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STANDARD FOR NONSHIELDED POWER CABLES RATED 2000 VOLTS OR LESS FOR THE DISTRIBUTION OF ELECTRICAL ENERGY

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STANDARD FOR

NONSHIELDED POWER CABLES
RATED 2000 VOLTS or Less
For The
DISTRIBUTION OF ELECTRICAL ENERGY

Standard #
NEMA WC70/ICEA S-95-658-1999

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FOREWORD

This Standards Publication for Nonshielded Cables Rated 0-2000 Volts was developed by the Insulated Cable Engineers Association (ICEA) and approved by the National Electrical Manufacturers Association (NEMA).

ICEA/NEMA Standards are adopted in the public interest and are designed to eliminate misunderstanding between the manufacturer and the user and to assist the user in selecting and obtaining the proper product for his particular need. Existence of an ICEA/NEMA Standard does not in any respect preclude the manufacture or use of products not conforming to the standard. The user of this Standard is cautioned to observe any health or safety regulations and rules relative to the manufacture and use of cable made in conformity with this Standard.

Requests for interpretation of this Standard must be submitted in writing to:

Insulated Cable Engineers Association
P.O. Box 440
South Yarmouth, Massachusetts 02664

An official written interpretation will be provided once approved by ICEA and NEMA. Suggestions for improvements gained in the use of this Standard will be welcomed by the Association.

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Section 1
GENERAL

1.1 SCOPE

These standards apply to materials, constructions, and testing of 2000 volt and below nonshielded thermoplastic, crosslinked polyethylene, and crosslinked rubber insulated wires and cables which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, either indoors, outdoors, aerial, underground, or submarine.

1.2 GENERAL INFORMATION

These standards cover the requirements for conductors, the insulations and protective coverings and general constructional and dimensional details common to most standard nonshielded types of wires and cables. Constructions of specific types are covered in Section 7 or in other ICEA documents. Where a conflict exists between the requirements of Section 7, or other ICEA documents, and those of Sections 1 to 6 inclusive, the requirements of specific types shall apply. See Appendix A for complete titles and dates of ICEA publications and ASTM Standards to which reference is made in this publication. See Section 6 for test procedures not elsewhere referenced. Recommended minimum bending radii are given in Appendix F.

In classifying crosslinked insulations and jackets in these standards, the term "rubber" when used alone without further description shall mean synthetic rubber.

Insulation thicknesses are designated in terms of cable insulation levels (see 3.3).

In classifying jackets and sheaths in these standards, the term "jacket" refers to a continuous nonmetallic covering and "sheath" to a continuous metallic covering.

In these standards, most units are expressed in the English system. For information only, their approximate metric equivalents are included.

Requirements of a referenced ASTM standard shall be determined in accordance with the procedure or method designated in the referenced ASTM standard unless otherwise specified in this standard.

1.3 INFORMATION TO BE SUPPLIED BY PURCHASER

When requesting design proposals from cable manufacturers, the prospective purchaser should furnish the following information:

1.3.1 Characteristics of System on Which Cable is to be Used

1. Current - alternating or direct.
2. Frequency - Hertz.
3. Normal operating voltage between phases or, in direct current, between conductors.
4. Number of phases and conductors.
5. Cable insulation level (see 3.3).
6. Minimum temperature at which cable will be installed.

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7. Description of installation.
   a. In buildings.
   b. In underground ducts.
   c. Aerial.
      (1) On messenger in metal rings.
      (2) Preassembled.
      (3) Field spun.
   d. Direct burial in ground.
   e. Submarine.
   f. Descriptions other than the foregoing.
8. Conditions of installation.
   a. Ambient temperature.
   b. Number of loaded cables in duct bank or conduit. Duct/conduit, give type conduit (magnetic/nonmagnetic), size, number of loaded conduits, ducts enclosed or exposed, and spacing between duct/conduits.
   c. Load factor.
   d. Method of bonding and grounding of sheaths.
   e. Wet or dry location.
9. Other special conditions.

1.3.2 Quantities and Description of Cable

1. Total number of feet, including test lengths, and shipping reel lengths if specific lengths are required.
2. Type of cable. Describe as single conductor, two-conductor, three-conductor, etc.
3. Rated circuit voltage, phase to phase.
4. Type of conductor - copper or aluminum.
5. Size of conductor – If conditions require other than standard stranding, a complete description should be given.
6. Type of insulation.
7. Thickness of insulation.
8. Type of outer covering.
9. Maximum allowable overall diameter. When duct space is not limited, it is desirable not to restrict the overall diameter.
10. Method of conductor identification.
11. Special markings.

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Section 2
CONDUCTOR

2.0 GENERAL

Conductors shall meet the requirements of the appropriate ASTM standards referenced in this Standard except that resistance will determine cross-sectional area as noted in 2.3 and diameters shall be in accordance with 2.4.

The following technical information on typical conductors may be found in Appendix G:

a. Approximate diameters of individual wires in stranded conductors.
b. Approximate conductor weights.

2.1 PHYSICAL AND ELECTRICAL PROPERTIES

The conductors used in the cable shall be copper in accordance with 2.1.1 or aluminum in accordance with 2.1.2, as applicable, except as noted in 2.0. Conductors shall be solid or stranded. The outer layer of an uncoated stranded copper conductor may be tin coated to obtain free stripping of an adjacent polymeric layer.

2.1.1 Copper Conductors

1. ASTM B 3 for Soft or Annealed Uncoated Copper.
2. ASTM B 5 for Electrical Grade Copper.
3. ASTM B 8 for Class A, B, C, or D Stranded Copper Conductors.
4. ASTM B 33 for Soft or Annealed Tin-Coated Copper Wire.
5. ASTM B 496 for Compact-Round Stranded Copper Conductors.
6. ASTM B 784 for Modified Concentric Lay Stranded Copper Conductor.
7. ASTM B 785 for Compact Round Modified Concentric Lay Stranded Copper Conductor.
8. ASTM B 787 for 19 Wire Combination Unilay-Stranded Copper Conductors.
9. ASTM B 835 for Compact Round Stranded Copper Conductors Using Single Input Wire Constructions.

2.1.2 Aluminum Conductors

1. ASTM B 230 for Electrical Grade Aluminum 1350-H19.
2. ASTM B 231 for Class A, B, C, or D Stranded Aluminum 1350 Conductors.
3. ASTM B 233 for Electrical Grade Aluminum 1350 Drawing Stock.
4. ASTM B 400 for Compact-Round Stranded Aluminum 1350 Conductors.
5. ASTM B 609 for Electrical Grade Aluminum 1350 Annealed and Intermediate Tempers.
6. ASTM B 786 for 19 Wire Combination Unilay-Stranded Aluminum 1350 Conductors.
7. ASTM B 800 for 8000 Series Aluminum Alloy Annealed and Intermediate Tempers.
8. ASTM B 801 for 8000 Series Aluminum Alloy Wires, Compact-Round, Compressed and Concentric-Lay Class A, B, C and D Stranded Conductors.
9. ASTM B 836 for Compact Round Stranded Aluminum Conductors Using Single Input Wire Constructions.

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2.1.3 Flexible Conductors

1. ASTM B 172 for Rope-Lay-Sranded Copper Conductors Having Bunch-Stranded Standard Specification for Members, for Electrical Conductors.
2. ASTM B 173 for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Standard Members, for Electrical Conductors.
3. ASTM B 174 for Bunch-Stranded Copper Conductors for Electrical Conductors.
4. For Flexible Aluminum Conductors consult manufacturer.

2.2 CONDUCTOR SIZE UNITS

Conductor size shall be expressed by cross-sectional area in thousand circular mils (kcmil). The AWG equivalents for small sizes shall be found in Table 2-3, or 2-3M.

2.3 CONDUCTOR DC RESISTANCE PER UNIT LENGTH

The dc resistance per unit length of each conductor in a production or shipping length of completed cable shall not exceed the value determined from the schedule of maximum dc resistances specified in Table 2-2 when using the appropriate nominal value specified in Table 2-4 or 2-4M. The dc resistance shall be determined in accordance with 2.3.1 or 2.3.2.

Where the outer layer of an uncoated stranded copper conductor is tin coated, the direct current resistance of the resulting conductor shall not exceed the value specified for an uncoated conductor of the same size.

When a sample is taken from a multiple conductor cable, the resistance shall comply with the appropriate maximum resistance value specified for a single conductor cable.

2.3.1 Direct Measurement of dc Resistance

The dc resistance per unit length shall be determined by dc resistance measurements made in accordance with ICEA Publication T-27-581/WC 53 to an accuracy of 2 Percent or better. If measurements are made at a temperature other than 25 °C, the measured value shall be converted to resistance at 25 °C by using the methods specified in ICEA T-27-581/NEMA WC53.

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 foot (0.305 m) long shall be cut from that reel length, and the direct-current resistance of each conductor shall be measured using a Kelvin-type bridge or a potentiometer.

2.3.2 Calculation of dc Resistance Per Unit Length

The dc resistance per unit length at 25 °C shall be calculated using the following formula:

$$R = K \bullet \frac{\rho}{A}$$

Where:

R = Conductor resistance in Ω/1000 ft.
k = Weight increment factor, as given in Table 2-1 as per the applicable ASTM standards.
ρ = Volume resistivity in Ω•cmil/ft., determined in accordance with ASTM B 193 using round wires.

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A = Cross-sectional area of conductor in kcmil, determined in accordance with ICEA T-27-581/NEMA WC 53 or ASTM B 258 for solid conductors or ASTM B 263 for concentric-lay, concentric-lay compressed or compact-stranded conductors.

When the volume resistivity is expressed in nanoohmmeter (nΩm) and area is expressed in square millimeters (mm^2) the resistance is expressed in milliohm per meter (mΩm).

2.4 CONDUCTOR DIAMETER

The average diameter of a conductor shall be measured in accordance with ICEA Publication T-27-581/WC53. The diameter shall not differ from the nominal values shown in Table 2-3 or 2-3M by more than ± 2 percent.

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Table 2-1
Weight Increment Factors

Conductor Type/Size	Weight Factor (k)
Solid All Sizes	1
Stranded, Class B, C and Dand Unilay strand Up to 2000 kcmil >2000 - 3000 kcmil	 1.02 1.03
Rope Lay Strand Having Concentric Stranded Members Classes G and H	
49 wires	1.03
133 wires	1.04
259 wires	1.045
427 wires	1.05
Over 427 wires	1.06
Bunched Strand, Single Bunches All Sizes	1.02
Rope-lay Strand Having Bunch-stranded Members, Classes I, K & M	
7 bunch stranded members	1.04
19 bunch stranded members	1.05
37 bunch stranded members	1.05
61 bunch stranded members	1.05
7 x 7 bunched stranded members	1.06
19 x 7 bunched stranded members	1.07
37 x 7 bunched stranded members	1.07
61 x 7 bunched stranded members	1.07

*Based on the method specified in either ASTM B 8, ASTM B 496, ASTM B 400, ASTM B 231 ASTM B 172. ASTM B 173, ASTM B 174, ASTM B 786, ASTM B 787, or ASTM B 801 as applicable.

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Table 2-2
Schedule for Establishing Maximum Direct Current Resistance Per Unit Length of Completed Cable Conductors listed in Tables 2-4 thru 2-6.

Cable Type	Maximum dc Resistance
Single Conductor Cables and Flat Parallel Cables	Table 2-3[a] Value Plus 2 Percent (R max = R x 1.02)
Multiple Conductor Cables & Twisted Assemblies of Single Conductor Cables	Table 2-3[a] Value Plus 2 Percent Plus One of the Following: 2 Percent - One Layer of Conductors (R max = R x 1.02 x 1.02) 3 Percent - More than One Layer of Conductors (R max = R x 1.02 x 1.03) 4 Percent - Pairs or other Precables Units (R max = R x 1.02 x 1.04)
Conductors listed in Tables 2-5 and 2-6	
Cable Type	Maximum dc Resistance
Single Conductor Cables and Flat Parallel	Table 2-5[a] or 2-6[a] Value Plus 2 Percent[b] (R max = R x 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-5[a] or 2-6[a] Value Plus 2 Percent[b] Plus 5 Percent (R max = R x 1.02 x 1.05)

[a]For conductor strandings or sizes not listed in Tables 2-4 through 2-6, the nominal direct current resistance per unit length of a completed single conductor cable shall be calculated using the following formula:

$$R = 10^{-3}\frac{f}{A}$$

Where:

R = Conductor resistance in Ω/1000 ft.
f = Factor from Table 2-7
A = Cross-sectional area of conductor in kcmil

For cross-sectional area determination refer to ICEA Publication T-27-581/WC 53.

[b]For 18 AWG Class K conductors specified in Table 2-6 this value shall be 3 percent.

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Table 2-3
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Solid	Stranded				
			Compact*	Compressed	Class B	Class C	Class D
AWG	kcmil	Inch	Inch	Inch	Inch	Inch	Inch
14	4.11	0.0641	---	0.0704	0.0727	0.0735	0.0735
13	5.18	0.0720	---	0.0792	0.0816	0.0825	0.0826
12	6.53	0.0808	---	0.0888	0.0915	0.0925	0.0931
11	8.23	0.0907	---	0.0998	0.103	0.104	0.104
10	10.39	0.1019	---	0.113	0.116	0.117	0.117
9	13.09	0.1144	---	0.126	0.130	0.131	0.132
8	16.51	0.1285	0.134	0.141	0.146	0.148	0.148
7	20.82	0.1443	---	0.158	0.164	0.166	0.166
6	26.24	0.1620	0.169	0.178	0.184	0.186	0.186
5	33.09	0.1819	---	0.200	0.206	0.208	0.209
4	41.74	0.2043	0.213	0.225	0.232	0.234	0.235
3	52.62	0.2294	0.238	0.252	0.260	0.263	0.264
2	66.36	0.2576	0.268	0.283	0.292	0.296	0.297
1	83.69	0.2893	0.299	0.322	0.332	0.333	0.333
1/0	105.6	0.3249	0.336	0.362	0.372	0.374	0.374
2/0	133.1	0.3648	0.376	0.406	0.418	0.420	0.420
3/0	167.8	0.4096	0.423	0.456	0.470	0.471	0.472
4/0	211.6	0.4600	0.475	0.512	0.528	0.529	0.530
	250	0.5000	0.520	0.558	0.575	0.576	0.576
	300	0.5477	0.570	0.611	0.630	0.631	0.631
	350	0.5916	0.616	0.661	0.681	0.681	0.682
	400	0.6325	0.659	0.706	0.728	0.729	0.729
	450	0.3708	0.700	0.749	0.772	0.773	0.773
	500	0.7071	0.736	0.789	0.813	0.814	0.815
	550	—	0.775	0.829	0.855	0.855	0.855
	600	—	0.813	0.866	0.893	0.893	0.893
	650	---	0.845	0.901	0.929	0.930	0.930
	700	—	0.877	0.935	0.964	0.965	0.965
	750	—	0.908	0.968	0.999	0.999	0.998
	800	---	0.938	1.000	1.030	1.032	1.032
	900	---	0.999	1.061	1.094	1.093	1.095
	1000	---	1.060	1.117	1.152	1.153	1.153
	1100	---	---	1.173	1.209	1.210	1.211
	1200	---	---	1.225	1.263	1.264	1.264
	1250	---	---	1.251	1.289	1.290	1.290
	1300	---	---	1.275	1.314	1.316	1.316
	1400	---	---	1.323	1.365	1.365	1.365
	1500	---	---	1.370	1.412	1.413	1.413
	1600	---	---	1.415	1.459	1.460	1.460
	1700	---	---	1.459	1.504	1.504	1.504
	1750	---	---	1.480	1.526	1.527	1.527
	1800	---	---	1.502	1.548	1.548	1.549
	1900	---	---	1.542	1.590	1.590	1.591
	2000	---	---	1.583	1.632	1.632	1.632
	2500	---	---	1.769	1.824	1.824	1.824
	3000	---	---	1.938	1.998	1.998	1.998

* Also applicable to Single-Input Wire (SIW) compact stranded conductors.

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Table 2-3 Cont'd
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Stranded			
		Modified Class B	Modified Compact	Combination Unilay	Unilay Compressed
AWG	kcmil	Inch	Inch	Inch	Inch
14	4.11	---	---	---	---
13	5.18	---	---	---	---
12	6.53	---	---	---	---
11	8.23	---	---	---	---
10	10.39	---	---	---	---
9	13.09	---	---	---	---
8	16.51	---	---	0.143	---
7	20.82	---	---	0.160	---
6	26.24	---	---	0.179	---
5	33.09	---	---	0.202	---
4	41.74	---	---	0.226	---
3	52.62	---	---	0.254	---
2	66.36	---	---	0.286	---
1	83.69	0.332	0.299	0.321	0.313
1/0	105.6	0.373	0.336	0.360	0.352
2/0	133.1	0.419	0.376	0.404	0.395
3/0	167.8	0.470	0.423	0.454	0.443
4/0	211.6	0.528	0.475	0.510	0.498
	250	0.575	0.520	0.554	0.542
	300	0.630	0.570	0.607	0.594
	350	0.681	0.616	0.656	0.641
	400	0.728	0.659	0.701	0.685
	450	0.772	0.700	0.744	0.727
	500	0.813	0.736	0.784	0.766
	550	0.855	0.775	---	0.804
	600	0.893	0.813	---	0.840
	650	0.929	0.845	---	0.874
	700	0.964	0.877	---	0.907
	750	0.998	0.908	---	0.939
	800	1.031	0.938	---	0.969
	900	1.094	0.999	---	1.028
	1000	1.152	1.060	---	1.084
	1100	1.209	---	---	1.137
	1200	1.263	---	---	1.187
	1250	1.289	---	---	1.212
	1300	1.315	---	---	1.236
	1400	1.364	---	---	1.282
	1500	1.412	---	---	1.327
	1600	1.458	---	---	1.371
	1700	1.504	---	---	1.413
	1750	1.526	---	---	1.434
	1800	1.548	---	---	1.454
	1900	1.590	---	---	1.494
	2000	1.632	---	---	1.533
	2500	1.824	---	---	---
	3000	1.998	---	---	---

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Table 2-3M (Metric)
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Solid	Stranded				
			Compact*	Class B Compressed	Class B	Class C	Class D
AWG or kcmil	mm^2	mm	mm	mm	mm	mm	mm
14	2.08	1.63	---	1.79	1.84	1.87	1.87
13	2.63	1.83	---	2.02	2.07	2.10	2.10
12	3.31	2.05	---	2.26	2.32	2.35	2.36
11	4.17	2.30	---	2.53	2.62	2.64	2.64
10	5.26	2.59	---	2.87	2.95	2.97	2.97
9	6.63	2.91	---	3.20	3.30	3.33	3.35
8	8.37	3.26	3.40	3.58	3.71	3.76	3.76
7	10.6	3.67	---	4.01	4.17	4.22	4.22
6	13.3	4.11	4.29	4.52	4.67	4.72	4.72
5	16.8	4.62	---	5.08	5.23	5.28	5.31
4	21.1	5.19	5.41	5.72	5.89	5.94	5.97
3	26 7	5.83	6.05	6.40	6.60	6.68	6.71
2	33.6	6.54	6.81	7.19	7.42	7.52	7.54
1	42.4	7.35	7.59	8.18	8.43	8.46	8.46
1/0	53.5	8.25	8.53	9.17	9.45	9.50	9.50
2/0	37.4	9.27	9.55	10.3	10.6	10.7	10.7
3/0	85.0	10.4	10.7	11.6	11.9	12.0	12.0
4/0	107	11.7	12.1	13.0	13.4	13.4	13.45
250	127	12.7	13.2	14.2	14.6	14.6	14.6
300	152	13.9	14.5	15.5	16.0	16.0	16.0
350	177	15.0	15.6	16.8	17.3	17.3	17.3
400	203	16.1	16.7	17.9	18.5	18.5	18.5
450	228	17.0	17.8	19.0	19.6	19.6	19.6
500	253	18.0	18.7	20.0	20.7	20.7	20.7
550	279	---	19.7	21.1	21.7	21.7	21.7
600	304	---	20.7	22.0	22.7	22.7	22.7
650	329	---	21.5	22.9	23.6	23.6	23.6
700	355	---	22.3	23.7	24.5	24.5	24.5
750	380	---	23.1	24.6	25.3	25.4	25.43
800	405	---	23.8	25.4	26.2	26.2	26.2
900	456	---	25.4	26.9	27.8	27.8	27.8
1000	507	---	26.9	28.4	29.3	29.3	29.3
1100	557	---	---	29.8	30.7	30.7	30.78
1200	608	---	---	31.1	32.1	32.1	32.1
1250	633	---	---	31.8	32.7	32.8	32.8
1300	659	---	---	32.4	33.4	33.4	33.4
1400	709	---	---	33.6	34.7	34.7	34.7
1500	760	---	---	34.8	35.9	35.9	35.9
1600	811	---	---	35.9	37.1	37.1	37.1
1700	861	---	---	37.1	38.2	38.2	38.2
1750	887	---	---	37.6	38.8	38.8	38.8
1800	912	---	---	38.2	39.3	39.3	39.3
1900	963	---	---	39.2	40.4	40.4	40.4
2000	1013	---	---	40.2	41.5	41.5	41.5
2500	1267	---	---	44.9	46.3	46.3	46.3
3000	1520	---	---	49.2	50.7	50.7	50.7

* Also applicable to Single-Input Wire (SIW) compact stranded conductors.

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Table 2-3M (Metric) Cont'd
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Concentric Lay Stranded			
		Modified Class B	Modified Compact	Combination Unilay	Unilay Compressed
AWG or kcmil	mm^2	mm	mm	mm	mm
14	2.08	---	---	---	---
13	2.63	---	---	---	---
12	3.31	---	---	---	---
11	4.17	---	---	---	---
10	5.26	---	---	---	---
9	6.63	---	---	---	---
8	8.37	---	---	3.63	---
7	10.6	---	---	4.06	---
6	13.3	---	---	4.55	---
5	16.8	---	---	5.13	---
4	21.1	---	---	5.74	---
3	26.7	---	---	6.45	----
2	33.6	---	---	7.26	---
1	42.4	8.433	7.595	8.15	7.95
1/0	53.5	8.534	8.534	9.14	8.94
2/0	37.4	9.550	9.550	10.3	10.03
3/0	85.0	10.744	10.744	11.5	11.25
4/0	107	12.065	12.065	13.0	12.65
250	127	14.605	13.208	14.1	13.77
300	152	16.022	14.478	15.4	15.09
350	177	17.297	15.646	16.7	16.28
400	203	18.491	16.739	17.8	17.40
450	228	19.609	17.780	18.9	18.47
500	253	20.650	18.694	19.9	19.46
550	279	21.717	19.685	---	20.42
600	304	22.682	20.650	---	21.34
650	329	23.597	21.463	---	22.20
700	355	24.486	22.276	---	23.04
750	380	25.349	23.063	---	23.85
800	405	26.187	23.825	---	24.61
900	456	27.788	25.375	---	26.11
1000	507	29.261	26.924	---	27.53
1100	557	30.709	---	---	28.88
1200	608	32.080	---	---	30.15
1250	633	32.741	---	---	30.78
1300	659	33.401	---	---	31.39
1400	709	34.646	---	---	32.56
1500	760	35.865	---	---	33.71
1600	811	37.059	---	---	34.82
1700	861	38.202	---	---	35.89
1750	887	38.760	---	---	36.42
1800	912	39.319	---	---	36.93
1900	963	40.386	---	---	37.95
2000	1013	41.453	---	---	38.94
2500	1267	---	---	---	---
3000	1520	---	---	---	---

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Table 2-4
Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25°C of Solid and Stranded Conductor

Conductor Size	Solid			Stranded*				
					Copper			
	Aluminum	Copper		Aluminum	Uncoated	Tin Coated		
AWG or kcmil		Uncoated	Coated	Class B, C, D	Class B, C, D	Class B	Class C	Class D
14	---	2.57	2.67	---	2.63	2.73	2.79	---
13	---	2.04	2.12	---	2.08	2.16	2.21	---
12	2.66	1.62	1.68	2.70	1.66	1.72	1.75	---
11	---	1.29	1.34	---	1.31	1.36	1.36	---
10	1.67	1.02	1.06	1.70	1.04	1.08	1.08	---
9	1.32	0.808	0.831	1.35	0.825	0.856	0.856	---
8	1.05	0.640	0.659	1.07	0.652	0.678	0.678	0.680
7	0.833	0.508	0.522	0.851	0.519	0.538	0.538	0.538
6	0.661	0.403	0.414	0.675	0.411	0.427	0.427	0.427
5	0.524	0.319	0.329	0.534	0.325	0.338	0.339	0.339
4	0.415	0.253	0.261	0.424	0.258	0.269	0.269	0.269
3	0.329	0.201	0.207	0.326	0.205	0.213	0.213	0.213
2	0.261	0.159	0.164	0.265	0.162	0.169	0.169	0.169
1	0.207	0.126	0.130	0.211	0.129	0.134	0.134	0.134
1/0	0.164	0.100	0.102	0.168	0.102	0.106	0.106	0.106
2/0	0.130	0.0794	0.0813	0.133	0.0810	0.0842	0.0842	0.0842
3/0	0.103	0.0630	0.0645	0.105	0.0642	0.0667	0.0669	0.0669
4/0	0.0819	0.0500	0.0511	0.0836	0.0510	0.0524	0.0530	0.0530
250	0.0694	---	---	0.0707	0.0431	0.0448	0.0448	0.0448
300	0.0578	---	---	0.0590	0.0360	0.0374	0.0374	0.0374
350	0.0495	---	---	0.0505	0.0308	0.0320	0.0320	0.0320
400	0.0433	---	---	0.0442	0.0269	0.0277	0.0280	0.0280
450	0.0385	---	---	0.0393	0.0240	0.0246	0.0249	0.0249
500	0.0347	---	---	0.0354	0.0216	0.0222	0.0224	0.0224
550	---	---	---	0.0321	0.0196	0.0204	0.0204	0.0204
600	---	---	---	0.0295	0.0180	0.0187	0.0187	0.0187
650	---	---	---	0.0272	0.0166	0.0171	0.0172	0.0173
700	---	---	---	0.0253	0.0154	0.0159	0.0160	0.0160
750	---	---	---	0.0236	0.0144	0.0148	0.0149	0.0150
800	---	---	---	0.0221	0.0135	0.0139	0.0140	0.0140
900	---	---	---	0.0196	0.0120	0.0123	0.0126	0.0126
1000	---	---	---	0.0177	0.0108	0.0111	0.0111	0.0112
1100	---	---	---	0.0161	0.00981	0.0101	0.0102	0.0102
1200	---	---	---	0.0147	0.00899	0.00925	0.00934	0.00934
1250	---	---	---	0.0141	0.00863	0.00888	0.00897	0.00887
1300	---	---	---	0.0136	0.00830	0.00854	0.00861	0.00862
1400	---	---	---	0.0126	0.00771	0.00793	0.00793	0.00801
1500	---	---	---	0.0118	0.00719	0.00740	0.00740	0.00747
1600	---	---	---	0.0111	0.00674	0.00694	0.00700	0.00700
1700	---	---	---	0.0104	0.00634	0.00653	0.00659	0.00659
1750	---	---	---	0.0101	0.00616	0.00634	0.00640	0.00640
1800	---	---	---	0.00982	0.00599	0.00616	0.00616	0.00622
1900	---	---	---	0.00931	0.00568	0.00584	0.00584	0.00589
2000	---	---	---	0.00885	0.00539	0.00555	0.00555	0.00560
1500	---	---	---	0.00715	0.00436	0.00448	---	---
3000	---	---	---	0.00596	0.00363	0.00374	---	---

Stranded includes compressed and compact conductors.

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Table 2-4M (Metric)
Nominal Direct Current Resistance in Milliohms Per Meter at 25°C of Solid and Stranded Conductor

Conductor Size	Solid			Stranded*				
	Aluminum	Copper		Aluminum	Copper			
					Uncoated	Tin Coated		
AWG or kcmil		Uncoated	Coated	Class B, C, D	Class B, C, D	Class B	Class C	Class D
14	---	8.43	8.76	---	2.63	2.73	2.79	---
13	---	6.69	6.96	---	2.08	2.16	2.21	---
12	8.73	5.32	5.51	8.86	1.66	1.72	1.75	---
11	---	4.23	4.40	---	1.31	1.36	1.36	---
10	5.48	3.35	3.48	5.58	1.04	1.08	1.08	---
9	4.33	2.65	2.73	4.43	0.825	0.856	0.856	---
8	3.44	2.10	2.16	3.51	0.652	0.678	0.678	0.680
7	2.73	1.67	1.71	2.79	0.519	0.538	0.538	0.538
6	2.17	1.32	1.36	2.21	0.411	0.427	0.427	0.427
5	1.72	1.05	1.08	1.75	0.325	0.338	0.339	0.339
4	1.36	0.830	0.856	1.39	0.258	0.269	0.269	0.269
3	1.08	0.659	0.679	1.10	0.205	0.213	0.213	0.213
2	0.856	0.522	0.538	0.872	0.162	0.169	0.169	0.169
1	0.679	0.413	0.426	0.692	0.129	0.134	0.134	0.134
1/0	0.538	0.328	0.335	0.551	0.102	0.106	0.106	0.106
2/0	0.426	0.260	0.267	0.436	0.0810	0.0842	0.0842	0.0842
3/0	0.338	0.207	0.212	0.344	0.0642	0.0667	0.0669	0.0669
4/0	0.269	0.164	0.168	0.274	0.0510	0.0524	0.0530	0.0530
250	0.228	---	---	0.232	0.0431	0.0448	0.0448	0.0448
300	0.190	---	---	0.194	0.0360	0.0374	0.0374	0.0374
350	0.162	---	---	0.166	0.0308	0.0320	0.0320	0.0320
400	0.142	---	---	0.145	0.0269	0.0277	0.0280	0.0280
450	0.126	---	---	0.129	0.0240	0.0246	0.0249	0.0249
500	0.114	---	---	0.116	0.0216	0.0222	0.0224	0.0224
550	---	---	---	0.105	0.0196	0.0204	0.0204	0.0204
600	---	---	---	0.0968	0.0180	0.0187	0.0187	0.0187
650	---	---	---	0.0892	0.0166	0.0171	0.0172	0.0173
700	---	---	---	0.0830	0.0154	0.0159	0.0160	0.0160
750	---	---	---	0.0774	0.0144	0.0148	0.0149	0.0150
800	---	---	---	0.0725	0.0135	0.0139	0.0140	0.0140
900	---	---	---	0.0643	0.0120	0.0123	0.0126	0.0126
1000	---	---	---	0.0581	0.0108	0.0111	0.0111	0.0112
1100	---	---	---	0.0528	0.00981	0.0101	0.0102	0.0102
1200	---	---	---	0.0482	0.00899	0.00925	0.00934	0.00934
1250	---	---	---	0.0462	0.00863	0.00888	0.00897	0.00887
1300	---	---	---	0.0446	0.00830	0.00854	0.00861	0.00862
1400	---	---	---	0.0413	0.00771	0.00793	0.00793	0.00801
1500	---	---	---	0.0387	0.00719	0.00740	0.00740	0.00747
1600	---	---	---	0.0364	0.00674	0.00694	0.00700	0.00700
1700	---	---	---	0.0341	0.00634	0.00653	0.00659	0.00659
1750	---	---	---	0.0331	0.00616	0.00634	0.00640	0.00640
1800	---	---	---	0.0322	0.00599	0.00616	0.00616	0.00622
1900	---	---	---	0.0305	0.00568	0.00584	0.00584	0.00589
2000	---	---	---	0.0290	0.00539	0.00555	0.00555	0.00560
1500	---	---	---	0.0235	0.00436	0.00448	---	---
3000	---	---	---	0.0195	0.00363	0.00374	---	---

*Stranded includes compressed and compact conductors.

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Table 2-5
Nominal Direct Current Resistance
at 25°C For Flexible Aluminum Conductors

Cndr Size	Class G		Class H		Class I	
AWG or kcmil	Ohms/1000 ft	milliohms/m	Ohms/1000 ft	milliohms/m	Ohms/1000 ft	milliohms/m
8	---	---	---	---	1.07	3.510
7	0.858	2.814	---	---	0.850	2.788
6	0.681	2.234	---	---	0.687	2.253
5	0.540	1.771	---	---	0.545	1.788
4	0.428	1.404	---	---	0.432	1.417
3	0.340	1.115	---	---	0.343	1.125
2	0.269	0.882	0.272	0.892	0.272	0.892
1	0.216	0.708	---	---	0.216	0.708
1/0	0.171	0.561	0.172	0.564	0.172	0.564
2/0	0.136	0.446	0.136	0.446	0.137	0.449
3/0	0.107	0.351	0.108	0.354	0.109	0.358
4/0	0.085	0.279	0.0857	0.281	0.0861	0.282
250	0.0725	0.238	0.0728	0.239	0.0735	0.241
300	0.0604	0.198	0.0607	0.199	0.0613	0.201
350	0.0518	0.170	0.0520	0.171	0.0525	0.172
400	0.0453	0.149	0.0445	0.149	0.0460	0.151
450	0.0403	0.132	0.0405	0.133	0.0409	0.134
500	0.0363	0.119	0.0364	0.119	0.0368	0.121
550	0.0331	0.108	0.0334	0.110	0.0334	0.110
600	0.0304	0.100	0.0306	0.100	0.0306	0.100
650	0.0280	0.0918	0.0283	0.0928	0.0286	0.0938
700	0.0260	0.0853	0.0263	0.0863	0.0265	0.0869
750	0.0243	0.0800	0.0245	0.0804	0.0247	0.0810
800	0.0228	0.0749	0.0230	0.0754	0.0232	0.0761
900	0.0202	0.0663	0.0204	0.0669	0.0206	0.0676
1000	0.0182	0.0597	0.0184	0.0604	0.0186	0.0610
1100	0.0166	0.0545	0.0167	0.0548	0.0169	0.0554
1200	0.0152	0.0499	0.0153	0.0502	0.0155	0.0508
1250	0.0146	0.0479	0.0147	0.0482	0.0148	0.0485
1300	0.0140	0.0459	0.0141	0.0463	0.0143	0.0469
1400	0.0130	0.0426	0.0131	0.0430	0.0133	0.0436
1500	0.0121	0.0397	0.0123	0.0403	0.0124	0.0407
1600	0.0115	0.0377	0.0115	0.0377	0.0116	0.0381
1700	0.0108	0.0354	0.0108	0.0354	0.0109	0.0358
1750	0.0105	0.0344	0.0105	0.0344	0.0106	0.0348
1800	0.0102	0.0335	0.0102	0.0335	0.0103	0.0338
1900	0.00968	0.0318	0.00968	0.0318	0.00977	0.0321
2000	0.00919	0.0301	0.00919	0.0301	0.00928	0.0304

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Table 2-6
Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25°C For Flexible Annealed Copper Conductors

Cndr. Size	Uncoated					Tin Coated				
AWG or kcmil	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
18	----	----	----	6.66	6.66	----	----	----	7.15	7.15
16	----	----	----	4.18	4.18	----	----	----	4.49	4.49
14	2.65	----	----	2.62	2.62	2.81	----	----	2.82	2.82
12	1.67	----	----	1.65	1.68	1.77	----	----	1.77	1.81
10	1.05	----	1.04	1.04	1.06	1.11	----	1.08	1.12	1.14
9	0.832	----	0.824	0.840	0.840	0.884	----	0.857	0.902	0.902
8	0.660	0.666	0.653	0.666	0.666	0.701	0.708	0.679	0.715	0.715
7	0.523	0.528	0.518	0.528	0.533	0.544	0.561	0.539	0.567	0.573
6	0.415	0.419	0.419	0.419	0.423	0.432	0.445	0.436	0.450	0.454
5	0.329	0.332	0.332	0.332	0.336	0.342	0.353	0.346	0.357	0.360
4	0.261	0.263	0.263	0.263	0.266	0.271	0.280	0.274	0.283	0.286
3	0.207	0.209	0.209	0.211	0.213	0.215	0.222	0.217	0.227	0.227
2	0.164	0.166	0.166	0.167	0.169	0.171	0.172	0.172	0.180	0.181
1	0.131	0.132	0.131	0.133	0.134	0.137	0.140	0.137	0.142	0.144
1/0	0.104	0.105	0.105	0.105	0.106	1.108	0.109	0.109	0.113	0.114
2/0	0.0826	0.0830	0.0834	0.0842	0.0850	0.0859	0.0863	0.0868	0.0904	0.0913
3/0	0.0655	0.0659	0.0662	0.0668	0.0674	0.0682	0.0685	0.0688	0.0717	0.0724
4/0	0.0520	0.0522	0.0525	0.0530	0.0535	0.0541	0.0543	0.0546	0.0569	0.0574
250	0.0442	0.0444	0.0448	0.0448	0.0453	0.0460	0.0462	0.0466	0.0481	0.0486
300	0.0368	0.0370	0.0374	0.0374	0.0377	0.0383	0.0385	0.0389	0.0401	0.0405
350	0.0316	0.0317	0.0320	0.0323	0.0323	0.0328	0.0330	0.0333	0.0347	0.0347
400	0.0276	0.0278	0.0280	0.0283	0.0283	0.0287	0.0289	0.0291	0.0304	0.0304
450	0.0246	0.0247	0.0249	0.0251	0.0251	0.0255	0.0257	0.0259	0.0270	0.0262
500	0.0221	0.0222	0.0224	0.0226	0.0226	0.0230	0.0231	0.0233	0.0243	0.0243
550	0.0202	0.0204	0.0204	0.0206	0.0206	0.0210	0.0212	0.0212	0.0221	0.0221
600	0.0185	0.0187	0.0187	0.0189	0.0189	0.0192	0.0194	0.0194	0.0203	0.0202
650	0.0171	0.0172	0.0174	0.0174	0.0174	0.0178	0.0179	0.0181	0.0187	0.0187
700	0.0159	0.0168	0.0162	0.0162	0.0162	0.0165	0.0167	0.0168	0.0174	0.0174
750	0.0148	0.0149	0.0151	0.0151	0.0151	0.0154	0.0155	0.0157	0.0162	0.0162
800	0.0139	0.0140	0.0141	0.0141	0.0141	0.0144	0.0146	0.0147	0.0152	0.0152
900	0.0123	0.0125	0.0126	0.0126	0.0126	0.0128	0.0130	0.0131	0.0135	0.0135
1000	0.0111	0.0112	0.0113	0.0113	0.0113	0.0115	0.0117	0.0118	0.0122	0.0121
1100	0.0101	0.0102	0.0103	----	----	0.0105	0.0106	0.0107	----	----
1200	0.00925	0.00934	0.00943	----	----	0.00962	0.00971	0.00981	----	----
1250	0.00888	0.00897	0.00905	----	----	0.00924	0.00933	0.00941	----	----
1300	0.00854	0.00862	0.00870	----	----	0.00888	0.00897	0.00905	----	----
1400	0.00793	0.00801	0.00808	----	----	0.00825	0.00833	0.00841	----	----
1500	0.00740	0.00747	0.00754	----	----	0.00770	0.00777	0.00785	----	----
1600	0.00701	0.00701	0.00707	----	----	0.00729	0.00729	0.00735	----	----
1700	0.00659	0.00659	0.00666	----	----	0.00686	0.00686	0.00692	----	----
1750	0.00641	0.00641	0.00647	----	----	0.00666	0.00666	0.00672	----	----
1800	0.00623	0.00623	0.00629	----	----	0.00648	0.00648	0.00654	----	----
1900	0.00590	0.00590	0.00596	----	----	0.00614	0.00614	0.00619	----	----
2000	0.00561	0.00561	0.00566	----	----	0.00583	0.00583	0.00588	----	----

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Table 2-6M (Metric)
Nominal Direct Current Resistance in Milliohms Per Meter at 25°C For Flexible Annealed Copper Conductors

Conductor Size	Uncoated					Tin Coated				
AWG or kcmil	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
18	---	---	---	21.8	---	---	---	---	23.4	23.4
16	---	---	---	13.7	13.7	---	---	---	14.7	14.7
14	8.69	---	---	8.59	8.59	9.21	---	---	9.24	9.24
12	5.47	---	---	5.41	5.51	5.80	---	---	5.80	5.93
10	3.44	---	3.41	3.41	3.47	3.64	---	3.54	3.67	3.73
9	2.72	---	2.70	2.75	2.75	2.89	---	2.81	2.95	2.95
8	2.16	2.18	2.14	2.18	2.18	2.29	2.32	2.22	2.34	2.34
7	1.71	1.73	1.69	1.73	1.74	1.78	1.84	1.76	1.85	1.87
6	1.36	1.37	1.37	1.37	1.38	1.41	1.45	1.43	1.47	1.48
5	1.07	1.08	1.08	1.08	1.10	1.12	1.15	1.13	1.17	1.18
4	0.856	0.862	0.862	0.862	0.872	0.888	0.918	0.898	0.928	0.938
3	0.679	0.685	0.685	0.692	0.698	0.705	0.728	0.711	0.744	0.744
2	0.537	0.544	0.544	0.547	0.554	0.560	0.564	0.564	0.590	0.593
1	0.429	0.433	0.429	0.436	0.439	0.449	0.459	0.449	0.465	0.472
1/0	0.341	0.344	0.344	0.344	0.347	3.634	0.357	0.357	0.370	0.373
2/0	0.270	0.272	0.273	0.276	0.278	0.281	0.283	0.284	0.296	0.299
3/0	0.214	0.216	0.217	0.219	0.221	0.223	0.224	0.225	0.235	0.237
4/0	0.170	0.171	0.172	0.173	0.175	0.177	0.178	0.179	0.186	0.188
250	0.145	0.145	0.146	0.146	0.148	0.150	0.151	0.152	0.157	0.159
300	0.120	0.121	0.122	0.122	0.123	0.125	0.126	0.127	0.131	0.132
350	0.103	0.104	0.105	0.105	0.105	0.107	0.108	0.109	0.113	0.113
400	0.0905	0.0912	0.0918	0.0928	0.0928	0.0941	0.0948	0.0954	0.0997	0.0997
450	0.0807	0.0810	0.0817	0.0823	0.0823	0.0836	0.0843	0.0850	0.0886	0.0859
500	0.0725	0.0728	0.0735	0.0741	0.0741	0.0754	0.0758	0.0764	0.0797	0.0797
550	0.0663	0.0669	0.0669	0.0676	0.0676	0.0689	0.0695	0.0695	0.0725	0.0725
600	0.0607	0.0613	0.0613	0.0620	0.0620	0.0630	0.0636	0.0636	0.0666	0.0663
650	0.0561	0.0564	0.0571	0.0571	0.0571	0.0584	0.0587	0.0594	0.0613	0.0613
700	0.0522	0.0551	0.0531	0.0531	0.0531	0.0541	0.0548	0.0551	0.0571	0.0571
750	0.0485	0.0489	0.0495	0.0495	0.0495	0.0505	0.0508	0.0515	0.0531	0.0531
800	0.0456	0.0459	0.0462	0.0462	0.0462	0.0472	0.0479	0.0482	0.0499	0.0499
900	0.0403	0.0410	0.0413	0.0413	0.0413	0.0420	0.0426	0.0430	0.0443	0.0443
1000	0.0364	0.0367	0.0371	0.0371	0.0371	0.0377	0.0384	0.0387	0.0400	0.0397
1100	0.0331	0.0335	0.0338	---	---	0.0344	0.0348	0.0351	---	---
1200	0.0303	0.0306	0.0309	---	---	0.0316	0.0318	0.0322	---	---
1250	0.0291	0.0294	0.0297	---	---	0.0303	0.0306	0.0309	---	---
1300	0.0280	0.0283	0.0285	---	---	0.0291	0.0294	0.0297	---	----
1400	0.0260	0.0263	0.0265	---	---	0.0271	0.0273	0.0276	---	---
1500	0.0243	0.0245	0.0247	---	---	0.0253	0.0255	0.0257	---	---
1600	0.0230	0.0230	0.0232	---	---	0.0239	0.0239	0.0241	---	---
1700	0.0216	0.0216	0.0218	---	---	0.0225	0.0225	0.0227	---	---
1750	0.0210	0.0210	0.0212	---	---	0.0218	0.0218	0.0220	---	---
1800	0.0204	0.0204	0.0206	---	---	0.0213	0.0213	0.0215	---	---
1900	0.0194	0.0194	0.0195	---	---	0.0201	0.0201	0.0203	---	---
2000	0.0184	0.0184	0.0186	---	---	0.0191	0.0191	0.0193	---	---

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Table 2-7
Factors for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet at 25°C**

	All Sizes Uncoated		Diameter of Individual Tin Coated Copper Wires In Inches for Stranded Conductors				
	Aluminum	Copper	0.460 to 0.290, Inclusive	Under 0.290 to 0.103, Inclusive	Under 0.103 to 0.0201, Inclusive	Under 0.0201 to 0.0111, Inclusive	Under 0 0111 to 0 0010, Inclusive
Conductivity, Percent	61	100	97.66	97.16	97.16	97.16	97.15
Rope Stranded							
49 strands	17865	10892	11153	11210	11327	11568	---
133 strands	18038	10998	11261	11319	11437	11681	---
259 strands	18125	11051	11315	11374	11492	11737	---
427 strands	18212	11104	11370	11428	11547	11793	---
Over 247 strands	18385	11209	11478	11537	11657	11905	---
Bunch Stranded							
All sizes	17691	10786	---	---	11217	11456	11579
Rope-stranded Bunches							
7 ropes of bunched strand	18038	10998	---	---	11437	11681	11806
19, 37, or 61 ropes of bunched strand	18212	11104	---	---	11547	11793	11920
7 x 7 ropes of bunched strand	18385	11209	---	---	11657	11905	12033
19, 37, or 61 x 7 ropes of bunched strand	18559	11315	---	---	11767	12018	12147
Concentric Stranded							
≤ 14 AWG to 2000 kcmil	17692	10786	11045	11102	11217	11456	11580
> 2000 to 3000 kcmil	17865	10892	11153	11211	11327	11568	11694
> 3000 to 4000 kcmil	18039	10998	11261	11319	11437	11680	11807
> 4000 to 5000 kcmil	18212	11104	11369	11428	11437	11792	11921

* The factors given in Table 2-7 shall be based on the following:

A. Resistivity

1. A volume resistivity of 10.575 Ω•cmil/ft (100 Percent conductivity) at 25°C for uncoated (bare) copper.
2. A 25°C volume resistivity converted from the 20°C values specified in ASTM B 33 for Tin coated copper.
3. A volume resistivity of 17.345 Ω•cmil/ft (61.0 Percent conductivity) at 25°C for aluminum.

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Section 3

INSULATION

3.1 MATERIAL

The insulation shall be a thermoplastic compound, a crosslinked polyethylene compound, or a crosslinked rubber compound. The insulating material shall meet the dimensional, electrical and physical requirements specified in Section 3.

Crosslinked polyethylene compound shall be either filled or unfilled. A filled crosslinked polyethylene insulation is one in which the mass fraction of carbon black and/or mineral fillers is 10 Percent or greater. An unfilled crosslinked polyethylene insulation is one in which the mass fraction of carbon black and/or mineral fillers is less than 10 Percent.

The insulation shall be applied directly to the surface of the conductor or optional separator.

3.2 INSULATION LEVELS

100 Percent Level - Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within 1 minute. While these cables are applicable to the great majority of cable installations which are on grounded systems, they may be used also on other systems for which the application of cables is acceptable provided the above clearing requirements are met in completely de-energizing the faulted section.

133 Percent Level - This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100 percent level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding 1 hour.

173 Percent Level - Cables in this category should be applied on systems where the time required to de-energize a gounded section is indefinite. Their use is recommended also for resonant grounded systems.

Note: In common with other electrical equipment, the use of cables is not recommended on systems where the ratio of the zero to positive phase reactance of the system at the point of cable application lies between -1 and -40 since excessively high voltages may be encountered in the case of ground faults.

3.3 INSULATION THICKNESSES

The insulation thickness given in Tables 3-3, 3-4, and 3-5, shall apply to rated circuit voltage, phase to phase, and are suitable for 100 and 133 Percent insulation levels.

The thicknesses of insulation given in Tables 3-3, 3-4, and 3-5, shall apply to single-conductor cables and to the individual conductors of multiple-conductor cables, except nonsheathed submarine cables. For nonsheathed submarine cables, see 3.4.

The average thickness of the insulation shall be not less than that given in Tables 3-3 through 3-5. The minimum thickness shall be not less than 90 percent of the values given in Tables 3-3 through 3-5 for the various insulation types and voltage ratings.

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3.3.1 The Thickness Of Insulation For Various Systems Shall Be Determined As Follows:

3.3.1.1 Three Phase Systems With 100 or 133 Percent Insulation Level

Use the thickness values given in Tables 3-3, 3-4 and 3-5 as applicable.

3.3.1.2 Delta Systems Where One Leg May Be Grounded For Periods Over One Hour

See 173 percent level in paragraph 3.2.

Multiply the phase to phase system voltage by 1.732. Use resulting voltage value to select the corresponding insulation thickness from Tables 3-3. 3-4 and 3-5 as applicable.

3.3.1.3 Single And Two Phase Systems With 100 and 133 Percent Insulation Level

Multiply the voltage to ground by 1.732. Use the resulting voltage value to select the corresponding insulation thickness from Tables 3-3, 3-4 or 3-5 as applicable. If this voltage exceeds 2000V, refer to ICEA Standard S-96-659.

3.4 ADDITIONAL INSULATION THICKNESS FOR NON-SHEATHED SUBMARINE CABLES

For submarine power cables without metallic sheaths:

(a) 30 mils (0.76 mm) shall be added to the thicknesses given in Table 3-3 for Class R Type insulations, and in Table 3-4 for Class E1 insulation only.

(b) 15 mils (0.38 mm) shall be added to the thicknesses given in Table 3-3 for Class T-1 and T-2 insulation.

(c) The insulation thickness given in Table 3-4 Class T-4 and E-2 shall not be less than 60 mils. (1.52mm)

3.5 REPAIRS

Repairs or joints in the insulation shall conform to the limitations on insulation thickness given in 3.3. Each length of insulated conductor containing repairs or joints shall meet the electrical requirements of Tables 3.3 through 3.5 as applicable.

3.6 INSULATION GRADES AND REQUIREMENTS

3.6.1 The Classes Of Insulation And Their General Characteristics Are Given In Table 3-1.

3.6.2 Voltage Tests

Each length of completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-3 through 3-5, as applicable. The test voltages shall be based on the rated voltage of the cable and the size of the conductor and not on the apparent thickness of the insulation.

3.6.3 Insulation Resistance

Each insulated conductor in the completed cable, when tested in accordance with Section 6.10.2, shall have an insulation resistance of not less than that corresponding to the insulation resistance constant (IRK) specified in Table 3-6 and 3-7 as applicable.

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When an insulated conductor is individually covered with a non metallic jacket, the insulation resistance shall not be less than 60 percent of that required for the insulation based on the thickness of the insulation.

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Table 3-1
Insulation Ratings

Insulation	Maximum Temperature,* °C	Suitability for Dry or Wet Locations**	Maximum Rated Circuit Voltage Phase to Phase***	Complies with Class	Thickness Table
Synthetic Rubber 90°C	90	Dry	2000	R-1	3-3
Silicone Rubber	125	Dry	2000	R-2	3-3
Silicone Rubber	90	Wet	2000	R-3	3-3
Chlorosulfonated Polyethylene	90	Dry or Wet	2000	R-4	3-3
Polyvinyl Chloride	60	Dry or Wet	600	T-1	3-3
Polyvinyl Chloride	75	Dry or Wet	600	T-2	3-3
Polyvinyl Chloride/Nylon	90	90 Dry or 75 Wet	600	T-3	3-5
Polyethylene	75	Dry or Wet	2000	T-4	3-4
Crosslinked Polyethylene	90	Dry or Wet	2000	X-1	3-4
Crosslinked Polyethylene	90	Dry or Wet	2000	X-2	3-4
Crosslinked Polyethylene	90	Dry or Wet	2000	X-3	3-4
TPE Thermoplastic Elastomer(Type I)	90	90 Dry or 75 Wet	600	T-5	3-4
TPE Thermoplastic Elastomer(Type II)	90	90 Dry or 75 Wet	600	T-6	3-4
Ethylene Propylene Rubber-Type I	90	Dry or Wet	2000	E-1	3-4
Ethylene Propylene Rubber-Type II	90	Dry or Wet	2000	E-2	3-4

*For emergency overload ratings, See Appendix C.

** Dry locations are environments free from moisture, such as in dry conduits, or under a continuous metallic sheath.

*** The rated circuit voltage as covered by this table is for cables as defined in the Scope of this publication and does not apply to submarine, borehole or specific types as covered in Section 7.

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Table 3-2
Voltage Test Reference Paragraphs

	Single Conductor Cables	Assemblies of Insulated Single Conductors	Assemblies of Insulated & Uninsulated Conductors	Multiple-Conductor Cables With Common Covering
Without metallic sheath or armor	6.10.1.1.3 or 6.10.1.1.4 or 6.10.1.2.3 or 6.10.1.2.4	6.10.1.1.3 or 6.10.1.1.4 or 6.10.1.2.3 or 6.10.1.2.4	6.10.1.1.3 or 6.10.1.1.4	6.10.1.1.3 or 6.10.1.1.4 ... ...
With metallic sheath or armor	6.10.1.1.3 or 6.10.1.1.4	6.10.1.1.3 or 6.10.1.1.4	6.10.1.1.3 or 6.10.1.1.4	6.10.1.1.3 or 6.10.1.1.4

See Section 6:

6.10.1.1.3 ac Voltage Withstand Test
6.10.1.1.4 dc Voltage Withstand Test
6.10.1.2.3 ac Spark Test
6.10.1.2.4 dc Spark Test

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Table 3-3
Conductor Sizes, Insulation Thicknesses and Test Voltages for Class R, T-1, and T-2 Insulations
(See Table 3-1 for Voltage Limitations of Various Grades of Insulation)

Rated Circuit Voltage Phase to Phase Volts[1]	Conductor Size AWG or kcmil[2]	Insulation Thickness[4][5] Mils	ac Test Voltage kV[3]	ac Spark Test Voltage kV	dc Spark Test Voltage, kV	ac Spark Test Voltage, kV
0-600	14-9	45	4.5	13.5	7.5	13.5
	8-2	60	6.0	18.0	10.0	18.0
	1-4/0	80	7.5	22.5	12.5	22.5
	225-500	95	8.5	25.5	15.0	25.5
	525-1000	110	10.0	30.0	17.5	30.0
	1025-2000	125	11.5	34.5	20.0	34.5
601-2000	14-9	80	7.5	22.5	12.5	22.5
	8-2	95	8.5	25.5	15.0	25.5
	1-4/0	110	10.0	30.0	17.5	30.0
	225-500	125	11.5	34.5	20.0	34.5
	525-2000	140	11.5	34.5	22.5	34.5

Note (1) The actual operating voltage shall not exceed the rated circuit voltage by more than
(a) 5 percent during continuous operation or
(b) 10 percent during emergencies lasting not more than 15 minutes.
Note (2) For cables or conditions of service where mechanical stresses govern, such as in submarine cables or long vertical risers, these minimum conductor sizes may not be strong enough.
Note (3) The a-c voltages are rms values.
Note (4) Insulation thicknesses are adequate for both 100 percent and 133 percent insulation levels.
Note (5) For single-conductor cables for installation in underground ducts or direct earth burial, add 15 mils (0.38 mm) to the insulation thicknesses given in Table 3-3 for insulation types T-1 and T-2.

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Table 3-4
Conductor Sizes, Insulation Thicknesses and Test Voltages
For Class T-4, T5, T6 and All Class X and E Insulations

Rated Circuit Voltage, Phase to Phase Volts[1]	Conductor Size AWG or kcmil[2]	Insulation Thickness[4] Mils		dc Test Voltage, kV	ac Test Voltage, kV	dc Spark Test Voltage, kV		ac Spark Test Voltage, kV	
		Col. A	Col. B			Col. A	Col. B	Col. A	Col. B
0-600	14-9[3]	45	30	3.5	10.5	16.0	10.5	10.0	7.5
	8-2	60	45	5.5	16.5	21.0	16.5	15.0	10.0
	1-4/0	80	55	7.0	21.0	23.0	21.0	17.5	12.5
	225-500	95	65	8.0	24.0	33.5	24.0	20.0	15.0
	525-1000	110	80	10.0	30.0	38.5	30.0	27.5	17.5
	1025-2000	125	100	11.5	34.0	44.0	34.0	31.0	20.0
601-2000	14-9[3]	60	45	5.5	16.5	21.0	16.5	15.0	10.0
	8-2	70	55	7.0	21.0	24.5	21.0	17.5	10.5
	1-4/0	90	65	8.0	24.0	31.5	24.0	20.0	15.0
	225-500	100	75	9.5	28.5	37.0	28.5	25.0	17.5
	525-1000	120	90	11.5	34.5	42.0	34.5	30.0	20.0
	1025-2000	140	115	13.5	40.0	49.0	40.0	35.0	24.0

(1) The actual operating voltage shall not exceed the rated circuit voltage by more than (a) 5 percent during continuous operation or
(b) 10 percent during emergencies lasting not more than 15 minutes.

(2) For cables or conditions of service where mechanical stresses govern, such as in submarine cables or long vertical risers, these minimum conductor sizes may not be strong enough.

(3) Single conductor cables in sizes 9 AWG and smaller shall not be used for direct burial.

(4) Column A thicknesses shall apply to single-conductor power cables and multiple conductors without an overall jacket for general application which employ a sunlight-resistant, carbon-black pigmented Insulation without further covering.
Column B thicknesses apply to multi-conductor cables with an outer covering and to single-conductor cables with an outer covering. The Column B thicknesses are considered adequate for electrical purposes and may be specified for sinle-conductor cables employing sunlight-resistant, carbon black pigmented insulation without further covering. These cables may be used in applications where installation and service conditions are such that the additional thickness for mechanical protection is not considered necessary for satisfactory operation.

Insulation thicknesses are adequate for both 100 percent and 133 percent insulation levels.

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TABLE 3-5
CONDUCTOR SIZES, INSULATION THICKNESS AND TEST VOLTAGES FOR CLASS T-3 POLYVINYL-CHLORIDE/NYLON-INSULATED POWER CABLES

Rated Circuit Voltage Phase to Phase	Conductor Size,	Insulation Thickness[2]		Test Voltage, kV,[3]		Spark Test Voltage	
		PVC	NYLON[4]				
Volts[1]	AWG or kcmil	mils	mils	ac	dc	ac	dc
0-600	14-11	15	4	2.0	6.0	6.0	7.5
	10- 9	20	4	2.0	6.0	6.0	7.5
	8-5	30	5	2.0	6.0	6.0	10.0
	4-2	40	6	2.0	6.0	6.0	10.0
	1-4/0	50	7	2.5	7.5	7.5	12.5
	250-500	60	8	3.0	9.0	9.0	15.0
	550-1000	70	9	3.5	10.5	10.5	17.5

Note (1) The actual operating voltage shall not exceed the rated circuit voltage by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.

Note (2) The thicknesses given in Table 3-5 apply to single conductors installed in conduits and to the individual conductors of all multiple-conductor cables having a common jacket or metallic sheath.Insulation thicknesses are adequate for both 100 percent and 133 percent insulation levels.

Note (3) ac voltages are rms values.

Note (4) Thicknesses shown for nylon are minimums.

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Table 3-6
Insulation Requirements

Properties	Insulation Class			
	R-1 Synthetic Rubber	R-2 Silicone Rubber	R-3 Silicone Rubber	R-4 CSPE Rubber
Physical Properties				
Tensile Strength, minimum, psi	700	800	800	1500
Elongation, minimum, percent	300	250	250	300
Set, maximum, percent	25	---	---	---
Air Oven Aging				
Minimum percent retention of original value	60	500[A]	500[A]	85
Tensile strength	60	125[B]	125[B]	50
Elongation				
After aging for	168	168	168	168
hours.	121	200	200	121
°C +/- 1°C				
Air Pressure Heat				
Minimum percent retention of original value	50	---	---	---
Tensile strength	50	---	---	---
Elongation				
After aging for	42	---	---	---
hours	127	---	---	---
°C +/- 1°C				
Oil Immersion				
Minimum percent retention of original value	---	---	---	60
Tensile strength	---	---	---	60
Elongation				
After aging for	---	---	---	18
hours	---	---	---	121
°C +/- 1°C				

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Table 3-6 (Continued)
Insulation Requirements

Properties	Insulation Class			
	R-1 Synthetic Rubber	**R-2 Silicone Rubber**	**R-3 Silicone Rubber**	R-4 CSPE Rubber
Electrical Properties				
After immersion in water °C ± 1°C	---	---	75	75
After 24 hours Permittivity (SIC) max.	---	---	6.0	10
Increase in capacitance maximum, percent				
1-14 days	---	---	10	6.0
7-14 days	---	---	3.0	2.0
Stability factor, after 14 days, maximum	---	---	---	1.0
Alternate Stability factor, difference 1-14 days, max..	---	---	---	0.5
Insulation Resistance				
IRK @ 15.6°C, minimum megohms - 1000 feet	4000	4000	4000	2000

NOTES
(A) Absolute value in psi.
(B) Absolute value in percent.
Note: A dash under any insulation indicates that a particular value for the applicable property is not required.

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Table 3-7
Insulation Requirements

Properties	Insulation Classes										
	X-1	X-2	X-3	E-1	E-2	T-1	T-2	T-3	T-4	T-5	T-6
	XLPE	XLPE	XLPE	EP Rubber		PVC	PVC	PVC/Nylon	PE	TPE	TPE
Initial Tensile Strength minimum, psi MPa	1800 12.4	1800 12.4	1800 12.4	700 4.8	1200 8.2	1500 10.3	2000 13.8	2000 13.8	1400 9.65	1500 10.3	1500 10.3
Initial Elongation at Rupture, min. %	250	250	150	250	150	100	150	150	350	300	300
Tensile Stress, at 100% Elongation minimum, psi	---	---	---	---	500	---	---	---	---	---	---
Retention, minimum % of Tensile Strength Elongation After Air Oven Exposure for hours °C ± 1°C	 75 75 168 121	 75 75 168 121	 85 60 168 121	 75 75 168 121	 75 75 168 121	 65 65 168 100	 80 75 168 121	 75 65 168 136	 75 75 48 100	 75 75 168 121	 75 75 168 121
Retention, minimum % of Tensile Strength Elongation After Oil Immersion for hours °C ± 1°C	 --- --- --- ---	 --- --- --- ---	 --- --- --- ---	 --- --- --- ---	 --- --- --- ---	 85 85 4 70	 85 85 4 70	 50 50 96 100	 --- --- --- ---	 --- --- --- ---	 --- --- --- ---
Heat Distortion Maximum % °C ± 1°C	--- ---	--- ---	--- ---	--- ---	--- ---	50 121	25 121	25 136	--- ---	25 121	25 121

NOTES:
(a) Optional test applies when flame retardancy is required.
(b) With Nylon removed.
* Only one of these requirements needs to be satisfied, not both.
Note: A dash under any insulation indicates that a particular value for the applicable property is not required.

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Table 3-7 (Continued)
Insulation Requirements

Properties	Insulation Classes										
	X-1	X-2	X-3	E-1	E-2	T-1	T-2	T-3	T-4	T-5	T-6
	XLPE	XLPE	XLPE	EP Rubber		PVC	PVC	PVC/Nylon	PE	TPE	TPE
Hot Creep (ICEA T-28-562) After Conditioning @ 150 ± 2°C											
Elongation, max %	175	100	100	50	50	---	---	---	---	---	---
Set, max., %	10	5	5	5	5	---	---	---	---	---	---
Heat Shock @ 121 ± 1°C	---	---	---	---	---	No Cracks	No Cracks	No Cracks	---	---	---
Type A Flame Test	---	Pass(a)	---	---	Pass(a)	Pass(a)	---	---	---	---	---
Type B Flame Test	---	---	Pass	---	---	Pass	Pass	Pass	---	---	---
Cold Bend After 1 Hour @ °C ± 2°C	---	---	---	---	---	-10	-30	-25	---	---	---
Minimum	---	---	---	---	---	No Cracks	No Cracks	No Cracks	---	---	---
Environmental Stress Cracking	---	---	---	---	---	---	---	---	No cracks	---	---
Wrap Test	---	---	---	---	---	---	---	No Cracks	---	---	---

NOTES:
(a) Optional test applies when flame retardancy is required.
(b) With Nylon removed.
* Only one of these requirements needs to be satisfied, not both.
Note: A dash under any insulation indicates that a particular value for the applicable property is not required.

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Table 3-7 (Continued)
Insulation Requirements

Properties	Insulation Classes										
	X-1	X-2	X-3	E-1	E-2	T-1	T-2	T-3	T-4	T-5	T-6
	XLPE	XLPE	XLPE	EP Rubber		PVC	PVC	PVC/Nylon	PE	TPE	TPE
Electrical Properties After Immersion Water @ °C ± 1°C	75	75	75	75	75	50	75	75	75	75	75
Permittivity (SIC) After 24 hrs , max.	6.0	6.0	6.0	6.0	6.0	10.0	10.0	10[b]	---	3.0	4.0
Increase in Capacitance Maximum:											
1-14 Days	3.0	3.0	4.0	5.0	5.0	10.0	4.0	6.0[b]	---	3.0	4.0
7-14 Days	1.5	1.5	2.0	3.0	3.0	5.0	2.0	3.0[b]	---	1.5	2.0
*Stability Factor After 4 days, maximum	1.0	1.0	1.0	1.0	1.0	---	---	---	---	1.0	1.0
*Alternate to Stability Factor, maximum Difference, 1-14 Days	0.5	0.5	0.5	0.5	0.5	---	---	---	---	0.5	0.5
Insulation Resistance Constant IRK @ 15.6°C Minimum, megohms-1000 feet	10000	10000	10000	10000	10000	2000	2000	3000	50,000	40,000	40,000

NOTES:
(a) Optional test applies when flame retardancy is required.
(b) With Nylon removed.
* Only one of these requirements needs to be satisfied, not both.
Note: A dash under any insulation indicates that a particular value for the applicable property is not required.

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Section 4
COVERINGS

4.1 JACKETS

4.1.1 Cross-linked and Thermoplastic Jackets - General

The jackets described in 4.1.3 through 4.1.13 may be applied directly over the insulation or over an assembly of unshielded insulated conductors. The jacket shall meet the requirements stated therein and those given in Table 4-1. The tests shall be made only on jackets having a nominal wall thickness of 30 mils (0.76 mm) or greater.

Jackets for application over metallic coverings are listed in 4.3.8 and 4.3.9. The jacket shall meet the requirements stated therein and in Table 4-1.

In classifying jackets and sheaths in these standards, the term "jacket" refers to nonmetallic coverings and "sheath" refers to continuous metallic coverings.

4.1.2 Repairs

The jacket may be repaired in accordance with good commercial practice. Cables with repaired jackets must be capable of meeting all applicable requirements of this standard.

4.1.3 Neoprene, Heavy-duty black (CR-HD)

This jacket shall consist of a cross-linked black neoprene compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.4 Neoprene, General Purpose (CR-GP)

This jacket shall consist of a cross-linked neoprene compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.5 Polyvinyl Chloride (PVC)

This jacket shall consist of a polyvinyl chloride compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.6 Low and Linear Low Density Polyethylene (LDPE & LLDPE)

This jacket shall consist of a low or linear low density polyethylene compound suitable for exposure to sunlight as demonstrated by the absorption coefficient test requirements. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.7 Medium Density Polyethylene (MDPE)

This jacket shall consist of a medium density polyethylene compound suitable for exposure to sunlight as demonstrated by the absorption coefficient test requirements. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

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4.1.8 High Density Polyethylene (HDPE)

This jacket shall consist of a high density polyethylene compound suitable for exposure to sunlight as demonstrated by the absorption coefficient test requirements. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.9 Nitrile-butadiene/Polyvinyl-Chloride,Heavy Duty (NB/PVC-HD)

This jacket shall consist of a cross-linked acrylonitrile-butadiene/polyvinyl-chloride compound. It shall be based on a fluxed blend of acrylonitrile-butadiene synthetic rubber and polyvinyl-chloride resin. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.10 Nitrile-butadiene/Polyvinyl-chloride, General-purpose Duty (NB/PVC-GP)

This jacket shall consist of a cross-linked acrylonitrile-butadiene/polyvinylchloride compound. It shall be based on a fluxed blend of acrylonitrile-butadiene synthetic rubber and polyvinyl-chloride resin. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.11 Chlorosulfonated Polyethylene, Heavy Duty (CSPE-HD)

This jacket shall consist of a cross-linked chlorosulfonated-polyethylene compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.12 Chlorinated Polyethylene, Thermoplastic (CPE-TP)

This jacket shall consist of a thermoplastic chlorinated polyethylene compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.13 Chlorinated Polyethylene, Cross-Linked, Heavy Duty (CPE-XL-HD)

This jacket shall consist of a cross-linked chlorinated polyethylene compound. When tested in accordance with Section 6, the jacket shall meet the applicable requirements of Table 4-1.

4.1.14 Optional Requirements

The following requirements are optional and shall not be required unless specifically requested.

4.1.14.1 Tray Cable Flame Test

This test shall be performed in accordance with ICEA T-30-520. Cable shall not propagate flame to the top of the test specimens.

4.1.14.2 Sunlight Resistant Jackets

Jackets intended for direct exposure to sunlight shall be qualified for such use. Tests shall be performed in accordance with either ASTM G23 or G26. A jacket is considered sunlight resistant if after 720 hours exposure the tensile and elongation properties retain a minimum of 80 Percent of their original values.

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4.1.15 Separator Under Jacket

If a separator is used over an assembly of conductors prior to jacketing, it shall consist of compatible material.

Table 4-1
JACKET REQUIREMENTS

Properties	CRHD	CRGP	PVC	LDPE& LLDPE	MDPE	HDPE	NBR/PVC HD	NBR/PVC GP	CSPE HD	CPE TP	CPE-XL HD
Unaged tensile strength at rupture, minimum psi	1800	1500	1500	1400	2000	2500	1800	1500	1800	1400	1800
Mpa	12.4	10.3	10.3	9.65	13.8	17.2	12.4	10.3	12.4	9.65	12.4
Unaged elongation at rupture, minimum %	300	250	100	350	300	300	300	250	300	150	300
Unaged tensile strength at rupture, minimum psi	1800	1500	1500	1400	2000	2500	1800	1500	1800	1400	1800
Mpa	12.4	10.3	10.3	9.65	13.8	17.2	12.4	10.3	12.4	9.65	12.4
Unaged Tensile stress at elongation %, minimum, psi	200						200		200	100	200
	500						500		500	1000	500
Mpa	3.45						3.45		3.45	6.89	3.45
Unaged Set, maximum %	20	20					30	30	30		
After air oven exposure at °C	100	100	100	100	100	100	100	100	100	121	100
for hours duration	168	168	120	48	48	48	168	168	168	168	168
Retention, minimum percentage of unaged tensile strength	50	50	85	75	75	75	50	50	85	85	85
elongation	50	50	60	75	75	75	50	50	65	50	65
After oil immersion test at °C	121	121	70				121	121	121	100	121
for hours duration	18	18	4				18	18	18	18	18
Retention, minimum percentage of unaged tensile strength	60	60	80				60	60	60	60	60
elongation	60	60	60				60	60	60	60	60
Hot Distortion at °C			121	90	100	110				121	
Maximum %			50	25	25	25				25	
Heat shock @ 121°C ±1°C, cracks allowed			No								
Environmental stress cracking, ‡ cracks allowed				Not	Not	Not††					
Cold Bend @ -35°C ±1°C, cracks allowed			No							No	
Absorption Coefficient, minimum ‡ milli (absorbance/meter)				320	320	320					
Base Resin Density (D^{23C}), g/cm^3, min.				0.910	0.926	0.941					
max.				0.925	0.940	0.965					
Hot Creep Test @ 150°C % elongation									100•		
% set									10•		

NOTE: Blank spaces indicate that the test for the applicable property does not apply to the material.

† Use Condition A with full-strength solution of Igepal CO 630 or equivalent, as defined in ASTM D1693

†† Use Condition B with full-strength solution of Igepal CO 630 or equivalent, as defined in ASTM D1693.

‡ In lieu of testing finished cable jackets, a certification by the manufacturer of the polyethylene compound that this requirement has been complied with shall suffice.

• This test can be used as an alternate to the set test to check cure for CSPE-HD jackets only. Only one test (unaged set or hot creep) need be performed.

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4.1.16 Jacket Thickness

The average thicknesses of jackets shall be not less than the applicable thickness given in Table 4-2 for single conductor cables and in Table 4-3 or 4-4 for multiple conductor cables. The minimum thickness shall be not less than 80 percent of the values given in these tables. (See Section 6 for method of measurement.)

Table 4-2
Jacket Thickness for Single-Conductor
Non-Shielded Cables
2000 Volts or Less

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	**mm**	**mils**	**mm**
0.250 or less	6.35 or less	15	0.38
0.251 - 0.425	6.38 - 10.80	30	0.76
0.426 - 0.700	10.82 - 17.78	45	1.14
0.701 - 1.500	17.81 - 38.10	65	1.65
1.501 - 2.500	38.13 - 63.50	95	2.41
2.501 & larger	63.53 & larger	125	3.18

These thicknesses apply to jackets only and do not apply to colored coatings used for the purpose of circuit identification on the individual conductors of multiple conductor cables.

Single-conductor cables in sizes 9 AWG and smaller shall not be used for direct earth burial.

NOTE - The jacket thickness for flat twin cable shall be based on the calculated major core diameter.

Table 4-3

Thickness of Optional Jacket
on Individual Conductors of Multiple-conductor Cables
Under a Common Jacket

Calculated Diameter of Individual Conductor Under Jacket		Jacket Thickness •	
inches	**mm**	**mils**	**mm**
0.250 or less	6.35 or less	15	0.38
0.251-0.425	6.38 - 10.80	25	0.64
0.426-0.700	10.82 - 17.78	30	0.76
0.701-1.500	17.81 - 38.10	50	1.27
1.501-2.500	38.13 - 63.50	80	2.03

• These thicknesses apply to jackets only and do not apply to colored coatings on the individual conductors of multiple-conductor cables.

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Table 4-4
Thickness of Common Overall Jacket
of Multiple-conductor Cable
(For All Voltages and All Uses)

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
0.425 or less	10.80 or less	45	1.14
0.426-0.700	10.82 - 17.78	60	1.52
0.701-1.500	17.81 - 38.10	80	2.03
1.501-2.500	38.13 - 63.50	110	2.79
2.501 and larger	63.53 and larger	140	3.56

Note 1: Table 4-4 applies to the common overall jacket for all round multiple-conductor cables and for flat twin cables.

Note 2: The jacket thickness for flat twin cable shall be based on the calculated major core diameter.

4.2 METALLIC AND ASSOCIATED COVERINGS

4.2.1 General

The requirements given in this section apply to cables applied under usual installation, operating, and service conditions.

Where unusual installation, operating, or service conditions exist, these conditions should be defined in order to allow any necessary cable design modifications before a final design is completed. In classifying jackets and sheaths in these standards, the term "jacket" refers to nonmetallic coverings and "sheath" refers to continuous metallic coverings.

The types of coverings and conditions of installation are as follows:

1. Metallic sheath, lead or aluminum.
   a. In conduit, ducts, troughs, or raceways.
   b. Suspended from aerial messenger.
   c. For other types of installations when suitably protected by metal armor or nonmetallic coverings.

2. Flat metal tape armor.
   a. Direct burial in trenches.
   b. Suspended from aerial messenger.

   Plain- or galvanized-steel tape armor, depending upon soil and water conditions, with a supplemental covering for corrosion protection is suitable for use on cables for direct burial and for shaft installations where the cable can be clamped at intervals.

   Galvanized-steel tape armor without supplemental coverings is suitable for use on cables to be suspended from an aerial messenger strand.

3. Interlocked metal tape armor or sealed continuously corrugated armor.

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a. Direct burial in trenches.*
b. Troughs.
c. Racks.
d. Raceways.
e. Suspended from aerial messenger.

Interlocked metal tape armor or continuously corrugated armor without an outer covering but with either a bedding or a jacket under the armor is suitable for cables for indoor use and for outdoor aerial service.

*Interlocked metal tape armor with either a bedding or a jacket under the armor and either a supplemental covering for corrosion protection or a thermoplastic jacket over the armor is suitable for underground installations.

4. Galvanized steel wire armor.
   a. Submarine cable.
   b. Dredge cable.
   c. Vertical riser, borehole, and shaft cable for end suspension.
   d. Direct burial in trenches and subjected to unusual longitudinal stress.

Jute or equivalent covering is not required on dredge and vertical riser cable. It is required on submarine, borehole, and shaft cable where severe installation and service conditions exist. It is required for direct burial cable. Jute or equivalent covering may be added where the conditions of transportation require protection for the galvanizing on the armor wires.

4.2.1.1 Divisions

Three divisions define specific installations:

Division I (See 4.3) concerns materials, construction, and requirements for metallic and associated coverings recommended for use under normal conditions of installation, operation, and maintenance of power cables. It also covers submarine cables.

The requirements of Division I as pertaining to quality of materials, design, and construction apply also to the following Divisions II and III, except as to particular details expressly set forth in each division or as otherwise modified.

Division II (See 4.4) concerns round wire armor for borehole, dredge, shaft, and vertical riser cables.

Division III (See 4.5) concerns round wire armor for buried cable.

4.3 DIVISION I

4.3.1 Smooth Metallic Sheaths

4.3.1.1 Lead Sheaths

4.3.1.1.1 Material

A sheath composed of commercially pure lead or an alloyed lead shall be tightly formed around the core of the cable. The lead shall be determined by the manufacturer and shall meet the requirements of

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ASTM B29 unless other compositions and test requirements are agreed upon between the manufacturer and the user. When chemical lead or copper lead is used, the mass fraction of the copper content shall be between 0.040 Percent and 0.080 Percent.

Lead stripped from new cable may be used, and when so used, it shall comply with the requirements given herein.

4.3.1.1.2 Thickness

The average thickness of a lead sheath not intended to have an overlying jacket shall be in accordance with Table 4-6. The minimum thickness shall be not less than 90 percent of the thickness specified in the table.

The average thickness of a lead sheath having an overlying jacket of either thermoset or thermoplastic compound shall be in accordance with Table 4-7 The minimum thickness shall be not less than 90 percent of the thickness specified in the table.

The thickness shall be measured in accordance with Section 6. There are situations where the above thicknesses may require an increase, especially on the smaller sizes of cable, such as when several cables are to be pulled together in one duct, or the sections to be pulled are extra long, or the handling during installation is severe or awkward, as in some transformer vaults.

4.3.1.1.3 Reapplication of Lead Sheaths

When the sheath does not meet the requirements of these standards it shall not be repaired. The lead may be stripped from the entire length of the cable and the cable resheathed.

Table 4-6
Thickness of Lead Sheath on Unjacketed Cables

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mm
0 - 0.425	0 - 10.80	45†	1.14
0.426 - 0.700	10.82 - 17.78	65†	1.65
0.701 - 1.050	17.81 - 26.67	80	2.03
1.051 - 1.500	26.70 - 38.10	95	2.41
1.501 - 2.000	38.13 - 50.80	110	2.79
2.001 - 3.000	50.83 - 76.20	125	3.18
3.001 and larger	76.23 and larger	140	3.56

* The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.

† In submarine cables, the thickness shall be 80 mils (2.03 mm).

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Table 4-7
Thickness of Lead Sheath for Cables Having a Cross-linked or Thermoplastic Jacket Over Lead Sheath

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mm
0 - 0.425	0 - 10.80	45†	1.14
0.426 - 0.700	10.82 - 17.78	55†	1.40
0.701 - 1.050	17.81 - 26.67	70	1.78
1.051 - 1.500	26.70 - 38.10	85	2.16
1.501 - 2.000	38.13 - 50.80	95	2.41
2.001 - 3.000	50.83 - 76.20	110	2.79
3.001 and larger	76.23 and larger	125	3.18

* The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.

† In submarine cables, the thickness shall be 70 mils (1.78 mm).

4.3.1.2 Aluminum Sheaths

4.3.1.2.1 Material

A smooth sheath of aluminum alloy 1060 or 1350 or other alloy having not less than 99.5 Percent aluminum shall be tightly formed around the core of the cable. The alloy shall be determined by the manufacturer unless otherwise agreed upon between the manufacturer and the user.

4.3.1.2.2 Thickness

The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimumthickness shall be not less than 90 percent of the thickness specified in the table. The thickness shall be measured in accordance with Section 6.

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Table 4-8
Thickness of Smooth Aluminum Sheath

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mm
0.400 or less	10.16 or less	35	0.89
0.401 - 0.740	10.19 - 18.80	45	1.14
0.741 - 1.050	18.82 - 26.67	55	1.40
1.051 - 1.300	26.70 - 33.02	65	1.65
1.301 - 1.550	33.05 - 39.37	75	1.90
1.551 - 1.800	39.40 - 45.72	85	2.16
1.801 - 2.050	45.75 - 52.07	95	2.41
2.051 - 2.300	52.10 - 58.42	105	2.67
2.301 - 2.550	58.45 - 64.77	115	2.92
2.551 - 2.800	64.80 - 71.12	125	3.18
2.801 - 3.050	71.15 - 77.47	135	3.43
3.051 - 3.300	77.50 - 83.82	145	3.68
3.301 - 3.550	83.85 - 90.17	155	3.94
3.551 - 3.800	90.30 - 96.52	165	4.19
3.801 - 4.050	96.55 - 102.9	175	4.45

* The thickness of the aluminum sheath for flat twin cable shall be based on the calculated major core diameter.

4.3.1.2.3 Reapplication of Aluminum Sheaths

When the sheath does not meet the requirements of these standards, it shall not be repaired, but the aluminum may be stripped from the entire length of the cable and the cable resheathed.

4.3.2 Flat Steel Tape Armor

Plain and zinc-coated flat steel strip in coils, applied in accordance with 4.3.2.4, shall be used as flat metal tape armor for cables. Supplementary outer coverings for corrosion or other protection shall be applied when required.

4.3.2.1 Tensile Strength and Elongation

The plain and zinc-coated strip shall have a tensile strength of not less than 40000 psi (276 MPa) nor more than 70000 psi (482 MPa). The tensile strength shall be determined on longitudinal specimens consisting of the full width of the strip when practical or on a straight specimen slit from the center of the strip. The strip shall have an elongation of not less than 10 percent in 10 inches (254 mm). The elongation shall be the permanent increase in length of a marked section of the strip, originally 10 inches (254 mm) in length, and shall be determined after the specimen has fractured. All tests shall be made prior to application of the strip to the cable.

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4.3.2.2 Galvanizing (Zinc Coating) Test

4.3.2.2.1 Weight of Coating

The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process. The weight of zinc coating shall be determined before application of the strip to the cable. The strip shall have a minimum weight of coating of 0.35 ounce per square foot (106.8 grams/meter^2) of exposed surface. The weight of coating shall be determined in accordance with the method described in ASTM A90.

4.3.2.2.2 Adherence of Coating

The zinc coating shall remain adherent without flaking or spalling when the strip is subjected to a 180-degree bend over a mandrel of 0.33 inch (8.38 mm) diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake and none of it can be removed from the strip by rubbing with the fingers.

Loosening or detachment during the adherence test of superficial, small particles of zinc formed by mechanical polishing of the surface of the zinc-coated strip shall not constitute failure.

4.3.2.3 Tape Size

4.3.2.3.1 Width

The nominal width of the metal tape shall be not greater than that specified in Table 4-9. For nominal width dimensions of 1.000 inch (25.4 mm) or less, the tolerance shall be 0.031 inch (0.79 mm). For nominal widths greater than 1.000 inch (25.4 mm), the tolerance shall be 0.047 inch (1.19 mm).

Table 4-9
Width of Steel Tape for Flat Armor
(Plain or Zinc Coated)

Calculated Diameter of Cable Under Bedding*		Nominal Width of Steel Tape	
inches	mm	inches	mm
0.450 or less	11.43 or less	0.750	19.0
0.451 - 1.000	11.46- 25.40	1.000	25.4
1.001 - 1.400	25.43 - 35.56	1.250	31.8
1.401 - 2.000	35.59 - 50.80	1.500	38.1
2.001 - 3.500	50.83 - 88.90	2.000	50.8
3.501 & larger	88.93 & larger	3.000	76.2

* For flat twin cable, the nominal width shall be based on the calculated major core diameter.

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4.3.2.3.2 Thickness

The nominal thickness of the steel tape shall be not less than that given in Table 4-10. See Section 6 for method of measuring metal tape thickness. The tolerance in the nominal thickness of the tape shall be 3 mils (0.08 mm).

For zinc coated steel tape the specified nominal thickness and tolerance shall apply to the stripped bare metal. The zinc-coated tape shall not be more than 20 Percent thicker than the stripped bare metal tape thickness.

Table 4-10
Thickness of Steel Tape for Flat Armor
(Plain or Zinc-Coated)

Calculated Diameter of Cable Under Bedding*		Nominal Thickness of Steel Tape	
inches	mm	mils	mm
1.000 or less	25.40 or less	20	0.51
1.001 & larger	25.43 & larger	30	0.76

* For flat twin cable, the nominal thickness shall be based on the calculated major core diameter.

4.3.2.4 Application, Lay, and Spacing of Tapes

Two metal tapes shall be applied helically in the same direction over the bedding except that they may be applied in opposite directions where the total area of the conductors is less than 50,000 circular mils (25.34 mm^2). When the bedding is helically applied tape, yarn or roving, the direction of lay of the inner metal tape shall be opposite to that of the outer bedding layer. The maximum space between the turns of the metal armor tapes shall not exceed 20 Percent of the width of the tape or 0.200 inch (5.08 mm), whichever is greater. When the two metal armor tapes are applied in the same direction, the outer tape shall be approximately centered over the space between the turns of the inner tape.

During or prior to application, the tapes shall be flushed with a suitable compound to deter corrosion unless a supplementary corrosion protective covering is applied.

4.3.3 Interlocked Metal Tape Armor

Flat metallic strip in coils shall be formed as interlocking armor for electrical cables. All tests shall be made prior to the application of the strip to the cable.

4.3.3.1 Steel Strip

Plain steel tape may be used for interlocked armor when a supplemental outer protective covering is furnished. Otherwise, the steel strip (except stainless) shall be zinc-coated. The requirements for the tensile strength of flat steel tape and for the zinc coating shall be in accordance with 4.3.2.1.

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4.3.3.1.1 Width

The maximum nominal width of metal tape shall not be greater than that specified in Table 4-11. For any nominal width of metal tape used, the width tolerance shall be 0.010 inch (0.25 mm) and -0.005 mils (0.13mm).

Table 4-11
Width of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Width of Metal Tape Armor	
inches	mm	inches	mm
0 - 0.500	0 - 12.70	0.500	12.7
0.501 - 1.000	12.73 - 25.40	0.750	19.0
1.001 - 2.000	25.43 - 50.80	0.875	22.2
2.001 & larger	50.83 & larger	1.000	25.4

4.3.3.1.2 Thickness

The nominal thickness of metal tape shall be not less than that given in Table 4-12. See Section 6 for method of measuring metal tape thickness. The tolerance in nominal thickness of the tape shall be ± 3 mils (0.08 mm).

For zinc coated steel tape, the specified nominal thickness and tolerance shall apply to the stripped bare metal. The zinc-coated tape shall not be more than 20 Percent thicker than the stripped bare metal tape thickness.

Table 4-12
Thickness of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Thickness			
		CuNi, Brass, Steel, Bronze, Stainless Steel, and Monel Tape		Aluminum and Zinc Tape	
inches	Mm	mils	mm	mils	mm
1.500 or less	38.10 or less	20	0.51	25	0.64
1.501 & larger	38.13 & larger	30	0.64	30	0.76

4.3.3.2 Non-magnetic Tape

When non-magnetic tapes, such as aluminum, brass, bronze, zinc or stainless steel tapes are used, the width shall be in accordance with 4.3.3.1.1 (except that the tolerance for aluminum shall be ±0.010 in (0.25 mm)) and the thickness shall be in accordance with 4.3.3.1.2.

Representative values of tensile strength and elongation for the nonmagnetic metals are given in Appendix E.

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4.3.4 Continuously Corrugated Metal Armor

Continuously corrugated armor shall be constructed by using a flat metal tape which is longitudinally folded around the cable core, seam welded, and corrugated or by applying over the cable core a seamless sheath or tube which is then corrugated. Supplementary outer coverings for corrosion or other protection of the armor shall be applied when required.

4.3.4.1 Type of Metal

4.3.4.1.1

When metal armor is formed from a flat metal tape, the tapes used shall be aluminum, copper, steel or alloys thereof.

4.3.4.1.2

When metal armor is formed by applying a seamless sheath or tube the metal shall be aluminum or an aluminum alloy.

4.3.4.2 Thickness

The minimum thickness of tape or of the sheath or tube before corrugation shall be as shown in Table 4-13.

Table 4-13
Minimum Thickness of Metal for Corrugated Armor

Calculated Diameter of Cable Under Armor		Aluminum		Copper		Steel	
inches	Mm	Mils	mm	mils	mm	Mils	mm
0 - 2.180	0 - 55.37	22	0.56	...	...	...	...
2.181 - 3.190	55.40 - 81.03	29	0.74	...	...	...	...
3.190 - 4.200	81.05 - 106.70	34	0.86	...	...	...	...
0 - 2.365	0 - 60.70	...	...	17	0.43	...	0.41
2.366 - 3.545	60.10 - 90.40	...	...	21	0.53	...	0.51
3.546 - 4.200	90.07 - 106.70	...	...	25	0.64	...	0.61
0 - 1.905	0 - 48.39	...	...	...	...	16	...
1.906 - 3.050	48.41 - 72.39	...	...	...	...	20	...
3.051 - 4.200	72.42 - 106.70	...	...	...	...	24	...

4.3.4.3 Flexibility

The armored cable shall be capable of being bent around a mandrel having a diameter of 14 times the cable diameter. The armor shall show no evidence of fracture visible to the unaided eye. The test shall be conducted in accordance with Section 6 procedures.

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4.3.5 Galvanized Steel Wire Armor

Zinc-coated low-carbon-steel wire shall be used for the armoring of borehole, vertical riser, submarine, and underground cables used for power circuits for normal use. For wire armor for special uses, see Divisions II and III (4.4 and 4.5). All tests shall be made prior to application of the wire to the cable.

4.3.5.1 Physical Requirements

The zinc-coated wire shall be uniform in diameter and free from cracks, splints or other flaws.

4.3.5.1.1 Tensile Strength

The zinc-coated wire shall have a tensile strength of not less than 50,000 psi (345 MPa) and not more than 70,000 psi (483 MPa). The tensile strength shall be tested in accordance with ASTM E 8.

4.3.5.1.2 Elongation

The zinc-coated wire shall have an elongation of not less than 10 percent in 10 inches (254 mm). The elongation shall be the permanent increase in length of a marked section of the wire originally 10 inches (254 mm) in length and shall be determined after the specimen has fractured.

4.3.5.1.3 Torsion Test

The zinc-coated wire shall withstand, with out fracture, the minimum number of twists specified in Table 4-14. This test shall be made on a sample of wire having an initial length of 6 inches (152 mm) between jaws of a standard torsion machine or equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 4-14
Number of Twists (Torsion Test)

Nominal Wire Diameter		Minimum Number of Twists
mils	mm	
238 – 166	6.05 - 4.22	7
165 – 110	4.19 - 2.79	10
109 - 65	2.77 - 1.65	14

4.3.5.2 Galvanizing (Zinc Coating) Tests

4.3.5.2.1 Weight of Zinc Coating

The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process. The weight of zinc coating shall be determined before the wire is applied to the cable. The wire shall have a minimum weight of coating per square foot of uncoated wire surface in accordance with Table 4-15. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90.

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Table 4-15
Minimum Weights of Zinc Coating

Size and Nominal Diameter of Coated Wire			Minimum Weight of Zinc Coating per Area of Exposed Surface	
Size BWG	Diameter		Ounces per Square Foot	Grams per Square Meter
	mils	mm		
4	238	6.05	1.00	305
5	220	5.59	1.00	305
6	203	5.16	1.00	305
8	165	4.19	0.90	275
10	134	3.40	0.80	244
12	109	2.77	0.80	244
14	83	2.11	0.60	183

4.3.5.2.2 Adherence of Coating

The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than 15 turns per minute in a closed helix of at least two turns around a cylindrical mandrel of the diameter specified in Table 4-16. The zinc coating shall be considered as meeting this requirement if, when the wire is wrapped about the specified mandrel, the coating does not flake and none of it can be removed from the wire by rubbing it with the fingers.

Loosening or detachment during the adherence test of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not constitute failure.

Table 4-16
Mandrel Diameter for Adherence of Coating Tests

Wire Diameter		Mandrel Diameter
mils	mm	
less than 134	less than 3.40	2 times wire diameter
134 & larger	3.40 & larger	3 times wire diameter

4.3.5.3 Size of Armor Wire

The size of armor wire for submarine cables shall be in accordance with Table 4-17. If the service requirements are exceptionally severe, larger sizes of armor wire may be required. Diameter tolerances for the armor wire sizes are given in Table 4-18.

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Table 4-17
Size of Galvanized Steel Armor for Submarine Cable

Calculated Diameter of Cable Under Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0-0.750	0 -19.05	12	109	2.77
0.751-1.000	19.08-25.40	10	134	3.40
1.001-1.700	25.43-43.18	8	165	4.19
1.701-2.500	43.21-63.50	6	203	5.16
2.501 & larger	63.53 & larger	4	238	6.05

Table 4-18
Tolerances in Diameter

Nominal Diameter of Coated Wire		Tolerance	
mils	mm	mils	mm
65 through 108	1.65 through 2.75	± 3	± 0.08
109 through 165	2.77 through 4.20	± 4	± 0.10
166 through 238	4.22 through 6.25	± 5	± 0.13

4.3.5.4 Lay

"Lay" is defined as follows: "The lay of any helical element of a cable is the axial length of one turn of a helix of that element."

4.3.5.4.1 Length

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter for all constructions except for dredge cable. For dredge cable, see 4.4.2.

4.3.5.4.2 Direction of Lay

Successive layers of bedding and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen to minimize birdcaging of the cable core being armored.

4.3.6 Bedding Over Cable Cores To Be Metallic Armored

4.3.6.1 Unsheathed or Unjacketed Cores

When an unsheathed and unjacketed cable core, is to have a flat steel tape or round wire armor applied, it shall be protected by a suitable tape (compound filled or equivalent) plus other bedding having a thickness in accordance with Table 4-19. When an interlocked metal tape armor or a continuously corrugated armor is to be applied, only a suitable tape bedding is required.

A compound filled tape is a fabric cloth treated on one or both sides with a non-conducting compound. When used, a tape shall be applied helically and overlapped not less than 10 percent of its width. (For cores having a diameter smaller than 0.300 inch (7.62 mm), serving(s) of jute or equivalent yarns may be substituted for the tape.)

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When flat steel tape, interlocked tape, or round wire armor will remain unjacketed and the cable is intended for use in below grade or potentially wet environments, cores having beddings of tapes or jute yarn shall be run through a hot asphalt compound or equivalent saturant. When intended for installation in permanently dry indoor above-grade locations, saturant compounds need not be applied to the core beddings.

When the armor will have an outer protective jacket, the cable core, with or without metallic shield tape and/or beddings, does not require exposure to saturant compounds.

The thickness of the bedding shall be in accordance with Table 4-19. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurements under and over the bedding.

Table 4-19
Thickness of Bedding Under Metallic Armor for Unsheathed and Unjacketed Cores

Calculated Diameter of Cable Under Bedding		Under Flat Steel & Interlocked Armor		Under Round Wire Armor	
inches	mm	Bedding thickness		Bedding thickness	
		mils	mm	mils	mm
0.450 & less	11.45 & less	30	0.76	80	2.03
0.451 - 0.750	11.46 - 19.05	45	1.14	80	2.03
0.751 - 1.000	19.06 - 25.40	45	1.14	95	2.41
1.001 - 2.500	25.41 - 63.50	65	1.65	110	2.79
2.501 & larger	63.51 & larger	65	1.65	125	3.18

4.3.6.2 Jacketed Cores or Sheathed Non-jacketed Cores

When a jacketed core is to be armored, any suitable tape or serving of jute or other roving may be used as a bedding if necessary.

When a core with an unjacketed sheath is to have a flat steel tape or round wire armor, it shall be protected with a suitable bedding having a thickness in accordance with Table 4-19. When an interlocked tape or continuously corrugated armor is to be applied, any suitable separator tape may be used over the sheath.

When the applied flat steel tape, interlocked tape, or round wire armor will remain unjacketed and the cable is intended for installation in below-grade or potentially wet environments, the metallic sheath and jute bedding layers applied over the sheath or core jacket shall be run through a hot asphalt or tar compound, or equivalent saturant. When intended for installation in a permanently dry indoor above-grade location, a cable core bedding does not require exposure to saturant compounds.

4.3.7 Outer Servings

4.3.7.1 Over Metallic Sheath Without Metallic Armor or Jacket

4.3.7.1.1

When specified for mechanical protection of the metallic sheath, the sheathed cable shall be run through hot asphalt or tar compound, or equivalent saturant, and served with one (or two if specified) closely wound lay of no. 16/3 impregnated jute yarn, or plied jute or other yarns of equivalent thickness. If two servings are used, they shall be closely wound and applied with opposite directions of lay, with each

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run through hot asphalt or tar compound, of equivalent saturant. For either one or two servings, the outer serving shall be further coated with some suitable material which will prevent sticking of adjacent turns of the cable when wound on a reel.

4.3.7.1.2 Thickness

The thickness of the single and double servings applied over metallic sheathed cable for mechanical protection shall be as given in Table 4-20.

Table 4-20
Thickness of Servings Over Metallic Sheath (Without Metallic Armor)

Calculated Diameter of Cable Under Serving*		Average Thickness of Serving			
inches	mm	One-Serving		Two-Servings	
		mils	mm	mils	mm
1.000 or less	25.40 or less	65	1.65	95	2.41
1.001 - 2.500	25.43 - 63.50	65	1.65	110	2.79
2.501 & larger	63.52 & larger	65	1.65	125	3.18

* The thickness of servings over metallic sheath for flat twin cable shall be based on the calculated major core diameter.

4.3.7.2 Over Metallic Armored Cables

4.3.7.2.1

When an outer serving is required, the armored cable shall first be run through hot asphalt or tar compound, or equivalent, then served with a layer of No. 16/3 impregnated jute or equivalent plied yarn applied with a close lay, again run through hot asphalt or tar compound or equivalent saturant, and finished by running through some suitable material which will prevent sticking of adjacent turns of the cable when wound on a reel.

4.3.7.2.2 Direction of Lay

The direction of lay of the serving shall be opposite to that of the armor in contact with it.

4.3.8 Cross-linked Jackets Over Metallic Coverings (Sheaths and Armors)

A cross-linked jacket, when applied over a smooth metallic sheath or armor, may be either a reinforced or a non-reinforced type.

4.3.8.1 Reinforced Cross-Linked Jacket

When a reinforced cross-linked jacket is applied it shall consist of a combination of treated fibrous reinforcing tapes and a neoprene jacket compound suitable for exposure to sunlight.

The physical properties of the neoprene jacket compound shall meet the following requirements:

Physical requirements (see Section 6)	
Tensile strength, minimum, psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	250
Set, maximum percent	20

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Aging requirements:	
After air oven test at 70 ± 1°C for 168 hr	
Tensile strength, minimum, psi	1000
MPa	6.89
Elongation at rupture, minimum, percent	200
After oil immersion test at 121 ± 1°C for 18 hr	
Tensile strength and elongation, minimum percentage of unaged value	60

Tests shall be made on samples removed from the finished cable or, where this is impractical, on a sample of the neoprene jacket compound which is identical with that on the cable and which has been given the same treatment as the neoprene jacket.

4.3.8.1.1 Thickness

The average thickness of the crosslinked jacket shall be not less than that specified in Table 4-21. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the jacket.

The minimum thickness shall be not less than 80 percent of the values given in Table 4-21.

Table 4-21
Thickness of Cross-Linked Jacket Over Metallic Sheaths Armor

Calculated Diameter Under Jacket		Thickness	
Inches	mm	mils	mm
1.500 or less	38.10 or less	65	1.65
1.501 - 3.000	38.13 - 76.20	95	2.41
3.001 and over	76.23 and over	125	3.18

4.3.8.2 Non-Reinforced Crosslinked Jacket

4.3.8.2.1
A non-reinforced crosslinked jacket, when used, shall be one of the following materials extruded directly over the metallic sheath or armor and shall meet the requirements of the referenced Section 4:

Neoprene, Heavy Duty Black	4.1.3
Nitrile-butadiene/Polyvinyl Chloride, Heavy Duty	4.1.9
Chlorosulfonated Polyethylene, Heavy Duty	4.1.11
Chlorinated Polyethylene, Heavy Duty, Crosslinked	4.1.13

4.3.8.2.2 Thickness

The average thickness of the non-reinforced crosslinked jacket shall be not less than that specified in Table 4-22. The average thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurements under and over the jacket. The minimum thickness shall be not less than 70 percent of the specified average.

The non-reinforced cross-linked jacket over a sheath or an armor shall not have irregularities as determined by the procedure given in ICEA T-27-581. The methods to be used are:

Method A for Neoprene
Method B for Nitrile-butadiene/PVC and Chlorosulfonated Polyethylene

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Method C for Cross-linked Chlorinated Polyethylene.

4.3.9 Thermoplastic Jackets Over Metallic Coverings (Sheaths or Armors)

Thermoplastic jackets, when used, shall be one of the following materials extruded over the metallic sheath and shall fit tightly thereto:

Polyvinyl chloride meeting the requirements given in 4.1.5, except that the cold bend requirements shall be as given in 4.3.9.3, or

Black chlorinated polyethylene meeting the requirements given in 4.1.12, except that the cold bend requirements shall be as given in 4.3.9.3, or

Black polyethylene meeting the requirements given in 4.1.6 for low & linear low density, or in 4.1.7 for a medium density, or in 4.1.8 for a high density material.

4.3.9.1 Thickness

The average thickness of the thermoplastic jacket shall be not less than that specified in Table 4-22. The minimum thickness shall be not less than 70 percent of the values given in the table. The average thickness of the jacket shall be taken as one-half the difference in diameters over and under the jacket as determined by circumference measurements. The minimum thickness of the jacket shall be determined by direct measurements with a micrometer microscope on a ring of jacket removed from the cable.

Table 4-22
Thickness of Extruded Non-Reinforced Crosslinked and Extruded Thermoplastic Jacket Over Metallic Sheath & Armors

Calculated Diameter Over Sheath		Thickness	
inches	mm	mils	mm
0.750 or less	19.05 or less	50	1.27
0.751 - 1.500	19.08 - 38.10	65	1.65
1.501 - 2.250	38.13 - 57.15	80	2.03
2.251 - 3.000	57.18 - 76.20	95	2.41
3.001 & larger	76.23 & larger	110	2.79

4.3.9.2 Tightness of Polyethylene Jacket to Sheath

The extruded jacket shall be removed for 5 inches (127 mm) from each end of a 12-inch (305 mm) sample of cable, leaving a 2-inch (50.8 mm) ring intact and undisturbed at the center. The sample shall then be inserted vertically in a hole in a flat rigid plate which is a least 10 mils (0.254 mm) larger than the diameter over the sheath but not over 40 mils (1.02 mm) larger. No movement of the 2-inch (50.8 mm) ring shall take place within a period of one minute when weight is applied to the upper end of the sample. The weight to be applied shall be equal to 10 lb (4.54 kg) per inch (25.4 mm) of outside diameter of the metallic sheath minus the weight of the prepared sample, rounded off to the nearer half pound (0.23 kg).

4.3.9.3 Cold Bend

When required, the manufacturer shall submit evidence that when similar thermoplastic jacketed cable has been subjected to the same cold bend test with the same frequency as required for the

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underlying core and at a test temperature of minus 10/C or colder, the jacket shall show no cracks visible to the normal unaided eye. (See Section 6)

4.3.9.4 Jacket Irregularity Inspection

The thermoplastic jacket over a sheath shall not have irregularities as determined by the procedure given in ICEA T-27-581. The methods to be used are:

Method B for Thermoplastic Chlorinated Polyethylene
Method C for Polyvinyl Chloride and for Polyethylene

4.4 DIVISION II

The requirements of Division I pertaining to quality of materials, design, and construction apply also to the borehole, dredge, shaft, and vertical riser cables except as expressly set forth in the following sections for the respective types of cable, or as otherwise modified.

4.4.1 Borehole Cable (Suspended at One End Only)

4.4.1.1 Armor

Galvanized round steel wire shall be used for borehole cable.

4.4.1.2 Size of Armor Wire

The size of the armor wire shall be as given in Table 4-23.

The tensile safety factor [based on 50000 psi (345 MPa)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table should be used.

4.4.1.3 Lay

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter. The armor shall be applied closely without appreciable space between the wires.

"Lay" is defined as: "The lay of any helical element of a cable is the axial length of one turn of a helix of that element."

4.4.1.4 Wire Band Serving

Where wire band servings over the armor are required for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be used. The length of the serving band and the spacing of the band throughout the length of the cable shall be in accordance with Table 4-27.

The wire bands shall be applied sufficiently tight to prevent their movement along the cable as a result of handling the cable during installation.

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Table 4-23
Size of Galvanized Steel Armor Wire for Borehole Cable

Calculated Diameter of Cable Under Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0.750 or less	19.05 or less	12	109	2.77
0.751-1.000	19.08-25.40	10	134	3.40
1.001-1.700	25.43-43.18	8	165	4.19
1.701-2.500	43.21-63.50	6	203	5.16
2.501 & larger	63.53 & larger	4	238	6.05

4.4.2 Dredge Cable

4.4.2.1 Armor

Galvanized round steel wire shall be used for dredge cable and shall be applied with a short lay. The pitch ratio limits shall be in accordance with Table 4-24.

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires. Where unusual service conditions exist, it may be desirable to modify the pitch ratio. If so, it should be defined before the cable design is finalized.

4.4.2.2 Size of Armor Wire

The size of the armor wires shall be as given in Table 4-25.

Table 4-24
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

Calculated Diameter Over the Armor Wires		Minimum Pitch Ratio
inches	mm	
2.500 or less	63.50 or less	2.5
2.501 & larger	63.53 & larger	3.0

Table 4-25
Size of Galvanized Steel Armor Wire for Dredge Cable

Calculated Diameter of Cable Under Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
1.700 or less	43.18 or less	12	109	2.77
1.701-2.500	43.21-63.50	10	134	3.40
2.501 & larger	63.53 & larger	8	165	4.19

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4.4.3 Shaft Cable

4.4.3.1 Armor

When shaft cable is clamped to the shaft structure or wall, the metallic coverings used (either tape or wire) shall comply with the applicable requirements of 4.3.

If, during installation, the shaft cable is suspended from one end, galvanized round steel wire armor shall be used. The size of the armor wires shall be as given in Table 4-26, but the tensile safety factor shall be not less than five.

Wire band servings in accordance with 4.4.1.4 shall be applied.

Table 4-26
Size of Galvanized Steel Armor Wire for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
1.000 or less	25.40 or less	12	109	2.77
1.001-1.700	25.43-43.18	10	134	3.40
1.701-2.500	43.21-63.50	8	165	4.19
2.501 & larger	63.53 & larger	6	203	5.16

Table 4-27
Spacing and Length of Band Servings

Calculated Diameter Over the Armor Wire		Maximum Band Spacing		Length of Band	
Inches	mm	feet	meters	inches	mm
1.500 or less	38.10 or less	50	15.2	3	76
1.501-2.500	38.13-63.50	35	10.7	4	102
2.501 & larger	63.53 & larger	25	7.6	4	102

4.4.4 Vertical Riser Cable

Vertical riser cable is for installation within buildings and is suspended at one end only.

4.4.4.1 Armor

Galvanized round steel wires shall be used for vertical riser cables.

4.4.4.2 Size of Armor Wire

4.4.4.2.1 Non-Sheathed Cable

Armor wires for cables without metallic sheaths shall be sized in accordance with Table 4-26. The tensile safety factor [based on 50000 psi (345 MPa)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table should be used.

Wire band servings in accordance with 4.4.1.4 shall be applied.

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4.4.4.2.2 Sheathed Cable

Armor wires for metallic sheathed vertical riser cable for indoor installation shall be in accordance with 4.4.1.2 for borehole cable, but with a tensile safety factor of not less than four.

Wire band servings in accordance with 4.4.1.4 shall be applied.

4.5 DIVISION III

4.5.1 Buried Land Cables

Division III gives details of construction of round wire armor for buried land cable with or without a sheath where greater longitudinal strength than that provided by flat tape armor is required, but not the strength of the regular armor required for submarine service.

The requirements of Division I pertaining to quality of materials, design, and construction apply also to the buried round wire armored cables except as set forth in the following sections.

4.5.1.1 Armor

The size of armor wire and the thickness of a jute or equivalent bedding shall be in accordance with Table 4-28.

The length of lay of the armor wires shall be not less than three nor more than twelve times their pitch diameter. This lay shall be used such that the armor will be applied closely without appreciable space between wires.

A jute or equivalent serving as specified in 4.3.7.2 shall be applied over the armor.

Table 4-28
Thickness of Jute Bedding and Size of Armor Wire (Division 3)

Calculated Diameter of Cable Under Bedding		Minimum Thickness of Bedding		Nominal Size of Armor Wire		
inches	mm	mils	mm	BWG	mils	mm
0.750 or less	19.05 or less	45	1.14	14	83	2.11
0.751 - 1.000	19.08 - 25.40	65	1.65	12	103	2.77
		80	2.03	10	134	3.40
1.004 - 1.700	25.43 - 43.18	80	2.03	8	165	4.19
		95	2.41	6*	263	5.16
1.701 – 2.500	43.21 - 63.50					
2.501 & larger	*63.53 & larger					

* For cable diameters over 2.500 inches (63.50 mm) where greater strength is desired than is obtainable with the No. 6 BWG wires or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils or 6.05 mm diameter) wire size may be used.

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Section 5

ASSEMBLY, FILLERS AND CONDUCTOR IDENTIFICATION

5.1 ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES

Multiple-conductor cables shall consist of two or more conductors and shall be assembled in accordance with Section 5, unless otherwise modified by Section 7.

5.1.1 Multiple-Conductor Round Cables With An Overall Covering

Conductors in a multiple-conductor round cable, with an overall covering, shall be cabled with a length of lay not to exceed values calculated from the factor given in Table 5-1. The direction of lay may be changed at intervals throughout the length of the cable. The intervals need not be uniform. In a cable in which the direction of lay is reversed :

a) Each area in which the lay is right- or left-hand for a minimum of five complete twists (full 360° cycles) shall have the conductors cabled with a length of lay that is not greater than the values calculated from the factor given in Table 5-1, and

b) The length of each lay-transition zone (oscillated section) between these areas of right- and left-hand lay shall not exceed 1.8 times the maximum length of lay values calculated from the factor given in Table 5-1.

c) The length of lay of the conductors in a multi-conductor cable shall be determined by measuring, parallel to the longitudinal axis of the cable, the pitch of each successive convolution of one conductor. When the direction of lay is reversed, the beginning and end of area reversal shall be defined on either side by the last convolution that does not exceed the maximum lay requirement on either side of the reversed area.

If the direction of lay is not reversed in a cable containing layers of conductors, the outer layer of conductors shall have a left-hand lay and the direction of lay of the conductors in the inner layers shall be governed by the cabling machine.

If the direction of lay is not reversed in a single layer cable, the conductors shall have a left-hand lay.

A left-hand lay is defined as a counterclockwise twist away from the observer.

Table 5-1

Number of Conductors in Cable	Factors for Maximum Length of Lay
2	30 times individual conductor diameter *
3	35 times individual conductor diameter *
4	40 times individual conductor diameter *
5 or more	15 times assembled diameter

* Conductor diameter is the calculated diameter of the individual conductor.

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5.1.2 Multiple-Conductor Assemblies Without Overall Covering

Multiple-conductor assemblies without an outer covering shall be cabled together with a left-hand lay. The maximum length of lay shall be 60 times the diameter of the largest insulated conductor.

5.1.3 Flat Twin Cables

For flat twin cables with diameters over the individual conductor of 0.500 inches (12.70 mm) or less, filling is not required. For cables with individual conductor diameters of more than 0.500 inches (12.70 mm), filling shall be used to give a substantially flat surface parallel to the plane of the major axis. Flat twin cables are not recommended where the diameter over the conductor insulation exceeds 1 inch (25.4 mm).

5.2 FILLERS

Fillers of suitable material shall be used in the interstices of the cables where necessary to give the completed cable a substantially circular cross section.

5.3 CONDUCTOR IDENTIFICATION

Where required, conductors shall be identified by any suitable means. Refer to ICEA Guide S-58-679 for suggested methods of identification.

5.4 GROUNDING CONDUCTORS

Assemblies of two, three and four-conductor insulated power cables requiring a grounding conductor shall have a grounding conductor size as shown in Table 5-2 unless otherwise specified. An insulated or uninsulated grounding conductor may be sectioned into several parts but no part shall be smaller than a No. 18 AWG and shall meet the requirements given in Sections 2 and 3.

Table 5-2
Grounding Conductor Size for
Cables Rated 0-2000 Volts

Power Conductor Size AWG or kcmil*		Minimum Grounding Conductor Size AWG	
Copper	Aluminum	Copper	Aluminum
14	12	14	12
12	10	12	10
10 - 8	8 - 6	10	8
6 - 4	4 - 2	8	6
3 - 2/0	1 - 3/0	6	4
3/0 - 250	4/0 - 350	4	2
300 - 400	400 - 600	3	1
450 - 650	700 - 1000	2	1/0
700 - 900	-----	1	2/0
1000	-----	1/0	3/0

* Consult manufacturer for grounding conductors for larger cables.

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Section 6

TESTING AND TEST METHODS

6.1 GENERAL

6.1.1 Testing and Test Frequency

All wires and cables shall be tested at the factory as necessary to determine their compliance with the requirements given in Sections 2, 3, 4, 5 and 7. When there is a conflict between the test methods given in Section 6 and publications of other organizations to which reference is made, the requirements given in Section 6 shall apply.

One program of sampling frequencies is given in ICEA T-26-465/NEMA WC 54 and referenced by test plan in Table 6-1.

Tests on samples shall be made on samples selected at random. Each test sample shall be taken from the accessible end of a different coil or reel. Each coil or reel selected and the sample taken from it shall be identified. The lengths of samples and numbers of test specimens to be prepared from each sample shall be as specified under the individual tests.

If all of the samples pass any test specified in this Standard, the quantity of cable they represent shall be considered as meeting the requirements of this standard with regard to that test. Failure of any sample shall not preclude resampling and retesting the length of cable from which the original sample was taken.

6.1.2 Test Methods

Not all of the tests described in Section 6 are applicable to every cable covered by this Standard, nor are all of the tests that apply to cables covered by this Standard described in Section 6. Refer to the sections of this Standard that set forth the specific requirements for each material and type of cable to determine what tests are applicable to each type of cable.

Except where test and measurement methods are specifically detailed or modified by Section 6 of this Standard, the methods and procedures used to determine compliance with the requirements in Sections 2, 3, 4, 5 and 7 are those applicable in ICEA T-27-581/NEMA WC 53 and/or the referenced editions of the other industry standards referenced in this Standard. Table 6-1 lists tests which are conducted according to other standards. Where noted, one or more portions of Section 6 of this Standard provide specific instructions and/or supersede portions of the referenced standard.

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Table 6-1

Test	Referenced Standard	ICEA/NEMA T-26-465/WC54 Suggested Frequency	Paragraphs of this Standard giving Additional Instructions
Conductor DC Resistance	T-27-581	100%	
Conductor Diameter Measurement	T-27-581	Plan F*	2.4
Thickness	T-27-581	Plan J	6.2
Tensile, Elongation & Set	ASTM D 412	Plan A	6.1.3, 6.4
Permanent Set	ASTM D470	Plan A	6.1.3, 6.4.1
Hot Creep	T-28-562	Plan D	
Solvent Extraction	ASTM D2765	ASTM D2765	
Heat (Distortion) Deformation	T-27-581	Plan A	6.1.3
Absorption Coefficient (for PE)	ASTM D3349	Plan E	6.1.3
Cold-Bend	T-27-581	Plan C	6.7.1
Flexibility of Armored Cable	T-27-581	Plan B	6.7.3
EM-60	T-27-581	Plan E	6.9
AC or DC Voltage Withstand	T-27-581	100%	6.10.1, 6.10.1.1
Insulation Resistance	T-27-581	Plan E	6.10.2
Environmental Stress Cracking	ASTM D1693	Plan E	6.1.3, 6.6.2
Oil Immersion	ASTM D 471	Plan A	6.5.3
Sunlight Resistance Test	ASTM G23 or G26	Plan E	6.6.3
Cable Tray Flame Test	T-30-520	Plan E	6.8
Wrap Test (PVC/Nylon)		Plan A	6.7.2

*Plan F: one sample from each end of a manufacturer's master length, or one sample from the outer end of each length is sufficient if at least one sample is taken every 10,000 feet (3,000m).

6.1.3 Number of Test Specimens from Samples

For each of the tests listed below, at least three test specimens are to be prepared from the sample(s) selected from each production lot to be tested. At least three of these specimens are to be tested, and the average of the results of these tests is to be recorded.

Determination of unaged properties:
- Tensile strength, tensile stress, ultimate elongation, or Permanent set

Accelerated aging tests:
- Air pressure heat or oxygen pressure
- Air oven aging
- Oil immersion
- Heat Deformation (Distortion)
- Absorption coefficient
- Environmental Stress cracking

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6.2 THICKNESS MEASUREMENTS

The thickness of bedding or serving under armor shall be determined by the use of a diameter tape and shall be considered as one half of the difference between the measurements under and over the bedding or serving. The measurement in each case shall be the average of five readings taken at different points along the bedding or serving. Thicknesses of other components shall be determined in accordance with ICEA T-27-581/NEMA WC 53.

6.3 SAMPLES AND SPECIMENS FOR PHYSICAL AND AGING TESTS

6.3.1 General

Physical and aging tests shall be those required by Sections 3, 4 and 7.

6.3.2 Sampling of Insulation

Samples of thermoplastic-insulated conductors for the unaged and aged physical tests shall be taken prior to the application of all coverings except those applied in the same process as the application of the insulation.

Samples of thermoset-insulated conductors for the unaged and aged physical tests shall be taken after curing of the insulation but prior to the application of all coverings except those applied over the insulation before it is cured or in the same process as the curing step. For insulation subjected to a second curing, samples of insulated conductors may be taken either before or after the second curing.

6.3.3 Sampling of Jackets

Samples of thermoplastic jacketed conductors for the unaged and aged physical tests involving the jacket shall be taken prior to the application of all coverings over the jacket except those applied in the same process as the application of the jacket.

If curing of the jacket is necessary, samples for the unaged and aged physical tests involving the jacket shall be taken after curing but prior to the application of all coverings except those applied over the jacket before it is cured or those applied in the same process as the curing step.

No tests shall be performed on jackets less than 30 mils (0.76 mm) in nominal thickness.

6.3.4 Size of Test Specimens

Unless otherwise allowed in this Section or otherwise called for in the instructions for a specific test, the test specimens shall be prepared using ASTM D412 Dies B, C, D or E, with specimen length before die cutting not less than the length of the die used. The length of all of the specimens prepared for each specific test shall be equal.

In the case of wire and cable smaller than size 6 AWG having an insulation thickness of 90 mils (2.29 mm) or less, the insulation test specimen shall be permitted to be the entire cross-section of the insulation. When the full cross-section is used, the specimen shall not be cut longitudinally.

In the case of wire and cable size 6 AWG and larger, or in the case of wire and cable smaller than size 6 AWG having an insulation thickness greater than 90 mils (2.29 mm), insulation specimens approximately square in section with a cross-section not greater than 0.025 square inch (16 mm^2) shall be cut from the insulation.

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In extreme cases, it may be necessary to use a segmental insulation specimen.

Specimens for tests on jacket compounds shall be taken from the completed wire or cable and cut parallel to the axis of the wire or cable. The test specimen shall be a segment cut with a sharp knife, or a shaped specimen cut out with a die, and shall have a cross-sectional area not greater than 0.025 square inch (16 mm^2) after irregularities, corrugations, and reinforcing cords or wires have been removed.

6.3.5 Specimens with Jackets

6.3.5.1 Removable Jackets

In the case of wires or cables having a thin jacket cured directly to the insulation, die-cut specimens of the jacket and insulation shall be prepared. The jacket shall be separated from the insulation by slitting the covering through to the conductor and pulling the jacket and insulation apart. This procedure may sometimes be facilitated by immersing the sample in hot water for a few minutes just prior to pulling off the jacket.

6.3.5.2 Non-Removable Jackets

If the jacket cannot be removed, specimens shall be prepared by planing or buffing. In some instances it may be possible to prepare specimens of one layer by planing but necessary to prepare specimens of the other layer by buffing.

If planing is employed, strips of the covering shall be cut from the conductor so that acceptable die-cut specimens can be prepared from these strips in such a manner that material from only one layer is present in the region between the gauge marks.

If buffing is employed, the buffing apparatus for this operation shall be equipped with a cylindrical table arranged so that it can be advanced very gradually. The conductor shall be removed from a short length of wire by slitting the covering. The length of covering shall be stretched into the clamps of the buffing apparatus so that it lies flat, with the layer to be removed toward the wheel. The layer to be removed shall be buffed off, with due care not to buff any further than necessary. If necessary, the process shall be repeated with another length of covering, except that the other layer shall be buffed off.

Die-cut specimens shall be prepared from the planed or buffed pieces after they have been allowed to recover for at least 30 minutes. In the case of specimens from small wires, it may be necessary to use a die having a constricted portion 1/8 inch (3.18 mm) wide.

6.3.6 Specimen Surface Irregularities

Test specimens shall have no surface incisions and shall be as free as possible from other imperfections. Where necessary, surface irregularities such as corrugations due to stranding, etc., shall be removed so that each test specimen will be smooth and of uniform thickness.

6.3.7 Specimens for the Aging Tests

Test specimens of similar size and shape shall be prepared from each sample in accordance with the appropriate instructions in 6.3.2 through 6.3.6. Test specimens shall be prepared and tested identically to the unaged test specimens.

Die-cut specimens shall be smoothed before being subjected to the aging tests wherever the thickness of the specimen is 90 mils (2.29 mm) or greater before smoothing.

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In the case of wire and cable smaller than 6 AWG having an insulation thickness less than 90 mils (2.29 mm), the insulation shall be subjected to the aging condition with the conductor removed and each end of the specimen suitably plugged.

The dimensions of specimens to be aged shall be determined before aging.

Specimens shall not be heated, immersed in water, nor subjected to any mechanical or chemical treatment not specifically described in this standard. Specimens for aging tests having cable tape applied prior to curing shall be aged with such tape removed.

Simultaneous aging of different compounds should be avoided. For example, high-sulfur compounds should not be aged with low-sulfur compounds, and those containing antioxidants should not be aged with those containing no antioxidant. Some migration is known to occur.

The test specimens shall be suspended vertically in such a manner that they are not in contact with each other or with the sides of the chamber.

Unless otherwise specified in the specific aging tests, the aged specimens shall have a rest period of not less than 16 hours nor more than 96 hours between the completion of the aging tests and the determination of physical properties. Physical tests on both the aged and unaged specimens shall be made at approximately the same time.

6.3.8 Calculation of Area of Test Specimens

6.3.8.1 Annular Specimens

Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the cross-sectional area of the conductor. The cross-sectional area of a stranded conductor shall be calculated from its maximum diameter and shall include the areas between the strands. For this calculation, the area of the conductor also includes the cross sectional area of any separator between the insulation and the conductor.

6.3.8.2 Thin Specimens that are Arcs of Annuli

When the specimen cross section is the thin outer portion of a sector of a circle, the area shall be calculated as the specimen thickness times the specimen width. This applies either to a straight test piece or to one stamped out with a die, and it assumes that corrugations have been removed.

6.3.8.3 Thick Specimens that are Arcs of Annuli

When the specimen cross-section is the thick outer portion of a sector of a circle, the area shall be calculated as the proportional part of the area of the total insulation cross-section.

6.3.8.4 Specimens that are Segments of Circles

When a slice cut from the insulation by a knife or plane moved parallel to the wire is used and when the cross-section of the slice is the cross-section of a segment of a circle, the area A shall be calculated as that of the segment of a circle as follows:

$$A = 0.25(D^2)\cos^{-1}[(D-2H)/D] - 0.5(D-2H)(DH-H^2)^{1/2}$$

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Where:

A = area of the segment, in square inches (or square mm).
D = outside diameter of insulated conductor, in inches(or mm).
H = height of the segment taken as the thickness along the center-line of the specimen, in inches (or mm).

In lieu of calculation, the values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.

6.3.8.5 Irregular Specimens

When the cross-section of the specimen is irregular, the area shall be calculated from a direct measurement of the specimen volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

6.4 TENSILE, ELONGATION AND SET TEST PROCEDURES

6.4.1 Test Specimens, Machine and Temperature

Test specimens shall be prepared in accordance with 6.3.

The testing machine shall comply with 6.1 of ASTM D412.

Tests shall be made at a room temperature of 25 ± 5 °C. The test specimens shall be kept at room temperature for not less than 30 minutes prior to the test.

6.4.2 Tensile Strength Test

Gauge marks shall be 2 inches (51 mm) apart when using specimens cut with ASTM Die B or E and 1 inch (25 mm) apart when using specimens cut with ASTM Die C or D, except that 1 inch (25 mm) gauge marks shall be used for polyethylene regardless of specimen length. Specimens shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (102 mm), except 2.5 inches (63.5 mm) for polyethylene. Specimens shall be stretched at the rate of 20 inches (508 mm) per minute jaw speed until they break.

The tensile and elongation determinations for compounds for which the compound manufacturer certifies that the base resin content is more than 50 percent by weight of polyethylene having a density of 0.926 g/cm^3 or greater, or compounds for which the additive-free density of the base polyethylene resin mixture is 0.926 g/cm^3 or greater, shall be permitted to be tested at a jaw separation rate of 2 inches (51 mm) per minute.

The specimen shall break between the gauge marks for the test to be valid. The tensile strength shall be calculated based on the area of the unstretched specimen. Specimen length, gauge mark distance, and jaw speed shall be recorded with the results.

6.4.3 Elongation Test

Elongation at rupture shall be determined simultaneously with the test for tensile strength and on the same specimen.

The elongation shall be taken as the distance between the gauge marks at rupture less the original gauge length marked on the specimen. The percentage of elongation at rupture is the elongation divided

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by the original gauge length and multiplied by 100. Specimen length, gauge mark distance, and jaw speed shall be recorded with the results.

6.4.4 Tensile Stress Test

The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the gauge marks indicate that the specimen is at its prescribed elongation. The tensile stress shall be calculated based on the area of the unstretched specimen.

6.5 AGING TESTS

6.5.1 Air Oven Aging Test

The test specimens shall be heated at the required temperature for the specified period in an oven having forced circulation of fresh air. The oven temperature shall be controlled to ± 1 °C and recorded.

6.5.2 Air Pressure Heat Test

The test specimens shall be heated in air at a pressure of 77 to 83 pounds per square inch (0.53 to 0.57 Megapascals) at the temperature and for the period specified. This test shall be conducted in a steam-jacketed bomb or other suitable and uniformly heated chamber. The bomb shall be so regulated that the temperature inside the chamber shall reach the test temperature within 15 minutes after inserting the test specimens. The air shall be substantially free from oil and moisture. The weight of the oxidizable substance in the bomb shall not exceed 2 grams per cubic inch (0.122 gm/cc.) of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to ± 1 °C and recorded.

6.5.3 Oil Immersion Test

The test specimens shall be completely immersed in ASTM Oil No. 2 or IRM 902 described in ASTM D 471, at the specified temperature for the specified time. The specimens shall then be removed from the oil, blotted lightly to remove excess oil, and preconditioned under the following conditions prior to testing for tensile strength and elongation:

Thermoset specimens: suspended in air at room temperature for 4 ± 0.5 hours.

Thermoplastic specimens: allowed to rest at room temperature for a period of 16 to 96 hours.

The calculations for tensile strength shall be based on the cross-sectional area of the specimen obtained before immersion in oil. Likewise, the elongation shall be based on the gauge marks applied to the specimen before immersion in the oil.

6.6 HEAT SHOCK AND ENVIRONMENTAL TESTS

6.6.1 Heat Shock

A sample of wire or cable shall be wound tightly around a mandrel having a diameter in accordance with Table 6-2, held firmly in place, and subjected to a temperature of 121 ± 1°C for 1 hour. At the end of the test period, the sample shall be examined without magnification for cracking of the insulation or jacket.

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Table 6-2

Outside Diameter of Cable		Number of Adjacent Turns	Mandrel Diameter as a Multiple of Cable O.D.
inches	mm.		
0 - 0.750	0 - 19.05	six 360° turns	3
0.751 - 1.500	19.08 - 38.10	one 180° bend	8
1.501 & larger	38.13 & larger	one 180° bend	12

6.6.2 Environmental Stress Cracking Test

Except as otherwise specified in this Section, this test shall be performed in accordance with ASTM D1693. Use Condition A for LDPE or LLDPE (ASTM D1248 Type I). Use Condition B for MDPE or HDPE (ASTM D1248 Types II, III, and IV). Conditions A and B are defined in ASTM D1693.

Test specimens shall be molded from material taken from the completed cable. The number of specimens shall be as specified in 6.1.3.

The cracking agent shall be Igepal CO-630 made by GAF Corporation, or its equivalent. The temperature chamber may be either a water bath or an oven, and it shall be controlled to 50 ± 1°C.

6.6.3 Sunlight Resistance Test

When this test is specified (see 5.1.14), five samples, each sufficiently large to produce two smaller samples, shall be prepared from material intended for extrusion or from completed cable. One of each smaller sample shall be subjected to the exposure cycles and the other shall serve as the comparative unexposed specimen.

The five samples for exposure shall be mounted vertically in the specimen drum of the carbon-arc-radiation and water-spray exposure equipment similar to the Type D apparatus in ASTM G 23 (or in the specimen rack of the xenon-arc-radiation and water-spray exposure equipment similar to Type B apparatus in ASTM G 26). The exposure time shall be 720 hours.

Following the exposure duration, one specimen shall be die-cut from each of the five exposed samples and from each of the unexposed samples. Each specimen shall be tested for tensile and elongation. The resulting test values of the five specimens of each group shall be averaged. The average tensile strength value and the average elongation value of the exposed samples shall be divided by the similarly respective average values of unexposed samples and converted to a percentage to determine the retention value.

6.7 BEND AND FLEXIBILITY TESTS

6.7.1 Cold-Bend Test

The cold bend test shall be performed in accordance with ICEA T-27-581/NEMA WC 53, using a mandrel of the diameter specified in Table 6-3.

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Table 6-3

Cable Construction to be Tested	Mandrel Diameter as a Multiple of Cable O.D.
Insulated conductors without further covering, or jacketed conductors with O.D. ≤ 0.800" (20.32 mm.)	8
Jacketed Conductors with O.D. > 0.800"	10

6.7.2 Wrap Test for Nylon-Covered Insulated Conductors

A sample with a nylon-covered insulated conductor shall be taken from the completed cable and wrapped four turns around a smooth metal mandrel having a diameter 6 times that of the sample. The ends of the sample shall be secured to the mandrel so that four complete turns of the sample will be exposed to the air between the securing means. The sample and mandrel shall be suspended for 24 hours in a full-draft circulating-air oven at a temperature of 95 ± 2 °C, after which the sample and mandrel shall be removed from the oven and cooled for 1 hour in a silica-gel desiccator or the equivalent at 25 ± 5 °C. The sample shall be straightened immediately upon removal from the desiccator and inspected for surface cracks.

6.7.3 Flexibility Test for Continuously Corrugated Armor

A suitable length of armored cable with any jacket removed shall be bent in a "U" bend around a mandrel having a diameter not greater than 14 times the cable diameter with sufficient tension so that it conforms closely to the periphery of the cylinder, straightened, and then bent 180 degrees in the reverse direction, completing one cycle. The rate of bend shall be such that the test is completed within 1 minute. The test is performed at room temperature.

6.8 FLAME TESTS

6.8.1 Apparatus

The test apparatus for the vertical flame tests shall consist of the following:

1. A test chamber of sheet metal 12 inches (305 mm) wide, 14 inches (356 mm) deep and 24 inches (610 mm) high. which is open at the top and front, and which is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.

2. A means for adjusting the position of the test specimen.

3. A suitable means for keeping the specimen taut.

4. A Tirrill burner mounted on a 20-degree angle block and equipped with an attached pilot light. The burner shall have a nominal bore of 3/8 inch (9.5 mm) and a length of approximately 4 inches (102 mm) above the primary air inlets.

5. An adjustable steel angle (jig) attached to the bottom of the chamber to insure the correct location of the burner with relation to the sample.

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6. A supply of ordinary illuminating gas at normal pressure.

7. A device capable of measuring time in seconds.

8. Flame indicators consisting of strips of gummed kraft paper of 5 mils (0.127 mm) nominal thickness and 2 inch (12.7 mm) width. (The paper used for the indicators is known as 60-pound stock and is substantially the same as that described in Federal Specification UU-T-111 covering "Tape, Paper, Gummed (Kraft)".)

9. A flat, horizontal layer of dry untreated surgical cotton shall be placed on the floor of the chamber and centered directly under the specimen so as to be able to catch all burning particles that might fall from the specimen. Cotton shall also be placed on the wedge and around the base of the burner. The upper surface of the cotton on the floor shall be no more than 9 1/2 inches (240 mm) below the point at which the inner blue cone of the flame touches the cable surface. (Not used for the Type B Vertical Flame Test)

6.8.2 Vertical Flame Test (Type A)

The test shall be made in a room which is generally free from drafts of air, although a ventilated hood may be used if air currents do not affect the flame. One end of the specimen 18 to 22 inches (457 to 559 mm) in length shall be clamped in position at the upper end of the chamber, and a suitable device shall be attached to keep the sample taut. If a clamp is used, it shall be attached at least 3 inches (76 mm) below the point at which the inner blue cone of the test flame is to be applied.

A paper indicator shall be applied to the specimen so that the lower edge is 10 inches (254 mm) above the point at which the inner blue cone of the test flame is to be applied. The indicator shall be wrapped once around the specimen, with the gummed side toward the conductor. The ends shall be pasted evenly together and shall project 3/4inch (19.0 mm) from the specimen on the opposite side of the specimen to that to which the flame is to be applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches (127 mm), with an inner blue cone 1 1/2inches (38.1 mm) high.

The burner, with only the pilot lighted, shall be placed in front of the sample so that the vertical plane through the stem of the burner includes the axis of the wire or cable. The angle block shall rest against the jig, which shall be adjusted so that there is a distance of 12 inches (38.1 mm) along the axis of the burner stem between the tip of the stem and the specimen surface. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the specimen. This valve shall be held open for 15 seconds and then closed for 15 seconds or until flaming of the specimen ceases of its own accord (whichever is longer). This process shall be repeated four times. During each application of the flame, the specimen shall be adjusted, if necessary, so that the top of the inner blue cone touches the specimen surface.

If more than 25 percent of the extended portion of the indicator is burned after the five applications of the flame, the wire is considered capable of conveying flame along its length. If flaming or glowing particles or drips ignite the cotton, the construction is considered capable of conveying flame to combustible materials in its vicinity.

The duration of burning of the specimen after each application of the flame shall be noted, and any specimen which continues to burn for more than 60 seconds shall be considered capable of conveying flame to combustible materials in its vicinity. If any specimen continues to burn for more than 60 seconds after any application of the flame prior to the fifth application, the test shall be terminated with that application.

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6.8.3 Vertical Flame Test (Type B)

The Type B Vertical Flame test is identical to the Type A test, except:

(1) The cotton is omitted.

(2) The gas valve shall be closed for 15 ± 0 seconds after each seconds after each of the first four applications and then reopened and the flame reapplied to the specimen regardless of whether or not the specimen is flaming.

6.9 ELECTRICAL ACCELERATED WATER ABSORPTION TEST (EM-60)

Except as noted below, these tests shall be performed in accordance with ICEA T-27-581/NEMA WC-53.

A test specimen of the insulated conductor shall be taken after any curing and prior to the application of any coverings. Not earlier than 48 hours after any curing, the specimen shall be immersed in water.

6.10 ELECTRICAL TESTS ON COMPLETED CABLES

6.10.1 Voltage Tests

These tests shall be performed in accordance with ICEA T-27-581/NEMA WC-53.

These tests consist of voltage tests on each length of completed cable. Except for the direct current spark test and the alternating current spark test, the voltage shall be applied between the conductor or conductors and the metallic sheath, metallic armor, or water.

6.10.1.1 Voltage Withstand Tests

6.10.1.1.1 Cables Without Metallic Sheath, Metallic Shield, or Metallic Armor

Single Conductor Cable and Assemblies without an overall jacket.

Single conductor cable and assemblies of single conductor cables shall be tested by either the alternating current voltage test in water (see 6.10.1.1.3), the direct current voltage test in water (see 6.10.1.1.4), the alternating current spark test (see 6.10.1.2.3) or the direct current spark test (see 6.10.1.2). When wet testing is utilized, the following shall apply:

1) Single conductor cable and parallel assemblies of single conductor cable shall be immersed in water for at least 6 hours and tested while still immersed.

2) Twisted assemblies of two or more conductors without an overall jacket or covering, shall be immersed in water for at least 1 hour and tested while still immersed.

3) Each insulated conductor shall be tested against all other conductors connected to the grounded water tank.

Multiple-Conductor Cable With An Overall Jacket

Multiple-conductor cables shall be tested prior to application of the jacket by either spark testing (see 6.10.1.2) or wet testing (see 6.10.1.1.1). After the overall jacket is applied, each insulated conductor shall be tested against all other conductors connected to ground. Immersion in water is not required.

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6.10.1.1.2 Cables With Metallic Sheath or Metallic Armor

All cables of this type shall be tested with the metallic sheath or armor grounded, without immersion in water, at the test voltage specified. For cables having a metallic sheath or armor over the individual conductor(s), the test voltage shall be applied between the insulated conductor(s) and ground. For multiple conductor cables with individual conductors having a metallic sheath or armor over the cable assembly, the test voltage shall be applied between each insulated conductor and all other conductors and ground.

6.10.1.1.3 AC Voltage Test

This test shall be made with an alternating potential from a transformer and generator of ample capacity but in no case less than 5 kilovoltamperes. The frequency of the test voltage shall be nominally between 49 and 61 hertz and shall have a wave shape approximating a sine wave as closely as possible.

The initially applied ac test voltage shall be not greater than the rated ac voltage of the cable under test.

The duration of the ac voltage test shall be 5 minutes.

6.10.1.1.4 DC Voltage Test

The equipment for the dc voltage test shall consist of a battery, generator, or suitable rectifying equipment and shall be of ample capacity.

The initially applied dc voltage shall be not greater than 3.0 times the rated ac voltage of the cable.

The duration of the dc voltage test shall be 5 minutes.

6.10.1.2 Spark Tests

6.10.1.2.1 Application

These tests shall apply to single conductor cables and assemblies consisting entirely of insulated single conductor cables. They are not applicable to cables with metallic shields, sheaths or armor.

6.10.1.2.2 Test Apparatus

The test apparatus shall consist of:

1. A source of direct current or single phase alternating current potential capable of maintaining the required voltage under all normal leakage current conditions.
2. An electrode capable of maintaining contact, throughout its length, with the entire exposed surface of every cable in the assembly.
3. A means of measuring voltage between the electrode and ground.
4. A means of indicating a fault (failure).

6.10.1.2.3 Alternating Current Spark Test Procedure

One side of the potential source shall be connected to the electrode and the other side of the potential source shall be connected to ground. The conductor(s) in the cable shall be tested to assure

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continuity when grounded at one or both ends. All ground connections shall be bonded (common) The fault indicator shall be connected to indicate abnormal current between electrode and ground.

After the specified voltage is applied, the entire length of cable shall be passed through the electrode in a manner and at a speed such that every section of cable surface will have maintained electrode contact for not less than 18 positive and negative voltage crests.

The maximum speed of the cable under test may be determined in either U.S. customary units or in metric equivalents as follows:

1. U. S. Customary Units Formula.

MS = 5/9 x F x EL

Where:

MS = Maximum speed in feet per minute.
F = Frequency in Hertz.
EL = Electrode length in inches.

2. Metric Formula.

MS = 1/150 x F x EL

Where:

MS = Maximum speed in meters per minute.
F = Frequency in Hertz.
EL = Electrode length in millimeters.

6.10.1.2.4 Direct Current Spark Test Procedure

The voltage shall be applied between the outside surface of the cable and the conductor(s) for not less than 0.05 second. The conductor(s) shall be grounded.

Where an assembly of twisted single conductor cables is subjected to the direct current spark test, the individual conductors shall be similarly tested prior to assembly.

6.10.1.2.5 Failure

Any indication by the fault indicator shall constitute a failure.

6.10.2 Insulation Resistance

When tested, insulation resistance shall be measured and the insulation resistance constant determined in accordance with ICEA T-27-581/NEMA WC 53. Insulation resistance measured at other temperatures shall be converted to insulation resistance at 15.6°C by the procedure detailed in ICEA T-27-581/NEMA WC 53.

The insulation resistance shall be measured after the completed cable alternating current voltage tests but before any direct current voltage withstand tests specified in 6.10.1.1.

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6.11 RETESTS

6.11.1 Thickness, Physical and Aging Tests

If the thickness of the insulation or of the jacket of any coil or reel is found to be less than the specified value, that coil or reel shall be considered as not conforming to this standard, and a thickness measurement on each of the remaining coils or reels shall be made.

If any test specimen fails to meet the requirements for Tensile Strength, Elongation, Tensile Stress, or Set, either before aging or after any of the aging protocols described in Section 6.5, that test shall be repeated on two additional specimens taken from the same sample. Failure of either of the additional specimens shall indicate failure of the sample to conform to this standard.

When ten or more samples are selected from any single lot, all coils or reels shall be considered as not conforming to this standard if more than 10 percent of the samples fail to meet the requirements of the tests listed in the previous two paragraphs. If 10 percent or less fail, each coil or reel shall be tested and shall be judged upon the results of such individual tests.

Where the number of samples selected in any single lot is less than ten, all coils or reels shall be considered as not conforming to this standard if more than 20 percent of the samples fail. If 20 percent or less fail, each coil, reel, or length shall be tested and shall be judged upon the results of such individual tests.

6.11.2 Other Tests

If any sample fails to pass any other test required by this Standard, resampling shall be carried out in accordance with T-26-465/NEMA WC 54.

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Section 7

CONSTRUCTIONS OF SPECIFIC TYPES

7.1 PREASSEMBLED AERIAL CABLES

7.1.1 Scope

This section covers single conductor - multiplexed conductor or multi-conductor with one or more completed cables which are attached to a messenger to form self-supporting aerial cable.

For selection of messengers and installation information refer to ICEA Guide for Selecting Aerial Cable Messengers and Lashing Wires, P-79-561.

7.1.2 Conductors

The conductors shall be stranded in accordance with Section 2, with a minimum size of 6 AWG.

7.1.3 Insulation

The insulation shall be in accordance with the applicable paragraphs of Section 3. The insulation shall be one of the classes given in Table 3-1.

7.1.4 Jacket

A jacket, if used, should be applied over the insulation of each conductor. The jacket material and thickness shall be as listed in Section 4.1.

7.1.5 Assembly

The conductors shall be assembled together with a suitable lay. The messenger shall be laid parallel to the axis of a single conductor or the assembled conductors. The assembled conductors shall be bound to the messenger by means of a binding strip. The binding strip shall be rectangular with rounded edges, and the nominal dimensions shall be as outlined in ICEA P-79-561. When requested, a round wire of appropriate size and strength can be used as the binding strip. A coating of compatible material on the binding strip or wire is acceptable.

7.1.6 Messenger

The messenger sizes and type shall be as covered in ICEA P-79-561. The messenger shall extend a minimum of 5 feet (1.52 meters) beyond each end of the conductors for use in installing the cable.

7.1.7 Design Criteria

All other design criteria shall be in accordance with the provisions listed in ICEA P-79-561.

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Section 8

APPENDICES

APPENDIX A

NEMA, ICEA, AND ASTM STANDARDS

A1 NEMA Publications †

WC 26 (1993) Wire and Cable Packaging

WC 53 (1990) ICEA T-27-581 Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables

WC 54 (1990) ICEA T-26-465 Guide for Frequency of Sampling Extruded Dielectric Power, Control, and Portable Cables For Test

A2 ICEA Publications •

P-32-382 (1994) Short Circuit Characteristics of Insulated Cables

P-79-561 (1985) Guide For Selecting Aerial Cable Messengers and Lashing Wires

T-25-425 (1981) Guide For Establishing Stability of Volume Resistivity For Conducting Polymeric Components of Power Cables

T-28-562 (1995) Test Method For Measurement of Hot Creep of Polymeric Insulation

T-30-520 (1986) Guide For Conducting Vertical Tray Flame Test

A3 ASTM Standards **

A 90-93 Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, Test Method for

B 3-95 Soft or Annealed Copper Wire, Specification for

B 5-89 Electrolytic Tough-Pitch Copper Refinery Shapes, Specification for

B 8-95 Concentric-Lay-Stranded Copper Conductors, Hard, Medium Hard, or Soft, Specification for

B 29-92 Pig Lead, Specification for

B 33-94 Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for

B 193-95 Resistivity of Electrical Conductor Materials, Specification for

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B 230-89	Aluminum 1350-H19 Wire for Electrical Purposes, Specification for
B 231-95	Concentric-Lay-Stranded Aluminum 1350 Conductors, Specification for
B 233-92	Aluminum 1350 Drawing Stock for Electrical Purposes, Specification for
B 258-81 (91)	Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors, Specification for
B 263-94	Determination of Cross-Sectional Area of Stranded Conductors, Method for
B 400-94	Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductors, Specification for
B 496-92	Compact Round Concentric-Lay-Stranded Copper Conductors, Specification for
B 609-91	Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes, Specification for
B 784-94	Modified Concentric-Lay-Stranded Copper Conductors for Use in Insulated Electrical Cables, Specification for
B 785-93	Compact Round Modified Concentric-Lay-Stranded Copper Conductors for Use in Insulated Electrical Cables, Specification for
B 786-93	19 Wire Combination Unilay-Stranded Aluminum 1350 Conductors for Subsequent Insulation, Specification for
B 787-93	19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation, Specification for
B 800-94	8000 Series Aluminum Alloy Wire for Electrical Purposes - Annealed and Intermediate Tempers, Specification for
B 801-95	Concentric-Lay-Stranded Conductors of 8000 Series Aluminum Alloy for Subsequent Covering or Insulation, Specification for
B 835-93	Compact Round SIW Stranded Copper Conductors, Specification for
B 836-93	Compact Round SIW Stranded Aluminum Conductors, Specification for
D 412-92	Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers - Tension, Test Methods for
D 470-93	Crosslinked Insulations and Jackets for Wire and Cable, Test Methods for
D 471-95	Rubber Property - Effect of Liquids, Test Method for
D 746-79 (87)	Brittleness Temperature of Plastics and Elastomers by Impact, Test Method for
D 1248-84 (89)	Polyethylene Plastics Molding and Extrusion Materials, Specification for
D 1693-94	Environmental Stress-Cracking of Ethylene Plastics, Test Method for

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D 2275-89(94) Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface, Test Method for

D 2765-90 Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics, Test Methods for

D 3349-93 Absorption Coefficient of Ethylene Polymer Material Pigmented with Carbon Black, Test Method for

D 4496-87(93) D-C Resistance or Conductance of Moderately Conductive Materials, Test Method of

E 8-95a Tension Testing of Metallic Materials, Test Methods for

G 23-93 Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials, Practice for

G 26-95 Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials, Practice for

† Available from: National Electrical Manufacturers Association
1300 North 17th Street Suite 1847
Rosslyn, VA USA 22209

* Available from: Insulated Cable Engineers Association, Inc.
P.O. Box 440
South Yarmouth, MA USA 02664

** Available from: American Society for Testing Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428

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APPENDIX B

DEFINITIONS OF MAXIMUM TEMPERATURES OF INSULATED CABLE CONDUCTORS

B.1 Maximum Conductor Temperature - Continuous Operation

The highest conductor temperature attained by any part of the cable under operating current load.

B.2 Maximum Conductor Temperature - Emergency Overload

The highest conductor temperature attained by any part of the cable during emergency overload of specified time, magnitude, and frequency of application.

B.3 Maximum Conductor Temperature - Short Circuit

The highest conductor temperature attained by any part of the cable during a short circuit of specified time and magnitude. Consult cable manufacturer for material temperature limitations and refer to ICEA Publication P-32-382, Short Circuit Characteristics of Insulated Cable.

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APPENDIX C

EMERGENCY OVERLOADS

Operation at the following conductor emergency overload temperatures shall not exceed 100 hours in any twelve consecutive months nor more than 500 hours during the lifetime of the cable:

Maximum Temperature Rating for Continuous Operation	Maximum Temperature Rating for Emergency Operation
75 °C	90 °C
90 °C	130 °C
125 °C	200 °C

Lower temperatures for emergency overload conditions may be required because of the type of material used in the cable joints and terminations, or because of cable environmental conditions.

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APPENDIX D

ABBREVIATIONS AND SYMBOLS

ac	alternating current
AWG	American Wire Gauge
BWG	Birmingham Wire Gauge
C	degree Celsius
dc	direct current
ft	foot(feet)
g/m	grams(s) per meter
Hz	hertz (electrical frequency, cycles per second)
in	inch(es)
kcmil	thousand(s) of circular mils (formerly MCM)
kg	kilogram(s)
km	kilometer(s)
kN/m	kilonewton(s) per meter
kV	kilovolt(s)
lb(s)	pound(s)
MPa	megapascal(s)
mm	millimeter(s)
psi	pound-force per square inch (lbf/in^2)
%	percent
±	plus or minus
s	second

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APPENDIX E

REPRESENTATIVE TENSILE STRENGTH and ELONGATION
OF NONMAGNETIC METALS

Metal	Tensile Strength		Elongation in a 2 in (50.8 mm) length,
	psi	Mpa	Percent
Aluminum	13000-45000	90-310	15-45
Cupro-Nickel	50000-70000	345-482	20-40
Low Brass	40000-50000	276-345	40-50
Commercial Bronze	35000-42000	241-289	40
Copper	35000-50000	241-345	1-35
Monel	75000	517	45
Stainless	82000-90000	565-620	50
Zinc	20000	138	60

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APPENDIX F

RECOMMENDED BENDING RADII FOR CABLES

F.1 Scope

This appendix contains recommended minimum values for the radii to which insulated cables may be bent for permanent training during installation. Larger bend radii shall be considered for conduit bends, sheaves, or other curved surfaces around which the cable may be pulled under tension while being installed. In all cases the minimum radii specified refers to the inner surface of the cable and not to the axis of the cable.

F.2 Nonshielded Power Cables Without Metallic Sheath or Armor

The minimum bending radius for a single conductor, a multiplexed assembly, or multiconductor nonshielded cable without any metallic sheath or armor is shown in Table F-1.

Table F-1

		Overall Diameter of Cable					
		inches	mm	inches	mm	inches	mm
Thickness of Conductor Insulation		1.000 & less	25.4 & less	1.001 - 2.000	25.4 - 50.8	2.001 & larger	50.8 & larger
inches	mm	Minimum Bending Radius as a Multiplier of Cable Diameter					
0.169 & less	4.31 & less	4		5		6	
0.170 & larger	4.32 & larger	5		6		7	

F.3 Nonshielded Cables With Metallic Sheath or Armor

The minimum bending radius for a single conductor, a multiplexed assembly or multiconductor nonshielded cable having a metallic sheath or armor is shown in Table F-2.

F.4 Drum Diameters of Reels

Refer to NEMA Publication WC26, Wire and Cable Packaging.

F.5 Installation Temperatures

All cables manufactured to this standard can be safely handled if not subjected to temperatures lower than -10 °C in the twenty-four hour period immediately preceding installation. For installation in colder temperatures, consult the cable manufacturer for recommendations

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Table F-2

Type of Cable Construction	Overall Diameter of Cable					
	inches	mm	inches	mm	inches	mm
	0.750 & less	19.0 & less	0.751 – 1.500	19.1 - 38.1	1.501 & larger	38.11 & larger
	Minimum Bending Radius as a Multiplier of Cable Diameter					
Lead Sheathed or Flat Tape Armored Cables,						
Single Conductor	12		12		12	
Multiplexed Singles	7		7		7	
Multiple-Conductor Cable	12		12		12	
Smooth Aluminum Sheathed Cables,						
Single Conductor	10		12		15	
Multiplexed Singles	6		7		9	
Multiple-Conductor Cable	10		12		15	
Interlocked Tape or Continuously Corrugated Armored Cables,						
Single conductor	7		7		7	
Multiplexed Singles	5		5		5	
Multiple-Conductor Cable	7		7		7	
Round Wire Armored, Single and Multiple-Conductor Cables,						
Dredge Cable	8		8		8	
All Other Types	12		12		2	

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APPENDIX G

ADDITIONAL CONDUCTOR INFORMATION

Table G-1
Solid Aluminum and Copper Conductors

Conductor Size AWG or kcmil	Approximate Weight			
	Aluminum		Copper	
	lb/1000 ft	g/m	lb/1000 ft	g/m
8	15.20	22.62	49.98	74.38
7	19.16	28.52	63.03	93.80
6	24.15	35.94	79.44	118.2
5	30.45	45.32	100.2	149.0
4	38.41	57.17	126.3	188.0
3	48.43	72.08	159.3	237.1
2	61.07	90.89	200.9	298.9
1	77.03	114.6	253.3	377.0
1/0	97.15	144.6	319.5	475.5
2/0	122.5	182.3	402.8	599.5
3/0	154.4	229.8	507.8	755.8
4/0	194.7	289.8	640.5	953.2
250	230.1	342.4	...	...
300	276.1	410.9	...	...
350	322.1	479.4	...	...
400	368.2	547.9	...	...
450	414.4	616.3	...	...
500	460.2	648.8	...	...

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Table G-2
Stranded Class B Aluminum and Copper Conductors

Conductor Size	Number of Strands	Approximate Diameter of Each Strand		Approximate Weight			
				Aluminum		Copper	
AWG or kcmil		mils	mm	lb per 1000 ft	g/m	lb per 1000 ft	g/m
8	7	48.6	1.23	15.5	23.1	51.0	75.9
7	7	54.5	1.39	19.5	29.1	64.2	95.7
6	7	61.2	1.56	24.6	36.7	80.9	121
5	7	68.8	1.75	31.1	46.2	102	152
4	7	77.2	1.96	39.2	58.3	129	192
3	7	86.7	2.20	49.4	73.5	162	242
2	7	97.4	2.47	62.3	92.7	205	305
1	19	66.4	1.69	78.6	117	259	385
1/0	19	74.5	1.89	99.1	147	326	485
2/0	19	83.7	2.13	125	186	411	611
3/0	19	94.0	2.39	157	234	518	771
4/0	19	105.5	2.68	199	296	653	972
250	37	82.2	2.09	235	349	772	1150
300	37	90.0	2.29	282	419	925	1380
350	37	97.3	2.47	329	489	1080	1610
400	37	104.0	2.64	376	559	1236	1840
450	37	110.3	2.80	422	629	1390	2070
500	37	116.2	2.95	469	699	1542	2300
550	61	95.0	2.41	517	768	1700	2530
600	61	99.2	2.52	563	838	1850	2760
650	61	103.2	2.62	610	908	2006	2990
700	61	107.1	2.72	657	978	2160	3220
750	61	110.9	2.82	704	1050	2316	3450
800	61	114.5	2.91	751	1120	2469	3680
900	61	121.5	3.09	845	1260	2780	4140
1000	61	128.0	3.25	939	1400	3086	4590
1100	91	109.9	2.79	1032	1540	3394	5050
1200	91	114.8	2.92	1126	1680	3703	5510
1250	91	117.2	2.98	1173	1750	3859	5740
1300	91	119.5	3.04	1220	1820	4012	5970
1400	91	124.0	3.15	1313	1960	4320	6430
1500	91	128.4	3.26	1408	2100	4632	6890
1600	127	112.2	2.85	1501	2240	4936	7350
1700	127	115.7	2.94	1596	2370	5349	7810
1750	127	117.4	2.98	1643	2440	5403	8040
1800	127	119.1	3.02	1691	2510	5562	8270
1900	127	122.3	3.11	1783	2650	5865	8730
2000	127	125.5	3.19	1877	2790	6176	9190

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Table G-3
Stranded Class C and D Aluminum and Copper Conductors

Conductor Size	Class C			Class D		
AWG or kcmil	Number of Strands	Approximate Diameter of Each Strand		Number of Strands	Approximate Diameter of Each Strand	
		mils	mm		mils	mm
8	19	29.5	0.749	37	21.1	0.536
7	19	33.1	0.841	37	23.7	0.602
6	19	37.2	0.945	37	26.6	0.676
5	19	41.7	1.06	37	29.9	0.759
4	19	46.9	1.19	37	33.6	0.853
3	19	52.6	1.34	37	37.7	0.958
2	19	59.1	1.50	37	42.4	1.08
1	37	47.6	1.21	61	37.0	0.940
1/0	37	53.4	1.36	61	41.6	1.06
2/0	37	60.0	1.52	61	46.7	1.19
3/0	37	67.3	1.71	61	52.4	1.33
4/0	37	75.6	1.92	61	58.9	1.50
250	61	64.0	1.63	91	52.4	1.33
300	61	70.1	1.78	91	27.4	1.46
350	61	75.7	1.92	91	62.0	1.57
400	61	81.0	2.06	91	66.3	1.68
450	61	85.9	2.18	91	70.3	1.79
500	61	90.5	2.30	91	74.1	1.88
550	91	77.7	1.97	127	65.8	1.67
600	91	81.2	2.06	127	68.7	1.74
650	91	84.5	2.15	127	71.5	1.82
700	91	87.7	2.23	127	74.2	1.88
750	91	90.8	2.31	127	76.8	1.95
800	91	93.8	2.38	127	79.4	2.02
900	91	99.4	2.53	127	84.2	2.14
1000	91	104.8	2.66	127	88.7	2.25
1100	127	93.1	2.36	169	80.7	2.05
1200	127	97.2	2.47	169	84.3	2.14
1250	127	99.2	2.52	169	86.0	2.18
1300	127	101.2	2.57	169	87.7	2.23
1400	127	105.0	2.67	169	91.0	2.31
1500	127	108.7	2.76	169	94.2	2.39
1600	169	97.3	2.47	217	85.9	2.18
1700	169	100.3	2.55	217	88.5	2.25
1750	169	101.8	2.59	217	89.8	2.28
1800	169	103.2	2.62	217	91.1	2.31
1900	169	106.0	2.69	217	93.6	2.38
2000	169	108.8	2.76	217	96.0	2.44

Note: The weights of Class C and D conductors are the same for the equivalent Class B conductor (see Table G-2)

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Table G-4
Rope-lay Aluminum and Copper Conductors, Class G

Cdr Size	No. of Strand	Sug-gested Constr-uction	Approximate Diameter of Each Strand		Approximate Outside Diameter		Approximate Weight			
							Aluminum		Copper	
AWG or kcmil			mils	mm	Inches	mm	#'s Per 1000 ft.	g/m	#'s Per 1000 t.	g/m
14	49	7x7	9.2	0.23	0.083	2.11	...	...	12.8	19.1
12	49	7x7	11.6	0.29	0 104	2.64	...	...	20.3	30.3
10	49	7x7	14.6	0.37	0.131	3.33	...	...	32.3	48.2
9	49	7x7	16 4	0 42	0.148	3.76	...	.	40.8	60.7
8	49	7x7	18 4	0.47	0.166	4.22	...	...	51	76.6
7	49	7x7	20.6	0.52	0.185	4.70	20	29 4	65	97.6
6	49	7x7	23.1	0.59	0.208	5.28	25	37.0	82	122
5	49	7x7	26.0	0.66	0.234	5.94	31	46.7	103	154
4	49	7x7	29.2	0.74	0.263	6.68	40	58.9	130	194
3	49	7x7	32.8	0.83	0.295	7.49	50	74.2	164	244
2	49	7x7	36.8	0.93	0.331	8.41	63	93.6	207	308
1	133	19x7	25.1	0.64	0.377	9.58	80	119	264	392
1/0	133	19x7	28.2	0.72	0.423	10.7	102	150	334	495
2/0	133	19x7	31.6	0.80	0.474	12.0	127	190	419	623
3/0	133	19x7	35.5	0.90	0.533	13.5	161	239	529	786
4/0	133	19x7	39.9	1.01	0.599	15.2	203	301	668	991
250	259	37x7	31.1	0.79	0.653	16.6	242	358	795	1175
300	259	37x7	34.0	0.86	0.714	18.1	287	429	945	1410
350	259	37x7	36.8	0.93	0.773	19.6	337	501	1110	1650
400	259	37x7	39.3	1.00	0.825	21.0	385	573	1265	1885
450	259	37x7	41.7	1.06	0.876	22.3	433	644	1425	2120
500	259	37x7	43.9	1.12	0.922	23.4	482	716	1585	2355
550	427	61x7	35.9	0.91	0.969	24.6	532	791	1750	2600
600	427	61x7	37.5	0.95	1.013	25.7	581	863	1910	2840
650	427	61x7	39.0	0.99	1.053	26.7	629	935	2070	3075
700	427	61x7	40.5	1.03	1.094	27.8	678	1005	2230	3310
750	427	61x7	41.9	1.06	1.131	28.7	725	1080	2385	3545
800	427	61x7	43.3	1.10	1.169	29.7	774	1150	2545	3785
900	427	61x7	45.9	1.17	1.239	31.5	869	1295	2860	4255
1000	427	61x7	48.4	1.23	1.307	33.2	967	1440	3180	4730
1100	427	61x7	50.8	1.29	1.372	34.8	1064	1580	3500	5205
1200	427	61x7	53.0	1.35	1.431	36.3	1158	1725	3810	5675
1250	427	61x7	54.1	1 37	1.461	37.1	1208	1800	3975	5910
1300	427	61x7	55.2	1.40	1.490	37.8	1257	1870	4135	6150
1400	427	61x7	57.3	1.46	1.547	39.3	1356	2015	4460	6620
1500	427	61x7	59.3	1.51	1.601	40.7	1452	2155	4775	7095
1600	703	37x19	47.7	1 21	1.670	42 4	1560	2325	5130	7640
1700	703	37x19	49.2	1.25	1.722	43.7	1660	2470	5460	8115
1750	703	37x19	49.9	1.27	1.747	44.4	1709	2540	5620	8355
1800	703	37x19	50.6	1.29	1.771	45.0	1756	2615	5775	8595
1900	703	37x19	52.0	1.32	1.820	46.2	1854	2760	6100	9070
2000	703	37x19	53.3	1.35	1.866	47 4	1950	2905	6415	9550

NOTE: Rope-lay aluminum Class G conductors are not recommended in sizes 8 AWG and smaller and individual aluminum wires in stranded conductors should not be smaller than 24 AWG.

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Table G-5
Rope-Lay Aluminum and Copper Conductors, Class H

Cdr Size, AWG or kcmil	Number of Strands	Suggested Construction	Approximate Diameter of each Strand		Approximate Outside Diameter		Approximate Weight			
							Aluminum		Copper	
			mils	mm	inches	mm	Lbs per 1000ft	g/m	Lbs per 1000ft	g/m
8	133	19x7	11.1	0.28	0.167	4.24	...	...	52	77.4
7	133	19x7	12.5	0.32	0.188	4.78	...	...	65	97.5
6	133	19x7	14.0	0.36	0.210	5.33	...	...	82	123
5	133	19x7	15.8	0.40	0.237	6.02	...	...	105	155
4	133	19x7	17.7	0.45	0.266	6.76	...	...	132	196
3	133	19x7	19.9	0.51	0.299	7.59	...	...	167	247
2	133	19x7	22.3	0.57	0.335	8.51	63	94.5	208	311
2	259	37x7	16.0	0.41	0.336	8.53	...	...	210	312
1	259	37x7	18.0	0.46	0.378	9.60	...	...	266	394
1/0	259	37x7	20.2	0.51	0.424	10.8	102	151	334	497
2/0	259	37x7	22.7	0.58	0.477	12.1	128	190	422	626
3/0	259	37x7	25.5	0.65	0.536	13.6	162	240	533	790
3/0	427	61x7	19.8	0.50	0.535	13.6	...	...	532	794
4/0	259	37x7	28.6	0.73	0.601	15.3	204	303	670	996
4/0	427	61x7	22.3	0.57	0.602	15.3	205	304	675	1000
250	427	61x7	24.2	0.61	0.653	16.6	242	360	795	1180
300	427	61x7	26.5	0.67	0.716	18.2	290	431	953	1420
350	427	61x7	28.6	0.73	0.772	19.6	337	503	1110	1655
400	427	61x7	30.6	0.78	0.826	21.0	386	575	1270	1890
450	427	61x7	32.5	0.83	0.878	22.3	436	647	1435	2130
500	427	61x7	34.2	0.87	0.923	23.4	483	719	1590	2365
550	703	37x19	28.0	0.71	0.980	24.9	538	798	1770	2625
600	703	37x19	29.2	0.74	1.022	26.0	584	871	1920	2865
650	703	37x19	30.4	0.77	1.064	27.0	634	944	2085	3105
700	703	37x19	31.6	0.80	1.106	28.1	686	1015	2255	3340
750	703	37x19	32.7	0.83	1.145	29.1	733	1090	2410	3580
800	703	37x19	33.7	0.86	1.180	30.0	778	1160	2560	3820
900	703	37x19	35.8	0.91	1.253	31.8	880	1305	2895	4295
1000	703	37x19	37.7	0.96	1.320	33.5	974	1450	3205	4775
1100	703	37x19	39.6	1.01	1.386	35.2	1075	1595	3535	5250
1200	703	37x19	41.3	1.05	1.446	36.7	1169	1740	3845	5730
1250	703	37x19	42.2	1.07	1.477	37.5	1221	1815	4015	5970
1300	703	37x19	43.0	1.09	1.505	38.2	1268	1885	4170	6205
1400	703	37x19	44.6	1.13	1.561	39.6	1363	2035	4485	6685
1500	703	37x19	46.2	1.17	1.617	41.1	1464	2180	4815	7160
1600	1159	61x19	37.2	0.94	1.674	42.5	1564	2325	5145	7640
1700	1159	61x19	38.3	0.97	1.724	43.8	1658	2470	5455	8115
1750	1159	61x19	38.9	0.99	1.751	44.5	1710	2540	5625	8355
1800	1159	61x19	39.4	1.00	1.773	45.0	1754	2615	5770	8595
1900	1159	61x19	40.5	1.03	1.823	46.3	1854	2760	6100	9070
2000	1159	61x19	41.5	1.05	1.868	47.4	1946	2905	6400	9550

NOTE: Individual aluminum wires in stranded conductors should not be smaller than 24 AWG.

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Table G-6
Aluminum and Copper Conductors, Class I
Each Individual Strand 24 AWG, 0.0201 Inch (0.511 mm)

Cdr Size	Suggested Construc-tion	Approx. Number of Strands	Approx. Outside Diameter		Approximate Weight			
					Aluminum		Copper	
AWG or kcmil			inches	mm	Lbs. per 1000 ft	g/m	Lbs. per 1000 ft	g/m
10	1x26	26	0.125	3.18	...	...	32.5	48.3
9	1x33	33	0.138	3.51	...	...	41	61.3
8	1x41	41	0.156	3.96	16	23.1	51	76.1
7	1x52	52	0.185	4.70	20	29.3	65	96.5
6	7x9	63	0.207	5.26	24	36.3	80	119
5	7x12	84	0.235	5.97	32	48.3	105	159
4	7x15	105	0.263	6.68	41	60.4	134	199
3	7x19	133	0.291	7.39	51	76.5	169	252
2	7x23	161	0.319	8.10	62	92.7	205	305
1	7x30	210	0.367	9.32	81	121	167	397
1/0	19x14	266	0.441	11.2	104	155	342	508
2/0	19x18	342	0.500	12.7	133	199	439	654
3/0	19x22	418	0.549	13.9	163	243	537	799
4/0	19x28	532	0.613	15.6	208	309	683	1015
250	7x7x13	637	0.682	17.3	251	374	825	1230
300	7x7x15	735	0.737	18.7	290	431	955	1420
350	7x7x18	882	0.800	20.3	348	517	1145	1700
400	7x7x20	980	0.831	21.1	386	575	1270	1890
450	7x7x23	1127	0.894	22.7	444	661	1460	2175
500	7x7x25	1225	0.941	23.9	483	719	1590	2365
550	7x7x28	1372	0.980	24.9	541	805	1780	2645
600	7x7x30	1470	1.027	26.1	579	862	1905	2835
650	19x7x12	1596	1.152	29.3	635	945	2090	3110
700	19x7x13	1729	1.194	30.3	687	1025	2260	3365
750	19x7x14	1862	1.235	31.4	740	1100	2435	3625
800	19x7x15	1995	1.290	32.8	793	1180	2610	3885
900	19x7x17	2261	1.372	34.8	901	1340	2965	4405
1000	19x7x19	2527	1.427	36.2	1005	1495	3305	4920
1100	19x7x21	2793	1.495	38.0	1111	1655	3655	5440
1200	19x7x22	2926	1.537	39.0	1164	1730	3830	5700
1250	19x7x23	3059	1.564	39.7	1216	1810	4000	5955
1300	19x7x24	3192	1.605	40.8	1269	1890	4175	6215
1400	19x7x26	3458	1.674	42.5	1386	2045	4560	6735
1500	19x7x28	3724	1.715	43.6	1482	2205	4875	7250
1600	19x7x30	3990	1.797	45.6	1587	2360	5220	7770
1700	19x7x32	4256	1.852	47.0	1693	2520	5570	8290
1750	19x7x33	4389	1.880	47.8	1746	2600	5745	8545
1800	19x7x34	4522	1.921	48.8	1800	2675	5920	8805
1900	19x7x36	4788	1.976	50.2	1905	2835	6265	9325
2000	19x7x37	4921	2.003	50.9	1958	2915	6440	9585

NOTE: Aluminum Class I conductors are not recommended in sizes 8 AWG and smaller.

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Table G-7
Copper Conductors, Class K
Each Individual Strand 30 AWG, 0.0100 Inch (0.254 mm)

Cndr Size	Suggested Construc-tion	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight	
AWG or kcmil			inches	mm	Lbs/1000 ft	g/m
20	1x10	10	0.038	0.97	3.2	4.59
18	1x16	16	0.048	1.22	5.0	7.35
16	1x26	26	0.060	1.52	8.0	11.9
14	1x41	41	0.078	1.98	12.8	18.8
12	1x65	65	0.101	2.57	20.3	29.9
10	1x104	104	0.126	3.20	32.5	47.8
9	7x19	133	0.150	3.81	42	62.3
8	7x24	168	0.157	3.99	53	78.7
7	7x30	210	0.179	4.55	66	98.4
6	7x38	266	0.210	5.33	84	125
5	7x48	336	0.235	5.97	106	157
4	7x60	420	0.272	6.91	132	197
3	19x28	532	0.304	7.72	169	252
2	19x35	665	0.338	8.59	211	315
1	19x44	836	0.397	10.1	266	395
1/0	19x56	1064	0.451	11.5	338	503
2/0	7x7x27	1323	0.470	11.9	425	632
3/0	7x7x34	1666	0.533	13.5	535	795
4/0	7x7x43	2107	0.627	15.9	676	1005
250	7x7x51	2499	0.682	17.3	802	1195
300	7x7x61	2989	0.768	19.5	960	1425
350	19x7x26	3458	0.809	20.5	1120	1665
400	19x7x30	3990	0.878	22.3	1290	1925
450	19x7x34	4522	0.933	23.7	1465	2180
500	19x7x38	5054	0.988	25.1	1635	2435
550	19x7x41	5453	1.056	26.8	1765	2630
600	19x7x45	5985	1.125	28.6	1940	2885
650	19x7x49	6517	1.166	29.6	2110	3140
700	19x7x52	6916	1.207	30.7	2240	3335
750	19x7x57	7581	1.276	32.4	2455	3655
800	19x7x60	7980	1.305	33.1	2585	3845
900	37x7x35	9065	1.323	33.6	2935	4370
1000	37x7x39	10101	1.419	36.0	3270	4870

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Table G-8
Copper Conductors, Class M
Each Individual Strand 34 AWG, 0.0063 Inch (0.160 mm)

Cndr Size AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight	
			Inches	mm	Lbs/1000ft	g/m
20	1x26	26	0.038	0.97	3.2	4.74
18	lx41	41	0.048	1.22	5.0	7.48
16	1x65	65	0.060	1.52	8.0	11.9
14	lx104	104	0.078	1.98	12.8	19.0
12	7x24	168	0.101	2.57	21.0	31.2
10	7x37	259	0.126	3.20	32.5	48.2
9	7x48	336	0.146	3.71	42	62.5
8	7x60	420	0.162	4.11	53	78.1
7	19x28	532	0.196	4.98	67	100.0
6	19x35	665	0.215	5.46	84	125
5	19x44	836	0.240	6.10	105	157
4	19x56	1064	0.269	6.83	134	200
3	7x7x27	1323	0.305	7.75	169	251
2	7x7x34	1666	0.337	8.56	212	316
1	7x7x43	2107	0.376	9.55	268	399
1/0	7x7x54	2646	0.423	10.7	337	501
2/0	19x7x25	3325	0.508	12.9	427	636
3/0	19x7x32	4256	0.576	14.6	547	814
4/0	19x7x40	5320	0.645	16.4	684	1020
250	19x7x48	o384	0.713	18.1	821	1220
300	19x7x57	7581	0.768	19.5	975	1450
350	37x7x34	8006	0.825	21.0	1130	1685
400	37x7x39	10101	0.901	22.9	1300	1930
450	37x7x44	11396	0.940	23.9	1465	2180
500	37x7x49	12691	0.997	25.3	1630	2430
550	61x7x32	13664	1.035	26.3	1755	2615
600	61x7x35	14945	1.084	27.5	1920	2860
650	61x7x38	16226	1.133	28.8	2085	3105
700	61x7x41	17507	1.183	30.0	2250	3350
750	61x7x44	18788	1.207	30.7	2415	3595
800	61x7x47	20069	1.256	31.9	2580	3840
900	61x7x53	22631	1.331	33.8	2910	4330
1000	61x7x59	25193	1.404	35.7	3240	4820

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