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*Power Cables Rated 2000 Volts or Less
for the Distribution of Electrical Energy*

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National Electrical Manufacturers Association

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FOREWORD

This Standards Publication for Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy 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, Inc.
Post Office Box 1568
Carrollton, Georgia 30112

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.

Section 1 GENERAL

1.1 SCOPE

This standard applies to materials, constructions, and testing of 2000 volts and less 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

This standard covers requirements for conductors, insulations and protective coverings and general constructional and dimensional details common to most standard types of wires and cables. Constructions of specific types are covered in Section 8 or in other ICEA standards. Where a conflict exists between the requirements of Section 8, or other ICEA documents, and those of Sections 1 to 7 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.

U.S. customary units, except for temperature, are specified throughout this standard. Approximate International System of Units (SI) equivalents are included for information only.

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 3.2).
6. Minimum temperature at which cable will be installed.

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. For duct/conduit, give type of 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.

Section 2 CONDUCTOR

2.0 GENERAL

Conductors shall meet the requirements of the appropriate ASTM standards referenced in 2.1 except that compliance with cross-sectional area is not required. Resistance will be determined in accordance with 2.3 and diameters will be in accordance with 2.4. Compliance with cross-sectional area is not required.

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.

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. Flexible conductors are referenced in 2.1.3.

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 787 for 19 Wire Combination Unilay-Stranded Copper Conductors.
8. ASTM B 835 for Compact Round Stranded Copper Conductors Using Single Input Wire Constructions.
9. ASTM B 902 for Compressed Round Stranded Copper Conductors, Hard, Medium-Hard, or Soft Using Single Input Wire Construction.

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.
10. ASTM B 901 for Compressed Round Stranded Aluminum Conductors Using Single Input Wire Construction.

2.1.3 Flexible Conductors

1. ASTM B 172 for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded 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.

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. The nominal cross sectional area within these tables is not a requirement.

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 WC 53.

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:

$$R = k \frac{\rho}{A}$$

Where:

- R = Conductor resistance in $\Omega/1000$ ft.
- k = Weight increment factor, as given in Table 2-1 as per the applicable ASTM standards.
- ρ = Volume resistivity in $\Omega \cdot \text{cmil}/\text{ft.}$, determined in accordance with ASTM B 193 using round wires.
- 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 nanoohm $\cdot$ meter ($\text{n}\Omega \cdot \text{m}$) and area is expressed in square millimeters (mm^2) the resistance is expressed in milliohm per meter ($\text{m}\Omega/\text{m}$).

2.4 CONDUCTOR DIAMETER

The average diameter of a conductor shall be measured in accordance with ICEA Publication T-27-581/WC 53. The diameter shall not differ from the nominal values shown in Table 2-3 or 2-3M by more than ± 2 percent.

Table 2-1
Weight Increment Factors *

Conductor Type/Size	Weight Factor (k)
Solid All Sizes	1
Stranded, Class B, C and D and Unilay strand Up to 2000 kcmil	1.02
>2000 - 3000 kcmil	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.

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 2-4 ^a Value Plus 2 Percent (R max = R x 1.02)
Multiple Conductor Cables & Twisted Assemblies of Single Conductor Cables	Table 2-4 ^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 Precabled 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 stranding's 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 $\Omega/1000$ ft.
 f = Factor from Table 2-7
 A = Cross-sectional area of conductor in kcmil

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

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

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
18	1.62	0.0403	---	---	0.046	---	---
16	2.58	0.0508	---	---	0.0576	---	---
15	3.26	0.0571	---	0.0629	0.0648	---	---
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.

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
18	1.62	---	---	---	---
16	2.58	---	---	---	---
15	3.26	---	---	---	---
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	---	---	---

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
18	0.823	1.02	---	---	1.17	---	---
16	1.31	1.29	---	---	1.47	---	---
15	1.65	1.45	---	---	1.65	---	---
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.

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
18	0.823	---	---	---	---
16	1.31	---	---	---	---
15	1.65	---	---	---	---
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	---	---	---	---

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

Conductor Size AWG or kcmil	Solid			Stranded*				
	Aluminum	Copper		Aluminum	Copper			
		Uncoated	Coated		Uncoated	Tin Coated		
		Uncoated	Coated	Class B, C, D	Class B, C, D	Class B	Class C	Class D
18	---	6.51	6.76	---	6.67	7.07	---	---
16	---	4.10	4.26	---	4.18	4.43	---	---
15	---	3.24	3.37	---	3.30	3.43	---	---
14	4.22	2.57	2.67	4.31	2.63	2.73	2.79	---
13	3.34	2.04	2.12	3.41	2.08	2.16	2.21	---
12	2.66	1.62	1.68	2.72	1.66	1.72	1.75	---
11	2.11	1.29	1.34	2.15	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.

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

Conductor Size AWG or kcmil	Solid			Stranded*				
	Aluminum	Copper		Aluminum Class B, C, D	Copper			
		Uncoated	Coated		Uncoated Class B, C, D	Tin Coated		
						Class B	Class C	Class D
18	---	21.33	22.15	---	21.86	21.99	---	---
16	---	13.43	13.96	---	13.70	13.78	---	---
15	---	10.62	11.04	---	10.82	10.67	---	---
14	13.85	8.42	8.75	14.1	8.62	8.49	9.14	9.27
13	10.96	6.68	6.95	11.2	6.81	7.08	7.24	7.27
12	8.71	5.31	5.50	8.91	5.44	5.64	5.73	5.73
11	6.91	4.23	4.39	7.04	4.29	4.46	4.46	4.55
10	5.47	3.34	3.47	5.57	3.41	3.54	3.54	3.64
9	4.32	2.65	2.73	4.42	2.70	2.80	2.80	2.86
8	3.44	2.10	2.16	3.51	2.14	2.22	2.22	2.23
7	2.73	1.67	1.71	2.79	1.70	1.76	1.76	1.76
6	2.17	1.32	1.36	2.21	1.35	1.40	1.40	1.40
5	1.72	1.05	1.08	1.75	1.07	1.11	1.11	1.11
4	1.36	0.830	0.856	1.39	0.846	0.882	0.882	0.882
3	1.08	0.659	0.679	1.10	0.672	0.699	0.699	0.699
2	0.856	0.522	0.538	0.872	0.531	0.554	0.554	0.554
1	0.679	0.413	0.426	0.692	0.423	0.440	0.440	0.440
1/0	0.538	0.328	0.335	0.551	0.335	0.348	0.348	0.348
2/0	0.426	0.260	0.267	0.436	0.266	0.276	0.276	0.276
3/0	0.338	0.207	0.212	0.344	0.211	0.219	0.219	0.219
4/0	0.269	0.164	0.168	0.274	0.167	0.172	0.174	0.174
250	0.228	...	...	0.232	0.141	0.147	0.147	0.147
300	0.190	...	...	0.194	0.118	0.123	0.123	0.123
350	0.162	...	...	0.166	0.101	0.105	0.105	0.105
400	0.142	...	...	0.145	0.0882	0.0909	0.0918	0.0918
450	0.126	...	...	0.129	0.0787	0.0807	0.0817	0.0817
500	0.114	...	...	0.116	0.0708	0.0728	0.0735	0.0735
550	...	...	...	0.105	0.0643	0.0669	0.0669	0.0669
600	...	...	...	0.0968	0.0590	0.0613	0.0613	0.0613
650	...	...	...	0.0892	0.0544	0.0561	0.0564	0.0567
700	...	...	...	0.0830	0.0505	0.0522	0.0525	0.0525
750	...	...	...	0.0774	0.0472	0.0485	0.0489	0.0492
800	...	...	...	0.0725	0.0443	0.0456	0.0459	0.0459
900	...	...	...	0.0643	0.0394	0.0403	0.0413	0.0413
1000	...	...	...	0.0581	0.0354	0.0364	0.0364	0.0367
1100	...	...	...	0.0528	0.0322	0.0331	0.0335	0.0335
1200	...	...	...	0.0482	0.0295	0.0303	0.0306	0.0306
1250	...	...	...	0.0462	0.0283	0.0291	0.0294	0.0294
1300	...	...	...	0.0446	0.0272	0.0280	0.0282	0.0283
1400	...	...	...	0.0413	0.0253	0.0260	0.0260	0.0263
1500	...	...	...	0.0387	0.0236	0.0243	0.0243	0.0245
1600	...	...	...	0.0364	0.0221	0.0228	0.0230	0.0230
1700	...	...	...	0.0341	0.0208	0.0214	0.0216	0.0216
1750	...	...	...	0.0331	0.0202	0.0208	0.0210	0.0210
1800	...	...	...	0.0322	0.0196	0.0202	0.0202	0.0204
1900	...	...	...	0.0305	0.0186	0.0192	0.0192	0.0193
2000	...	...	...	0.0290	0.0177	0.0182	0.0182	0.0184
2500	...	...	...	0.0235	0.0143	0.0147	...	...
3000	...	...	...	0.0195	0.0119	0.0123	...	...

* Stranded includes compressed and compact conductors.

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

Conductor Size AWG or kcmil	Class G		Class H		Class I	
	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

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

Conductor Size AWG or kcmil	Uncoated					Tin Coated				
	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	----	----

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

Conductor Size AWG or kcmil	Uncoated					Tin Coated				
	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
18	---	---	---	21.8	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	0.363	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	---	---

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	96.16	94.16	93.15
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 427 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 $\Omega \cdot \text{cmil/ft}$ (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 $\Omega \cdot \text{cmil/ft}$ (61.0 Percent conductivity) at 25°C for aluminum.

B. Increase in Resistance Due to Stranding

1. The value of K (weight increment factor) given in Table 2-1.

† See Table 2-2 for Use of Factors.

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 grounded 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, 3-5, and 3-6, 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, 3-5, and 3-6, 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 thickness of the insulation shall be not less than that given in Tables 3-3 through 3-6 for the various insulation types and voltage ratings.

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, 3-5, and 3-6 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, 3-5, and 3-6 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, 3-5, or 3-6 as applicable. If this voltage exceeds 2000V, refer to ICEA Standard S-96-659.

3.3.1.4 Direct Current Systems

Cables for use on direct current systems, up to and including 2000 volts, use the same insulation thickness as for three-phase ac systems, in accordance with 3.3.1.1.

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 3-7 and 3-8 as applicable.

3.6 INSULATION CLASSES AND REQUIREMENTS

3.6.1 Insulation Classes and Characteristics

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 paragraph 6.10 and the type of voltage specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-3 through 3-6, 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 3-7 and 3-8 as applicable.

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.

**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	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
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
Polyvinyl Chloride	60	Dry or Wet	600	T-1	3-6
Polyvinyl Chloride	75	Dry or Wet	600	T-2	3-6
Polyvinyl Chloride/Nylon	90	90 Dry or 75 Wet	600	T-3	3-5
Polyethylene	75	Dry or Wet	2000	T-4	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 8.

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 Test

6.10.1.1.4 dc Voltage Test

6.10.1.2.3 ac Spark Test

6.10.1.2.4 dc Spark Test

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

Rated Circuit Voltage Phase to Phase Volts*	Conductor Size AWG or kcmil**	Insulation Thickness ***				ac Test Voltage kV†	dc Test Voltage kV	ac Spark Test Voltage kV†	dc Spark Test Voltage kV
		Nominal		Minimum Point					
		mils	mm	mils	mm				
0-600	18-16	30	0.762	28	0.635	1.0	---	---	---
	14-9	45	1.143	40	1.016	4.5	13.5	7.5	13.5
	8-2	60	1.524	55	1.397	6.0	18.0	10.0	18.0
	1-4/0	80	2.032	75	1.905	7.5	22.5	12.5	22.5
	225-500	95	2.413	90	2.286	8.5	25.5	15.0	25.5
	525-1000	110	2.794	105	2.667	10.0	30.0	17.5	30.0
	1025-2000	125	3.175	120	3.048	11.5	34.5	20.0	34.5
601-2000	14-9	80	2.032	75	1.905	7.5	22.5	12.5	22.5
	8-2	95	2.413	90	2.286	8.5	25.5	15.0	25.5
	1-4/0	110	2.794	105	2.667	10.0	30.0	17.5	30.0
	225-500	125	3.175	120	3.048	11.5	34.5	20.0	34.5
	525-2000	140	3.556	130	3.302	11.5	34.5	22.5	34.5

* 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.

** 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.

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

† The ac voltages are rms values.

Table 3-4
Conductor Sizes, Insulation Thicknesses and Test Voltages
For Class T-4, T-5, T-6 and All Class X and E 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 ⁽³⁾								ac Test Voltage, kV	dc Test Voltage, kV	ac Spark Test Voltage, kV		dc Spark Test Voltage, kV	
		Nominal Columns				Minimum Point Columns						Column		Column	
		A		B		A		B				A	B	A	B
		mils	mm	mils	mm	mils	mm	mils	mm			A	B	A	B
0 – 600	14 – 9 ⁽³⁾	45	1.016	30	0.762	40	1.016	28	0.635	3.5	10.5	10.0	7.5	16.0	10.5
	8 – 2	60	1.397	45	1.143	55	1.397	40	1.016	5.5	16.5	15.0	10.0	21.0	16.5
	1 – 4/0	80	2.032	55	1.397	75	1.778	50	1.270	7.0	21.0	17.5	12.5	28.0	21.0
	225 – 500	95	2.413	65	1.651	90	2.159	60	1.524	8.0	24.0	20.0	15.0	33.5	24.0
	525 – 1000	110	2.640	80	2.032	105	2.667	75	1.905	10.0	30.0	27.5	17.5	38.5	30.0
	1025 - 2000	125	3.175	100	2.540	120	3.048	95	2.413	11.5	34.0	31.0	20.0	44.0	34.0
601 - 2000	14 – 9 ⁽³⁾	60	1.397	45	1.016	55	1.397	40	1.016	5.5	16.5	15.0	10.0	21.0	16.5
	8 – 2	70	1.778	55	1.397	65	1.651	50	1.270	7.0	21.0	17.5	12.5	24.5	21.0
	1 – 4/0	90	2.159	65	1.651	85	2.159	60	1.524	8.0	24.0	20.0	15.0	31.5	24.0
	225 – 500	105	2.667	75	1.778	95	2.413	70	1.778	9.5	28.5	25.0	17.5	37.0	28.5
	525 – 1000	120	3.048	90	2.159	115	2.921	85	2.159	11.5	34.5	30.0	20.0	42.0	34.5
	1025 - 2000	140	3.556	115	2.921	130	3.302	110	2.640	13.5	40.0	35.0	24.0	49.0	40.0

* 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.

** 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.

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

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

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 single-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.

†† ac voltages are rms values.

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 Volts*	Conductor Size AWG or kcmil	Insulation Thickness**						ac Test Voltage***	dc Test Voltage	Spark Test Voltage, kV***	
		PVC				Nylon					
		Nominal		Minimum		Minimum					
		mils	mm	mils	mm	mils	mm				
0 – 600	18 - 16	15	0.381	14	0.356	4	0.102	1.2	---	6.0	6.0
	14 – 11	15	0.381	14	0.356	4	0.102	2.0	6.0	6.0	7.5
	10 – 9	20	0.508	19	0.508	4	0.102	2.0	6.0	6.0	7.5
	8 – 5	30	0.762	28	0.483	5	0.127	2.0	6.0	6.0	10.0
	4 - 2	40	1.016	35	0.889	6	0.152	2.0	6.0	6.0	10.0
	1 – 4/0	50	1.397	45	1.143	7	0.178	2.5	7.5	7.5	12.5
	225 – 500	60	1.524	55	1.397	8	0.203	3.0	9.0	9.0	15.0
	525 – 1000	70	1.778	65	1.651	9	0.229	3.5	10.5	10.5	17.5

* 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

** 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 common jacket or metallic sheath. Insulation thicknesses are adequate for both 100 percent and 133 percent insulation levels.

*** ac voltages are rms values.