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Thermoplastic-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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Foreword▲

This Standards Publication for Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy was developed by the Insulated Cable Engineers Association and approved by the National Electrical Manufacturers Association.

ICEA/NEMA Standards are adopted in the public interest and are designed to eliminated 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 the Insulated Cable Engineers Association, P.O. Box P, South Yarmouth, Massachusetts 02664. An offical written interpretation will be provided. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

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Part 2 Conductors
Part 3 Insulation
Part 4 Shielding and Coverings
Part 5 Assembly, Fillers, and Conductor Identification
Part 6 Testing and Test Methods
Part 7 Constructions of Specific Types
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*A more detailed Table of Contents follows.

Throughout text, please read "kcmil" wherever text says "MCM." The preferred "kcmil" will be inserted as revisions are made to other text on a page. ●

For the sake of uniformity, all appendices in NEMA WC 3-1980 (ICEA S-19-81 Sixth Edition), NEMA WC 5-1973 (R 1979) (ICEA S-61-402 Third Edition), NEMA WC 7-1982 (ICEA S-66-524 Second Edition), and NEMA WC 8-1976 (R 1982) (ICEA S-68-516) are lettered the same. ●

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Part 1 ▲
GENERAL

1.1 SCOPE

These standards apply to materials, constructions, and testing of thermoplastic-insulated wires and cables which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, either indoors, aerial, underground, or submarine.

The thermoplastic insulations and jackets covered in this publication are compounds made from polyvinyl chloride, or the copolymer of vinyl chloride and vinyl acetate, or polyethylene.

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 types of wires and cables. Constructions of specific types are covered in Part 7. Where a conflict exists between the requirements of Part 7 and those of Parts 1 to 6, inclusive, the requirements of Part 7 shall apply. See Appendix E for complete titles and dates of ICEA Publications and ASTM Standards to which reference is made in this publication. See Part 6 for test procedures not elsewhere referenced.

Insulation thicknesses are designated in terms of cable insulations levels (see 3.2).

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

1.3 INFORMATION TO BE SUPPLIED BY PURCHASER*

When requesting 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, if direct current, between conductors.
4. Number of phases and conductors. If series lighting, give open-circuit voltage and state whether system is operated with or without protectors.
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) On messenger with marlin ties.
      (3) Preassembled.
      (4) Field spun.
   d. Direct burial in ground.
   e. Submarine.
   f. Descriptions other than the foregoing.
8. Conditions of installations.
   a. Ambient temperature.
   b. Number of loaded cables in duct bank or conduit. If in conduit, give type of conduit (metallic or nonmetallic), number of loaded conduits, enclosed or exposed, and spacing between conduits.
   c. Load factor.
   d. Method of bonding and grounding of metallic coverings (including shields).
   e. Wet or dry location.

1.3.2 Quantities and Description of Cable ▲

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

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Part 2
CONDUCTORS

2.0 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 the standard.

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

a. Approximate diameters of individual wires in stranded conductors.

b. Approximate diameters of conductors not listed in Table 2-6.

c. Approximate conductor weights.

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2.1 Wires, Physical and Electrical Properties. The wires used in conductors shall be copper in accordance with 2.1.1 or aluminum in accordance with 2.1.2.

2.1.1 Copper Wires. Copper wires shall meet the requirements of 2.1.1.1 and either 2.1.1.2 or 2.1.1.3. The 2.1.1.3 option shall apply only to non-compressed and non-compact conductors.

2.1.1.1 Copper wires shall meet the chemical requirements of ASTM B 5.

2.1.1.2 Soft or annealed copper wires intended for a stranded conductor shall meet the elongation, finish, and coating continuity requirements of one of the following:

1. ASTM B 3 for uncoated wires.
2. ASTM B 33 for tin-coated wires.
3. ASTM B 189 for lead or lead-alloy-coated wires.

2.1.1.3 Copper wires removed from a concentric lay stranded conductor, annealed after stranding, shall meet the elongation requirements of ASTM B 8, Sections 7.4, 7.5, and 7.6.

2.1.2 Aluminum Wires. Aluminum wires shall meet the requirements of 2.1.2.1 and either 2.1.2.2 or 2.1.2.3. The 2.1.2.3 option shall apply only to non-compressed and non-compact conductors. The requirements of 2.1.2.2 or 2.1.2.3 shall not apply if the requirements of 2.3.1 or 2.3.2 are met.

2.1.2.1 Aluminum 1350 wires shall meet the chemical requirements of ASTM B 233. Aluminum alloy wires shall contain a minimum of 97 percent aluminum by weight.

2.1.2.2 Aluminum 1350 and aluminum alloy wires intended for a stranded conductor shall meet one of the following:

1. Hard-drawn wire shall meet the tensile, elongation, finish, and brittleness requirements of ASTM B 230.
2. Annealed or intermediate temper wire shall meet the tensile and finish requirements of ASTM B 609.

2.1.2.3 Aluminum 1350 and aluminum alloy wires removed from a concentric lay stranded conductor shall meet the tensile requirements and bending properties of ASTM B 231, Sections 8.5 and 8.6 or 9.2 and 9.4.

2.2 Solid Conductors. Solid conductors shall meet the requirements of 2.2.1 or 2.2.2.

2.2.1 A solid copper conductor shall consist of a single round wire meeting the requirements given in 2.1.1.1 and 2.1.1.2.

2.2.2 A solid aluminum 1350 or aluminum alloy conductor shall consist of a single round wire meeting the requirements given in 2.1.2.1, 2.2.2.1, and Table 2-1 and the finish requirements of ASTM B 230. Tensile strength of aluminum 1350 and aluminum alloy conductors and elongation of aluminum alloy conductors shall be determined according to ASTM B 230.

2.2.2.1 Size 12 to 8 American Wire Gauge (AWG) solid aluminum conductors shall be an aluminum alloy with an elongation at rupture of not less than 10 percent in 10 inches.

2.3 Stranded Conductors. Stranded conductors shall consist of a number of wires individually meeting the appropriate requirements of 2.1. All

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Table 2-1

Solid Aluminum 1350 and Aluminum Alloy Conductors

Conductor Size	Tensile Strength			
	Aluminum 1350		Aluminum Alloy	
AWG	psi	MPa	psi	MPa
12-8	...	...	15000-22000	103-152
7-1	12000-22000	83-152	12000-22000	83-152
1/0 and larger	8500-22000	59-152	8500-22000	59-152

wires in a stranded conductor shall be of the same material and temper.

Exception: Coated wires shall be permitted to be used in only the outer layer of an uncoated conductor in order to obtain free stripping of the adjacent polymeric layer. The direct current resistance of the resulting conductor shall not exceed the value specified for an uncoated conductor of the same size.

The requirements for lay, joints and number of wires shall be in accordance with one of the following:

1. ASTM B 8 for concentric-lay Class B, C, or D stranded copper conductors.
2. ASTM B 172 for rope-lay stranded copper conductors with bunch-stranded members.
3. ASTM B 173 for rope-lay stranded copper conductors with concentric-stranded members.
4. ASTM B 174 for bunch-stranded copper conductors.
5. ASTM B 496 for compact-round stranded copper conductors.
6. ASTM B 231 for concentric-lay Class B, C, or D stranded aluminum 1350 or aluminum alloy conductors.
7. ASTM B 400 for compact-round stranded aluminum 1350 or aluminum alloy conductors.

2.3.1 Concentric-lay-stranded aluminum conductors, including compressed strand, if tested as a unit as an alternative to 2.1.2.2 or 2.1.2.3 and before application of any coverings, shall meet the tensile requirements and bending properties of ASTM B 231, Sections 8.2 to 8.4 and 8.6 or Sections 9.3 and 9.4.

2.3.2 Compact stranded aluminum conductors, if tested as a unit as an alternative to 2.1.2.2 and before application of any coverings, shall meet the tensile requirements of ASTM B 400, Section 8.2 or Section 9.

2.4 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 2-7.

2.5 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 2-3 when using the appropriate nominal value specified in Table 2-4, Table 2-5, and Table 2-6. The dc resistance shall be determined in accordance with 2.5.1 or 2.5.2. ▲

Where the resistance is measured on a sample taken from a multiple conductor cable, or where the resistance is calculated, the appropriate maximum resistance value specified for a single conductor cable shall apply.

2.5.1 Direct Measurement of dc Resistance Per Unit Length. The dc resistance per unit length shall be determined by dc resistance measurements made in accordance with 6.3.1 to an accuracy of 2 percent or better. If measurements are made at a temperature other than 25 °C (77 °F), the measured value shall be converted to resistance at 25 °C (77 °F) by using either of the following:

1. The appropriate multiplying factor from Table 6-1.

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2. A multiplying factor calculated using the applicable formula in the footnote to Table 6-1.

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 foot (30.5 cm) 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.

Where an uninsulated conductor is in contact with another metallic or conductive component of the cable, measurements shall be made on a sample taken from the completed cable.

2.5.2 Calculation of dc Resistance Per Unit Length. The dc resistance per unit length at 25 °C (77 °F) shall be calculated using the following formula:

$$R = K\rho/A$$

Where:

R = Conductor resistance in Ω/1000 ft.

K = Weight increment factor, as given in Table 2-2.

ρ = Volume resistivity in Ω·cmil/ft., determined in accordance with ASTM B 193 using round wires

A = Cross-sectional area of conductor in kcmil, determined in accordance with 6.3.2.1 or 6.3.2.2 for solid, concentric-lay, rope-lay, and bunch-stranded conductors or 6.3.2.2 for compressed or compact-stranded conductors.

When the volume resistivity is expressed in nanoohm meter (nΩ·m) and area is expressed in square millimeters (mm^2) the resistance is expressed in milliohm per meter (mΩ/m).

Table 2-2

Weight Increment Factors*, K

Solid Conductors	1
Concentric-Lay Strand, Classes B, C, and D	
up to 2000 kcmil	1.02
> 2000—3000 kcmil	1.03
> 3000—4000 kcmil	1.04
> 4000—5000 kcmil	1.05
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, and M	
7 bunch stranded members	1.04
19	1.05
37	1.05
61	1.05
7 × 7 bunch stranded members	1.06
19 × 7	1.07
37 × 7	1.07
61 × 7	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 or ASTM B 174 as applicable.

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2.6 Conductor Diameter. The diameter of a conductor having a diameter less than 0.750 inch (19 mm) shall be measured in accordance with 6.3.3.1. The diameter of a conductor having a diameter 0.750 inch (19 mm) or larger shall be measured in accordance with 6.3.3.1 or 6.3.3.2. The diameter shall not differ from the nominal values shown in Table 2-7 by more than plus or minus 5 percent.

2.6.1 The 5 percent diameter tolerance for solid and stranded conductors is provided to enable a designer of connectors to determine the range of conductor sizes which will fit a particilar connector; however, a conductor meeting the minimum diameter requirement does not necessarily meet the requirement for maximum dc resistance given in 2.5.

NEMA Authorized Engineering Information 7-14-1982.

2.6.2 If one or more layers of any concentric lay stranded Class B, C, or D conductor is compressed to reduce the noncompressed outside diameter, the compression shall not exceed 3 percent.

2.7 Stress Control Layer

Conductors to be insulated for a rated circuit voltage above 2000 volts shall be covered with a separate stress controlling material compatible with the conductor and the insulation. The material shall have allowable operating temperatures at least equal to those given for the insulation.

2.7.1 The stress control layer shall be a polymeric covering consisting of a conducting tape, extruded material or extruded material over conducting tape. The layer shall have a minimum thickness of 2.5 mils (0.06mm).

2.7.1.1 Extrudable material, prior to application to the conductor, when tested according to 6.6 shall meet the following requirements:

Elongation after air oven test at 121 °C ± 1 °C for 168 hours minimum percent	100
Brittleness temperature not warmer than °C	– 10

2.7.1.1.1 The resistivity of an extruded conducting material when measured according to 6.9.4 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

● **2.7.1.2**

● Paragraph 2.7.1.2 rescinded 7-11-1984.

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Table 2-3▲

Schedule for Establishing Maximum Direct Current Resistance Per Unit Length of Completed Cable

Cables with Conductors of Table 2-4	
Cable Type	Maximum dc Resistance
Single Conductor Cables and Flat Parallel Cable	Table 2-4[a] Value Plus 2% (R max = R × 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-4[a] Value Plus 2% Plus One of the Following: 2% - One Layer of Conductors (R max = R × 1.02 × 1.02) 3% - More than One Layer of Conductors (R max = R × 1.02 × 1.03) 4% - Pairs or other Precabled Units (R max = R × 1.02 × 1.04)

Cables with Conductors of Table 2-5 or 2-6	
Cable Type	Maximum dc Resistance
Single Conductor Cables and Flat Parallel Cables	Table 2-5[a] or 2-6[a] Value Plus 2%[b] (R max = R × 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-5[a] or 2-6[a] Value Plus 2%[b] Plus 5% (R max = R × 1.02 × 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 from the factors given in Table 2-8 using the following formula:

$R = 10^{-3}f/A$

Where: R = Conductor resistance in Ω/1000 ft
f = Factor from Table 2-8
A = Cross-sectional area of conductor in kcmil

See 2.5.2 for cross-sectional area determination

[b] For 20 AWG and 18 AWG Class K conductors specified in Table 2-6 this value shall be 3 percent.

▲ Editorially revised.

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Table 2-4

Nominal Direct Current Resistance in Ohms Per 1000 Feet** at 25 °C (77 °F) of Solid and Concentric Lay Stranded Conductor

Conductor Size	Solid			Concentric Lay Stranded*				
	Aluminum	Copper		Aluminum	Copper			
AWG or kcmil		Uncoated	Coated	Class, B, C, D	Uncoated	Coated		
					Class B, C, D	Class B	Class C	Class D
22	27.1	16.5	17.2	27.4	16.7	17.9	...	...
20	16.9	10.3	10.7	17.3	10.5	11.1	...	...
19	13.5	8.20	8.52	13.7	8.33	8.83	...	...
18	10.7	6.51	6.76	10.9	6.67	7.07	...	...
17	8.45	5.15	5.35	8.54	5.21	5.52	...	...
16	6.72	4.10	4.26	6.85	4.18	4.43	...	...
15	5.32	3.24	3.37	5.41	3.30	3.43	...	...
14	4.22	2.57	2.67	4.31	2.63	2.73	2.79	2.83
13	3.34	2.04	2.12	3.41	2.08	2.16	2.21	2.22
12	2.66	1.62	1.68	2.72	1.66	1.72	1.75	1.75
11	2.11	1.29	1.34	2.15	1.31	1.36	1.36	1.39
10	1.67	1.02	1.06	1.70	1.04	1.08	1.08	1.11
9	1.32	0.808	0.831	1.35	0.825	0.856	0.856	0.874
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	0.336	0.205	0.213	0.213	0.213
2	0.261	0.159	0.164	0.266	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	0.00897
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
2500	...	...	...	0.00715	0.00436	0.00448	...	...
3000	...	...	...	0.00596	0.00363	0.00374	...	...
3500	...	...	...	0.00515	0.00314	0.00323	...	...
4000	...	...	...	0.00451	0.00275	0.00283	...	...
4500	...	...	...	0.00405	0.00247	0.00254	...	...
5000	...	...	...	0.00364	0.00222	0.00229	...	...

* Concentric lay stranded includes compressed and compact conductors.

** Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

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Table 2-5

Nominal Direct Current Resistance in Ohms Per 1000 Feet*
at 25 °C (77 °F) For Flexible Aluminum Conductors

Conductor Size AWG or kcmil	Class G	Class H	Class I
8	...	...	1.07
7	0.858	...	0.850
6	0.681	...	0.687
5	0.540	...	0.545
4	0.428	...	0.432
3	0.340	...	0.343
2	0.269	0.272	0.272
1	0.216	...	0.216
1/0	0.171	0.172	0.172
2/0	0.136	0.136	0.137
3/0	0.107	0.108	0.109
4/0	0.0852	0.0857	0.0861
250	0.0725	0.0728	0.0735
300	0.0604	0.0607	0.0613
350	0.0518	0.0520	0.0525
400	0.0453	0.0455	0.0460
450	0.0403	0.0405	0.0409
500	0.0363	0.0364	0.0368
550	0.0331	0.0334	0.0334
600	0.0304	0.0306	0.0306
650	0.0280	0.0283	0.0286
700	0.0260	0.0263	0.0265
750	0.0243	0.0245	0.0247
800	0.0228	0.0230	0.0232
900	0.0202	0.0204	0.0206
1000	0.0182	0.0184	0.0186
1100	0.0166	0.0167	0.0169
1200	0.0152	0.0153	0.0155
1250	0.0146	0.0147	0.0148
1300	0.0140	0.0141	0.0143
1400	0.0130	0.0131	0.0133
1500	0.0121	0.0123	0.0124
1600	0.0115	0.0115	0.0116
1700	0.0108	0.0108	0.0109
1750	0.0105	0.0105	0.0106
1800	0.0102	0.0102	0.0103
1900	0.00968	0.00968	0.00977
2000	0.00919	0.00919	0.00928

*Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

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Table 2-6

Nominal Direct Current Resistance in Ohms Per 1000 Feet* at 25 °C (77 °F) For Flexible Annealed Copper Conductors

Conductor Size	Uncoated					Coated				
	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
AWG or kcmil										
20	...	...	...	10.6	10.6	...	...	...	11.4	11.4
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	0.108	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	...	...

* Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

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Table 2-7

Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters*					
			Concentric Lay Stranded				
		Solid	Compact	Compressed	Class B	Class C	Class D
AWG	kcmil	Inch	Inch	Inch	Inch	Inch	Inch
22	0.812	0.0253	...	...	...	...	...
20	1.02	0.0320	...	...	...	...	...
19	1.29	0.0359	...	...	...	...	...
18	1.62	0.0403	...	...	...	...	...
17	2.05	0.0453	...	...	...	...	...
16	2.58	0.0508	...	...	...	...	...
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	10.38	0.1019	...	0.112	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	0.361	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	0.6708	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	0.998	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

* Diameters in millimeters shall be obtained by multiplying the above values in inches by 25.4.

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Table 2-8 *

Factors** for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet

Conductivity, Percent	All Sizes, Uncoated		Diameter of Individual 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
	61	100	97.66	97.16	96.16	94.16	93.15
	25 °C	25 °C	25 °C	25 °C	25 °C	25 °C	25 °C
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 × 7 ropes of bunched strand	18385	11209	...	...	11657	11905	12033
19, 37, or 61 × 7 ropes of bunched strand	18559	11315	...	...	11767	12018	12147
Concentric Stranded							
Up 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	11547	11792	11921

* The factors given in Table 2-8 shall be based on the following:

A. Resistivity
1. A volume resistivity of 10.575 Ω·cmil/ft (100 % 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 or ASTM B 189 for coated copper.
3. A volume resistivity of 17.345 Ω·cmil/ft (61.0% conductivity) at 25 °C for aluminum.

B. Increase in Resistance Due to Stranding
1. The value of K (weight increment factor) given in Table 2-2.

** See Table 2-3 for Use of Factors.

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Table 2-5 ▲

Rope-lay Aluminum and Copper Conductors. Class H

Conductor Size. AWG or MCM *	No. of Strands	Suggested Con-struction †	Nominal Diameter of Each Strand		Approximate Outside Diameter ‡		Approximate Weight ‡			
							Aluminum		Copper	
			mils	mm	inches	mm	Pounds per 1000 Feet	kg/km	Pounds per 1000 Feet	kg/km
8	133	19 x 7	11.1	0.28	0.167	4.24	..	....	52	77.4
7	133	19 x 7	12.5	0.32	0.188	4.78	..	....	65	97.5
6	133	19 x 7	14.0	0.36	0.210	5.33	..	....	82	123
5	133	19 x 7	15.8	0.40	0.237	6.02	..	....	105	155
4	133	19 x 7	17.7	0.45	0.266	6.76	..	....	132	196
3	133	19 x 7	19.9	0.51	0.299	7.59	..	....	167	247
2	133	19 x 7	22.3	0.57	0.335	8.51	63	94.5	208	311
2	259	37 x 7	16.0	0.41	0.336	8.53	..	....	210	312
1	259	37 x 7	18.0	0.46	0.378	9.60	..	....	266	394
1/0	259	37 x 7	20.2	0.51	0.424	10.8	102	151	334	497
2/0	259	37 x 7	22.7	0.58	0.477	12.1	128	190	422	626
3/0	259	37 x 7	25.5	0.65	0.536	13.6	162	240	533	790
3/0	427	61 x 7	19.8	0.50	0.535	13.6	...	..	532	794
4/0	259	37 x 7	28.6	0.73	0.601	15.3	204	303	670	996
4/0	427	61 x 7	22.3	0.57	0.602	15.3	205	304	675	1000
250	427	61 x 7	24.2	0.61	0.653	16.6	242	360	795	1180
300	427	61 x 7	26.5	0.67	0.716	18.2	290	431	953	1420
350	427	61 x 7	28.6	0.73	0.772	19.6	337	503	1110	1655
400	427	61 x 7	30.6	0.78	0.826	21.0	386	575	1270	1890
450	427	61 x 7	32.5	0.83	0.878	22.3	436	647	1435	2130
500	427	61 x 7	34.2	0.87	0.923	23.4	483	719	1590	2365
550	703	37 x 19	28.0	0.71	0.980	24.9	538	798	1770	2625
600	703	37 x 19	29.2	0.74	1.022	26.0	584	871	1920	2865
650	703	37 x 19	30.4	0.77	1.064	27.0	634	944	2085	3105
700	703	37 x 19	31.6	0.80	1.106	28.1	686	1015	2255	3340
750	703	37 x 19	32.7	0.83	1.145	29.1	733	1090	2410	3580
800	703	37 x 19	33.7	0.86	1.180	30.0	778	1160	2560	3820
900	703	37 x 19	35.8	0.91	1.253	31.8	880	1305	2895	4295
1000	703	37 x 19	37.7	0.96	1.320	33.5	974	1450	3205	4775
1100	703	37 x 19	39.6	1.01	1.386	35.2	1075	1595	3535	5250
1200	703	37 x 19	41.3	1.05	1.446	36.7	1169	1740	3845	5730
1250	703	37 x 19	42.2	1.07	1.477	37.5	1221	1815	4015	5970
1300	703	37 x 19	43.0	1.09	1.505	38.2	1268	1885	4170	6205
1400	703	37 x 19	44.6	1.13	1.561	39.6	1363	2035	4485	6685
1500	703	37 x 19	46.2	1.17	1.617	41.1	1464	2180	4815	7160
1600	1159	61 x 19	37.2	0.94	1.674	42.5	1564	2325	5145	7640
1700	1159	61 x 19	38.3	0.97	1.724	43.8	1658	2470	5455	8115
1750	1159	61 x 19	38.9	0.99	1.751	44.5	1710	2540	5625	8355
1800	1159	61 x 19	39.4	1.00	1.773	45.0	1754	2615	5770	8595
1900	1159	61 x 19	40.5	1.03	1.823	46.3	1854	2760	6100	9070
2000	1159	61 x 19	41.5	1.05	1.868	47.4	1946	2905	6400	9550

* The minimum size of individual aluminum wires is 24 AWG, 0.0201 inch (0.511 mm).

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Table 2-6 ▲

Aluminum and Copper Conductors, Class I

Each Individual Strand 24 AWG, 0.0201 Inch (0.511 mm)

Conductor Size, AWG or MCM *	Suggested Construction †	Nominal Number of Strands	Approximate Outside Diameter ‡		Approximate Weight ‡			
					Aluminum		Copper	
			inches	mm	Pounds per 1000 Feet	kg/km	Pounds per 1000 Feet	kg/km
10	1 x 26	26	0.125	3.18	..	....	32.5	48.3
9	1 x 33	33	0.138	3.51	..	....	41	61.3
8	1 x 41	41	0.156	3.96	16	23.1	51	76.1
7	1 x 52	52	0.185	4.70	20	29.3	65	96.5
6	7 x 9	63	0.207	5.26	24	36.3	80	119
5	7 x 12	84	0.235	5.97	32	48.3	105	159
4	7 x 15	105	0.263	6.68	41	60.4	134	199
3	7 x 19	133	0.291	7.39	51	76.5	169	252
2	7 x 23	161	0.319	8.10	62	92.7	205	305
1	7 x 30	210	0.367	9.32	81	121	267	397
1/0	19 x 14	266	0.441	11.2	104	155	342	508
2/0	19 x 18	342	0.500	12.7	133	199	439	654
3/0	19 x 22	418	0.549	13.9	163	243	537	799
4/0	19 x 28	532	0.613	15.6	208	309	683	1015
250	7 x 7 x 13	637	0.682	17.3	251	374	825	1230
300	7 x 7 x 15	735	0.737	18.7	290	431	955	1420
350	7 x 7 x 18	882	0.800	20.3	348	517	1145	1700
400	7 x 7 x 20	980	0.831	21.1	386	575	1270	1890
450	7 x 7 x 23	1127	0.894	22.7	444	661	1460	2175
500	7 x 7 x 25	1225	0.941	23.9	483	719	1590	2365
550	7 x 7 x 28	1372	0.980	24.9	541	805	1780	2645
600	7 x 7 x 30	1470	1.027	26.1	579	862	1905	2835
650	19 x 7 x 12	1596	1.152	29.3	635	945	2090	3110
700	19 x 7 x 13	1729	1.194	30.3	687	1025	2260	3365
750	19 x 7 x 14	1862	1.235	31.4	740	1100	2435	3625
800	19 x 7 x 15	1995	1.290	32.8	793	1180	2610	3885
900	19 x 7 x 17	2261	1.372	34.8	901	1340	2965	4405
1000	19 x 7 x 19	2527	1.427	36.2	1005	1495	3305	4920
1100	19 x 7 x 21	2793	1.495	38.0	1111	1655	3655	5440
1200	19 x 7 x 22	2926	1.537	39.0	1164	1730	3830	5700
1250	19 x 7 x 23	3059	1.564	39.7	1216	1810	4000	5955
1300	19 x 7 x 24	3192	1.605	40.8	1269	1890	4175	6215
1400	19 x 7 x 26	3458	1.674	42.5	1386	2045	4560	6735
1500	19 x 7 x 28	3724	1.715	43.6	1482	2205	4875	7250
1600	19 x 7 x 30	3990	1.797	45.6	1587	2360	5220	7770
1700	19 x 7 x 32	4256	1.852	47.0	1693	2520	5570	8290
1750	19 x 7 x 33	4389	1.880	47.8	1746	2600	5745	8545
1800	19 x 7 x 34	4522	1.921	48.8	1800	2675	5920	8805
1900	19 x 7 x 36	4788	1.976	50.2	1905	2835	6265	9325
2000	19 x 7 x 37	4921	2.003	50.9	1958	2915	6440	9585

* Aluminum conductors are for use in sizes 8 AWG and larger only.

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Table 2-7▲
Copper Conductors. Class K
Each Individual Strand 30 AWG, 0.0100 Inch (0.254 mm)

Conductor Size, AWG or MCM	Suggested Construction *	Nominal Number of Strands	Approximate Outside Diameter †		Approximate Weight †	
			inches	mm	Pounds per 1000 Feet	kg/km
20	1 x 10	10	0.038	0.97	3.2	4.59
18	1 x 16	16	0.048	1.22	5.0	7.35
16	1 x 26	26	0.060	1.52	8.0	11.9
14	1 x 41	41	0.078	1.98	12.8	18.8
12	1 x 65	65	0.101	2.57	20.3	29.9
10	1 x 104	104	0.126	3.20	32.5	47.8
9	7 x 19	133	0.150	3.81	42	62.3
8	7 x 24	168	0.157	3.99	53	78.7
7	7 x 30	210	0.179	4.55	66	98.4
6	7 x 38	266	0.210	5.33	84	125
5	7 x 48	336	0.235	5.97	106	157
4	7 x 60	420	0.272	6.91	132	197
3	19 x 28	532	0.304	7.72	169	252
2	19 x 35	665	0.338	8.59	211	315
1	19 x 44	836	0.397	10.1	266	395
1/0	19 x 56	1064	0.451	11.5	338	503
2/0	7 x 7 x 27	1323	0.470	11.9	425	632
3/0	7 x 7 x 34	1666	0.533	13.5	535	795
4/0	7 x 7 x 43	2107	0.627	15.9	676	1005
250	7 x 7 x 51	2499	0.682	17.3	802	1195
300	7 x 7 x 61	2989	0.768	19.5	960	1425
350	19 x 7 x 26	3458	0.809	20.5	1120	1665
400	19 x 7 x 30	3990	0.878	22.3	1290	1925
450	19 x 7 x 34	4522	0.933	23.7	1465	2180
500	19 x 7 x 38	5054	0.988	25.1	1635	2435
550	19 x 7 x 41	5453	1.056	26.8	1765	2630
600	19 x 7 x 45	5985	1.125	28.6	1940	2885
650	19 x 7 x 49	6517	1.166	29.6	2110	3140
700	19 x 7 x 52	6916	1.207	30.7	2240	3335
750	19 x 7 x 57	7581	1.276	32.4	2455	3655
800	19 x 7 x 60	7980	1.305	33.1	2585	3845
900	37 x 7 x 35	9065	1.323	33.6	2935	4370
1000	37 x 7 x 39	10101	1.419	36.0	3270	4870

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Table 2-8 ▲
Copper Conductors, Class M
Each Individual Strand 34 AWG, 0.0063 Inch (0.160 mm)

Conductor Size, AWG or MCM	Suggested Construction *	Nominal Number of Strands	Approximate Outside Diameter †		Approximate Weight †	
			inches	mm	Pounds per 1000 Feet	kg/km
20	1 x 26	26	0.038	0.97	3.2	4.74
18	1 x 41	41	0.048	1.22	5.0	7.48
16	1 x 65	65	0.060	1.52	8.0	11.9
14	1 x 104	104	0.078	1.98	12.8	19.0
12	7 x 24	168	0.101	2.57	21.0	31.2
10	7 x 37	259	0.126	3.20	32.5	48.2
9	7 x 48	336	0.146	3.71	42	62.5
8	7 x 60	420	0.162	4.11	53	78.1
7	19 x 28	532	0.196	4.98	67	100.0
6	19 x 35	665	0.215	5.46	84	125
5	19 x 44	836	0.240	6.10	105	157
4	19 x 56	1064	0.269	6.83	134	200
3	7 x 7 x 27	1323	0.305	7.75	169	251
2	7 x 7 x 34	1666	0.337	8.56	212	316
1	7 x 7 x 43	2107	0.376	9.55	268	399
1/0	7 x 7 x 54	2646	0.423	10.7	337	501
2/0	19 x 7 x 25	3325	0.508	12.9	427	636
3/0	19 x 7 x 32	4256	0.576	14.6	547	814
4/0	19 x 7 x 40	5320	0.645	16.4	684	1020
250	19 x 7 x 48	6384	0.713	18.1	821	1220
300	19 x 7 x 57	7581	0.768	19.5	975	1450
350	37 x 7 x 34	8806	0.825	21.0	1130	1685
400	37 x 7 x 39	10101	0.901	22.9	1300	1930
450	37 x 7 x 44	11396	0.940	23.9	1465	2180
500	37 x 7 x 49	12691	0.997	25.3	1630	2430
550	61 x 7 x 32	13664	1.035	26.3	1755	2615
600	61 x 7 x 35	14945	1.084	27.5	1920	2860
650	61 x 7 x 38	16226	1.133	28.8	2085	3105
700	61 x 7 x 41	17507	1.183	30.0	2250	3350
750	61 x 7 x 44	18788	1.207	30.7	2415	3595
800	61 x 7 x 47	20069	1.256	31.9	2580	3840
900	61 x 7 x 53	22631	1.331	33.8	2910	4330
1000	61 x 7 x 59	25193	1.404	35.7	3240	4820

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Table 2-9 ▲
Compact Round Stranded Conductors, Copper or Aluminum

Conductor Size, AWG or MCM	Number of Strands	Nominal Overall Diameter	
		inches	mm
8	7	0.134	3.40
6	7	0.169	4.29
4	7	0.213	5.41
2	7	0.268	6.81
1	19	0.299	7.59
1/0	19	0.336	8.53
2/0	19	0.376	9.55
3/0	19	0.423	10.74
4/0	19	0.475	12.07
250	37	0.520	13.21
300	37	0.570	14.48
350	37	0.616	15.65
400	37	0.659	16.74
450	37	0.700	17.78
500	37	0.736	18.69
550	61	0.775	19.69
600	61	0.813	20.65
650	61	0.845	21.46
700	61	0.877	22.28
750	61	0.908	23.06
800	61	0.938	23.83
900	61	0.999	25.37
1000	61	1.060	26.92

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Table 2-10 ▲

Nominal Direct-current Resistance of Aluminum and Annealed Uncoated Copper Conductors (Solid)

Conductor Size, AWG or MCM	20°C				25°C			
	Aluminum		Copper		Aluminum		Copper	
	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km
22	....	....	16.2	53.2	....	....	16.5	54.2
20	16.6	54.5	10.1	33.2	16.9	55.6	10.3	33.9
19	13.2	43.3	8.05	26.4	13.5	44.2	8.21	26.9
18	10.5	34.3	6.39	21.0	10.7	35.0	6.51	21.4
17	8.29	27.2	5.05	16.6	8.45	27.7	5.15	16.9
16	6.59	21.6	4.02	13.2	6.72	22.1	4.10	13.4
15	5.21	17.1	3.18	10.4	5.32	17.5	3.24	10.6
14	4.14	13.6	2.52	8.28	4.22	13.8	2.57	8.44
13	3.28	10.8	2.00	6.56	3.35	11.0	2.04	6.69
12	2.60	8.54	1.59	5.21	2.66	8.72	1.62	5.31
11	2.07	6.78	1.26	4.14	2.11	6.92	1.29	4.22
10	1.64	5.37	0.999	3.28	1.67	5.48	1.02	3.34
9	1.30	4.26	0.793	2.60	1.33	4.35	0.808	2.65
8	1.03	3.38	0.628	2.06	1.05	3.45	0.640	2.10
7	0.817	2.68	0.498	1.63	0.833	2.73	0.508	1.67
6	0.648	2.13	0.395	1.30	0.661	2.17	0.403	1.32
5	0.514	1.69	0.313	1.03	0.524	1.72	0.320	1.05
4	0.407	1.34	0.249	0.815	0.416	1.36	0.253	0.831
3	0.323	1.06	0.197	0.647	0.330	1.08	0.201	0.659
2	0.256	0.841	0.156	0.513	0.261	0.858	0.159	0.523
1	0.203	0.667	0.124	0.407	0.207	0.680	0.126	0.415
1/0	0.161	0.528	0.0983	0.322	0.164	0.539	0.100	0.329
2/0	0.128	0.419	0.0779	0.256	0.130	0.428	0.0795	0.261
3/0	0.101	0.333	0.0618	0.203	0.103	0.339	0.0630	0.207
4/0	0.0804	0.264	0.0490	0.161	0.0820	0.269	0.0500	0.164
250	0.0680	0.223	.....	.....	0.0694	0.228	.....	.....
300	0.0567	0.186	.....	.....	0.0578	0.190	.....	.....
350	0.0486	0.159	.....	.....	0.0496	0.163	.....	.....
400	0.0425	0.139	.....	.....	0.0434	0.142	.....	.....
450	0.0378	0.124	.....	.....	0.0386	0.127	.....	.....
500	0.0340	0.112	.....	.....	0.0347	0.114	.....	.....

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Table 2-11 ▲
Nominal Direct-current Resistance of Annealed Coated Copper Conductors, Solid

Conductor Size, AWG	20°C Copper ohms per 1000 Feet	20°C Copper ohms per km	25°C Copper ohms per 1000 Feet	25°C Copper ohms per km
22	16.9	55.3	17.2	56.4
20	10.5	34.6	10.7	35.2
19	8.37	27.5	8.53	28.0
18	6.64	21.8	6.77	22.2
17	5.26	17.2	5.36	17.6
16	4.18	13.7	4.26	14.0
15	3.31	10.9	3.37	11.1
14	2.63	8.61	2.67	8.78
13	2.08	6.83	2.12	6.96
12	1.65	5.42	1.68	5.53
11	1.31	4.30	1.34	4.39
10	1.04	3.41	1.06	3.48
9	0.816	2.68	0.832	2.73
8	0.647	2.12	0.659	2.16
7	0.513	1.68	0.523	1.72
6	0.407	1.33	0.415	1.36
5	0.323	1.06	0.329	1.08
4	0.256	0.839	0.261	0.856
3	0.203	0.666	0.207	0.679
2	0.161	0.528	0.164	0.538
1	0.128	0.418	0.130	0.427
1/0	0.101	0.330	0.103	0.337
2/0	0.0798	0.262	0.0814	0.267
3/0	0.0633	0.208	0.0645	0.212
4/0	0.0502	0.165	0.0512	0.168

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Table 2-12 ▲

Nominal Direct-current Resistance of Aluminum and Annealed Uncoated Copper Conductors
Concentric Stranded Classes B, C and D and Compact Stranded

Conductor Size, AWG or MCM	20°C				25°C			
	Aluminum		Copper		Aluminum		Copper	
	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km
22	...	...	...	...	...	...	...	...
20	...	...	10.3	33.9	...	...	10.5	34.6
19	...	...	...	...	...	...	...	...
18	...	...	6.51	21.4	...	...	6.64	21.8
17	...	...	...	...	...	...	...	...
16	...	...	4.10	13.4	...	...	4.18	13.7
15	...	...	...	...	...	...	...	...
14	...	...	2.57	8.45	...	...	2.63	8.61
13	...	...	2.04	6.69	...	...	2.08	6.83
12	2.66	8.71	1.62	5.32	2.71	8.89	1.65	5.42
11	2.11	6.92	1.29	4.22	2.15	7.06	1.31	4.30
10	1.67	5.48	1.02	3.34	1.70	5.59	1.04	3.41
9	1.33	4.35	0.808	2.65	1.35	4.44	0.824	2.70
8	1.05	3.45	0.641	2.10	1.07	3.52	0.653	2.14
7	0.833	2.73	0.508	1.67	0.850	2.79	0.518	1.70
6	0.661	2.17	0.403	1.32	0.674	2.21	0.411	1.35
5	0.524	1.72	0.320	1.05	0.535	1.75	0.326	1.07
4	0.416	1.36	0.253	0.832	0.424	1.39	0.258	0.848
3	0.330	1.08	0.201	0.660	0.336	1.10	0.205	0.673
2	0.261	0.857	0.159	0.523	0.267	0.875	0.163	0.533
1	0.207	0.680	0.126	0.415	0.211	0.694	0.129	0.423
1/0	0.164	0.539	0.100	0.329	0.168	0.550	0.102	0.335
2/0	0.130	0.428	0.0795	0.261	0.133	0.436	0.0811	0.266
3/0	0.103	0.339	0.0631	0.207	0.105	0.346	0.0643	0.211
4/0	0.0820	0.269	0.0500	0.164	0.0836	0.274	0.0510	0.167
250	0.0694	0.228	0.0423	0.139	0.0708	0.232	0.0432	0.142
300	0.0578	0.190	0.0353	0.116	0.0590	0.194	0.0360	0.118
350	0.0496	0.163	0.0302	0.0992	0.0506	0.166	0.0308	0.101
400	0.0434	0.142	0.0265	0.0868	0.0442	0.145	0.0270	0.0885
450	0.0385	0.126	0.0235	0.0771	0.0393	0.129	0.0240	0.0786

(Continued)

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Table 2-12 (Continued) ▲

Nominal Direct-current Resistance of Aluminum and Annealed Uncoated Copper Conductors, Concentric Stranded Classes B, C and D and Compact Stranded

Conductor Size, AWG or MCM	20°C				25°C			
	Aluminum		Copper		Aluminum		Copper	
	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km
500	0.0347	0.114	0.0212	0.0694	0.0354	0.116	0.0216	0.0708
550	0.0315	0.103	0.0192	0.0631	0.0322	0.106	0.0196	0.0643
600	0.0289	0.0948	0.0176	0.0578	0.0295	0.0967	0.0180	0.0590
650	0.0267	0.0875	0.0163	0.0534	0.0272	0.0893	0.0166	0.0544
700	0.0248	0.0813	0.0151	0.0496	0.0253	0.0829	0.0154	0.0506
750	0.0231	0.0759	0.0141	0.0463	0.0236	0.0774	0.0144	0.0472
800	0.0217	0.0711	0.0132	0.0434	0.0221	0.0726	0.0135	0.0442
900	0.0193	0.0632	0.0118	0.0386	0.0197	0.0645	0.0120	0.0393
1 000	0.0173	0.0569	0.0106	0.0347	0.0177	0.0580	0.0108	0.0354
1 100	0.0158	0.0517	0.00962	0.0316	0.0161	0.0528	0.00987	0.0322
1 200	0.0145	0.0474	0.00882	0.0289	0.0147	0.0484	0.00899	0.0295
1 250	0.0139	0.0455	0.00846	0.0278	0.0142	0.0464	0.00863	0.0283
1 300	0.0133	0.0438	0.00814	0.0267	0.0136	0.0447	0.00830	0.0272
1 400	0.0124	0.0406	0.00756	0.0248	0.0126	0.0415	0.00771	0.0253
1 500	0.0116	0.0379	0.00705	0.0231	0.0118	0.0387	0.00719	0.0236
1 600	0.0108	0.0356	0.00661	0.0217	0.0111	0.0363	0.00674	0.0221
1 700	0.0102	0.0335	0.00622	0.0204	0.0104	0.0341	0.00635	0.0208
1 750	0.00991	0.0325	0.00605	0.0198	0.0101	0.0332	0.00616	0.0202
1 800	0.00963	0.0316	0.00588	0.0193	0.00983	0.0323	0.00599	0.0197
1 900	0.00913	0.0300	0.00557	0.0183	0.00931	0.0306	0.00568	0.0186
2 000	0.00867	0.0285	0.00529	0.0174	0.00885	0.0290	0.00539	0.0177
2 500	0.00701	0.0230	0.00427	0.0140	0.00715	0.0234	0.00436	0.0143
3 000	0.00584	0.0192	0.00356	0.0117	0.00596	0.0195	0.00363	0.0119
3 500	0.00505	0.0166	0.00308	0.0101	0.00515	0.0169	0.00314	0.0103
4 000	0.00442	0.0145	0.00270	0.00885	0.00451	0.0148	0.00275	0.00902
4 500	0.00397	0.0190	0.00242	0.00794	0.00405	0.0133	0.00247	0.00810
5 000	0.00357	0.0117	0.00218	0.00715	0.00364	0.0120	0.00222	0.00729

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Table 2-13 ▲

Nominal Direct-current Resistance of Annealed Coated Copper Conductors, Concentric Stranded Class B

Conductor Size, AWG or MCM	20°C		25°C		Conductor Size, AWG or MCM	20°C		25°C	
	ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km		ohms per 1000 Feet	ohms per km	ohms per 1000 Feet	ohms per km
22	...	...	...	...	400	0.0272	0.0893	0.0278	0.0911
20	11.0	36.0	11.2	36.7	450	0.0242	0.0794	0.0247	0.0809
19	...	...	...	...	500	0.0218	0.0714	0.0222	0.0729
18	6.92	22.7	7.05	23.1	550	0.0200	0.0656	0.0204	0.0669
17	...	...	...	...	600	0.0183	0.0602	0.0187	0.0613
16	4.35	14.3	4.44	14.6	650	0.0168	0.0550	0.0171	0.0560
15	...	...	...	...	700	0.0156	0.0510	0.0159	0.0520
14	2.68	8.78	2.73	8.96	750	0.0145	0.0476	0.0148	0.0486
13	2.12	6.96	2.16	7.10	800	0.0136	0.0447	0.0139	0.0455
12	1.69	5.53	1.72	5.64	900	0.0121	0.0397	0.0123	0.0405
11	1.34	4.39	1.36	4.47	1000	0.0109	0.0357	0.0111	0.0364
10	1.06	3.48	1.08	3.54	1100	0.00990	0.0325	0.0101	0.0331
9	0.841	2.76	0.857	2.81	1200	0.00907	0.0298	0.00925	0.0304
8	0.666	2.19	0.679	2.23	1250	0.00871	0.0286	0.00888	0.0291
7	0.528	1.73	0.539	1.77	1300	0.00838	0.0275	0.00854	0.0280
6	0.419	1.38	0.427	1.40	1400	0.00778	0.0255	0.00793	0.0260
5	0.333	1.09	0.339	1.11	1500	0.00726	0.0238	0.00740	0.0243
4	0.267	0.865	0.269	0.882	1600	0.00681	0.0223	0.00694	0.0228
3	0.209	0.686	0.213	0.699	1700	0.00641	0.0210	0.00653	0.0214
2	0.166	0.544	0.169	0.555	1750	0.00622	0.0204	0.00634	0.0208
1	0.131	0.431	0.134	0.440	1800	0.00605	0.0198	0.00617	0.0202
					1900	0.00573	0.0188	0.00584	0.0192
1/0	0.104	0.342	0.106	0.349	2000	0.00544	0.0179	0.00555	0.0182
2/0	0.0827	0.271	0.0843	0.277	2500	0.00440	0.0144	0.00448	0.0147
3/0	0.0656	0.215	0.0669	0.219	3000	0.00367	0.0120	0.00374	0.0123
4/0	0.0515	0.169	0.0525	0.172	3500	0.00317	0.0104	0.00323	0.0106
250	0.0440	0.144	0.0449	0.147	4000	0.00278	0.00911	0.00283	0.00928
300	0.0367	0.120	0.0374	0.123	4500	0.00249	0.00817	0.00254	0.00833
350	0.0314	0.103	0.0321	0.105	5000	0.00224	0.00735	0.00229	0.00750

▲ Revised 9-20-1978.

Table 2-14 ●
Nominal Direct-current Resistance of Annealed Coated Copper Conductors, Concentric Stranded, Class C and D

Conductor Size, AWG or MCM	Class C				Class D			
	20°		25°		20°		25°	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
14	2.73	8.97	2.79	9.14	2.76	9.07	2.82	9.24
13	2.17	7.12	2.21	7.26	2.17	7.12	2.21	7.26
12	1.72	5.64	1.75	5.76	1.72	5.64	1.75	5.76
11	1.34	4.39	1.36	4.47	1.37	4.48	1.39	4.57
10	1.06	3.48	1.08	3.55	1.08	3.55	1.10	3.62
9	0.840	2.76	0.857	2.81	0.858	2.82	0.875	2.87
8	0.666	2.19	0.679	2.23	0.666	2.19	0.679	2.23
7	0.528	1.73	0.539	1.77	0.528	1.73	0.539	1.77
6	0.419	1.38	0.427	1.40	0.419	1.38	0.427	1.40
5	0.332	1.09	0.339	1.11	0.332	1.09	0.339	1.11
4	0.264	0.865	0.269	0.882	0.264	0.865	0.269	0.882
3	0.209	0.686	0.213	0.699	0.209	0.686	0.213	0.699
2	0.166	0.544	0.169	0.555	0.166	0.544	0.169	0.555
1	0.131	0.431	0.134	0.440	0.131	0.431	0.134	0.440
1/0	0.104	0.342	0.106	0.348	0.104	0.342	0.106	0.348
2/0	0.0827	0.271	0.0843	0.276	0.0827	0.271	0.0843	0.276
3/0	0.0656	0.215	0.0668	0.219	0.0656	0.215	0.0668	0.219
4/0	0.0520	0.171	0.0530	0.174	0.0520	0.171	0.0530	0.174
250	0.0440	0.144	0.0449	0.147	0.0440	0.144	0.0449	0.147
300	0.0367	0.120	0.0374	0.123	0.0367	0.120	0.0374	0.123
350	0.0314	0.103	0.0320	0.105	0.0314	0.103	0.0320	0.105
400	0.0275	0.0902	0.0280	0.0920	0.0275	0.0902	0.0280	0.0920
450	0.0244	0.0802	0.0249	0.0818	0.0244	0.0802	0.0249	0.0818
500	0.0220	0.0722	0.0224	0.0736	0.0220	0.0722	0.0224	0.0736
550	0.0200	0.0656	0.0204	0.0669	0.0200	0.0656	0.0204	0.0669
600	0.0183	0.0602	0.0187	0.0613	0.0183	0.0602	0.0187	0.0613
650	0.0169	0.0555	0.0173	0.0566	0.0169	0.0555	0.0173	0.0566
700	0.0157	0.0516	0.0160	0.0526	0.0157	0.0516	0.0160	0.0526
750	0.0147	0.0481	0.0150	0.0491	0.0147	0.0481	0.0150	0.0491
800	0.0138	0.0451	0.0140	0.0460	0.0138	0.0451	0.0140	0.0460
900	0.0122	0.0401	0.0125	0.0409	0.0122	0.0401	0.0125	0.0409
1000	0.0109	0.0357	0.0111	0.0364	0.0110	0.0361	0.0112	0.0368
1100	0.0100	0.0328	0.0102	0.0335	0.0100	0.0328	0.0102	0.0335
1200	0.00917	0.0301	0.00935	0.0307	0.00917	0.0301	0.00935	0.0307
1250	0.00880	0.0289	0.00897	0.0294	0.00880	0.0289	0.00897	0.0294
1300	0.00846	0.0278	0.00863	0.0283	0.00846	0.0278	0.00863	0.0283
1400	0.00778	0.0255	0.00793	0.0260	0.00786	0.0258	0.00801	0.0263
1500	0.00726	0.0238	0.00740	0.0243	0.00733	0.0241	0.00748	0.0245
1600	0.00688	0.0226	0.00701	0.0230	0.00688	0.0226	0.00701	0.0230
1700	0.00647	0.0212	0.00660	0.0216	0.00647	0.0212	0.00660	0.0216
1750	0.00629	0.0206	0.00641	0.0210	0.00629	0.0206	0.00641	0.0210
1800	0.00605	0.0198	0.00617	0.0202	0.00611	0.0201	0.00623	0.0204
1900	0.00573	0.0188	0.00584	0.0192	0.00579	0.0190	0.00590	0.0194
2000	0.00544	0.0179	0.00555	0.0182	0.00550	0.0180	0.00561	0.0184

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Table 2-15 ●

Nominal Direct-current Resistance of Class G Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
14	2.60	8.53	2.65	8.69	2.76	9.06	2.81	9.23	.....	....	.....	....
12	1.64	5.37	1.67	5.47	1.74	5.70	1.77	5.81	.....	....	.....	....
10	1.03	3.38	1.05	3.44	1.09	3.59	1.11	3.66	.....	....	.....	....
9	0.816	2.68	0.832	2.73	0.867	2.84	0.884	2.90	.....	....	.....	....
8	0.647	2.12	0.660	2.16	0.687	2.25	0.701	2.30	.....	....	.....	....
7	0.513	1.68	0.523	1.72	0.534	1.75	0.544	1.78	0.841	2.76	0.858	2.82
6	0.407	1.34	0.415	1.36	0.423	1.39	0.432	1.42	0.667	2.19	0.681	2.23
5	0.323	1.06	0.329	1.08	0.336	1.10	0.342	1.12	0.529	1.74	0.540	1.77
4	0.256	0.840	0.261	0.856	0.266	0.873	0.271	0.890	0.420	1.38	0.428	1.40
3	0.203	0.666	0.207	0.679	0.211	0.693	0.215	0.706	0.333	1.09	0.340	1.11
2	0.161	0.528	0.164	0.539	0.167	0.549	0.171	0.560	0.264	0.866	0.269	0.883
1	0.129	0.423	0.131	0.431	0.134	0.440	0.137	0.448	0.211	0.693	0.216	0.707
1/0	0.102	0.335	0.104	0.342	0.106	0.348	0.108	0.355	0.167	0.549	0.171	0.560
2/0	0.0810	0.266	0.0826	0.271	0.0843	0.276	0.0859	0.282	0.133	0.436	0.136	0.445
3/0	0.0643	0.211	0.0655	0.215	0.0668	0.219	0.0682	0.224	0.105	0.346	0.107	0.353
4/0	0.0510	0.167	0.0520	0.171	0.0530	0.174	0.0541	0.177	0.0836	0.274	0.0852	0.280
250	0.0434	0.142	0.0442	0.145	0.0451	0.148	0.0460	0.151	0.0711	0.233	0.0725	0.238
300	0.0361	0.119	0.0368	0.121	0.0376	0.123	0.0383	0.126	0.0592	0.194	0.0604	0.198
350	0.0310	0.102	0.0316	0.104	0.0322	0.106	0.0328	0.108	0.0508	0.167	0.0518	0.170
400	0.0271	0.0889	0.0276	0.0906	0.0282	0.0924	0.0287	0.0943	0.0444	0.146	0.0453	0.149
450	0.0241	0.0790	0.0246	0.0806	0.0250	0.0822	0.0255	0.0838	0.0395	0.130	0.0403	0.132

(Continued)

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Table 2-15 (Continued) ●

Nominal Direct-current Resistance of Class G Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
500	0.0217	0.0711	0.0221	0.0725	0.0225	0.0740	0.0230	0.0754	0.0355	0.117	0.0363	0.119
550	0.0198	0.0650	0.0202	0.0662	0.0206	0.0676	0.0210	0.0689	0.0325	0.106	0.0331	0.109
600	0.0182	0.0595	0.0185	0.0607	0.0189	0.0619	0.0192	0.0631	0.0298	0.0976	0.0304	0.0996
650	0.0168	0.0550	0.0171	0.0560	0.0174	0.0572	0.0178	0.0583	0.0275	0.0901	0.0280	0.0919
700	0.0156	0.0510	0.0159	0.0520	0.0162	0.0531	0.0165	0.0541	0.0255	0.0837	0.0260	0.0854
750	0.0145	0.0476	0.0148	0.0486	0.0151	0.0495	0.0154	0.0505	0.0238	0.0781	0.0243	0.0797
800	0.0136	0.0447	0.0139	0.0455	0.0142	0.0464	0.0144	0.0474	0.0223	0.0732	0.0228	0.0747
900	0.0121	0.0397	0.0123	0.0405	0.0126	0.0413	0.0128	0.0421	0.0198	0.0651	0.0202	0.0664
1000	0.0109	0.0357	0.0111	0.0364	0.0113	0.0372	0.0115	0.0379	0.0179	0.0586	0.0182	0.0598
1100	0.0099	0.0325	0.0101	0.0331	0.0103	0.0338	0.0105	0.0344	0.0162	0.0532	0.0166	0.0543
1200	0.00908	0.0298	0.00925	0.0304	0.00944	0.0310	0.00962	0.0316	0.0149	0.0488	0.0152	0.0498
1250	0.00871	0.0286	0.00888	0.0291	0.00906	0.0297	0.00924	0.0303	0.0143	0.0469	0.0146	0.0478
1300	0.00838	0.0275	0.00854	0.0280	0.00871	0.0286	0.00888	0.0291	0.0137	0.0451	0.0140	0.0460
1400	0.00778	0.0255	0.00793	0.0260	0.00809	0.0265	0.00825	0.0271	0.0128	0.0418	0.0130	0.0427
1500	0.00726	0.0238	0.00740	0.0243	0.00755	0.0248	0.00770	0.0253	0.0119	0.0390	0.0121	0.0398
1600	0.00687	0.0225	0.00701	0.0230	0.00715	0.0234	0.00729	0.0239	0.0113	0.0370	0.0115	0.0377
1700	0.00647	0.0212	0.00659	0.0216	0.00673	0.0221	0.00686	0.0225	0.0106	0.0348	0.0108	0.0355
1750	0.00628	0.0206	0.00641	0.0210	0.00653	0.0214	0.00666	0.0219	0.0103	0.0338	0.0105	0.0345
1800	0.00611	0.0200	0.00623	0.0204	0.00635	0.0208	0.00648	0.0212	0.0100	0.0328	0.0102	0.0335
1900	0.00579	0.0190	0.00590	0.0194	0.00602	0.0197	0.00614	0.0201	0.00949	0.0311	0.00968	0.0317
2000	0.00550	0.0180	0.00561	0.0184	0.00572	0.0188	0.00583	0.0191	0.00901	0.0296	0.00919	0.0302

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Table 2-16 ●

Nominal Direct-current Resistance of Class H Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
8	0.653	2.14	0.666	2.19	0.694	2.28	0.708	2.32	.....	.....	.....	.....
7	0.518	1.70	0.528	1.73	0.550	1.81	0.561	1.84	.....	.....	.....	.....
6	0.411	1.35	0.419	1.38	0.437	1.43	0.445	1.46	.....	.....	.....	.....
5	0.326	1.07	0.332	1.09	0.346	1.14	0.353	1.16	.....	.....	.....	.....
4	0.258	0.848	0.263	0.864	0.274	0.900	0.280	0.918	.....	.....	.....	.....
3	0.205	0.673	0.209	0.686	0.218	0.714	0.222	0.728	.....	.....	.....	.....
2 (133 Wire)	0.163	0.533	0.166	0.544	0.169	0.555	0.172	0.565	0.266	0.874	0.272	0.892
2 (259 Wire)	0.163	0.536	0.167	0.546	0.173	0.569	0.177	0.580	.....	.....	.....	.....
1	0.130	0.425	0.132	0.433	0.138	0.451	0.140	0.460	.....	.....	.....	.....
1/0	0.103	0.337	0.105	0.343	0.107	0.350	0.109	0.357	0.168	0.552	0.172	0.563
2/0	0.0814	0.267	0.0830	0.272	0.0847	0.278	0.0863	0.283	0.133	0.438	0.136	0.447
3/0 (259 Wire)	0.0646	0.212	0.0659	0.216	0.0672	0.220	0.0685	0.225	0.106	0.347	0.108	0.354
3/0 (427 Wire)	0.0649	0.213	0.0662	0.217	0.0689	0.226	0.0703	0.231	.....	.....	.....	.....
4/0 (259 Wire)	0.0512	0.168	0.0522	0.171	0.0533	0.175	0.0543	0.178	0.0840	0.275	0.0857	0.281
4/0 (427 Wire)	0.0515	0.169	0.0525	0.172	0.0535	0.176	0.0546	0.179	0.0844	0.277	0.0861	0.282
250	0.0436	0.143	0.0444	0.146	0.0453	0.149	0.0462	0.152	0.0714	0.234	0.0728	0.239
300	0.0363	0.119	0.0370	0.121	0.0378	0.124	0.0385	0.126	0.0595	0.195	0.0607	0.199
350	0.0311	0.102	0.0317	0.104	0.0324	0.106	0.0330	0.108	0.0510	0.167	0.0520	0.171
400	0.0272	0.0893	0.0278	0.0911	0.0283	0.0929	0.0289	0.0947	0.0446	0.146	0.0455	0.149
450	0.0242	0.0794	0.0247	0.0810	0.0252	0.0826	0.0257	0.0842	0.0397	0.130	0.0405	0.133

(Continued)

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Table 2-16 (Continued) ●

Nominal Direct-current Resistance of Class H Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
500	0.0218	0.0715	0.0222	0.0729	0.0227	0.0743	0.0231	0.0758	0.0357	0.117	0.0364	0.120
550	0.0200	0.0656	0.0204	0.0669	0.0208	0.0682	0.0212	0.0695	0.0328	0.108	0.0334	0.110
600	0.0183	0.0601	0.0187	0.0613	0.0191	0.0625	0.0194	0.0637	0.0300	0.0985	0.0306	0.101
650	0.0169	0.0555	0.0172	0.0566	0.0176	0.0577	0.0179	0.0588	0.0277	0.0910	0.0283	0.0928
700	0.0157	0.0515	0.0160	0.0525	0.0163	0.0536	0.0167	0.0546	0.0257	0.0845	0.0263	0.0862
750	0.0147	0.0481	0.0149	0.0490	0.0152	0.0500	0.0155	0.0510	0.0240	0.0788	0.0245	0.0804
800	0.0137	0.0451	0.0140	0.0460	0.0143	0.0469	0.0146	0.0478	0.0225	0.0739	0.0230	0.0754
900	0.0122	0.0401	0.0125	0.0409	0.0127	0.0417	0.0130	0.0425	0.0200	0.0657	0.0204	0.0670
1000	0.0110	0.0361	0.0112	0.0368	0.0114	0.0375	0.0117	0.0382	0.0180	0.0591	0.0184	0.0603
1100	0.00999	0.0328	0.0102	0.0334	0.0104	0.0341	0.0106	0.0347	0.0164	0.0538	0.0167	0.0548
1200	0.00916	0.0301	0.00934	0.0306	0.00953	0.0313	0.00971	0.0319	0.0150	0.0493	0.0153	0.0503
1250	0.00879	0.0289	0.00897	0.0294	0.00915	0.0300	0.00933	0.0306	0.0144	0.0473	0.0147	0.0483
1300	0.00846	0.0277	0.00862	0.0283	0.00879	0.0289	0.00897	0.0294	0.0139	0.0455	0.0141	0.0464
1400	0.00785	0.0258	0.00801	0.0263	0.00817	0.0268	0.00833	0.0273	0.0129	0.0422	0.0131	0.0431
1500	0.00733	0.0240	0.00747	0.0245	0.00762	0.0250	0.00777	0.0255	0.0120	0.0394	0.0123	0.0402
1600	0.00687	0.0225	0.00701	0.0230	0.00715	0.0234	0.00729	0.0239	0.0113	0.0370	0.0115	0.0377
1700	0.00647	0.0212	0.00659	0.0216	0.00673	0.0221	0.00686	0.0225	0.0106	0.0348	0.0108	0.0355
1750	0.00628	0.0206	0.00641	0.0210	0.00653	0.0214	0.00666	0.0219	0.0103	0.0338	0.0105	0.0345
1800	0.00611	0.0200	0.00623	0.0204	0.00635	0.0208	0.00648	0.0212	0.0100	0.0328	0.0102	0.0335
1900	0.00579	0.0190	0.00590	0.0194	0.00602	0.0197	0.00614	0.0201	0.00949	0.0311	0.00968	0.0317
2000	0.00550	0.0180	0.00561	0.0184	0.00572	0.0188	0.00583	0.0191	0.00901	0.0296	0.00919	0.0302

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Table 2-17 ●

Nominal Direct-current Resistance of Class 1 Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
10	1.02	3.34	1.04	3.41	1.06	3.48	1.08	3.55	....	....	....	....
9	0.808	2.65	0.824	2.70	0.840	2.76	0.857	2.81	....	....	....	....
8	0.641	2.10	0.653	2.14	0.666	2.19	0.679	2.23	1.05	3.45	1.07	3.52
7	0.508	1.67	0.518	1.70	0.528	1.73	0.539	1.77	0.833	2.73	0.850	2.79
6	0.411	1.35	0.419	1.38	0.427	1.40	0.436	1.43	0.674	2.21	0.687	2.26
5	0.326	1.07	0.332	1.09	0.339	1.11	0.346	1.13	0.534	1.75	0.545	1.79
4	0.258	0.848	0.263	0.864	0.269	0.882	0.274	0.899	0.424	1.39	0.432	1.42
3	0.205	0.673	0.209	0.686	0.213	0.699	0.217	0.713	0.336	1.10	0.343	1.12
2	0.163	0.533	0.166	0.544	0.169	0.555	0.172	0.565	0.266	0.874	0.272	0.892
1	0.129	0.423	0.131	0.431	0.134	0.440	0.137	0.448	0.211	0.693	0.216	0.707
1/0	0.103	0.338	0.105	0.345	0.107	0.352	0.109	0.359	0.169	0.555	0.172	0.566
2/0	0.0818	0.268	0.0834	0.274	0.0851	0.279	0.0868	0.285	0.134	0.440	0.137	0.449
3/0	0.0649	0.213	0.0662	0.217	0.0675	0.221	0.0688	0.226	0.106	0.349	0.109	0.356
4/0	0.0515	0.169	0.0525	0.172	0.0535	0.176	0.0546	0.179	0.0844	0.277	0.0861	0.282
250	0.0440	0.144	0.0448	0.147	0.0457	0.150	0.0466	0.153	0.0721	0.237	0.0735	0.241
300	0.0366	0.120	0.0374	0.123	0.0381	0.125	0.0389	0.127	0.0601	0.197	0.0613	0.201
350	0.0314	0.103	0.0320	0.105	0.0327	0.107	0.0333	0.109	0.0515	0.169	0.0525	0.172
400	0.0275	0.0902	0.0280	0.0919	0.0286	0.0938	0.0291	0.0956	0.0451	0.148	0.0460	0.151
450	0.0244	0.0801	0.0249	0.0817	0.0254	0.0833	0.0259	0.0850	0.0400	0.131	0.0409	0.134
500	0.0220	0.0721	0.0224	0.0736	0.0229	0.0750	0.0233	0.0765	0.0360	0.118	0.0368	0.121

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Table 2-17 (Continued) ●

Nominal Direct-current Resistance of Class I Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper				Aluminum			
	20°C		25°C		20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
550	0.0200	0.0656	0.0204	0.0669	0.0208	0.0682	0.0212	0.0695	0.0328	0.108	0.0334	0.110
600	0.0183	0.0601	0.0187	0.0613	0.0191	0.0625	0.0194	0.0637	0.0300	0.0985	0.0306	0.101
650	0.0171	0.0560	0.0174	0.0571	0.0178	0.0582	0.0181	0.0594	0.0280	0.0918	0.0286	0.0937
700	0.0159	0.0520	0.0162	0.0530	0.0165	0.0541	0.0168	0.0552	0.0260	0.0853	0.0265	0.0870
750	0.0148	0.0485	0.0151	0.0495	0.0154	0.0505	0.0157	0.0515	0.0243	0.0796	0.0247	0.0812
800	0.0139	0.0455	0.0141	0.0464	0.0144	0.0473	0.0147	0.0483	0.0227	0.0746	0.0232	0.0761
900	0.0123	0.0405	0.0126	0.0412	0.0128	0.0421	0.0131	0.0429	0.0202	0.0663	0.0206	0.0677
1000	0.0111	0.0364	0.0113	0.0371	0.0115	0.0379	0.0118	0.0386	0.0182	0.0597	0.0186	0.0609
1100	0.0101	0.0331	0.0103	0.0337	0.0105	0.0344	0.0107	0.0351	0.0165	0.0543	0.0169	0.0554
1200	0.00925	0.0303	0.00943	0.0309	0.00962	0.0316	0.00981	0.0322	0.0152	0.0497	0.0155	0.0507
1250	0.00888	0.0291	0.00905	0.0297	0.00923	0.0303	0.00941	0.0309	0.0146	0.0477	0.0148	0.0487
1300	0.00854	0.0280	0.00870	0.0286	0.00888	0.0291	0.00905	0.0297	0.0140	0.0459	0.0143	0.0468
1400	0.00793	0.0260	0.00808	0.0265	0.00824	0.0270	0.00841	0.0276	0.0130	0.0426	0.0133	0.0435
1500	0.00740	0.0243	0.00754	0.0247	0.00769	0.0252	0.00785	0.0257	0.0121	0.0398	0.0124	0.0406
1600	0.00694	0.0228	0.00707	0.0232	0.00721	0.0237	0.00735	0.0241	0.0114	0.0373	0.0116	0.0381
1700	0.00653	0.0214	0.00666	0.0218	0.00679	0.0223	0.00692	0.0227	0.0107	0.0351	0.0109	0.0358
1750	0.00634	0.0208	0.00647	0.0212	0.00659	0.0216	0.00672	0.0221	0.0104	0.0341	0.0106	0.0348
1800	0.00617	0.0202	0.00629	0.0206	0.00641	0.0210	0.00654	0.0214	0.0101	0.0332	0.0103	0.0338
1900	0.00584	0.0192	0.00596	0.0195	0.00607	0.0199	0.00619	0.0203	0.00958	0.0314	0.00977	0.0320
2000	0.00555	0.0182	0.00566	0.0186	0.00577	0.0189	0.00588	0.0193	0.00910	0.0298	0.00928	0.0304

● Added 9-20-1978.

Table 2-18 ●

Nominal Direct-current Resistance of Class K Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper			
	20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
20	10.4	34.0	10.6	34.7	11.1	36.5	11.4	37.2
18	6.53	21.4	6.66	21.8	7.01	23.0	7.15	23.4
16	4.10	13.5	4.18	13.7	4.40	14.4	4.49	14.7
14	2.57	8.44	2.62	8.61	2.76	9.07	2.82	9.24
12	1.62	5.32	1.65	5.42	1.74	5.71	1.77	5.82
10	1.02	3.34	1.04	3.41	1.09	3.59	1.12	3.66
9	0.824	2.70	0.840	2.76	0.885	2.90	0.902	2.96
8	0.653	2.14	0.666	2.19	0.701	2.30	0.715	2.35
7	0.518	1.70	0.528	1.73	0.556	1.83	0.567	1.86
6	0.411	1.35	0.419	1.38	0.441	1.45	0.450	1.48
5	0.326	1.07	0.332	1.09	0.350	1.15	0.357	1.17
4	0.258	0.848	0.263	0.864	0.277	0.910	0.283	0.928
3	0.207	0.679	0.211	0.692	0.222	0.729	0.227	0.743
2	0.164	0.538	0.167	0.549	0.176	0.578	0.180	0.589
1	0.130	0.427	0.133	0.435	0.140	0.458	0.142	0.467
1/0	0.103	0.338	0.105	0.345	0.111	0.363	0.113	0.370
2/0	0.0826	0.271	0.0842	0.276	0.0887	0.291	0.0904	0.297
3/0	0.0655	0.215	0.0668	0.219	0.0703	0.231	0.0717	0.235
4/0	0.0520	0.170	0.0530	0.174	0.0558	0.183	0.0569	0.187
250	0.0440	0.144	0.0448	0.147	0.0472	0.155	0.0481	0.158
300	0.0366	0.120	0.0374	0.123	0.0393	0.129	0.0401	0.132
350	0.0317	0.104	0.0323	0.106	0.0340	0.112	0.0347	0.114
400	0.0277	0.0910	0.0283	0.0928	0.0298	0.0977	0.0304	0.0996
450	0.0247	0.0809	0.0251	0.0825	0.0265	0.0869	0.0270	0.0886
500	0.0222	0.0728	0.0226	0.0742	0.0238	0.0782	0.0243	0.0797
550	0.0202	0.0662	0.0206	0.0675	0.0217	0.0711	0.0221	0.0725
600	0.0185	0.0607	0.0189	0.0619	0.0199	0.0651	0.0203	0.0664
650	0.0171	0.0560	0.0174	0.0571	0.0183	0.0601	0.0187	0.0613
700	0.0159	0.0520	0.0162	0.0530	0.0170	0.0558	0.0174	0.0569
750	0.0148	0.0485	0.0151	0.0495	0.0159	0.0521	0.0162	0.0531
800	0.0139	0.0455	0.0141	0.0464	0.0149	0.0489	0.0152	0.0498
900	0.0123	0.0405	0.0126	0.0412	0.0132	0.0434	0.0135	0.0443
1000	0.0111	0.0364	0.0113	0.0371	0.0119	0.0391	0.0122	0.0399

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Table 2-19 ●
Nominal Direct-current Resistance of Class M Stranded Conductors

Conductor Size, AWG or MCM	Annealed Uncoated Copper				Annealed Coated Copper			
	20°C		25°C		20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
20	10.4	34.0	10.6	34.7	11.1	36.5	11.4	37.2
18	6.53	21.4	6.66	21.8	7.01	23.0	7.15	23.4
16	4.10	13.5	4.18	13.7	4.40	14.4	4.49	14.7
14	2.57	8.44	2.62	8.61	2.76	9.07	2.82	9.24
12	1.65	5.42	1.68	5.53	1.77	5.82	1.81	5.93
10	1.04	3.41	1.06	3.48	1.12	3.66	1.14	3.73
9	0.824	2.70	0.840	2.76	0.88	2.90	0.902	2.96
8	0.653	2.14	0.666	2.19	0.701	2.30	0.715	2.35
7	0.523	1.72	0.533	1.75	0.561	1.84	0.573	1.88
6	0.415	1.36	0.423	1.39	0.446	1.46	0.454	1.49
5	0.329	1.08	0.336	1.10	0.353	1.16	0.360	1.18
4	0.261	0.856	0.266	0.87	0.280	0.919	0.286	0.937
3	0.209	0.685	0.213	0.69	0.222	0.729	0.227	0.743
2	0.166	0.543	0.169	0.554	0.178	0.583	0.181	0.595
1	0.131	0.431	0.134	0.439	0.141	0.463	0.144	0.472
1/0	0.104	0.342	0.106	0.348	0.112	0.367	0.114	0.374
2/0	0.0834	0.279	0.0850	0.279	0.0895	0.294	0.0913	0.299
3/0	0.0661	0.217	0.0674	0.221	0.0710	0.233	0.0724	0.237
4/0	0.0524	0.172	0.0535	0.175	0.0563	0.185	0.0574	0.188
250	0.0444	0.146	0.0453	0.148	0.0477	0.156	0.0486	0.159
300	0.0370	0.121	0.0377	0.123	0.0397	0.130	0.0405	0.133
350	0.0317	0.104	0.0323	0.106	0.0340	0.112	0.0347	0.114
400	0.0277	0.0910	0.0283	0.0928	0.0298	0.0977	0.0304	0.0996
450	0.0247	0.0809	0.0251	0.0825	0.0256	0.0841	0.0262	0.0858
500	0.0222	0.0728	0.0226	0.0742	0.0238	0.0782	0.0243	0.0797
550	0.0202	0.0662	0.0206	0.0675	0.0217	0.0711	0.0221	0.0725
600	0.0185	0.0607	0.0189	0.0619	0.0199	0.0651	0.0202	0.0664
650	0.0171	0.0560	0.0174	0.0571	0.0183	0.0601	0.0187	0.0613
700	0.0159	0.0520	0.0162	0.0530	0.0170	0.0558	0.0174	0.0569
750	0.0148	0.0485	0.0151	0.0495	0.0159	0.0521	0.0162	0.0531
800	0.0139	0.0455	0.0141	0.0464	0.0149	0.0489	0.0152	0.0498
900	0.0123	0.0405	0.0126	0.0412	0.0132	0.0434	0.0135	0.0443
1000	0.0111	0.0364	0.0113	0.0371	0.0119	0.0391	0.0121	0.0399

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Table 2-20 ▲

Factors for Determining Nominal Resistance of Stranded Conductors per 1000 Feet

	All Sizes, Uncoated				Diameter of Individual Coated Copper Wires in Inches for Stranded Conductors									
					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 0.0030, Inclusive	
	Aluminum		Copper											
Minimum Conductivity, Percent	61		100		97.66		97.16		96.16		94.16		93.15	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
Concentric Stranded														
Up to 2000 MCM	17342	17691	10579	10786	10832	11045	10888	11102	11001	11217	11235	11456	11356	11579
Rope Stranded														
49 strands	17512	17865	10682	10892	10938	11153	10994	11210	11109	11327	11345	11568	...	...
133 strands	17682	18038	10786	10998	11044	11261	11101	11319	11217	11437	11455	11681	...	...
259 strands	17767	18125	10838	11051	11097	11315	11155	11374	11271	11492	11511	11737	...	...
427 strands	17852	18212	10890	11104	11150	11370	11208	11428	11325	11547	11566	11793	...	...
Over 427 strands	18022	18385	10993	11209	11257	11478	11315	11537	11432	11657	11676	11905	...	...
Bunch Stranded														
All sizes	17342	17691	10579	10786	...	...	...	...	11001	11217	11235	11456	11356	11579
Rope-stranded Bunches														
7 ropes of bunched strand	17682	18038	10786	10998	...	...	...	...	11217	11437	11455	11681	11579	11806
19, 37, or 61 ropes of bunched strand	17852	18212	10890	11104	...	...	...	...	11325	11547	11566	11793	11690	11920
7 x 7 ropes of bunched strand	18022	18385	10993	11209	...	...	...	...	11432	11657	11676	11905	11801	12033
19, 37, or 61 x 7 ropes of bunched strand	18192	18559	11097	11315	...	...	...	...	11540	11767	11786	12018	11913	12147

The direct-current resistance of the conductor per 1000 feet at 20°C or 25°C shall not exceed by more than 2 percent the value calculated by dividing the appropriate factor from the above table by the nominal circular mil area of the conductor as given in 2.5.1.2. For the resistance of conductors of multiple-conductor cables, see 2.5.2.3.

The factors in the above table are based on the following:

A. Copper

1. A resistance of 10.371 ohms—circular mil foot at 20°C and 10.575 ohms—circular mil foot at 25°C for 100 percent conductivity.
2. Conductivity for coated copper wire corresponding to resistivities specified in ASTM B 33 or ASTM B 189 (see Appendix E).

B. Aluminum

1. A resistance of 17.002 ohms—circular mil foot at 20°C and 17.345 ohms—circular mil foot at 25°C for 61 percent conductivity.

C. Weight and resistance allowance for stranding.

1. For concentric stranded, Classes B, C and D Up to 2,000 MCM 2%
2. For rope stranded, Classes G and H
   - 49 Strands 3%
   - 133 Strands 4%
   - 259 Strands 4.5%
   - 427 Strands 5%
   - Over 427 Strands 6%
3. Bunch stranded (single bunches)—all sizes 2%
4. Rope-stranded bunches
   - 7 ropes of bunched strands 4%
   - 19, 37 or 61 ropes of bunched strands.... 5%
   - 7 x 7 ropes of bunched strands 6%
   - 19, 37 or 61 x 7 ropes of bunched strands.. 7%

▲ Formerly Table 2-14; revised 9-20-1978.

Table 2-21▲
Temperature Correction Factors for Resistance of Copper Conductors

Temperature, Degrees C	Multiplying Factors for Reduction to 20°C	Multiplying Factors for Reduction to 25°C
0	1.085	1.107
5	1.063	1.084
10	1.041	1.061
15	1.020	1.040
20	1.000	1.020
25	0.981	1.000
30	0.962	0.981
35	0.944	0.963
40	0.927	0.945
45	0.911	0.928
50	0.895	0.912
55	0.879	0.896
60	0.864	0.881
65	0.850	0.866
70	0.836	0.852
75	0.822	0.838
80	0.809	0.825
85	0.797	0.812
90	0.784	0.800

The correction factors given in this table are satisfactory for most applications. They are based upon copper having 100 percent conductivity and are derived from the formulae:

$$R_1 = R_2 \frac{254.5}{234.5 + T_2}$$

$$R_3 = R_2 \frac{259.5}{234.5 + T_2}$$

Where—

R_1 = Resistance at 20°C.

R_2 = Measured resistance at test temperature, T_2.

R_3 = Resistance at 25°C.

For more accurate determination of resistance, allowing for different conductivities, see "Copper Wire Tables", National Bureau of Standards, Handbook No. 100 and ASTM B 193.

Table 2-22▲
Temperature Correction Factors for Resistance of Aluminum Conductors

Temperature, Degrees C	Multiplying Factors for Reduction to 20°C	Multiplying Factors for Reduction to 25°C
0	1.088	1.110
5	1.064	1.085
10	1.042	1.063
15	1.020	1.041
20	1.000	1.020
25	0.980	1.000
30	0.961	0.981
35	0.943	0.962
40	0.925	0.944
45	0.908	0.927
50	0.892	0.910
55	0.876	0.894
60	0.861	0.878
65	0.846	0.863
70	0.832	0.849
75	0.818	0.835
80	0.805	0.821
85	0.792	0.808
90	0.780	0.796

The correction factors given in this table are satisfactory for most applications. They are based upon aluminum having 61 percent conductivity and are derived from the formulae:

$$R_1 = R_2 \frac{248}{228 + T_2}$$

$$R_3 = R_2 \frac{253}{228 + T_2}$$

Where—

R_1 = Resistance at 20°C.

R_2 = Measured resistance at test temperature, T_2.

R_3 = Resistance at 25°C.

▲ Tables 2-21 and 2-22 formerly Tables 2-15 and 2-16; revised 9-20-1978.

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Part 3
INSULATION

3.1 Material The insulation shall be a thermoplastic type of compound meeting the dimensional, electrical, and physical requirements specified in Part 3.

3.2 Insulation Thicknesses. The insulation thicknesses given in Tables 3-1 and 3-2 are based on the rated circuit voltage, phase to phase, and on the cable insulation level.

The thicknesses of insulation given in Tables 3-1 and 3-2 shall apply to single-conductor cables and to the individual conductors of multiple-conductor cables, except as otherwise specified in 3.3 and 3.4.

The average thickness of the insulation shall be not less than that given in Tables 3-1 and 3-2. The minimum thickness shall be not less than 90 percent of the values given in Tables 3-1 and 3-2. (See 6.4.3 for method of measurement.)

3.2.1 The thickness of insulation for the various systems shall be determined as follows:

▲3.2.1.1 Three-Phase Systems With 100 or 133 Percent Insulation Level. Use the thickness values given in the respective columns of Tables 3-1 and 3-2.

3.2.1.2 Delta Systems Rated 2001 Volts and Over Where One Leg May Be Grounded for Periods Over 1 Hour. See 173 percent level in † † note following Table 3-2.

▲3.2.1.3 Single- and Two-Phase Systems With 100 Percent Insulation Level. Multiply the voltage to ground by 1.73 and use the resulting voltage value to select the corresponding insulation thickness in the 100 percent insulation level columns of Tables 3-1 and 3-2.

3.2.1.4 Single- and Two-Phase Systems With 133 Percent Insulation Level. Select the thickness for the circuit voltage (phase to phase) from the 133 percent insulation level column of Tables 3-1 and 3-2.

3.2.1.5 Direct-current Systems Up to and Including 2000 Volts. Consider the same as single-phase alternating-current systems in accordance with 3.2.1.3 and 3.2.1.4. For direct-current systems over 2000 volts, consult the manufacturer.

▲3.3 Insulation Thicknesses for Submarine Power Cables and Control Cables

3.3.1 For submarine power and control cables with polyvinyl-chloride insulation and without a thermoplastic jacket or a metallic sheath, 15 mils (0.38 mm) shall be added to the insulation thicknesses given in Table 3-1. For polyethylene-insulated submarine power and control cables, the insulation thickness shall be as given in Table 3-2 except that, for cable without a jacket or a sheath, it shall be not less than 60 mils.

3.3.2 For single-conductor polyvinyl-chloride-insulated power cables without a thermoplastic jacket or continuous metallic sheath and for installation in underground ducts or direct earth burial, 15 mils (0.38 mm) shall be added to the insulation thicknesses given in Table 3-1.

▲3.4 Insulation Thicknesses for Series Lighting Circuits. The average thickness of insulation for cables for use on series lighting circuits shall be not less than that given in Table 3-3. The minimum thickness shall be not less than 90 percent of the values given in Table 3-3. (See 6.4.3 for method of measurement.)

3.5 Repairs. Repairs or joints in the insulation shall conform to the limitations on insulation thickness given in 3.2. Each length of insulated conductor containing repairs or joints shall meet the electrical tests specified in 3.7 through 3.9, as applicable.

3.6 Insulation Types and Requirements

3.6.1 The types of insulations shall be (1) polyvinyl chloride (including copolymers of vinyl chloride and vinyl acetate) (see 3.7 and 3.8) and (2) polyethylene (see 3.9).

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▲3.6.2 **Voltage Tests (See 6.11).** Completed cable shall be tested in accordance with the paragraphs specified in Table 3-4. The cable shall withstand, without failure, the test voltages given in Table 3-1, 3-2, or 3-3, 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 Constants. The insulation resistance constants of insulations shall be in accordance with 3.7, 3.8, or 3.9, as applicable (see 6.12 for test methods).

Table 3-4
Schedule of Voltage Tests

	Single-conductor Cables	Assemblies of Insulated Single Conductors	Assemblies of Insulated and Uninsulated Conductors	Multiple-conductor Cables with Common Covering
1. Cables Without Insulation Shield				
a. 0-2000 Volts				
▲ (1) Without metallic sheath or armor	6.11.2 or 6.11.3 or 6.11.4a or 6.11.4b	6.11.2 or 6.11.3 or 6.11.4a or 6.11.4b	6.11.2 or 6.11.3	6.11.2 or 6.11.3
(2) With metallic sheath or armor.	6.11.2 or 6.11.3	6.11.2 or 6.11.3	6.11.2 or 6.11.3	6.11.2 or 6.11.3
b. 2001-5000 Volts	6.11.2 or 6.11.3	6.11.2 or 6.11.3	6.11.2 or 6.11.3	6.11.2 or 6.11.3
2. Cables With Insulation Shield				
a. 0-5000 Volts	6.11.2	6.11.2	6.11.2	6.11.2
b. 5001 volts and over	6.11.2 and 6.11.3	6.11.2 and 6.11.3	6.11.2 and 6.11.3	6.11.2 and 6.11.3

▲ See Part 6 for:
6.11.2 alternating-current voltage test
6.11.3 direct-current voltage test
6.11.4a alternating-current spark test
6.11.4b direct-current spark test

▲ Editorially revised.

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Table 3-1
Conductor Sizes, Insulation Thicknesses and Test Voltages for Polyvinyl-chloride-insulated Power Cables †

Rated Circuit Voltage, Phase to Phase, Volts **	Conductor Size, AWG or kcmil▲	Insulation Thickness for 100 and 133 Percent Insulation Levels *		Test Voltage, kV, for 100 and 133 Percent Insulation Levels *		d-c Spark Test Voltage, kV, for 100 and 133 Percent Insulation Levels	a-c Spark Test Voltage, kV, for 100 and 133 Percent Insulation Levels
		mils	mm	a-c	d-c		
0-600	18-16 ‡	30	0.76	1.5	...	...	...
	14-9 ‡	45	1.14	3.0	9.0	9.0	7.5
	8-2	60	1.52	3.5	10.5	10.5	10.0
	1-4/0	80	2.03	4.0	12.0	12.5	12.5
	225-500	95	2.41	5.0	15.0	15.0	15.0
	501-1000	110	2.79	6.0	18.0	18.0	17.5
	Over 1000	125	3.18	7.0	21.0	21.0	20.0

* See †† note following Table 3-2.

† For series lighting cables, see Table 3-3. For control cables, see 7.4.

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

** 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 1—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 2—The thicknesses given in Table 3-1 apply to aerial cables and to single conductors installed in conduits above ground and to the individual conductors of all multiple-conductor cables having a common jacket or metallic sheath over the assembly, with the following exceptions:

For single-conductor cables for installation in underground ducts or direct earth burial and for all submarine cables, add 15 mils (0.38 mm) to the insulation thicknesses given in Table 3-1 when such cables do not have a thermoplastic jacket or metallic sheath over the assembly.

NOTE 3—a-c voltages are rms values. ‡‡

NOTE 4—a-c spark test voltages are taken from Table 47.1 of UL Standard 83, Thermoplastic Insulated Wires, 6th Edition. ‡‡

‡‡ Approved by NEMA as Authorized Engineering Information.

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Table 3-2

Conductor Sizes, Insulation Thicknesses and Test Voltages for Polyethylene-insulated Power Cables *

Rated Circuit Voltage, Phase to Phase, Volts †	Conductor Size, AWG or kcmil ▲	Insulation Thickness ## for 100 and 133 Percent Insulation Levels † †				a-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels † †		d-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels † †		d-c Spark Test Voltage, kV, for 100 and 133 Percent Insulation Levels	
		Column A		Column B							
		mils	mm	mils	mm	Column A	Column B	Column A	Column B	Column A	Column B
0-600	14-9 ‡	45	1.14	30	0.76	4.0	3.5	12.0	10.5	16.0	10.5
	8-2	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5
	1-4/0	80	2.03	55	1.40	7.0	7.0	21.0	21.0	28.0	21.0
	225-500	95	2.41	65	1.65	8.0	8.0	24.0	24.0	33.5	24.0
	525-1000	110	2.79	80	2.03	10.0	10.0	30.0	30.0	38.5	30.0
601-2000	14-9 ‡	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5
	8-2	70	1.78	55	1.40	7.0	7.0	21.0	21.0	24.5	21.0
	1-4/0	90	2.29	65	1.65	8.0	8.0	24.0	24.0	31.5	24.0
	225-500	105	2.67	75	1.90	9.5	9.5	28.5	28.5	37.0	28.5
	525-1000	120	3.05	90	2.29	11.5	11.5	34.5	34.5	42.0	34.5
		100 Percent Insulation Level #		133 Percent Insulation Level		100 Percent Insulation Level #	133 Percent Insulation Level	100 Percent Insulation Level#	133 Percent Insulation Level		
						NONSHIELDED * * *					
2001-5000	8-4/0	110	2.79	110	2.79	13	13	35	35	....	....
	225-500	120	3.05	120	3.05	13	13	35	35	....	....
	525-1000	130	3.30	130	3.30	13	13	35	35	....	....
						SHIELDED					
2001-5000	8-1000	90	2.29	90	2.29	13	13	...	...	....	....
5001-8000	6-1000	115	2.92	140	3.56	18	22	45	45	....	....
8001-15000	2-1000 * *	175	4.45	215	5.46	27	33	70	80	....	....
15001-25000	1-1000	260	6.60	345	8.76	38	49	100	125	....	....
25001-28000	1-1000	280	7.11	...	....	42	..	105	...	....	....
28001-35000	1/0-1000	345	8.76	...	....	49	..	125	...	....	....

See Part 3, Page 5, for notes applying to Table 3-2.

▲ Editorially revised.

(Continued)

Notes applying to Table 3-2.

* For series lighting cables, see Table 3-3. For control cables, see 7.4.

† 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.

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

** For 133 percent insulation level, the minimum conductor size is 1 AWG.

†† The selection of the cable insulation level to be used in a particular installation shall be made on the basis of the applicable phase-to-phase voltage and the general system category as outlined below:

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. Also they may be used when additional insulation strength over the 100 percent level category is desirable.

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. Consult the manufacturer for insulation thicknesses.

‡‡ 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.

Where additional insulation thickness is desired, it shall be the same as for the 133 percent insulation level.

***Where cable is provided with a protective covering, these insulation thicknesses shall be 90 mils (2.29 mm) for all conductor sizes listed. Refer to 4.2 for limitations on the use of non-shielded cables rated 2001-5000 volts.

##—Column A thicknesses (0-2000 volts) apply to single-conductor power cables for general application when a black pigmented insulation is used without a further covering. Column B thicknesses (0-2000 volts) apply to multiple-conductor cables with an outer covering and to single-conductor cables with an outer covering. ▲

NOTE 1—To limit the maximum voltage stress on the insulation at the conductor to a safe value, the minimum size of the conductor shall be in accordance with Table 3-2.

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. (This paragraph is approved by NEMA as Authorized Engineering Information.) ▲

NOTE 2—Polyethylene insulation used on non-shielded cable without an outer covering shall be black pigmented insulation meeting the requirements for both polyethylene insulation (see 3.9) and polyethylene jacket (see 4.3.2). ▲

NOTE 3—Polyethylene insulation used on non-shielded cable without an outer covering for rated circuit voltages of 2001-5000 volts shall be discharge resistant when tested in accordance with 4.3.4.

NOTE 4—Carbon-black-pigmented polyethylene insulation shall not be used on power cable rated over 5000 volts. ▲

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Table 3-3
Conductor Sizes, Insulation Thicknesses and Test Voltages for
Thermoplastic-insulated Series Lighting Cables

Circuit Voltage, Volts * †	Conductor Size, AWG	Insulation Thickness * mils	Insulation Thickness * mm	Test Voltage, kV a-c	Test Voltage, kV d-c	d-c Spark Test Voltage, kV
		POLYVINYL-CHLORIDE-INSULATED CABLES				
0-3000	8	110	2.79	10.0	30.0	....
	6-4	125	3.18	10.0	30.0	....
3001-5000	8-4	155	3.94	13.0	35.0	....
		POLYETHYLENE-INSULATED CABLES				
0-1000	10-8 ‡	45	1.14	5.5	16.5	16.5
	6-4	55	1.40	7.0	21.0	21.0
1001-2000	10-8 ‡	55	1.40	7.0	21.0	21.0
	6-4	65	1.65	8.0	24.0	24.0
2001-3000	10-8 ‡	75	1.90	10	30	....
	6-4	90	2.29	10	30	....
3001-6000	8-4	110	2.79	13	35	....
6001-9000	8-4	150	3.81	19	55	....

* A separate jacket is not required. If protectors are employed, the thickness shall be determined by the full-load voltage. If the circuit is to be operated without protectors, the thickness shall be determined by the open-circuit voltage.

† The highest circuit voltage at each step represents the maximum operating voltage recommended for that thickness of insulation.

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

The following tabulation of series lighting transformer ratings is representative of those in common use * *:

Rating, kW	6.6 Ampere Secondary: Full-load Voltage, Volts, With Protectors	6.6 Ampere Secondary: Open-circuit Voltage, Volts, Without Protectors	20 Ampere Secondary: Full-load Voltage, Volts, With Protectors	20 Ampere Secondary: Open-circuit Voltage, Volts, Without Protectors
10	1515	2090	500	690
15	2272	3090	750	1020
20	3030	4115	1000	1360
25	3787	5110	1250	1685
30	4545	6130	1500	2020
40	6060	8180	2000	2700

* * This paragraph is approved by NEMA as Authorized Engineering Information.

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3.7 Polyvinyl Chloride 60°C. This insulation is suitable for use at conductor temperatures not exceeding 60°C (140°F), in dry or wet locations, at a maximum voltage rating of 600 volts for power circuits, 1000 volts for control circuits, and 5000 volts for series lighting circuits.

▲3.7.1 Physical and Aging Requirements (See 6.4). The insulation shall meet the following requirements:

Physical Requirements	
Tensile strength, minimum	
psi	1500
MPa	10.3
Elongation at rupture, minimum, percent	100
Aging Requirements	
After air oven test at 100°C ± 1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	65
Elongation at rupture, minimum, percentage of unaged value	65 *
After oil immersion at 70°C ± 1°C for 4 hours	
Tensile strength, minimum, percentage of unaged value	85 *
Elongation at rupture, minimum, percentage of unaged value	85 *
Heat distortion, 121°C ± 1°C, maximum, percentage of unaged value	50
Heat shock, 121°C ± 1°C	no cracks
Cold bend, -10°C ± 1°C	no cracks
Flame test	see 6.5

* For sizes 6 AWG and larger where buffed die-cut specimens are used, the minimum elongation and tensile strength, as a percentage of the unaged values, shall be not less than the following:

1. Elongation after air oven test 45%
2. Tensile strength after oil immersion 80%
3. Elongation after oil immersion 60%

3.7.2 Electrical Requirements

3.7.2.1 Voltage Tests. See 3.6.2.

▲3.7.2.2 Insulation Resistance Test (See 6.12). Each insulated conductor, size 14 AWG and larger, in the completed cable shall be tested and shall have an insulation resistance not less than that corresponding to a constant of 500 at 15.6°C (60°F). The insulation resistance test is not required when the direct current spark test or the alternating current spark test is performed (see 3.6.2).

Electrical Method (EM-60) at 50°C ± 1°C	
Dielectric constant after 24 hours, maximum	10.0
Increase in capacitance, maximum, percent	
1 to 14 days	10.0
7 to 14 days	5.0

3.7.3 Accelerated Water Absorption Requirements (See 6.7) ▲

The insulation shall meet the following requirements:

▲3.7.3.1 Dielectric Strength Retention (See 6.7.4). The dielectric strength of the insulation shall be tested at 50°C ± 1°C and shall be not less than 50 percent of the original dielectric strength.

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3.8 Polyvinyl Chloride 75°C. This insulation is suitable for use at conductor temperatures not exceeding 75°C (167°F), in dry or wet locations, at a maximum voltage rating of 600 volts for power circuits, 1000 volts for control circuits, and 5000 volts for series lighting circuits.

▲3.8.1 Physical and Aging Requirements (See 6.4). The insulation shall meet the following requirements:

Physical Requirements	
Tensile strength, minimum	
psi	2000
MPa	13.8
Elongation at rupture, minimum, percent	150
Aging Requirements	
After air oven test at 121°C ± 1°C for 168 hours	
Tensile strength, percentage of unaged value	
Maximum	120
Minimum	80
Elongation at rupture, minimum, percentage of unaged value	75 *
After oil immersion at 70°C ± 1°C for 4 hours	
Tensile strength, minimum, percentage of unaged value	85 *
Elongation at rupture, minimum, percentage of unaged value	85 *
Heat distortion, 121°C ± 1°C, maximum, percentage of unaged value	25
Heat shock, 121°C ± 1°C	no cracks
Cold bend, -30°C ± 1°C	no cracks
Flame Test	see 6.5

* For sizes 6 AWG and larger where buffed die-cut specimens are used, the minimum elongation and tensile strength, as a percentage of the unaged values, shall be not less than the following:

1. Elongation after air oven test 50%
2. Tensile strength after oil immersion 80%
3. Elongation after oil immersion 60%

3.8.2 Electrical Requirements

3.8.2.1 Voltage Tests. See 3.6.2.

▲3.8.2.2 Insulation Resistance Test (See 6.12) Each insulated conductor, size 14 AWG and larger, in the completed cable shall be tested and shall have an insulation resistance not less than that corresponding to a constant of 2000 at 15.6°C (60°F). The insulation resistance test is not required when the direct current or the alternating current spark test is performed (see 3.6.2).

Electrical Method (EM-60) at 75°C ± 1°C	
Dielectric constant after 24 hours, maximum	10.0
Increase in capacitance, maximum, percent	
1 to 14 days	4.0
7 to 14 days	2.0

3.8.3 Accelerated Water Absorption Requirements (See 6.7)▲

The insulation shall meet the following requirements:

▲3.8.3.1 Dielectric Strength Retention (See 6.7.4) The dielectric strength of the insulation shall be tested at 75°C ± 1°C and shall be not less than 60 percent of the original dielectric strength.

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3.9 Polyethylene Insulation. This insulation is suitable for use in dry or wet locations at conductor temperatures not exceeding 75°C (167°F) for normal operation, 95°C (203°F) for emergency overload conditions up to 5000 volts, 90°C (194°F) for emergency overload conditions from 5001 through 35000 volts, and 150°C (302°F) for short-circuit conditions. The polyethylene, before application to the conductor, shall comply with the requirements of ASTM D 1248*, Type I; Classes† A, B or C; Category 4 or 5; Grade E4 or E5. The requirements of ASTM D 1248 shall not apply to insulation removed from the conductor. The insulation on the conductor shall be free from any contaminants or porosity visible to the eye with not more than five times magnification.

* See Appendix E.

† See Note 4, Table 3-2. ●

3.9.1 Physical and Aging Requirements. The insulation shall be tested in accordance with 6.4.11, 6.4.12, 6.9.1, and 6.9.2 and shall meet the following requirements:

Physical Requirements (see 6.4)	
Tensile strength, minimum	
psi	1400
kgf/mm^2	0.98
Elongation at rupture, minimum, percent	350
Aging Requirements (see 6.4)	
After air oven test at 100°C ± 1°C for 48 hours	
Tensile strength, minimum, percentage of unaged value	75
Elongation at rupture, minimum, percentage of unaged value	75
Environmental cracking (see 6.9.1) ‡	no cracks
Absorption coefficient, minimum milli(absorbance/meter)†† (see 6.9.2)	320 ‡‡

‡ Applies to insulations for rated voltages of 2001 through 35,000 volts.

†† Applies to ASTM D 1248, Class C materials.

‡‡ 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.

●Editorially revised.

3.9.2 Electrical Requirements

3.9.2.1 Voltage Tests. See 3.6.2.

3.9.2.2 Insulation Resistance Test. Each insulated conductor in the completed cable shall be tested in accordance with 6.12 and shall have an insulation resistance not less than that corresponding to a constant of 50 000 (30 000 for composite insulations in accordance with 7.4.3 based on the total composite wall thickness) at 15.6°C (60°F). The insulation resistance test is not required when the direct-current or the alternating-current spark test is performed (see 3.6.2).

3.9.2.3 Partial-discharge Extinction Level. Each length of completed power cable rated for service at 2001 volts and above with insulation shielding on the individual conductors shall be tested in accordance with 6.13 and shall meet the following requirements:

Rated Circuit Voltage, Phase to Phase, Volts	Minimum Partial-discharge Extinction Level, kV	
	100 Percent Insulation Level	133 Percent Insulation Level
2001-5000	4	5 **
5001-8000	6	8
8001-15000	11	15
15001-25000	19	26
25001-28000	21	..
28001-35000	26	..

** Unless otherwise indicated, the cable will be rated 100 percent insulation level.

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Part 4
SHIELDING AND COVERINGS

SHIELDING (SEE APPENDIX G) ▲

4.1 SHIELDING OF INSULATED CABLE ▲

Shielding of insulated cables shall consist of a conductor stress control layer (see 2.7) and insulation shielding.

4.1.1 Insulation Shield System ▲

The insulation shield system shall consist of a nonmetallic covering directly over the insulation and a nonmagnetic metal component directly over or embedded in the nonmetallic covering. The nonmetallic covering shall comply with 4.1.1.1. The metal component shall comply with 4.1.1.2. The insulation shield system shall be resistant to or protected against chemical action from other cable components.

4.1.1.1 NONMETALLIC COVERING

A conducting nonmetallic covering which meets the requirements of Table 4-a or Table 4-b shall be applied over the insulation in one or more layers in direct contact and shall be plainly identified as being conducting. Identification shall be provided for each distinctive layer.

If one of the layers is a coating, it shall be applied directly over the insulation.

The tension necessary to remove an extruded covering from cable at room temperature shall be not less than 3 pounds (13.3 N) for cables rated 2001 through 25,000 volts and not less than 4 pounds (17.8 N) for cables rated 25,001 through 35,000 volts (see Part 6).

For removability of insulation shields, see Appendix G, par. G6. ▲

This sentence is approved by NEMA as Authorized Engineering Information.

4.1.1.2 METAL COMPONENT

A nonmagnetic metal component consisting of a tape or tapes, wires, straps, or sheaths shall be applied over or embedded in the conducting nonmetallic covering. The metal components shall be electrically continuous throughout each cable length and shall be in contact with the nonmetallic covering. Metal components shall be applied in such a manner that electrical continuity or contiguity will not be distorted or disrupted during normal installation bending (see Appendix H). ▲

Metal tape(s) shall be of copper at least 2.5 mils (0.0635 mm) thick or of other nonmagnetic metal tape(s) having equivalent conductance. Wires, straps, or sheaths shall be of copper and have a total area at any cross section of at least 5000 circular mils per inch (0.1 mm²/mm) of insulated conductor diameter, or of other nonmagnetic metals having equivalent conductance. ▲

Metal tapes, wires, straps, and sheaths may be used in combination providing they are compatible and meet the requirements of the preceding paragraph.

Metal components embedded in a conducting nonmetallic covering shall not be exposed nor become exposed during normal installation bending (see Appendix H). ▲

NOTE—Additional conductance may be required in the metal component depending upon installation and electrical system characteristics, particularly in regard to the functioning of overcurrent protective devices, available fault current and the manner in which the system may be grounded.

This paragraph is approved by NEMA as Authorized Engineering Information.

4.1.2 Multiple-Conductor Cables (See 4.2)

When shielding is required on multiple-conductor cables, the shields shall be applied over the individual conductors.

4.1.3 Conductor Identification (See 5.5) ▲

4.2 SHIELDING LIMITS FOR POWER CABLE FOR FIXED LOCATIONS ▲

4.2.1 Insulation shielding shall be used on power cables for fixed locations when intended for operation above the three-phase (line-to-line) operating voltages given in Table 4-1. To obtain the equivalent three-phase voltage for single-phase or two-phase alternating current systems or for direct current systems, multiply the line-to-line voltage by the factors given in Table 4-1.

4.2.2* ● Shielding should be considered where any of the following conditions exists:

1. Connections to aerial lines.
2. Transition from conducting to nonconducting environment.
3. Transition from moist to dry earth.
4. Dry soil, such as in the desert.
5. Damp conduits.

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▲ Editorially revised.
● Editorially renumbered.

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▲**4.2.3 Single-Conductor Series Lighting Cable** Insulation shielding shall be used on single-conductor series lighting cable when intended for operation above the open-circuit voltages given in Table 4-1.

▲**4.2.4 Multiple-Conductor Series Lighting Cable.*** Manufacturer's recommendations should be obtained for shielding limits for multiple-conductor series lighting cables.

*This section is approved by NEMA as Authorized Engineering Information.

Table 4a
Requirements for Nonmetallic Conducting Coverings using Nonembedded Metal Components

Aging Requirements (see 6.4)—after air oven test at 100°C ± 1°C for 48 hours—elongation at rupture, minimum, percent	100†
Brittleness Temperature (see 6.6), not warmer than	-10°C†
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C (see 6.9.4), ohm-meters	500

†For extruded coverings only.

▲ Paragraph editorially renumbered.

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Table 4b ●

Requirements for Extruded Nonmetallic Conducting Coverings using Embedded Metal Components

Thickness, Minimum (see 6.4)	
Total	in accordance with 4.3.4
Between insulation and metal component	
mils	5
mm	0.127
Physical Requirements (see 6.4)	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	100
Aging Requirements (see 6.4)—after air oven test at 121°C ± 1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percent	100
Brittleness Temperature (see 6.6), not warmer than	-10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C (see 6.9.4), ohm-meters	500

● Added 7-13-1977.

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Table 4-1 ▲

Operating Voltage Limits, kV, above which Insulation Shielding is Required
(See 4.1.1 and 4.1.2) (See Part 7 for Exceptions)

A.	Power Cable—100 and 133 Percent Insulation Level	
1.	Single conductor (including assemblies of single conductors)	
a.	With metallic sheath or armor	5 kV
b.	All others	2 kV
2.	Multiple conductor with common covering	
a.	With discharge-resisting jacket	5 kV
b.	With nondischarge-resisting jacket	2 kV
c.	With metallic sheath or armor	5 kV

B. Single-conductor Series Lighting Cable	Open-circuit Voltage	
	With Protectors	Without Protectors
1. With discharge-resisting jacket	7 kV	5 kV
2. With nondischarge-resisting jacket	4 kV	3 kV
3. With metallic sheath or armor	7 kV	5 kV

Multiplying Factors for Equivalent Three-phase Voltages for Single- or Two-phase a-c Systems or for d-c Systems		
Single- and Two-phase a-c Systems*	Single- and Two-phase a-c Systems* over 5000 Volts	
and d-c Systems 5000 Volts or Less	One Side Grounded	Ungrounded and Midpoint Grounded
1	1.73	0.866

* Where it is not definitely specified that a line operates as an isolated single- or two-phase system, it shall be considered as a branch of a 100 percent insulation level three-phase circuit, and the rating shall be the line-to-line voltage of this 100 percent insulation level three-phase circuit.

▲ Revised 7-13-1977.

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JACKETS●

4.3a General. Jackets shall be of one of the types covered in 4.3 except that, for cable with an embedded metal component, the jacket shall be a nonmetallic conducting covering meeting the requirements of Table 4b. For jackets over metallic coverings, see 4.4. ●

4.3 Thermoplastic Jackets. These jackets consist of a moisture-resisting thermoplastic compound for use as the covering or jacket on insulated wires or cables. They shall meet the applicable requirements of 4.3.5 and 4.3.1, 4.3.2, or 4.3.3. The tests shall be made only on jackets having a nominal wall thickness of 30 mils (0.76 mm) or greater.▲

4.3.1 Polyvinyl Chloride. This jacket shall consist of a polyvinyl chloride compound suitable for a minimum installing temperature of −10°C (+14°F). When tested in accordance with Part 6, the jacket shall meet the following requirements and, when applicable, the requirements given in 4.3.4. ▲●

Physical Requirements	
Tensile strength, minimum	
psi	1500
●MPa	10.3
Elongation at rupture, minimum, percent	100
Aging Requirements	
After air oven test at 100°C ± 1°C for 5 days	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	60
After oil immersion at 70°C ± 1°C for 4 hours	
Tensile strength, minimum, percentage of unaged value	80
Elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121°C ± 1°C, maximum, percent	50
Heat shock, 121°C ± 1°C	no cracks
Cold bend, -35°C ± 1°C	no cracks

4.3.2 Polyethylene, Black. This jacket shall consist of black polyethylene compound suitable for exposure to sunlight and other atmospheric environments at temperatures between −55°C (−67°F) through +75°C (+167°F), and a minimum installing temperature of −40°C (−40°F). When tested in accordance with part 6 [except that the gauge marks shall be 1 inch (25.4 mm) apart and the distance between jaws 2.5 inches (63.5 mm), the jacket shall meet the following requirements and, when applicable, the requirements given in 4.3.4:

Physical Requirements	
Tensile strength, minimum	
psi	1400
●MPa	9.65
Elongation at rupture, minimum, percent	350
Aging Requirements	
After air oven test at 100°C ± 1°C for 48 hours	
Tensile strength, minimum, percentage of unaged value	75
Elongation at rupture, minimum, percentage of unaged value	75
Heat distortion, 90°C ± 1°C, maximum, percent	25
Environmental cracking	no cracks
Absorption coefficient, minimum, milli(absorbance/meter)	320 *

* 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.

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▲ Revised 9-15-1983.

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● **4.3.3 Chlorinated Polyethylene, Thermoplastic.** This jacket shall consist of a thermoplastic chlorinated polyethylene compound. When tested in accordance with part 6, the jacket shall meet the following requirements and, when applicable, the requirements in 4.3.4:

Physical requirements	
Tensile strength, minimum	
psi	1400
†MPa	9.65
Tensile stress at 100 percent elongation minimum	
psi	1000
†MPa	6.89
Elongation at rupture, minimum, percent	150
Aging requirements	
After air oven test at 121 °C ± 1 °C for 168 hours—Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 100 °C ± 1 °C for 18 hours—Tensile strength and elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121 °C ± 1 °C, maximum, percent	25
Cold bend, minus 35 ± 1 °C	No cracks

▲ **4.3.4 Discharge-Resisting Jackets.** The jackets described in 4.3.1, 4.3.2, and 4.3.3, when used on single-conductor nonshielded cables rated 2001 through 5000 volts phase to phase (see Table 4-1), shall meet the following additional requirements when samples are selected and tested in accordance with Part 6.†

▲ **4.3.4.1 Specific Surface Resistivity.** The specific surface resistivity shall be not less than 200,000 megohms.

▲ **4.3.4.2 U-Bend Discharge.** There shall be no cable failures nor cracks in the jacket.

▲ **4.3.5 Jacket Thickness.** The average thickness of a jacket shall be not less than the applicable value given in Tables 4-2, 4-3, 4-4, and 4-5. For the jacket thickness of cables not shown in these tables, see Table 4-6. The minimum thickness shall be not less than 80 percent of the applicable value given in these tables. (See 6.4 for method of measurements.)†

▲ **4.3.6 Separator Under Jacket.** If used, a separator shall consist of a material which is compatible with the other components of the cable.

▲ **4.3.7 Spark Test of Jackets Over Metallic Shielded Power Cable.** The jackets (see par. 4.3.1, 4.3.2, and 4.3.3) over each length of shielded power cable (see par. 4.1) shall withstand without failure the alternating current spark test voltages given in the following table. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic shield for not less than 0.15 second.

Thickness of Jacket		a-c Spark-test Voltage
mils	mm	kV
45	1.14	4.0
60	1.52	5.5
80	2.03	7.0
110	2.79	10.0
140	3.56	12.5

● Added 9-15-1983.
▲ Revised 9-15-1983.
† Editorially revised.

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Table 4-2

Single-conductor Polyethylene-insulated Nonshielded Cable—0-5000 Volts*
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial and Direct Burial †)

Size, AWG or MCM	Jacket Thickness					
	0-600 Volts		601-2000 Volts		2001-5000 Volts*	
	mils	mm	mils	mm	mils	mm
14	15	0.38	15	0.38	..	....
12	15	0.38	15	0.38	..	....
10	15	0.38	15	0.38	..	....
9	15	0.38	15	0.38	..	....
8	15	0.38	15	0.38	30	0.76
6	30	0.76	30	0.76	30	0.76
4	30	0.76	30	0.76	45	1.14
2	30	0.76	30	0.76	45	1.14
1	45	1.14	45	1.14	45	1.14
1/0	45	1.14	45	1.14	45	1.14
2/0	45	1.14	45	1.14	45	1.14
3/0	45	1.14	45	1.14	65	1.65
4/0	45	1.14	45	1.14	65	1.65
250	65	1.65	65	1.65	65	1.65
300	65	1.65	65	1.65	65	1.65
350	65	1.65	65	1.65	65	1.65
400	65	1.65	65	1.65	65	1.65
450	65	1.65	65	1.65	65	1.65
500	65	1.65	65	1.65	65	1.65
600	65	1.65	65	1.65	65	1.65
750	65	1.65	65	1.65	65	1.65
1000	65	1.65	65	1.65	65	1.65

For single-conductor polyvinyl-chloride-insulated nonshielded cable, see Table 4-6, Column 1.

* See 4.1 and 4.2 for shielding requirements. ▲

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

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Table 4-3
Single-conductor Polyethylene-insulated Metallic Shielded Cables
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial and Direct Burial)

Size, AWG or MCM	Jacket Thickness									
	2001-5000 Volts * 100 and 133 Percent Insulation Level		5001-8000 Volts 100 Percent Insulation Level		5001-8000 Volts 133 Percent Insulation Level		8001-15000 Volts 100 Percent Insulation Level		8001-15000 Volts 133 Percent Insulation Level	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
8	45	1.14	..	....	...	....	...	....	...	....
6	60	1.52	60	1.52	60	1.52.	...	....	...	....
4	60	1.52	60	1.52	60	1.52	...	....	...	....
2	60	1.52	60	1.52	60	1.52	80	2.03	...	....
1	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
1/0	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
2/0	60	1.52	80	2.03	80	2.03	80	2.03	80	2.03
3/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
4/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
250	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
300	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
350	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
400	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
450	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
500	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
600	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
750	80	2.03	80	2.03	80	2.03	80	2.03	110	2.79
1000	80	2.03	80	2.03	110	2.79	110	2.79	110	2.79

For all other sizes and voltages not tabulated above see Table 4-6, Column 2.

* See 4-1 and 4-2 for shielding requirements. ▲

(Continued)

▲ Revised 3-21-1973.

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Table 4-3 (Continued)
Single-conductor Polyethylene-insulated Metallic Shielded Cables
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial and Direct Burial)

Size, AWG or MCM	Jacket Thickness							
	15001-25000 Volts 100 Percent Insulation Level		15001-25000 Volts 133 Percent Insulation Level		25001-28000 Volts 100 Percent Insulation Level		28001-35000 Volts 100 Percent Insulation Level	
	mils	mm	mils	mm	mils	mm	mils	mm
8	...	....	...	....	...	....	...	....
6	...	....	...	....	...	....	...	....
4	...	....	...	....	...	....	...	....
2	...	....	...	....	...	....	...	....
1	80	2.03	80	2.03	80	2.03	...	....
1/0	80	2.03	80	2.03	80	2.03	80	2.03
2/0	80	2.03	80	2.03	80	2.03	80	2.03
3/0	80	2.03	80	2.03	80	2.03	80	2.03
4/0	80	2.03	80	2.03	80	2.03	80	2.03
250	80	2.03	80	2.03	80	2.03	80	2.03
300	80	2.03	80	2.03	80	2.03	80	2.03
350	80	2.03	80	2.03	80	2.03	80	2.03
400	80	2.03	110	2.79	80	2.03	110	2.79
450	80	2.03	110	2.79	80	2.03	110	2.79
500	80	2.03	110	2.79	80	2.03	110	2.79
600	110	2.79	110	2.79	110	2.79	110	2.79
750	110	2.79	110	2.79	110	2.79	110	2.79
1000	110	2.79	110	2.79	110	2.79	110	2.79

For all other sizes and voltages not tabulated above see Table 4-6, Column 2.

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Table 4-4
Individual Conductors of Multiple-conductor Cables Under a Common Covering

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.

Table 4-5
Common Overall Jacket of Multiple-conductor Cables
(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 4-5 applies to all round multiple-conductor cables having a common overall jacket.

NOTE 2—For flat twin cable, use the calculated major core diameter under the jacket to determine the jacket thickness.

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Table 4-6
Single- and Multiple-conductor Wires and Cables
(All Uses Except Communication and Portable Cables ‡)

Calculated Diameter of Cable Under Jacket		Jacket Thickness							
		Single-conductor Cable				Multiple-conductor Cables *			
		(1)		(2)		(3)		(4)	
		Nonshielded		Shielded **		Individual Conductors †		Overall	
inches	mm	mils	mm	mils	mm	mils	mm	mils	mm
0.250 or less	6.35 or less	15	0.38	45	1.14	15	0.38	45	1.14
0.251-0.425	6.38-10.80	30	0.76	45	1.14	25	0.64	45	1.14
0.426-0.700	10.82-17.78	45	1.14	60	1.52	30	0.76	60	1.52
0.701-1.500	17.81-38.10	65	1.65	80	2.03	50	1.27	80	2.03
1.501-2.500	38.13-63.50	95	2.41	110	2.79	80	2.03	110	2.79
2.501 and larger	63.53 and larger	125	3.18	140	3.56	..	....	140	3.56

* Under common jacket.

† 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.

** In calculating the diameter under the jacket of single-conductor shielded cables, 90 mils (2.29 mm), which was used in calculating the values given in Table 4-3, shall be added to the metallic conductor diameter plus twice the insulation thickness given in Table 3-2.

NOTE—For flat twin cable, use the calculated major core diameter under the jacket to determine the jacket thickness from Column 4.

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METALLIC AND ASSOCIATED COVERINGS

4.4 Metallic and Associated Coverings

4.4.1 Scope. Section 4.4 covers the following:

Division I. (See 4.4.3 through 4.4.15.) Materials, constructions and requirements for metallic and associated coverings recommended for use under normal conditions of installation, operation and maintenance of power, control, and lighting circuit wires and cables. It also covers submarine cables.

Division II. (See 4.4.16 through 4.4.22.) Round wire armor for borehole, dredge, shaft, and vertical riser cable.

Division III. (See 4.4.23 through 4.4.25.) Round wire armor for buried cable.

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

4.4.2 General

4.4.2.1 Unusual Conditions. The standards given in this section apply under usual installation, operating and service conditions. Where unusual installation, operating or service conditions exist, modifications may be necessary and these conditions should be defined before cable design is completed.

4.4.2.2 Types of Metallic Coverings. The types and conditions of installation are as follows:

(a) Metallic sheath, lead or aluminum
  (1) Conduit, ducts, troughs or raceways.
  (2) Suspended from aerial messenger.
  (3) When protected by metal armor or nonmetallic coverings for other types of installation.

(b) Flat metal tape armor
  (1) Direct burial in trenches.
  (2) Suspended from aerial messenger.

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

Galvanized-steel tape armor without an outer fibrous covering is for use on cables to be suspended from an aerial messenger strand.

(c) Interlocked metal tape armor *
  (1) Direct burial in trenches.
  (2) Troughs.
  (3) Racks.
  (4) Raceways.
  (5) Suspended from aerial messenger.

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

Interlocked-metal tape armor with either a fibrous bedding or a thermoplastic jacket under the armor and either a fibrous covering or a thermoplastic jacket over the armor is for underground installations.

(d) Galvanized steel wire armor
  (1) Submarine cable.
  (2) Dredge cable.
  (3) Vertical riser, borehole, and shaft cable for end suspension.
  (4) Direct burial in trenches and subjected to unusual longitudinal stress.

Jute 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 covering may be desirable where the conditions of transportation require protection for the galvanizing on the armor wires. †

* Interlocked steel tape armor used for service entrance cable or for building cable such as Types AC, ACT, ACL and ACV is not within the scope of these standards.

† This paragraph is approved by NEMA as Authorized Engineering Information.

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DIVISION I ▲

Metallic and Associated Coverings for Insulated Cables

4.4.3 Scope

Division I applies to the metallic coverings described in the following sections, together with the necessary fibrous or thermoplastic beddings and protective coverings; to nonmetallic coverings over metallic sheath; and to their application over insulated electric cable for use on power, control and lighting circuits.

4.4.4 Metallic Sheath

A lead or smooth aluminum sheath shall be used with or without supplementary protection when an impervious covering is required.

4.4.4.1 TYPE OF LEAD

A sheath of commercially pure lead (or an alloyed lead) shall be tightly formed around the core of the cable. This lead shall meet the requirements of ASTM B29. The types of lead used shall be as follows:

Corroding	Chemical
Desilverized A	Acid
Soft, undesilverized	Copper (copper bearing)

When chemical, acid, or copper lead is used, the copper content shall be between 0.040 and 0.080 percent by weight.

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

4.4.4.2 THICKNESS OF LEAD

The average thickness of the lead sheath shall be in accordance with Table 4-7. The minimum thickness shall in no case be less than 90 percent of the thickness specified in the table. Where protective jackets are used over the lead sheath, see 4.4.14.6 for the thickness of the lead sheath.

There are special cases where the above thicknesses may require an increase, especially on the smaller sizes of cable, if several cables are to be pulled in together in one duct; if the sections are extra long; or if the handling is severe or awkward during installation as in some transformer vaults.

4.4.4.3 MEASUREMENT OF THICKNESS OF LEAD

The thickness shall be measured in accordance with 6.8.

4.4.4.4 REAPPLICATION OF LEAD SHEATHS

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

4.4.4.5 TYPE OF ALUMINUM

A smooth sheath of aluminum alloy 1060 or 1350 shall be tightly formed around the core of the cable.

4.4.4.6 THICKNESS OF ALUMINUM

The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall in no case be less than 90 percent of the thickness specified in the table.

Table 4-7
Thickness of 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	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.
†For submarine cables, the thickness of the lead sheath for the first two core diameter classifications shall be 80 mils (2.03 mm).

Table 4-8
Thickness of Smooth Aluminum Sheath

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mm
0–0.400	0–10.16	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	90.20–96.52	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.

▲ Division I editorially revised throughout.

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4.4.4.7 Measurement of Thickness of Aluminum

The thickness shall be measured in accordance with 6.8.

4.4.4.8 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 re-sheathed.

4.4.5 Protective Jackets

See 4.4.14.

4.4.6 Flat Metal Tape Armor

4.4.6.1 Scope

This section covers plain and zinc-coated flat steel strip-in coils for use as flat armor for electrical cables. The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process.

4.4.6.2 Tensile Strength and Elongation

The plain and zinc-coated strip shall have a tensile strength of not less than 4000 psi (276 MPa) nor more than 70,000 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.

4.4.6.3 Galvanizing Test

4.4.6.3.1 Weight of Zinc Coating

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. (See Appendix E.)

4.4.6.3.2 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 ⅛ inch (3.18 mm) in 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.

4.4.6.4 Width

The nominal width of metal tapes shall be not greater than that specified in Table 4-9.

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For nominal widths 1.000 inch (25.4 mm) or less, the tolerance in width shall be ±30 mils. For nominal widths greater than 1.000 inch (25.4 mm), the tolerance in width shall be ±45 mils.

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

Calculated Diameter of Cable Under Jute Bedding*		Nominal Width of Metal Tape	
inches	mm	inches	mm
0–0.450	0–11.43	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 and larger	88.93 and larger	3.000	76.2

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

4.4.6.5 THICKNESS

The nominal thickness of metal tape shall be not less than that given in Table 4-10. See 6.8.2 for method of measuring metal tape thickness.

The tolerance in the nominal thickness of both plain and zinc-coated tape shall be ±3 mils.

The zinc-coated tape shall not at any place be more than 20 percent thicker than the stripped tape thickness, which should be the specified nominal thickness for bare metal. The tolerance for nominal thickness of bare metal should apply to the stripped tape.

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

Calculated Diameter of Cable Under Jute Bedding*		Nominal Thickness of Metal Tape	
inches	mm	mils	mm
0–1.000	0–25.40	20	0.51
1.001 and larger	25.43 and larger	30	0.76

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

4.4.6.6 APPLICATION, LAY, AND SPACING

Two metal tapes shall be applied helically in the same direction over the jute bedding except that they may be applied in opposite directions where the total area of the conductors is less than 50000 circular mils (25.34 mm²). The direction of lay of the inner tape shall be opposite to that of the jute bedding. When applied in the same direction as the inner tape, the outer tape shall be approximately centered over the spaces between the convolutions of the inner tape. The maximum space between turns shall not exceed 20 percent of the width of the tape or 0.200 inch, (5.08 mm), whichever is the greater.

During or prior to application, the tapes shall be flushed with a suitable compound to deter corrosion.

4.4.7 Interlocked Metal Tape Armor

4.4.7.1 SCOPE

This section covers flat metallic strip-in coils for use as interlocking armor for electrical cables. All tests shall be made prior to the application of the strip to the cable.

4.4.7.2 STEEL TAPE

Steel tape (except stainless) without a protective covering shall be zinc-coated. The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process. If an outer jute or other protective covering is furnished, plain steel tape may be used. The quality of the steel tape and the requirements for the galvanizing shall be those specified in 4.4.6.2 and 4.4.6.3 for flat steel tape.

4.4.7.3 WIDTH

The nominal width of metal tape may be less than but shall not be greater than that specified in Table 4-11.

For any width of metal tape used, the tolerance in width shall be +10 mils or −5 mils, except for aluminum which shall be ±10 mils.

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 and larger	50.83 and larger	1.000	25.4

4.4.7.4 THICKNESS

The nominal thickness of metal tape shall be not less than that given in Table 4-12. See 6.8.2 for method of measuring metal tape thickness.

The tolerance in nominal thickness of the tape shall be ±3 mils. The zinc-coated tape shall not, at any place, be more than 20 percent thicker than the stripped tape thickness, which should be the specified nominal thickness for bare metal. The

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tolerance for nominal thickness of bare metal should apply to the stripped tape.

Table 4-12
Thickness of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Thickness: Ambrac, Brass, Steel, Stainless Steel, Bronze and Monel Tape		Nominal Thickness: Aluminum and Zinc Tape	
inches	mm	mils	mm	mils	mm
0-1.500	0-38.10	20	0.51	25	0.64
1.501 & larger	38.13 & larger	25	0.64	30	0.76

4.4.7.5 NONMAGNETIC TAPE

When nonmagnetic tapes such as aluminum, brass, bronze, zinc, or stainless steel are used, the widths shall be in accordance with 4.4.7.3 and the thicknesses in accordance with 4.4.7.4.

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

4.4.7a Continuously Corrugated Metal Armor

4.4.7a.1 SCOPE

This section covers the requirements applicable to continuously corrugated metal armored cable. The metal armor is formed by 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.

4.4.7a.2 TYPE OF METAL

4.4.7a.2.1 When metal armor is formed by a flat metal tape, the tapes used shall be aluminum, copper, steel, or alloys thereof.

4.4.7a.2.2 When metal armor is formed by applying a seamless sheath or tube, the metal shall be aluminum or an aluminum alloy.

4.4.7a.2.3 The minimum thickness of tape or of the sheath or tube before corrugation shall be as shown in Table 4-12a.

4.4.7a.3 FLEXIBILITY

4.4.7a.3.1 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 the procedure given in Part 6.

4.4.7a.4 CORROSION PROTECTION

4.4.7a.4.1 When required a corrosion protective covering shall be applied over the armor.

4.4.8 Galvanized Steel Wire Armor

4.4.8.1 SCOPE

This section covers zinc-coated low-carbon-steel wire for use in the armoring of borehole, vertical riser, submarine, and underground cables used for power, control, and lighting circuits for normal use. For wire armor for special uses see Divisions II and III. All tests shall be made prior to application of the wire to the cable.

4.4.8.2 TENSILE STRENGTH, ELONGATION AND TORSION

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

4.4.8.2.1 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 (482 MPa). The

Table 4-12a
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	81.05-106.7	34	0.86	...	...	...	..
0-2.365	0- 60.7	...	...	17	0.43	..	
2.366-3.545	60.10- 90.4	...	...	21	0.53	...	
3.546-4.200	90.07-106.7	...	...	25	0.64	..	..
0-1.905	0- 48.39	...	...	...	...	16	0.41
1.906-3.05	48.41- 72.39	...	...	...	...	20	0.51
3.051-4.200	72.42-106.7	...	...	...	...	24	0.61

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tensile strength shall be tested in accordance with ASTM E8. (See Appendix E.)

4.4.8.2.2 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.

4.4.8.2.3 TORSION TEST

The zinc-coated wire shall withstand, without fracture, the minimum number of twists specified in Table 4-13. 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 4-13
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

4.4.8.3 GALVANIZING TESTS

4.4.8.3.1 WEIGHT OF ZINC COATING

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 4-14. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A90. (See Appendix E.)

4.4.8.3.2 ADHERENCE OF COATING

The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than fifteen turns per minute in a closed helix of at least two turns around a cylindrical mandrel of the diameter specified in Table 4-15. 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 of 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.

4.4.8.4 SIZE OF ARMOR

The sizes of armor wire for Division I applications including submarine cables are given in Table 4-16.

If the service requirements are exceptionally severe, larger sizes of armor wire may be required. (This sentence has been approved by NEMA as Authorized Engineering Information.)

The tolerance in diameter for galvanized steel wire shall be as shown in Table 4-17.

Table 4-14
Minimum Weights of Zinc Coating

Nominal Diameter of Coated Wire		Size, BWG	Minimum Weight of Zinc Coating	
mils	mm		Ounces per Square Foot of Exposed Wire Surface	Grams per Meter[1] of Exposed Wire Surface
238	6.05	4	1.00	305
220	5.59	5	1.00	305
203	5.16	6	1.00	305
165	4.19	8	0.90	275
134	3.40	10	0.80	244
109	2.77	12	0.80	244
83	2.11	14	0.60	183

Table 4-15
Mandrel Diameter for
Adherence of Coating Tests

Wire Diameter		Mandrel Diameter
mils	mm	
238-134	6.05-3.40	3 times wire diameter
133 and smaller	3.38 and smaller	2 times wire diameter

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Table 4-16
Size of Galvanized Steel Armor Wire for Division I Applications Including Submarine Cable

Calculated Diameter of Cable Under Jute 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 and larger	63.53 and larger	4	238	6.05

Table 4-17
Tolerances in Diameter

Nominal Diameter of Coated Wire		Tolerances, inches
mils	mm	
238-166	6.05-4.22	±0.005
165-109	4.20-2.77	±0.004
108-65	2.74-1.65	±0.003

4.4.8.5 LAY

The length of lay of the armor wire 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 4.4.19.3.

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

4.4.8.6 DIRECTION OF LAY

Successive layers of jute and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen that bird-caging of the cable being armored shall be reduced to a minimum.

4.4.9 Jute Bedding for Armored Cable (See 4.4.11 for Interlocked Armored Cable)

4.4.9.1 APPLICATION

Metallic-sheathed cable to be armored shall be served with a bedding of impregnated jute yarn or roving. If the cable is without metallic sheath, the core shall be covered as specified in 4.4.12. In no event shall the metallic sheath or the core without metallic sheath be run through hot asphalt or tar compound.

4.4.9.2 DIRECTION OF LAY

The direction of lay of the jute bedding or serving shall be opposite to that of the armor directly in contact with it, except as allowed in 4.4.8.6. Adjacent layers of jute shall be applied with opposite directions of lay.

4.4.9.3 THICKNESS (See Part 6)

The thickness of jute bedding under the armor in the finished cable shall be not less than that specified in Table 4-18.

4.4.10 Jute Serving Overall for Armored Cable (See 4.4.11 for Interlocked Armored Cable)

4.4.10.1 APPLICATION

When an outer jute serving is required, the armored cable shall first be run through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 1⅝) impregnated jute yarn applied with a short close lay, again run through hot asphalt or tar compound and finished by running through some suitable material which will prevent sticking of adjacent turns of the cable when wound on a reel.

4.4.10.2 DIRECTION OF LAY

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

4.4.11 Jute for Interlocked Armored Cable

4.4.11.1 JUTE BEDDING

If jute bedding is required, the application and direction of lay shall be in accordance with 4.4.9.1 and 4.4.9.2. The thickness shall be as specified for metal taped cable in Table 4-18. (See Part 6.)

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Table 4-18
Thickness of Jute Bedding for Armored Cable

Calculated Diameter of Cable Under Jute Bedding*		Minimum Thickness of Jute Bedding					
				Round Wire Armored Cable			
		Metal Taped		Sheathed or Jacketed		Nonsheathed or Nonjacketed	
inches	mm	mils	mm	mils	mm	mils	mm
0.450 or less	11.43 or less	30	0.76	45	1.14	80	2.03
0.451-0.750	11.46-19.05	45	1.14	45	1.14	80	2.03
0.751-1.000	19.08-25.40	45	1.14	65	1.65	95	2.41
1.001-2.500	25.43-63.50	65	1.65	80	2.03	110	2.79
2.501 and larger	63.53 and larger	65	1.65	95	2.41	125	3.18

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

4.4.11.2 JUTE SERVING OVERALL

If jute serving overall is required, it shall be in accordance with 4.4.10.

4.4.12 Core Covering For Nonsheathed and Nonjacketed Cable with Metallic Armor

Over the core of nonsheathed and nonjacketed cable with metallic armor, there shall be applied tape, fibrous covering, jute, or other suitable protective covering. Tape shall be used over cores having a diameter of 0.300 inch (7.62 mm) or larger.

4.4.13 Core Covering for Jacketed Cable Under Armor

4.4.13.1 FLAT STEEL TAPE ARMOR

Where a flat steel tape armor is used, a jute bedding shall be applied over the jacket before application of the armor. The thickness of the jute bedding shall be in accordance with Table 4-18. (See Part 6.)

4.4.13.2 INTERLOCKED ARMOR

Interlocked armor shall be applied directly over the covering, no bedding being necessary.

4.4.13.3 ROUND WIRE ARMOR

Where round wire armor is used, a jute bedding shall be applied over the jacket before application of the armor. The thickness of the jute bedding shall be in accordance with Table 4-18. (See Part 6.)

4.4.14 Thermoplastic Jacket Over Metallic Sheath

4.4.14.1 THERMOPLASTIC JACKETS

Thermoplastic jackets, when used, shall be extruded over the metallic sheath and shall fit tightly thereto. They shall be either:

1. Polyvinyl chloride meeting the requirements given in 4.3.1, except that the cold bend requirements shall be given in 4.4.14.4, or
2. Black polyethylene meeting the requirements given in 4.3.2, or
3. Black chlorinated polyethylene meeting the requirements given in 4.3.3 except that the cold bend requirements shall be as given in 4.4.14.4. ●

4.4.14.2 THICKNESS

The average thickness of the thermoplastic jacket shall be not less than that specified in Table 4-19. The minimum thickness shall be not less than 70 percent of the values given in the table. The average thickness of the jacket

Table 4-19
Thickness of Thermoplastic Jacket Over Metallic Sheath

Calculated Diameter Over Sheath		Thickness of Jacket	
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 and larger	76.23 and larger	110	2.79

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shall be taken as one-half the difference in diameters over and under the jacket as determined by circumference measurements. (See Part 6.)

4.4.14.3 Tightness of Application of Polyethylene Jacket to Sheath

The 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 at 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 1 minute when weight is applied to the upper end of the sample. The weight to be applied shall be equal to 10 pounds per inch (1.77 kN/m) of outside diameter of the metallic sheath minus the weight of the prepared sample, rounded off to the nearer half pound.

4.4.14.4 Cold Bend

When required, the manufacturer shall submit evidence that the jacket has been tested on similar cable and meets the following requirement. The jacketed cable shall be subjected to the same bend test and with the same frequency as required for the underlying core. The test temperature shall be minus 10°C or colder. After the final bend, the jacket shall show no cracks visible to the normal unaided eye. (See Part 6.)

4.4.14.5 Spark Test

The jacket on each length of cable shall withstand the alternating current spark-test voltage given in Table 4-20. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic sheath for not less than 0.15 second.

4.4.14.6 Thickness of Lead Sheath

When a thermoplastic jacket is applied over a lead sheath, the average thickness of the lead sheath shall be in accordance with Table 4-21. The minimum thickness shall be not less than 90 percent of the values given in the table. (See 6.8.3.)

4.4.14.7 Thickness of Aluminum Sheath

When a thermoplastic jacket is applied over an aluminum sheath, the average thickness of the aluminum sheath shall be the same as that given in Table 4-8. (See 6.8.3.)

Table 4-20
Spark-Test Voltage
for Thermoplastic Jacket

Thickness of Jacket		a-c Spark-test Voltage, kV
mils	mm	
50	1.27	4.5
60	1.52	5.5
65	1.65	6.0
75	1.90	6.5
80	2.03	7.0
85	2.16	7.5
95	2.41	8.5
110	2.79	10.0

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Table 4-21
Thickness of Lead Sheath for Cables Having Thermoplastic Jacket Over The Lead Sheath

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mils
0.425 or less	10.80 or less	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.
†For submarine cables, these thicknesses shall be 70 mils (1.78 mm).

4.4.15 Thermoplastic Jacket Over Metallic Armor

Thermoplastic jackets, when used, shall be extruded over the metallic armor and shall fit tightly thereto. They shall be either:

1. Polyvinyl chloride meeting the requirements of 4.3.1, except that the cold bend requirements shall be as given in 4.4.14.4, or
2. Black polyethylene meeting the requirements of 4.3.2, or
3. Black chlorinated polyethylene meeting the requirements given in 4.3.3 except that the cold bend requirements shall be as given in 4.4.14.4. ●

4.4.15.1 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 value given in the table. The minimum and maximum thickness of the jacket shall be determined directly with a micrometer, a steel scale with pocket glass, or a micrometer microscope on a ring of jacket removed from the cable. The average of these determinations shall be taken as the average thickness of the jacket.

4.4.15.2 SPARK TEST

The jacket on each length of cable shall withstand without failure the alternating current spark-test voltage given in Table 4-20. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic armor for not less than 0.15 second.

Division II

Round Wire Armor for Borehole, Dredge, Shaft, and Vertical Riser Cable

4.4.16 Scope

Division II gives details of construction of armor applicable particularly to borehole, dredge, shaft, and vertical riser cables.

4.4.17 General

The requirements of Division I pertaining to quality of materials, design, and construction apply also to borehole, dredge, shaft, and vertical riser cable (which are designed for special uses), except as to the particular details expressly set forth in the following sections for the respective types of cable, or as otherwise modified. ▲

4.4.18 Borehole Cable (Suspended at One End Only)

4.4.18.1 ARMOR

Galvanized round steel wire shall be used for borehole cable.

Table 4-22
Thickness of Thermoplastic Jacket Over Metallic Armor

Calculated Diameter of Cable Under Thermoplastic Jacket		Jacket Thickness			
		All Cables (Except Interlocked or Corrugated Armored)		Cables With Interlocked or Corrugated Armor	
inches	mm	mils	mm	mils	mm
0.750 or less	19.05 or less	50	1.27	50	1.27
0.751–1.500	19.08–38.10	65	1.65	50	1.27
1.501–2.250	38.13–57.15	80	2.03	60	1.52
2.251–3.000	57.18–76.20	95	2.41	75	1.90
3.001 and larger	76.23 and larger	110	2.79	85	2.16

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

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

Calculated Diameter of Cable Under Jute 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 and larger	63.53 and larger	4	238	6.05

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] 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.

4.4.18.3 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 follows: "The lay of any helical element of a cable is the axial length of a turn of the helix of that element."

4.4.19 Dredge Cable

4.4.19.1 Armor. Galvanized round steel wire shall be used for dredge cable and shall be applied with a short lay.

4.4.19.2 Size of Armor Wire. The size of the armor wires shall be as given in Table 4-24.

Table 4-24
Size of Galvanized Steel Armor Wire for Dredge Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0-1.700	0-43.18	12	109	2.77
1.701-2.500	43.21-63.50	10	134	3.40
2.501 and larger	63.53 and larger	8	165	4.19

4.4.19.3 Pitch Ratio. The pitch ratio limits shall be in accordance with Table 4-25.

Table 4-25
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

Calculated Diameter Over the Armor Wire		Minimum Pitch Ratio
inches	mm	
0-2.500	0-63.50	2.5
2.501 and larger	63.53 and larger	3.0

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 above pitch ratio. If so, it should be defined before the cable design is finalized.

4.4.20 Shaft Cable. When shaft cable is clamped to the shaft structure or wall, the metallic coverings used (either tape or wire) shall comply with the requirements of 4.4.3 through 4.4.15. 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.

4.4.21 Vertical Riser Cable (Suspended at One End Only)

4.4.21.1 Nonsheathed Cable for Installation Within Buildings

4.4.21.1.1 Armor. Galvanized round steel wire shall be used for vertical riser cable.

4.4.21.1.2 Size of Armor Wire. The size of the armor wires shall be as given in Table 4-26.

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

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0-1.000	0-25.40	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 and larger	63.53 and larger	6	203	5.16

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] 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.

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4.4.21.2 Size of Armor Wire for Sheathed Vertical Riser Cable. The size of armor wire for sheathed vertical riser cable for indoor installation shall be in accordance with 4.4.18.2 for borehole cable, but with a tensile safety factor of not less than four.

4.4.22 Wire-band Serving. Where wire-band servings directly over the armor are required for cable suspended vertically from one end, No. 12 BWG (0.109 inch) 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 accance 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.

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
0-1.500	0-38.10	50	15.2	3	76.2
1.501-2.500	38.13-63.50	35	10.7	4	102
2.500 and larger	63.53 and larger	25	7.6	4	102

Division III
ROUND WIRE ARMOR FOR BURIED CABLE
(4.4.23 THROUGH 4.4.25)

4.4.23 Scope. Division III gives details of construction of armor for buried land cables 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.

4.4.24 General. The requirements of Division I (4.4.3 through 4.4.15) pertaining to quality of materials, design and construction apply also to buried round wire armored cables, except as to particular details expressly set forth in the following sections or as otherwise modified.

4.4.25 Armor Wire and Jute Servings (Sheathed, Jacketed, Nonsheathed and Nonjacketed Cables). The size of armor wire and thickness of jute 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 serving as specified in 4.4.10 shall be applied over the armor.

Table 4-28
Thickness of Jute Bedding and Size of Armor Wire

Calculated Diameter of Cable Under Jute Bedding		Minimum Thickness of Jute Bedding		Nominal Size of Armor Wire		
inches	mm	mils	mm	BWG	mils	mm
0-0.750	0-19.05	45	1.14	14	83	2.11
0.751-1.000	19.08-25.40	65	1.65	12	109	2.77
1.001-1.700	25.43-43.18	80	2.03	10	134	3.40
1.701-2.500	43.21-63.50	80	2.03	8	165	4.19
2.501 and larger	63.53 and larger	95	2.41	6	203*	5.16*

* For cable diameters over 2.500 inches (63.50 mm) where greater strength is desired than obtainable with No. 6 BWG (203 mils) or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils) wire may be used.

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Part 5▲
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

5.1 ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES

Multiple-conductor cables shall be assembled in accordance with Part 5 unless otherwise modified by Part 7.

5.2 MULTIPLE-CONDUCTOR ROUND CABLES

Where cables consist of a core of conductors without a layer of conductors over them, the individual conductors shall be cabled together with a left-hand lay.

Where one layer of conductors is involved, the layer shall have a left-hand lay. Where more than one layer of conductors is involved, the outer layer shall have a left-hand lay.

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

Where necessary, the interstices shall be filled to give the completed cable a substantially circular cross section (see 5.4).

The length of lay of the individual conductors in the outer layer of any cable shall not exceed the value calculated from the factor given in the following table. For cables with four or less conductors, the individual conductor diameter is the calculated overall diameter of the individual conductor. For cables with five or more conductors, the assembled diameter is the calculated diameter over the assembled conductors. When more than one layer of conductors is involved, the lay of the conductors in the inner layers shall be governed by the construction of the cabling machine.

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

* For conductor assemblies without an overall covering, the maximum length of lay shall be 60 times the diameter of the largest insulated conductor.

5.3 FLAT TWIN CABLES

For flat twin cables with diameters over the individual conductor of 0.500 inch (12.70 mm) or less, filling is not required. For flat twin cables with diameters over the individual conductor of more than 0.500 inch (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).

5.4 FILLERS

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

5.5 CONDUCTOR IDENTIFICATION▲

5.5.1 Power Cables

When required, conductors shall be identified by any suitable means.

5.5.2 Control Cables

(See Part 7.)▲

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Part 6
TESTING AND TEST METHODS

6.1 TESTING ▲

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

Tests shall consist of the following, as required, namely, (1) tests on samples—see 6.2 to 6.10, inclusive, and 6.14, (2) electrical tests on entire lengths of completed cables—see 6.11 to 6.13, inclusive, and (3) conductor resistance tests—see 6.3—on samples or on entire lengths of completed cables.

The test methods described in Part 6 are not completely applicable to all types of wires and cables, nor do they include every test applicable to a particular type of wire or cable. To determine which tests are to be made, refer to the parts in this publication which set forth the requirements to be met by the particular material or type of cable.

6.2 TESTS ON SAMPLES

Tests shall be made on samples selected at random. Each test sample shall be taken from the accessible end of different coils or reels. Each coil or reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be as specified under the individual tests.

6.3 CONDUCTOR TEST METHODS ▲

When samples are measured, they shall be selected in accordance with Table 6-1a.

6.3.1 Method for Direct Current Resistance Determination

Measurements shall be made either on a sample at least 1 foot (30.5 cm) long or on the entire length of completed cable. When the nominal resistance is less than 1 ohm, the measurement shall be made with a Kelvin-type bridge or a potentiometer. When the nominal resistance is 1 ohm or more, the measurement shall be made with a Kelvin-type bridge, or a Wheatstone bridge, or a potentiometer.

When measurements are made on a sample, either as original measurements or for verification, the following precautions shall be taken:

1. Current contacts shall be made in such a way as to assure essentially uniform current density among the wires.

2. When potential leads are used, the distance between each potential contact and the corresponding current contact shall be at least equal to 1½ times the circumference of the specimen. When a Kelvin-type bridge is used, the yoke resistance (between reference standard and test specimen) shall be appreciably smaller than that of either the reference standard or the test specimen unless a suitable lead compensation is used, or it is known that the coil and lead ratios are sufficiently balanced so that variation in yoke resistance will not decrease the bridge accuracy below that given in item 4.

3. The distance between potential electrodes shall be measured to an accuracy of ± 0.05 percent. To assure this accuracy in measuring the length between potential contacts, the surface in contact with the test specimen shall be a substantially sharp knife edge.

4. Resistance measurements shall be made to an accuracy of ±0.15 percent. To assure a correct reading, the reference standard and the test specimen should be allowed to come to the same temperature as the surrounding medium. (If the reference standard is made of manganin, it is possible to obtain correct readings with the test specimen at reference temperatures other than room temperature.) ▲

5. In all resistance measurements, the measuring current raises the temperature of the medium. Therefore, the magnitude of the current shall be low and the time of its use short enough so that changes in resistance cannot be detected with the galvanometer.

6. In bridge measurements, the potential contact resistance shall be as low as possible. If low contact resistance cannot be achieved, appropriate contact-resistance corrective circuits shall be used. To eliminate errors due to contact potential, two readings, one direct and one with current reversed, shall be taken in direct succession. Check tests may be made by turning the specimen end for end and repeating the test. The material used for the two potential contacts shall be the same to minimize imbalanced contact potentials. If necessary, the contact surfaces shall be cleaned.

6.3.2 Methods for Cross-Sectional Area Determination

6.3.2.1 Cross-Sectional Area by Diameter Measurement

The cross-sectional area shall be calculated as follows:

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Table 6-1
Factors for Converting Measured dc Resistance to 25 °C (77 °F)

Temperature, Degrees, C	Multiplying Factor for Copper	Multiplying Factor for Aluminum
0	1.107	1.110
5	1.084	1.085
10	1.061	1.063
15	1.040	1.041
20	1.020	1.020
25	1.000	1.000
30	0.981	0.981
35	0.963	0.962
40	0.945	0.944
45	0.928	0.927
50	0.912	0.910
55	0.896	0.894
60	0.881	0.878
65	0.866	0.863
70	0.852	0.849
75	0.838	0.835
80	0.825	0.821
85	0.812	0.808
90	0.800	0.796

The correction factors are based upon copper having 100 percent conductivity and aluminum having 61 percent conductivity. The factors are derived from the formulae:

$$R_1 = R_2 \frac{259.5}{234.5 + T_2} \quad \text{for copper}$$

$$R_1 = R_2 \frac{253}{228 + T_2} \quad \text{for aluminum}$$

Where:

R_1 = Resistance at 25 °C
R_2 = Measured resistance at test temperature T_2.

For more accurate determination of resistance, allowing for different conductivities, see "Copper Wire Tables," National Bureau of Standards Handbook 100; or "Aluminum Wire Tables," National Bureau of Standards Handbook 109, and ASTM B193. (This paragraph is approved by NEMA as Authorized Engineering Information.)

Table 6-1a
Number of Samples

Quantity of Completed Cable Ordered		Number of Samples
feet	meters	
Less than 2000	Less than 610	0
2000-10000	610-3048	1
Each 10000 or fraction thereof from 10000-50000	Each 3048 or fraction thereof from 3048-15240	1
Each additional 50000 or fraction thereof	Each additional 15 240 or fraction thereof	1

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Table 6-2
Number and Length of Samples

Quantity of Completed Cable Ordered		Size of Conductor		Number of Samples	Minimum Length of Each Sample	
feet	meters	kcmil	mm²		conductor feet	conductor meters
Less than 2000	Less than 610	Less than 250	Less than 127	none	...	...
Less than 1000	Less than 305	250 and larger	127 and larger	none	...	...
2000–50 000	610–15,240	Less than 250	Less than 127	1	6	1.8
1000–25 000	305–7620	250 and larger	127 and larger	1	3	0.9
More than 25 000	More than 7620					
First 25 000	First 7620	250 and larger	127 and larger	1	3	0.9
Each additional 25 000	Each additional 7620	250 and larger	127 and larger	1	3	0.9
More than 50 000	More than 15 240					
First 50 000	First 15 240	Less than 250	Less than 127	1	6	1.8
Each additional 50 000	Each additional 15 240	Less than 250	Less than 127	1	6	1.8

Table 6-3
Number and Length of Samples

Quantity of Completed Cable Ordered		Nominal Overall Diameter of Cable		Number of Samples	Minimum Length of Each Sample	
feet	meters	inches	mm		cable feet	cable meters
Less than 2000	Less than 610	Less than 1.0	Less than 25.4	none	...	...
Less than 1000	Less than 305	1.0 and larger	25.4 and larger	none	...	...
2000-50000	610-15240	Less than 1.0	Less than 25.4	1	6	1.8
1000-25000	305-7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
		2.0 and larger	50.8 and larger	1	2	0.6
More than 50000	More than 15240					
First 50000	First 15240	Less than 1.0	Less than 25.4	1	6	1.8
Each additional 50000	Each additional 15240	Less than 1.0	Less than 25.4	1	6	1.8
More than 25000	More than 7620					
First 25000	First 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
Each additional 25000	Each additional 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
More than 25000	More than 7620					
First 25000	First 7620	2.0 and larger	50.8 and larger	1	2	0.6
Each additional 25000	Each additional 7620	2.0 and larger	50.8 and larger	1	2	0.6

6.4.4 Sampling of Insulation for Physical and Aging Tests

Samples of insulated conductors for the unaged and aged physical tests shall be selected in accordance with Table 6-2.

6.4.5 Sampling of Jacket for Physical and Aging Tests

Samples of jacketed cable for the unaged and aged physical tests shall be selected in accordance with Table 6-3. No tests shall be made on jackets less than 30 mils (0.76 mm) in thickness.

6.4.6 Number of Test Specimens

From each of the samples selected in accordance with 6.4.4 and 6.4.5, test specimens shall be prepared in accordance with Table 6-4.▲

Table 6-4

Test	Total Number of Test Specimens
Determination of unaged properties—tensile strength and ultimate elongation	3†
Accelerated aging tests	
Air oven	3†
Oil immersion	3†
Heat Shock	1*
Heat distortion	3†
Cold bend	1*
▲Flame test	1*
Environmental cracking	See 6.9
Absorption coefficient	See 6.9
Stripping	1*
Wrap	1*

*For the heat-shock, cold-bend, flame, stripping, and wrap tests, only one specimen shall be tested.

†One test specimen out of three shall be tested and the other two specimens held in reserve, except that when only one sample is selected in accordance with 6.4.4 and 6.4.5, all three test specimens shall be tested and the average of the results reported.

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6.4.7 Size of Specimens

The test specimens shall be prepared using either ASTM D412 Die B or E with specimen length not less than 6 inches (152 mm) or ASTM D412 Die C or D with specimen length not less than 4.5 inches (114 mm).

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 test specimen shall be permitted to be the entire section of the insulation. When the full cross-section is used, the specimens 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), specimens rectangular in section with cross-section not greater than 0.025 square inch (16 mm^2) shall be cut from the insulation. In extreme cases, it may be necessary to use a segmental specimen. (This sentence is approved by NEMA as Authorized Engineering Information.)

Specimens for test 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.

6.4.8 Preparation of Specimens of Insulation and Jacket

The test specimen 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 the test specimen will be smooth and of uniform thickness.

6.4.9 Specimen for Accelerated Aging Test

Specimens shall not be heated, immersed in water, nor subjected to any mechanical or chemical treatment not specifically described in this standard.

6.4.10 Calculation of Area of Test Specimens

6.4.10.1 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 area of the conductor. The area of a stranded conductor shall be calculated from its maximum diameter.

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6.4.10.2 Where a slice cut from the insulation by a knife held tangent 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 shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken.

When the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

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. *

6.4.10.3 When the conductor is large and the insulation thin and when a portion of a sector of a circle has to be taken, the area shall be calculated as the thickness times the width.

This applies either to a straight test piece or to one stamped out with a die and assumes that corrugations have been removed. *

6.4.10.4 When the conductor is large and the insulation thick and when a portion of a sector of a circle has to be taken, the area shall be calculated as the proportional part of the area of the total cross-section.

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

6.4.11 Physical Test Procedures (See 6.4 for Test Samples and Specimens)

6.4.11.1 Test Temperature. Physical tests shall be made at a room temperature not less than 20°C (68°F) nor more than 28°C (82.4°F). The test specimens shall be kept at room temperature for not less than 30 minutes prior to the test.

6.4.11.2 Type of Testing Machine. The testing machine shall be in accordance with 6.1 of ASTM D 412.

6.4.11.3 Tensile Strength Test. The tensile strength test shall be made with specimens prepared in accordance with 6.4.6 and 6.4.7. The length of all of the specimens for the test shall be equal. Gauge marks shall be 2 inches (51 mm) when using 6 inch (152 mm) specimens and 1 inch (25 mm) apart when using 4.5 inch (114 mm) specimens except that 1 inch (25 mm) 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. The specimen shall be stretched at the rate of 20 inches (508 mm) per minute jaw speed until it breaks.

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 high density polyethylene (having a density of 0.926 Mg/m³ or greater or total base polyethylene resin content (having a density of 0.926 Mg/m³ or greater), shall be permitted to be tested at a jaw separation rate of 2 inches per minute (51 mm per minute) as an alternate to 20 inches per minute (508 mm per minute). Specimens shall break between the gauge marks and the tensile strength shall be calculated on the area of the unstretched specimen. Specimen length, gauge mark distance, and jaw speed shall be recorded with the results. ▲

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

6.4.12 Aging Test

6.4.12.1 Aging Test Specimens. Test specimens of similar size and shape shall be prepared from each sample selected in accordance with 6.4.4 and 6.4.5, three for the determination of the initial or unaged properties, and three for each aging test required for the insulation or jacket being tested. One specimen of each three shall be tested and the other two held as spares except that, where only one sample is selected, all three specimens shall be tested and the average of the results reported.

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In the case of wire and cable smaller than 6 AWG having an insulation thickness less than 90 mils (2.92 mm), the insulation shall be subjected to the aging condition with the conductor removed and each end of the specimen suitably plugged.

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

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

Simultaneous aging of different compounds should be avoided. Some migration of plasticizer is known to occur. (This paragraph is approved by NEMA as Authorized Engineering Information.)

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 oven.

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.

6.4.12.2 Air Oven 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 recorded automatically on a chart, and controlled to ± 1°C.

6.4.12.3 Oil Immersion Test for Polyvinyl Chloride Insulation and Jacket. The following test specimens shall be immersed in ASTM Oil No. 2, described in Table I of ASTM D 471, at 70°C ± 1°C for 4 hours:

1. Insulated conductors in sizes smaller than 6 AWG, except for the ends.
2. Die-cut specimens of the insulation in sizes 6 AWG and larger.
3. Die-cut specimens of the jacket.

At the end of this time, the specimens shall be removed from the oil, blotted to remove excess oil and allowed to rest at room temperature for a period of 16 to 96 hours. The tensile strength and elongation of the specimens shall then be determined in accordance with 6.4.11 at the same time that the original properties are determined.

6.4.13 Heat Shock. Samples (see 6.4.4 and 6.4.5) of polyvinyl chloride insulated conductor and jacketed cable shall be tightly wound around a mandrel having a diameter in accordance with Tables 6-4 and 6-5. The samples shall be held firmly in place and subjected to a temperature of 121°C ± 1°C for 1 hour.

Table 6-4
Insulated Conductor

Conductor Size, AWG or MCM	Diameter of Mandrel as a Multiple of the Insulated Conductor Diameter	Number of Turns
8 and smaller	1	6
6-2	2	6
1	2	1
1/0-4/0	2	1/2 (180-degree U bend)
250 and larger	5	1/2 (180-degree U bend)

Series lighting cables, sizes 8, 6 and 4 AWG, shall be wound six turns around a mandrel which is two times the insulated conductor diameter.

Table 6-5
Jacketed Cable

Outside Diameter of Wire or Cable		Diameter of Mandrel as a Multiple of the Outside Diameter of Cable	Number of Adjacent Turns
inches	mm		
0-0.750	0-19.05	3	6
0.751-1.500	19.08-38.10	8	180-degree bend
1.501 and larger	38.13 and larger	12	180-degree bend

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6.4.14 Heat Distortion

6.4.14.1 Test Specimen

6.4.14.1.1 Polyvinyl Chloride Insulation on Conductors of Sizes 4/0 AWG and Smaller. The initial diameter of a 1-inch (25.4 mm) specimen of the insulated conductor shall be measured with a micrometer caliper having a flat surface on both the anvil and spindle. The diameter of the uninsulated conductor shall be measured also, and the original thickness of the insulation, T_1, shall be calculated as follows:

$$T_1 = \frac{D - C}{2}$$

Where—

T_1 = Original thickness of the insulation.

D = Initial diameter of the insulated conductor.

C = Diameter of the uninsulated conductor.

6.4.14.1.2 Polyvinyl Chloride Insulation on Conductors of Sizes Larger Than 4/0 AWG and Polyvinyl Chloride and Polyethylene Jackets. A sample approximately 8 inches (203 mm) long shall be prepared to have a thickness of 50 mils (1.27 mm) ± 10 mils and smooth surfaces. From this sample, test specimens (see 6.4.4 and 6.4.5) 1 inch (25.4 mm) long and 9/16 inch (14.3 mm) ± 1/16 inch wide shall be prepared. Where the diameter of the cable does not permit the preparation of a specimen 9/16 inch (14.3 mm) wide, a molded sheet of the same compound may be used.

The thickness of the specimen, T_1, shall be measured with a Randall & Stickney, or equivalent, gauge having a 3/8-inch (9.5 mm) foot with no loading other than the 85 grams of the gauge.

6.4.14.2 Test Procedure. The following steps shall be completed in 3 hours. A Randall & Stickney gauge, or the equivalent, with a load as indicated in Table 6-6 on the foot shall be placed in an oven which is preheated to the specified temperature. At the end of 1 hour, the test specimen shall be placed in the oven, and both the gauge and the test specimen shall remain in the oven for 1 hour. At the end of this 1-hour period, the specimen shall be placed directly under the foot of the gauge and allowed to remain in the oven under load for 1 hour at the specified temperature.

At the end of this period, the dial of the gauge shall be read for:

1. The value of F for insulated conductors 4/0 AWG and smaller, and the thickness of the insulation, T_2, shall be calculated as follows:

$$T_2 = \frac{F - C}{2}$$

2. The value of T_2 for insulated conductors larger than 4/0 AWG and jackets.

The distortion shall be calculated as follows:

$$\text{Distortion, percent} = \frac{T_1 - T_2}{T_1} \times 100$$

Where—

T_2 = Thickness of the insulation after the heat distortion test.

F = Final outside diameter as read from the gauge.

C = Diameter of the uninsulated conductor.

The gauge loads for the heat distortion test shall be as indicated in Table 6-6:

Table 6-6

	Load on Gauge, Grams
Polyvinyl chloride insulated conductor size, AWG	
18	300
16	400
14-8	500
6-1	750
1/0-4/0	1000
Polyvinyl chloride insulated conductors larger than 4/0 AWG and all polyvinyl chloride and polyethylene jackets—smoothed samples	2000
Polyvinyl chloride insulated series lighting cable, all sizes	1000

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6.4.15 Cold Bend

6.4.15.1 Polyvinyl-chloride Insulation. The insulation shall not show any cracks when a sample of insulated conductor which has been subjected to the specified temperature for 1 hour is, upon removal from the cooling chamber, immediately wound around a mandrel at least six adjacent turns for sizes 3/0 AWG and smaller or, for sizes larger than 3/0 AWG, bent 180 degrees around a mandrel. The mandrel diameters shall be in accordance with Table 6-7. The bending shall be accomplished at an approximately uniform rate so that the time consumed is not more than 1 minute.

Table 6-7
Polyvinyl-chloride-insulated Conductors

Conductor Size, AWG or MCM	Diameter of Mandrel		Number of Turns
	inches	mm	
18	5/16	7.9	6
16	5/16	7.9	6
14	1/2	12.7	6
12	9/16	14.3	6
10	5/8	15.9	6
8	3/4	19.0	6
6	1 1/4	31.8	6
4	1 3/8	34.9	6
2	1 9/16	39.7	6
1	2 11/16	68.3	6
1/0	2 7/8	73.0	6
2/0	3	76.2	6
3/0	3 1/4	82.6	6
4/0	3 1/2	88.9	1/2 (180-degree U bend)
250-500	8 X cable diameter		1/2 (180-degree U bend)
Over 500	10 X cable diameter		1/2 (180-degree U bend)
Series lighting cable, all sizes	5 X cable diameter		1/2 (180-degree U bend)

6.4.15.2 Polyvinyl-chloride Jacket. The test specimen shall be subjected to the specified temperature for 1 hour and then bent 180 degrees around a mandrel having a diameter in accordance with Table 6-8 immediately upon its removal from the cooling chamber. The bend shall be made at a uniform rate, and the time required shall not exceed 1 minute.

Table 6-8

Outside Diameter of Wire or Cable		Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
inches	mm	
0-0.800	0-20.32	8
0.801 and larger	20.35 and larger	10

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6.4.16 Wrap Test. The specimen with the 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 specimen. The ends of the specimen shall be secured to the mandrel so that four complete turns of the specimen will be exposed to the air between the securing means. The specimen and mandrel shall be suspended for 24 hours in a full-draft circulating-air oven at a temperature of 95.0°C ± 2.0°C (203.0°F ± 3.6°F), after which the specimen and mandrel shall be removed from the oven and cooled for 1 hour in a silica-gel desiccator or the equivalent at 24.0°C ± 0°C (75.2°F ± 5.4°F). The specimen shall be straightened immediately upon removal from the desiccator and inspected for surface cracks. ●

● Added 9-20-1978.

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6.5 Flame Test ▲

6.5.1 The test apparatus shall consist of the following:

1. 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 which is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.

2. Means for adjusting the position of the test specimen.

3. A 4-pound (1.8-kg) weight (for 8 AWG and smaller sizes) to be attached to the lower end of the test specimen to keep it taut.

4. Tirrill burner with an attached pilot light and mounted on a 20-degree angle block. 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 test specimen.

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

7. Watch or clock with a hand which makes one complete revolution per minute.

8. Flame indicators consisting of strips of 60-pound (27.2-kg) gummed kraft paper having a nominal thickness of 5 mils (0.127 mm) and a width of ½ inch (12.7 mm).*

*The paper used for the indicators is known to the trade as 60-pound stock and is material substantially the same as that described in Federal Specification UU-T-111 covering "Tape, Paper, Gummed (Kraft)."†

6.5.2 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 a test specimen having a length of approximately 22 inches (559 mm) shall be clamped in position at the upper end of the chamber; for sizes 8 AWG and smaller, a 4-pound (1.8-kg) weight shall be attached to the lower end of the test specimen to keep it taut. 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 3/4 inch (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 1/2 inches (38.1 mm) high.

6.5.3 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 angleblock shall rest against the jig, which shall be adjusted so that there is a distance of 1 1/2 inches (38.1 mm) along the axis of the burner stem between the tip of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for 15 seconds. 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 surface of the specimen. 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 to have conveyed flame. The duration of burning of the specimen after the fifth application of the flame shall be noted, and any specimen which continues to burn for more than 1 minute shall be considered to have failed this test.

6.6 Physical Tests for Semiconducting Material Intended for Extrusion

6.6.1 Test Sample. One test sample shall be molded from each lot of semiconducting material intended for extrusion on the cable.

6.6.2 Test Specimens. For each test, three test specimens, each approximately 6 inches (152 mm) long and not greater than 0.025 square inch (16 square mm) in cross-section, shall be cut out of the test sample with a die. All three test specimens shall be tested and the results averaged.

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6.6.3 Elongation. This test shall be conducted in accordance with 6.4.11 and 6.4.12.

6.6.4 Brittleness Test. This test shall be conducted in accordance with ASTM D 746, using Specimen A.

6.7 Accelerated Water Absorption Tests

6.7.1 General. No test sample shall be taken for 5000 feet (1524 meters) or less. One test sample for each test shall be taken for the first 5001 to 20,000 feet (1524 to 6096 meters) of each cable construction and one additional sample for each additional 100,000 feet (30,480 meters). The gross length of each sample required by the electrical method shall be 15 feet (4.57 meters) and, by the gravimetric method, 11 inches (279 mm).

These tests shall not be made on cables which have a nonconductive separator between the conductor and insulation, insulations less than 45 mils (1.14 mm) thick, and insulations having a covering which cannot be removed without damage to the insulation.

6.7.2 Electrical Method (EM-60). A 15-foot (4.57-meter) test specimen of the insulated conductor shall be used.

The middle 10 feet (3.05 meters) of the test specimen shall be immersed in tap water which is maintained at the temperature specified in Part 3 for a period of 14 days, keeping the 2½ foot (0.76 meter) portion of each end above water as leakage insulation. A tightly fitting cover shall be placed directly above the water surface, with suitable water-tight bushings for the ends of the specimen. The water level shall be kept constant.

The capacitance of the insulation shall be determined at an average stress of 80 volts per mil at approximately 60 hertz after 1, 7, and 14 days' immersion. The increase in capacitance from 1 to 14 days and from 7 to 14 days shall be expressed as a percentage of the 1- and 7-day values, respectively.

The dielectric constant (specific inductive capacity) of the insulation at 60 hertz shall be calculated as follows:

$$\text{Dielectric constant} = 13600\ C \log_{10} \frac{D}{d}$$

Where:

C = Capacitance in microfarads of the 10-foot (3.05-meter) section.
D = Diameter over the insulation.
d = Diameter under the insulation.

6.7.3 ▲

▲ Rescinded 5-12-1982.

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6.7.4 Dielectric Strength Retention. Twenty samples, each at least 5 feet (1.5 meters) long, shall be cut from a reel or coil chosen at random. The sample shall be either 14 AWG solid or 14 AWG stranded, with a 45 mil (1.14 mm) wall of insulation.

Ten identified samples shall be immersed, except for the ends, for 14 days in water at the specified temperature. Immediately thereafter, all twenty samples shall be immersed, except for the ends, in water at 20°C to 30°C for 1 hour. At least 3 feet (0.9 meters) of each sample shall be immersed.

After the twenty samples have been immersed, an alternating current test voltage, starting at zero, shall be applied across the insulation and increased at the rate of 500 volts per second until breakdown occurs.

The dielectric strength retention shall be calculated as follows:

$$\text{Dielectric strength retention, percent} = \frac{B}{A} \times 100$$

Where:

B = Average breakdown voltage of the ten samples immersed for 14 days at the specified temperature.

A = Average breakdown voltage of the ten samples not immersed for 14 days at the specified temperature.

6.8 Thickness of Coverings

6.8.1 Nonmetallic Tape. Nonmetallic tape when not bonded to the underlying material, shall be removed from not less than 6 inches (152 mm) of the insulated conductor or assembled core. The thickness of the tape shall be determined by means of a dial micrometer having a presser foot 0.25 inch (6.35 mm) ±0.01 inch in diameter and exerting a total force of 3.0±0.1 ounces (85±3 grams), the load being applied by means of a weight. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

6.8.2 Metallic Shielding Tape or Steel Tape. Metallic shielding tape or steel tape shall be removed from not less than 6 inches (152 mm) of the insulated conductor or assembled core. The thickness of the tape shall be measured by means of a micrometer caliper having flat surfaces on both the anvil and the end of spindle and graduated to read directly at least to mils, and preferably to tenths of a mil. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

6.8.3 Metallic Sheaths. The thickness of the sheath shall be determined by measurements made with a micrometer caliper having a rounded anvil. The measurements shall be made directly on two specimens of the sheath removed from the cable, one from each end of the reel length. At least five separate measurements, approximately equally spaced around the circumference, shall be made on each specimen, and the average of all the measurements on the two specimens shall be considered as the average thickness of the sheath. The minimum of all of the measurements obtained shall be considered as the minimum thickness of the sheath.

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Specimens of the sheath shall be free from external mechanical injury, not less than 3 inches (76.2 mm) long, with the ends cut perpendicular to the axis, and shall be taken before the cable is shipped.

6.8.4 Jute Beddings and Servings. The thickness of jute bedding under the armor shall be determined by the use of a diameter tape and shall be considered as 1/2 of the difference in the measurements under and over the serving. The measurement in each case shall be the average of five readings taken at different points along the serving.

6.8.5 Thermoplastic Coverings Over Metallic Sheaths. The minimum thickness of the covering shall be determined by direct measurement with a micrometer, a steel scale with pocket glass, or a micrometer microscope on a ring of covering removed from the cable.

6.8.6 Thermoplastic Coverings Over Metallic Armor. The minimum and maximum thickness of the covering shall be determined directly with a micrometer, a steel scale with pocket glass, or a micrometer microscope on a ring of covering removed from the cable. The average of these determinations shall be taken as the average thickness of the jacket.

6.9 Additional Tests

6.9.1 Environmental Cracking. Except as otherwise specified in 6.9.1.1 and 6.9.1.2, the test shall be made in accordance with ASTM D 1693.

6.9.1.1 Test Specimen. The number and length of samples shall be selected in accordance with 6.4.5. Three test specimens approximately 1.5 inch (38.1 mm) long, 0.5 inch (12.7 mm) wide and 0.125 inch (3.18 mm) thick from each sample shall be molded from material taken from the completed cable. The temperature of the molded specimens shall be lowered at any suitable rate. A slit made with a razor blade, approximately 0.75 inch (19.0 mm) long and from 0.020 to 0.025 inch (0.51 to 0.64 mm) deep, shall be centrally located on one of the 1.5 inch X 0.5 inch (38.1 X 12.7 mm) surfaces.

6.9.1.2 Test Procedure. The specimens shall be bent with the slit on the outside and placed in a test tube 200 millimeters long and 32 millimeters in outside diameter. The cracking agent (Igepal CO-630 made by the GAF Corporation, or its equivalent) shall be added to completely cover the specimen. The test tube, suitably closed by means such as foil-covered cork, shall be placed in an oven at 50°C ± 1°C for 48 hours. At the end of this period, the specimens shall be removed, allowed to cool to room temperature, and inspected for cracking.

6.9.2 Absorption Coefficient Test. The number and length of samples shall be selected in accordance with 6.4.5. Three test specimens shall be taken from each sample. One test specimen out of three shall be tested and the other two specimens held in reserve, except that when only one sample is selected in accordance with 6.4.5, all three test specimens shall be tested and the average of the results reported. The absorption coefficient of polyethylene compounds shall be determined in accordance with ASTM D 3349.

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6.9.3 Tests for Discharge-resisting Jackets

6.9.3.1 General. The samples shall be taken from the completed cable. No sample shall be taken from the first 5000 feet (1524 meters). One sample shall be taken from the first 5001 to 20,000 feet (1524 to 6096 meters) of each cable construction and one additional sample for each additional 100,000 feet (30,480 meters).

6.9.3.2 Specific Surface Resistivity. A sample of the completed cable of suitable length shall be immersed, except for the ends, in water at room temperature for 48 hours. At the end of this period, the sample shall be removed from the water. The excess surface moisture shall be wiped off with blotting paper and the sample allowed to remain at room temperature for 10 minutes. Two 1-inch-(25.4-mm-) wide foil electrodes shall be wound around the cable surface with a 6-inch (152-mm) spacing. A 250-500 volt direct-current potential shall be applied between the two electrodes and the resistance shall be measured in accordance with ASTM D 257. The specific surface resistivity shall be calculated by the following formula:

$$P = 0.524\ RD$$

Where—

P = Specific surface resistivity.

R = Surface resistance in megohms per 6-inch spacing.

D = Cable diameter in inches.

6.9.3.3 U-bend Discharge. A sample of the completed cable shall be bent, in the form of a U, 180 degrees around a mandrel having a diameter in accordance with Table 6-9.

Table 6-9

Conductor Size, AWG or kcmil	Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
8-2	6
1-3/0	8
4/0-500	10
Over 500	12

The sample shall be mounted with the apex of the U above and in contact with a smooth metal plate and with the legs of the U perpendicular to the plate. After not less than 30 minutes nor more than 45 minutes following the bending, a source of 60-hertz alternating-current potential of 125 volts per mil of nominal insulation thickness shall be applied between the conductor and the metal plate. This potential shall be maintained continuously for at least 6 hours. This test shall be made at room temperature.

6.9.4 Volume Resistivity

6.9.4.1 Test Sample

One sample shall be taken from each lot or from each 25000 feet of completed cable, whichever is less.

6.9.4.2 Conductor Stress Control ▲

The sample shall be cut in half longitudinally and the conductor removed. Four silver-painted electrodes shall be applied to the conductor stress control layer. The two potential electrodes shall be at least 2 inches (50.8 mm) apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode. When a high degree of accuracy is not required, this test may be made with only two electrodes spaced at least 2 inches (50.8 mm) apart.▲

The power of the test circuit shall not exceed 100 milliwatts. The test shall be made at the specified temperature with either alternating- or direct-current voltage.

The volume resistivity shall be calculated as follows:

$$\blacktriangle \quad P = \frac{R(D^2 - d^2)}{100\ L}$$

where—

▲P = Volume resistivity in ohm-meters.
R = Measured resistance in ohms.
▲D = Diameter over the conductor stress control layer in inches.
d = Diameter over the conductor in inches.
L = Distance between potential electrodes in inches.

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6.9.4.3 INSULATION SHIELD ▲

Four silver-painted annular-ring electrodes shall be applied to the surface of the shield layer The two potential electrodes shall be at least 2 inches (50.8 mm)'apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode. When a high degree of accuracy is not required, this test may be made with only two electrodes spaced at least 2 inches (50.8 mm) apart.▲

The power of the test circuit shall not exceed 100 milliwatts. The test shall be made at the specified, temperature with either alternating or direc current voltage.

The volumn resistivity shall be calculated as follows:

$$\blacktriangle \quad P = \frac{2R\,(D^2 - d^2)}{100L}$$

Where—

▲ P = Volume resistivity in ohm-meters
R = Measured resistance in ohm.
▲ D = Diameter over the insulation shield layer in inches.
d = Diameter over the insulation in inches.
L = Distance between the potential electrodes in inches.

6.9.5 Stripping Test for Cables with Extruded Thermoplastic Insulation Shields. Test samples and specimens shall be selected in accordance with Table 6-3 and 6.4.6. The test specimen shall be approximately 15 inches long, and all coverings over the extruded insulation shield shall be removed.

Starting at one end, two parallel longitudinal cuts 1/2 inch (12.7 mm) apart and not less than 12 inches (305 mm) long shall be made through the insulation shield. The specimen shall be rotated 180 degrees and two identical cuts shall be made starting from the same end. Each 1/2-inch (12.7 mm) strip shall be peeled back from the cut end for a distance of 2 inches (50.8 mm).

The specimen shall be mounted horizontally in a testing machine and secured at each end. The 2-inch (50.8 mm) end of the peeled strip shall be gripped in the testing machine in such a manner that it can be pulled at an angle of 90 degrees to the cable axis.

Each strip shall be peeled from the cable at a constant speed not exceeding 1/2 inch (12.7 mm) per second for a distance of not less than 10 inches (254 mm).

The angle of pull shall be maintained as close as possible to 90 degrees throughout the test.

The tension necessary to remove the strip shall be monitored continuously and the minimum value shall be recorded.

6.10 Retests

6.10.1 Physical and Aging Properties and Insulation and Jacket Thicknesses. (See 6.4 and the exceptions given in 6.10.2.)

If any test specimen fails to meet the requirements of any of the following tests, either before or after aging, that test shall be repeated on two additional specimens taken from the same sample:

6.4.3	Measurement of Thickness
6.4.11.3	Tensile Strength
6.4.11.4	Elongation
6.4.12	Aging
6.4.14	Heat Distortion
6.6	Physical Tests for Semiconducting Material Intended for Extrusion

Failure of either of the additional specimens shall indicate failure of the sample to conform to this standard.

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.

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 for physical and aging properties and thickness. 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

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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.

6.10.2 Tests on Samples, Except Physical and Aging Properties and Insulation and Jacket Thicknesses. (See 6.10.1)

6.10.2.1 If all of the samples pass all of the following tests, the lot of cable which they represent shall be considered as meeting the requirements of this standard.

6.4.13	Heat Shock
6.4.15	Cold Bend
▲6.5	Flame Test
6.7	Accelerated Water Absorption
6.8	Thickness of Coverings
6.9	Additional Tests
▲6.14	Flexibility of Corrugated Armor

6.10.2.2 If any sample fails to pass any of these tests, the length of cable from which the sample was taken shall be considered as not meeting the requirements of the test which it failed, and another sample shall be taken from each of the two other lengths of cable in the lot of cable under test. If either of the second samples fails to pass the test, the lot of cable shall be considered as not meeting the requirements of this standard. If both such second samples pass the test, the lot of cable (except the length represented by the first sample) shall be considered to meet the requirements of this standard.

6.10.2.3 Failure of any sample shall not preclude resampling and retesting the length of cable from which the original sample was taken.

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ELECTRICAL TESTS ON COMPLETED CABLES

6.11 Voltage Tests

6.11.1 General. 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 shield, metallic armor, or water, and the rate of increase from the initially applied voltage to the specified test voltage shall be approximately uniform and shall be not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds.

6.11.2 Alternating-current 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 25 and 60 hertz and shall have a wave shape approximating a sine wave as closely as possible.

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

The duration of the alternating-current voltage test shall be 5 minutes.

6.11.3 Direct-current Voltage Test. This test is applicable to cables without insulation shield rated up through 5000 volts and to all cables rated 5001 volts and above and shall be made after the insulation resistance test described in 6.12. The equipment for the direct-current voltage test shall consist of a battery, generator or suitable rectifying equipment and shall be of ample capacity.

The initially applied direct-current voltage shall be not greater than 3.0 times the rated alternating-current voltage of the cable.

The duration of the direct-current voltage test shall be 15 minutes for cables with insulation shield and 5 minutes for cables without insulation shield.

6.11.4a Alternating-current Spark Test

6.11.4a.1 Application. This test shall apply to single-conductor cable and assemblies of single-conductor cables rated 0 through 2000 volts.

This test shall not apply to:

(a) Multiconductor cables other than assemblies of single-conductor cables.
(b) Cables with insulation shield.
(c) Cables with metallic sheath or armor.
(d) Assemblies containing uninsulated conductors.
(e) Cables rated above 2000 volts.

6.11.4a.2 Test Apparatus. Test apparatus shall consist of:

(a) A source of single-phase alternating-current potential capable of maintaining the required voltage under all normal leakage current conditions.
(b) An electrode capable of maintaining contact, throughout its length, with the periphery of the cable under test.
(c) A means of measuring voltage between electrode and ground.
(d) A means of indicating a fault (failure).

6.11.4a.3 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 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: †

(a) U.S. Customary Units Formula for Determining Maximum Speed of Cable

$$MS = 5/9 \times F \times EL$$

Where—

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

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(b) Equivalent Metric Formula for Determining Maximum Speed of Cable

$$MS = 1/150 \times F \times EL$$

Where—

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

6.11.4a.4 Failure. Any indication by the fault indicator shall constitute a failure.

6.11.4b Direct-current Spark Test. This test is applicable to single-conductor cables and assemblies of insulated single-conductor cables without insulation shield, and without metallic sheath or metallic armor, rated 0 through 2000 volts. The equipment for the direct-current spark test shall consist of a direct-current sparker of ample voltage and a suitable electrode. The sparker shall be capable of maintaining the specified test voltage under all normal conditions of leakage current. 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.

The electrode shall make contact with the entire exposed surface of a single-conductor cable and of an assembly of twisted single-conductor cables.

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.

6.11.5 Cables Without Metallic Sheath, Metallic Shield, or Metallic Armor. Except for the direct current spark test (see 6.11.4b) and the alternating current spark test (see 6.11.4a), single-conductor cables of this type which are twisted together into an assembly 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; all other single-conductor and multiple-conductor cables of this type shall be immersed in water for at least 6 hours and tested while still immersed. Each insulated conductor shall be tested against all other conductors connected to the grounded water tank. ▲

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6.11.6 Cables With Metallic Sheath, Metallic Shield or Metallic Armor. All cables of this type shall be tested with the metallic sheath, shield or armor grounded, without immersion in water, at the test voltage specified. For cables having a metallic sheath, shield 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 nonshielded individual conductors having a metallic sheath, shield or armor over the cable assembly, the test voltage shall be applied between each insulated conductor and all other conductors and ground.

6.11.7 Voltage Tests After Installation. If voltage tests are made after installation, they shall be made immediately. The test voltage shall be a direct-current voltage as given in Table 6-10 or 6-11 and shall be applied in accordance with 6.11.1 and 6.11.3.

Table 6-10
d-c Test Voltage After Installation for Polyethylene-Insulated Power Cables

Rated Circuit Voltage, Phase to Phase, Volts	Conductor Size, AWG or kcmil ▲	Test Voltage, kV	
		100 Percent Insulation Level	133 Percent Insulation Level
2001-5000	8-1000	25	25
5001-8000	6-1000	35	35
8001-15000	2-1000	55	65
15001-25000	1-1000	80	100
25001-28000	1-1000	85	...
28001-35000	1/0-1000	100	...

Table 6-11
d-c Test Voltage After Installation for Thermoplastic-Insulated Series Lighting Cables

Circuit Voltage, Volts	Conductor Size, AWG	Test Voltage, kV
POLYVINYL-CHLORIDE-INSULATED CABLES		
0-5000	8-4	25.0
POLYETHYLENE-INSULATED CABLES		
2001-3000	10-4	25
3001-6000	8-4	25
6001-9000	8-4	45

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6.12 Insulation Resistance

6.12.1 Test Apparatus. The test apparatus shall consist of a source of constant potential of from 100 to 500 volts and such other apparatus as is listed in ASTM D 257 (see Appendix E).

6.12.2 Test Procedure. The insulation resistance shall be measured after the completed cable alternating-current voltage tests or before any direct-current voltage tests specified in 6.11. Where the voltage tests are made on wire or cable immersed in water, the insulation resistance shall be measured while the cable is still immersed. Single-conductor cables shall be tested between the conductor and metallic sheath or water. Multiple-conductor cables with nonshielded conductors shall be tested between each conductor and all other conductors and sheath or water. Multiple-conductor cables with shielded conductors shall be tested between the conductor and shield. The conductor under test shall be connected to the negative terminal of the test equipment and readings shall be taken after an electrification of 1 minute.

Each coil, reel or length of wire or cable shall have an insulation resistance in megohms—1000 feet at a temperature of 15.6°C (60°F) of not less than the value of R calculated as follows:

$$R = K \log_{10} \frac{D}{d}$$

Where—

R = Insulation resistance in megohms—1000 feet.

K = Constant for the grade of insulation. (See Part 3.)

D = Diameter over the insulation.

d = Diameter under the insulation.

If the temperature at the time of measurement differs from 15.6°C (60°F), the insulation resistance shall be corrected to that at 15.6°C (60°F) by multiplying the measured value by the proper correction factor given in Table 6-12, using the coefficient (see 6.12.3) for the particular grade of insulation and temperature in question. The temperature of the water shall be not less than 10°C (50°F) nor more than 29.4°C (85°F).

6.12.3 Determination of Temperature Correction Factors for Insulation Resistance. Three samples, preferably of 14 AWG solid wire with a 45-mil (1.14-mm) wall of insulation, shall be selected as representative of the insulation under consideration. The samples shall be of sufficient length to yield insulation resistance values under 25000 megohms at the lowest water bath temperature.

The three samples shall be immersed in a water bath equipped with heating, cooling and circulating facilities, with the ends of the samples extended at least 2 feet (0.6 meter) above the surface of the water and properly prepared for minimum leakage. The samples shall be left in the water at room temperature for 16 hours before adjusting the bath temperature to 10°C or before transferring the samples to a 10°C test temperature bath.

The resistance of the conductor shall be measured at suitable intervals until it remains unchanged for at least 5 minutes. The insulation will then be at the temperature of the bath as read on the bath thermometer. Insulation resistance shall then be measured in accordance with 6.12.2.

Each of the three samples shall be exposed to successive water temperatures of 10°C, 16°C, 22°C, 28°C, and 35°C and, returning, 28°C, 22°C, 16°C and 10°C. Insulation resistance readings shall be taken at each temperature after equilibrium has been established.

The two sets of readings taken at the same temperature shall be averaged and, together with the reading at 35°C, plotted on semi-log paper. The insulation resistance value at 15.6°C (60°F) shall be read from the plot.

The 0.55°C (1°F) coefficient shall be calculated by dividing the insulation resistance at 15.6°C (60°F) by that at 16.1°C (61°F).

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Table 6-12
Temperature Correction Factors for Insulation Resistance to 15.6°C (60°F)

Temperature		Coefficient for 1°F									
F	C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
50	10.0	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35	0.32
51	10.6	0.77	0.70	0.65	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.82	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.87	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60	0.57
56	13.3	0.89	0.86	0.82	0.76	0.76	0.74	0.71	0.69	0.66	0.64
57	13.9	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.71
58	14.4	0.94	0.93	0.91	0.90	0.88	0.86	0.85	0.83	0.82	0.80
59	15.0	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.24	1.27
63	17.2	1.09	1.13	1.16	1.19	1.23	1.26	1.30	1.34	1.38	1.42
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.47	1.53	1.58
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.62	1.70	1.78
66	18.9	1.20	1.27	1.35	1.42	1.50	1.59	1.69	1.78	1.88	1.98
67	19.4	1.23	1.32	1.41	1.51	1.62	1.72	1.84	1.96	2.09	2.21
68	20.0	1.27	1.37	1.48	1.60	1.72	1.85	1.99	2.15	2.31	2.48
69	20.6	1.31	1.43	1.55	1.69	1.84	2.00	2.18	2.36	2.57	2.77
70	21.1	1.35	1.48	1.63	1.79	1.97	2.17	2.38	2.60	2.85	3.10
71	21.7	1.39	1.54	1.72	1.90	2.11	2.34	2.59	2.87	3.17	3.46
72	22.2	1.43	1.60	1.80	2.02	2.26	2.53	2.82	3.15	3.52	3.90
73	22.8	1.47	1.67	1.89	2.14	2.42	2.72	3.08	3.46	3.90	4.37
74	23.3	1.52	1.74	1.98	2.27	2.58	2.94	3.35	3.81	4.31	4.88
75	23.9	1.56	1.80	2.08	2.40	2.76	3.18	3.65	4.19	4.78	5.47
76	24.4	1.61	1.87	2.19	2.54	2.96	3.43	3.98	4.61	5.30	6.12
77	25.0	1.66	1.95	2.30	2.70	3.17	3.70	4.34	5.08	5.88	6.85
78	25.6	1.71	2.02	2.41	2.86	3.39	4.00	4.73	5.59	6.51	7.68
79	26.1	1.76	2.11	2.53	3.03	3.62	4.33	5.16	6.14	7.27	8.59
80	26.7	1.81	2.19	2.66	3.21	3.87	4.67	5.61	6.72	8.07	9.65
81	27.2	1.87	2.28	2.80	3.40	4.15	5.04	6.12	7.43	8.98	10.80
82	27.8	1.92	2.37	2.94	3.60	4.43	5.45	6.69	8.18	9.92	12.10
83	28.3	1.98	2.47	3.08	3.82	4.72	5.89	7.28	9.00	11.00	13.60
84	28.9	2.04	2.57	3.23	4.05	5.04	6.35	7.92	9.90	12.2	15.2
85	29.4	2.10	2.67	3.40	4.30	5.42	6.84	8.67	10.8	13.5	17.0

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6.13 Partial Discharge Test Procedure

Refer to ICEA Publication T-24-380. ●

6.14 Method for Flexibility Test for Continuously Corrugated Armor

A suitable length of armored cable with jacket removed, if any, shall be bent in a "U" bend around a mandrel having a diameter equal to not greater than 14 times the cable diameter with sufficient tension so 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.

6.15 ▲

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Part 7
CONSTRUCTIONS OF SPECIFIC TYPES

The requirements of Parts 1 through 6 shall be met except as otherwise modified in Part 7.

7.1 Pole and Bracket Cable

7.1.1 Scope. This section applies to flat-twin pole and bracket cable insulated with polyvinyl chloride and belted with polyethylene. This cable is intended for use in series street lighting circuits in both interior and exterior installations for operation at temperatures not exceeding 75°C. The conductor sizes covered are 10, 8 and 6 AWG. The insulation and belt thicknesses are based on a maximum of 600 volts between conductors and on open-circuit voltages from 3001 to 9000 volts.

7.1.2 Conductors

7.1.2.1 The conductors shall be of annealed uncoated copper or annealed coated copper and shall meet the requirements of 2.1.1 and 2.3.

7.1.2.2 The sizes, minimum number of strands, average cross-sectional areas and approximate diameters of the conductors shall be as shown in Table 7.1-1.

The area of cross-section of any conductor shall be not less than 98 percent of the area given in Table 7.1-1.

7.1.3 Insulation

7.1.3.1 The polyvinyl chloride insulation shall meet the requirements given in 3.7, except that both the tensile strength and elongation after 168 hours at 100°C ± 1°C shall be not less than 85 percent of the unaged values, and the cold bend test shall be conducted at -30°C, ±1°C.

7.1.3.2 The average thickness of the insulation shall be not less than that given in Table 7.1-2. The minimum thickness shall be not less than 90 percent of the values given in the table. The thickness shall be measured in accordance with 6.4.3.

7.1.3.3 One conductor shall be colored black and the other white or natural.

7.1.4 Conductor Assembly. The two insulated conductors shall be laid flat and parallel.

Table 7.1-1

Size, AWG	Minimum Number of Strands per Conductor	Average Cross-sectional Area, CM	Approximate Diameter inches	Approximate Diameter mm
10	19	10,380	0.117	2.97
8	19	16,510	0.148	3.76
6	19	26,240	0.186	4.72

Table 7.1-2
Construction and Test Requirements for Pole and Bracket Cable

Open-circuit Voltage, Volts	Conductor Size, AWG	Thickness Insulation mils	Thickness Insulation mm	Thickness Belt mils	Thickness Belt mm	Minimum Outside Diameter Major inches	Minimum Outside Diameter Major mm	Minimum Outside Diameter Minor inches	Minimum Outside Diameter Minor mm	Test Voltages, kV a-c 5 Min	Test Voltages, kV d-c 15 Min
3001-6000	10	45	1.14	95	2.41	0.610	15.5	0.400	10.2	13	35
	8	45	1.14	95	2.41	0.670	17.0	0.430	10.9	13	35
	6	60	1.52	95	2.41	0.810	20.6	0.500	12.7	13	35
6001-9000	10	45	1.14	110	2.79	0.640	16.3	0.430	10.9	19	55
	8	45	1.14	110	2.79	0.700	17.8	0.460	11.7	19	55
	6	60	1.52	110	2.79	0.840	21.3	0.530	13.5	19	55

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7.1.5 Belt

7.1.5.1 The belt shall be a heat- and light-stabilized black polyethylene insulation and shall meet the physical and aging requirements for polyethylene insulation as given in 3.9.1. It shall be applied in a flat configuration. Fillers shall not be used. The belt insulation shall fill the interstices of the cable.

7.1.5.2 The average thickness of the belt shall be not less than that given in Table 7.1-2. The minimum thickness shall be not less than 90 percent of the values given in the table.

7.1.6 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.1 except as otherwise specified in 7.1.6.1 through 7.1.6.4. ▲

7.1.6.1 The completed cable shall withstand the following voltage tests after being immersed in water for at least 6 hours.

7.1.6.2 An alternating-current test voltage of 3000 volts shall be applied between conductors for 5 minutes.

7.1.6.3 The conductors shall be connected together, and the alternating-current and direct-current test voltages given in Table 7.1-2 shall be applied between the conductor and water.

7.1.6.4 Cold Bend Test. The polyethylene belt shall not show any cracks when conditioned and tested in accordance with 6.4.15.1. The cable shall be bent around its minor axis. The insulated conductor diameter given in 6.4.15.1 shall be taken as the minor axis of the cable. Cracking of the polyvinyl chloride insulation on the individual conductors under this test shall not constitute failure. ▲

7.1.7 Outside Diameters. The outside diameters of the completed cable shall be not less than that given in Table 7.1-2, with a tolerance of +10 percent. ▲

7.1.8 Bending Radius *. The minimum radius to which these cables may be bent around their minor axis in service is 2 inches (50.8 mm), with a maximum of 1/2 turn (180-degree U bend). ▲

7.1.9 Terminations *. Suitable high-temperature terminations are recommended where the cable will be exposed to temperatures, in close proximity to the luminaire, in excess of 75°C. ▲

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7.3 NEUTRAL-SUPPORTED SECONDARY AND SERVICE DROP CABLES†

7.3.1 Scope. This section covers secondary and service drop cables composed of one or more polyethylene-insulated conductors and one neutral conductor for use as the supporting member. These cables are for use on circuits not exceeding 600 volts phase to phase and at conductor temperatures not exceeding 75°C (167°F).

7.3.2 Conductors

7.3.2.1 Insulated Conductors

7.3.2.1.1 COPPER. Conductors shall be annealed uncoated copper and shall meet the requirements given in Part 2. Size 8 AWG shall be solid or Class B stranded in accordance with Table 2-7. Sizes 6 AWG and larger shall be Class B stranded in accordance with Table 2-7.▲

7.3.2.1.2 ALUMINUM Conductors shall be aluminum 1350 with a minimum tensile strength of 17,000 psi (117 MPa). Sizes 6 and 4 AWG shall be solid in accordance with ASTM B 230 or ASTM B 609 before insulating and with Table 2-7, Class A or B stranded in accordance with ASTM B 231, or compact round stranded in accordance with ASTM B 400. Sizes larger than 4 AWG shall be Class A or B stranded in accordance with ASTM B 231 or compact round stranded in accordance with ASTM B 400.▲

7.3.2.1.3 Direction of Lay. The direction of lay of the outer layer of stranded conductors shall be left hand or right hand.

7.3.2.2 Neutral Conductors. Neutral conductors shall be uncovered or covered and the sizes and composition shall be in accordance with Table 7.3-1.

7.3.2.2.1 COPPER. Conductors shall be hand-drawn uncoated copper and shall meet the requirements of ASTM B 1 and B 8. Sizes 2 AWG and smaller shall be solid or Class B stranded in accordance with Table 2-7. Sizes larger than 2 AWG shall be Class B stranded in accordance with Table 2-7.▲

7.3.2.2.2 Aluminum. Conductors shall be hard-drawn aluminum 1350. The stranding shall be in accordance with Class A, Table 2, of ASTM B 231 for sizes up through 2/0 AWG and in accordance with Class B, Table 3, of ASTM B 231 for sizes 3/0 AWG and larger. The direction of lay of the outer layer shall be right hand.

7.3.2.2.3 Copper and Copper-covered-steel Composite. Conductors shall be concentric-lay stranded-copper and copper-covered-steel composite conductors and shall meet the requirements given in the applicable sections of ASTM B 229.

7.3.2.2.4 Aluminum Conductors — Steel Reinforced. Aluminum conductors steel reinforced (ACSR) shall meet the requirements of ASTM B 232.

The stranding shall be as follows:

(a) Sizes 4/0 AWG and smaller—7-wire strand (6 aluminum around 1 steel).

(b) Sizes larger than 4/0 AWG—19-wire strand (18 aluminum around 1 steel) or, where greater strength is required, 24 or 26 aluminum wires around a 7-wire steel strand.

7.3.2.2.5 ALUMINUM ALLOY CONDUCTORS—5005-H19. Conductors shall meet the requirements of ASTM B 397. The stranding shall be 7-wire strand for sizes 246.9 kcmil and smaller and 19-wire strand for sizes larger than 246.9 kcmil.▲

7.3.2.2.6 ALUMINUM ALLOY CONDUCTORS—6201-T81. Conductors shall meet the requirements of ASTM B 399. The stranding shall be 7-wire strand for sizes 246.9 kcmil and smaller and 19-wire strand for sizes larger than 246.9 kcmil.▲

7.3.3 Insulation

7.3.3.1 Physical and Aging Requirements.

7.3.3.1.1 LOW-DENSITY POLYETHYLENE. The polyethylene before application to the conductor shall comply with the requirements of ASTM D 1248, Type I, Class C, Category 4 or 5, Grade E5 or J3. The requirements of ASTM D 1248 do not apply to insulation removed from the conductor. The insulation shall meet the requirements of 3.9.1 when tested in accordance with Part 6.▲

† Par. 7.2 rescinded 5-28-1981.
▲ Editorially revised.

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7.3.3.1.2 High-density Polyethylene. The polyethylene shall be suitable for exposure to sunlight and other atmospheric environments at temperatures between -55°C and +75°C and a minimum installing temperature of -40°C. The compound shall be black complying with the requirements of ASTM D 1248, Type III, Class C, Category 5, Grade J5 or E11. The requirements of ASTM D 1248 do not apply to insulation removed from the conductor. When tested in accordance with Part 6, the insulation shall meet the following requirements except that the rate at which specimens are stretched during tensile and elongation tests shall be 2 inches per minute:

Physical Requirements	
Tensile strength, minimum	
psi	2500
▲ MPa	17.2
Elongation at rupture, minimum, percent	300
Aging Requirements	
After air oven test at 100°C ± 1°C for 48 hours—tensile strength and elongation at rupture—minimum percentage of unaged value	75
Absorption coefficient, minimum milli(absorbance/meter)	320†

† 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.

7.3.3.2 Thickness of Insulation. The average thickness of the insulation shall be not less than the following:

Conductor Size, AWG or kcmil▲	Thickness mils	mm
8-2	45	1.14
1-4/0	60	1.52
250-500	80	2.03

The minimum thickness shall be not less than 90 percent of the foregoing values.

7.3.4 Assembly

7.3.4.1 Twisted Assemblies. One or more insulated conductors shall be twisted around the neutral conductor without fillers with a lay of 25 to 60 times the diameter of one of the insulated conductors. The direction of lay shall be the same as that of the outer layer of wires of the neutral conductor.

7.3.4.2 Parallel Assemblies With Insulated Aluminum Conductors. One or more insulated aluminum conductors shall be laid flat and parallel to a neutral. The neutral shall be on the outside of the assembly and shall be bound to the conductor with a suitable aluminum or aluminum alloy wire or strip having a breaking strength not less than 150 pounds and applied with a lay of 3 to 6 inches.

7.3.4.3 Neutral Conductor. The size of the neutral conductor shall be in accordance with Table 7.3-1 for copper insulated power conductors and Table 7.3-2 for aluminum insulated power conductors.

7.3.5 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.3 except that each length of completed cable shall successfully withstand, after immersion in water for 1 hour, an alternating-current voltage of 2500 volts applied for 1 minute between each insulated power conductor and ground.

Table 7.3-1
Neutral Conductors for Use With Copper Power Conductors

Copper Insulated Power Conductor Sizes, AWG	Neutral Conductor Sizes, AWG	
	Copper	Copper Covered Steel*
8	8	8 C
6	6	6 C
6	8	8 C
4	4	4 A
4	6	6 C
2	2	2 F
2	4	4 A
1	1	1 F
1	3	3 A
1/0	1/0	1/0 F
1/0	2	2 F
2/0	2/0	2/0 F
2/0	1	1 F

* See ASTM B 229 (see Appendix E) for letter designations and constructions.

▲ Editorially revised.

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Table 7.3-2 ●
Neutral Conductors for Use With Aluminum Power Conductors

Aluminum Insulated Power Conductor Sizes, AWG or MCM	Neutral Conductor Sizes, AWG				
	Copper	Copper Covered Steel*	Aluminum 1350	ACSR	Aluminum Alloy 5005-H19 6201-T81
6	8	8 C	6	6	6
4	6	6 C	4	4	4
4	8	8 C	...	6	6
2	4	4 A	2	2	2
2	6	6 C	...	4	4
1/0	2	2 F	1/0	1/0	1/0
1/0	4	4 A	...	2	2
2/0	1	1 F	2/0	2/0	2/0
2/0	3	3 A	...	1	1
3/0	1/0	1/0 F	3/0	3/0	3/0
3/0	2	2 F	...	1/0	1/0
4/0	2/0	2/0 F	4/0	4/0	4/0
4/0	1	1 F	...	2/0	2/0
266.8	...	...	266.8	266.8	312.8
	...	...	...	167.8	195.7
366.4	...	...	366.4	336.4	394.5
	...	...	...	211.6	246.9
397.5	...	...	397.5	397.5	465.4
	...	...	...	266.8	312.8
477.0	...	...	477.0	477.0	559.5
	...	...	...	336.4	394.5

* See ASTM B 229 (see Appendix E) for letter designations and construction.

● Added 9-20-1978.

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7.4 Control Cables

7.4.1 Scope. This section covers multiple-conductor thermoplastic-insulated control cables for use aerially and in ducts, conduits and trays, and for direct burial. The different types of cables are for service as follows:

7.4.1.1 Type A. Supervisory cables for monitoring, data recording and conveyance of information, such as communication, telemetering, temperature, pressure, flow, indicating lights — maximum circuit voltage rating 300 volts.

7.4.1.2 Type B. Control cables for operation and interconnection of protective devices and for general use — maximum circuit voltage rating 600 volts.

7.4.1.3 Type C. Control cables for connection to circuits with heavy magnetic trip of break devices, where inductively induced over-voltages may occur — maximum circuit voltage rating 1000 volts.

7.4.1.4 Type D. Control, pilot wire and supervisory cables used in conjunction with high-voltage lines and installed parallel to such lines where faults in the high-voltage cables will result in above-ground voltage in the control cable sheaths or surrounding ground-maximum circuit voltage rating 600 volts; insulation level to ground 5000 volts.

7.4.2 Conductors

7.4.2.1 Conductors shall be made of annealed uncoated copper wire in accordance with Part 2.

7.4.2.2 Sizes 22, 20, 19, 18 and 16 AWG shall be solid or Class B stranded. Sizes 14, 12, 10 and 9 AWG shall be Class B or C stranded.

7.4.3 Insulation

7.4.3.1 Types. The insulation shall meet the requirements of 3.7, 3.8 or 3.9.

7.4.3.2 Thickness. The average total thickness of insulation shall be not less than that given in Table 7.4-1. The minimum total thickness shall be not less than 90 percent of that given in the table.

7.4.3.2.1 In multiple-conductor polyethylene-insulated cables for the 1000-volt rating or less, 4 mils (0.10 mm) nominal thickness of nylon may be substituted for 4 mils (0.10 mm) of polyethylene to provide a total thickness as given in Table 7.4-1, except that in no case shall the thickness of polyethylene be less than 15 mils (0.38 mm). The nylon-covered insulated conductor shall be tested in accordance with 6.4.16 and shall show no cracks. Wrinkles in the covering shall not constitute failure.

7.4.3.2.2 In multiple-conductor polyethylene-insulated cables for the 1000-volt rating, 15 mils (0.38 mm) nominal thickness of polyvinyl chloride, or 10 mils (0.25 mm) nominal thickness for the 600-volt rating may be substituted for 15 or 10 mils (0.38 or 0.25 mm), respectively, of polyethylene to provide a total insulation thickness as given in Table 7.4-1. The polyvinyl chloride covering shall meet the requirements of 3.8.

Table 7.4-1
Insulation Thickness

Conductor Size, AWG	Voltage Rating, Volts *											
	300				600				1000			
	Polyvinyl Chloride		Polyethylene		Polyvinyl Chloride		Polyethylene		Polyvinyl Chloride		Polyethylene	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
22-20	20	0.51	15	0.38	...	...	...	...	...	...	...	...
19	20	0.51	15	0.38	30	0.76	25	0.64	...	...	...	...
18	25	0.64	20	0.51	30	0.76	25	0.64	...	...	...	...
16	25	0.64	20	0.51	30	0.76	25	0.64	...	...	...	...
14	25	0.64	20	0.51	45	1.14	30	0.76	60	1.52	45	1.14
12	...	...	...	...	45	1.14	30	0.76	60	1.52	45	1.14
10	...	...	...	...	45	1.14	30	0.76	60	1.52	45	1.14
9	...	...	...	...	45	1.14	30	0.76	60	1.52	45	1.14

* These voltage ratings represent the maximum rated circuit voltage.

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7.4.4 Covering Over Insulation

7.4.4.1 The individual conductors of multiple-conductor cables need not have any covering over the insulation.

7.4.5 Conductor Identification ▲

7.4.5.1 Conductor identification, if used, shall be by any suitable means (see Appendix K). ▲

7.4.6 Assembly

7.4.6.1 The conductors or pairs shall be assembled in accordance with Part 5. If conductor identification is used and if it follows a designated sequence of colors, numbers or other markings, the conductors or pairs shall be assembled in the same sequence, with the first designated conductor in the innermost layer. A separator tape may be used over the assembly. ▲

7.4.7 Overall Jacket

7.4.7.1 Type A, B and C cables shall have a jacket which meets the requirements of one of the following:

Polyvinyl chloride 4.3.1
Polyethylene 4.3.2
● Chlorinated polyethylene, thermoplastic. 4.3.3

7.4.7.2 The average thickness of the jacket shall be not less than that given in Table 7.4-2. The minimum thickness at any point shall be no less than 80 percent of that given in the table.

7.4.8 Type D Cables

7.4.8.1 Type D cables shall have a core corresponding to Type B or C as required and as covered by 7.4.2 through 7.4.6.

7.4.8.2 These cables are for varied types of exposure. The design of the protective belt as well as the degree of shielding needed and outer protection will depend on conditions of use. No general recommendations are given. (This paragraph is approved by NEMA as Authorized Engineering Information.)

7.4.9 Tests

7.4.9.1 The cable shall meet the requirements specified in 7.4 when tested in accordance with Part 6.

7.4.9.2 Electrical tests on completed cable shall be in accordance with 6.11 and 6.12, except that the tests may be made without immersing the cable in water, in which case the tests shall be made between each conductor and all other conductors connected to ground.

7.4.9.3 The insulated conductors shall withstand for 5 minutes either the alternating-current or direct-current test voltage given in Table 7.4-3.

Table 7.4-2
Overall Jacket Thickness

Calculated Diameter of Cable Under Jacket		Overall Jacket Thickness	
inches	mm	mils	mm
▲ 0.425 and less	▲ 10.80 and 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

▲ Editorially revised.
● Added 9-15-1983.

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Table 7.4-3
Insulation Thicknesses and Test Voltages*

Polyvinyl Chloride Insulation			Polyethylene Insulation or Polyethylene Plus Polyvinyl Chloride or Nylon		
Thickness	Test Voltage, kV		Thickness	Test Voltage, kV	
inches	ac	dc	inches	ac	dc
.020	1.0	3.0	.015	1.5	4.5
.025	1.0	3.0	.020	2.0	6.0
.030	1.5	4.5	.025	2.5	7.5
.045	3.0	9.0	.030	3.0	9.0
.060	3.5	10.5	.045	4.5	13.5

*Where the insulation thickness is increased for mechanical reasons, the test voltage shall be determined by the insulation thickness given in Table 7.4-1 for the size of the conductor and the rated voltage of the cable.

7.5 CONCENTRIC NEUTRAL UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES – POLYETHYLENE INSULATED

7.5.1 Scope

This section covers two-conductor concentric-neutral power cables consisting of one polyethylene-insulated central conductor and the copper concentric conductor applied helically overall. These cables are intended for use on single-phase primary underground residential distribution systems operating at 2001 to 35000 volts phase-to-phase 100 % insulation level. For ampacities, see Appendix F.

7.5.2 Central Conductor

Central conductors shall be annealed copper or aluminum. The minimum conductor size shall be in a accordance with Table 7.5-1.

Table 7.5-1
Minimum Conductor Size

Rated Voltage Phase-to-Phase, Volts	Minimum Conductor Size, AWG
2001-15000	4
15001-28000	1
28001-35000	1/0

7.5.2.1 Copper.

The conductor shall be (1) annealed uncoated copper or annealed coated copper in sizes 4 through 4/0 AWG either Class B or C stranded, or (2) uncoated copper, compact stranded, in accordance with Part 2.

7.5.2.2 Aluminum.

The conductor shall be aluminum 1350 either solid (through 4/0 AWG), Class B or C stranded, or compact stranded, in accordance with Part 2.

7.5.2.3 Conductor Stress Control Layer.

The conductor shall be covered with a stress control layer in accordance with Part 2.

7.5.3 Insulation.

The shielded central conductor shall be insulated with polyethylene which meets the requirements of 3.9. The average thickness of the insulation shall be not less than that given in Table 3-2 for 100 percent insulation level. The minimum thickness shall be not less than 90 percent of the values given in the table.

7.5.4 Insulation Shielding and Protective Covering

A layer of conducting nonmetallic material meeting the requirements of 4.1.1 shall be extruded directly over the insulation to serve as both an electrostatic shield and a protective covering. The thickness of the extruded insulation shielding at any location when measured on completed cable shall be in accordance with Table 7.5-2.

The conducting layer shall be compatible with the insulation and shall be legibly identified as being conducting.

Table 7.5-2
For Cables with or without Overall Jacket

Calculated Insulation Diameter	Insulation Shield Thickness		
Inches	Minimum Point, inch*	Maximum Point, inch	Maximum Indent, inch
1.000 or less	.030	.070	.015
1.001-1.500	.040	.085	.015
1.501-2.000	.055	.100	.020
2.001 and larger	.055	.115	.020

*Note: The minimum point does not apply to locations under the metallic shield indent.

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7.5.5 Concentric Conductor

The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B5 and resistivity, tensile and elongation requirements of ASTM B3 for uncoated wires, ASTM B33 for tin-coated wires or ASTM B189 for lead-alloy-coated wires. The number of wires of a specified size shall be not less than that given in Table 7.5-3 for cables used in single-phase systems.

The nominal diameters and circular mil area of the wires in Table 7.5-3 shall be as follows:

AWG Size	Diameter, inches	Area, kcmil
14	0.0641	4.11
12	0.0808	6.53
10	0.1019	10.38
9	0.1144	13.09

The individual wires comprising a given concentric conductor may vary ±5% in diameter from the appropriate nominal value given above, but the total circular mil area of the specified concentric conductor shall be at least 98% of the product of the appropriate number of wires given in Table 7.5-3 times the appropriate nominal circular mil area tabulated above.

The wires of the concentric conductor shall be applied directly over the conducting material given in 7.5.4 with a lay of not less than six (6) nor more than ten (10) times the diameter over the concentric wires.

7.5.6 Optional Jackets Applied Over A Concentric Conductor

The jackets shall be either nonconducting or conducting depending upon installation requirements. If non-conducting compound is used, it shall meet the physical and aging requirements of 4.3.1 through 4.3.3 as applicable.

Table 7.5-3
Full Neutral Concentric Conductor

Insulated Conductor Size, AWG or kcmil		Concentric Conductor, Minimum Number of Wires			
Copper	Aluminum	14 AWG	12 AWG	10 AWG	9 AWG
. . .	4	6	. . .	. . .	. . .
4	2	10	. . .	. . .	. . .
3	1	13	. . .	. . .	. . .
2	1/0	16	10*	. . .	. . .
1	2/0	20*	13	. . .	. . .
1/0	3/0	25*	16	10*	. . .
2/0	4/0	32*	20*	13	10*
3/0	250	. . .	25*	16	13*
4/0	350	. . .	32*	20*	16

*Alternate constructions

Table 7.5-4
Partial-Discharge Level

Rated Circuit Voltage, Phase to Phase, Volts	Minimum Partial-discharge Extinction Level, kV
2001-5000	5
5001-8000	7
8001-15000	13
15001-25000	22
25001-28000	25
28001-35000	31

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If conducting compound is used, it shall meet the physical and aging requirements of Table 7.5-6.

CAUTION: Cable users should be aware that some types of jackets may alter the physical and electrical characteristics of the cable components. (This sentence is approved by NEMA as Authorized Engineering Information.)

7.5.6.1 Extruded-to-fill Type Jacket

The jacket material shall cover the concentric conductor and fill the spaces between wires. The jacket material shall be in contact with the insulation shielding, but shall strip freely.

When measured over the wires, the average jacket thickness shall be not less than the appropriate value given in Table 7.5-5.

The minimum thickness over the wires shall be not less than 80 percent of the specified average thickness.

After a jacket has been applied, the indent of the extruded insulation shield caused by the metallic shield shall not be more than the specified maximum indent value found in Table 7.5-2.

7.5.6.2 Overlaying Type Jacket

If a nonmetallic tape is applied over the concentric conductors of the cable and the jacket is conducting, then the tape shall be conducting. When the jacket is nonconducting, the tape shall be either conducting or nonconducting. A conducting tape shall be clearly identified as being conducting.

The average jacket thickness when measured over the wires shall be not less than specified in Table 4-6. The minimum thickness at any point shall be not less than 80 percent of the specified average thickness.

After a jacket has been applied, the indent of the extruded insulation shield caused by the metallic shield shall not be more than the specified maximum indent value found in Table 7.5-2.

7.5.6.3 Identification

When a conducting material is used for the overall jacket, the cable legend shall identify the material as being conducting.

7.5.6.4 Spark Test for Nonconducting Jackets

A nonconducting jacket over concentric neutral conductors shall withstand an alternating current spark test voltage. The voltage for extruded-to-fill type jackets is given in Table 7.5-5. The voltage for overlaying type jackets is in accordance with 4.3.7. The voltage shall be applied between an electrode at the outside surface of the jacket, and the concentric neutral conductor shall be connected to ground during the test. The spark test shall be conducted in accordance with 6.11.4a.3 and 6.11.4a.4.

Table 7.5-5
Jacket Thickness and Test Voltage

Calculated Diameter over Concentric Conductor	Average Jacket Thickness	AC Spark-Test Voltage (kV) for Non-conducting Jackets
inches	inches	kilovolts
1.500 or less	.050	4.5
Over 1.500	.080	7.0

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7.5.7 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.5. The partial-discharge extinction level shall be in accordance with Table 7.5-4. The electrical requirement tests shall be made without immersion in water.

Table 7.5-6
Properties of Thermoplastic Conducting Jackets

Physical Requirements	
Tensile strength, minimum psi	1200
Elongation at rupture, minimum percent	100
Aging Requirements:	
After air oven aging at 100°C ± 1°C for 48 hrs:	
Tensile strength, minimum percent of unaged value	75
Elongation at rupture, minimum percent	100
Heat Distortion, maximum percent:	
Air oven at 90°C ± 1°C	25
Volume Resistivity:	
At room temperature (23°C ± 2°C) and 90°C ± 1°C, max. meter-ohms	100
Brittleness Temperature, °C, not warmer than	-10

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Part 8
APPENDICES

Part 8 is classified by NEMA as Authorized Engineering Information.

Appendix A● ▲
ABBREVIATIONS AND SYMBOLS

a-c	—alternating-current	kg	—kilogram(s)
AWG	—American wire gauge	km	—kilometer(s)
BWG	—Birmingham wire gauge	kN/m	—kilonewton per meter
C	—Celsius (centigrade)	kV	—kilovolt(s)
d-c	—direct-current	MPa	—megapascals
F	—Fahrenheit	mm	—millimeter(s)
g/m	—grams per meter	psi	—pounds per square inch
Hz	—hertz (electrical frequency in cycles per second)	%	—percent
kcmil	—thousands of circular mils (formerly MCM)	±	—plus or minus

Appendix B
REPRESENTATIVE TENSILE STRENGTH AND ELONGATION OF NONMAGNETIC METALS

Metal	Tensile Strength		Elongation 2-inch (50.8 mm) Length, Percent
	psi	MPa ▲	
Aluminum	13,000–45,000	90-310	15–45
Ambrac	50,000–70,000	345-482	20–40
Low Brass	40,000–50,000	276-345	40–50
Commercial Bronze	35,000–42,000	241-289	40
Copper	35,000–50,000	241-345	1–35
Monel	75,000	517	45
Stainless Steel	82,000–90,000	565-620	50
Zinc	20,000	138	60

Appendix C ●
DEFINITIONS FOR MAXIMUM TEMPERATURE OF CONDUCTORS IN INSULATED WIRE AND CABLE

C1.1 MAXIMUM CONDUCTOR TEMPERATURE—OPERATING

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

C1.2 MAXIMUM CONDUCTOR TEMPERATURE—EMERGENCY OVERLOAD

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

C1.3 MAXIMUM CONDUCTOR TEMPERATURE—SHORT CIRCUIT

The highest conductor temperature attained by any part of the cable line during a short circuit of specified time and magnitude.

● Appendices A and C formerly Appendices F and G respectively.
▲ Editorially revised.

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APPENDIX D
EMERGENCY OVERLOAD RATINGS FOR THERMOPLASTIC-INSULATED CABLES

Voltage Rating, Volts *	Maximum Temperature Rating of Insulation, Degrees C	
	60	75
	Maximum Emergency Overload Temperatures, Degrees C	
0-2000	85	95
2001-5000	...	95
5001-35000	...	90

* Polyvinyl-chloride-insulated conductors for power cables are rated 600 volts and less.

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

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Appendix E ▲
REFERENCED PUBLICATIONS AND STANDARDS

E1.1 ICEA PUBLICATIONS

P-46-426/IEEE Std 135 (SH007096) — *Power Cable Ampacities*[2]

T-24-380, rev. 12/80 — *Guide for Partial-Discharge Test Procedure*[3]

E1.2 ASTM STANDARDS[4]

A 90-81 — *Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, Test Method for*
B 1-81 — *Hard-Drawn Copper Wire, Specification for*
B 2-81 — *Medium-Hard-Drawn Copper Wire, Specification for*
B 3-74 (1980) — *Soft or Annealed Copper Wire, Specification for*
B 5-83a — *Electrolyic Tough-Pitch Copper Refinery Shapes, Specification for*
B 8-81 — *Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Specification for*
B 29-79 (1984) — *Pig Lead, Specification for*
B 33-81 — *Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for*
B 172-71 (1980) — *Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, Specification for*
B 173-71 (1980) — *Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors, Specification for*
B 174-71 (1980) — *Bunch-Stranded Copper Conductors for Electrical Conductors, Specification for*
B 189-81 — *Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, Specification for*
B 193-78 (1983) — *Resistivity of Electrical Conductor Materials, Test Method for*
B 229-81 — *Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors, Specification for*
B 230-82 — *Aluminum-Alloy 1350-H19 Wire, for Electrical Purposes, Specification for*
B 231-81 — *Concentric-Lay-Stranded Aluminum-Alloy 1350 Conductors, Specification for*
B 232-81 — *Concentric-Lay-Stranded Aluminum Conductors, Coated Steel-Reinforced (ACSR), Specification for*
B 233-78 — *Aluminum-Alloy 1350 Redraw Rod for Electrical Purposes, Specification for*
B 263-58 (1981) — *Cross-Sectional Area of Stranded Conductors, Method for Determination of*
B 397-81 — *Concentric-Lay-Stranded Aluminum-Alloy 5005-H19 Conductors, Specification for*
B 399-81 — *Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors, Specification for*
B 400-81 — *Compact-Round Concentric-Lay-Stranded 1350 Aluminum-Alloy Conductors, Specification for*
B 496-81 — *Compact-Round Concentric-Lay-Stranded Copper Conductors, Specification for*
B 609-81 — *Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes, Specification for*
D 257-78 — *DC Resistance or Conductance of Insulating Materials, Test Method for*
D 412-83 — *Rubber Properties in Tension, Test Method for*
D 471-79 — *Rubber Property—Effect of Liquids, Test Method for*
D 746-79 — *Brittleness Temperature of Plastics and Elastomers by Impact, Test Method for*
D 1248-84a — *Polyethylene Plastics Molding and Extrusion Materials, Specification for*
D 1693-70 (1980) — *Environmental Stress-Cracking of Ethylene Plastics, Test Method for*
D 3349-74 (1980) — *Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic Film, Test Method for*
E 8-84 — *Tension Testing of Metallic Materials, Methods of*

E1.3 NEMA STANDARDS PUBLICATION

WC 26-1984 *Wire and Cable Packaging*

[1]Copies may be obtained from NEMA Sales Office, National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, DC 20037, USA.
[2]Copies may be obtained from IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854, USA.
[3]Copies may be obtained from the Insulated Cable Engineers Association, Inc., P.O. Box P, South Yarmouth, MA 02664, USA.
[4]Copies may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.
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Appendix F●
AMPACITIES FOR TWO-CONDUCTOR CONCENTRIC-NEUTRAL SINGLE-PHASE PRIMARY UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES (SEE PART 7)

Conductor Size, AWG or kcmil▲	Copper				Aluminum			
	Direct Buried*	In Buried Duct*	In Air†	In Duct In Air†	Direct Buried*	In Buried Duct*	In Air†	In Duct In Air†
	Cables Rated 5 kV 90°C							
4	169	111	114	97	132	88	90	76
3	193	128	132	111	...	...	...	...
2	219	144	152	126	174	115	120	100
1	249	165	174	144	199	132	139	116
1/0	284	188	200	163	226	150	160	131
2/0	324	217	233	189	256	172	186	149
3/0	368	247	268	215	291	195	211	170
4/0	425	288	316	250	335	226	247	197
250	...	...	...	...	370	252	278	219
300	...	...	...	...	418	287	319	250
	Cables Rated 15 kV 90°C							
4	162	116	120	100	128	91	95	79
3	186	132	138	114	...	...	...	...
2	210	150	158	131	168	119	125	103
1	240	171	181	148	193	137	145	119
1/0	273	194	208	169	218	155	166	135
2/0	313	224	240	196	248	177	190	154
3/0	358	255	278	222	284	201	218	176
4/0	410	293	324	257	324	230	253	201
250	...	...	...	...	360	257	285	225
300	...	...	...	...	403	291	324	254

*Ambient temperature of 20°C; 100 percent load factor; thermal resistivity RHO-90

The multiplying correction factors for load factors of 75 and 50 percent shall be:

Rating of Cable, kV	Correction Factors			
	75 Percent Load Factor		50 Percent Load Factor	
	Cable Only	In Duct	Cable Only	In Duct
5	1.09	1.04	1.16	1.07
15	1.08	1.04	1.16	1.07

Continuous loading at maximum rating may result in moisture migration away from cables and increased thermal resistivity. See "Power Cable Ampacities," ICEA Publication No. P-46-426 (IEEE Publication No. S-135), Section 5, Page XIII.
†Ambient temperature of 40°C; 30 to 100 percent load factor.

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Appendix G ●
SHIELDING

G1 DEFINITION OF SHIELDING

G1.1 Shielding of an electric power cable is the practice of confining the dielectric field of the cable to the insulation of the conductor or conductors. It is accomplished by means of a conductor stress control layer and an insulation shield. ▲

G2 FUNCTIONS OF SHIELDING

G2.1 A conductor stress control layer is employed to preclude excessive voltage stress on voids between conductor and insulation. To be effective, it must adhere to or remain in intimate contact with the insulation under all conditions. ▲

G2.2 An insulation shield has a number of functions:

1. To confine the dielectric field within the cable.
2. To obtain symmetrical radial distribution of voltage stress within the dielectric, thereby minimizing the possibility of surface discharges by precluding excessive tangential and longitudinal stresses.
3. To protect cable connected to overhead lines or otherwise subject to induced potentials.
4. To limit radio interference.
5. To reduce the hazard of shock. This advantage is obtained only if the shield is grounded. If not grounded, the hazard of shock may be increased.

G3 USE OF INSULATION SHIELDING

G3.1 The use of shielding involves consideration of installation and operating conditions. Definite rules cannot be established on a practical basis for all cases, but the following features should be considered as a working basis for the use of shielding.

G3.2 Where there is no metallic covering or shield over the insulation, the electric field will be partly in the insulation and partly in whatever lies between the insulation and ground. The external field, if sufficiently intense in air, will generate surface discharge and convert atmospheric oxygen into ozone which may be destructive to insulations and to protective jackets. If the surface of the cable is separated from ground by a thin layer of air and the air gap is subjected to a voltage stress which exceeds the dielectric strength of air, a discharge will occur, causing ozone formation.

G3.3 The ground may be either a metallic conduit, a damp nonmetallic conduit or a metallic binding tape or rings on an aerial cable, a loose metallic sheath, etc. Likewise, damage to nonshielded cable may result when the surface of the cable is moist, or covered with soot, soapy grease or other conducting film and the external field is partly confined by such conducting film so that the charging current is carried by the film to some spot where it can discharge to ground. The resultant intensity of discharge may be sufficient to cause burning of the insulation or jacket.

G3.4 Where nonshielded cables are used in underground ducts containing several circuits which must be worked on independently, the external field, if sufficiently intense, can cause shocks to those who handle or contact energized cable. In cases of this kind, it may be advisable to use shielded cable. Shielding used to reduce hazards of shock should have a resistance low enough to operate protective equipment in case of fault. In some cases, the efficiency of protective equipment may require proper size ground wires as a supplement to shielding. The same considerations apply to exposed installations where cables may be handled by personnel who may not be acquainted with the hazards involved.

G4 GROUNDING OF THE INSULATION SHIELD

G4.1 The insulation shield must be grounded at least at one end and preferably at two or more locations. It is recommended that the shield be grounded at cable terminations and at splices and taps. Stress cones should be made at all shield terminations.

G4.2 The shield should operate at or near ground potential at all times. Frequent grounding of shields reduces the possibility of open sections on nonmetallic covered cable. Multiple grounding of shields is desirable in order to improve the reliability and safety of the circuit. All grounding connections should be made to the shield in such a way as to provide a permanent low resistance bond. Shielding which does not have adequate ground connection due to discontinuity of the shield or to improper termination may be more dangerous than nonshielded nonmetallic cable and hazardous to life.

● Appendix G formerly Appendix A.
▲ Editorially revised.

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G5 SHIELD MATERIALS

G5.1 Two distinct types of materials are employed in constructing cable shields.

G5.1.1 Nonmetallic shields may consist of a conducting tape or a layer of conducting compound. The tape may be conducting compound, fibrous tape faced or filled with conducting compound, or conducting fibrous tape.

G5.1.2 Metallic shields should be nonmagnetic and may consist of tape, braid, concentric serving of wires, or a sheath.

G6 SPLICES AND TERMINATIONS

G6.1 To prevent excessive leakage current and flashover, metallic and nonmetallic insulation shields, including any conducting residue on the insulation surface, must be removed completely at splices and terminations.

G6.2 An outer extruded insulation shield shall be removable without damaging or imparting conductivity to the underlying insulation. This may be accomplished by the aid of heat (air or flame) or by the use of a suitable solvent.

Appendix H ●
RECOMMENDED BENDING RADII FOR CABLES

H1.1 SCOPE

This appendix contains the minimum values for the radii to which insulated cables may be bent for permanent training during installation. These limits do not apply to conduit bends, sheaves or other curved surfaces around which the cable may be pulled under tension while being installed. Larger radii bends are required for such conditions. In all cases the minimum radii specified refers to the inner surface of the cable and not to the axis of the cable. ▲

H2.1 POWER CABLES WITHOUT METALLIC SHIELDING OR ARMOR

The minimum bending radii for both single- and multiple-conductor cable with or without lead sheath and without metallic shielding or armor are shown in Table H-1.

H3.1 POWER CABLES WITH METALLIC SHIELDING OR ARMOR

H3.1.1 Interlocked Armored Cables

The minimum bending radius for interlocked armored cables except tape shielded cables shall be in accordance with Table H-1 but not less than seven times the overall diameter of the cable. For tape shielded cable, see H3.1.3.1.

H3.1.2 Flat Tape and Wire Armored Cables

The minimum bending radius for all flat tape armored and all wire armored cables is twelve times the overall diameter of cable.

H3.1.3 Shielded Cables

H3.1.3.1 TAPE SHIELDED CABLES

The minimum bending radius for a single conductor cable is twelve times the overall diameter.

For multiconductor or multiplexed cables having individually taped shielded conductors, the minimum bending radius is twelve times the diameter of the individual conductors or seven times the overall diameter, whichever is greater.

For multiconductor cables having an overall tape shield over the multiconductor assembly, the minimum bending radius is twelve times the overall diameter of the cable.

H3.1.3.2 WIRE SHIELDED CABLES

The minimum bending radii for all cables with wire shielding, except armored cables, are given in H2.1. For armored Cables, see H3.1.1 and H3.1.2.

H4.1 POLE AND BRACKET CABLE FOR SERIES LIGHTING CIRCUITS

The minimum bending radius is 2 inches (50.8 mm) with a maximum bend of 180 degrees.

H5.1 DRUM DIAMETERS OF REELS

See NEMA Pub. No. WC 26-1984,* *Wire and Cable Packaging,* which is quoted in Table H-2.

● Appendix H formerly Appendix C.
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*Editorially revised on July 22, 1987.

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Table H-1

Thickness of Conductor Insulation		Overall Diameter of Cable					
		inches	mm	inches	mm	inches	mm
		1.000 and less	25.4 and less	1.001 to 2.000	25.4 to 50.8	2.001 and over[4]	50.8 and over
mils	mm	Minimum Binding Radius as a Multiple of Cable Diameter					
155 and less	3.94 and less	4		5		6	
170–310	4.32–7.87	5		6		7	
325 and over	8.26 and over	...		7		8	

Table H-2
Excerpt from ICEA/NEMA Standards Publication, *Drum Diameters of Reels for Wires and Cables*, ICEA Publication No. A-9-428 (Second Edition), NEMA Publication No. WC 6-1975 (R 1980)

Type of Cable	Minimum Drum Diameter as a Multiple of Outside Diameter† of Cable
A. Single- and multiple-conductor nonmetallic-covered cable	
1. Nonshielded and wire shielded, including cables with concentric wires	
a. 0–2000 Volts	10
b. Over 2000 Volts	
(1) Nonjacketed with concentric wires	14
(2) All others	12
2. Tape Shielded	14
B. Single- and multiple-conductor metallic-covered cable	
1. Tubular metallic sheathed	
a. Lead	14
b. Aluminum	
(1) Outside diameter–1.750" and less	25
(2) Outside diameter–1.751" and larger	30
2. Wire armored	16
3. Flat tape armored	16
4. Corrugated metallic sheathed	14
5. Interlocked armor	14
C. Multiple single conductors cabled together without common covering, including self-supporting cables–The circumscribing overall diameter shall be multiplied by the factor given in item A or B and then by the reduction factor of 0.75.	
D. Combinations–For combinations of the types described in items A, B and C, the highest factor for any component type shall be used.	
E. Single- and multiple-conductor cable in collable nonmetallic duct	
Outside diameter of duct, inches–0.0 –0.50	26
0.51–1.00	24
1.01–1.25	22
1.26–1.50	21
Over 1.50	20

†Outside Diameter—

1. When metallic-sheathed cables are covered only by a thermosetting or thermoplastic jacket, the "outside diameter" is the diameter over the metallic sheath itself. In all other cases, the outside diameter is the diameter outside of all the material on the cable in the state in which it is to be wound upon the reel.
2. For "flat-twin" cables (where the cable is placed upon the reel with its flat side against the drum), the minor outside diameter shall be multiplied by the appropriate factor to determine the minimum drum diameter.
3. The multiplying factors given for item E refer to the outside diameter of the duct.

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Appendix K
Conductor Identification for Control Cables

K1 SCOPE

This appendix contains recommendations for conductor identification of conductors in control cables if such identification is used.

K2 NATIONAL ELECTRICAL CODE APPLICATIONS

The *National Electrical Code* specifies that conductors colored white be used only as grounded conductors and that conductors colored green or green/yellow be used only as grounding conductors and that neither white nor green be used in any manner on ungrounded conductors. Tables K-2 and K-4 provide color sequences which do not include white or green conductors. If grounded and/or grounding conductors are used in the cable, they shall be colored white or green, respectively, and inserted as the second and/or third designated conductor in the first sequence of circuit identification only. Where these conductors are required, they should be specified.

K3 METHODS OF CONDUCTOR IDENTIFICATION

K3.1 Method 1– Colored Compounds with Tracers

This method uses base colors with tracers in accordance with Table K-1 or K-2. These color combinations should be repeated in regular sequence as necessary.

Base and tracer colors should be recognizably the color combinations given in the tables and should approximately match the color shades given in Table K-6.

Base colors may be obtained by suitable color coatings applied to the insulation or jacket surface or by colored insulation or jacket compound.

Tracers should be colored stripes or bands marked on the surface of the insulation or jacket in such a manner as to afford distinctive coding throughout the length. Tracers may be continuous or broken lines, such as a series of dots or dashes, and should be applied longitudinally, annularly, spirally, or in other distinctive patterns.

K3.2 Method 2–Neutral Colored Compounds with Tracers

This method uses a neutral background or base color, such as tan, on all conductors, with tracers as defined in Method 1 and in accordance with Table K-3 or K-4. These color combinations should be repeated in regular sequence as necessary.

K3.3 Method 3–Neutral or Single-Color Compounds with Surface Printing of Numbers and Color Designations

This method uses a single-color insulation or covering on all conductors with printed conductor numbers and color designations in accordance with Table K-1 or K-2. These color combinations should be repeated in regular sequence as necessary.

For example, using Table K-2, for conductors 1 to3, inclusive:

1–Black	1–Black	1–Black, etc.
2–Red	2–Red	2–Red, etc.
3–Blue	3–Blue	3–Blue, etc.

K3.4 Method 4–Neutral or Single-Color Compounds with Surface Printing of Numbers

This method uses a single color insulation or covering on all conductors with each conductor numbered in sequence by surface printing, beginning with the number 1.

K3.5 Method 5–Individual Color Coding With Braids

This method uses colored braids over the insulated conductors in accordance with Table K-2 or K-5. The shades of the colors should approximate those identified by the numbers given in Table K-6.

The tracers should consist of three carriers with each carrier composed of a minimum of two ends. Where two tracers are used, they should be crossed.

K3.6 Method 6–Layer Identification

This method uses a distinctively identified conductor in each layer.

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K3.7 Method 7—Paired Conductors

One conductor of each pair should be coded "white" or "black" and the other conductors should be coded in accordance with the sequence given in Table K-2 or K-5, omitting white or black, respectively. This color sequence should be repeated as necessary.

Table K-1
COLOR SEQUENCE▲

Conductor Number	Background or Base Color	Tracer Color	Conductor Number	Background or Base Color	Tracer Color
1	Black	...	11	Blue	Black
2	White	...	12	Black	White
3	Red	...	13	Red	White
4	Green	...	14	Green	White
5	Orange	...	15	Blue	White
6	Blue	...	16	Black	Red
7	White	Black	17	White	Red
8	Red	Black	18	Orange	Red
9	Green	Black	19	Blue	Red
10	Orange	Black	20	Red	Green
			21	Orange	Green

Table K-2
COLOR SEQUENCE▲

Conductor Number	Background or Base Color	Tracer Color	Conductor Number	Background or Base Color	Tracer Color
1	Black	...	19	Orange	Blue
2	Red	...	20	Yellow	Blue
3	Blue	...	21	Brown	Blue
4	Orange	...	22	Black	Orange
5	Yellow	...	23	Red	Orange
6	Brown	...	24	Blue	Orange
7	Red	Black	25	Yellow	Orange
8	Blue	Black	26	Brown	Orange
9	Orange	Black	27	Black	Yellow
10	Yellow	Black	28	Red	Yellow
11	Brown	Black	29	Blue	Yellow
12	Black	Red	30	Orange	Yellow
13	Blue	Red	31	Brown	Yellow
14	Orange	Red	32	Black	Brown
15	Yellow	Red	33	Red	Brown
16	Brown	Red	34	Blue	Brown
17	Black	Blue	35	Orange	Brown
18	Red	Blue	36	Yellow	Brown

NOTE—See K.2 for *National Electrical Code* applications.

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Table K-3
COLOR SEQUENCE▲

Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)	Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)
1	Black	...	11	Blue	Black
2	White	...	12	Black	White
3	Red	...	13	Red	White
4	Green	...	14	Green	White
5	Orange	...	15	Blue	White
6	Blue	...	16	Black	Red
7	White	Black	17	White	Red
8	Red	Black	18	Orange	Red
9	Green	Black	19	Blue	Red
10	Orange	Black	20	Red	Green
			21	Orange	Green

Table K-4
COLOR SEQUENCE ▲

Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)	Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)
1	Black	...	19	Orange	Blue
2	Red	...	20	Yellow	Blue
3	Blue	...	21	Brown	Blue
4	Orange	...	22	Black	Orange
5	Yellow	...	23	Red	Orange
6	Brown	...	24	Blue	Orange
7	Red	Black	25	Yellow	Orange
8	Blue	Black	26	Brown	Orange
9	Orange	Black	27	Black	Yellow
10	Yellow	Black	28	Red	Yellow
11	Brown	Black	29	Blue	Yellow
12	Black	Red	30	Orange	Yellow
13	Blue	Red	31	Brown	Yellow
14	Orange	Red	32	Black	Brown
15	Yellow	Red	33	Red	Brown
16	Brown	Red	34	Blue	Brown
17	Black	Blue	35	Orange	Brown
18	Red	Blue	36	Yellow	Brown

NOTE—See K.2 for *National Electrical Code* applications.

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Table K-5
Color Sequence

Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color	Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color
1	Black	. . .	. . .	20	Red	Green	. . .
2	White	. . .	. . .	21	Orange	Green	. . .
3	Red	. . .	. . .	22	Black	White	Red
4	Green	. . .	. . .	23	White	Black	Red
5	Orange	. . .	. . .	24	Red	Black	White
6	Blue	. . .	. . .	25	Green	Black	White
7	White	Black	. . .	26	Orange	Black	White
8	Red	Black	. . .	27	Blue	Black	White
9	Green	Black	. . .	28	Black	Red	Green
10	Orange	Black	. . .	29	White	Red	Green
11	Blue	Black	. . .	30	Red	Black	Green
12	Black	White	. . .	31	Green	Black	Orange
13	Red	White	. . .	32	Orange	Black	Green
14	Green	White	. . .	33	Blue	White	Orange
15	Blue	White	. . .	34	Black	White	Orange
16	Black	Red	. . .	35	White	Red	Orange
17	White	Red	. . .	36	Orange	White	Blue
18	Orange	Red	. . .	37	White	Red	Blue
19	Blue	Red	. . .				

Table K-6
Shades of Color

Color	Munsell Notation*
Black	N2/
White	N9/
Red	2.5 R 4/12
Blue	2.5 PB 4/10
Green	2.5 G 5/12
Orange	2.5 YR 6/14
Yellow	5 Y 8.5/12
Brown	2.5 YR 3.5/6

*Munsell Color System is published by Munsell Color–Macbeth Division, 2441 North Calvert St, Baltimore, MD 21218.

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Appendix L●
ADDITIONAL CONDUCTOR INFORMATION

Table L-1
Solid Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Approximate Weight			
	Aluminum		Copper	
	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
22	...	...	1.94	2.88
20	...	...	3.10	4.61
19	...	...	3.90	5.81
18	...	...	4.92	7.32
17	...	...	6.21	9.24
16	...	...	7.81	11.6
15	...	...	9.87	14.7
14	...	...	12.4	18.5
13	...	...	15.7	23.4
12	6.01	8.94	19.8	29.4
11	7.57	11.3	24.9	37.1
10	9.56	14.22	31.43	46.77
9	12.04	17.92	39.62	58.95
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	...	...

NEMA Authorized Engineering Information 7-14-1982.

● Appendix L formerly Appendix J.

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Table L-2
Concentric Stranded Class B Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Number of Strands	Approximate Diameter of Each Strand		Approximate Outside Diameter		Approximate Weight			
						Aluminum		Copper	
		mils	mm	inches	mm	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
22	7	9.6	0.244	0.029	0.737	...	...	1.975	2.941
20	7	12.1	0.307	0.036	0.914	...	...	3.154	4.705
19	7	13.6	0.345	0.041	1.04	...	...	3.974	5.922
18	7	15.2	0.386	0.046	1.17	...	...	5.015	7.462
17	7	17.2	0.437	0.052	1.32	...	...	6.324	9.429
16	7	19.2	0.488	0.058	1.47	...	...	7.974	11.86
15	7	21.6	0.549	...	...	...	...	9.959	14.98
14	7	24.2	0.615	...	...	...	...	12.68	18.88
13	7	27.2	0.691	...	...	...	...	16.01	23.82
12	7	30.5	0.775	...	...	6.13	9.12	20.16	30.00
11	7	34.3	0.871	...	...	7.72	11.5	25.49	37.80
10	7	38.5	0.978	...	...	9.75	14.5	32.06	47.71
9	7	43.2	1.10	...	...	12.3	18.3	40.42	60.14
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	5249	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 L-3
Concentric Stranded Class C and D Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Class C			Class D		
	Number of Strands	Approximate Diameter of Each Strand		Number of Strands	Approximate Diameter of Each Strand	
		mils	mm		mils	mm
22	...	...	...	...	...	...
20	...	...	...	...	...	...
19	...	...	...	...	...	...
18	...	...	...	...	...	...
17	...	...	...	...	...	...
16	...	...	...	...	...	...
15	...	...	...	...	...	...
14	19	14.7	0.373	37	10.5	0.267
13	19	16.5	0.419	37	11.8	0.300
12	19	18.5	0.470	37	13.3	0.338
11	19	20.8	0.528	37	14.9	0.378
10	19	23.4	0.594	37	16.7	0.424
9	19	26.2	0.665	37	18.8	0.478
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	57.4	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 Class D conductors are the same as for the equivalent Class B conductor (see Table L-2).

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Table L-4
Rope-Lay Aluminum and Copper Conductors, Class G

Conductor 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	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
14	49	7×7	9.2	0.23	0.083	2.11	...	...	12.8	19.1
12	49	7×7	11.6	0.29	0.104	2.64	...	...	20.3	30.3
10	49	7×7	14.6	0.37	0.131	3.33	...	...	32.3	48.2
9	49	7×7	16.4	0.42	0.148	3.76	...	...	40.8	60.7
8	49	7×7	18.4	0.47	0.166	4.22	...	...	51	76.6
7	49	7×7	20.6	0.52	0.185	4.70	20	29.4	65	96.6
6	49	7×7	23.1	0.59	0.208	5.28	25	37.0	82	122
5	49	7×7	26.0	0.66	0.234	5.94	31	46.7	103	154
4	49	7×7	29.2	0.74	0.263	6.68	40	58.9	130	194
3	49	7×7	32.8	0.83	0.295	7.49	50	74.2	164	244
2	49	7×7	36.8	0.93	0.331	8.41	63	93.6	207	308
1	133	19×7	25.1	0.64	0.377	9.58	80	119	264	392
1/0	133	19×7	28.2	0.72	0.423	10.7	102	150	334	495
2/0	133	19×7	31.6	0.80	0.474	12.0	127	190	419	623
3/0	133	19×7	35.5	0.90	0.533	13.5	161	239	529	786
4/0	133	19×7	39.9	1.01	0.599	15.2	203	301	668	991
250	259	37×7	31.1	0.79	0.653	16.6	242	358	795	1175
300	259	37×7	34.0	0.86	0.714	18.1	287	429	945	1410
350	259	37×7	36.8	0.93	0.773	19.6	337	501	1110	1650
400	259	37×7	39.3	1.00	0.825	21.0	385	573	1265	1885
450	259	37×7	41.7	1.06	0.876	22.3	433	644	1425	2120
500	259	37×7	43.9	1.12	0.922	23.4	482	716	1585	2355
550	427	61×7	35.9	0.91	0.969	24.6	532	791	1750	2600
600	427	61×7	37.5	0.95	1.013	25.7	581	863	1910	2840
650	427	61×7	39.0	0.99	1.053	26.7	629	935	2070	3075
700	427	61×7	40.5	1.03	1.094	27.8	678	1005	2230	3310
750	427	61×7	41.9	1.06	1.131	28.7	725	1080	2385	3545
800	427	61×7	43.3	1.10	1.169	29.7	774	1150	2545	3785
900	427	61×7	45.9	1.17	1.239	31.5	869	1295	2860	4255
1000	427	61×7	48.4	1.23	1.307	33.2	967	1440	3180	4730
1100	427	61×7	50.8	1.29	1.372	34.8	1064	1580	3500	5205
1200	427	61×7	53.0	1.35	1.431	36.3	1158	1725	3810	5675
1250	427	61×7	54.1	1.37	1.461	37.1	1208	1800	3975	5910
1300	427	61×7	55.2	1.40	1.490	37.8	1257	1870	4135	6150
1400	427	61×7	57.3	1.46	1.547	39.3	1356	2015	4460	6620
1500	427	61×7	59.3	1.51	1.601	40.7	1452	2155	4775	7095
1600	703	37×19	47.7	1.21	1.670	42.4	1560	2325	5130	7640
1700	703	37×19	49.2	1.25	1.722	43.7	1660	2470	5460	8115
1750	703	37×19	49.9	1.27	1.747	44.4	1709	2540	5620	8355
1800	703	37×19	50.6	1.29	1.771	45.0	1756	2615	5775	8595
1900	703	37×19	52.0	1.32	1.820	46.2	1854	2760	6100	9070
2000	703	37×19	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 L-5
Rope-Lay Aluminum and Copper Conductors, Class H

Conductor 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	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
8	133	19×7	11.1	0.28	0.167	4.24	...	...	52	77.4
7	133	19×7	12.5	0.32	0.188	4.78	...	...	65	97.5
6	133	19×7	14.0	0.36	0.210	5.33	...	...	82	123
5	133	19×7	15.8	0.40	0.237	6.02	...	...	105	155
4	133	19×7	17.7	0.45	0.266	6.76	...	...	132	196
3	133	19×7	19.9	0.51	0.299	7.59	...	...	167	247
2	133	19×7	22.3	0.57	0.335	8.51	63	94.5	208	311
2	259	37×7	16.0	0.41	0.336	8.53	...	...	210	312
1	259	37×7	18.0	0.46	0.378	9.60	...	...	266	394
1/0	259	37×7	20.2	0.51	0.424	10.8	102	151	334	497
2/0	259	37×7	22.7	0.58	0.477	12.1	128	190	422	626
3/0	259	37×7	25.5	0.65	0.536	13.6	162	240	533	790
3/0	427	61×7	19.8	0.50	0.535	13.6	...	...	532	794
4/0	259	37×7	28.6	0.73	0.601	15.3	204	303	670	996
4/0	427	61×7	22.3	0.57	0.602	15.3	205	304	675	1000
250	427	61×7	24.2	0.61	0.653	16.6	242	360	795	1180
300	427	61×7	26.5	0.67	0.716	18.2	290	431	953	1420
350	427	61×7	28.6	0.73	0.772	19.6	337	503	1110	1655
400	427	61×7	30.6	0.78	0.826	21.0	386	575	1270	1890
450	427	61×7	32.5	0.83	0.878	22.3	436	647	1435	2130
500	427	61×7	34.2	0.87	0.923	23.4	483	719	1590	2365
550	703	37×19	28.0	0.71	0.980	24.9	538	798	1770	2625
600	703	37×19	29.2	0.74	1.022	26.0	584	871	1920	2865
650	703	37×19	30.4	0.77	1.064	27.0	634	944	2085	3105
700	703	37×19	31.6	0.80	1.106	28.1	686	1015	2255	3340
750	703	37×19	32.7	0.83	1.145	29.1	733	1090	2410	3580
800	703	37×19	33.7	0.86	1.180	30.0	778	1160	2560	3820
900	703	37×19	35.8	0.91	1.253	31.8	880	1305	2895	4295
1000	703	37×19	37.7	0.96	1.320	33.5	974	1450	3205	4775
1100	703	37×19	39.6	1.01	1.386	35.2	1075	1595	3535	5250
1200	703	37×19	41.3	1.05	1.446	36.7	1169	1740	3845	5730
1250	703	37×19	42.2	1.07	1.477	37.5	1221	1815	4015	5970
1300	703	37×19	43.0	1.09	1.505	38.2	1268	1885	4170	6205
1400	703	37×19	44.6	1.13	1.561	39.6	1363	2035	4485	6685
1500	703	37×19	46.2	1.17	1.617	41.1	1464	2180	4815	7160
1600	1159	61×19	37.2	0.94	1.674	42.5	1564	2325	5145	7640
1700	1159	61×19	38.3	0.97	1.724	43.8	1658	2470	5455	8115
1750	1159	61×19	38.9	0.99	1.751	44.5	1710	2540	5625	8355
1800	1159	61×19	39.4	1.00	1.773	45.0	1754	2615	5770	8595
1900	1159	61×19	40.5	1.03	1.823	46.3	1854	2760	6100	9070
2000	1159	61×19	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 L-6
Aluminum and Copper Conductors, Class I
Each Individual Strand 24 AWG, 0.0201 Inch (0.511 mm)

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight			
					Aluminum		Copper	
			inches	mm	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
10	1×26	26	0.125	3.18	...	...	32.5	48.3
9	1×33	33	0.138	3.51	...	...	41	61.3
8	1×41	41	0.156	3.96	16	23.1	51	76.1
7	1×52	52	0.185	4.70	20	29.3	65	96.5
6	7×9	63	0.207	5.26	24	36.3	80	119
5	7×12	84	0.235	5.97	32	48.3	105	159
4	7×15	105	0.263	6.68	41	60.4	134	199
3	7×19	133	0.291	7.39	51	76.5	169	252
2	7×23	161	0.319	8.10	62	92.7	205	305
1	7×30	210	0.367	9.32	81	121	267	397
1/0	19×14	266	0.441	11.2	104	155	342	508
2/0	19×18	342	0.500	12.7	133	199	439	654
3/0	19×22	418	0.549	13.9	163	243	537	799
4/0	19×28	532	0.613	15.6	208	309	683	1015
250	7×7×13	637	0.682	17.3	251	374	825	1230
300	7×7×15	735	0.737	18.7	290	431	955	1420
350	7×7×18	882	0.800	20.3	348	517	1145	1700
400	7×7×20	980	0.831	21.1	386	575	1270	1890
450	7×7×23	1127	0.894	22.7	444	661	1460	2175
500	7×7×25	1225	0.941	23.9	483	719	1590	2365
550	7×7×28	1372	0.980	24.9	541	805	1780	2645
600	7×7×30	1470	1.027	26.1	579	862	1905	2835
650	19×7×12	1596	1.152	29.3	635	945	2090	3110
700	19×7×13	1729	1.194	30.3	687	1025	2260	3365
750	19×7×14	1862	1.235	31.4	740	1100	2435	3625
800	19×7×15	1995	1.290	32.8	793	1180	2610	3885
900	19×7×17	2261	1.372	34.8	901	1340	2965	4405
1000	19×7×19	2527	1.427	36.2	1005	1495	3305	4920
1100	19×7×21	2793	1.495	38.0	1111	1655	3655	5440
1200	19×7×22	2926	1.537	39.0	1164	1730	3830	5700
1250	19×7×23	3059	1.564	39.7	1216	1810	4000	5955
1300	19×7×24	3192	1.605	40.8	1269	1890	4175	6215
1400	19×7×26	3458	1.674	42.5	1386	2045	4560	6735
1500	19×7×28	3724	1.715	43.6	1482	2205	4875	7250
1600	19×7×30	3990	1.797	45.6	1587	2360	5220	7770
1700	19×7×32	4256	1.852	47.0	1693	2520	5570	8290
1750	19×7×33	4389	1.880	47.8	1746	2600	5745	8545
1800	19×7×34	4522	1.921	48.8	1800	2675	5920	8805
1900	19×7×36	4788	1.976	50.2	1905	2835	6265	9325
2000	19×7×37	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 L-7
Copper Conductors, Class K
Each Individual Strand 30 AWG, 0.0100 Inch (0.254 mm)

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight	
			Inches	mm	Pounds per 1000 Feet	g/m
20	1 × 10	10	0.038	0.97	3.2	4.59
18	1 × 16	16	0.048	1.22	5.0	7.35
16	1 × 26	26	0.060	1.52	8.0	11.9
14	1 × 41	41	0.078	1.98	12.8	18.8
12	1 × 65	65	0.101	2.57	20.3	29.9
10	1 × 104	104	0.126	3.20	32.5	47.8
9	7 × 19	133	0.150	3.81	42	62.3
8	7 × 24	168	0.157	3.99	53	78.7
7	7 × 30	210	0.179	4.55	66	98.4
6	7 × 38	266	0.210	5.33	84	125
5	7 × 48	336	0.235	5.97	106	157
4	7 × 60	420	0.272	6.91	132	197
3	19 × 28	532	0.304	7.72	169	252
2	19 × 35	665	0.338	8.59	211	315
1	19 × 44	836	0.397	10.1	266	395
1/0	19 × 56	1064	0.451	11.5	338	503
2/0	7 × 7 × 27	1323	0.470	11.9	425	632
3/0	7 × 7 × 34	1666	0.533	13.5	535	795
4/0	7 × 7 × 43	2107	0.627	15.9	676	1005
250	7 × 7 × 51	2499	0.682	17.3	802	1195
300	7 × 7 × 61	2989	0.768	19.5	960	1425
350	19 × 7 × 26	3458	0.809	20.5	1120	1665
400	19 × 7 × 30	3990	0.878	22.3	1290	1925
450	19 × 7 × 34	4522	0.933	23.7	1465	2180
500	19 × 7 × 38	5054	0.988	25.1	1635	2435
550	19 × 7 × 41	5453	1.056	26.8	1765	2630
600	19 × 7 × 45	5985	1.125	28.6	1940	2885
650	19 × 7 × 49	6517	1.166	29.6	2110	3140
700	19 × 7 × 52	6916	1.207	30.7	2240	3335
750	19 × 7 × 57	7581	1.276	32.4	2455	3655
800	19 × 7 × 60	7980	1.305	33.1	2585	3845
900	37 × 7 × 35	9065	1.323	33.6	2935	4370
1000	37 × 7 × 39	10101	1.419	36.0	3270	4870

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

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outisde Diameter		Approximate Weight	
			inches	mm	Pounds per 1000 Feet	g/m
20	1×26	26	0.038	0.97	3.2	4.74
18	1×41	41	0.048	1.22	5.0	7.48
16	1×65	65	0.060	1.52	8.0	11.9
14	1×104	104	0.078	1.98	12.8	19.0
12	7×24	168	0.101	2.57	21.0	31.2
10	7×37	259	0.126	3.20	32.5	48.2
9	7×48	336	0.146	3.71	42	62.5
8	7×60	420	0.162	4.11	53	78.1
7	19×28	532	0.196	4.98	67	100.0
6	19×35	665	0.215	5.46	84	125
5	19×44	836	0.240	6.10	105	157
4	19×56	1064	0.269	6.83	134	200
3	7×7×27	1323	0.305	7.75	169	251
2	7×7×34	1666	0.337	8.56	212	316
1	7×7×43	2107	0.376	9.55	268	399
1/0	7×7×54	2646	0.423	10.7	337	501
2/0	19×7×25	3325	0.508	12.9	427	636
3/0	19×7×32	4256	0.576	14.6	547	814
4/0	19×7×40	5320	0.645	16.4	684	1020
250	19×7×48	6384	0.713	18.1	821	1220
300	19×7×57	7581	0.768	19.5	975	1450
350	37×7×34	8806	0.825	21.0	1130	1685
400	37×7×39	10101	0.901	22.9	1300	1930
450	37×7×44	11396	0.940	23.9	1465	2180
500	37×7×49	12691	0.997	25.3	1630	2430
550	61×7×32	13664	1.035	26.3	1755	2615
600	61×7×35	14945	1.084	27.5	1920	2860
650	61×7×38	16226	1.133	28.8	2085	3105
700	61×7×41	17507	1.183	30.0	2250	3350
750	61×7×44	18788	1.207	30.7	2415	3595
800	61×7×47	20069	1.256	31.9	2580	3840
900	61×7×53	22631	1.331	33.8	2910	4330
1000	61×7×59	25193	1.404	35.7	3240	4820

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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