856	0.852
64	147.2	0.869	0.866	0.853	0.849
65	149.0	0.866	0.863	0.850	0.846
66	150.8	0.863	0.860	0.847	0.843
67	152.6	0.860	0.857	0.844	0.840
68	154.4	0.858	0.855	0.842	0.838
69	156.2	0.855	0.852	0.839	0.835
70	158.0	0.852	0.849	0.836	0.832
71	159.8	0.849	0.846	0.833	0.829
72	161.6	0.846	0.843	0.830	0.826
73	163.4	0.844	0.841	0.828	0.824
74	165.2	0.841	0.838	0.825	0.821
75	167.0	0.838	0.835	0.822	0.818
76	168.8	0.835	0.832	0.819	0.815
77	170.6	0.833	0.829	0.817	0.813

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
78	172.4	0.830	0.827	0.814	0.810
79	174.2	0.828	0.824	0.812	0.808
80	176.0	0.825	0.821	0.809	0.805
81	177.8	0.822	0.818	0.807	0.802
82	179.6	0.820	0.816	0.804	0.800
83	181.4	0.817	0.813	0.802	0.797
84	183.2	0.815	0.811	0.799	0.795
85	185.0	0.812	0.808	0.797	0.792
86	186.8	0.810	0.806	0.794	0.790
87	188.6	0.807	0.803	0.792	0.787
88	190.4	0.805	0.801	0.789	0.785
89	192.2	0.802	0.798	0.787	0.782
90	194.0	0.800	0.796	0.784	0.780

[a] No referee resistance measurement is to be made at a temperature outside the range of 15 – 30°C (59 – 86°F). See 220.7.

221 – 227 *Reserved for Future Use*

WIRE BRAID AND SERVING COVERAGE

228 Measurements and Calculations

228.1 Where a wire covering consists of multiple braids or servings (wraps), separate coverage determinations are to be made for each wire braid and serving. Measurements and calculations are specified for braids and servings of both round and flat wires on round and flat underlying constructions.

228.2 In any one braid or serving, all of the wires are assumed to be of the same metal, the same metal coating (where a metal coating is used), and the same diameter where the wires are round or the same width and thickness where the wires are flat. A wire braid is assumed to be fabricated on a machine using the same number of carriers in each direction and the same number of round or flat wires in each carrier (N in the notes to Table 228.1 provides for weighting of the value for N where not all carriers have the same number of wires).

228.3 The method described here uses measurements made on the finished product. For this method, the coverage of each wire braid and serving in a cord or cable is to be determined from calculations using the measurements, formulas, and number of decimal places specified in Table 228.1 for wire-braid constructions and in Table 228.2 for wire servings.

228.4 For a wire braid, the number of plaits laid in one direction along 1 inch or 20 millimeters of the axial length of the wire braid is to be counted to the nearest tenth of a plait by means of a standard braid counter (see 228.5) at three places that are at least 2 inches or 50 mm apart in any 12-inch or 300-mm section in the center 3 ft or 1 m of a straight 5-ft or 1500-mm specimen of the wire-braid-covered conductor, assembly, or core. The average of the three measurements made in inches is to be expressed to the nearest tenth of a plait and taken as P the number of picks per inch for that wire braid. The average of the three measurements made in millimeters is to be divided by 20. The result expressed to the nearest hundredth of a plait is to be taken as P the number of picks per millimeter for that wire braid.

228.5 Where a braid counter is not available, the count is to be made along 6 inches or 150 mm of the braid at one place in the 12-inch or 300-mm section. This measurement in inches is to be divided by 6. The result expressed to the nearest tenth of a plait is to be taken as P the number of picks per inch for that wire braid. This measurement in millimeters is to be divided by 150. The result expressed to the nearest hundredth of a plait is to be taken as P the number of picks per millimeter for that wire braid.

Table 228.1
Coverage calculations for a wire braid

SHAPE **Makeup of construction under braid**	**Shape of a braid wire**	**Calculations**		
		Name	**Formulas** The notes to this table specify how to determine the value of each parameter to enter in the formulas shown in this column. Use the formulas in the sequence shown reading down this column. Use of other formulas is appropriate where the formulas are applicable, agreed upon, and recorded.	**Number of decimal places**
ROUND 1, 3, 4, or more conductors or other round elements or assemblies or an entire round cable core or 2 or more twisted pairs or 1 parallel or twisted pair of conductors or other round elements. Fillers are included. Pair is round.	Round	Braid Angle (a)	$\tan a = 2 \times 3.1416 \times P(D + 2d)/C$	3
			Determine a (arctan)	Nearest degree
			Determine sin a	3
		1-way coverage (F)	$F = (N \times P \times d)/\sin a$	3
		2-way (total) coverage (G)	$G = 2F - F^2$	3
		Percent Total coverage (K)	$K = 100 \times G$	Nearest percent
	Flat	Substitute these formulas: $\tan a = 2 \times 3.1416 \times P(D + 2t)/C$ $F = (N \times P \times w)/\sin a$		

Table 228.1 Continued on Next Page

Table 228.1 Continued

FLAT Parallel or twisted pair(s) of conductors or other round elements. Fillers are not included. Pair is not round.	Round	Same formulas substituting D_{eq} for D.
	Flat	Same formulas substituting D_{eq} for D.

C = total number of carriers in the wire braid.

d = diameter of one round braid wire to the nearest 0.0001 inch or 0.001 mm.

D = diameter of the round assembly under the wire braid measured to the nearest 0.001 inch or 0.1 mm.

D_{eq} = equivalent diameter over the two parallel or twisted round coaxial elements or insulated conductors under the wire braid determined to the nearest 0.001 inch or 0.1 mm by means of a diameter tape or by dividing the measured circumference of the flat pair by 3.1416 (p).

N = number of round or flat wires in one carrier of the wire braid.
N is to be weighted where several carriers have fewer wires than the rest:

$$N_{weighted} = \frac{(\text{number of carriers having r wires x r}) + (\text{number of carriers having s wires x s})}{\text{number of carriers having r wires + number of carriers having s wires}}$$

$N_{weighted}$ is to be expressed to the third decimal place.

P = picks per inch or picks per millimeter determined as indicated in 228.4 and 228.5.

t = thickness of one flat braid wire to the nearest 0.001 inch or 0.1 mm.

w = width of one flat braid wire to the nearest 0.001 inch or 0.1 mm.

Table 228.2
Coverage calculations for a wire serving (spiral shield or reverse spiral shield)

SHAPE **Makeup of construction under serving (wrap)**	**Shape of a serving wire**	**Calculations**		
		Name	**Formulas** The notes to this table specify how to determine the value of each parameter to enter in the formulas shown in this column. Use the formulas in the sequence shown reading down this column. Use of other formulas is appropriate where the formulas are applicable, agreed upon, and recorded.	**Number of decimal places**
ROUND 1, 3, 4, or more conductors or other round elements or assemblies or an entire round cable core or 2 or more twisted pairs or 1 parallel or twisted pair of conductors or other round elements. Fillers are included. Pair is round.	Round	Serving angle (a)	*tan a = 3.1416 x (D + d)/L*	3
			Determine a (arctan)	Nearest degree
			Determine cos a	3
		Coverage (B)	*B = (H x d)/[3.1416 x (D + d) x cos a]*	3
		Percent coverage (K)	*K = 100 x B*	Nearest percent
	Flat	Substitute these formulas: *tan a = 3.1416 x (D + t)/L* *B = (H x w)/[3.1416 x (D + t) x cos a]*		
FLAT Parallel or twisted pair(s) of conductors or other round elements. Fillers are not included. Pair is not round.	Round	Same formulas substituting D_{eq} for D.		
	Flat	Same formulas substituting D_{eq} for D.		

Table 228.2 Continued on Next Page

Table 228.2 Continued

d = diameter of one round serving wire to the nearest 0.0001 inch or 0.001 mm.
D = diameter of the round assembly under the wire serving measured or calculated to the nearest 0.001 inch or 0.1 mm.
D_{eq} = equivalent diameter over the two parallel or twisted round coaxial elements or insulated conductors under the wire serving determined to the nearest 0.001 inch or 0.1 mm by means of a diameter tape or by dividing the measured circumference of the flat pair by 3.1416 (p).
H = number of round or flat wires in the wire serving.
L = lay length to the nearest 0.01 inch or 0.1 mm along the cord or cable axis for one complete turn of a serving wire around the round or flat construction under the serving.
t = thickness of one flat serving wire to the nearest 0.001 inch or 0.1 mm.
w = width of one flat serving wire to the nearest 0.001 inch or 0.1 mm.

229 – 239 *Reserved for Future Use*

THICKNESSES OF INSULATION AND JACKET

240 Thicknesses of Insulation on Thermoplastic- and Thermoset-Insulated Wires and Cable

Average thickness

240.1 Measurements from which the average thickness of insulation is to be determined are to be made by means of one of the following instruments:

a) Use of a machinist's micrometer caliper is appropriate. The caliper is to have flat surfaces on the anvil and on the end of the spindle and is to be calibrated to read directly to at least 0.001 inch or 0.01 mm with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.002 mm.

b) Use of a dead-weight dial micrometer is appropriate. The micrometer is to exert 10 ±2 gf or 0.10 ±0.02 N on a sample through a flat, rectangular presser foot 0.078 by 0.375 inch or 1.98 by 9.52 mm. The anvil of the instrument is to be of the same dimensions as the presser foot. The instrument is to be calibrated as indicated in (a).

240.2 During the measurements, the sample, the measuring instrument, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F).

240.3 Measurements are to be made on a sample length of finished wire (single conductor or insulated conductor removed from a cable) from which any jacket or other covering has been removed without damaging or stressing the insulation. For the 14 – 9 AWG sizes, the sample is to be at least 60 inches or 1500 mm long and, figuring from one end of the sample, measurement is to be made of the maximum and minimum diameters over the insulation at each of five points 10, 20, 30, 40, and 50 inches from that end or 254, 508, 762, 1016 and 1270 mm from that end. For the 8 AWG – 2000 kcmil sizes, the sample is to be 24 inches or 610 mm long and, figuring from one end of the sample, measurement is to be made of the maximum and minimum diameters over the insulation at each of five points 4, 8, 12, 16, and 20 inches from that end or 102, 203, 305, 406 and 508 mm from that end. Each of the ten measurements (two at each point) is to be estimated to the nearest 0.0001 inch (0.1 mil) or 0.002 mm and recorded. The insulation is to be removed for a short distance at one end of the sample without damage to the conductor or any separator, and the maximum and minimum diameters are then to be measured over the conductor or any separator and recorded as estimates to the nearest 0.0001 inch or 0.002 mm.

240.4 The average of the two recorded measurements over the conductor or any separator is to be subtracted from the average of the ten recorded measurements over the insulation. The result is to be divided by two and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the average thickness of insulation for comparison with the minimum average thickness specified for the construction in the wire standard.

240.5 ROUNDING TO THE NEAREST 0.001 inch – A figure in the third decimal place is to remain unchanged where the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or where the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth). A figure in the third decimal place is to be increased by 1 where the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or where the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

240.6 ROUNDING TO THE NEAREST 0.01 mm – A figure in the second decimal place is to remain unchanged where the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even, or where the figure in the third decimal place is 5 and the figure in the second decimal place is even (0, 2, 4, and so forth). A figure in the second decimal place is to be increased by 1 where the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even, or where the figure in the third decimal place is 5 and the figure in the second decimal place is odd (1, 3, 5, and so forth).

240.7 Where the results obtained via the procedures described in 240.1 – 240.4 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to measure the maximum and minimum thicknesses of insulation directly at each of the five points described in 240.3. To accomplish this, five sections 4 inches or 100 mm long are to be cut from the sample from 240.3 with one of the five points at the center of each section. Without damaging or stressing the insulation, the conductor and any separator are to be removed and the five tubes of insulation are to be cut in two at their centers. Each cut is to be clean and perpendicular to the longitudinal axis of the tube. This yields ten specimens for measurement; however, measurements are to be made on only five specimens – on one specimen from each tube. The clean-cut end of each of the five specimens is to be viewed through the instrument and the maximum and minimum thicknesses of each are to be found and recorded to the nearest 0.0001 inch or 0.001 mm. The average of the ten measurements is to be calculated and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the average thickness specified in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

Minimum thickness at any point

240.8 The point of minimum diameter over the insulation is to be determined with the instrument used for the measurements specified in 240.3. The sample from 240.3 is to be used unless it has been cut as indicated in 240.7, in which case, a second sample of the same length is to be used.

240.9 With the point of minimum diameter at its center, a section 4 inches or 100 mm long is to be cut from the sample. Without damaging or stressing the insulation, the conductor and any separator are to be removed and the tube of insulation is to be cut in two at the point of minimum diameter to yield two specimens for measurement. The cut is to be clean and perpendicular to the longitudinal axis of the tube.

240.10 Measurements of the minimum thickness of insulation are to be made by means of a dead-weight pin-gauge dial micrometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen through a flat, rectangular presser foot 0.043 inch by 0.312 inch or 1.09 mm by 7.92 mm. The pin is to be 0.437 inch or 11.10 mm long and 0.020 inch or 0.51 mm in diameter (a pin 0.043 inch or 1.09 mm in diameter is appropriate for wires and cables having strands larger than 0.043 inch or 1.09 mm in diameter). The instrument is to be calibrated to read directly to at least 0.001 inch or 0.01 mm with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.002 mm. See 240.2.

240.11 While the presser foot of the dial micrometer is raised from the pin, one of the specimens from 240.9 is to be placed on the pin (clean-cut end first) so that the entire length of the pin contacts the interior of the insulation. The presser foot is to be lowered gently onto the specimen and a reading estimated to the nearest 0.0001 inch or 0.002 mm is to be taken immediately and recorded. The presser foot is then to be raised, the specimen is to be rotated on the pin, and a second reading is to be taken and recorded. This procedure is to be repeated until the thinnest point of the insulation is found and recorded. The specimen is not to be rotated while in contact with the presser foot.

240.12 The procedures described in 240.11 are to be repeated with the second specimen.

240.13 The smallest of all of the readings recorded for both specimens is to be rounded off as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the minimum thickness at any point of the insulation for comparison with the minimum thickness at any point specified for the construction in the wire standard.

240.14 Where the results obtained via the procedures described in 240.8 – 240.13 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to view the clean-cut end of one of the two specimens. The point of minimum thickness is to be located and the thickness reading is to be recorded. The recorded value is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the minimum thickness at any point specified for the construction in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

241 – 249 *Reserved for Future Use*

250 Thicknesses of Insulation on Flexible Cord and on Fixture Wire

250.1 Except as noted in 250.11, the difference method is to be employed to determine the average thickness of the insulation on any conductor and to determine the minimum thickness at any point of the insulation on a conductor having a core diameter smaller than the 0.043 inch or 1.09 mm diameter of the gauge pin specified in 250.6 – 250.10 – for example, a 24, 22, or 20 AWG conductor, an 18 AWG solid conductor, or a tinsel-cord conductor.

250.2 The difference method is to consist of determining the average diameter over the insulation and subtracting from it the diameter of the conductor plus any separator, with the difference divided by two and the result taken as the average thickness of the insulation. Measurements are to be made either with a machinist's micrometer caliper having flat surfaces on both the anvil and the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, or by means of a dead-weight dial micrometer having an anvil and presser foot 0.078 inch wide and 0.375 in long (1.98 by 9.52 mm) and resting on a specimen with 10 ±2 gf or 0.10 ±0.02 N.

250.3 Five sets of measurements are to be taken along the specimen and the average of the five sets of measurements determined. Each set of measurements is to consist of the determination of the maximum and the minimum diameters at the place measured.

250.4 Instead of the machinist's micrometer caliper or dead-weight dial micrometer, a simply manipulated optical device accurate to at least 0.001 inch or 0.01 mm is appropriate to use. When using an optical device, specimens are to be cut perpendicular to the axis of the conductor.

250.5 Where the results of measurements by these methods do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. When measured by means of an optical device, it is appropriate for the average thickness of insulation on a stranded conductor to be 3 mils or 0.08 mm less than specified for the construction in the wire standard.

250.6 Except as noted in 250.9, it is appropriate to determine the minimum thickness at any point of the insulation on a conductor having a core diameter of at least 0.043 inch or 1.09 mm – such as an 18 AWG stranded conductor or any larger conductor – and the minimum thickness at any point of the insulation and the web of a parallel cord by means of a pin-gauge dial micrometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen. The pin is to be 0.437 inch or 11.10 mm long and 0.043 inch or 1.09 mm in diameter, and the end of the presser foot that touches the specimen is to be a flat rectangle 0.043 inch wide by 0.312 inch long or 1.09 mm by 7.92 mm.

250.7 The copper conductor(s) and any separator(s) are to be removed. In the case of a parallel cord, each specimen for the measurement of the distance between copper conductors specified in the wire standard is to be cut down on one side to the bottom of the cavity left by one conductor (directly opposite the cavity left by the adjacent conductor) to accommodate the presser foot.

250.8 The specimen is to be placed on the pin, the presser foot brought to rest gently on the specimen, and the reading taken immediately. The specimen is to be located on the pin with the entire length of the presser foot making contact with the specimen. The specimen is to be rotated and several measurements made to determine the actual minimum thickness at any point. The presser foot is not to be in contact with the specimen while the specimen is being rotated.

250.9 Instead of the pin-gauge dial micrometer, it is appropriate to use a simply manipulated optical device accurate to at least 0.001 inch or 0.01 mm. When using an optical device, specimens are to be cut perpendicular to the axis of the conductor.

250.10 Where the results of these measurements do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. When measured by means of an optical device, it is appropriate for the minimum thickness at any point of the insulation on a stranded conductor to be 3 mils or 0.08 mm less than specified for the construction in the wire standard.

250.11 Where the core diameter of a conductor is less than 0.043 inch or 1.09 mm, it is appropriate to determine the average and minimum thicknesses of insulation by means of a pin-gauge dial micrometer where a pin having a diameter less than 0.043 inch or 1.09 mm is used. The wire standards typically specify this pin as 0.020 inch or 0.51 mm in diameter.

251 – 259 *Reserved for Future Use*

260 Thicknesses of Jacket on Thermoplastic- and Thermoset-Insulated Wires and Cables

260.1 Two 6-inch or 150-mm lengths are to be cut from a sample length of the finished, jacketed wire or cable. Each cut is to be clean and in a plane perpendicular to the longitudinal axis of the wire or cable. The two lengths are to be taken from portions of the wire or cable that are at least 10 ft or 3 m apart.

260.2 The conductor or conductors and any separator(s) are to be removed and each hollow section is to be slit longitudinally. In the absence of a tape or braid between the insulation and jacket that facilitates separation of the two in the case of a thermoset-insulated wire or cable, each section is to be split, skived, or buffed on the inside surface to just remove all traces of the insulation. A 3/8-inch or 10-mm slice is to be cut from the center of each of the resulting hollow lengths of PVC or nylon or thermoset jacket. Each cut is to be clean and in a plane perpendicular to the longitudinal axis of the hollow length. The slices are not to be stressed or strained more than the minimum to accomplish the cuts (stretching and squashing alter the dimensions).

260.3 The measurements from which the thicknesses are determined are to made 30 min or more after any splitting, skiving, or buffing. They are to be made by means of a dead-weight pin-gauge dial micromometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen through a flat, rectangular presser foot measuring 0.043 inch by 0.312 inch or 1.09 mm by 7.92 mm. The pin is to be 0.437 inch or 11.10 mm long and 0.020 inch or 0.51 mm in diameter. The instrument is to be calibrated to read directly to at least 0.001 inch or 0.01 mm with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.002 mm. See 240.2 regarding the temperature at which measurements are to be made.

260.4 While the presser foot of the dial micrometer is raised from the pin, one of the slices is to be hung at a location on the pin that enables the entire length of the presser foot to contact the outer surface of the PVC or nylon or thermoset jacket and the entire inner surface of the slice to be contacted by the pin. The presser foot is to be lowered gently onto the slice, and a reading estimated to the nearest 0.0001 inch or 0.002 mm is to be taken immediately and is to be recorded. This procedure is to be repeated until a total of five readings is made, each being at a different part of the slice and one being at the thinnest part of the PVC or nylon or thermoset jacket. The presser foot is not to be in contact with the jacket while the slice is being moved from one position of measurement to the next.

260.5 The procedures described in 260.4 are to be repeated with the second slice of PVC or nylon or thermoset jacket.

260.6 The average of all of the readings recorded for both slices of PVC or thermoset jacket from pump cable is to be calculated and rounded off as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the average thickness of the PVC or thermoset jacket for comparison with the minimum average thickness specified for the construction in the wire standard. See 260.8 concerning referee measurements.

260.7 The smallest of all of the readings recorded for both slices is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the minimum thickness at any point of the PVC or nylon or thermoset jacket for comparison with the minimum thickness at any point of the jacket specified for the construction in the wire standard. See 260.8 concerning referee measurements.

260.8 Where the results obtained via the procedures described in 260.3 – 260.7 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to locate and measure the maximum and minimum thicknesses on each of the slices. The maximum and minimum thicknesses of each slice are to be recorded to the nearest 0.0001 inch or 0.001 mm. The average of the four measurements is to be calculated and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the average thickness of the jacket specified for the construction in the wire Standard. The smallest of the four measurements is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the minimum thickness of the jacket specified for the construction in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

261 – 279 *Reserved for Future Use*

280 Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable

280.1 The average thickness of a jacket is to be determined by the difference method, which is to consist of determining the average diameter over a specimen of finished cord and subtracting from it the diameter of the core. The difference is then to be divided by two and the result taken as the thickness of the jacket. Five sets of measurements are to be taken along the specimen and the average of the five sets of measurements determined. Each set of measurements is to consist of the determination of the maximum and minimum diameters at the place measured. Measurements are to be made either with a machinist’s micrometer caliper having flat surfaces on both the anvil and the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, or by means of a similarly calibrated dead-weight dial micrometer having an anvil and presser foot 0.078 inch wide and 0.375 inch long or 1.98 mm by 9.52 mm resting on a specimen with 10 ±2 gf or 0.10 ±0.02 N. The entire surface of the spindle of the machinist’s micrometer caliper or the presser foot of the dial micrometer is to be in contact with the specimen during each measurement. Where the results of measurements by this method do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm.

280.2 The minimum thickness at any point of a jacket is to be determined by measuring a specimen that has been removed from the conductor assembly of the cord and buffed to just remove all traces left by the core. The specimen is to be selected, unless its cross section is the complete cross section of the jacket, to include the thinnest portion of the jacket as determined visually. Measurements are to be made with a machinist’s micrometer caliper as described in 280.1, with the dead-weight dial micrometer described in 280.3, or by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. The entire surface of the spindle of the machinist’s micrometer caliper or the presser foot of the dial micrometer is to be in contact with the specimen during each measurement.

280.3 The dead-weight dial micrometer referenced in 280.2 is to have a presser foot 0.250 ±0.010 inch or 6.4 ±0.2 mm in diameter and is to exert a total of 3.0 ±0.1 ozf or 0.84 ±0.02 N or 85 ±3 gf on the specimen – the load being applied by means of a weight.

281 – 399 *Reserved for Future Use*

PHYSICAL PROPERTIES TESTS OF INSULATION AND JACKET

400 General

400.1 The descriptions of the test apparatus and methods in Sections 420, 440, 470 and 480 apply to the determination of the physical properties of aged and unaged specimens of compounds that are used as conductor insulation and as jackets.

401 – 419 *Reserved for Future Use*

420 Apparatus

Power-driven testing machine

420.1 Measurement of ultimate elongation and tensile strength are to be made on a power-driven machine provided with a device that indicates the actual maximum load at which a specimen breaks. Where a machine of the spring-balance type is used, the spring is to be kept from recoiling. The machine is to be adjusted to make the speed of the power-actuated grip 20 ±1 in/min or 500 ±25 mm/min (unless specified otherwise in the applicable part of Specific Materials, Section 50, of this standard, or in the applicable wire standard, such as 2.0 ±0.2 in/min or 50 ±5 mm/min for PE as specified in note [c] to Table 50.136). The applied tension as indicated by a dial or scale is to be accurate to 2 percent or less of the value read, and a set of weights is to be on hand for calibrating the machine. A method for calibrating the machine is given in the American Society for Testing and Materials ″Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension″ (ASTM D 412-98).

Die-cut specimens

420.2 The die used to cut the sample material into specimens is to produce specimens of a dumbbell shape. ASTM die C is to be used to produce dumbbell specimens having a constricted portion 1/4 inch or 6 mm wide, plus the other dimensions shown in Figure 420.1. Where the amount of material is inadequate for die C, it is appropriate to use ASTM die D, which produces dumbbell specimens having a constricted portion 1/8 inch or 3 mm wide and other dimensions smaller than those produced by die C.

Recovery-test apparatus

420.3 Recovery tests are to be made on the power-driven machine described in 420.1 where the machine enables instant stopping of the movable grip. Otherwise, the apparatus shown in Figure 420.2 and Table 420.1 is to be employed. The spools ″a″ are to be free to slide on the shaft ″b″ and are to be slotted to engage pins ″c″, which act as clutches. The movable grips are to be attached to strips of rawhide belt lacing 5/8 inch or 16 mm in width, which are to pass through clamps ″d″ and then to the spools. The grips illustrated are the ones that are to be used for die-cut specimens. For tubular specimens, roll-type grips are to be used.

420.4 The specimen marker is to consist of a stamp with parallel metal blades capable of marking fine lines with ink on a specimen without damaging the insulation or jacket. The lines (bench marks) are to be 1 inch or 25 mm apart, are to be applied at right angles to the longitudinal axis of the wire, cable, or cord, and are to be centrally located on the constricted portion of the specimen. Because the width of a mark increases while a specimen is being stretched, measurement of elongation is to be made with reference to the center of each mark – that is, with reference to a point halfway between the edges of each mark.

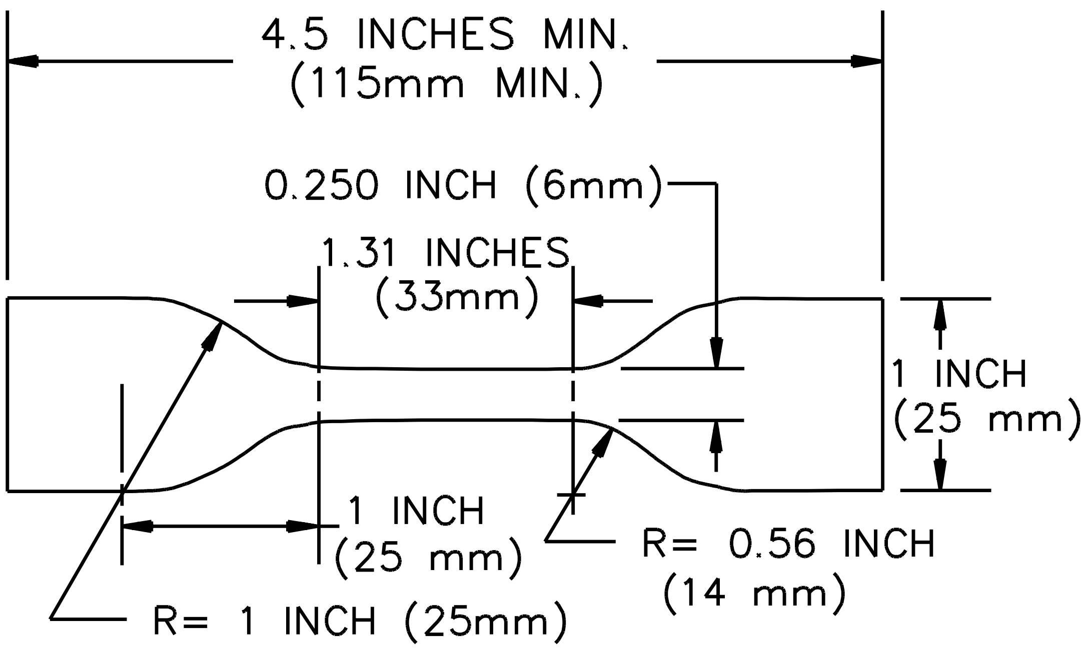
Splitting or skiving machine

420.5 A power-driven splitting or skiving machine is to consist of an adjustable upper pressure roller, a band knife or a rotary bell knife, and a power-driven feed roller that passes a sample across the knife blade thereby separating or slicing the sample into layers, with no resulting heating of the sample material from which die-cut specimens are to be prepared. It is appropriate to use the machine to achieve the following:

a) To produce a strip of insulation from a 6 AWG or larger conductor or a strip of jacketing material, and

b) To remove irregularities from samples of insulation, jacket, or the like that are not thinner than about 30 mils or 0.76 mm.

Figure 420.1
Die-cut specimen



NT160

Table 420.1
Decimal-inch and millimeter dimensions of recovery-test machine

Dimension in drawing	Dimension in decimal inches	Dimension in millimeters
1/8 inch	0.125	3.18
3/16	0.188	4.76
1/4	0.250	6.35
5/16	0.312	7.92
3/8	0.375	9.52
1/2	0.500	12.7
19/32	0.594	15.09
5/8	0.625	16
11/16	0.688	17.48
3/4	0.750	19.1
7/8	0.875	22.2
1	1.000	25.4
1-1/16	1.062	27.0
1-1/8	1.125	28.6
1-1/4	1.250	31.8
1-17/64	1.266	32.2
1-1/2	1.5	38
1-3/4	1.75	44.5
2-3/8	2.375	60.3
3-1/4	3.250	82.6
3-7/8	3.875	98.4
6	6	152
1 ft 6 inches	18	457
2 8	32	813

Buffing machine

420.6 A power-driven buffing machine (grinding wheel) is appropriate for buffing irregularities from the samples from which die-cut specimens are to be prepared. The abrasive wheel is to be of about No. 36 grit (particle size of 0.019 inch or 0.486 mm). The wheel is to run true and is not to vibrate. The diameter of the wheel is not specified; however, 4-3/4 – 6-1/4 inch or 0.12 – 0.16 m has been found appropriate. The rotary velocity of the wheel is to be 2500 – 3500 r/min. The diameter and rotary velocity of the wheel are to be selected to give the wheel a peripheral speed (rpm $\times \pi \times$ wheel diameter) of 3000 – 5000 ft/min or 15 – 25 m/s. CAUTION – The maximum wheel diameter stated in this paragraph and the maximum wheel rpm stated in this paragraph shall not be used together as this combination will result in a peripheral speed above 5000 ft/min or 25 m/s. This applies even for wheels that are marked as being intended for a peripheral speed above 5000 ft/min or 25 m/s. The machine is to have a slow feed that applies light pressure and removes very little material at one cut, thereby not overheating the specimen or the wheel.

Machine for stretching copper

420.7 A hand- or power-driven machine with steel grips is appropriate for stretching copper for the purpose of removing a copper conductor from the insulation.

Apparatus for aging

Specimen separation

420.8 In each type of apparatus, provision is to be made for suspending each specimen vertically within the chamber without touching the sides of the chamber or any other specimen.

Air-oven aging

420.9 The apparatus for the air-oven aging of specimens is to be as indicated in ASTM D 5423-93(R1999) (Type II ovens) and ASTM D 5374-93(R1999) and is to circulate the air within the aging chamber at high velocity. Fresh air is to be admitted, continuously, to the chamber to maintain normal oxygen content in the air surrounding the specimens. The exhaust ports of the oven are to be adjusted to achieve 100– 200 complete fresh-air changes per hour. The blower, fan, or other means for circulating the air is to be located entirely outside the aging chamber. The oven is to maintain the specified temperature within ±1.0°C (±1.8°F).

421 – 439 *Reserved for Future Use*

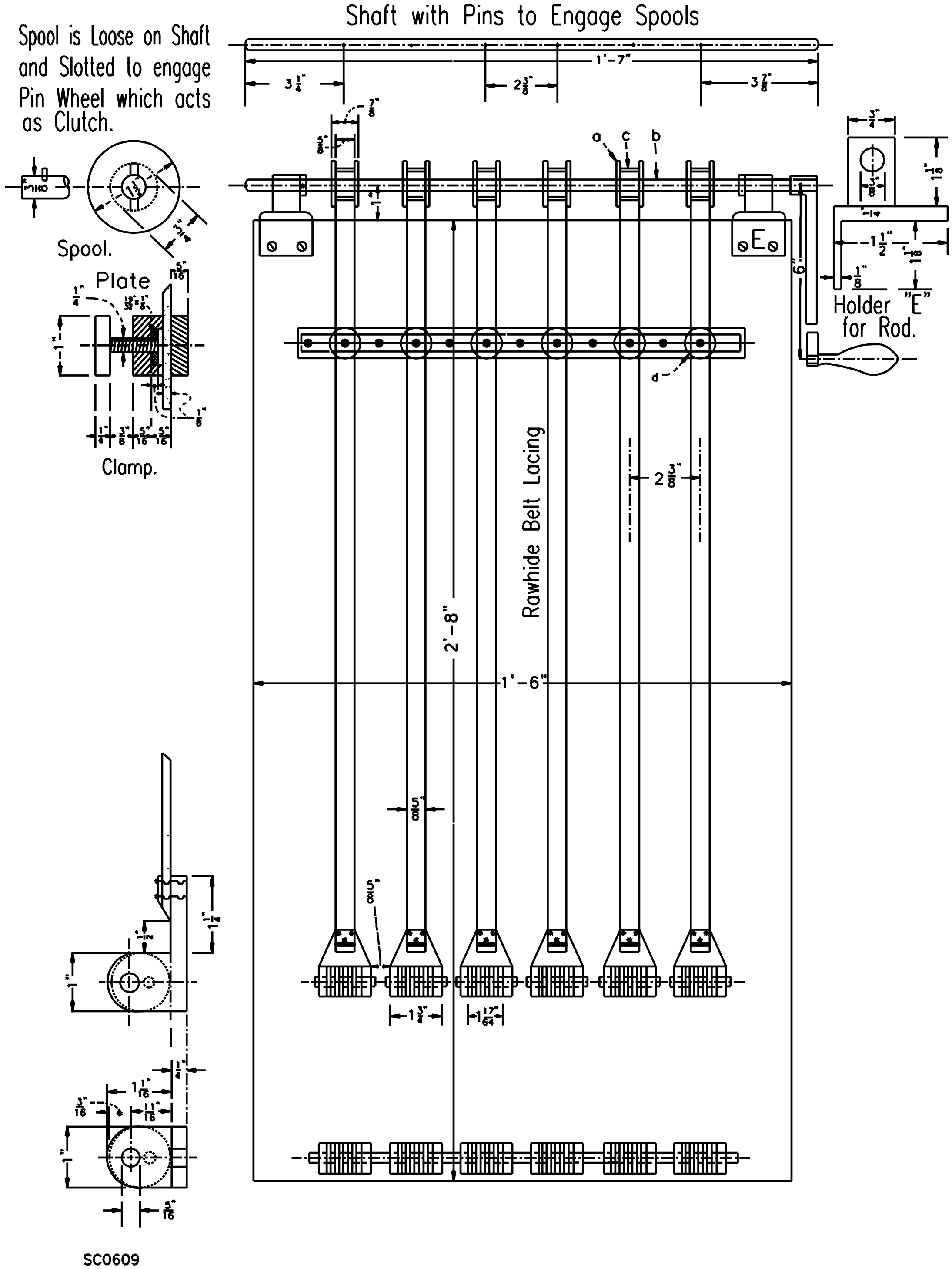
440 Preparation of Specimens

All specimens

440.1 Samples for the physical tests of aged and unaged specimens are to be taken from a coil or reel of finished wire, cable, and/or cord or from the product during manufacture at any point following the cross-linking process in the case of thermosets. The tests are to be conducted at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unless the manufacturer desires to have them made sooner, the measurements of tensile strength and ultimate elongation are not to be made until at least 48 h after the wire, cable, or cord is manufactured.

440.2 For an unjacketed conductor smaller than 6 AWG, except as noted in 440.11, a test specimen is to consist of a length of the complete tube formed by the insulation; however, in the case of a parallel cord, the specimen is to be the unseparated double tube where there is too little material for preparation of a die-cut specimen. For a jacketed conductor, for a 6 AWG or larger conductor, and for a conductor having insulation more than 95 mils or 2.41 mm thick, the tube of insulation is to be cut longitudinally and either any irregularities are to be removed by means of a splitting or skiving machine (see 420.5) or a slow-feed grinding machine (see 420.6), or a strip of the insulation material is to be produced with parallel and smooth surfaces by machine splitting or skiving or, for XL and PE only (see 440.3), by machine planing. The tube, with irregularities removed, or the strip is then to be laid out flat to form a rectangle from which a test specimen is to be cut with a die. A test specimen of a jacket is to be die-cut from a sample that has been cut longitudinally, removed from the conductor assembly, and then prepared as indicated for the insulation. The test specimen is not to have any surface incisions or other imperfections.

Figure 420.2
Recovery-test machine



See Table 420.1 for decimal-inch and millimeter dimensions

440.3 When removing fabric impressions or other unevenness by buffing, the buffing is not to be carried beyond the point at which the unevenness just disappears. When splitting or skiving is used to remove fabric impressions or other unevenness, it is appropriate to remove material past the point at which the unevenness disappears; however, no more additional material is to be removed than required to supply resistance to the blade for an even cut. When removing one layer from a double-layer construction, the buffing, splitting, or skiving is not to be carried beyond the point at which the removed layer just disappears. For reducing the thickness of the sample for the preparation of test specimens, it is appropriate to split or skive the insulation to the required thickness or to slice the insulation nearly to the required thickness and then finish by buffing. In any case, the final split or skived surface(s) or the final buffed surface is (are) to be smooth. Use of specimens of XL or PE material that are die-cut from strips of the material produced by machine planing is appropriate where the planed surfaces are flat, parallel, and smooth. Any splitting, skiving, planing, or buffing is to be completed at least 30 min prior to testing of the specimens.

Specimens from solid conductors

Removal of fibrous insulation or covering

440.4 Where the conductor has a fibrous covering, a sample of the wire about 2 ft or 600 mm in length is to be laid out straight on a table having a smooth, level surface. The fibrous covering is to be cut by means of a plane with a sharp blade adjusted to cut to a depth not greater than the thickness of the fibrous covering. This procedure is also to be followed in the case of the individual fibrous-covered wires of a multiple-conductor wire, cable, or assembly after removal of the outer covering. After the fibrous covering is cut, it is to be taken off by hand and the insulation is to be inspected. Any portion of the insulation showing any physical damage is not to be retained for test purposes. Where a rough edge remains at the seams following the separation of individual wires made by a strip process, such irregularities are to be removed by buffing or filing.

440.5 A braid, wrap, or jacket on a thermoplastic-insulated fixture wire is to be removed from a sample as indicated in 440.4.

Diameters

440.6 The sample is to be cut into specimens of a convenient length. The insulation is then to be cut circumferentially at a distance of 1/2 inch or 13 mm from each end of each specimen, the cut ends of insulation are to be removed, and the exposed ends of the conductor are to be freed from any adhering particles of insulation by means of a wooden blade.

440.7 Measurements to 0.001 inch or 0.01 mm of the diameter of the conductor and the diameter over the insulation are to be made with a machinist’s micrometer caliper, dead-weight dial micrometer, or optical device as described in 240.1– 240.7. The diameter of each exposed end section of the copper is to be measured at a point 1/4 inch or 6 mm from the end, and the average of the two measurements is to be taken as the diameter of the conductor.

440.8 Measurements of the maximum and minimum diameters over the insulation are to be made at a point halfway between the ends of the specimen and at points 1 inch or 25 mm to each side to the mid-point. The average of the maximum and minimum diameters at each point is to be determined, and the lowest of the three averages is to be used as the diameter of the specimen in calculating its cross-sectional area.

Conductor removal

440.9 GENERAL – After the measurements of the diameter of the conductor and insulation are obtained, the conductor is to be removed from the insulation by one of the methods described in 440.10, 440.11, and 440.12.

440.10 STRETCHING – The free ends of the conductor are to be clamped in the steel jaws of the machine mentioned in 420.7 and the conductor is to be stretched to its breaking point to facilitate its removal from the insulation. The unbroken end of the conductor is then to be clamped in a vise and the insulation is to be gently and slowly pulled from the copper by hand. During this operation, the tube of insulation is not to be twisted over a quarter of a turn at any point, and is not to be compressed length-wise, which strains it.

440.11 MERCURY – This method applies only in the case of conductors coated with tin or other metal. The specimen is to be prepared and measured as described in 440.4 – 440.8, after which it is to be immersed in pure mercury at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) until the conductor can be removed from the insulation without damage to the insulation. The specimen is then to be taken out of the mercury, wiped off, and the insulation pulled from the conductor by hand. DANGER – Mercury is poisonous, particularly when its vapors are inhaled. Mercury evaporates at room temperature so, in addition to wearing plastic or rubber gloves to keep mercury from the hands, it is mandatory to use mercury only under an operating fume hood.

440.12 DIE-CUT SPECIMENS – Preparatory to making die-cut specimens, the insulation is to be cut through to the conductor longitudinally and then the conductor is to be removed.

440.13 Where a jacket is applied directly to thermoset insulation, it is usual to prepare die-cut specimens of the insulation and jacket together. An effort is to be made to separate the jacket from the insulation by slitting the covering (insulation plus jacket) through to the conductor and then pulling the jacket and insulation apart by means of pliers. Sometimes this procedure is facilitated by immersing the sample in hot water for a few minutes just prior to pulling the jacket and insulation apart.

440.14 Where the jacket cannot be separated from the insulation, specimens are to be prepared by splitting, skiving, or buffing. Where buffing is used, the apparatus for this operation is to be equipped with a cylindrical table capable of being advanced very gradually.

440.15 To prepare specimens by buffing, two 8-inch or 200-mm lengths of the finished wire are to be taken, and the conductor is to be removed from the covering (insulation plus jacket) after slitting the covering through to the conductor. One length of covering is to be stretched into the clamps of the buffing apparatus to make the covering lie flat, with the jacket toward the wheel. The jacket is then to be buffed away without buffing any farther than is required. This process is to be repeated with the other length of covering, except that the sample is to be reversed in the clamps and the insulation is to be buffed away.

440.16 Die-cut specimens are to be prepared as indicated in 440.22 – 440.24 from the samples from 440.14 and 440.15 after the split, skived, or buffed samples have recovered for at least 30 min. In case of a sample from a small wire, it is appropriate to use a die having a constricted portion 0.125 inch or 3 mm wide.

Bench marks

440.17 Each specimen is then to be examined. Any specimen that shows physical damage is to be discarded and a new specimen is to be prepared. Two marks, 1 inch or 25 mm apart and equidistant from the center of the specimen, are to be placed on the specimen by means of the marker described in 420.4. These bench marks are to be at right angles to the direction of pull in the testing machine. The marks are not to be wide and the specimen is to be completely at rest while being marked.

Specimens from stranded conductors

Diameters

440.18 After the removal of any material applied over the insulation, a sample is to be cut into specimens of a convenient length, the insulation is to be removed from the ends of the conductor, and measurements are to be made of the diameter over the conductor and over the insulation as described for a solid conductor in 440.7 and 440.8.

Conductor removal

440.19 The individual strands of the conductor are to be removed from the insulation by means of a pair of pliers or by the wire-stretching machine described in 420.7, without damaging the specimen. Where difficulty is experienced in removing strands coated with tin or other metal, the sample is to be immersed in mercury as described for solid conductors in 440.11, after which the strands are easily removable.

Die-cut specimens

440.20 Where the conductor has a jacket applied directly to thermoset insulation, die-cut specimens are to be prepared as described in 440.13 – 440.16 and 440.22 – 440.24.

Bench marks

440.21 Each specimen is to be examined. Any specimen that shows physical damage is to be discarded and a new specimen is to be prepared. Two 1-inch or 25-mm bench marks are then to be placed on the specimen as described for a solid conductor in 440.17.

Die-cut specimens

440.22 A sample is to be cut into sections (typically 7 inches or 180 mm) and the insulation on each section is to be cut through to the conductor longitudinally (or, in the case of a jacket or a fibrous covering, the jacket or fibrous covering on each section is to be cut through to the conductor assembly) and the conductor is to be removed. This section of insulation is to be split or skived or buffed to remove any irregularities and a test specimen is then to be cut from it with a die as described in 420.2 and 440.23 and is then to be marked with two lines 1 inch or 25 mm apart. The width of the specimen between the two marks is to be checked.

440.23 The use of a press for operating the die reduces variations between specimens. However, where the die is struck with a mallet, all points or cutting edges of the die are to be in contact with the insulation before the die is struck. The cutting is to be done on a smooth surface that is of a material that does not damage the cutting edges of the die.

440.24 The thickness of the specimen is to be taken as the smallest of four measurements to 0.001 inch or 0.01 mm, two of which are to be made at 1/2-inch or 13-mm intervals between the bench marks on one edge beginning 1/4 inch or 6 mm from either mark, with the other two measurements being made at corresponding points on the opposite edge. These measurements are to be made with a dead-weight dial micrometer having a presser foot 0.250 ±0.010 inch or 6.4 ±0.2 mm in diameter and exerting a total of 3.0 ±0.1 ozf or 85 ±3 gf or 0.84 ±0.02 N on the specimen – the load being applied by means of a weight. The presser foot is to be at least 1/16 inch or 2 mm onto the edge of the specimen for each measurement. Where the results of measurements by this method do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm.

441 – 459 *Reserved for Future Use*

460 Recovery

460.1 The recovery test is to be conducted using specimens that have not been subjected previously to any test. Each specimen is to be clamped in position, with both marks visible between the grips. The grips are to be adjusted symmetrically to distribute the tension uniformly over the cross section of the specimen. The movable grip is to be adjusted to make the test piece taut, not under tension. The temperature of the ambient air is to be recorded.

460.2 The grips are to be separated at a rate of 20 ±1 in/min or 500 ±25 mm/min until the specified elongation is reached. The specimen is to be held in the stretched position for 2 min, released immediately without snapping back, rested for 2 min, and the distance between the marks is then to be measured to the nearest 0.01 inch or 0.1 mm and is to be recorded. Just before releasing the specimen, the distance between the marks is to be observed again. Where it has decreased because of slipping of the specimen in the grips, the test is to be repeated with another specimen.

461 – 469 *Reserved for Future Use*

470 Ultimate Elongation and Tensile Strength

470.1 Ultimate-elongation and tensile-strength tests are to be conducted simultaneously, using specimens that have not been subjected previously to any test. Any paper separator that cannot be removed without damage to the insulation or jacket is to be wet with water or a half-and-half mixture of ethylene or propylene glycol and water just prior to being clamped in the grips. Each specimen (tubular or die-cut) is to be clamped in position with both 1-inch or 25-mm bench marks outside of and between the grips. The marks on a tubular specimen are to be just outside of the grips and centered between the grips (the distance between a mark and the adjacent grip is not to exceed 1/2 inch or 13 mm). The movable grip is to be adjusted to make the specimen (tubular or die-cut) taut, not under tension. The grips are then to be separated at a rate of 20 ±1 in/min or 500 ±25 mm/min (2.0 ±0.2 in/min or 50 ±5 mm/min for high-density PE as specified in note [c] to Table 50.136) until the specimen is ruptured. During separation, the distance between the bench marks is to be measured continuously by an operator using the manual scale method, or the operator is to make the elongation measurement by means of an extensometer. A video or laser extensometer is appropriate. A mechanical extensometer is appropriate where the length of the specimen results in there being room between the grips for the sensor carriages to be connected and where the drag and the contact forces comply with both of the following:

a) Counter weights are to balance the mass of the sensor carriages to the degree that the drag is not greater than 0.05 lbf or 0.22 N or 23 gf.

b) Each carriage contact is to apply the same force to the specimen. The contact force of each sensor carriage on the specimen is to be adjusted to the minimum that keeps the carriage from slipping on the specimen. That minimum force is not to damage the specimen or result in the specimen parting at either carriage contact.

The distance between the bench marks at the instant of rupture is to be recorded with an accuracy of at least 0.1 inch or 2 mm. The ultimate elongation, in percent, is to be taken as 100 times the increase in distance between the bench marks divided by the original distance of 1 inch or 25 mm.

470.2 After rupture of the specimen, the maximum load in pounds force, meganewtons, newtons, or kilograms force is to be noted from the dial or scale and recorded together with the original dimensions of the specimen for use in calculating the tensile strength. Where a specimen breaks within one of the jaws at a value below that specified as the minimum, the test results are to be disregarded and the test is to be repeated with another specimen.

470.3 The cross-sectional area of a tubular specimen is to be computed by means of the formula

$$A = 0.7854\,(D^2 - d^2)$$

in which:

A is the cross-sectional area of the specimen in square inches, square meters, square centimeters, or square millimeters;

D is the diameter over the insulation in inches, meters, centimeters, or millimeters; and

d is the diameter of the conductor in inches, meters, centimeters, or millimeters.

470.4 The cross-sectional area of a tubular specimen with an irregular interior or exterior surface, such as caused by ridges on the outer surface or by coarse stranding, and the cross-sectional area of an integral parallel specimen is to be computed by means of whichever of the following formulas is applicable:

$$A_{in^2} = \frac{W}{163.87\ G}$$

in which:

A is the cross-sectional area of the specimen in square inches,

W is the weight in grams (to the nearest 0.1 g) of a 10-inch length of insulation, and

G is the specific gravity of the compound determined as indicated in 470.5 – 470.9; or

$$A_{m^2} = \frac{4 \times 10^{-6}\,W}{G}$$

$$A_{cm^2} = \frac{0.04\,W}{G}$$

$$A_{mm^2} = \frac{4\,W}{G}$$

in which:

A is the cross-sectional area of the specimen in square meters, square centimeters, or square millimeters;

W is the weight in grams of a 250-mm length of insulation; and

G is the specific gravity of the compound determined as indicated in 470.5 – 470.9.

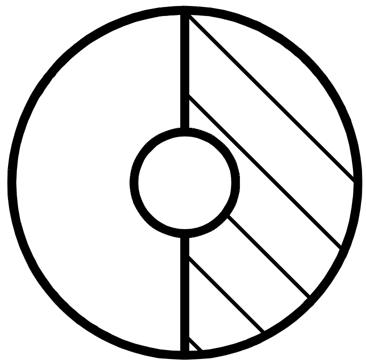
470.5 For use in any of the cross-sectional-area formulas in 470.4, the specific gravity G of a tubular specimen of irregular cross section of an integral parallel specimen is to be determined to two decimal places by the displacement method using a precision balance of a type that either yields the specific gravity G by direct reading (a Young's gravitometer) or requires calculation. All of the equipment, the water, the ethyl alcohol, and the specimen are to be at the same temperature (any convenient room temperature) throughout the procedure.

470.6 A clean 10-inch or 250-mm length adjacent to that used for preparation of the physical-properties specimens is to be cut from the finished integral parallel cord or wire or cable and the conductor(s), any covering(s) over the insulation, and any separator are to be removed. To reduce the likelihood of air being trapped in the hollow left by removal of the conductor(s), the length is to be cut parallel to its longitudinal axis through both walls of the hollow tube to result in samples with cross sections having the shapes shown shaded and unshaded in Figure 470.1. All of the cut surfaces of the sample are to be smooth.

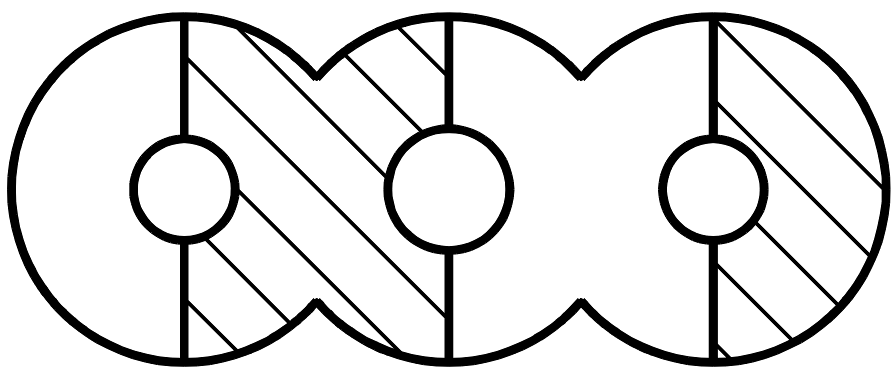
470.7 The samples are to be cut into lengths of 2 inches or 50 mm. A single short length is to be used as the specimen where it weighs 5 g or more. Several short lengths are to be used as the specimen where one short length weighs less than 5 g. The single short length or the bundle of short lengths is to be tied at its center with wire that is not larger in diameter than 0.0050 inch or 0.127 mm (No. 36 AWG) and is to be suspended by the wire from the weighing arm of balance.

470.8 Where a Young's gravitometer is used, the beam weights are to be adjusted to bring the pointer to rest at the infinity mark on the scale. A beaker or other wide-mouth container is to be filled with ethyl alcohol and placed on the platform in the instrument. The specimen is to be lifted by the wire and fully immersed in the alcohol and then removed from the alcohol and rinsed with distilled or demineralized water that is virtually free of air. The container of alcohol is to be removed and replaced with a similar container filled with virtually air-free distilled or demineralized water. The specimen is again to be lifted by the wire and then fully immersed in the water. The ethyl alcohol acts as a wetting agent and thereby helps to keep air bubbles from clinging to the specimen or wire while the specimen and wire are in the water. However, any bubbles that do remain are to be removed by rubbing the bubbles with a fine wire or by agitation of the specimen. Neither the suspending wire nor the specimen is to touch the container. The vibrator in the instrument is to be activated to assist the balance in reaching equilibrium. After equilibrium is reached, the specific gravity G is to be read to two decimal places directly from the scale.

Figure 470.1
Cross sections of samples after longitudinal cutting



single conductor

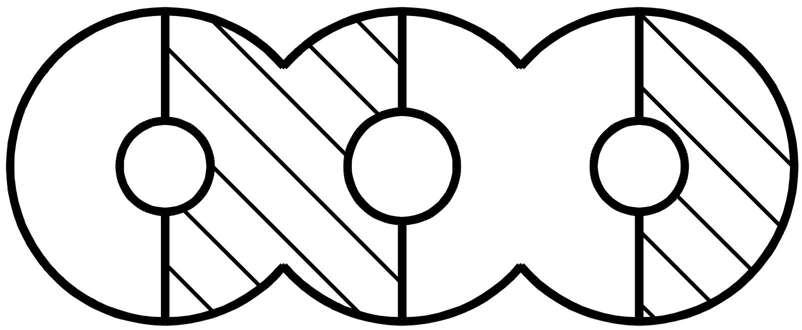


3 circuit conductors no grounding
conductor Types SRD and SRDT

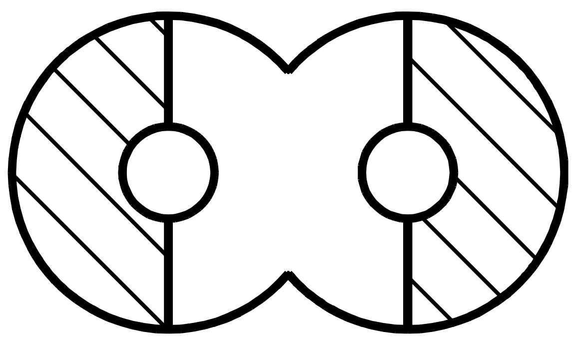
S4216

The vertical lines indicate the cutting that is required

Figure 470.1 (Cont'd)



2 circuit conductors with grounding conductor
Types SPT-1, SPT-2, SPT-3, and HPN



2 circuit conductors no grounding Types TPT,
clock, SP-1, SP-2, SP-3, SPT-1, SPT-2, SPT-3, and HPN

S4217

470.9 Where a balance other than a Young's gravitometer is used, the weight W_1 in air of the specimen without its suspending wire is to be determined to the nearest 5 mg. A beaker or other wide-mouth container is to be filled with ethyl alcohol and placed on a stationary support platform below the weighing arm of the balance. The specimen is to be lifted by the wire and fully immersed in the alcohol and then removed from the alcohol and rinsed with distilled or demineralized water that is virtually free of air. The container of alcohol is to be removed and replaced with a similar container filled with virtually air-free distilled or demineralized water. The specimen is again to be lifted by the wire and then fully immersed in the water. The ethyl alcohol acts as a wetting agent and thereby helps to keep air bubbles from clinging to the specimen or wire while the specimen and wire are in the water. However, any bubbles that do remain are to be removed by rubbing the bubbles with a fine wire or by agitation of the specimen. Neither the suspending wire nor the specimen is to touch the container. The weight W_2 in water of the fully immersed specimen and its partially immersed suspending wire is then to be determined to the nearest 5 mg. The point at which the wire meets the surface of the water is to be marked on the wire and the specimen is to be removed from the water and the wire. The wire is then to be reimmersed in the water to the depth of the mark and its weight W_3 is to be accurately determined. The specific gravity G of the specimen is to be calculated to two decimal places by means of the formula

$$G = \frac{W_1}{W_1 - W_2 + W_3}$$

470.10 The tensile strength of the specimen is then to be computed by means of the formula

$$S = \frac{P}{A}$$

or, for a die-cut specimen

$$S = \frac{P}{WT}$$

in which:

S is the tensile strength in pounds force per square inch, meganewtons per square meter, newtons per square centimeter, or kilograms force per square millimeter;

P is the maximum load in pounds force, meganewtons, or kilograms force;

W is the width of the specimen in inches, meters, centimeters, or millimeters; and

T is the thickness of the specimen in inches, meters, centimeters, or millimeters.

471 – 479 *Reserved for Future Use*

480 Accelerated Aging

General

480.1 Where die-cut specimens are not employed, the specimens of conductor insulation are to be lengths of individual conductors from which the conductor and any material applied over the insulation have been removed. Where die-cut specimens are employed, all splitting, skiving, buffing, planing, and die-cutting operations are to be completed at least 30 min before the specimens are placed in the chamber for aging or are immersed in oil. Measurements for determining the cross-sectional area are to be made as described for the physical tests of insulation and are to be made after the 30-min recovery period and before the specimens are aged or are immersed in oil. In the cases of immersion in ASTM Reference Fuel C and of air-oven aging, the bench marks for the determination of elongation are to be placed on the specimens after the specimens are removed from the immersion vessel or from the chamber in which they were aged. For oil immersion, the marks are to be placed on the specimens before they are immersed in oil.

480.2 Physical tests are to be made on both aged and unaged specimens at the same time and at a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unaged specimens are to be maintained at this room temperature for not less than 30 min prior to being subjected to the physical tests. Specimens that have been subjected to air-oven aging are to rest for not less than 16 h and not more than 96 h at this room temperature following their removal from the Fuel C or oven and prior to their being subjected to the physical tests. Specimens that have been subjected to oil immersion are to be blotted lightly to remove any excess oil and are then to be suspended in air at the above-mentioned room temperature for 3.5 – 4.5 h before being subjected to the physical tests. Specimens that are to be aged in an oven are to be suspended vertically and are not to touch one another or the sides of the chamber at any time. Specimens having widely different properties or composition are to be aged in separate ovens. See 420.8 and 420.9.

Air-oven aging

480.3 The specimens are to be heated at the required temperature for the specified time in an oven complying with 420.9, and oven temperatures are to be recorded throughout the time of heating.

480.4 *Reserved for Future Use*

Oil immersion

480.5 The oil referred to in the following paragraphs is IRM902. ASTM D 471-98 specifies this oil as a standard test liquid.

480.6 The immersion vessel is to be a test tube having an overall diameter of at least 1 inch or 25 mm and a length of at least 6 inches or 150 mm. The tube is to be filled with oil and then placed in a bath having an automatic temperature control that maintains the specimens at the specified temperature. Specimens of finished 14 – 7 AWG wires with or without the conductor removed are to be bent at the center to form a narrow U and are then to be suspended vertically in the oil with the ends of each specimen projecting above the oil. Specimens of Types THWN-2, THWN, and THHN wire are to be immersed without removal of the nylon jacket. After immersion for the specified length of time, each specimen is to be cut in half at the center of the U bend to result in two specimens for physical tests from each length immersed. A larger vessel is to be used for die-cut specimens that are to be suspended vertically in the oil.

480.7 Except for specimens of oil-resistant Type TFN and Type TFFN wires (see 480.8), the oil-immersion vessel for flexible cord and elevator cable is to be a stainless-steel beaker or cup with a flat-plate cover and having a capacity of 500 mL. The vessel is to be filled with oil and placed in a liquid bath or a full-draft circulating-air oven. The bath is to be provided with a stirring device and automatic temperature control and is to employ a liquid for maintaining the specimens at the specified temperature. The oil in the immersion vessel is to be heated to the specified temperature before the specimens are immersed. Die-cut specimens are to be suspended vertically in the oil. Specimens of conductor insulation are to be immersed in the form of a vertical U, with the ends of each specimen (conductor or conductors removed or in place) projecting above the oil.

480.8 For specimens of oil-resistant Type TFN and Type TFFN fixture wires, the immersion vessel is to be a test tube having an overall diameter of at least 1 inch or 25 mm and a length that facilitates immersion of a straight specimen at least 6 inches or 150 mm long. The tube is to be filled with oil and placed in a bath or a full-draft circulating-air oven having an automatic temperature control that maintains the specimens at the specified temperature. Specimens of finished wire with or without the conductor removed are to be bent at the center to form a narrow U and are then to be suspended vertically in the oil, with the ends of each specimen projecting above the oil. The specimens are to be immersed without removal of the nylon jacket. After immersion for the specified length of time, each specimen is to be cut in half at the center of the U bend to result in two specimens for physical tests from each length immersed.

Gasoline immersion

480.9 The immersion vessel and specimens for the immersion tests of gasoline-resistant Type TFN and TFFN fixture wires are to be as indicated in 480.8, with 1 inch or 25 mm of tap water at the bottom and the remainder of the vessel filled with ASTM Reference Fuel C, which is described in ASTM D 471-98.

480.10 The immersion vessel and specimens for gasoline immersion of other than Type TFN and TFFN are to be as indicated in 480.6, with 1 inch or 25 mm of tap water at the bottom and the remainder of the vessel filled with ASTM Reference Fuel C (see ASTM D 471-98).

480.11 ASTM Reference Fuel C can be made by mixing equal volumes of iso-octane and toluene. The following precautionary statements apply

Iso-octane:

DANGER – Extremely Flammable. Harmful where inhaled. Vapor may cause flash fire.

Do not smoke.

Eliminate all sources of ignition, especially electrical equipment that is not explosion-proof.

Use and store in closed containers.

Use forced ventilation.

Avoid build-up of vapor.

Do not breathe vapor.

Protect eyes and skin from contact.

Toluene:

DANGER – Flammable. Vapor harmful where inhaled. Central nervous system depressant. Vapor and liquid irritate eyes, mucous membranes, and skin.

Do not smoke.

Eliminate all sources of ignition.

Use and store in closed containers.

Use forced ventilation.

Do not breathe vapor.

Protect eyes and skin from contact.

481 Long-Term Aging

481.1 The temperature rating of a material is to be determined using the method of testing and evaluation described in 481.2 – 481.8.

481.2 Specimens of insulation or jacket material are to be prepared as described in Preparation of Specimens, Section 440. The prepared specimens are to be placed in a full-draft circulating-air oven that complies with 420.9. The oven is to be operating at the temperature specified in 481.3 at the time that the specimens are placed. The total number of specimens in the oven is to enable removal of specimens in sets of at least six at a time at intervals of 90, 120, and 150 days and, at the manufacturer's request, at additional intervals of 180 and 210 days.

481.3 The oven operating temperature T_{test} is to be 102 percent of the desired temperature rating expressed on the absolute (Kelvin) scale. This temperature is to be calculated using the following formula. T_{test} is to be rounded to the nearest whole number.

$$T_{test\ (°C)} = 1.02 \times [273.15 + T_{rating\ (°C)}] - 273.15$$

481.4 After each of the aging intervals indicated in 481.2, a set of specimens is to be removed from the oven and the specimens in that set are to be tested individually for ultimate elongation as described in Ultimate Elongation and Tensile Strength, Section 470. The elongation value resulting for each specimen is to be expressed and recorded in percent. The elongation values for six specimens are to be averaged for each aging time interval. Each of the averages is to be recorded to the nearest whole percent.

481.5 The formula for elongation (mathematical model) is:

$$E(t) = E_{90} \times e^{-R(t-90)}$$

The variables in the formula are the elongation in percent $E_{(t)}$, the time in days t, the regression constant E_{90} (the elongation computed at 90 days), and the decay constant R.

481.6 The variables in the formula transformed as $Y = In[E(t)]$, $B = In[E_{90}]$, and $T = (t - 90)$ put the formula into a linear form:

$$Y = B - RT$$

481.7 Using the 90-day and longer-term data, the constants B and R are to be determined by least squares linear regression. The projected elongation at 300 days is then to be calculated.

481.8 The elongation calculated for 300 days shall not be less than 50 percent.

482 – 489 *Reserved for Future Use*

COMPOUND ANALYSIS

Polyvinyl Chloride (PVC) Compounds

490 Infrared Spectroscopy

490.1 GENERAL – Infrared Analysis is to be used to provide a method for the identification of PVC wire and cable compounds. Interpretation of infrared spectral transmittance is to be used to identify the composition of a compound by comparing the compound's infrared spectra to the spectra of materials having known compositions.

490.2 The analysis is to be performed with a Fourier Transform Infrared (FTIR) Spectrometer and/or a Dispersive Infrared Spectrophotometer. The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the sample versus the number of wavelengths in one centimeter [the reciprocal wavelength (cm^{-1}) or ″wavenumber″] of the radiation. Percent transmittance is to be expressed on the ordinate and wavenumber on the abscissa. The infrared spectra obtained by the methods described is to consist of a wavenumber range of at least 4000– 400 reciprocal centimeters.

490.3 SAMPLE PREPARATION / TEST PROCEDURE– The PVC compound is to be separated into solvent-soluble and solvent-insoluble fractions by use of a centrifuge and/or by filtration. Stabilized (peroxide-inhibited) tetrahydrofuran (THF) **See 490.4**, or other solvents with demonstrated comparable solubilities, are to be used. Stabilized (peroxide-inhibited) THF is the solvent of choice and centrifugation is the preferred fraction-separation method of choice. The solvents are to be readily evaporable by gentle heating and are not to react with the PVC material. The THF stabilizer/peroxide inhibitor component shall not be present in quantities detectable in the infrared spectra. Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

490.4 PARTICULAR CAUTIONS WITH THF, AN ETHER– Tetrahydrofuran (THF) is indicated as a solvent in Infrared Spectroscopy, Section 490, Elemental Analysis, Section 492, and Gel Permeation Chromatography, Section 493 of this standard, and use of ***stabilized*** THF is specified. **Unstabilized THF shall not be used.** Stabilization of an ether inhibits the formation of peroxides, which are explosive when concentrated. Peroxides often concentrate as an ether is stored or exposed to air for a prolonged period; as an ether is distilled, heated to dryness, or otherwise evaporates; as heat/shock/friction are applied; and upon disposal in a manner in which incompatible materials are mixed.

490.5 The solvent-soluble compound fraction is to be cast on an optically transparent potassium bromide (KBr) crystal. The crystal is to be placed in an explosion-proof oven to evaporate the solvent, leaving a thin film of the soluble compound fraction on the KBr crystal. The crystal is then to be placed directly into the sample holder of the instrument for recording the infrared spectrum.

490.6 The insoluble portion is to be washed with additional solvent, centrifuged, and then decanted to remove the soluble compound components (resin, plasticizer, and the like). The insoluble portion is to be placed in an explosion-proof oven to evaporate the solvent. After drying, the insolubles are to be mixed with powdered spectroscopic-grade potassium bromide (KBr) and ground in a vibrating ball mill. A quantity of this mixture that produces a disk typically 1 mm thick and 1/2 inch or 12.7 mm in diameter is then to be placed in an evacuable die. The die is to be put under a vacuum and mechanical pressure of 10,000 – 15,000 lbf/in^2 or 69 – 103 MPa or 7 – 11 kgf/mm^2 is to be applied. The pressed disk is to be removed from the die, put into a disk holder, and then placed directly into the sample holder of the instrument for recording the infrared spectrum.

490.7 In the event that the PVC compound is not soluble in stabilized THF or hot ortho-dichlorobenzene, the IR spectrum is to be created from the preparation techniques described in Infrared Spectroscopy, Section 494 of this standard.

490.8 Pyrolytic Gas Chromatography (Section 495) is appropriate in place of Infrared Analysis of the PVC compound where the compound is not soluble in stabilized THF or in ortho-dichlorobenzene and the IR sample preparation techniques described in Infrared Spectroscopy, Section 494, are not effective.

490.9 REPORT – The individual spectra are to include all of the following:

a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The sample preparation procedure or preparation code.

d) The instrument parameters (number of scans, resolution, slit program, and the like).

e) The test date and operator identification.

491 Determination of the Ash Content

491.1 GENERAL – This method is to be used to determine the amount of noncombustible components in a PVC wire and cable material. This is similar to the direct-calcination procedure (Method A) described in ISO 3451-89, Part 5, covering methods for the ash-content analysis of polyvinyl chloride (PVC) materials.

491.2 MATERIALS AND EQUIPMENT – The following equipment is to be used in conducting the test:

a) An analytical balance capable of weighing to the nearest 0.1 mg.

b) Silica or platinum crucibles of a size fillable to no more than half way by the test portion.

c) A fume hood over the burner specified in (d) and a fume hood over the furnace specified in (e).

d) Burner apparatus consisting of a Bunsen burner with a tripod and a clay triangle for supporting the crucible above the burner flame.

e) A muffle furnace controlled thermostatically to a temperature of 850 ±50°C (1562 ±90°F).

f) A desiccator containing an effective drying agent that does not react with the ash components.

491.3 TEST PROCEDURE – A sample of the PVC compound (typically 4 – 5 grams) is to be placed in a weighed crucible that has been dried to a constant weight. The weight of the dried crucible plus the sample is to be recorded. Under the fume hood, the crucible is to be heated using the burner apparatus in a manner that burns the sample slowly and does not result in any loss of the ash. When the smoking ceases, the crucible is to be placed in a muffle furnace under an operating fume hood and heated at 850 ±50°C (1562 ±90°F) for 30 min. The crucible is to be removed from the furnace, cooled in a desiccator, and weighed. The crucible is to be returned to the furnace for an additional 30 min and then is to be cooled and reweighed. This calcination procedure is to be repeated until constant mass is reached – that is, until the results of two consecutive weighings do not differ by more than 0.5 mg. However, the duration of heating in the furnace is not to exceed a total of 3 h. Where a constant mass is not attained in 3 h, the mass (weight) after 3 hours is to be used for calculating the results.

491.4 At least two determinations are to be performed and the mean of the results calculated. Where the individual test results differ from one another by more than 10 percent of the mean, the procedure is to be repeated until two successive results do not differ by more than 10 percent of the mean.

491.5 CALCULATIONS – The ash content is to be calculated in percent by dividing the weight of the residue after ignition at 850 ±50°C (1562 ±90°F) by the original weight of the sample and multiplying by 100. The average of the results of the two or more determinations is to be recorded as the ash content.

491.6 REPORT – The report is to include each of the following:

a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.

b) The name and/or trade name of the material manufacturer and the assigned code (file number).

c) The weights recorded to the nearest 0.1 mg.

d) The average ash content calculated to the nearest 0.1 percent.

e) The test date(s) and operator identification.

492 Elemental Analysis

492.1 GENERAL – Elemental Analysis is to be used to provide quantitative data on the lead, cadmium, barium, or zinc content of a PVC wire and cable compound. The heat stabilizer system typically consists of compounds of one or more of these metals.

492.2 The analysis is to be performed on an atomic absorption (AA) spectrophotometer by the flame technique. The instrument is to be calibrated using standards of known metallic content. The sample solutions are then to be analyzed and the values derived by plotting the readings on the calibration curve.

492.3 One of two sample preparation methods is to be used as described in this section. Where the Perchloric / Nitric Acid Digestion method (Method 1) cannot be used, Method 2 is to be employed. In either case, quantitative metal content comparisons are to be made between data derived only from the same sample preparation method.

492.4 Precautions are to be taken for the safe handling, storage, and disposal of each solvent and acid employed.

492.5 SAMPLE PREPARATION METHOD 1 (PERCHLORIC / NITRIC ACID DIGESTION FOR LEAD, CADMIUM, ZINC, AND BARIUM) – Under an operating fume hood, the PVC sample (250 – 325 mg) is to be digested on a hot plate in an equal mixture of concentrated perchloric acid (69 – 72 percent) **See 492.6** and concentrated nitric acid (69 – 71 percent). This digestion is to proceed over moderate heat in an oxidizing state until all of the polymeric and other carbon-based materials are decomposed. The solution is to be cooled. The solution is then to be filtered. The digestion beaker and filter paper are to be washed with several portions of hot, dilute nitric acid. The filtrate and washings are to be diluted to a known volume and analyzed.

492.6 PARTICULAR CAUTIONS WITH PERCHLORIC ACID, AN OXIDIZING MATERIAL – Perchloric acid is indicated as half of the digestive mixture in 492.5 of this Standard, and use in a ***concentrated*** (69 – 72 percent) form is specified. Perchloric acid can ignite upon contact with combustible material or a dehydrating agent or upon disposal in a manner in which incompatible materials are mixed. Perchloric acid in any concentration destroys living tissue upon contact.

492.7 SAMPLE PREPARATION METHOD 2 (NITRIC ACID DIGESTION OF THE THF-INSOLUBLE PORTION FOR LEAD, CADMIUM, AND ZINC) – The PVC sample (250 – 325 mg) is to be dissolved in a test tube using stabilized tetrahydrofuran (THF) **See 490.4** or another solvent with demonstrated comparable compound component solubilities and Pb, Cd, Zn, and Ba recoveries. The solution is to be centrifuged to separate the insolubles. The THF/PVC resin solution is to be decanted, and the insoluble portion washed with additional solvent, centrifuged, and decanted to remove the soluble compound components. The insoluble pellet is then to be dried in an explosion-proof oven. After drying, the pellet is to be dissolved in dilute nitric acid and the solution is to be filtered. The tube and filter are to be washed several times with hot, dilute nitric acid. The sample is to be diluted to a known volume and analyzed.

492.8 SAMPLE PREPARATION METHOD 2 (HYDROCHLORIC ACID DIGESTION OF THE SAMPLE ASH FOR BARIUM) – The PVC sample (1.0 – 1.2 g) is to be ashed slowly using a ceramic crucible in a muffle furnace by raising the temperature from 250 to 650°C in steps. The final temperature is to be held for 30 min. The ash is to be digested with a hot, 50-percent solution of hydrochloric acid. The solution is then to be filtered. The crucible and filter are to be washed several times with hot, 10-percent hydrochloric acid. The sample solution is to be diluted to a known volume and analyzed.

492.9 REPORT – The report is to include each of the following:

a) The sample preparation method used (Method 1 or Method 2) and complete identification of the PVC material tested– including the designation for the material and the form and color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The sample weight, initial volume including any dilutions, and the AA spectrophotometer response.

d) The type of metal and its content in the material expressed in parts per thousand of the compound.

e) The test date(s) and operator identification.

493 Gel Permeation Chromatography

493.1 GENERAL – Gel Permeation Chromatography (GPC) is a type of liquid chromatography that employs a porous gel as a separation medium. GPC typically is used to analyze large compounds such as polymers that are not appropriate for traditional chromatographic separation media. The method described here is designed to analyze the organic-soluble non-resin PVC wire and cable compound components (for example, plasticizers) that appear within the working range of the column bank.

493.2 This analysis is to be performed with small-particle-and-pore-size cross-linked spherical polystyrene/divinylbenzene matrix-column packing material. Compound components that appear within the working range of the column bank are to be evaluated. Refractive Index and Ultraviolet detection are to be used for qualitative evaluations. Quantitative evaluations are to be performed by the internal standard method (relative to a plasticizer standard) employing refractive-index detection. Relative quantitative calculation is to be derived from detector responses of the sample and from the plasticizer/internal standard calibration curve. For the chromatograph mobile phase and as the solvent for sample and standards preparation, stabilized tetrahydrofuran (THF) **See 490.4** or another solvent with demonstrated comparable PVC resin and compound component solubilities, chromatographic resolutions, and detector responses is to be used. Comparisons are to be made between data derived only from use of the same solvents.

493.3 Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

493.4 STANDARDS PREPARATION – The standards are to consist of three stabilized tetrahydrofuran (THF) solutions containing different concentrations of a typical vinyl-compound plasticizer and identical concentrations (approximately 0.2 percent by volume) of the internal standard. The plasticizer concentrations are to represent typically 5, 25, and 50 percent of the sample mass diluted to the same volume.

493.5 SAMPLE PREPARATION – A sample of the PVC compound (typically 250 mg) is to be combined with stabilized THF and the internal standard. The compound/internal standard/THF solution is to be agitated to dissolve the resin and then is to be transferred to a volumetric flask. Additional portions of stabilized THF are to be added to the initial compound/internal standard/THF container and agitated to extract any residual compound components or internal standard. The washes are to be added to the volumetric flask and brought to a final concentration near 5 mg/ml (compound/stabilized THF). The volumetric solution is then to be filtered to remove particulates before entering the sample loop of the chromatograph.

493.6 REPORT – The report is to contain each of the following:

a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The sample weights, dilution volumes, detector responses, and calibration curve slopes.

d) A refractive index chromatogram including all of the evaluated components.

e) The average relative percent of compound results of the quantified components to the nearest 0.01 percent.

f) The test date(s) and operator identification.

Nylon and TPE compounds

494 Infrared Spectroscopy

494.1 GENERAL – Infrared Analysis is to be used as the method for the identification of nylon or TPE wire and cable compounds. Interpretation of infrared spectral transmittance is to be used to identify the composition of a compound by comparing the compound's infrared spectra to the spectra of materials having known compositions.

494.2 The analysis is to be performed with a Fourier Transform Infrared (FTIR) Spectrometer and/or a Dispersive Infrared Spectrophotometer. The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the sample versus the number of wavelengths in one centimeter [the reciprocal wavelength (cm^{-1}) or ″wavenumber″] of the radiation. Percent transmittance is to be expressed on the ordinate and wavenumber on the abscissa. The infrared spectra obtained by the methods described is to consist of a wavenumber range of at least 4000– 400 reciprocal centimeters.

494.3 SAMPLE PREPARATION – The general polymer-specimen preparation techniques for infrared analysis include solvent casts, potassium bromide (KBr) pellets, solvent-slurry KBr pellets, glass-plate cast films, and reflectance accessories. Solvents typically include chloroform, o-dichlorobenzene, formic acid, and m-cresol. Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

494.4 Thermoplastic/solvent solutions are to be placed or ″cast″ on an optically transparent salt crystal [on potassium bromide (KBr), for example] from which the solvent is to be evaporated by gentle heating, thereby leaving a uniform thin film of polymer. The salt plate is then to be mounted directly in the instrument and the infrared spectrum of the material recorded. For nylon materials that are soluble in formic acid, the polymer solution is to be cast on a glass plate. After evaporation of the solvent, the thin polymer film is to be removed from the glass, placed in a film holder, and mounted in the instrument for recording the infrared spectrum.

494.5 The solvents used are to be those that dissolve the nylon or TPE material without reacting with it and are readily evaporated by gentle heating. Examples of solvents for certain polymer types are:

a) Chloroform – For many thermoplastic polymers (for example, styrenic TPE compounds).

b) o-Dichlorobenzene – For many TPE compounds.

c) Formic Acid – For many nylons (polyamides).

d) m-Cresol – For certain nylons (polyamides).

494.6 High-molecular-weight, high-crystalline, heavily filled, or cross-linked nylon or TPE materials that are insoluble in all volatile solvents are to be prepared by the pressed halide disk-or-pellet technique. A few milligrams of the material are to be removed from the surface of a sample by a razor blade or fine file. These scrapings or filings are to be ground in a vibrating ball mill for 3 – 5 min. To minimize scattering effects, the particles are to be reduced to a size (typically 2 (m) that is smaller than the shortest wavelength to be scanned. The ground specimen is to be intimately mixed with powdered spectroscopic-grade potassium bromide (KBr), and a quantity of this mixture that produces a disk typically 1 mm thick and 1/2 inch or 12.7 mm in diameter is to be placed in an evacuable die. The die is to be put under a vacuum and mechanical pressure of 10,000– 15,000 lbf/in^2 or 69 – 103 MPa or 7 – 11 kgf/mm^2 is to be applied. The pressed disk is to be removed from the die, put into a disk holder, and then placed directly into the sample holder of the instrument for recording the infrared spectrum of the material.

494.7 REPORT – The individual spectra are to be marked with each of the following:

a) Complete identification of the nylon or TPE material tested – including the designation for the material and the form and color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The sample preparation procedure or the preparation code.

d) The instrument parameters (number of scans, resolution, slit program, and the like).

e) The test date(s) and operator identification.

495 Pyrolytic Gas Chromatography

495.1 GENERAL – Pyrolytic Gas Chromatography is to be used to identify nylon or TPE wire and cable compounds. A gas chromatograph equipped with a pyrolysis accessory is to be used for volatilizing the solid specimens for analysis. The pyrolysis products are to be swept through the column of the gas chromatograph by means of a carrier gas. The results are to be recorded as a plot of time (measured from the start of the analysis) versus the detector response to the individual fractions produced by the pyrolysis. This plot is to be used as the ″pyrogram″ of the material.

495.2 This identification technique is to be used where infrared analysis is not effective, as when the nature of certain resins or additives makes it difficult to prepare specimens for the infrared method. Typically, this applies to materials with a high carbon black or metallic content.

495.3 INSTRUMENTATION – The gas chromatograph, pyrolysis devices, and columns are not specified as long as the parameters and the system hardware are identical for all test data that are being compared. Typically, thermal-conductivity or flame-ionization detection is to be used for pyrolysis gas chromatography, with helium or nitrogen as the carrier gas.

495.4 REPORT – The individual pyrogram is to include each of the following:

a) Complete identification of the nylon or TPE material tested – including the designation for the material and the form and color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The operating conditions or instrument method reference for the analysis.

d) The test date(s) and operator identification.

496 Thermogravimetry

496.1 The test method for determination of the rapid thermal decomposition of a solid nylon or TPE wire and cable material by Thermogravimetry is to be as described in the Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method (TGA), ASTM D 3850-94(R2000), except that the specimen is to be heated at the rate of 20°C (36°F) per minute in a nitrogen atmosphere. Additional testing using different test parameters is to be conducted where agreeable to those concerned.

496.2 ASTM D 3850 describes a method in which small pieces cut from a test specimen are heated at a controlled rate until degradation is complete. The resulting thermogram, which plots percent specimen mass versus increasing temperature, is to be used to identify the tested material.

496.3 The individual curve is to include each of the following:

a) Complete identification of the nylon or TPE material tested – including the designation for the material, the generic type of material, and the color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The operating conditions used for the Thermogravimetry.

d) The test date(s) and operator identification.

497 Differential Scanning Calorimetry

497.1 The test method for determining the transition temperatures of solid nylon or TPE wire and cable compounds by Differential Scanning Calorimetry (DSC) is to be as described in the Standard Test Method for Transition Temperatures of Polymers by Thermal Analysis, ASTM D 3418-99, except that the specimen is to be heated at the rate of 20°C (36°F) per minute in a nitrogen atmosphere without a preliminary thermal cycle. Additional testing using different test parameters is to be conducted where agreeable to those concerned.

497.2 ASTM D 3418 describes a method in which thin sections of the material are heated at a controlled rate through the thermal transitions of interest. The resulting thermogram, which plots these transitions as heat flow versus increasing temperature, is to be used to characterize the tested material.

497.3 The individual curve is to be marked with each of the following:

a) Complete identification of the nylon or TPE material tested – including the designation for the material, the generic type of material, and the color of the sample.

b) The name and/or tradename of the material manufacturer and the assigned code (file number).

c) The operating conditions used for the Differential Scanning Calorimetry.

d) The test date(s) and operator identification.

498 and 499 *Reserved for Future Use*

CONDUCTOR CORROSION

500 General

500.1 A copper or copper-clad aluminum conductor removed from unaged specimens of the finished wire, cable, or cord and from specimens aged at elevated temperature as described in the physical-properties requirements in Specific Materials, Section 50, 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. The examination is to be made with normal or corrected vision without magnification.

501 – 519 *Reserved for Future Use*

INSULATION FALL-IN

520 Test

520.1 A 3-inch or 75-mm length of the insulation is to be stripped from a sample length of the finished stranded conductor, and the outer surface of the conductor is to be cleaned with a wire brush to remove the visible insulation. The outermost strands are to be peeled back where any insulation is found on the portions of these strands that were not accessible to the wire brush or on the remainder of the conductor beneath these strands, the wire or cable does not comply.

521 – 539 *Reserved for Future Use*

HEAT SHOCK

540 Test

540.1 The test of flexible-cord and fixture-wire conductor insulation, parallel-cord insulation, and other insulation is to be made using specimens of finished individual conductors (unseparated in the case of a parallel cord). The test of jacket material is to be made using specimens of the complete wire, cable, or cord or Type TFN and TFFN fixture wires (nylon in place). Each specimen is to be tightly wound for six complete turns (except as specified for the larger sizes of jacketed constructions) around a mandrel having the specified diameter. Successive turns are to be made in contact with one another, and both ends of the specimen are to be securely held in place. The specimens are to be examined on their inside and outside surfaces after heating for 1 h to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) in a full-draft circulating-air oven that complies with 420.9. Circumferential depressions in the outer surface indicate cracks on the inside surface of the insulation or jacket of most materials. Circumferential depressions in a fluoropolymer outer surface are indications of cracking or yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

540.2 In the case of a Type TW, THW-2, THHW, THW, THWN-2, THWN, THHN, TBS, or other wire having a 1 AWG or smaller conductor, four adjacent turns are to be tightly wound around the mandrel and both ends of the specimen are to be securely held in place by means of friction tape. In the case of a Type TW, THW-2, THHW, THW, THWN-2, THWN, THHN, TBS, or other cable having a 1/0 AWG or larger conductor, a U bend is to be made with the specimen in contact with the mandrel for not less than 180°, and the specimen is to be securely held in place. The specimens are to be examined on their inside and outside surfaces after heating for 1 h to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) in a full-draft circulating-air oven that complies with 420.9. Circumferential depressions in the outer surface indicate cracks on the inside surface of most materials. Circumferential depressions in a fluoropolymer outer surface are indications of cracking or yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

541 – 559 *Reserved for Future Use*

DEFORMATION

560 Test

560.1 For the No. 14 – 4/0 AWG sizes of thermoplastic-insulated, thermoset-insulated, or other wire, the insulation thickness T_1 is to be determined from measurements made at a marked position on a 1-inch or 25-mm length of the finished, insulated conductor. The diameter D_1 over the insulation is to be measured to the nearest 0.001 inch or 0.01 mm by means of a dead-weight dial micrometer whose presser foot puts a load of 85 ±3 gf or 0.84±0.02 N or 3.0 ±0.1 ozf on the specimen. The presser foot is to have a flat, round face whose diameter is 0.250 ±0.010 inch or 6.4±0.2 mm. The anvil of the instrument is to be round, is to be at least 1.5 inches or 38 mm in diameter, and is to be parallel to the face of the presser foot. The diameter d over the conductor, or over any separator, is to be measured by means of the same dial micrometer. The thickness T_1 is then to be calculated to the nearest 0.001 inch or 0.01 mm from the formula

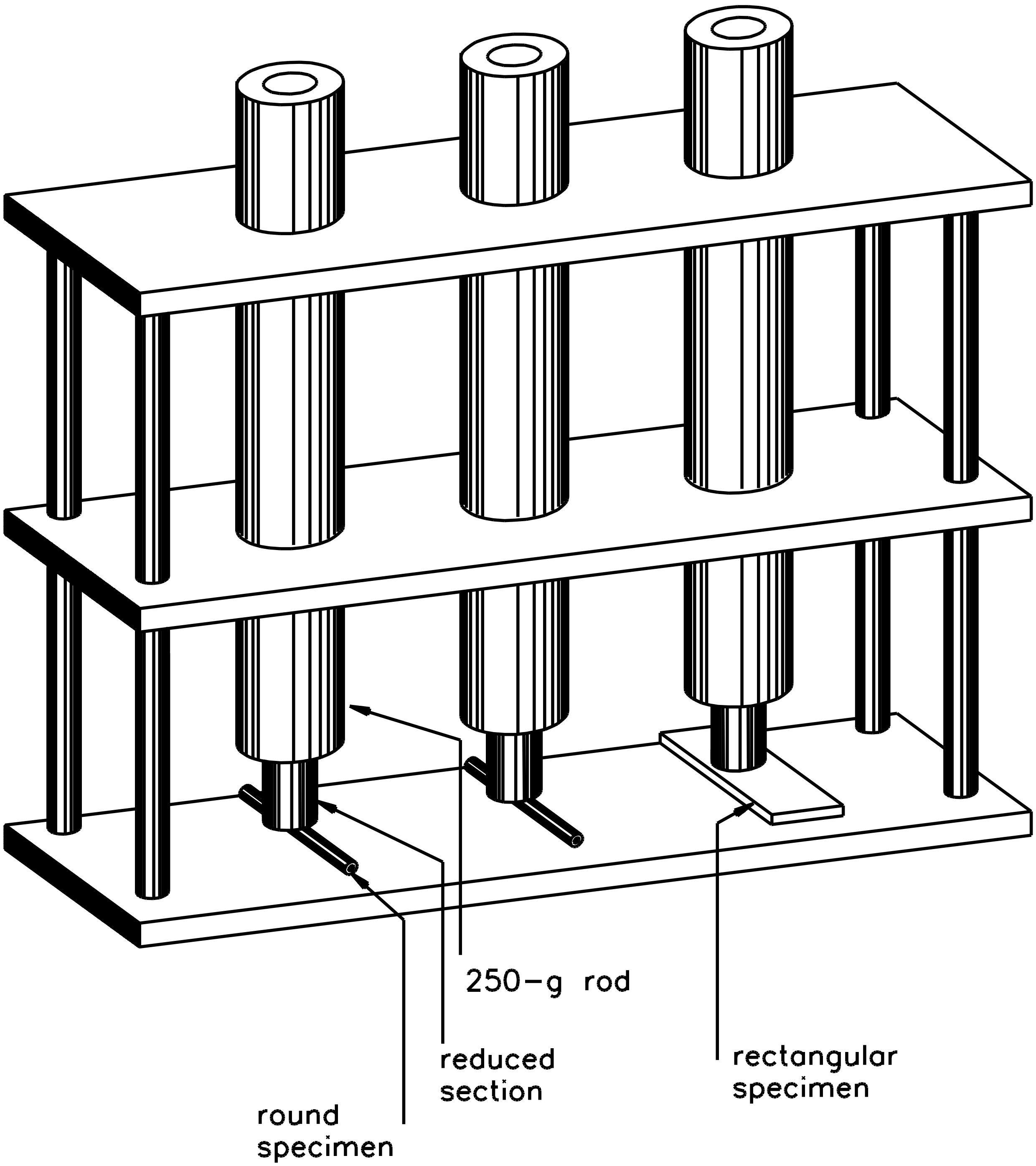
$$T_1 = \frac{D_1 - d}{2}$$

560.2 For the 250 – 2000 kcmil sizes of thermoplastic-insulated, thermoset-insulated, or other wire, and for the jacket removed from finished jacketed cable or flexible cord, a sample of insulation or jacket 8 inches or 200 mm long is to be removed from the finished insulated cable, conductor, or cord. A rectangular specimen 1 inch long and 9/16 inch wide or 25 mm by 14 mm is to be sliced from the sample and then buffed or planed or split or skived as indicated in 440.3 to a uniform thickness of not more than 0.060 inch or 1.52 mm, with both surfaces smooth. At a marked position, the thickness T_1 of a rectangular specimen is to be measured to the nearest 0.001 inch or 0.01 mm by means of the dead-weight dial micrometer described in 560.1. The entire surface of the presser foot is to be in contact with the rectangular specimen during each measurement.

560.3 The insulated conductors of a parallel cord are to be separated. The insulation thickness T_1 of an insulated conductor from a parallel or jacketed cord or from a fixture wire is to be determined as indicated in 560.1 from measurements made at a marked position on a 1-inch or 25-mm length of insulated conductor from the finished flexible cord or fixture wire.

560.4 The apparatus for this test is illustrated in Figure 560.1. The apparatus is to be of brass and is to consist of three rods that are free to move vertically in a support frame. The assembly is to be constructed for use in a heated oven. Each rod is to be straight and 0.750 ±0.010 inch or 19.0 ±0.2 mm in diameter. The weight of each rod is to be 250 g. The lower end of each rod is to be reduced in diameter to 0.375 ±0.010 inch or 9.5 ±0.2 mm for the final 3/4-inch or 19-mm length of the rod. The lower end of the reduced-diameter section is to be flat, round, without sharp edges, and both concentric with and perpendicular to the longitudinal axis of the rod. The lower end of the reduced section is to serve as the foot that presses on a specimen during a test. The force on the specimen is to be the sum of the force exerted by the rod (250 g or 2.45 N) plus that of any weight to be placed on the upper end of the rod to make the total force equal the load specified in the wire standard. Each weight is to be indent stamped with its exact weight.

Figure 560.1
Deformation test apparatus with specimens in place
Added weights are not shown



SM378

560.5 The frame is to consist of three flat, rectangular plates spaced 2-1/4 inches or 57 mm apart (vertical separation) and parallel to one another in a rigid assembly. The dimensions of the plates are to be the same (plates measuring 8-1/2 inches by 2-3/4 inches by 1/4 inch or 216 mm by 70 mm by 6 mm are typical). The upper surface of the lower plate is to be the surface against which each rod presses a specimen during a test. That surface is to be horizontal during a test. That surface is to be smooth (the surface is to be refinished when repeated testing indents the surface or makes it rough to the touch). Identically located holes are to be provided through the center and upper plates to serve as guides and supports for the rods, which are to be free to move vertically and not otherwise. The diameter of each hole is to be larger than the 3/4-inch-diameter or 19-mm-diameter portion of a rod for clearance of vertical movement of a rod in the hole. Horizontal separation (2-3/4 inches or 70 mm is typical) between the rods is to enable weights to be in place on all three rods at the same time with a clearance (1/4 inch or 6 mm is typical) between the weights. Each rod is to project a distance above the upper plate that enables a weight to be placed on the upper end of the rod without the weight touching the upper plate while the rod is resting on the lower plate (no specimen under the rod). Means integral with the frame is to keep the frame above the floor of the oven and stable during a test (3/8 inch or 9.5 mm is typical).

560.6 With the applicable weight (where needed) in place on each rod that is to be used for a test, the apparatus is to be placed beside one or more test specimens in an air oven (a dead-air, full-draft, or internal-fan oven is appropriate) that has been preheated to a temperature of 150.0 ±1.0°C (302.0 ±1.8°F) for specimens from wire or cord with Class 36 TPE insulation or jacket, 100.0 ±1.0°C (212.0±1.8°F) for specimens of Class 30 PE insulation, 136.0 ±1.0°C (276.8 ±1.8°F) for specimens from Type THHN wire, and 121.0 ±1.0°C (249.8 ±1.8°F) for all other specimens. The specimens and the loaded apparatus are to remain side by side in the oven for 60 min of preliminary heating at full draft. At the end of the 60 min, one rod is to be lifted and a specimen is to be centered under it. The loaded rod is to be lowered and gently bear on the specimen at the marked position. The rod is to continue to bear on the specimen while the apparatus and the specimen remain in the oven for an additional 60 min. The entire surface of the foot of the rod is to be in contact with any specimen that is rectangular.

560.7 At the end of the second 60 min, the rod is to be lifted and the specimen under it is to be removed. The specimen diameter (round specimen) or thickness (rectangular specimen) is to be measured for determination of the specimen thickness T_2 to the nearest 0.001 inch or 0.01 mm. The measurement is to be made at the marked position in the same way as the specimen was measured for determining T_1. In the case of a round specimen, the diameter d over the conductor or any separator is not to be remeasured – that is, in the calculation of T_2, it is appropriate to use the measured value of d that was used in calculating T_1. To minimize the time that the specimen has to recover before its deformed diameter or thickness is measured, measurement is to be made in a short time after the rod is lifted. Where more that 15 s elapses between the time at which the rod is lifted and the time of measurement, the specimen is to be discarded and the test is to be repeated with a new specimen. The percent deformation is to be calculated for the specimen from the following formula. The calculated percentage is to be compared with the maximum deformation stated in the requirement in the wire standard.

$$\text{Deformation in percent} = \frac{100 \times (T_1 - T_2)}{T_1}$$

560.8 Where the calculation for the single specimen shows a greater deformation than the maximum stated in the requirement, the test is to be repeated using three new specimens (see special case in 560.9). At the end of the second 60 min, these three specimens are not to be removed from under the rods at the same time. Instead, the procedure of lifting the rod, removing the specimen, and quickly making the measurement is to be followed for each specimen in turn. Each of the three specimens is to show a deformation equal to or less than the maximum stated in the requirement in the wire standard.

560.9 In the event that a single round specimen containing a stranded conductor deforms more than stated in the requirement in the wire standard, it is appropriate to conduct a test using a single new specimen in which the stranded conductor has been replaced with a solid conductor of a diameter that fits snugly inside the insulation and not tightly enough to stress the tube of insulation. A test is not to be made on an insulation into which a solid conductor has been inserted to replace the original stranded conductor without there first being noncompliance of that insulation tested with the stranded conductor in place – that is, a stranded conductor is to be replaced with a solid conductor for referee testing only. Where a single referee specimen shows a greater deformation than the maximum stated in the requirement, the referee testing is to be repeated as described in 560.7 using three new specimens in which the conductor has similarly been replaced. Each of the three new referee specimens is to comply.

561 – 579 *Reserved for Future Use*

COLD BEND

580 Test

580.1 The test of single-conductor insulation is to be made using specimens of finished individual conductors. The test of parallel-cord insulation and of jacket material is to be made using specimens of the complete construction. After the specimens, together with a metal mandrel(s) having the specified diameter, have been cooled for a period of 4 h in a cold chamber maintained at the specified low temperature, and while they are at that low temperature, each specimen is to be tightly wound for six complete turns (except as specified for the larger sizes of jacketed constructions) onto the mandrel. The winding is to be done at a rate of about 3 seconds per turn (18 ±3 seconds for six turns), and successive turns are to be in contact with one another. The test is to be performed in the cold chamber where space and mounting means are available in the chamber. Where this is not practical, it is appropriate to remove a specimen and a mandrel from the test chamber and perform the test outside the chamber. In either case, the winding is to be completed within 30 seconds of the time that the cold chamber is opened. Insulating gloves are to be worn by the person performing the test. Circumferential depressions in the outer surface indicate cracks on the inside surface of the insulation or jacket of most materials. Circumferential depressions in a fluoropolymer surface are yield marks (locally stronger points) rather than indicators of cracking.

581 and 582 *Reserved for Future Use*

FLEXIBILITY AT LOW TEMPERATURE

583 Test

583.1 After cooling for 4 h to –25.0 ±2.0°C (–13.0 ±3.6°F), finished cable shall be undamaged by the bending described in 583.2 – 583.15.

583.2 Two straight specimens at least 30 inches or 760 mm long are to be cut from a sample length of finished cable without bending the cut ends of any conductor. Both specimens are to be bent (see 583.12) around one diameter of mandrel (see 583.3) where the cable is round. Where the cable is flat, two different diameters of mandrel (see 583.3) are required, one of the specimens being bent flatwise around the smaller mandrel and the other being bent edgewise around the larger mandrel.

583.3 A series of mandrels is to be stocked in which the diameters are either within 1 mil of being integral multiples of 200 mils (0.2 inch) or within 0.01 mm of being integral multiples of 5 mm. The method by which the particular diameter or diameters of mandrel for a test are to be determined is explained in 583.4– 583.9. Measurements for use in the determination are to be made on only one of the specimens of cable.

583.4 In testing a round cable, the diameter over the outer surface of the cable is to be measured. In testing a flat cable, measurements are to be made of the lengths of the major and minor axes over the outer surface of the cable. The instruments specified in 583.5 and 583.6 for making these measurements are to be calibrated to facilitate estimation of each measurement to 0.1 mil or 0.001 mm.

583.5 A dead-weight dial micrometer is to be used to measure a diameter or length of axis that is not larger than 0.500 inch or 12.7 mm. The anvil and presser foot are to be 0.078 inch or 1.98 mm wide and 0.375 inch or 9.52 mm long. The foot is to exert a total of 10 ±2 gf or 0.10 ±0.02 N on a specimen.

583.6 A machinist's micrometer caliper with a ratchet is to be used to measure a diameter or length of axis that is longer than 0.500 inch or 12.7 mm. The surfaces of the anvil and the end of the spindle are to be flat.

583.7 The measurements are to be made in a plane that is perpendicular to the longitudinal axis of the cable. Except in the case indicated in 583.8, at least four measurements are to be made of each length of axis or diameter. Each measurement is to be estimated to the nearest 0.1 mil or 0.001 mm and recorded. The largest and smallest recorded measurements of the diameter or of each length of axis are to be identified as such on the data sheet, and the two are to be averaged. Each average is to be recorded.

583.8 Where, on the smaller cables, only one measurement of the length of the major axis is practical, the single measurement is to be recorded as the average length of the major axis.

583.9 The two diameters of mandrel that are to be used with a flat cable are to be determined by first multiplying the average length of the major axis by 20 and multiplying the average length of the minor axis by 4. The single diameter of mandrel that is to be used with a round cable is to be determined by first multiplying the average diameter by 6. The result of each multiplication is to be rounded as indicated in 240.5 (measurements in inches) or 240.6 (measurements in millimeters) to the nearest integral multiple of 200 mils or 5 mm. In each case, the rounded result is the diameter of mandrel that is to be used in the test.

583.10 The apparatus for this test is to consist of a sharp knife for opening the cable; round metal cylinders for use as the mandrels specified in 583.3 – 583.9; and a dry-ice cabinet or a mechanical refrigerator, either one of which is to be capable of sustained operation at a low temperature of −25.0 ±2.0°C (−13.0 ±3.6°F). The mandrels are to be secured within the cold chamber in a manner that enables the bending operation to be conducted in the chamber and at the low temperature, and facilitates the release of mandrels from the chamber while the bent specimens are securely in place on them.

583.11 The cold chamber is to be precooled to the low temperature before the specimens are placed in the chamber. Both straight specimens are to be cooled for 4 h to the low temperature.

583.12 After the full period of cooling, each specimen is to be bent for 180° around the applicable mandrel (see 583.3) while both the mandrel and specimen are maintained at the low temperature. While in the bent position, each specimen is to be secured to the mandrel. The assemblies of mandrel and specimen are then to be removed from the chamber and, while it is still on the mandrel, the overall covering is to be examined for the damage described in 583.15.

583.13 A separate specimen is to be used for each size of mandrel, and no specimen is to be bent more than once.

583.14 Both specimens are to be cut open and their interiors examined for the damage described in 583.15.

583.15 Any cable from which a specimen exhibits any of the damage described in this paragraph does not comply. There are not to be ruptures of any fibrous material in the cable. There is not to be a part, split, or crack larger than 1/16 inch or 1.5 mm in the tape-and-finish outer covering on Type SE cable. In the absence of rubbing, there is not to be any flaking of the treating or finishing compounds used with the fibrous outer layer of a layered covering. No cracks, tears, or splits are to be in the insulation, any individual jacket over the insulation, in any web, or in any overall jacket. Circumferential depressions in the outer surface of a jacket or the insulation indicate cracks on the inside surface. Circumferential depressions in a fluoropolymer surface are yield marks (locally stronger points) rather than indicators of cracking.

584 – 592 *Reserved for Future Use*

IMPACT AT ABNORMALLY LOW TEMPERATURE

593 Test

593.1 Specimens are to be impacted on anvils consisting of 8-inch or 203-mm lengths of 2x4 spruce lumber having no surface imperfections or knots. The wood anvil is to be inspected after each specimen is impacted and replaced where it shows any indentations.

593.2 The impact energy is to be provided by a weight of 3 lb or 1.36 kg in the form of a circular steel cylinder having a diameter of 1 inch or 25 mm and a flat impact face that is perpendicular to the longitudinal axis of the weight and has rounded edges.

593.3 The impact specimens are to consist of ten separate 5-inch or 130-mm sections cut from a straight sample length of the finished wire or cable.

593.4 The specimens and wood anvils are to be cooled for at least 4 h in a cold chamber maintained at a temperature of −40.0 ±2.0°C (−40.0 ±3.6°F). The impact weight and the remainder of the test apparatus are to be in thermal equilibrium with the surrounding air in the test room at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F).

593.5 At the conclusion of at least 4 h of cooling, one of the wood anvils is to be removed from the cold chamber and is to be secured to a concrete floor, the building framework, or another solid support that does not absorb the impact. The impact weight is to be supported with its lower face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary anvil is to be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary anvil. A set of rails or other vertical guide(s) is to constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the wire or cable. The rails or other guide(s) are not to interfere with the free fall of the impact weight. The top of the guide(s) is to have a means for releasing the impact weight to fall freely from any chosen height and strike the wire or cable. The weight is also to be kept from striking the wire or cable more than once during each drop.

593.6 One of the test specimens of the wire or cable is to be removed from the cold chamber and is to be tested as follows without delay and within 15 s of being removed from the chamber. Insulating gloves are to be worn by the person conducting the test. The time in seconds between removal of the specimen from the chamber and the impact is to be noted and recorded. The impact weight is to be secured several specimen diameters (several times the length of the minor axis in the case of a flat cable) above the anvil and the specimen is to be placed and held on the cold anvil with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the anvil, and in the vertical plane containing the coincident vertical lines described in 593.5. In the case of a flat cable, the specimen is to be flatwise on the anvil. The position of the impact weight is to be adjusted to place the lower face of the weight 36 inches or 915 mm above the upper surface of the specimen. The impact weight is to be released from this height, is to fall freely in the guides, is to strike the specimen once, and is then immediately to be raised up to and secured at the 36-inch or 915-mm height. After warming in still air at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) for 24 h, the specimen is to be examined for cracks, ruptures, and like damage in each of its nonmetallic components – insulation, jacket, other covering, etc. The examinations are to be made with normal or corrected vision without magnification.

593.7 Each of the remaining nine specimens is to be tested in succession as described in 593.6 for a total of ten strikes. The wire or cable does not comply where more than two out of ten specimens show any cracking, rupturing, or like damage.

594 *Reserved for Future Use*

CRUSHING RESISTANCE

595 Test

595.1 The test specimen is to consist of a minimum 100-inch or 2540-mm straight length of the finished solid 14 AWG wire without any conditioning. The specimen is to be tested at each of ten points evenly spaced along its length. These points are not to be closer together than 10 inches or 254 mm, and no point is to be closer than 5 inches or 127 mm to an end of the specimen. At each test point, the specimen is to be crushed between a flat, horizontal steel plate and a solid steel rod in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. Each plate is to be 2 inches or 50 mm wide. A solid steel rod 3/4 inch or 19 mm in diameter and of the same length as the plates is to be bolted or otherwise secured to the upper face of the lower plate. The longitudinal axes of the plates and the rod are to be in the same vertical plane. The specimen, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 25.0 ±5.0°C (77.0 ±9.0°F) throughout the test.

595.2 The specimen is to be connected in series with a buzzer or other low-voltage indicator and a supply circuit, one leg of which is to be earth-grounded. All metal parts of the crushing apparatus are to be connected to earth ground.

595.3 The upper steel plate in the compression machine is to be raised several specimen diameters above the steel rod, and the first test point on the specimen is to be placed and held on the steel rod with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the plates and the rod. The upper steel plate is to be moved down until it is snug against the specimen. The downward motion of the plate is then to be continued at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min increasing the force on the specimen until the indicator signals that contact has occurred between the specimen conductor and the plate or rod. The force indicated by the dial on the compression machine at the moment of contact is to be recorded. The crushing procedure is to be repeated at each of the remaining nine test points. The wire does not comply where the average of the ten crushing forces is less than 225 lbf or 1000 N or 102 kgf.

596 – 600 *Reserved for Future Use*

601 Crushing-Resistance Test of Round Type NM Cable

601.1 The cable is to be crushed between flat, horizontal steel plates in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. Each plate is to be 2 inches or 50 mm wide. The cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 23.0 ±5.0°C (73.4 ±9.0°F) throughout the test.

601.2 The cable is to be tested in a continuous length of at least 100 inches or 2.55 m, with the cable being crushed at ten points along that length. The first test is to be conducted 9 inches or 230 mm from one end of the test length and the nine remaining tests are to be conducted at succeeding intervals of at least 9 inches or 230 mm down the length of the cable.

601.3 The insulated circuit conductors and the two steel plates are to be connected to low-voltage indicators (buzzers or the like) and to power supplies for the purpose of indicating a short circuit between circuit conductors or between any circuit conductor and the steel plates. The grounding conductor in the test length of the cable is to be out of the circuit.

601.4 The upper steel plate in the compression machine is to be raised several cable diameters above the lower plate, and the cable at the first test point is to be placed and held on the lower plate with the longitudinal axis of the cable horizontal, perpendicular to the longitudinal axes of the plates, and in the vertical plane that laterally bisects the plates. The upper steel plate is to be moved down until it is snug against the cable. The downward motion of the plate is then to be continued at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min increasing the force on the cable until one or more of the indicators signal that contact has occurred between the circuit conductors or between one or more of the circuit conductors and ground. The force indicated by the dial on the compression machine at the moment of contact is to be recorded.

601.5 The length of cable being tested is to be advanced to and crushed at each of the successive test points for a total of ten crushes. The average of the ten crushing trials is to be calculated and recorded.

602 – 619 *Reserved for Future Use*

620 Crushing-Resistance Test of Types XHHW-2, XHHW, and XHH

620.1 Ten specimens of the finished wire in each of the sizes 14 and 2 AWG are to be tested. Each specimen is to be placed between 2-inch-wide or 50-mm-wide, flat, horizontal steel plates in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. The length of the specimen is to be parallel to the 2-inch or 50-mm dimension of the plates. The plates are to be connected together, to the metal of the testing machine, and to earth. The wire, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test. Each specimen is to be tested separately and is to be subjected to an increasing force until a short circuit occurs (as indicated by a low-voltage buzzer circuit or the equivalent) between the conductor in the wire and one or both of the earth-grounded plates. The force at which a short circuit occurs is to be recorded in each case.

621 – 699 *Reserved for Future Use*

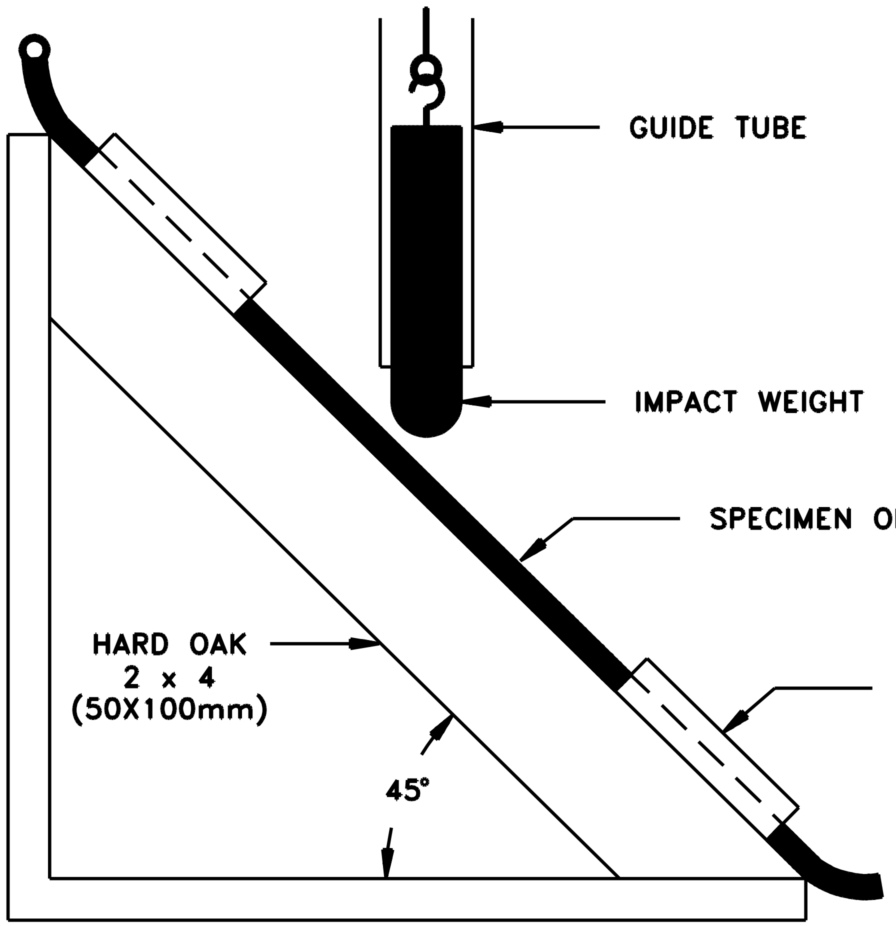
DIELECTRIC TESTS

700 Dielectric Breakdown Test of Types XHHW-2, XHHW, and XHH after Glancing Impact

700.1 Both ends of each of six 15-inch or 380-mm specimens of the finished solid 14 AWG wire are to be secured to one of the broad faces of a hard oak board measuring 2 inches by 4 inches or 50 mm by 100 mm in cross section without damage to the insulation and in a manner that results in the wires being straight and parallel to the longitudinal axis of the board. The board is to be rigidly supported, with the plane formed by the wires inclined 45° from the horizontal and each wire in a vertical plane.

700.2 A weight of 1 lb or 0.454 kg consisting of a solid circular steel cylinder that is 3/4 inch or 20 mm in diameter, has all surfaces smooth, and has one end rounded to a hemisphere is to be supported with its longitudinal axis vertical and in a vertical plane containing one of the wires. The hemispherical end is to be down and centered 18 inches or 460 mm above the midpoint of the length of the wire. A straight vertical tube having a 13/16-inch or 22-mm inside diameter is to surround the cylinder and serve as a guide to keep the cylinder vertical while the cylinder is falling and after it has struck the wire. The inside surface of the guide tube is to be smooth and the tube is to be of a length that keeps the cylinder from coming out of the guide tube. See Figure 700.1.

Figure 700.1
Glancing-impact apparatus



SB1251

Dimensions are shown in inches (millimeters)

700.3 While the specimens of wire, the apparatus, and the surrounding air are in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F), the cylinder is to be released, is to fall freely in the guide tube and strike the wire once, and is then immediately to be raised back up to and be secured at the 18-inch or 460-mm height. This process is to be repeated for each of the five remaining specimens of wire.

700.4 Each of the impacted specimens is to have its impacted area immersed in tap water that is at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F). The water is to be in an earth-grounded metal container whose inside metal surface is directly and entirely in contact with the water (not painted, enameled, or otherwise insulated). The insulation in the impacted area of each specimen is to be stressed electrically to breakdown by means of a 48 – 62 Hz sinusoidal or nearly sinusoidal rms potential applied between the conductor in the specimen and the earth-grounded water container. The test potential is to be supplied by an isolation transformer complying with 820.1.

700.5 The applied potential is to be increased from near zero at a uniform or nearly uniform rate that is not less than 100 percent of the voltage rating for the product in 60 s, and is not more than 100 percent in 10 s (the rate of increase is not to exceed 500 V/s in any case). The increase is to continue in this manner until breakdown occurs. The breakdown potential for each of the six impacted specimens is to be recorded, and the average of these potentials is to be calculated and recorded. It is appropriate to discard one individual breakdown value that differs widely from most of the other individual values. Where one is discarded, none of the remaining values shall be less than 10 percent of the breakdown voltage of the unimpacted wire.

700.6 Each of six 15-inch or 380-mm or longer wire specimens not subjected to the impact is to be subjected to the dielectric-breakdown procedures with the center portion of its length immersed in water as described in 700.4 and 700.5. The breakdown potential is to be recorded for each of these specimens, and the average of these potentials is to be calculated and recorded.

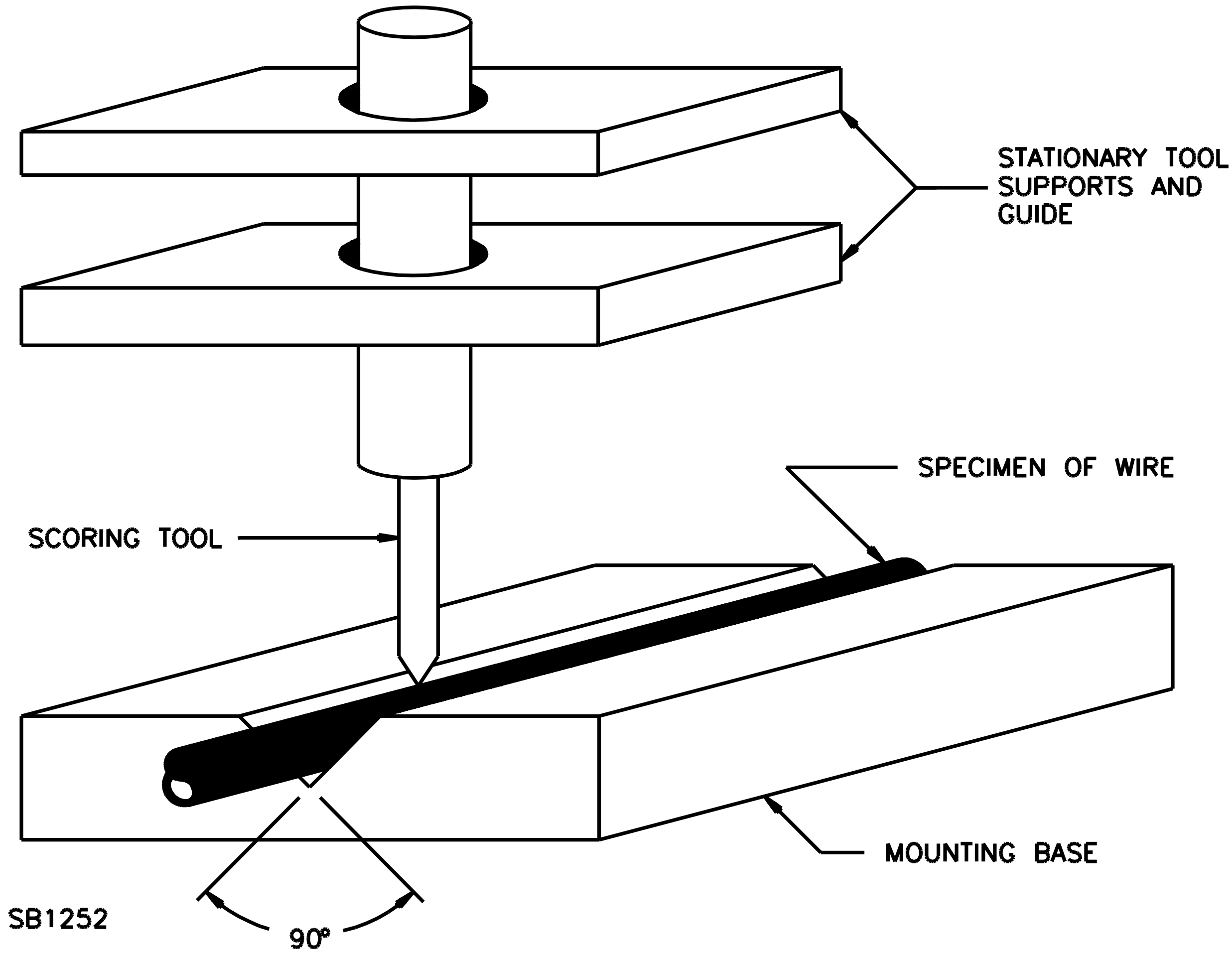
701 – 719 *Reserved for Future Use*

720 Dielectric Breakdown Test of Types XHHW-2, XHHW, and XHH after Scoring

720.1 The test is to be made using the apparatus illustrated in Figure 720.1 or such apparatus in multiple. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test. Six straight, untwisted 15-inch or 380 mm specimens are to be cut from a sample length of finished solid 14 AWG Type XHHW-2, XHHW, or XHH wire. Each specimen is to be placed in a 90° V-shaped slot in the mounting base as shown in Figure 720.1 and is to have its ends secured to keep the specimen from moving in the slot. The longitudinal axes of the specimens are to be parallel to one another. The mounting base is to be secured to a flat, horizontal table that moves in a horizontal plane in a direction parallel to the longitudinal axes of the specimens. The longitudinal axes of the specimens are to be horizontal.

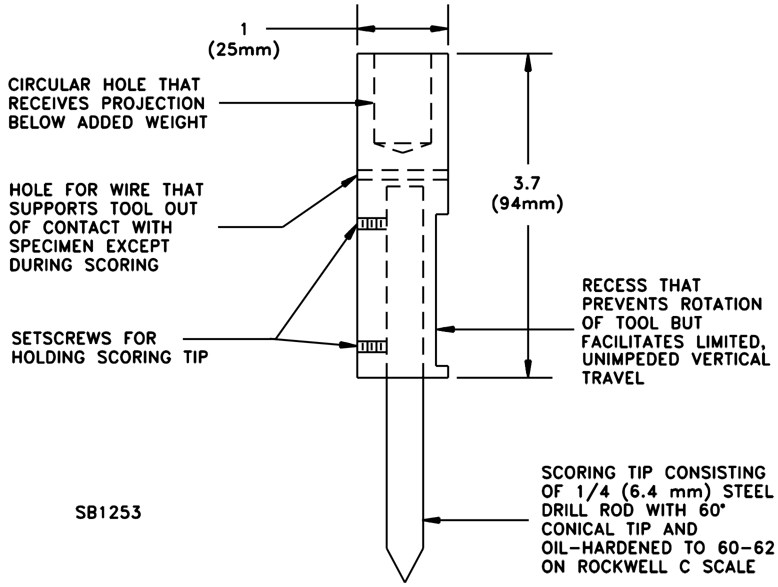
720.2 Identical scoring tools, the essentials of which are detailed in Figure 720.2, are to be placed in the stationary tool supports and guide (see Figure 720.1) above each specimen, with each tool supported (by means of a wire) so that its scoring point is above and out of contact with the specimen. The longitudinal axis of each tool is to be vertical and in the same plane as the longitudinal axis of the specimen under the tool.

Figure 720.1
Scoring Apparatus



See Figure 720.2 for details of scoring tool

Figure 720.2
Scoring tool



Dimensions are shown in inches (millimeters)

720.3 While the table is at one end of its travel, the wire supporting each tool is to be removed and the tool is to be lowered gently to bring its point to bear on the specimen. The point is to bear on a specimen with 14.0 ±0.1 ozf or 3.89 ±0.03 N or 397 ±3 gf. The table is then to be started in horizontal reciprocating motion (simple harmonic motion) at the rate of 28 cycles per minute parallel to the longitudinal axes of the specimens, each cycle consisting of one complete back-and-forth motion with a 6-inch or 150-mm stroke. Each stroke is to be centered on the longitudinal axis of the tool. The table is to be stopped after seven complete, continuous cycles, and each tool is then immediately to be raised away from its specimen and is to be supported (by means of the wire) out of contact with the specimen.

720.4 Each of the scored specimens is to have its scored area immersed in tap water that is at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F). The water is to be in an earth-grounded metal container whose inside metal surface is directly and entirely in contact with the water (not painted, enameled, or otherwise insulated). The insulation in the scored area of each specimen is to be stressed electrically to breakdown by means of a 48 – 62 Hz sinusoidal or nearly sinusoidal rms potential applied between the conductor in the specimen and the earth-grounded water container. The test potential is to be supplied by an isolation transformer complying with 820.1.

720.5 The applied potential is to be increased from zero at a uniform or nearly uniform rate that is not less than 100 percent of the voltage rating for the product in 60 s, and is not more than 100 percent in 10 s (the rate of increase is not to exceed 500 V/s in any case). The increase is to continue in this manner until breakdown occurs. The breakdown potential for each of the six scored specimens is to be recorded, and the average of these potentials is to be calculated and recorded. It is appropriate to discard one individual breakdown value that differs widely from most of the other individual values. Where one is discarded, none of the remaining values shall be less than 10 percent of the breakdown voltage of the unscored wire.

720.6 Each of six 15-inch or 300-mm or longer wire specimens not subjected to the scoring is to be subjected to the dielectric-breakdown procedure with the center portion of its length immersed in water as described in 720.4 and 720.5. The breakdown potential is to be recorded for each of these specimens and the average of these potentials is to be calculated and recorded.

721 – 759 *Reserved for Future Use*

760 Dielectric Voltage-Withstand Test of Straight Foil-Wrapped Specimens

760.1 The test specimen is to be a 60-inch or 1500-mm straight length of finished wire with its center 36-inch or 915-mm section wrapped tightly with metal foil. The potential is to be applied between the conductor and the foil.

760.2 The wire is to be stressed by means of an isolation transformer that complies with 820.1.

760.3 The applied potential is to be increased from near zero at a uniform or nearly uniform rate that is not less than 100 percent of the voltage rating of the wire or cable in 60 s, and is not more than 100 percent in 10 s (the rate of increase is not to exceed 500 V/s in any case). The increase is to continue in this manner until the voltage reaches the specified rms test potential. Where this level is reached without breakdown, the voltage is to be held constant at the specified level for 5 min and is then to be reduced to near zero at the rate mentioned above. The wire or cable does not comply where breakdown occurs at less than the potential specified in the wire standard while the applied potential is being increased or decreased or in less than 5 min at the potential specified in the wire standard.

761 – 779 *Reserved for Future Use*

780 Dielectric Voltage-Withstand Test of Foil-Wrapped U-Bend Specimens

780.1 A 15-inch or 380-mm specimen is to be bent 90° around a mandrel having the same diameter as the specimen. Two bends in the same plane are to be made 2 inches or 50 mm apart near the center of the specimen, and pressure is to be applied to keep the specimen from slipping. Metal foil is then to be wrapped tightly around a 5-inch or 125-mm section of the U-bend specimen, including both bends.

780.2 The specimen is then to be tested as indicated in 760.2 and 760.3. The test time is to be 60 s. The wire does not comply where there is a dielectric breakdown or where the overall braid ruptures because of the bending.

781 – 799 *Reserved for Future Use*

800 Dielectric Voltage-Withstand Test for Cord Conductors

800.1 The test potential shall be applied between each circuit conductor and every other circuit conductor and each grounding conductor. In a multiple-layer cable, the potential shall be applied between each circuit conductor and every adjacent circuit conductor and, where there are one or more grounding conductors, the potential shall be applied between each grounding conductor and every circuit conductor adjacent to it. In the case of a construction that includes a metal shield, the test shall be repeated with the test potential applied between the shield and all of the insulated (circuit and grounding) conductors connected together.

800.2 In a multiple-layer cable, it is appropriate to conduct the test by interconnecting the alternate conductors in each layer and applying the test potential between the two groups and then interconnecting all of the conductors of each layer and applying the test potential between successive layers.

800.3 The test potential is to be supplied by an isolation transformer complying with 820.1. The test potential is to be applied as indicated in 820.4.

801 – 819 *Reserved for Future Use*

820 Dielectric Voltage-Withstand Test of Coils and Reels in Water

820.1 The apparatus is to consist of a tank in which the test coil is to be immersed in water; an earth-grounding electrode or its equivalent (an earth-grounded metal tank whose inside metal surface is directly and entirely in contact with the water – not painted, enameled, or otherwise insulated); a circuit breaker, lamp bank, or other means for indicating the flow of breakdown current in the test circuit; and a testing transformer that complies with the following. The test potential is to be supplied by a 48 – 62 Hz isolation transformer whose output potential is continuously variable from near zero to at least the specified rms test potential at a rate not exceeding 500 V/s. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage is to be monitored continuously by a voltmeter that, where of the analog rather than digital type, shall have a response time that does not introduce a lagging error greater than 1 percent of full scale at the specified rate of increase in voltage, and that has an overall accuracy that does not introduce an error exceeding 5 percent. The maximum current output of which the transformer is capable shall enable routine testing of full reels of the wire or cable without tripping of the circuit breaker by the charging current. The water is to be at any convenient temperature and no correction factor is to be used.

820.2 In preparing the coil or reel for the test, each end of the wire or cable is to be brought out well above the water level in the tank. Any fibrous covering and separator are to be removed from the surface of the insulation for about 6 inches or 150 mm at each end to assist in reducing surface leakage and the likelihood of surface breakdown. It is appropriate to dip the insulation at the ends in melted paraffin to keep moisture from forming a conductive path from the conductor metal across the surface of the insulation to the water. The coil or reel is then to remain immersed in water for not less than 6 h before the test potential is applied.

820.3 One side of the test circuit is to be connected to the conductor of the wire and the other side to an electrode that is earth-grounded and is in contact with the water in which the coil is immersed.

820.4 The applied potential is to be increased from near zero at an uniform or nearly uniform rate that is not less than 100 percent of the potential rating of the wire or cable in 60 s, and is not more than 100 percent in 10 s (the rate of increase is not to exceed 500 V/s in any case). The increase is to continue in this manner until the voltage reaches the level of the rms test potential specified. Where this level is reached without breakdown, the voltage is to be held constant at the specified level for 60 s and is then to be reduced to near zero at the rate mentioned above. The wire or cable does not comply where breakdown occurs at less than the potential specified in the wire standard while the applied potential is being increasing or decreased, or in less than 60 s at the potential specified in the wire standard.

820.5 Breakdown usually is revealed by a current rush resulting from the decreased resistance of the circuit and is indicated by the tripping of a circuit breaker, the illumination of a bank of lamps connected in series with the test coil, or other means. Where the current output of which the transformer is capable is large, breakdown often is observed by a flash at the point on the cable at which the breakdown takes place. Where other means do not do so, the insulation resistance determined at room temperature as described in Insulation-Resistance Test in Water, Section 920, indicates a breakdown. It is partly to provide this positive check that the voltage test is made first.

821 – 829 *Reserved for Future Use*

830 Dielectric Voltage-Withstand Tests for Power-Limited Circuit Cable and for Cable for Power-Limited Fire-Alarm Circuits

830.1 The equipment is to consist of either a d-c power supply complying with 830.2 or an a-c power supply complying with 830.3, and also a circuit breaker, current meter, or other means for indicating a heavy flow of current in the test circuit. The maximum current output of which the d-c or a-c supply is capable shall enable routine testing of full reels of the cable without tripping of the circuit breaker by the charging current.

830.2 For a d-c test, the power supply is to have an output potential of the voltage specified for a d-c test of the cable type. Any ripple shall not exceed 1 percent. After a fault, the test potential shall recover to the specified voltage before testing another conductor.

830.3 For an a-c test, the test potential is to be supplied by a 48 – 62 Hz isolation transformer whose output is continuously variable from near zero to an rms potential of at least the specified voltage. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage is to be monitored continuously by a voltmeter that, where of the analog rather than digital type, shall have a response time that does not introduce a lagging error greater than 1 percent of full scale at 50 V/s, and that has an overall accuracy that does not introduce an error exceeding 5 percent.

830.4 The full test potential is to be applied for the specified number of seconds between each conductor and the earth-grounded cable elements (all other conductors and any shield(s) and/or metal covering connected together and to earth ground). During each application, observation is to be made to determine whether there is any current leakage or rupture of the insulation as indicated by such means as the tripping of the circuit breaker or a deflection of the needle of the current meter. At least once every 24 h, the test leads are to be connected together and the circuit is to be closed to make certain that the current-indicating means is functioning as intended and that the circuit is complete. Where multiple test leads are used, each shall be tested.

831 – 899 *Reserved for Future Use*

SPARK TEST

900 Method

900.1 A spark tester shall include a voltage source, electrode, voltmeter, fault-signal device or system, and the appropriate electrical connections. The ability of the equipment to comply with the requirements in 900.2 – 900.17 shall be certified at least annually by an accredited independent calibration service or its equivalent such as checking the test potential with a voltmeter whose calibration is traceable. Calibration shall be traceable to a National Institute of Standards and Technology (USA) standard or to other national physical measures recognized as equivalent by NIST.

900.2 The voltage source of a spark tester shall maintain the test voltage specified in the wire Standard under all normal conditions of leakage current. The core of a transformer and one end of its secondary winding shall be solidly connected to earth ground. A voltage source shall not be connected to more than one electrode.

900.3 The electrode shall be of the link- or bead-chain type and shall make intimate contact throughout its entire length with the surface of the wire being tested.

900.4 The bottom of the metal electrode enclosure shall be U- or V-shaped, the chains shall have a length appreciably greater than the depth of the enclosure, and the width of the trough shall be (typically 1-1/2 inches or 40 mm) greater than the diameter of the largest size of wire that is tested.

900.5 For a bead-chain electrode, the longitudinal and transverse spacings of the chains and the diameter of each bead shall comply with Table 900.1. The vertical spacing between beads in each chain shall not exceed the diameter of a bead.

900.6 The electrode shall have an earth-grounded metal screen or an equivalent guard that protects operating personnel against electric shock from the electrode and associated live parts.

900.7 The voltmeter shall be connected in the circuit to indicate the actual test potential at all times.

900.8 The equipment shall include a light, counter, or other device or system that gives a signal in the event of a fault. When a fault is detected, the signal shall be maintained until the indicator is reset manually.

Table 900.1
Maximum center-to-center spacings of bead chains

Diameter of a bead[a]		Longitudinal spacing within each row[a]		Transverse spacing between rows[a]			
				Chains staggered		Chains not staggered	
inch	mm	inch	mm	inch	mm	inch	mm
3/16	5.0	1/2	13	1/2	13	3/8	10
3/32	2.5	The chains shall be staggered and shall touch one another in the longitudinal and transverse directions.					

[a] A diameter and spacings other than indicated comply where investigation shows that the chains contact an equal or greater area of the outer surface of the wire.

900.9 The spark test shall be conducted as the wire is being cut just prior to storage in or shipping from the factory in which the wire is made. The insulation at points of repair shall be resparked.

900.10 Wire that has been spark-tested in compliance with 900.9 need not be resparked after any of the following further-processing operations at the wire factory:

a) Cutting into lengths shorter than 200 ft or 60 m.

b) Striping that does not require heat curing.

c) Color coating that does not require heat curing.

900.11 The length of the electrode is not specified; however, the rate of speed at which the wire travels through the electrode shall keep any point on the wire in contact with the electrode for not less than a total of 18 positive and negative crests of the supply voltage (the equivalent of 9 full cycles of the supply voltage). The maximum speed of the wire is to be determined by means of whichever of the following formulas is applicable

$$\text{feet per minute} = (5/9) \times (\text{frequency in hertz}) \times (\text{electrode length in inches})$$

or

$$\text{meters per minute} = (1/150) \times (\text{frequency in hertz}) \times (\text{electrode length in millimeters})$$

For convenience, Table 900.2 shows the formulas for several frequencies.

900.12 The conductor of the wire shall be earth-grounded during the spark test. Where the conductor coming from the pay-off reel is bare, the conductor shall be earth-grounded at the pay-off reel or at another point at which continuous contact with the bare conductor, prior to the insulating process, is maintained and the conductor is not required to be tested for continuity or earth-grounded at the take-up reel. Where the conductor coming from the pay-off reel is insulated, an earth-ground connection shall be made at either the pay-off or take-up reel. However, for the 10 and smaller AWG sizes, an earth-ground connection shall be made at both the pay-off and the take-up reels where the 10 and smaller AWG sizes are not tested for continuity and found to be of one integral length. In any case, each earth-ground connection shall be bonded directly to the earth ground in the spark tester.

900.13 To determine whether or not a wire is continuous, the conductor is to be connected in series with a lamp, buzzer, bell, or other indicator and a power supply. The conductor is continuous from end-to-end of the finished wire where the lamp lights, the bell or buzzer sounds, or another indicator signal is given.

Table 900.2
Formula for maximum speed of wire in terms of electrode length L

Nominal supply frequency in Hertz	Feet per minute (L in inches)	Meters per minute (L in millimeters)
50	$27.8L_{in}$	$0.333L_{mm}$
60	$33.3L_{in}$	$0.400L_{mm}$
100	$55.6L_{in}$	$0.667L_{mm}$
400	$222L_{in}$	$2.67L_{mm}$
1000	$556L_{in}$	$6.67L_{mm}$
3000	$1667L_{in}$	$20.0L_{mm}$
4000	$2222L_{in}$	$26.7L_{mm}$

900.14 For the factory production continuity testing of a wire, it is the manufacturer's choice whether to substitute either of the following for the test in 900.13: a continuous eddy-current procedure complying with 900.15 and 900.16, or a continuous differential capacitive-current procedure complying with 900.17.

900.15 The eddy-current test arrangement shall include equipment that complies with each of the following:

a) The equipment is to apply current at one or several frequencies in the range of 1 – 125 kHz to a test coil for the purpose of inducing eddy currents in the conductor moving through the coil at production speed.

b) The equipment is to detect the variation in impedance of the test coil caused by each break in the conductor.

c) The equipment is to provide a visual indication to the operator.

900.16 The longitudinal axis of the conductor is to be coincident with the electrical center of the test coil. The wire is to have little or no vibration as it passes through the test coil and is to clear the coil by a distance that is not greater than 1/2 inch or 13 mm. Variations in the speed of the wire through the test coil are to be limited to plus 50 percent and minus whatever percentage (50 percent maximum) keeps the signal amplitude from falling below the level at which a break can be detected. Separate calibration, balance, and adjustments for sensitivity, maximum signal-to-noise ratio, and maximum rejection of signals indicating gradual variations in diameter and other slow changes are to be made for each size, type of stranding, and conductor material. Calibration without any wire in the test coil is to be made at least daily to check whether the equipment is functioning. The temperature along the length of the wire being tested is not to vary from the temperature at which the equipment was calibrated, balanced, and so forth for the size, type of stranding, and conductor material unless the variations are gradual and are without hot or cold spots that cause false signals.

900.17 The differential capacitive-current procedure shall include equipment that complies with each of the following:

a) The equipment is to be used in conjunction with a 1 – 3 kHz or higher-frequency spark tester.

b) Two pickup electrodes are to be located in tandem either along the portion of the conductor being tested that is moving from the grounded pay-off reel toward the spark electrode, or along the portion of the conductor being tested that is moving toward the grounded take-up reel from the spark electrode.

c) As each break in the conductor is passing from the first pickup electrode toward the second, the equipment is to detect the difference between the voltage capacitively coupled from the conductor under test to the pickup electrode nearest the spark electrode and the lower voltage coupled to the pickup electrode nearest the grounded reel.

d) The equipment is to show a visual indication to the operator.

901 – 909 *Reserved for Future Use*

910 Spark Tests for Power-Limited Circuit Cable and for Cable for Power-Limited Fire-Alarm Circuits

910.1 A d-c or a-c spark tester for power-limited circuit cable and for cable for power-limited fire-alarm circuits shall include a voltage source, an electrode, a voltmeter, a system for detecting and counting signaling faults, and the appropriate electrical connections. The ability of the equipment to comply with the requirements in 910.2 – 910.15 shall be certified at least annually by an accredited independent calibration service or its equivalent such as by checking the test potential with an applicable voltmeter whose calibration is traceable. Calibration shall be traceable to a National Institute of Standards and Technology (USA) standard or to other national physical measures recognized as equivalent by NIST.

910.2 The voltage source of a d-c or a-c spark tester for power-limited circuit cable and for cable for power-limited fire-alarm circuits shall maintain the following test voltage under all normal conditions of leakage current:

a) A sinusoidal or nearly sinusoidal rms potential of the voltage specified for an a-c test of the cable type.

b) The voltage specified for a d-c test of the cable type. The current output of which the d-c power supply is capable shall not exceed 5 mA. Any ripple shall not exceed 1 percent. After a fault, the d-c test voltage shall recover to the specified level in 5 milliseconds or less time unless 2 ft or less of the product or 610 mm or less of the product travels through the electrode in the time it takes for the full voltage recovery.

910.3 One terminal of the d-c power supply, and the core of a transformer and one end of its secondary winding in an a-c power supply, shall be solidly connected to earth ground. A voltage source shall not be connected to more than one electrode.

910.4 The electrode of a d-c or a-c spark tester for power-limited circuit cable and for cable for power-limited fire-alarm circuits shall be of the link- or bead-chain type or shall be of another type, which shall be evaluated. A link- or bead-chain electrode shall make intimate contact throughout its entire length with the surface of the insulated conductor or pair of conductors being tested.

910.5 The bottom of a metal link- or bead-chain electrode enclosure shall be U- or V-shaped, the chains shall have a length appreciably greater than the depth of the enclosure, and the width of the trough shall be greater (typically 1-1/2 inches or 40 mm) than the diameter of the largest product being tested.

910.6 For a bead-chain electrode, the longitudinal and transverse spacings of the chains and the diameter of each bead shall comply with Table 910.1. The vertical spacing between beads in each chain shall not exceed the diameter of a bead.

Table 910.1
Maximum center-to-center spacings of bead chains

Diameter of a bead[a]		Longitudinal spacing within each row[a]		Transverse spacing between rows[a]			
				Chains staggered		Chains not staggered	
inch	mm	inch	mm	inch	mm	inch	mm
3/16	5.0	1/2	13	1/2	13	3/8	10
3/32	2.5	The chains shall be staggered and shall touch one another in the longitudinal and transverse directions.					

[a] A diameter and spacings other than as indicated comply where investigation shows that the chains contact an equal or greater area of the outer surface of the insulated conductor or initial assembly of conductors.

910.7 The electrode shall have an earth-grounded metal screen or an equivalent guard that protects operating personnel against electric shock from the electrode and associated live parts.

910.8 The voltmeter shall be connected in the circuit to indicate the actual test potential at all times.

910.9 The equipment shall include a fault detector, fault counter, and a means of signaling each fault that occurs. When a fault is detected, the signal shall be maintained until the indicator is reset manually.

910.10 The fault detector shall detect a voltage breakdown of the insulation. A breakdown is characterized by arcing between the electrode and the earth-grounded conductor(s) under test. A breakdown is defined as a decrease of 25 percent or more from the test voltage applied between the electrode and the earth-grounded conductor(s).

910.11 The fault detector shall consist of a trigger circuit that converts an input pulse of short time duration to an output pulse of a magnitude and duration that reliably operates the fault-indicating circuit.

910.12 The fault counter shall accommodate the faults as a numerically increasing sequence and shall display the accumulated total. The response time of the fault counter shall result in the counter registering faults spaced no farther than 24.0 inches or 610 mm apart for any combination of product speed and counter response time. This distance is to be calculated as follows:

$$\text{Distance between faults} = \text{Product speed expressed as inches per second or } 0.2 \times \text{feet per minute or } 0.656 \times \text{meters per minute} \times \text{Counter response time in seconds}$$

910.13 For a d-c test using a link- or bead-chain electrode, the surface of the insulated conductor(s) shall be in intimate contact with the link or bead chains for a distance of 5.0 ±1.0 inches or 125 ±25 mm.

910.14 The length of a link- or bead-chain electrode is not specified for an a-c test; however, the rate of speed at which the insulated conductor(s) travel through the electrode shall keep any point on the product in contact with the electrode for not less than a total of 18 positive and negative crests of the a-c supply voltage (the equivalent of a full 9 cycles of the a-c supply voltage). The maximum speed of the product is to be determined for an a-c test by means of whichever of the following formulas is applicable:

$$\text{feet per minute} = (5/9) \times (\text{frequency in hertz}) \times (\text{electrode length in inches})$$

or

$$\text{meters per minute} = (1/150) \times (\text{frequency in hertz}) \times (\text{electrode length in millimeters})$$

For convenience, Table 910.2 shows the formulas for seven frequencies.

Table 910.2
Formula for maximum speed of wire in terms of electrode length L of link- or bead-chain electrode

	Formula	
Nominal supply frequency in Hertz	**Feet per minute (L in inches)**	**Meters per minute (L in millimeters)**
50	$27.8L_{in}$	$0.333L_{mm}$
60	$33.3L_{in}$	$0.400L_{mm}$
100	$55.6L_{in}$	$0.667L_{mm}$
400	$222L_{in}$	$2.67L_{mm}$
1000	$556L_{in}$	$6.67L_{mm}$
3000	$1667L_{in}$	$20.9L_{mm}$
4000	$2222L_{in}$	$26.7L_{mm}$

910.15 The conductor(s) being tested shall be earth-grounded during the spark test. Where the conductor(s) coming from the pay-off reel(s) are bare, the conductor(s) shall be earth-grounded at the pay-off reel or at another point at which continuous contact with the bare conductor, prior to the insulating process, is maintained and the conductor is not required to be tested for continuity or earth-grounded at the take-up reel. Where the conductor coming from a pay-off reel is insulated, an earth-ground connection shall be made at each pay-off reel and at the take-up reel unless each conductor is tested for continuity as described in the wire Standard before the spark test is made and is found to be of one integral length. In any case, each earth-ground connection shall be bonded directly to the earth ground in the spark tester.

911 – 918 *Reserved for Future Use*

INSULATION RESISTANCE

919 Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance

919.1 Two specimens, conveniently of a 18 or 16 AWG solid conductor with a wall of insulation whose average thickness is 10 – 15 mils or 0.25 – 0.38 mm, are to be selected as representative of the insulation of interest. The specimens are to be of a length (at least 200 ft or 60 m) that yields insulation-resistance values that are stable within the calibrated range of the measuring equipment at the lowest water-bath temperature.

919.2 The two specimens are to be immersed in a water bath equipped with heating, cooling, and circulating facilities. The ends of the specimens are to extend at least 24 inches or 600 mm above the surface of the water to reduce electrical leakage. The specimens are to be in the water at room temperature for 16 h before adjusting the bath temperature to 50.0°F (10.0°C) or before transferring the specimens to a 50.0°F (10.0°C) bath.

919.3 The d-c resistance of the metal conductor is to be measured at applicable intervals of time until the temperature remains unchanged for at least 5 min. The insulation is then to be taken as being at the temperature of the bath indicated on the bath thermometer.

919.4 Each of the two specimens is to be exposed (919.3 applies) to successive water temperatures of 50.0, 61.0, 72.0, 82.0, and 95.0°F (10.0, 16.1, 22.2, 27.8, and 35.0°C) and, returning, 82.0, 72.0, 61.0, and 50.0°F (27.8, 22.2, 16.1, and 10.0°C). Insulation-resistance readings are to be taken at each temperature after equilibrium is established.

919.5 The two sets of readings (four readings in all) taken at the same temperature are to be averaged for the two specimens. These four average values and the average of the single readings at 95.0°F (35.0°C) are to be plotted on semilog paper. A continuous curve (usually a straight line) is to be drawn through the five points. The value of insulation resistance at 60.0°F (15.6°C) is then to be read from the graph.

919.6 The resistivity coefficient C for a 1.0°F (0.55°C) change in temperature is to be calculated to two decimal places by dividing the insulation resistance at 60.0°F (15.6°C) read from the graph by the insulation resistance at 61.0°F (16.1°C). In Table 919.1, C heads the column of multiplying factors M that applies to the particular insulation.

Table 919.1
Multiplying factor M[a] for adjusting insulation resistance to 60.0°F (15.6°C)

Temperature		Resistivity Coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	4.4	0.55	0.46	0.38	0.31	0.26	0.22	0.18	0.15	0.12	0.10
41	5.0	0.48	0.40	0.33	0.28	0.28	0.23	0.19	0.16	0.14	0.12
42	5.6	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.15	0.13
43	6.1	0.60	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.17	0.15
44	6.7	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.19	0.16
45	7.2	0.64	0.56	0.48	0.42	0.36	0.32	0.28	0.24	0.21	0.18
46	7.8	0.66	0.58	0.50	0.44	0.39	0.34	0.30	0.26	0.23	0.20
47	8.3	0.68	0.60	0.53	0.47	0.42	0.37	0.33	0.29	0.26	0.23
48	8.9	0.70	0.56	0.56	0.50	0.44	0.40	0.36	0.32	0.29	0.26
49	9.4	0.72	0.65	0.59	0.53	0.48	0.42	0.39	0.35	0.32	0.29
50	10.0	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.32
51	10.6	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.57
56	13.3	0.89	0.86	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.64
57	13.9	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.73	0.71
58	14.4	0.94	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.81	0.80
59	15.0	0.97	0.95	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.12	1.17	1.17	1.19	1.21	1.23	1.25
63	17.2	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76
66	18.9	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.87	1.97
67	19.4	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21
68	20.0	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.20	2.48
69	20.6	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.56	2.77
70	21.1	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11
71	21.7	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48
72	22.2	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90
73	22.8	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	3.88	4.36
74	23.8	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89

Table 919.1 Continued on Next Page

Table 919.1 Continued

Temperature		Resistivity Coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
75	23.9	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47
76	24.4	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13
77	25.0	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87
78	25.6	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69
79	26.1	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	7.26	8.61
80	26.7	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65
81	27.2	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.8
82	27.8	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.1
83	28.3	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.0	13.6
84	28.9	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.2	15.2
85	29.4	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.8	13.6	17.0

[a] Calculated from the formula $M = C^{(t - 60)}$ in which C is determined as described in 919.1 – 919.6 and t is the temperature of the cable in degrees F.

920 Insulation-Resistance Test in Water

920.1 The insulation-resistance test equipment and procedures shall be applicable. Otherwise they are not specified. A megohm bridge used for this purpose shall be of applicable range and calibration, shall present readings that are accurate to 10 percent or less of the value indicated by the meter, and shall apply a d-c potential of 100 – 500 V to the insulation for 60 s prior to each reading. The duration of each reading shall be 60 s.

920.2 The center 50-ft or 20-m sections of 55-ft or 22-m coils of the samples of a thermoplastic- or thermoset-insulated wire or cable are to be prepared as described in 820.2, and the water temperature is to be maintained within 1.0°C (1.8°F) of being constant at any temperature in the range of 10.0 – 29.4°C (50.0 – 85.0°F) for the entire 6-h or longer immersion previous to the measurement of resistance. The ends of the samples used in the tests at 60°C (140°F) or 75°C (167°F) are to be brought well away from the tank.

920.3 The specimen for the determination of insulation resistance of a flexible-cord conductor or a fixture wire is to be a coil or reel of the finished insulated conductor (or a coil of finished cord in the case of a parallel cord) neither less than 50 ft nor more than 5000 ft in length or neither less than 15 m nor more than 1500 m in length.

920.4 Each end of the fixture wire or the flexible cord is to be brought out well above the water level in the tank. The conductors of a parallel cord are to be joined together. The ends are to be dipped in melted paraffin, or a guard circuit is to be employed, to keep moisture from forming a conducting path between the surface of the insulation and the conductor. The coil is then to remain immersed in water for not less than 12 h, except that it is appropriate to immerse a coil no longer than 250 ft or 75 m for less than 12 h but not less than 4 h. The temperature of the water is to be maintained within 1.0°C (1.8°F) of being constant at any temperature in the range of 10.0 – 26.7°C (50.0 – 80.0°F) for the entire immersion time previous to the measurement of resistance.

920.5 A retest at 15 ±1°C (59 ±2°F) is to be made for a coil that does not show complying test results when the water temperature is at a different temperature.

920.6 Where coils are connected together for the insulation-resistance test and complying results are not obtained, the individual coils are to be retested to determine which ones have insulation resistance that complies.

921 – 999 *Reserved for Future Use*

STABILITY FACTOR

1000 Test

1000.1 Tests are to be made using three 15-ft or 5-m specimens of insulated conductor. Specimens of insulated cord conductors are to be without any polyester-tape or similarly non-absorbent separator, and are to be selected before assembly into finished cord. Specimens of a Type XHHW-2, RHW-2, XHHW, or RHW wire or cable are to be selected after cross-linking and before any covering is applied. Not less than 48 h after cross-linking of the conductor insulation, each specimen is to be dried for 24 h in air at 70.0 ±2.0°C (158.0 ±2.6°F) and is then to be cooled in air to 50°C (122°F) before being immersed in water.

1000.2 The middle 120-inch or 3048-mm section of each specimen is to be immersed continuously in tap water at a temperature of 50.0 ±1.0°C (122.0 ±1.8°F) for 14 d for cord conductors and in tap water at a temperature of 75.0 ±1.0°C (167.0 ±1.8°F) for 14 d for a Type XHHW or RHW wire or cable and in tap water at a temperature of 90.0 ±1.0°C (194.0 ±1.8°F) for 14 d for a Type XHHW-2 or RHW-2 wire or cable. The 30-inch or 762-mm end portions of each specimen are to be kept dry above the water as leakage insulation. A tight-fitting cover for the tank is to be placed directly above the surface of the water, the level of which is to be kept constant.

1000.3 The percentage power factor of each specimen is to be measured with 60 Hz current at average stresses of 80 and 40 volts per mil or 3150 and 1575 volts per millimeter after 1 d and 14 d total immersion, and each result is to be expressed to the nearest 0.1. The stability factor of each specimen is then to be computed and expressed to the nearest 0.1.

1000.4 The stability-factor difference is then to be computed for each specimen by subtracting the stability factor determined after 1 d from the stability factor determined after 14 d. The stability-factor difference is to be expressed to the nearest 0.1.

1001 – 1019 *Reserved for Future Use*

CAPACITANCE AND RELATIVE PERMITTIVITY

1020 Test

1020.1 The capacitance of the insulation is to be measured with bridge apparatus as the average from three specimens after immersion of the specimens for 24 h, 7 d, and 14 d, respectively, in tap water at 30.0 ±1.0°C (86.0 ±1.8°F) for 60°C (140°F) insulation, at 75.0 ±1.0°C (167.0 ±1.8°F) for 75°C (167°F) insulation, and at 90.0 ±1.0°C (194.0 ±1.8°F) for 90°C (194°F) insulation. Each result is to be expressed to the nearest picofarad. The increases in capacitance from 1 d to 14 d and from 7 d to 14 d are to be expressed as percentages of the 1-d and 7-d values, respectively.

1020.2 The capacitance of the insulation is to be determined, using a sinusoidal or nearly sinusoidal current at a frequency of 1000 Hz or 60 Hz, by means of a capacitance bridge. Where measured at 1000 Hz, the potential impressed upon the insulation is not to exceed 10 V. Where measured at 60 Hz, the potential impressed upon the insulation is to result in an average stress of 80 volts per mil of insulation or 3150 volts per millimeter of insulation.

1020.3 The test is to be made on a 15-ft or 5-m specimen of finished wire, from which any covering(s) over the insulation have been removed, including any flame-retardant coating. It is appropriate in the case of a Type XHHW-2, RHW-2, XHHW, or RHW wire or cable or of a cord conductor to select the specimen from production after cross-linking and before any covering is applied (including any flame-retardant coating). The nylon jacket is to be removed from Type THWN-2 or THWN wire and from a nylon-jacketed insulated conductor from a service cord.

1020.4 The center 120-inch or 3048-mm section of the specimen is to be immersed in tap water for 14 d, with a 30-inch or 976-mm portion at each end kept dry above the water as leakage insulation. The water temperature and the depth of immersion of the specimen are to be the same whenever readings are taken. The relative permittivity (dielectric constant) of the insulation is to be determined after 1 d by means of the formula

$$\epsilon_r = 13{,}600 \times C \times \log_{10} \frac{DIA}{dia}$$

in which:

> ε_r *is the relative permittivity (formerly SIC),*
>
> *C is the capacitance in microfarads of the immersed 120-inch or 3048-mm portion of the sample,*
>
> *DIA is the measured diameter over the insulation in inches or millimeters, and*
>
> *dia is the measured diameter under the insulation in inches or millimeters.*

1021 – 1039 *Reserved for Future Use*

MECHANICAL WATER ABSORPTION

1040 Test

1040.1 The absorption of water is to be expressed as milligrams mass per square inch of exposed surface or as milligrams mass per square centimeter of exposed surface and is to be determined after a 168-h immersion of the specimen in tap water at 70.0 ±1.0°C (158.0 ±1.8°F) for insulation having a temperature rating of 60°C (140°F), and at 82.0 ±1.0°C (179.6 ±1.8°F) for insulation having a temperature rating of 75°C (167°F).

1040.2 Where the conductor size is 1 AWG or smaller, the specimens to be used are to be 11-inch or 280-mm lengths of the wire or cable or cord conductor. Where the conductor size is 1/0 AWG or larger, the specimens are to be cut from the insulation in segments 4 inches long by 1 inch wide and 0.04 inch thick or 100 mm by 25 mm by 1 mm. The test procedure for a No. 1 AWG or smaller conductor is described in 1040.3 – 1040.8 and, for a No. 1/0 AWG or larger conductor, is described in 1040.9.

1040.3 Any jacket or other covering(s), including a coating to improve the resistance of the insulated conductor to flame, outside of the insulation is (are) to be removed or specimens are to be selected before application of any jacket or other covering (including a coating to improve the resistance of the insulated conductor to flame), leaving the insulation completely exposed. The surface of the finished insulated conductor is to be cleaned of all fibers and particles of foreign material by means of a cloth wet with ethyl alcohol. The specimens are to be dried in a vacuum over calcium chloride for 48 h at 70.0 ±1.0°C (158.0 ±1.8°F) and subsequently cooled to room temperature in a desiccator. Each specimen is to be weighed to the nearest milligram promptly after removal from the desiccator, and this weight is to be designated as W_1. Each specimen is then to be bent into the form of a U around a mandrel having a diameter four times the measured diameter of the specimen.

1040.4 The water bath is to consist of a vitreous-enameled-steel or glass vessel containing tap water, and is to be automatically controlled so that the water temperature is maintained at the specified temperature. The vessel is to have a close-fitting sheet-metal cover plate of brass or other nonferrous metal and is to have holes that just accommodate the specimens.

1040.5 The ends of each specimen are to be inserted through two holes in the cover plate so that 10 inches or 250 mm of the specimen are exposed below the plate. Rubber stoppers having holes bored to fit the specimens tightly, or accurately drilled, close-fitting washers of the same nonferrous metal as the cover plate described in 1040.4, are to be used to complete the closure of the hole in the cover plate and to assist in holding the specimens in place. The water level is to be maintained flush with the underside of the cover plate. Water is not to touch the ends of the specimens.

1040.6 The specimens are to remain in the water for 168 h, after which the cover plate with the specimens is to be removed from the vessel and transferred to a similar vessel filled with tap water at room temperature. The rubber stoppers or the metal washers are then to be taken off of one specimen at a time, each specimen is to be removed and shaken to dispose of loose water, and any remaining surface moisture is to be blotted off lightly with a clean, lintless, absorbent cloth. Each specimen is to be weighed again to the nearest milligram within 3 min after removal from the water, and this weight is to be designated as W_2.

1040.7 The specimens are then to be dried in a vacuum over calcium chloride for 48 h at 70.0 ±1.0°C (158.0±1.8°F), cooled to room temperature in a desiccator, and weighed to the nearest milligram promptly after removal from the desiccator. This weight is to be designated as W_3.

1040.8 Moisture absorption (MWA) in milligrams per square inch or in milligrams per square centimeter is to be determined by one or the other of the following formulas depending on whether W_3 is less or greater than W_1

$$MWA = \frac{W_2 - W_3}{S} \quad \text{if } W_3 \text{ is less than } W_1$$

or

$$MWA = \frac{W_2 - W_1}{S} \quad \text{if } W_3 \text{ is greater than } W_1$$

in which:

W_1 is original weight of the sample in milligrams,

W_2 is the weight of the sample in milligrams after immersion,

W_3 is the weight of the sample in milligrams after final drying, and

S is the area of the immersed surface of the sample in square inches or square centimeters (circumference times length immersed).

1040.9 Where segments of insulation are used as specified in 1040.2, the specimens are to be buffed, split, or skived to remove all corrugations and are then to be cleaned, dried, cooled, and weighed as described in 1040.3, after which they are to be placed in a water bath at the specified temperature for 168 h. They are then to be transferred to tap water at room temperature, removed one at a time, shaken, blotted, and reweighed as described in 1040.6. The specimens are then to be dried, cooled, and weighed again as outlined in 1040.7. The formulas in 1040.8 also apply to segment specimens, except that the immersed surface in square inches or square centimeters is to be determined by means of the following formula, in which all dimensions are expressed in inches or all dimensions are expressed in centimeters. T in the formula is the thickness of the buffed, split, or skived specimen.

$$S = 2(\text{length} \times \text{width}) + 2T \times (\text{length} + \text{width})$$

1041 and 1042 *Reserved for Future Use*

SWELLING AND BLISTERING IN WATER

1043 Test

1043.1 Finished cord that has a circular cross section is to be used for this test. Dye or another means that is durable in hot water and does not damage the cord is to be used to mark five test points along either a 32-ft or 10-m length of the cord. On a 32-ft specimen, the marks are to be 7 ft apart at points measuring 2, 9, 16, 23, and 30 ft from one end. On a 10-m specimen, the marks are to be 2 m apart at points measuring 1, 3, 5, 7, and 9 m from one end. The maximum and minimum diameters of the cord are to be measured to the nearest 0.001 inch or 0.01 mm at each of the five marked points. Each measurement is to be made by means of a machinist's micrometer caliper calibrated to read directly to at least 0.001 inch or 0.01 mm and having flat surfaces on both the anvil and the end of the spindle. The sum of the ten measurements is to be divided by 10 and recorded as d, the average diameter of the cord before immersion.

1043.2 The specimen is to be coiled, with the coil being relaxed and circular and at least 24 inches or 600 mm in overall diameter. The coil is to be immersed in tap water that is maintained at a temperature of 50.0 ±1.0°C (122.0 ±1.8°F), with a length of 12 inches or 300 mm that is kept dry and extending above the water at each end. The water bath is to have a width or diameter that accommodates the coil laid horizontal in the bath without any turn of the coil touching a vertical surface of the tank. The cord is to remain immersed continuously for 336 h (14 d) and is then to be removed from the water, uncoiled, and laid straight on a surface that is dry, flat, horizontal, and at room temperature. Without delay, all surface moisture is to be blotted from the surface of the cord by means of a clean, absorbent cloth that is free of lint.

1043.3 The cord does not comply where there is any evidence of blistering. Where there is no blistering, the maximum and minimum diameters of the cord are to be measured immediately at each of the five marked points. The sum of these ten measurements is to be divided by 10 and recorded as D, the average diameter of the cord after immersion. The cord does not comply where the increase I in average diameter (swelling) calculated as follows exceeds 20.0 percent.

$$I = 100(D - d)/d$$

1044 – 1059 *Reserved for Future Use*

FLAME TESTS

1060 Vertical Flame and FT1 Tests

1060.1 A vertical specimen of the finished wire, cable, or cord:

a) Shall not convey flame along its length, and

b) Shall not convey flame to combustible materials in its vicinity

during, between, or after five 15-s applications of a standard test flame. The standard test flame is to be nominally 125 mm high and is to produce heat at the nominal rate of 500 W (1700 Btu/h). The period between applications is to be 15 s regardless of whether flaming of the specimen ceases of its own accord within 15 s of the previous application. ***Except that cotton is not to be used, for an FT1 test***, this test is to be conducted as described in 1080.2 – 1080.11 and 1060.2 using one of the fuels described in 1080.3 and the standard laboratory burner and calibration as specified in 1080.1. The results of this test are to be judged as indicated in 1060.3.

1060.2 The burner is to be tilted forward into position to apply the gas flame to the specimen, kept there for 15 s, quickly tilted back to the stop to remove the flame from the specimen for 15 s, and so forth for a total of five 15-s applications of the gas flame to the specimen with 15 s between applications. The gas flame is to be reapplied to the specimen 15 s after the previous application regardless of whether flaming of the specimen ceases of its own accord within 15 s of the previous application.

1060.3 Where any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers, and brown scorching, are to be ignored) after any of the five applications of flame, the wire, cable, or cord is to be judged capable of conveying flame along its length. Where any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton (***does not apply to an FT1 test***) on the burner, wedge, or testing surface (flameless charring of the cotton is to be ignored), the wire, cable, or cord is to be judged capable of conveying flame to combustible materials in its vicinity. Where any specimen continues to flame longer than 60 s after the five applications of the gas flame, the wire, cable, or cord is to be judged capable of conveying flame to combustible materials in its vicinity.

1061 Cable Flame Test

1061.1 A vertical specimen of the finished cable:

a) Shall not convey flame along its length, and

b) Shall not convey flame to combustible materials in its vicinity

during, between, or after three 60-s applications of a standard test flame. The standard test flame is to be nominally 125 mm high and is to produce heat at the nominal rate of 500 W (1700 Btu/h). The period between applications is to be 30 s regardless of whether flaming of the specimen ceases of its own accord within 30 s of the previous application. This test is to be conducted as described in 1080.2– 1080.11 and 1061.2 using one of the fuels described in 1080.3 and the standard laboratory burner and calibration as specified in 1080.1. The results of this test are to be judged as indicated in 1061.3.

1061.2 The burner is to be tilted forward into position to apply the gas flame to the specimen, kept there for 60 s, quickly tilted back to the stop to remove the flame from the specimen for 30 s, and so forth for a total of three 60-s applications of the gas flame to the specimen with 30 s between applications. The gas flame is to be reapplied to the specimen 30 s after the previous application regardless of whether flaming of the specimen ceases of its own accord within 30 s of the previous application.

1061.3 Where any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers, and brown scorching, are to be ignored) following the three applications of flame, the cable is to be judged capable of conveying flame along its length. Where any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or testing surface (flameless charring of the cotton is to be ignored), or continues to flame longer than 60 s after three applications of the gas flame, the cable is to be judged capable of conveying flame to combustible materials in its vicinity.

1062 – 1079 *Reserved for Future Use*

1080 VW-1 (Vertical-Specimen) Flame Test

1080.1 A vertical specimen:

a) Shall not convey flame along its length, and

b) Shall not convey flame to combustible materials in its vicinity

during, between, or after any of five 15-s applications of a standard test flame. The standard test flame is to be nominally 125 mm high and is to produce heat at the nominal rate of 500 W (1700 Btu/h). The period between applications is to be 15 s where the specimen flaming ceases within 15 s or less time, or the duration of the specimen flaming where the specimen flame persists longer than 15 s. This test is to be conducted as described in 1080.2 – 1080.13 using one of the fuels described in 1080.3 and the standard laboratory burner[a] described in ASTM D 5025-99. The gas flame produced by the burner is to be calibrated as described in ANSI/ASTM D 5207-98. The results of this test are to be judged as indicated in 1080.14.

[a]Sources of burners that comply with ASTM D 5025-99:

a supplier
Catalog No. 13–1927–000
Atlas Electric Devices Company
4114 North Ravenswood Avenue
Chicago, IL 60613

a manufacturer
UL flame test Tirrill burner with
ASTM D 5025 orifice:
0.90 ±0.03 mm orifice diameter
1.60 ±0.05 mm orifice length
Humboldt Manufacturing Company
7302 West Agatite Avenue
Norridge, IL 60656

1080.2 This test is to be conducted in a draft-free chamber having an air-tight, windowed sash, door, or other means for access and viewing. Each linear interior dimension of the chamber is to be at least 24 inches or 610 mm. The actual dimensions are to result in an interior volume of the chamber of at least 140 ft^3 or 4 m^3, including the volume of the exhaust transition. The size of the exhaust transition, if any, is not specified. At least 70 ft^3 or 2 m^3 of this volume is to be above the area of the gas and specimen flames as space for the heat and smoke to accumulate and not influence the flames. The chamber volume at or below the level of the flames is not to contain obstructions to the natural flow of chamber air supplying oxygen to the flames. The chamber is to have an air-tight glove box for arm-and-hand access to the apparatus or other means for adjusting the apparatus while the access is completely closed. The interior of the chamber is to be visible without obstruction while the access is closed. The chamber is to be fitted with an exhaust blower for pulling smoke and fumes out of the test area after the test. A tight-sealing damper is to be located between the chamber and the blower to prevent drafts while the blower is not operating. The exhaust blower is not to be operated during the test or during calibration. Immediately after each calibration and each test, the damper is to be opened and the blower is to be operated to purge the chamber of all smoke and fumes.

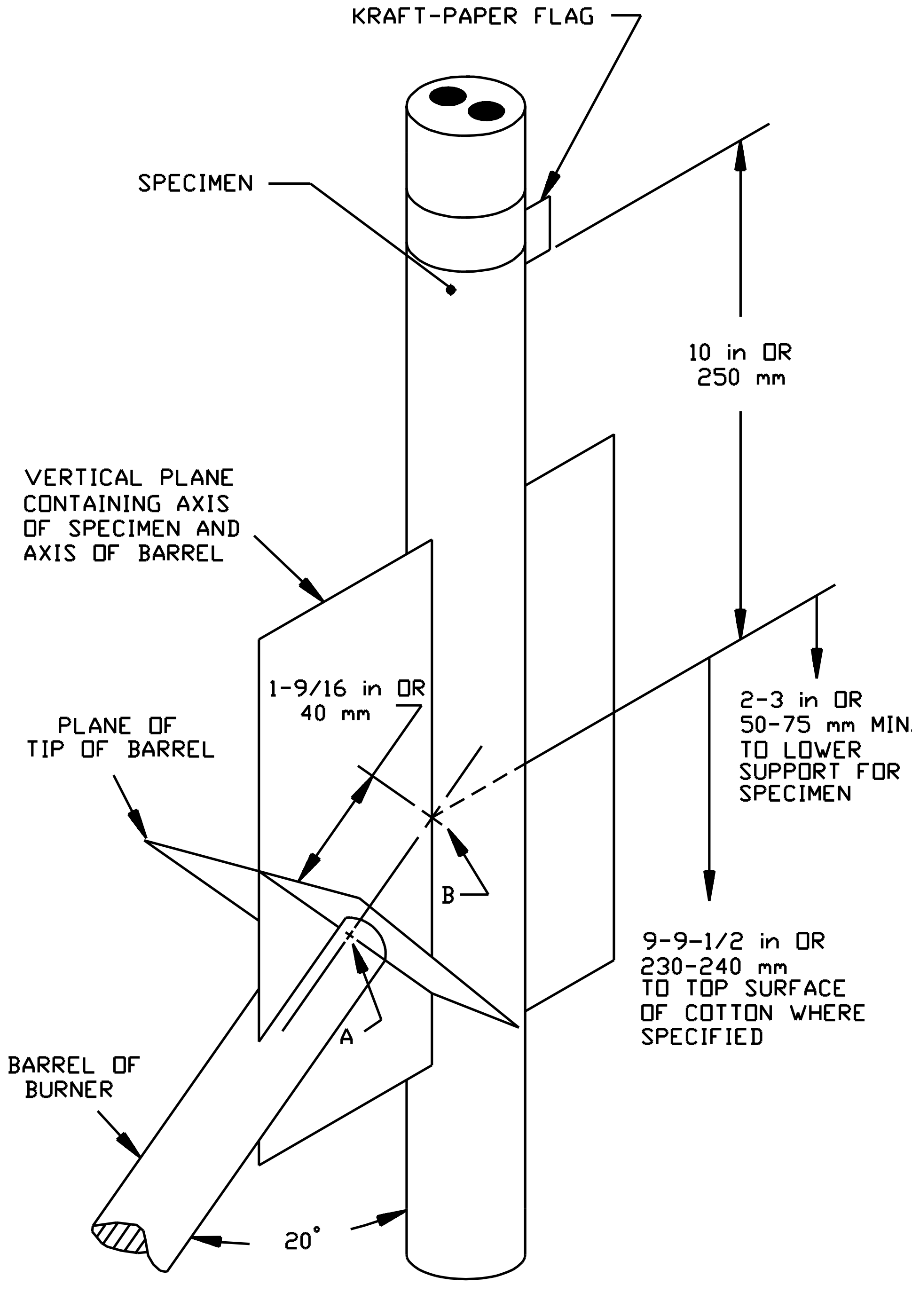
1080.3 For referee purposes, the fuel for this test is to be technical-grade methane (at least 98.0 percent pure) having a nominal heating value of 1000 Btu (thermochemical) per cubic foot or 37.3 MJ/m^3 or 8.9 kilocalories (thermochemical) per cubic meter. Otherwise, it is appropriate to use methane of a different grade, natural gas from a cylinder or a gas main, or propane. In each such case, the gas is to be of a grade that enables the test flame to be calibrated.

1080.4 The burner flame is to be calibrated at least every 30 days and each time that a cylinder of gas is changed (see 1080.7) or any of the equipment is changed. Where the gas used is other than the grade of methane specified for referee purposes, the burner flame is to be calibrated each day immediately before testing is begun.

1080.5 This test is to be performed on unaged specimens. The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 25.0 ±10°C or 77 ±18°F throughout the test.

1080.6 The test is to be conducted in the draft-free chamber described in 1080.2. The burner mounted on the wedge is to be placed directly on the floor of the chamber or, for ease of testing, on a bench within the chamber. The testing surface (chamber floor or bench top) is to be at least 4 ft or 1200 mm below the top of the chamber walls (at the transition to the exhaust). The dimensions of the testing surface of the bench are to accommodate the rectangular layer of cotton described below. A specimen 18 inches or 455 mm long cut from a straight sample length of the finished cord, wire, cable, or cord conductor is to be secured with its longitudinal axis vertical. Where required, lab stands or other appropriate supports, which will create no updrafts or impede the air supply to the flame, are to be used to hold the specimen in place. A flat, horizontal layer of dry (untreated), pure, surgical cotton not more than 1/4 inch or 6 mm thick is to cover an area of testing surface not less than 12 inches or 305 mm wide by 14 inches or 355 mm deep and centered on the vertical axis of the test specimen. There are not to be any openings through the layer of cotton. The upper surface of the cotton is to be 9 – 9-1/2 inches or 230 – 240 mm below point B, which is the point at which the tip of the blue inner cone of the 500-W test flame touches the specimen (this is shown in Figure 1080.1).

Figure 1080.1
Dimensions for VW-1 and other vertical-specimen flame tests



FT131E

Proportions exaggerated for clarity of detail

1080.7 Before each test and while the barrel is vertical and the burner is well away from the specimen, the gas flame is to be checked to make certain that its overall height is 125±10 mm or 4-7/8 inches and that the blue inner cone is 40 ±2 mm or 1-9/16 inches high, as established during calibration. A flame that changes from blue to luminous without any change of the settings is an indication that the fuel-gas content of the cylinder is exhausted and that the denser depletion-indicator material (propane, for example), which some suppliers add to their cylinders, is being burned instead. In this case, the cylinder is to be labeled as empty and then returned for refilling. Where the overall flame is blue and the height of the blue inner cone is other than 40 ±2 mm or 1-9/16 inches without any change of the settings, the contents of the cylinder likely are at low pressure. A gas-supply gauge pressure of 10 – 20 lbf/in^2 or 69 – 138 kPa or 690 – 1380 mbar or 700 – 1400 gf/cm^2 has been found to be adequate to maintain the required flame. A cylinder shall not be used when this range of pressure is no longer sustainable at room temperature.

1080.8 A wedge (typical dimensions are shown in Figure 1080.2) to which the base of the burner is to be secured is to angle the barrel 20° from the vertical while the longitudinal axis of the barrel remains in a vertical plane. A layer of dry (untreated), pure, surgical cotton not more than 1/4 inch or 6 mm thick is to be clamped or otherwise secured to the wedge and on and around the base of the burner. The wedge is to be positioned to place the longitudinal axis of the barrel in the vertical plane that contains the longitudinal axis of the specimen. The wedge is also to be positioned to place point A, which is the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel, 1-9/16 inches or 40 mm from point (B) at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone is to touch the center of the front of the specimen during each application of the test flame.

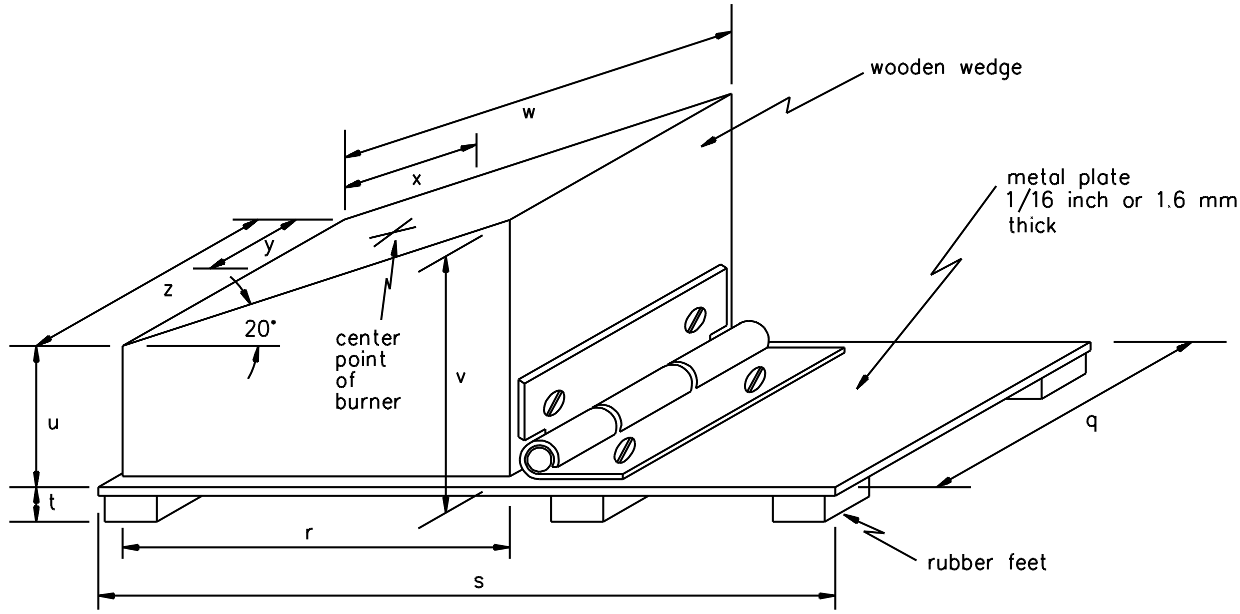
1080.9 The burner is to be mounted on the wedge. The wedge is to be hinged as shown in Figure 1080.2 to enable the gas flame to be repeatedly tilted away from and then returned precisely to application to the specimen. Tilting of the burner away from and toward the specimen is to be by mechanical means or by hand. The tilt away is to be against a stop (the metal plate) that results in the gas flame angling away from the specimen beyond a vertical position. The motion of the burner is not to disturb the layer of cotton on the floor of the enclosure or result in the cotton coming away from the wedge or the base of the burner.

1080.10 A strip of unreinforced 60-lb or 98-g/m^2 kraft paper that is 1/2 inch or 10 mm wide, at or near 5 mils or 0.1 mm thick, and is gummed on one side is to be used to make an indicator flag. The gumming is to be moistened just enough to facilitate adhesion. With the gum toward the specimen, the strip is to be wrapped around the specimen once with its lower edge 10 inches or 250 mm above B, the point at which the blue inner cone is to touch the specimen. The ends of the strip are to be pasted together evenly and trimmed to result in a flag that projects 3/4 inch or 20 mm from the specimen toward the rear of the draft-free chamber, with the flag in the vertical plane described in 1080.8 (see Figure 1080.1). In testing a flat specimen, the flag is to project from the center of the rear broad face of the specimen and the test flame is to be applied to the front broad face. The lower clamp or other support for the specimen is to be adjusted vertically to keep it from being any closer than 2 – 3 inches or 50 – 75 mm to point B.

1080.11 The burner is to be supported as indicated in 1080.9 in a position tilted away from the specimen and is then to be lit. Where the burner has a pilot light, the pilot light is to be disconnected for this test.

1080.12 The lit burner is to be tilted forward into position to apply the gas flame to the specimen, kept there for 15 s, quickly tilted back to the stop to remove the gas flame from the specimen for 15 s (the gas flame is to remain away from the specimen longer where flaming of the specimen persists– see 1080.13), and so forth for a total of five 15-s applications of the gas flame to the specimen with 15 s (longer where flaming of the specimen persists – see 1080.13) between applications. The gas flame is to be reapplied to the specimen 15 s after the previous application where flaming of the specimen ceases of its own accord within 15 s or less time of the previous application.

Figure 1080.2
Typical wedge hinged to plate



SM665

Rubber feet are to be used with this design to keep the assembly from shifting in position as the wedge is tilted back and forth during a test. Two of the rubber feet are to be under the area of the hinge to keep the plate from deflecting during motion of the wedge.

q	3-1/4 inches	83 mm	v	3-1/4 inches	83 mm
r	5-1/16	129	w	5-3/8	137
s	11	279	x	2	51
t	25/64	10	y	1-1/2	38
u	1-1/2	38	z	3	76

1080.13 Where flaming of the specimen persists longer than 15 s after the previous application of the gas flame, the gas flame is not to be reapplied until flaming of the specimen ceases of its own accord. The gas flame is to be reapplied as soon as flaming of the specimen ceases. Tilting the burner forward to apply the gas flame to the specimen and back to remove the gas flame from the specimen are both to be accomplished rapidly and with minimal movement of the air around the specimen.

1080.14 Where any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers, and brown scorching, are to be ignored) after any of the five applications of flame, the wire, cable, or cord is to be judged capable of conveying flame along its length. Where any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or testing surface (flameless charring of the cotton is to be ignored), or continues to flame longer than 60 s after any application of the gas flame, the wire, cable, or cord is to be judged capable of conveying flame to combustible materials in its vicinity.

1081 – 1089 *Reserved for Future Use*

1090 Horizontal-Specimen Appliance-Wire Flame Test

1090.1 A horizontal specimen of finished appliance wire:

a) Shall not convey flame along its length, and

b) Shall not convey flame to combustible materials in its vicinity

after a single 30-s application of a 225-W test flame (770 Btu/h) nominally 50 mm high. This test is to be conducted as described in 1080.2 – 1080.5 and 1090.2 – 1090.6 (specimen supported horizontally) using one of the fuels described in 1080.3 and the standard laboratory burner[a] described in ASTM D 5025-99. The gas flame produced by the burner is to be calibrated as described in ANSI/ASTM D 5207-98 with the following modifications to adapt the procedure for the 125-mm flame to the 50-mm flame:

c) The copper slug used for the 125-mm flame is also to be used for the 50-mm flame. For the 50-mm flame, the slug is to be positioned 25 mm or 1 inch above the tip of the burner during the calibration procedure.

d) The starting gas-flow rate for methane is to be 405 ±10 mL/min with a back pressure of 45 ±5 mm water.

e) The needle valve and air-inlet openings on the burner are to be adjusted until the overall height of the flame is 50 ±4 mm or 2 inches and the height of the blue inner cone is 16.5 ±1.5 mm or 11/16 inch.

f) The time for the temperature to rise from 100 to 700°C (212 to 1292°F) is to be 84 ±2 s.

The results of this test are to be judged as indicated in 1090.7.

[a] See note [a] to 1080.1 for examples of burners that comply with ASTM D 5025-99.

1090.2 The test is to be conducted in the draft-free chamber described in 1080.2. The burner is to be placed directly on the floor of the chamber or, for ease of testing, on a bench within the chamber. The testing surface (chamber floor or bench top) is to be at least 4 ft or 1200 mm below the top of the chamber walls (at the transition to the exhaust). The dimensions of the testing surface of the bench are to accommodate the rectangular layer of cotton described below. A specimen 24 inches or 610 mm long cut from a sample length of the appliance wire is to be secured with its longitudinal axis horizontal. The specimen supports are to be 22 inches or 560 mm apart, and three metal rods or equivalent permanent means whose free ends are no closer than 3/4 inch or 20 mm to the specimen are to be used to indicate three points on the specimen measuring 2 inches or 51 mm, 7 inches or 178 mm, and 13 inches or 330 mm from the left-hand point of support of the specimen. Where required, lab stands or other appropriate supports, which will create no updrafts or impede the air supply to the flame, are to be used to hold the test apparatus in place. A flat, horizontal layer of dry (untreated), pure, surgical cotton not more than 1/4 inch or 6 mm thick is to cover an area of the testing surface not less than 24 inches or 610 mm wide by 12 inches or 305 mm deep and centered on the horizontal axis of the test specimen. There are not to be any openings through the layer of cotton. The upper surface of the cotton is to be 9 – 9-1/2 inches or 230 – 240 mm below the lower surface of the specimen (this is shown in Figure 1090.1). A flat specimen is to be tested with its flat surfaces horizontal and with the gas flame applied to the center of the bottom flat surface.

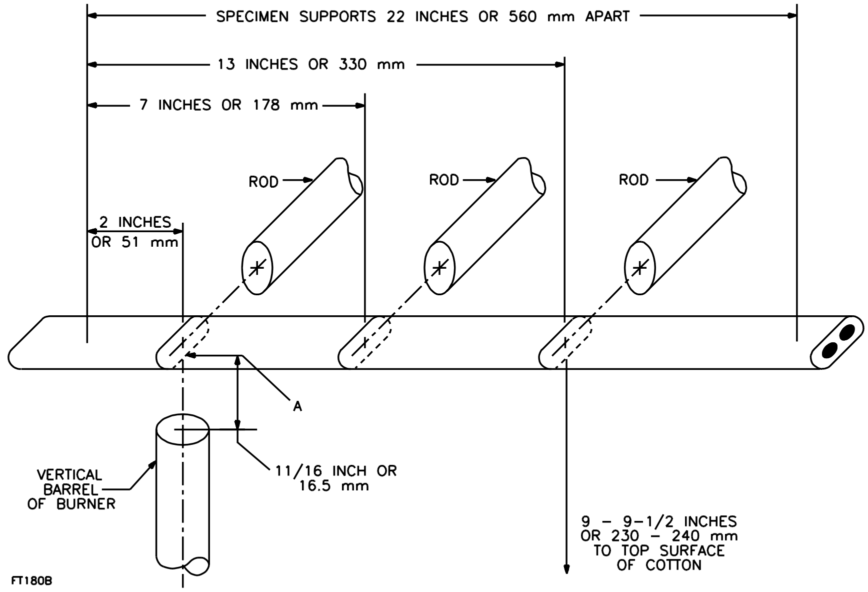
1090.3 Before each test and while the barrel is vertical and the burner is well away from the specimen, the gas flame is to be checked to make certain that its overall height is 50 ±4 mm or 2 inches and that the blue inner cone is 17 ±1 mm or 11/16 inch high, as established during calibration. A flame that changes from blue to luminous without any change of the settings is an indication that the fuel-gas content of the cylinder is exhausted and that the denser depletion-indicator material (propane, for example), which some suppliers add to their cylinders, is being burned instead. In this case, the cylinder is to be labeled as empty and then returned for refilling. Where the overall flame is blue and the height of the blue inner cone is other than 17 ±1 mm or 11/16 inch without any change of the settings, the contents of the cylinder likely are at low pressure. A gas-supply gauge pressure of 10 – 20 lbf/in^2 or 69 – 138 kPa or 690 – 1380 mbar or 700 – 1400 gf/cm^2 has been found adequate to maintain the required flame. A cylinder shall not be used when this range of pressure is no longer sustainable at room temperature.

1090.4 The burner is to be secured in an adjustable support jig with the longitudinal axis of the barrel vertical. A layer of dry (untreated), pure surgical cotton not more than 1/4 inch or 6 mm thick is to be placed around the base of the burner. The jig is to be positioned to place the longitudinal axis of the barrel in the vertical plane that intersects the specimen perpendicularly at the marker located 2 inches or 51 mm from the left-hand point of support of the specimen. The jig is also to be positioned to place the intersection of the longitudinal axis of the barrel and the plane of the tip of the barrel 16.5 ±1.5 mm or 11/16 inch below the point (A) at which the extended longitudinal axis of the barrel meets the outer surface of the underside of the specimen at the 2-inch or 51-mm marker. Point A is the point on the surface of the underside of the specimen at which the tip of the blue inner cone is to touch the specimen.

1090.5 The support for the burner is to be arranged to enable the burner to be swung or slid into the position described in 1090.4 and quickly removed. The motion of the burner is not to disturb the layer of cotton on the testing surface or result in the cotton coming away from the base of the burner.

1090.6 The burner is to be supported as indicated in 1090.5 in a position away from the specimen and then lit (where the burner has a gas pilot light, the pilot is not be to be used). The lit burner is to be moved into position to apply the tip of the blue inner cone of its flame to the underside of the specimen at the 2-inch or 51-mm marker (point A), kept there for 30 s, removed to a position well away from the specimen, and then extinguished by closing the gas supply valve. Note is to be taken and recorded of whether any flaming of the specimen progresses beyond the 7-inch or 178-mm marker. Where flaming of the specimen passes this marker, the amount of time that the specimen flame takes to progress from the 7-inch or 178-mm marker toward the 13-inch or 330-mm marker is to be noted and divided into the total length of specimen burned between the 7-inch or 178-mm and the 13-inch or 330-mm markers. Note is also to be taken and recorded of whether particles or drops that ignite any of the cotton are emitted by the specimen during or after application of the gas flame.

Figure 1090.1
Dimensions for horizontal-specimen appliance-wire flame test



Proportions exaggerated for clarity of detail

1090.7 Where any specimen flames at a rate greater than 1 inch/min or 25 mm/min between the markers at 7 inches or 178 mm and 13 inches or 330 mm, measured as described in 1090.6, the appliance wire is to be judged capable of conveying flame along its length. Where any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner or testing surface (flameless charring of the cotton is to be ignored) the appliance wire is to be judged capable of conveying flame to combustible materials in its vicinity.

1091 – 1099 *Reserved for Future Use*

1100 Horizontal-Specimen / FT2 Flame Test

1100.1 A horizontal specimen of the finished wire, cable, cord, or assembly:

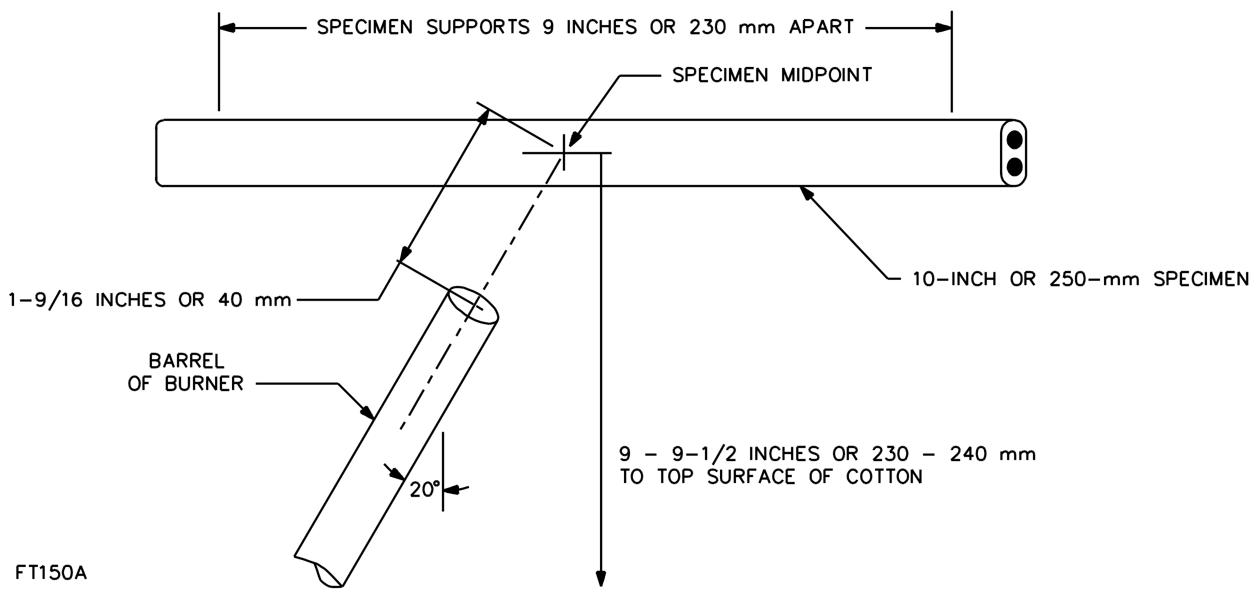
a) Shall not convey flame along its length, and

b) Shall not convey flame to combustible materials in its vicinity

during, or after a single 30-s application of a standard test flame. The standard test flame is to be nominally 125 mm high and is to produce heat at the nominal rate of 500 W (1700 Btu/h). This test is to be conducted as described in 1080.2 – 1080.5, 1100.2 (specimen supported horizontally), 1080.7–1080.9, 1080.11, and 1100.3 using one of the fuels described in 1080.3 and the standard laboratory burner and calibration as specified in 1080.1. The results of this test are to be judged as indicated in 1100.4.

1100.2 This test is to be conducted in the draft-free chamber described in 1080.2. The burner is to be placed directly on the floor of the chamber or, for ease of testing, on a bench within the chamber. The testing surface (chamber floor or bench top) is to be at least 4 ft or 1200 mm below the top of the chamber walls (at the transition to the exhaust). The dimensions of the testing surface of the bench are to accommodate the rectangular layer of cotton described below. A 10-inch or 250-mm specimen cut from a sample length of the finished wire, cable, cord, or assembly is to be secured with its longitudinal axis horizontal. The specimen supports are to be 9 inches or 230 mm apart. Where required, lab stands or other appropriate supports, which will create no updrafts or impede the air supply to the flame, are to be used to hold the test apparatus in place. A flat, horizontal layer of dry (untreated), pure, surgical cotton not more than 1/4 inch or 6 mm thick is to cover an area of the testing surface not less than 12 inches or 305 mm wide by 14 inches or 355 mm deep and centered on the horizontal axis of the test specimen. There are not to be any openings through the layer of cotton. The upper surface of the cotton is to be 9 – 9-1/2 inches or 230 – 240 mm below the point on the surface of the specimen at which the tip of the blue inner cone touches the specimen (this is shown in Figure 1100.1). A flat specimen is to be tested with its flat surfaces vertical and with the gas flame applied to the center of one flat surface.

Figure 1100.1
Dimensions for horizontal-specimen / FT2 flame test
Proportions exaggerated for clarity of detail



FT150A

1100.3 The burner is to be tilted forward into position to apply the gas flame to the specimen, kept there for 30 s and quickly tilted back to the stop to remove the flame from the specimen. Tilting the burner forward to apply the gas flame to the specimen midpoint and back to remove the gas flame from the specimen are both to be accomplished rapidly and with minimal movement of the air around the specimen. Note is to be taken and recorded of the length of the charred portion of the specimen and whether particles or drops that ignite any of the cotton are emitted by the specimen during or after application of the gas flame.

1100.4 Where any specimen chars for a total length that exceeds 100 mm or 3-15/16 inches, the wire, cable, cord, or assembly is to be judged capable of conveying flame along its length. Where any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or testing surface (flameless charring of the cotton is to be ignored), the wire, cable, cord, or assembly is to be judged capable of conveying flame to combustible material in its vicinity.

1101 – 1159 *Reserved for Future Use*

1160 UL Vertical-Tray Flame Test

This test method is described in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

1161 – 1163 *Reserved for Future Use*

1164 FT4/IEEE 1202 Vertical-Tray Flame Test

This test method is described in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

1165 – 1199 *Reserved for Future Use*

SUNLIGHT RESISTANCE

1200 Carbon-Arc and Xenon-Arc Tests

1200.1 As specified in the wire standard, this test is to be conducted on five complete specimens.

1200.2 The specimens are to be conditioned either by xenon-arc radiation and water spray as described in 1200.3 – 1200.6, or by carbon-arc radiation and water spray as described in 1200.7 – 1200.10, and then are to be prepared and tested for retention of tensile strength and ultimate elongation as described in 1200.11– 1200.15. For the conditioning of flat cable, one of the broad faces of the cable is to face the arc(s). For the conditioning of a jacket, the outer surface of the jacket specimen is to face the arc(s). The long dimension of each specimen is to be parallel to the arc(s). The temperature and the cycling are to be programmed automatically.

1200.3 CONDITIONING BY XENON-ARC – The specimens are to be mounted in the specimen holders of xenon-arc-radiation and water-spray exposure equipment as specified in the American Society of Testing and Materials ″Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Nonmetallic Materials″, ASTM G 155-00, and ″Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources″, ASTM G151–00. The radiation is to be produced by a lamp assembly of the long-arc water-cooled type. The lamp assembly is to consist of a quartz xenon burner tube that is centered inside concentric inner and outer cylindrical optical filter tubes of soda borosilicate glass (7740 Pyrex glass or its equivalent). Operation of the lamp assembly is to maintain a level of spectral irradiance at the specimens of at least 0.35 W/m^2 monitored at a wavelength of 3400 Å or 340 nm. The spectral power distribution of the emission from the tubes is to comply with Table 1 of ASTM G155–00.

1200.4 Radiation from the xenon arc is to be kept by positive, nonmakeshift means from reaching persons within sight of the apparatus. The inner and outer optical filters are to be replaced at intervals that minimize the risk of spontaneous breakage of the filters because of stresses that develop in the glass from exposure to the arc. For this safety reason, and also to maintain the levels of irradiation, ASTM suggests replacing the inner filter after no more than 400 h of use and the outer filter after no more than 2000 h of use.

1200.5 All points of each specimen are to be subjected to a fine spray of water once during the 18 min portion of a 2 h programmed cycle of 102 min of light followed by 18 min of light and water spray each time that the cycle is repeated as noted in 1200.6. The water used in the spray is to be clean (it is not to leave any deposit on the specimens and is not to stain the specimens), its pH is to be 6.0 – 8.0, and its temperature is to be 16.0 ±5.0°C (60.0 ±9.0°F). The water used in the spray is not to be recirculated unless these conditions are maintained. While the xenon arc is in operation and the spray is off, the equilibrium black-panel temperature at the specimens is to be 63.0 ±3.0°C (145.0 ±5.4°F).

1200.6 With the xenon arc operating continuously, and with prudent attention to the risk to eyesight and to other health risks presented by the arc, the water spray is to be operated for 18 min on and 102 min off. This 2 h cycle is to be repeated resulting in the total elapsed operating time specified in the wire standard. The apparatus is to be turned off after the specified total operating time. The specimens are to be removed from the test apparatus and kept in still air under conditions of ambient room temperature and atmospheric pressure for not less than 16 and not more than 96 hours before being subjected to physical tests.

1200.7 CONDITIONING BY TWIN CARBON-ARCS – The specimens are to be mounted in the specimen holder of carbon-arc-radiation and water-spray exposure equipment as specified in the American Society for Testing and Materials ″Standard Practice for Operating Carbon-Arc Type Light Apparatus for Exposure of Nonmetallic Materials″, ASTM G 153–00, and ″Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources″, ASTM G151–00. The apparatus is to include twin arcs struck between two sets of vertical carbon electrodes that are 1/2 inch or 13 mm in diameter and are individually enclosed in clear globes of heat-resistant optical glass (9200-PX Pyrex glass or its equivalent) that is opaque at wavelengths shorter than 2750 Å or 275 nm (1 percent transmission at 275 nm as the nominal cutoff point) and whose transmission improves to 91 percent at 3700 Å or 370 nm. The globes are to be replaced after whichever of the following occurs first: either 2000 h of use or appearance in the globes of pronounced discoloration, milkiness, or both. The globes are to be washed with detergent and water, rinsed thoroughly, and air dried at room temperature immediately before each day’s operation. The spectral power distribution of the emission from the globes is to comply with Table 1 of ASTM G153–00.

1200.8 Radiation from the carbon arcs is to be kept by positive, nonmakeshift means from reaching persons within sight of the apparatus. Ventilation is to keep the products of combustion in the carbon arcs from contaminating the specimens, and these products and the ozone generated are to be kept from being in any significant concentration in air breathed by persons.

1200.9 All points of each specimen are to be subjected to a fine spray of water once during the 3 min portion of a 20 min programmed cycle of 17 min of light followed by 3 min of light and water spray each time that the cycle is repeated as noted in 1200.10. The water is to be clean (it is not to leave any deposit on the specimens and is not to stain the specimens), its pH is to be 6.0 – 8.0, its temperature is to be 16.0 ±5.0°C (60.0 ±9.0°F), and the water is not to be recirculated unless these conditions are maintained. While the carbon arcs are in operation and the spray is off, the equilibrium black-panel temperature at the specimens is to be 63.0 ±2.5°C (145.0 ±4.5°F).

1200.10 With the carbon arcs operating continuously and carrying a current of 15 – 17 A each at a drop in rms potential of 120 – 145 V, and with prudent attention to the risk to eyesight and to other health risks presented by the arcs, the spray is to be operated for 3 min on and 17 min off. This 20 min cycle is to be repeated six times resulting in operation with each specimen being subjected to radiation from the arcs for a total of 102 min and to the water spray with radiation from the arcs for a total of 18 min. This sequence is to be repeated resulting in the total elapsed operating time specified in the wire standard. The apparatus is to be turned off after the total specified operating time. The specimens are to be removed from the test apparatus and retained in still air under conditions of ambient room temperature and atmospheric pressure for not less than 16 and not more than 96 hours before being subjected to physical tests.

1200.11 PREPARATION AFTER CONDITIONING – The core (the conductors, insulation, any fillers, and the like) of a cable or flexible cord having a separable overall jacket is to be removed from the five conditioned specimens and from five identical unconditioned specimens. Die-cut specimens are to be prepared from the jacket conditioned in the apparatus and are to include the portions of the jacket closest to the arcs. The surfaces facing the arcs are not to be buffed, skived, or planed away.

1200.12 The conductor is to be removed from the five conditioned specimens and from five identical unconditioned specimens of a thermoplastic-insulated cable. Die-cut specimens are to be prepared from the insulation and nylon jacket conditioned in the apparatus and are to include the portions of the insulation and nylon jacket closest to the arcs. The surfaces facing the arcs are not to be buffed away.

1200.13 The conductor (conductor plus insulation in the case of a single-conductor cable with a separable jacket) is to be removed from each of the five conditioned specimens and from each of the five identical unconditioned specimens of a thermoset-insulated cable. Die-cut specimens are to be prepared from the single-conductor insulation or jacket or from the overall jacket of the multiple-conductor cable conditioned in the apparatus and are to include the portions of the insulation or jacket closest to the arcs. The surfaces facing the arcs are not to be buffed or planed away.

1200.14 In the case of a service cable, all materials other than the individual jacket or unjacketed insulation and the overall jacket or PVC finish are to be removed from five identical unconditioned specimens. Tubular specimens are to be used in the case of specimens having an inside diameter no larger than 0.130 inch or 3.3 mm. Die-cut specimens are to be prepared from specimens having larger inside dimensions. In any case, the PVC finish, the individual or overall jacket, or the insulation is not to be buffed or otherwise prepared.

1200.15 TESTING AND PROPERTY-RETENTION LIMITS– The five conditioned specimens and the five unconditioned specimens are to be tested separately and in close succession for tensile strength and ultimate elongation. Nylon jackets are to be tested at a speed of 2 inches/min. The respective averages are to be calculated from the five tensile-strength and ultimate-elongation values obtained for the conditioned specimens and are to be divided by the averages of the five tensile-strength and ultimate-elongation values obtained for the unconditioned specimens. The wire, cable, or flexible cord is not appropriate for sunlight-resistant use where either the tensile-strength or ultimate-elongation ratio is less than 0.85 after 300 h of carbon-arc exposure or xenon-arc exposure or is less than 0.80 after 720 h of carbon-arc exposure or xenon-arc exposure, as specified in the wire standard. Service cable that does not comply with the requirement for 85 percent retention of physical properties and is retested after the sequence of exposures (100, 300, and 500 h) specified in UL 854 does not comply where the requirements for 65 percent retention and 15 and 5 percent rates of decrease are not met as stated in UL 854.

1201 – 1249 *Reserved for Future Use*

GLASS CONTENT

1250 Test

1250.1 In the case of an all-glass or glass-and-cotton or glass-and-rayon braid from Type SA wire or an all-glass or glass-and-cotton or glass-and-rayon braid from other wire, the test is to be made on specimens prepared from the finished braid. The braid is to be removed from a 40-inch or 1-m sample length of the finished wire and is to be cut into short sections about 1/8 inch or 3 mm in length. Reinforcing threads and binder threads of cotton or other organic material are not to be removed, even where such threads serve as an identifying marker. The short pieces are then to be well mixed and the saturant is to be removed from them by means of an organic solvent.

1250.2 A specimen of the extracted braid containing glass and weighing 5 g is to be dried to a constant weight W_1 in a weighed crucible at a temperature of 110 ±5°C (230 ±9°F), ignited in an electric furnace at a temperature of 800 ±20°C (1472 ±36°F) for 1 h, cooled to room temperature in a desiccator, and then weighed again W_2. The percentage of glass in the specimen is then to be calculated by means of the formula

$$70 \leq X_{all-glass} = \frac{100 W_2}{W_1}$$

in which:

X is the percentage of glass,

W_1 is the weight of the dried specimen before ignition, and

W_2 is the weight after ignition and drying.

1251 – 1269 *Reserved for Future Use*

TIGHTNESS OF INSULATION

1270 Test for Tightness of Conductor Insulation in Decorative-Lighting Cords and Wire

1270.1 A sample of the wire or the individual cord conductor 11 inches or 275 mm long is to have 2 inches or 50 mm of insulation and any separator stripped from one end. At the other end of the sample, the insulation is to be slit longitudinally for a length of 3 inches or 75 mm, thereby resulting in a specimen of insulated conductor 6 inches or 150 mm long. The 3-inch or 75-mm conductor is to be cut and removed and the empty insulation and any separator are to be taped back together. A weight for exerting a pull of 4 lbf or 18 N or 1.81 kgf is to be attached to the specimen by tying the taped insulation to the weight. The bare conductor at the other end of the specimen is to be secured in a clamp, vise, or other support and the weight is to be gently lowered and released so that it is supported by the specimen. With the weight and specimen thus suspended vertically, slipping of the conductor, separator, or combination of conductor and separator more than 1/8 inch or 3 mm (as observed at the top of the specimen at the point at which the bare conductor enters the insulation and any separator) during a period of 60 s does not comply.

1271 – 1279 *Reserved for Future Use*

1280 Test for Tightness of Circuit-Conductor Insulation in Integral Parallel Cord Other Than Tinsel Cord

1280.1 A 16-inch or 407-mm length of cord is to have 2 inches or 51 mm of insulation and any separator stripped from both circuit conductors at each end to result in a 12-inch or 305-mm test specimen. One bare circuit conductor is to be cut off even with the insulation at one end of the specimen, and the other bare circuit conductor is to be cut off even with the insulation at the other end of the specimen. Any grounding conductor is to be cut off even with the insulation at both ends of the specimen. A weight for exerting a pull of 8 lbf or 35.6 N or 3.63 kgf is to be attached to the stripped circuit conductor at one end, and the weight and attached specimen are then to be supported at the stripped end of the other circuit conductor. With the weight and specimen thus suspended, slipping of either conductor, separator, or combination of conductor and separator more than 1/8 inch or 3.2 mm (as observed where the conductor was cut off even with the insulation) during a period of 30 s does not comply.

1281 – 1299 *Reserved for Future Use*

LEAKAGE

1300 Test of Type TBS for Surface Leakage Resistance

1300.1 Metal foil bands are to be wrapped tightly around a specimen of the finished wire with a spacing of 2 inches or 50 mm between the bands. The specimen is then to be suspended in a closed chamber over an open container of water at a temperature of 23.0 ±1.0°C (73.4 ±1.8°F). After a period of 18 h in the saturated, moist atmosphere in the chamber at the specified temperature, the specimen is to be removed, any surface condensation is to be removed with fresh blotting paper, and the surface resistance between the two bands is to be measured by an appropriate method.

1300.2 The surface leakage resistance is to be determined from the formula

$$R_s = R_m \frac{C}{D}$$

in which:

> R_s *is the surface leakage resistance in megohms,*
>
> R_m *is the measured resistance in megohms,*
>
> *C is the circumference of the specimen in inches or millimeters, and*
>
> *D is the distance between the foil bands in inches or millimeters.*

1301 – 1319 *Reserved for Future Use*

1320 A-C Leakage-Current Tests of Low-Leakage-Current Service Cords

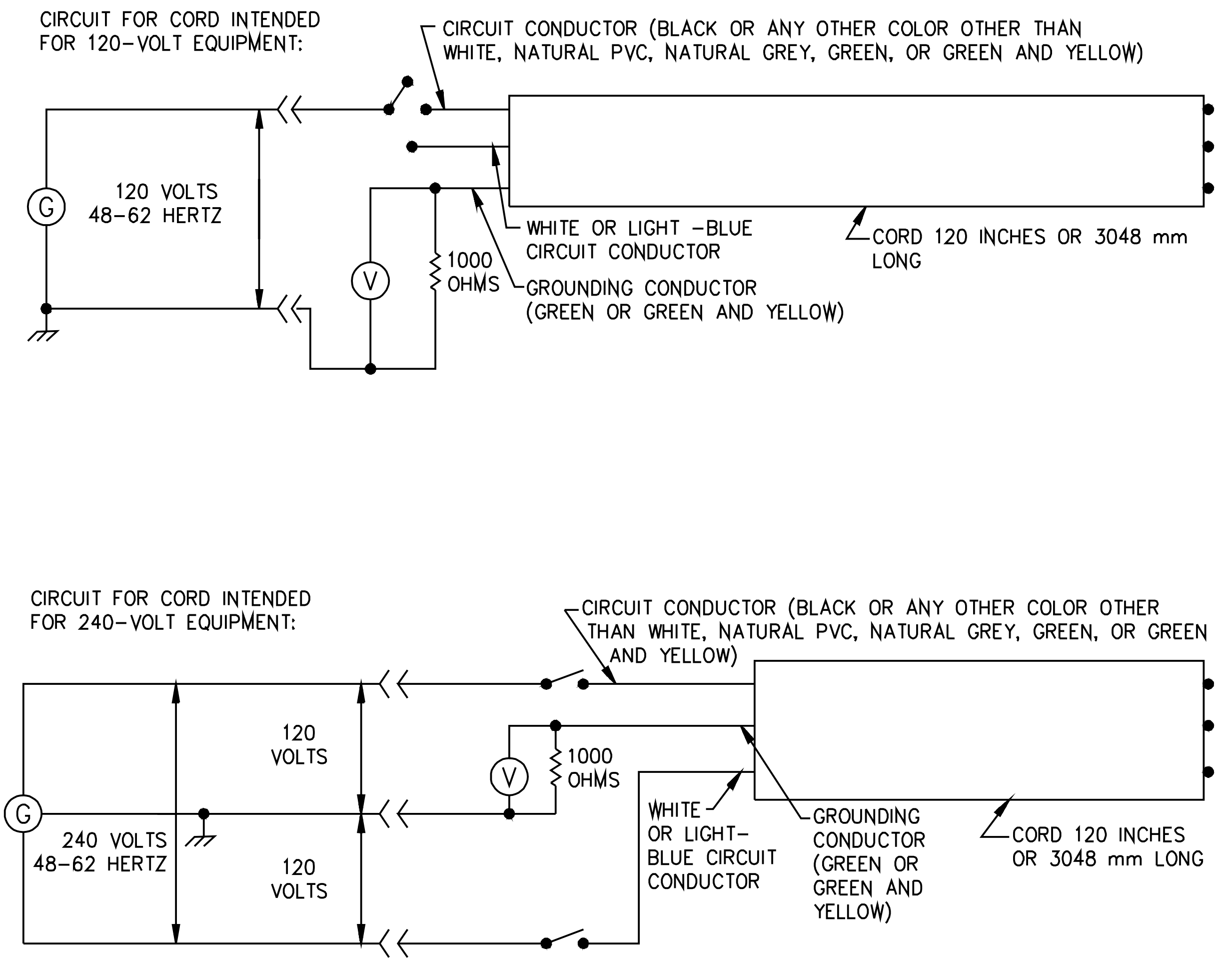
Each circuit conductor to grounding conductor

1320.1 A 120-inch or 3048-mm length of the finished cord is to be formed into a coil of exactly two complete turns and is to be placed on a dry, flat, horizontal wooden board nominally 3/4 inch or 20 mm thick. At one end of the cord, the ends of all three of the conductors are to be flush with the end of the jacket and in a plane perpendicular to the longitudinal axis of the cord. This is to be accomplished without contamination or deformation at the cut ends that results in distortion of the test results caused by surface leakage. At the other end of the cord, the circuit conductors and the grounding conductor are to be connected to an sinusoidal or nearly sinusoidal 48 – 62 Hz 120- or 240-V supply circuit as shown in the applicable part of Figure 1320.1, the choice of supply circuit depending on whether the cord is intended for use with 120- or 240-V equipment.

1320.2 The exact value of the resistor is to be determined by means of an accurate bridge, and the voltmeter is to be an oscilloscope, vacuum-tube voltmeter, or other high-impedance type. It is convenient to have the resistance exactly at 1000 ohms and the voltmeter calibrated to read directly in millivolts because, in such case, the meter readings for a 120-inch or 3048-mm cord are numerically equal to the current flow in microamperes per 10 ft or 3048 mm of the cord.

Figure 1320.1

Circuit for measuring a-c leakage current from each circuit conductor to grounding conductor



SC1611

1320.3 The circuit conductors are to be energized separately and in succession and the reading of the voltmeter recorded for each. The leakage current from each circuit conductor to the grounding conductor is to be calculated by dividing the voltage indicated by the voltmeter by the accurately known resistance of the resistor. The highest of the two leakage currents is to be used in choosing the range of current that determines the ″µA to green″ value for the cord-surface marking.

Each circuit conductor through jacket to foil

1320.4 A straight 120-inch or 3048-mm length of the finished cord is to be wrapped for its entire length with strip metal foil. The foil is to be in intimate contact with the jacket throughout the length of the cord. The straight length of foil-wrapped cord is to be placed on a dry, flat, horizontal wooden board nominally 3/4 inch or 20 mm thick. This is to be accomplished without contamination or deformation at the cut ends that results in distortion of the test results caused by surface leakage. At one end of the cord, the ends of all three of the conductors are to be flush with the end of the jacket and in a plane perpendicular to the longitudinal axis of the cord. At the other end of the cord, the grounding conductor is to be cut off flush with the end of the jacket, and the circuit conductors and foil are to be connected to a sinusoidal or nearly sinusoidal 48 – 62 Hz 120- or 240-V supply circuit as shown in the applicable part of Figure 1320.2, the choice of supply circuit depending on whether the cord is intended for use with 120 or 240 V equipment. See 1320.2.

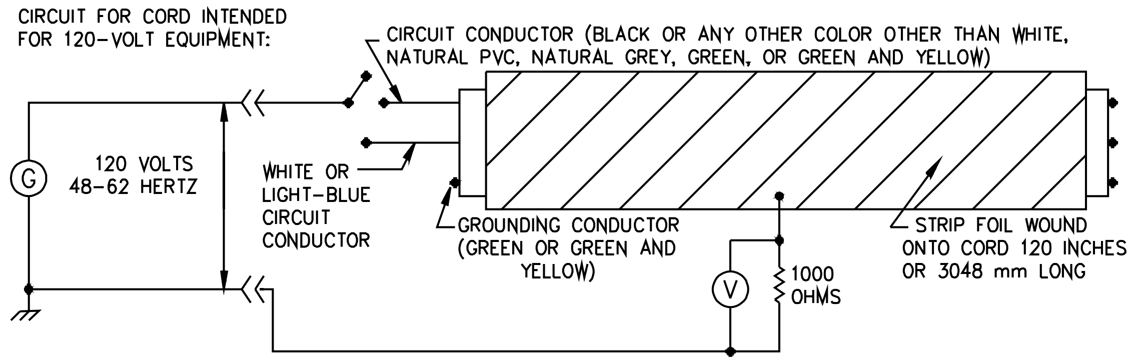
1320.5 The circuit conductors are to be energized separately and in succession and the reading of the voltmeter recorded for each. The leakage current from each circuit conductor through the jacket to the foil is to be calculated by dividing the voltage indicated by the voltmeter by the accurately known resistance of the resistor. The highest of the two leakage currents is to be used in choosing the range of current that determines the ″µA thru jacket″ value for the cord-surface marking.

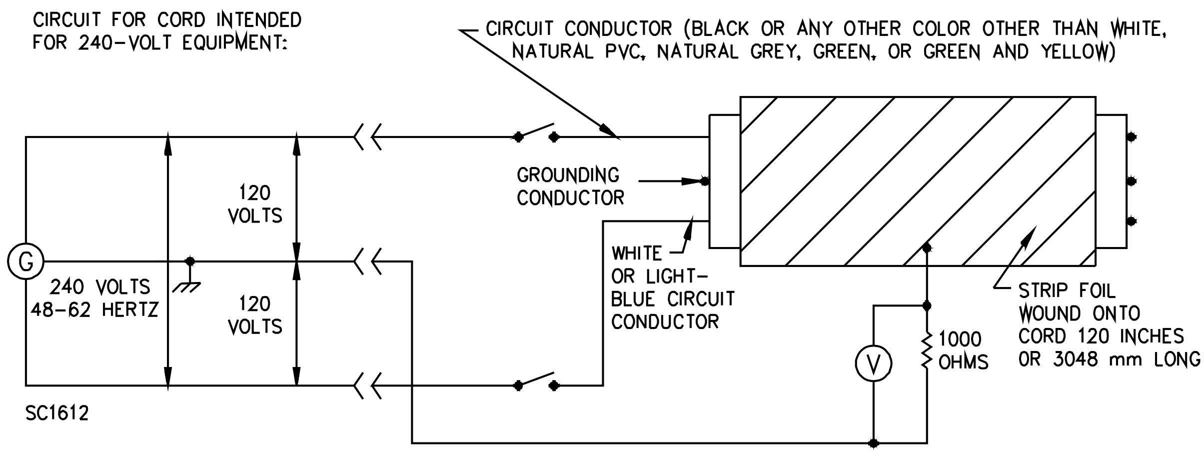
1321 – 1339 *Reserved for Future Use*

1340 Test for D-C Resistance of Nonintegral Cord Jacket

1340.1 A length of at least 4 inches or 102 mm of the complete, finished cord is to be tested, The test is to be conducted at any convenient temperature and humidity; however, for referee purposes, the sample is to be conditioned for 96 h in air maintained at a temperature of 23.0 ±2.0°C (73.4 ±3.6°F) and at a relative humidity of 50 ±5 percent. The entire length and circumference of the outer surface of the jacket is to be wiped three or more times with a soft, clean, lintless, absorbent cloth with only the cloth touching the center 2-inch or 51-mm portion of the sample. Two strips of metal foil 1/2 inch or 13 mm wide are then to be wrapped around the cord with the strips in intimate contact with the jacket, within the center 2-inch or 51-mm portion of the sample, and separated by a distance of 0.500 inch or 13 mm. Only air is to touch the jacket between the strips during application of the foil and during the rest of the test. Each of the foil strips is to be connected to a megohm bridge or equivalent equipment that supplies a direct potential of 500 V and is capable of measuring a resistance of 100 megohms with a 3-percent or smaller error. The jacket does not comply where, while 500 V dc is applied between the two foil strips, the resistance reading is less than 100 megohms.

Figure 1320.2
Circuit for measuring a-c leakage current from each circuit conductor through the cord jacket





SC1612

1341 – 1399 *Reserved for Future Use*

IMPACT RESISTANCE

1400 Test

1400.1 The impact anvil is to consist of a solid rectangular block of steel 8 inches long, 6 inches wide, and 4-1/8 inches high or 203 mm by 152 mm by 105 mm. The block is to be secured to a rigid support such as to a vertical steel load-bearing building column or to a concrete floor immediately adjacent to such a column.

1400.2 The impact energy is to be supplied by a 1-lb or 454-g steel weight that is 1-1/2 inches or 38 mm in diameter and 2 inches or 51 mm high. The lower end of the weight is to serve as the impact face of the weight and is to be flat and perpendicular to the longitudinal axis of the weight. The edges of the impact face are to be rounded. The end of the weight that is opposite to the impact face is to have an attachment by means of which the machine is to lift, suspend, and release the weight to fall freely.

1400.3 The weight is to be supported with its impact face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary anvil is to be coincident with a vertical line through the dimensional center of the impact face of the weight. A vertical guide is to constrain the weight and keep its impact face horizontal while the weight is falling and after it has struck the specimen. The guide is not to interfere with the free fall of the weight. A mechanism is to be provided at the top of the guide for releasing the weight to fall freely through the height and strike the specimen. The weight is to be kept from striking the specimen more than once during each drop.

1400.4 The specimens, the anvil, the weight, and the remainder of the test equipment are to be in thermal equilibrium with one another and the surrounding air at a temperature of 25.0 ±5.0°C (77.0 ±9.0°F) throughout the test.

1400.5 A 100-inch or 2540-mm straight length of the finished wire is to be tested without any conditioning. The specimen is to be tested at each of ten points that are evenly spaced along its length. These points are not to be closer together than 10 inches or 254 mm, and no point is to be closer than 5 inches or 127 mm to an end of the specimen. The weight is to be secured several specimen diameters above the anvil and the specimen is to be placed across the width of the anvil, with the first test point at the center of the length of the anvil. For a distance of at least 10 inches or 254 mm to each side of the test point, the longitudinal axis of the specimen is to be horizontal and in the vertical plane that contains the coincident vertical lines described in 1400.3. The conductor in the specimen is to be connected in series with a 3-W 120-V neon lamp to the energized conductor of a 120-V 48 – 62 Hz a-c supply circuit. The weight and all metal parts of the impact apparatus are to be connected together, to earth ground, and to the grounded supply wire.

1400.6 The position of the weight is to be adjusted to place the impact face of the weight 24 inches or 610 mm above the upper surface of the specimen. The weight is to be released from this height. The weight is to fall freely in the guide, is to strike the specimen once, and is then immediately to be raised to and secured at the 24-inch or 610-mm height. Each of the remaining nine test points on the specimen is to be impacted in the same way. The impact resistance of the wire is not in compliance where the conductor is visible at more than two of the test points or where the lamp lights momentarily or longer at more than two of the test points.

1401 – 1499 *Reserved for Future Use*

ABRASION OF 22 AWG TYPE XTW AND CXTW WIRE AND CORD

1500 Test

1500.1 Six straight specimens 40 inches or 1000 mm long are to be cut from a sample length of the finished wire or straightened conductor from the finished cord and are to be tested without any conditioning. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 23.0 ±8.0°C (73.4 ±14.4°F) throughout the test.

1500.2 One end of each specimen is to be attached to a horizontal reciprocating table while the table is at one end of its travel. The other end of each specimen is to be attached to a weight that exerts 4.0 ±0.5 ozf or 1.1 ±0.1 N or 113 ±13 gf. Each specimen is to be laid over a quarter cylinder to whose outer surface an unused sheet of Grade 1/2 (medium) emery cloth is attached. The radius of the surface of the emery cloth is to be 3.5 inches or 90 mm. The longitudinal axis of the cylinder is to be horizontal and perpendicular to each of the vertical planes that contain the specimens as they move on and are abraded by the emery cloth.

1500.3 The table is to be started in its horizontal reciprocating motion (simple harmonic motion) at the rate of 28 cycles per minute, each cycle consisting of one complete back-and-forth motion with a stroke of 6-1/4 inches or 160 mm. The table is to be stopped every 50 cycles and the emery cloth is to be shifted slightly to one side so that in subsequent cycles each specimen is abraded by a fresh surface of the cloth. The wire or cord does not comply where the strands are exposed anywhere on any of the six specimens in 400 or fewer cycles of the abrasion.

1501 – 1509 *Reserved for Future Use*

ABRASION

1510 Test

1510.1 Six straight specimens of the finished solid 14 AWG wire 40 inches or 1000 mm long are to be tested without any conditioning. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 25.0 ±5.0°C (77.0±9.0°F) throughout the test.

1510.2 One end of each specimen is to be attached to a horizontal, reciprocating table while the table is at one end of its travel. The other end of each specimen is to be attached to a weight that exerts 12.0 ±0.5 ozf or 3.3 ±0.1 N or 340 ±13 gf. Each specimen is to be laid over a quarter cylinder to whose outer surface an unused sheet of Grade 1/2 (medium) emery cloth is attached. The radius of the surface of the emery cloth is to be 3.5 inches or 90 mm. The longitudinal axis of the cylinder is to be horizontal and perpendicular to each of the vertical planes that contain the specimens as they move on and are abraded by the emery cloth.

1510.3 The table is to be started in its horizontal reciprocating motion (simple harmonic motion) at the rate of 28 cycles per minute, each cycle consisting of one complete back-and-forth motion with a stroke of 6-1/4 inches or 160 mm. The table is to be stopped every 50 cycles and the emery cloth is to be shifted slightly to one side so that in subsequent cycles each specimen is abraded by a fresh surface of the cloth. The wire does not comply where the nylon jacket and insulation on any of the six specimens wear through and expose the conductor in 800 or fewer cycles.

1511 – 1519 *Reserved for Future Use*

FLEXING OF 22 AWG TYPE XTW AND CXTW WIRE AND CORD

1520 Test

1520.1 Six specimens are to be cut from a sample length of the finished wire or cord and are to be tested without any conditioning. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 23.0 ±8.0°C (73.4±14.4°F) throughout the test.

1520.2 Each specimen is to be bent into the form of a flat-bottomed square-cornered U with the legs of the U straight and of equal length. The bottom of the U in each case is to be taped to the underside of a movable round horizontal rod (A in Figure 1520.1) with the axis of the conductor or conductors parallel to the longitudinal axis of the movable rod and the legs of the U extending vertically downward between a pair of fixed round rods (B in Figure 1520.1) that are 0.50 inch or 12.7 mm in diameter. A weight exerting 0.75 ±0.01 ozf or 0.210 ±0.003 N or 21.3 ±0.3 gf is to be attached to the free end of each leg. The conductors of the specimens are to be connected in series. The longitudinal axes of the two fixed rods are to be in a horizontal plane and are to be parallel to one another and to the longitudinal axis of the movable rod to which the specimens are taped. The distance between the two rods is to be adjusted to result in the specimens hanging midway between the rods, with a space from specimen to rod of near 1/32 inch or 1 mm on each side. A current of 1.5 A is to be passed through the conductor(s).

1520.3 The movable rod is to be started in the pivoted motion (simple harmonic motion) depicted by the dashed lines in Figure 1520.1 at the rate of 12 cycles per minute, each cycle consisting of one complete back-and-forth motion through an angle of 180° centering about the points of flexure. The motion is to be stopped after 6000 cycles and each specimen is to be cut open and examined for broken strands at the points of flexure against the two fixed rods. The wire or cord does not comply where more than half of the strands are broken in any leg of any specimen (12 legs in all) in the 6000 cycles of flexing.

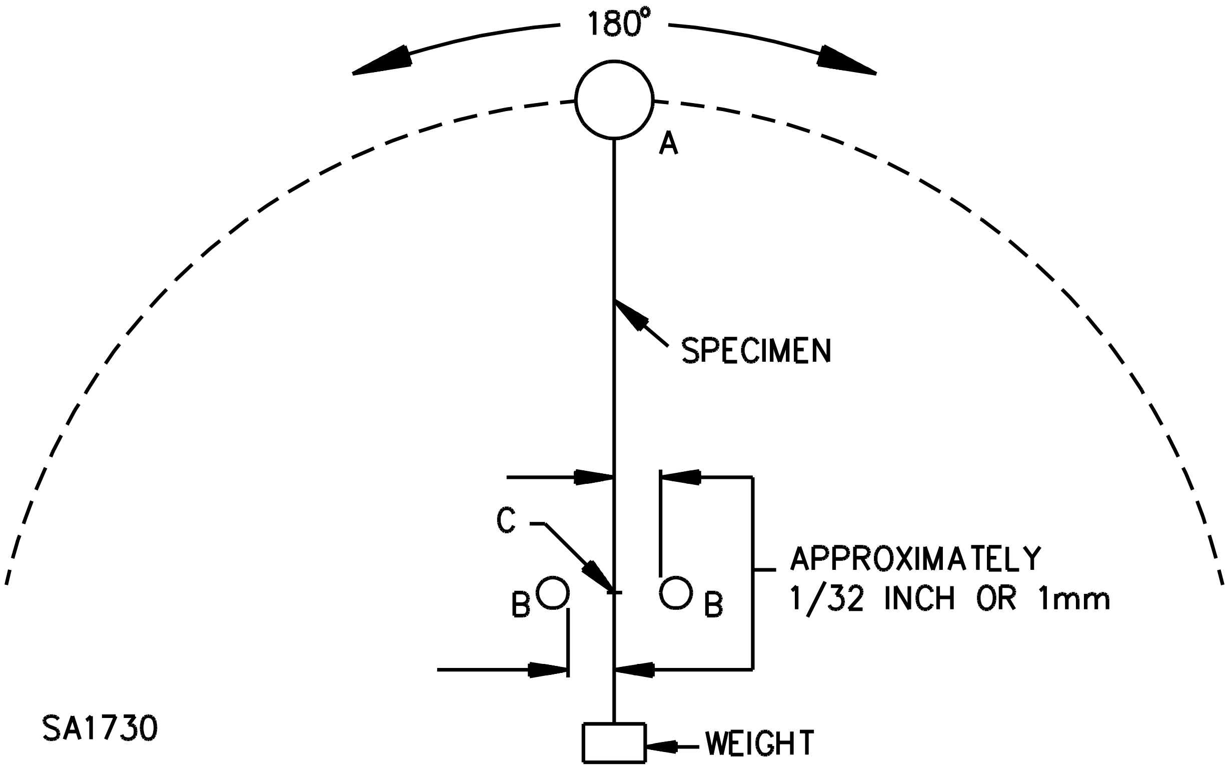
1521 – 1539 *Reserved for Future Use*

CRACKING OF NYLON COVERING ON COAXIAL-CABLE MEMBERS OF ELEVATOR CABLES OR OF NYLON JACKET ON TYPES TFN, TFFN, AND SPT-1 AND OF INSULATED CONDUCTORS IN SERVICE CORDS

1540 Test

1540.1 The apparatus for the air-oven aging of the specimen is to be as described in 420.8 and 420.9. The temperature of the oven and duration of the aging are to be the same as for the insulation material over which the nylon is used and are dependent upon the temperature rating of the cord, coaxial member, or wire. The finished coaxial-cable member for or from an elevator cable, or an insulated and jacketed conductor taken from the finished cord or fixture wire (complete jacketed cord in the case of nylon-jacketed Type SPT-1) is to be used as the test specimen. Following the air-oven aging, the specimen is to be removed from the oven and cooled in still air to a room temperature of 23.0 ±8.0°C (73.4 ±14.4°F) for 16 – 96 h prior to flexing. Each specimen is to be tightly wound for six complete turns around a mandrel having the same diameter as the coaxial-cable member or the insulated and jacketed conductor. Successive turns are to be in contact with one another and both ends of the specimen are to be securely held in place by means of friction tape. Wrinkling or folds of the nylon do not constitute noncomplying performance.

Figure 1520.1
End view of flexing



A – Movable rod.

B – Fixed rods.

C – Point of flexure.

1541 – 1559 *Reserved for Future Use*

FLEXING OF TYPE SF-1, SF-2, SFF-1, AND SFF-2 FIXTURE WIRES

1560 Test

1560.1 The physical properties of a finished fixture wire employing Class 22 silicone rubber shall make specimens that have been aged for 60 d at the specified temperature in a full-draft, circulating-air oven show neither rupture of the braid nor cracking of the insulation when cooled to room temperature and wrapped for six complete turns around a mandrel. The mandrel diameter shall be 1/4 inch or 6.5 mm for Type SF-1 and SFF-1 wires, and 1/2 inch or 13 mm for Type SF-2 and SFF-2 wires.

1561 – 1581 *Reserved for Future Use*

FLEXING OF SHIELDED CORDS

1582 Test

1582.1 Six specimens, each about 15 ft or 5 m long, are to be cut from a sample length of the finished shielded flexible cord. The specimens are to be tested without being conditioned in any way. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 23.0 ±8.0°C (73.4 ±14.4°F) throughout the test.

1582.2 The test is to be made using the apparatus diagrammed in Figure 1582.1, or such apparatus in multiple. The pulleys are to be mounted on the shuttle so that the specimen is horizontal as it passes between the pulleys. The weight, pulleys, and current used in the test are to be as indicated in Table 1582.1. The clamps at the ends of the specimens are to be positioned as shown in relation to the stops so that the pull is always applied by the weight away from which the shuttle is moving. The circuit conductors in the specimen(s) are to be connected in series and are to carry the current indicated in Table 1582.1 throughout the test. The circuit is to include a means for counting the number of cycles until 15,000 cycles have been completed or until a circuit conductor opens, thereby opening the circuit and stopping the test.

Figure 1582.1
Apparatus for flexing of shields

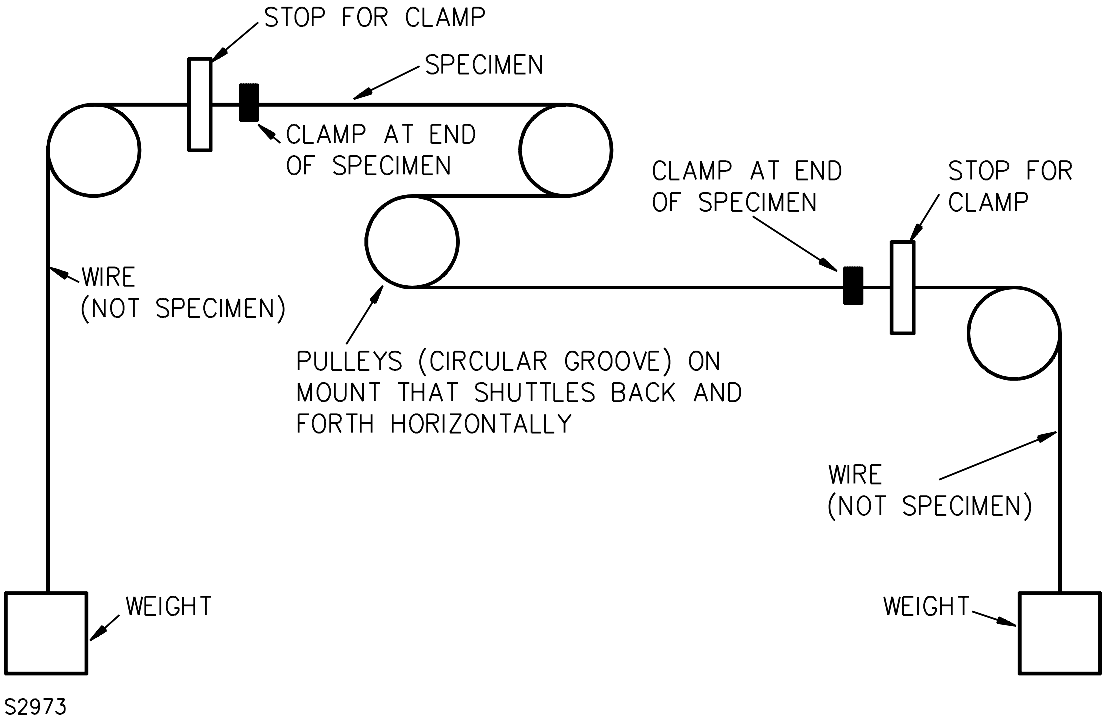


Table 1582.1
Weight, pulley diameter, and current for flexing test

AWG size of circuit conductors in cord	Force exerted by a weight at each end of cord specimen			Diameter at bottom of pulley (circular groove)		Current in circuit conductors	
						Cord with 2 circuit conductors	Cord with 3 circuit conductors
	kgf	N	lbf	mm	inch	A	A
18	1	9.79	2.2	80	3.15	10	7
17	1	9.79	2.2	80	3.15	12	–
16	1.5	14.7	3.3	120	4.72	13	10
15	1.5	14.7	3.3	120	4.72	–	–
14	1.5	14.7	3.3	120	4.72	18	15
12	1.5	14.7	3.3	120	4.72	25	20
10	1.5	14.7	3.3	120	4.72	30	25
8	1.5	14.7	3.3	120	4.72	40	35
6	1.5	14.7	3.3	120	4.72	55	45
4	1.5	14.7	3.3	120	4.72	70	60
2	1.5	14.7	3.3	120	4.72	95	80

1582.3 With a specimen(s) in place and rated current flowing in the circuit conductors, the shuttle is to be started in its horizontal reciprocating motion. The motion is to be constant at the rate of 0.33 m/s or 12 cycles per minute, each cycle consisting of one complete back-and-forth motion through a stroke of approximately 1 m or 39.4 inches. The motion is to be continued until 15,000 cycles have been completed or a circuit conductor opens and the test stops automatically after fewer cycles.

1582.4 The cord does not comply where any circuit conductor opens in fewer than 15,000 cycles in any of six specimens.

1583 – 1589 *Reserved for Future Use*

MANDREL TEST OF NYLON JACKET ON TYPE THWN-2, THWN, AND THHN WIRES

1590 Test

1590.1 A specimen of finished 14, 12, or 10 AWG Type THWN-2, THWN, or THHN wire is to be wrapped for four turns around a smooth metal mandrel of a diameter six times that of the specimen. The ends of the specimen are to be secured to the mandrel so that four complete turns of the specimen are exposed to the air between the securing means. The specimen and mandrel are to be suspended for 24 h in a full-draft circulating-air oven operating at a temperature of 95.0 ±1.0°C (203.0 ±1.8°F), after which the specimen and mandrel are to be removed from the oven and cooled for 1 h in a desiccator maintained at 24.0 ±3.0°C (75.2 ±5.4°F). The specimen is to be unwound at a rate of 4 seconds per turn immediately upon removal from the desiccator and is then to be inspected for surface cracks. Any cracking of the jacket on any specimen constitutes noncomplying performance.

1591 – 1599 *Reserved for Future Use*

1600 Comparison of Metal Sheaths

1600.1 CRUSHING TEST – The cable is to be crushed between a flat, horizontal steel plate and a solid steel rod by the application of dead weight or in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. Each plate is to be 2 inches or 50 mm wide. A solid steel rod 3/4 inch or 19 mm in diameter and of a length equal to at least 6 inches or 150 mm is to be bolted or otherwise secured to the upper face of the lower plate. The longitudinal axes of the plates and the rod are to be in the same vertical plane. The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another and the surrounding air at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test.

1600.2 The cable with the metal sheath under evaluation is to be tested in a continuous length of at least 36 inches or 915 mm, with this cable (test cable) being crushed at three points along that length. The points at which the test cable is to be crushed are to be measured and marked with chalk or another innocuous means on the test length before the test is begun. The first mark is to be placed 9 inches or 230 mm from one end of the test length and the two remaining marks are to be made at succeeding intervals of 9 inches or 230 mm down the length of the test cable.

1600.3 The test cable at the first mark is to be placed and held on the steel rod, with the longitudinal axis of the cable horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the upper and lower plates and the rod. The upper steel plate is to be made snug against the cable. In a test using a dead weight(s) to crush the test cable, weight exerting the force determined in a separate test on the comparison cable (control) is to be placed gently on the upper plate. In a test using a compression machine, the upper plate is to be moved downward at the rate of 0.50 ±0.05 in/min or 10±1 mm/min thereby increasing the force on the test cable until the maximum level is reached at which the comparison cable (control) resisted rupture in a separate test. That level of force is to be held constant for 60 s and is then to be reduced to zero by removing the dead weight(s) or, in the compression machine, by raising the upper steel plate at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min until the test cable is free.

1600.4 The test cable is to be advanced and crushed at each of the successive marks for a total of three crushes. The overall jacket or metal covering and the insulation on each conductor are to be examined at each of the three points at which the test cable was crushed. The test cable is not eligible for the 200 lbf or 890 N or 91 kgf reduced limit stated in the wire Standard for crushing the insulation on its conductors where the overall covering or any of the insulation is split, torn, cracked, or otherwise ruptured at any of the three points. Flattening of the jacket or the insulation, or both of these, without rupture is to be disregarded.

1600.5 IMPACT TEST – A solid rectangular block of steel 4-3/4 inches or 212 mm long by 3 inches or 76 mm wide by 5 inches or 127 mm high, with its upper face (4-3/4 inches by 3 inches or 212 mm by 76 mm) horizontal, is to be secured to a concrete floor, the building framework, or another solid support.

1600.6 An impact weight of 3 lb or 1.36 kgf is to be used. The impact weight is to consist of a solid steel cylinder having a diameter of 1-1/4 inches or 31.8 mm, with the edges of its lower face (the face that strikes the cable) rounded to a radius of 1/16 inch or 1.5 mm.

1600.7 The impact weight is to be supported with its lower face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary block is to be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary block. A set of rails or other vertical guides is to constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the cable. The rails or other guides are not to interfere with the free fall of the impact weight. A means is to be at the top of the guides for releasing the impact weight to fall freely from any chosen height and strike the cable. The weight is to be kept from striking the cable more than once during each drop.

1600.8 The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test.

1600.9 The cable with the metal sheath under evaluation is to be tested in a continuous length of at least 11 ft or 3.35 m, with ten strikes being made on that length of this cable (test cable). The points at which the test cable is to be struck are to be measured and marked with chalk or by another innocuous means on the test length before the test is begun. The first mark is to be placed 12 inches or 305 mm from one end of the test length and the nine remaining marks are to be made at succeeding intervals of 12 inches or 305 mm down the length of cable.

1600.10 Each of the insulated circuit conductors in the test cable is to be connected in series with a 3-W 120-V neon lamp to the energized conductor of a 2-wire 120-V 48 – 62 Hz grounded a-c supply circuit. The metal sheath in the test cable is to be connected to all parts of the impact apparatus, to earth ground, and to the grounded supply wire.

1600.11 The impact weight is to be secured several cable diameters above the stationary steel block, and the test cable at the first mark is to be placed and held on the steel block, with the longitudinal axis of the cable horizontal and in the vertical plane containing the coincident vertical lines mentioned in 1600.7. The position of the impact weight is to be adjusted to place the lower face of the weight the same distance above the upper surface of the test cable as it was released from and resulted in contact in a separate test on the comparison cable (control). The impact weight is to be released from this height, is to fall freely in the guides, is to strike the test cable once, and is then immediately to be raised up to and secured at the initial height. Note is to be taken and recorded of whether any or all of the neon lamps light during the impact indicating a momentary or other contact between the circuit conductors or between one or more of the circuit conductors and the metal sheath.

1600.12 The test cable is to be advanced to and impacted at each of the successive marks for a total of ten strikes. The test cable is not eligible for the 200 lbf or 890 N or 91 kgf reduced limit stated in the wire standard for crushing the insulation on its conductors where any lamp lights at more than two of the ten impact points.

1601 – 1609 *Reserved for Future Use*

MOISTURE ABSORPTION BY FIBROUS COVERINGS OTHER THAN TAPE

1610 Test

1610.1 The apparatus for this test is to consist of a desiccator containing anhydrous calcium chloride, a set of mandrels having diameters as indicated in Table 1610.1, a quick-damping balance accurate to 10 mg, and an agitated constant-temperature bath of tap water maintained at a temperature of 21.0 ±1.0°C (69.8±1.8°F). The bath is either to be fitted with a cover to keep out dust or is to be placed within a tight enclosure during the test. Where at any time the water becomes dirty or shows the presence of a surface film of dust or wax, it is to be replaced with fresh water.

1610.2 Before cutting a test specimen to size, the coil or other sample of the wire, cable, or assembly that is to be tested is to attain a room temperature of 21.0 ±1.0°C (69.8 ±1.8°F). Handling and flexing of samples to be tested are to be reduced to the absolute minimum required for conducting the test.

1610.3 A specimen 24 ±1/4 inches or 610 ±6 mm long is to be cut from the coil or other sample of wire, cable, or assembly and is to be bent around a mandrel of the diameter indicated in Table 1610.1 (single conductor) or in Table 1610.2 (multiple-conductor cable or assembly). For a 2 AWG or smaller wire and for a multiple-conductor cable or assembly for which the factor F in Table 1610.2 is 2 or 3, the maximum number of complete turns that fit on the mandrel are to be made around the mandrel with the wire tight on the mandrel, adjacent turns 1/8 – 1/4 inch or 3 – 6 mm apart, and with a 2– 2-1/2-inch or 50 – 60-mm straight length at each end of the specimen extending away from the mandrel. For wire sizes larger than 2 AWG and for a multiple-conductor cable or assembly for which the factor F in Table 1610.2 is 4.5, 6, 9, or 10, a half turn is to be made around the mandrel.

Table 1610.1
Mandrel diameters for moisture and cold-bend tests on single conductors

Size of conductor	Diameter of mandrel	
	inches	mm
14 AWG	0.313	8
13	0.350	9
12	0.375	9
11	0.415	11
10	0.563	14
9	0.585	15
8	0.688	17
7	0.740	19
6	1.250	32
5	1.305	33
4	1.375	35
3	1.458	37
2	1.563	40
1	2.688	68
1/0	2.875	73
2/0	3.000	76
3/0	3.250	83
4/0	3.500	89
250 kcmil	5.188	132
300	5.500	140
350	5.875	149
400	6.250	159
450	6.625	168
500	6.750	171
550	10.500	267
600	11.000	279
650	11.250	286
700	11.500	292
750	12.000	305
800	12.250	311
900	12.875	327
1000	13.500	343
1100	17.000	432
1200	17.250	438
1250	17.500	445

Table 1610.1 Continued on Next Page

Table 1610.1 Continued

Size of conductor	Diameter of mandrel	
	inches	mm
1300	17.750	451
1400	18.125	460
1500	18.500	470
1600	18.875	479
1700	19.375	492
1750	19.750	502
1800	19.875	505
1900	20.125	511
2000	20.500	521

Table 1610.2
Mandrel-diameter factor F for moisture and cold-bend tests on multiple-conductor cables and assemblies

Calculated diameter over the finished cable or assembly		Factor F by which the calculated diameter over the finished cable or assembly is to be multiplied to obtain the mandrel diameter
inches	mm	
0 – 0.375	0 – 9.52	2
0.376 – 0.500	9.53 – 12.70	3
0.501 – 0.750	12.71 – 19.05	4.5
0.751 – 1.125	19.06 – 28.58	6
1.126 – 1.500	28.59 – 38.10	9
over 1.500	over 38.10	10

1610.4 The specimen is to be removed from the mandrel without disturbing its form and is to be placed in the desiccator over anhydrous calcium chloride at a temperature of 21.0 ±1.0°C (69.8 ±1.8°F) for at least 18 h. It is then to be removed from the desiccator and weighed to the nearest 10 mg. The weight is to be recorded as W.

1610.5 The specimen is then to be immersed in the tap-water bath, with 1 ±1/8 inch or 25 ±3 mm of each end of the coil or 180° bend projecting above the surface of the water. After 24 h of immersion, the specimen is to be removed from the bath, shaken vigorously for 5 s to remove adherent moisture and weighed again 2 min after removal from the bath. This weight is to be recorded as W_1. All fibrous coverings other than tape are then to be removed from the full length of the specimen. The conductor(s), insulation, and any tape are then to be weighed. In the case of an assembly for use in armored cable, any overall fibrous covering and any fibrous covering on the individual wires are to be taken together in one test and a second test is to be made on only the fibrous covering on the individual wires. This weight is to be recorded as W_2.

1610.6 The moisture absorbed by the specimen is not to be adjusted for the portion of the specimen projecting above the water. The percentage of absorption is to be calculated (to 0.1 percent) by means of the expression

$$\frac{100(W_1 - W)}{W - W_2}$$

1611 – 1629 *Reserved for Future Use*

FALLING PARTICLES AND DRIPPING FROM FIBROUS-COVERED WIRE AND CABLE

1630 Test

1630.1 A 7-inch or 180-mm specimen of the finished fibrous-covered wire or cable is to be secured in a horizontal position above the floor of a full-draft circulating-air oven for 7 h at the rated temperature of the wire or cable ±1.0°C (±1.8°F). The saturant, finish, and any lubricant comply where, with a clean sheet of aluminum foil or white paper covering the entire floor of the oven for the 7 h, drippings or particles or drippings and particles do not fall from the wire or cable onto the paper or foil.

1631 – 1669 *Reserved for Future Use*

ARCING OF TYPE HPN CORD

1670 Flame Test

1670.1 One end of a sample length of finished Type HPN cord having two circuit conductors with or without one grounding conductor is to be cut off, with the face of the cut end flat and perpendicular to the longitudinal axis of the cord. The cord is to be laid out straight and flat on a horizontal, electrically nonconductive, noncombustible surface, with 4 inches or 100 mm of the cord at the cut end extending beyond the edge of the supporting surface. The circuit conductors at the end of the cord opposite the cut end are to be connected to a 120 V 48 – 62 Hz sinusoidal or nearly sinusoidal rms branch-circuit supply that has a 15-A fuse or circuit breaker, and has a capacity that enables short circuiting of the circuit to cause the fuse or circuit breaker to open. Any grounding conductor is not to be connected.

1670.2 A Tirrill, Bunsen, or similar appropriate gas burner having a vertical barrel that has an inside diameter of 3/8 inch or 9.5 mm and extends 4 inches or 102 mm above the air inlets is to be lit and adjusted for a steady flame with an overall height of 1-1/2 inches or 38 mm with the temperature at its tip 816°C (1500°F) or higher as measured using a chromel-alumel (nickel-chromium and nickel-manganese-aluminum) thermocouple. With its barrel vertical, the burner is to be placed under the free end of the cord with the tip of the blue inner cone touching the flat underside of the cord at a point that is midway between the conductors and 1/2 inch or 13 mm from the cut end. The flame is to be applied for 120 s and then removed. The cord does not comply where arcing occurs between the conductors during application of the flame or where the fuse or circuit breaker opens.

1671 – 1679 *Reserved for Future Use*

1680 Broken-Strands Test

1680.1 For each test, the specimen is to be 40 inches or 1 m long and is to be taken from a length of the finished cord containing two circuit conductors with or without a grounding conductor. Both ends of each circuit conductor are to be bared for electrical connection. Any grounding conductor is to be present and disregarded. A commercially available strain-relief bushing for the type and size of cord being tested is to be assembled to the cord as intended at a point 24 inches or 610 mm from one end of the specimen.

1680.2 By means of the bushing, the specimen is to be secured in a flexing machine with the 24-inch or 610-mm end of the cord hanging vertically below the bushing. The circuit conductors are to be connected in series with one another, a lamp or other device to signal breakage of a circuit conductor, and a 48 – 62 Hz, 24-V rms supply circuit that operates at a current not exceeding 200 mA. A weight exerting the force indicated in Table 1680.1 is to be secured to the cord at a point 8-1/2 inches or 215 mm below the bushing.

Table 1680.1
Weight for strand-breaking flexing

AWG size of circuit conductors	Weight		
	lbf	N	gf
18	2	8.9	907
17	2.5	11.1	1134
16	3	13.3	1361
14	4	17.8	1814
12	5	22.2	2268

1680.3 The machine is to flex the cord edgewise at the point of exit of the cord from the bushing. The flexing is to be by simple harmonic motion at a rate at or near 12 cycles per minute. Each cycle is to consist of flexing the cord from its original vertical position to a horizontal position 90° to one side, back through 180° from that position to a similar horizontal position to the other side, and then back to the original vertical position. The circuit conductors in the cord are to remain in the same vertical plane throughout the flexing. The flexing is to continue until all of the strands of one circuit conductor break as indicated by the lamp or other signal device. Breakage of a circuit conductor is to stop the flexing machine.

1680.4 The strain-relief bushing is to be removed and the specimen is to be examined for damage to the insulation. Where there is any splitting, cracking, or other visible damage to the insulation or where any strand(s) extend through the insulation, the specimen is to be discarded and a new specimen is to be prepared, flexed until one circuit conductor breaks, and examined for damage to the insulation. For this flexing procedure, the weight attached to the cord is to be reduced (steps of 4 ozf, 1.1 N, or 113 gf typically are convenient) to result in the flexing breaking a circuit conductor without any visible damage to the insulation.

1680.5 The undamaged specimen is to be wrapped with four single layers of bleached cheesecloth that is 2 inches or 50 mm wide, runs 14 – 15 yd/lb or 26 – 28 m^2/kg, and has what is known in the trade as a count of 32 by 28 (a square 1 inch on a side has 32 threads in one direction and 28 threads in the other direction or a square 1 cm on a side has 13 threads in one direction and 11 threads in the other direction). The cheesecloth is to be tight on the specimen, centered over the break in the circuit conductor, and held in place by a strain-relief bushing that is larger than the one indicated in 1680.1 (see Table 1680.2 for some appropriate cord/bushing combinations). The bushing is to be assembled to the cheesecloth-wrapped cord at a point 1/4 inch or 5 mm from the break in the circuit conductor.

Table 1680.2
Combinations of cord and bushing

Cord construction	Typical bushing[a]
18/2, 18/3, 16/2	SR-4K-1
16/3	SR-5W-1
14/2, 14/3 smaller dimensions	SR-33-1
14/2, 14/3 larger dimensions	SR-34-2

[a] The specific bushings shown are not required. These particular bushings are mentioned as a guide because the selection of bushings is difficult and these have been used successfully in a number of tests. Different bushings are to be used where required by the dimensions of the cord being tested and the layering of cheesecloth over the cord. The designations shown are for Heyco bushings made by the Heyman Manufacturing Company of Kenilworth, New Jersey 07033.

1680.6 By means of the bushing, the specimen is to be secured in a vertical sheet-metal bracket. As shown in Figure 1680.1, the longitudinal axis of the specimen is to be horizontal at the point at which the bushing passes through the vertical surface of the bracket. The cheesecloth-wrapped break in the circuit conductor is to be in front of the bracket.

1680.7 The bared ends of the broken circuit conductor are to be connected in series with a variable resistor, an a-c ammeter of applicable range, overcurrent protection, and a 48 – 62 Hz supply circuit of 120 ±2 V as shown in Figure 1680.1. A 120-V neon lamp is to be connected either in parallel with the broken circuit conductor, or in parallel with the variable resistor. The lamp acts as an indicator of the circuit being opened (lamp lit where in parallel with the broken conductor, lamp dark where in parallel with the resistor) and closed (lamp dark where in parallel with the broken conductor, lamp lit where in parallel with the resistor) in the specimen as the specimen is flexed. The unbroken circuit conductor and any grounding conductor are to be present and are not to be in the circuit.

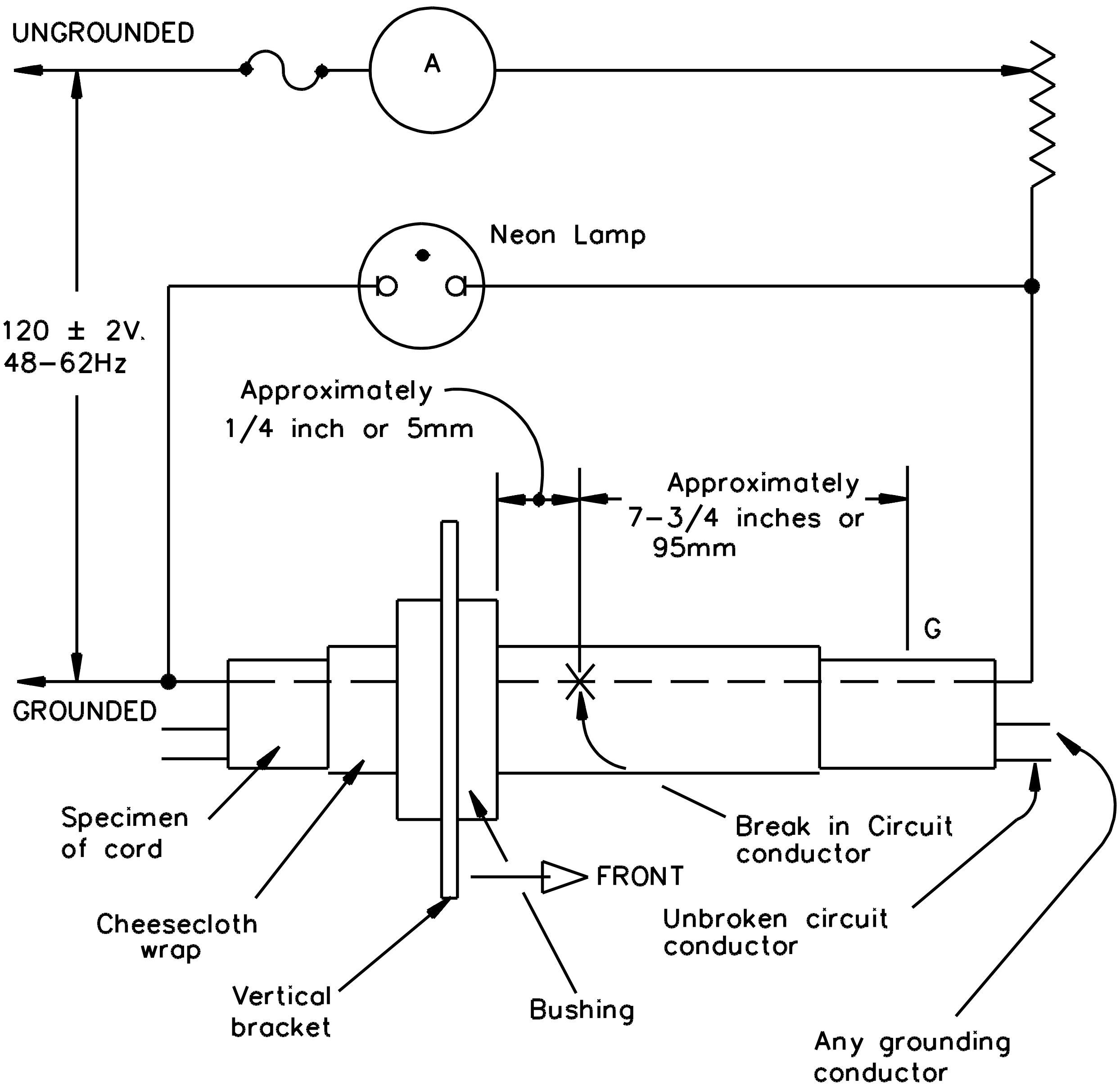
1680.8 The variable resistor is to be adjusted to result in the current indicated in Table 1680.3 flowing in the broken circuit conductor.

Table 1680.3
Current in the broken circuit conductor

AWG size of circuit conductors in cord	RMS current in amperes
18	10.0 ±0.5
16	15.0 ±0.5
14	20.0 ±0.5
12	30.0 ±0.5

1680.9 While the current is flowing, the specimen is to be grasped 7-3/4 inches or 197 mm from the break in the circuit conductor (point G in Figure 1680.1). Without physically straining the insulation, the cord is to be moved back and forth to result in the circuit being opened and closed at the break in the circuit conductor as indicated by the neon lamp lighting and going dark. Each cycle of make and break is to take 3 – 4 s. The test is to be discontinued after 20 cycles of opening and closing the circuit.

Figure 1680.1
Arcing circuit



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1680.10 Where the insulation is perforated as evidenced by flaming, glowing, or charring of the cheesecloth, the test is to be stopped. Perforation in 20 or fewer cycles constitutes noncompliance.

1680.11 Where 20 cycles is not completed on an unperforated specimen because contact is no longer made between the broken ends of the circuit conductor, that specimen is to be discarded and the test is to be repeated with a new specimen.

1681 – 1689 *Reserved for Future Use*

DURABILITY OF INDELIBLE-INK PRINTING

1690 Test

1690.1 Two straight 300-mm or 12-inch specimens of the single- or multiple-conductor construction are to be cut from a sample length of any convenient size of the finished wire or cable on which the ink printing is being evaluated. The specimens are to be handled minimally and are not to be wiped, scraped, or otherwise cleaned in any way.

1690.2 One of the specimens is to be aged in a circulating-air oven that complies with 420.8 and 420.9, including 100 – 200 fresh-air changes per hour, operating for the time and at the temperature specified for the insulation or jacketing material whose outer surface is printed, and is then to be removed from the oven and kept in still air to cool to room temperature for 60 min before being tested. The one remaining specimen is to rest for at least 24 h in still air at 23.0 ±5.0°C (73.4 ±9.0°F) before being tested.

1690.3 The test is to be made using a weight whose lower face is machined to a flat, rectangular surface measuring 25 mm by 50 mm or 1 inch by 2 inches. The height of the weight is to be uniform to ensure even distribution of the weight throughout the area of the lower face. Clamps or other means are to be provided for securing to the lower face of the weight a layer of craft felt (composition not specified) that is 1.2 mm or 0.047 inch thick. Without the felt in place, the weight and the means for securing the felt to the weight are to exert 450 ±5 g or 1 lbf ±0.2 ozf or 4.45 ±0.06 N on a specimen. It is appropriate to use the felt for several tests; however, the felt is to be replaced as soon as the fibers flatten or become soiled. While not in use, the weight is to be stored resting on one of its surfaces that is not covered with felt. The apparatus and the specimens are to be in thermal equilibrium with the surrounding air at a temperature of 23.0 ±5.0°C (73.4 ±9.0°F) throughout the test. Each specimen is to be placed on a solid, flat, horizontal surface with the printing up and at the center of the length of the specimen. The ends of each specimen are to be bent around supports or otherwise secured to keep the printed area of the insulation or jacket from rotating out from under the weight.

1690.4 The felted surface of the weight is to be placed on the printed area of a specimen with the felted surface horizontal and with the 50-mm or 2-inch dimension of the felted surface parallel to the length of the specimen. With the weight so resting on the specimen, the felt is to be slid lengthwise by hand along the printed area of the specimen for a total of three cycles. Each cycle is to consist of one complete back-and-forth motion covering the entire length of the specimen. The three cycles of rubbing are to be completed at an even pace, taking a total time of 5 – 10 s. The procedure is to be repeated on the second specimen. Where the printing is illegible on either of the two specimens, the ink printing on the wire or cable does not comply.