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CROSS LINKED THERMOSETTING POLYETHYLENE INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

Prepared and Sponsored by:

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

Approved and Published by:

National Electrical Manufacturers Association
1300 North 17th Street
Rosslyn, VA 22209

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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 eliminate misunderstanding between the manufacturer and the user and to assist the user in selecting and obtaining the proper product for his particular need. Existence of an ICEA/NEMA Standard does not in any respect preclude the manufacture of 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 official 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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CROSS-LINKED-THERMOSETTING-POLYETHYLENE-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Section 1
GENERAL

1.1 SCOPE

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

1.2 GENERAL INFORMATION

These standards cover the requirements for conductors, the insulations and protective coverings, and general constructional and dimensional details common to most standard types of wires and cables. Constructions of specific types are covered in Section 7. Where a conflict exists between the requirements of Section 7 and those of Sections 1 to 6, inclusive, the requirements of Section 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.

Insulation thicknesses are designated in terms of cable insulation 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: (This paragraph approved by NEMA as Authorized Engineering 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 operating 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.
   f. Thermal resistivity (rho) of soil.

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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Section 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 2-7.
c. Approximate conductor weights.

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 B230. 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.

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

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2.3 STRANDED CONDUCTORS

Stranded conductors shall consist of a number of wire individually meeting the appropriate requirements of 2.1. All wires in a stranded conductor shall be of the same material and temper. There shall be no water in the stranded conductor of the cable as shipped.

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 dc 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 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 copper conductors.
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 alterative 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 OF 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.
2. A multiplying factor calculated using the applicable formula in the footnote to Table 6-1.

If verification is required for the dc 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 dc 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).

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

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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 ±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 that will fit a particular connector; however, a conductor meeting the minimum diameter requirement does not necessarily meet the requirement for maximum dc resistance given in 2.5.

2.6.2 If one or more layers of any concentric lay-stranded Class B,C, or D conductor is compressed to reduce the non-compressed 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 (0.06 mm).

Table 2-2
Weight Increment Factors*, K

Solid Conductors	1
Concentric-lay Strand, Class 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
More than 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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2.7.1.1 Extrudable material, prior to application to the conductor, when tested according to 6.4.15 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 6.12 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

Table 2-3
Schedule for Establishing Maximum DC Resistance Per Unit Length of Completed Cable

Non-Portable Cables	
Cable Type	**Maximum DC Resistance**
Single Conductor Cable 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)

Portable Cables and Flexible Cords	
Cable Type	**Maximum DC Resistance**
Single Conductor Cable and Flat Parallel Cable	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 dc 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.

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Table 2-4
Nominal DC 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 Class B,C,D	Coated Class B	Coated Class C	Coated 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 DC 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 DC Resistance in Ohms Per 1000 Feet* At 25°C (77°F)
For Flexible Annealed Copper Conductors

Conductor Size	Uncoated					Coated				
AWG or kcmil	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
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 Aluminum 61	All Sizes, Uncoated Copper 100	Diameter of Individual Coated Copper Wires in Inches for Stranded Conductors: 0.460 to 0.290, Inclusive 97.66	Under 0.290 to 0.103, Inclusive 97.16	Under 0.103 to 0.0201, Inclusive 96.16	Under 0.0201 to 0.0111, Inclusive 94.16	Under 0.0111 to 0.0010, Inclusive 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	...
More than 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
>2000–3000 kcmil	17865	10892	11153	11211	11327	11568	11694
>3000–4000 kcmil	18309	10998	11261	11319	11437	11680	11807
>4000–5000 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 percent conductivity) at 25°C for uncoated (bare) copper.
2. A 25°C volume resistivity converted from the 20°C values specified in ASTM B 33 or ASTM B 189 for coated copper.
3. A volume resistivity of 17.345 Ω · cmil/ft. (61.0 percent conductivity) at 25°C for aluminum.

B. Increase in Resistance Due to Stranding

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

† See Table 2-3 for Use of Factors.

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Section 3
INSULATION

3.1 MATERIAL

The insulation shall be a filled or unfilled cross-linked thermosetting polyethylene meeting the dimensional, electrical, and physical requirements specified in Section 3. A filled cross-linked-polyethylene insulation is one that contains 10 percent or more of carbon black and/or mineral fillers by weight. An unfilled crosslinked-polyethylene insulation is one that contains up to 2-1/2 percent carbon black for cables rated up to and including 5 kV and no carbon black for cables rated above 5 kV.

This insulation is suitable for use on power cables in wet or dry locations at conductor temperatures no exceeding 90°C (194°F) for normal operation, 130°C (266°F) for emergency overload conditions (see Appendix D), and 250°C (482°F) for short-circuit conditions.

The insulation on the conductor shall be free from any contaminants or porosity visible to the eye with not more than five times magnification.

3.2 INSULATION THICKNESS

The insulation thicknesses given in Table 3-1A are based on the rated circuit voltage, phase-to-phase, and on the cable insulation level.

The thicknesses of insulation given in Table 3-1A shall apply to single-conductor cables and to the individual conductors of multiple-conductor cables, except nonsheathed submarine cables and portable power cables. For nonsheathed submarine cables, see 3.3. For portable power cables, see 7.4.

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

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

3.2.1 For Three-Phase Systems with 100 or 133 Percent Insulation Level

Use the thickness values given in the respective columns of Table 3-1A or Table 3-1B as applicable.

3.2.2 Delta Where One Leg May be Grounded for Periods Over 1 Hour

See 173 percent level in note following Table 3-1B.

3.2.3 Single- and Two-Phase Systems with 100 Percent Insulation Level

For nonshielded cables, multiply the voltage to ground by 1.73 and use the resulting voltage value to select the corresponding insulation thickness from Column A or Column B of Table 3-1A, as applicable.

For shielded cables, multiply the voltage to ground by 1.73 and select the corresponding insulation thickness from the 100 percent insulation level or 133 percent insulation level Column in Table 3-1B, as applicable.

3.2.4 Direct Current Systems

Up to and including 2000 volts, consider the same as three-phase ac systems in accordance with 3.2.1. Over 2000 volts, consult the manufacturer.

3.3 INSULATION THICKNESS FOR SUBMARINE CABLES

The insulation thickness shall be as given in Table 3-1A and Table 3-1B, except the average thickness shall not be less than 60 mils for cables without a jacket or a sheath for voltage classifications up to and including 2 kV.

3.4 REPAIRS

Repairs in 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 requirements of 3.6 or 3.7, as applicable.

3.5 INSULATION CLASSES AND REQUIREMENTS

3.5.1 Classes

The classes of insulation shall be as follows:

a. 2000 volts or less (see 3.6).
b. 2001 volts and above (see 3.7).

3.5.2 Voltage Tests

Completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-1A and Table 3-B 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.

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Table 3-1A
NONSHIELDED CABLES CONDUCTOR SIZES, INSULATION THICKNESSES AND TEST VOLTAGES

Rated Circuit Voltage, Phase-to-Phase Volts[3]	Conductor Size, AWG or kcmil	Insulation Thickness[1]				ac Test Voltage[2], kV		dc Test Voltage, kV		dc Spark Test Voltage, kV		ac Spark Test Voltage[2], kV	
		mils	mm	mils	mm								
		Column A		Column B		Column A	Column B	Column A	Column B	Column A	Column B	Column A	Column B[4]
0–600	14–9[5]	45	1.14	30	0.76	4.0	3.5	12.0	10.5	16.0	10.5	10.0	7.5
	8–2	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5	15.0	10.0
	1–4/0	80	2.03	55	1.40	7.0	7.0	21.0	21.0	28.0	21.0	17.5	12.5
	225–500	95	2.41	65	1.65	8.0	8.0	24.0	24.0	33.5	24.0	20.0	15.0
	525–1000	110	2.79	80	2.03	10.0	10.0	30.0	30.0	38.5	30.0	27.5	17.5
	1025–2000	125	3.18	100	2.54	11.5	11.5	34.0	34.0	44.0	34.0	31.0	20.0
601–2000	14–9[5]	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5	15.0	10.0
	8–2	70	1.78	55	1.40	7.0	7.0	21.0	21.0	24.5	21.0	17.5	12.5
	1–4/0	90	2.29	65	1.65	8.0	8.0	24.0	24.0	31.5	24.0	20.0	15.0
	225–500	105	2.67	75	1.90	9.5	9.5	28.5	28.5	37.0	28.5	25.0	17.5
	525–1000	120	3.05	90	2.29	11.5	11.5	34.5	34.5	42.0	34.5	30.0	20.0
	1025–2000	140	3.56	115	2.92	13.5	13.5	40.0	40.0	49.0	40.0	35.0	24.0
2001–5000[6]	8–1000												

[1] Column A thicknesses (2000 volts or less) apply to single-conductor power cables for general application which employ a sunlight-resistant, carbon-black pigmented insulation without further covering.

Column B thicknesses (2000 volts or less) apply to multiple-conductor cables with an outer covering and to single-conductor cables with an outer covering.

The Column B thicknesses are considered adequate for electrical purposes and may be specified for single-conductor cables employing sunlight-resistant, carbon black pigmented insulation without further covering. These cables may be used in applications where installation and service conditions are such that the additional thickness for mechanical protection is not considered necessary for satisfactory operation.

Column A and Column B insulation thicknesses are adequate for both 100 percent and 133 percent insulation levels. For 173 percent insulation level, consult the manufacturer. Refer to Table 3-1B for insulation level definitions.

[2] All ac voltages are rms values.

[3] 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.

[4] Column B ac spark test voltages for conductor sizes through 1000 cmil are taken from 42.1 of UL Standard 44, *Rubber Insulated Wires and Cables*, 13th Edition.

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

[6] For single conductor with or without jacket, see 7.5 and 7.6. For single and multiple-conductor cables with a metallic sheath or armor and for multiple-conductor cables with a discharge-resistant jacket (see Table 4-3), the insulation thickness shall be 90 mils (2.29 mm) and the test voltage shall be 13 kV dc (see 3.5.2).

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Table 3-1B
Shielded Cables
Conductor Sizes, Insulation Thicknesses and Test Voltages+++

Rated Circuit Voltage, Phase-+ Volts	Conductor Size, AWG or kcmil++	Insulation Thickness • 100 Percent Insulation Level mils	mm	133 Percent Insulation Level mils	mm	ac Test Voltage, kV** 100 Percent Insulation Level	133 Percent Insulation Level	dc Test Voltage, kV 100 Percent Insulation Level	133 Percent Insulation Level
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	–

• 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 also be used on other systems for which the application of cable is acceptable (see note below) provided the above clearing requirements are met in completely de-energizing the faulted section.

Where additional insulation thickness is desired, it shall be the same for the 133 percent insulation level for rated circuit voltages over 5000 volts.

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. They may be used when additional insulation strength over the 100 percent level category is desirable for rated circuit voltages over 5000 volts.

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.

** All ac voltages are rms values.

+ 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 no more than 15 minutes.

++ To limit the maximum voltage stress on the insulation at the conductor to a safe value, the conductor size shall not be less than the minimum size shown for each rated circuit voltage category

+++ Consult the manufacturer for recommended insulation thicknesses and corresponding test voltages which are not listed.

NOTE: In common with other electrical equipment, the use of cables is not recommended on systems where the ratio of the zero to positive phase reactance of the system at the point of cable application lies between -1 and - 0 since excessively high voltages may be encountered in the case of ground faults.

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3.5.3 Insulation Resistance Constants

The insulation resistance constants of insulations shall be in accordance with 3.6 or 3.7, as applicable (see 6.15 for test method).

3.6 INSULATION FOR CABLES RATED 0 THROUGH 2000 VOLTS

3.6.1 Physical and Aging Requirements

When tested in accordance with Section 6, the insulation shall meet the following requirements.

Physical Requirements		
Tensile strength, minimum		
psi		1800
MPa		12.5
Elongation at rupture, minimum, percent		250
Aging Requirements		
After air oven test at 121°C±1°C for 168 hours—Tensile strength and elongation at rupture, minimum, percentage of unaged value		75
After hot creep test at 150°C±2°C	**Unfilled**	**Filled**
*Hot creep elongation, maximum percent	175	100
*Hot creep set, maximum, percent	10	5

*If this value is exceeded, the Solvent Extraction Test may be performed and will serve as a referee method to determine compliance (maximum percent after 20 hours drying time—30).

3.6.2 Electrical Requirements

3.6.2.1 VOLTAGE TESTS

See 3.5.2.

3.6.2.2 INSULATION RESISTANCE

(See 6.15) Each insulated conductor in the completed cable shall have an insulation resistance not less than the corresponding to a constant of 10,000 at 15.6°C (60°F).

3.6.3 Accelerated Water Absorption Requirements

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Electrical Method (60 Hz) at 75 ± 1°C	
Dielectric constant after 1 day, maximum	6.0
Increase in capacitance, maximum, percent	
1 to 14 days	3.0
7 to 14 days	1.5
Stability factor after 14 days, maximum*	1.0
Alternate to stability factor-stability factor difference, 1 to 14 days, maximum*	0.5

* Only one of these two requirements need be satisfied, not both.

3.7 INSULATION FOR CABLES RATED 2001 VOLTS AND ABOVE

3.7.1 Physical and Aging Requirements

When tested in accordance with Section 6, the insulation shall meet the following requirements.

Physical Requirements		
Tensile strength, minimum		
psi		1800
MPa		12.5
Elongation at rupture, minimum, percent		250
Aging Requirements		
After air oven test at 121°C±1°C for 168 hours—Tensile strength and elongation at rupture, minimum, percentage of unaged value		75
After hot creep test at 150°C±2°C	**Unfilled**	**Filled**
*Hot creep elongation, maximum percent	175	100
*Hot creep set, maximum, percent	10	5

*If this value is exceeded, the Solvent Extraction Test may be performed and will serve as a referee method to determine compliance (maximum percent after 20 hours drying time—30).

3.7.2 Electrical Requirements

3.7.2.1 VOLTAGE TESTS

See 3.5.2.

3.7.2.2 INSULATION RESISTANCE

(See 6.15) Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20,000 at 15.6°C (60°F).

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3.7.2.3 Partial-Discharge Extinction Level

(See ICEA T-24-380.) Each length of completed power cable rated for service at 2001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

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 at the 100 percent insulation level.

3.7.3 Additional Requirements

3.7.3.1 U-Bend Discharge

(See 6.11.) Single-conductor nonshielded cables rated at 2001–5000 volts shall not fail or show any cracks, when tested in accordance with 6.11.

3.7.3.2 Surface Resistivity

(See 6.11.) Single-conductor nonshielded cables rated at 2001–5000 volts shall have a specific surface resistivity of not less than 200,000 megohms when tested in accordance with 6.11.

3.7.3.3 Accelerated Water Absorption Requirements

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Electrical Method (60 Hz) at 75 ± 1°C	
Dielectric constant after 24 hours, maximum	3.5
Increase in capacitance, maximum, percent	
1 to 14 days	3.0
7 to 14 days	1.5
Stability factor after 14 days, maximum*	1.0
Alternate to stability factor-stability factor difference, 1 to 14 days, maximum*	0.5

* Only one of these two requirements need be satisfied, not both.

3.7.3.4 Capacity and Power Factor

(See 6.5). The insulation on cables rated at 5001 volts and above shall have a specific inductive capacity not exceeding 3.5 and a power factor not exceeding 2.0 percent.

3.7.3.5 Inspection for Evidence of Water

Each length of completed shielded cable 2001 volts and above shall be inspected for evidence of water in accordance with 6.19. If evidence of water is present, the affected cable length shall be dried by a suitable method.

Table 3-2
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*	6.14.2 or 6.14.3 or 6.14.4 or 6.14.5	6.14.2 or 6.14.3 or 6.14.4 or 6.14.5	6.14.2 or 6.14.3	6.14.2 or 6.14.3
2. With metallic sheath or armor	6.14.2 or 6.14.3	6.14.2 or 6.14.3	6.14.2 or 6.14.3	6.14.2 or 6.14.3
b. 2001-5000 Volts	6.14.2 or 6.14.3	6.14.2 or 6.14.3	6.14.2 or 6.14.3	6.14.2 or 6.14.3
2. Cables with Insulation Shield				
a. 2001 volts and higher	6.14.2	6.14.2	6.14.2	6.14.2

*See Section 6 for:
6.14.2 AC voltage test
6.14.3 DC voltage test
6.14.4 AC spark test
6.14.5 DC spark test

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Section 4
SHIELDING AND COVERINGS

SHIELDING (SEE APPENDIX G)

4.1 SHIELDING OF INSULATED CABLE

Shielding of insulated cables shall consist of conductor shielding and insulation shielding. For conductor shielding, see 2.7.

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 that meets the requirements of Table 4-1 or Table 4-2 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 6.12.4).

For removability of insulation shields, see Appendix G, G6.1. (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 copper at least 2.5 mils (0.0635 mm) thick or of other nonmagnetic metal tapes 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 mm^2/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 4-3. To obtain the equivalent three-phase voltage for single-phase or two-phase ac systems or for dc systems, multiply the line-to-line voltage by the factors given in Table 4-3.

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; or
5. Damp conduits.

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

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Table 4-1
Requirements for Nonmetallic Conducting Coverings Using Nonembedded Metal Components

	Thermoplastic	Thermoset
Aging Requirements (see 6.4.15)		
After air oven test at 100°C±1°C for 48 hours – elongation at rupture, minimum, percent	100*	...
After air oven test at 121°C±1°C for 168 hours – elongation at rupture, minimum, percent	...	100*
Brittleness Temperature (see 6.4.15), not warmer than	–10°C*	–10°C*
Volume Resistivity, maximum at room temperature and at rated temperature ±1°C (see 6.12), ohm-meters	500	500

*For extruded coverings only.

Table 4-2
Requirements for Extruded Nonmetallic Conducting Coverings Using Embedded Metal Components

Thickness, Minimum (see 6.4)		
Total	in accordance with	4.4.4
Between insulation and metal components		
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 6.4.15), not warmer than		–10°C
Volume Resistivity, maximum at room temperature and at rated temperature ±1°C (see 6.12), ohm-meters		500

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Table 4-3
Operating Voltage Limits, kV, above which Insulation Shielding is Required

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. With discharge-resisting jacket (See 7.5 and 7.6)		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
Multiplying Factors for Equivalent Three-phase Voltage for Single- or Two-phase AC Systems or for DC Systems		
Single- and Two-Phase AC Systems* and DC Systems 5000 Volts or Less	**Single- and Two-phase AC Systems* Over 5000 Volts**	
	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.

JACKETS

4.3 GENERAL

Jackets shall be one of the types covered in 4.4 except that, for cable with an embedded metal component, the jacket shall be a nonmetallic conducting covering meeting the requirements of Table 4-2. For jackets over metallic coverings, see 4.5.

4.4 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 4.4.1 through 4.4.7. The tests shall be made only on jackets having a nominal wall thickness of 30 mils (0.76 mm) or greater.

4.4.1 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 6.4 and 6.10, the jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.6.

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 test 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

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4.4.2 Polyethylene, Black

This jacket shall consist of a black polyethylene compound suitable for exposure to sunlight and other atmospheric environments at temperature 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 6.4 [except that the gauge marks shall be 1 inch (25.4 mm) apart and the distance between jaws 2.5 inches (63.5 mm)] and 6.10, the jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.6:

Type I Polyethylene (LDPE/LLDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	1700
MPa	11.7
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.910–0.925**
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
Heat Distortion, 100°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

Type II Polyethylene (MDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	2300
MPa	15.9
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.926-0.940**
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
Heat Distortion, 110°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

Type III Polyethylene (HDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	2500
MPa	17.2
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.941–0.965**
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
Heat Distortion, 110°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

* Use condition A for Type I and use condition B for Types II and III, with a full strength solution of Igepal CO-630 or equivalent as defined in ASTM D1693

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

4.4.3 Chlorinated Polyethylene, Thermoplastic

This jacket shall consist of a thermoplastic chlorinated polyethylene compound. When tested in accordance with 6.4 and 6.10, the jacket shall meet the following requirements and, when applicable, the requirement in 4.4.6.

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	50
Heat distortion, 121°C±1°C, maximum, percent	25
Cold bend, -35°C±1°C	No cracks

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4.4.4 Jacket Thickness

The average thicknesses of jackets shall be not less than the applicable values given in Tables 4-4, 4-5, 4-6, or 4-7. For the jacket thicknesses of cables not shown in these tables, see Table 4-8. The minimum thickness shall be not less than 80 percent of the values given in these tables. (See 6.4.3 for method of measurement.)

4.4.5 Separator Under Jacket

If used, a separator shall consist of a material that is compatible with the other components of the cable.

4.4.6 Discharge Resisting Jackets

(See Table 4-3.) For single-conductor non-shielded cables rated 2001-5000 volts phase-to-phase, see 7.5 and 7.6

For multiple-conductor non-shielded cables rated 2001-5000 volts phase-to-phase, the overall jacket shall meet the requirements of 4.4.1, 4.4.2, or 4.4.3 and, in addition, shall have a specific surface resistivity of not less than 200,000 megohms (see 6.11.1 and 6.11.2).

4.4.7 Irregularity Inspection

Jackets shall not have irregularities as determined by the procedure given in ICEA T-27-581. The method used:

Method B	Method C
Chlorinated Polyethylene Thermoplastic (4.4.3)	Polyvinyl Chloride (4.4.1)
	Polyethylene (4.4.2)

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Table 4-4
Jacket Thickness for Single-Conductor Non-shielded Cable – 2000 Volts or Less (For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial†)

Size, AWG or kcmil	2000 Volts or Less	
	mils	mm
14	15	0.38
12	15	0.38
10	15	0.38
9	15	0.38
8	15	0.38
6	30	0.76
4	30	0.76
2	30	0.76
1	45	1.14
1/0	45	1.14
2/0	45	1.14
3/0	45	1.14
4/0	45	1.14
250	65	1.65
300	65	1.65
350	65	1.65
400	65	1.65
450	65	1.65
500	65	1.65
600	65	1.65
750	65	1.65
1000	65	1.65

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

4.5 METALLIC AND ASSOCIATED COVERINGS

4.5.1 Scope

This section covers the following:

Division I – (See 4.5.3 through 4.5.16.) 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 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shaft, and vertical riser cable.

Division III – (See 4.5.24 through 4.5.26.) Round wire armor for buried cable.

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

4.5.2 General

4.5.2.1 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.

4.5.2.2 Types of Metallic Coverings

The types and conditions of installation are as follows:

1. Metallic sheath, lead, or aluminum.
   a. Conduit, ducts, troughs, or raceways.
   b. Suspended from aerial messenger.
   c. When protected by metal armor or non-metallic coverings for other types of installation.
2. Flat metal tape armor.
   a. Direct burial in trenches.
   b. Suspended from aerial messenger.

Plain- or galvanized-steel tape armor, depending upon soil and water conditions, with 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.

3. Interlocked metal tape armor.*
   a. Direct burial in trenches.
   b. Troughs.
   c. Racks.
   d. Raceways.
   e. Suspended from aerial messenger.

*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.

Interlocked-metal tape armor without an outer covering but with either a fibrous bedding or 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.

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Table 4-5
Jacket Thicknesses for Single-Conductor Metallic Shielded Cables
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial)

Size, AWG or kcmil	2001–5000 Volts		5001–8000 Volts				8001–15000 Volts			
	100 and 133 Percent Insulation Level		100 Percent Insulation Level		133 Percent Insulation Level		100 Percent Insulation Level		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

Size, AWG or kcmil	15001–25000 Volts				25001–28000 Volts		28001–35000 Volts	
	100 Percent Insulation Level		133 Percent Insulation Level		100 Percent Insulation Level		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 4-8, Column (2).

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Table 4-6
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 4-7
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 4-7 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.

Table 4-8
Single- and Multiple-Conductor Wires and Cables (All Uses Except Communication and Portable Cables‡)

Calculated Diameter of Cable Under Jacket		Jacket Thickness							
		Single-conductor Cables				Multiple-conductor Cables*			
		(1) Nonshielded		(2) Shielded**		(3) Individual Conductors†		(4) 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 4-5) shall be added to the metallic conductor diameter plus twice the insulation thickness given in Table 3-1.

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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4. Galvanized steel wire armor.
   a. Submarine cable.
   b. Dredge cable.
   c. Vertical riser, borehold, and shaft cable for end suspension.
   d. 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. (This paragraph is approved by NEMA as Authorized Engineering Information.)

DIVISION I
Metallic and Associated Coverings for Insulated Cables

4.5.3 Scope

Division I applies to the metallic coverings described in the following sections, together with the necessary fibrous, thermosetting, 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.

4.5.4 Metallic Sheath

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

4.5.4.1 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.

If lead stripped from new cable is used, it shall comply with the requirements given herein.

4.5.4.2 Thickness of Lead

The average thickness of the lead sheath shall be in accordance with Table 4-9. 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 4.5.14 and 4.5.15 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 cables, 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. (This sentence is approved by NEMA as Authorized Engineering Information.)

Table 4-9
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).

4.5.4.3 Measurement of Thickness of Lead

The thickness shall be measured in accordance with 6.8.

4.5.4.4 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.

4.5.4.5 Type of Aluminum

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

4.5.4.6 Thickness of Aluminum

The average thickness of the aluminum sheath shall be in accordance with Table 4-10. The minimum thickness shall in no case be less than 90 percent of the thickness specified in the table.

4.5.4.7 Measurement of Thickness of Aluminum

The thickness shall be measured in accordance with 6.8.

4.5.4.8 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 resheathed. (This sentence is ap-

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proved by NEMA as Authorized Engineering Information.)

Table 4-10
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.

4.5.5 Jute Serving over Metallic Sheath without Metallic Armor

4.5.5.1 Jute Servings

The thickness of one serving (or two servings) of jute applied over metallic sheathed cable for mechanical protection shall be as given in Table 4-11.

Table 4-11
Thickness of Jute Servings Over Metallic Sheath (Without Metallic Armor)

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

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

4.5.5.2 Application

When jute servings are required, the metallic sheathed cable shall be run through hot asphalt or tar compound and served with a closely wound lay of No. 16/3 impregnated jute yarn or plied jute of equivalent thickness. If two servings are required, they shall be closely wound and applied with opposite directions of lay. The inner serving shall be an impregnated jute yarn that shall be run through hot asphalt or tar compound before the application of the outer serving which shall be No. 16/3 impregnated jute yarn or plied jute of equivalent thickness.

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

4.5.6 Flat Metal Tape Armor

4.5.6.1 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 hot-dip or the electro-galvanizing process such that all surfaces of the finished tape width are coated, including edges.

4.5.6.2 Tensile Strength and Elongation

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

4.5.6.3 Galvanizing Test

4.5.6.3.1 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 specified is the total amount on both surfaces and edges and shall be determined in accordance with the method described in ASTM A90.

4.5.6.3.2 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 1/8 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 or none of it can be removed from the strip by rubbing with the fingers.

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

4.5.6.4 WIDTH

The nominal width of metal tapes shall be not greater than that specified in Table 4-12.

For nominal widths 1.000 inch (25.4 mm) or less, the tolerance in width shall be ±31 mils. For nominal widths greater than 1.000 inch (25.4 mm), the tolerance in width shall be ±47 mils.

Table 4-12
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
0.450 or less	11.43 or less	0.750	19.0
0.451–1.000	11.46–25.40	1.000	25.4
1.001–1.400	25.43–35.56	1.250	31.8
1.401–2.000	35.59–50.80	1.500	38.1
2.001–3.500	50.83–88.90	2.000	50.8
3.501 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.

4.5.6.5 THICKNESS

The nominal thickness of metal tape shall be not less than that given in Table 4-13. See 6.7.2 for method of measuring metal tape thickness.

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

4.5.6.6 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 mm^2). 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.

Table 4-13
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
1.000 or less	25.40 or less	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.

4.5.7 Interlocked Metal Tape Armor

4.5.7.1 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.

4.5.7.2 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 such that all surfaces of the finished tape width are coated, including the edges. 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 4.5.6.2 and 4.5.6.3 for flat steel tape.

4.5.7.3 WIDTH

The nominal width of metal tape may be less than but shall not be greater than that specified in Table 4-14.

Table 4-14
Width of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Width of Metal Tape Armor	
inches	mm	inches	mm
0.500 or less	12.70 or less	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

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.

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4.5.7.4 THICKNESS

The nominal thickness of metal tape shall be not less than that given in Table 4-15. See 6.7.2 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 tolerance for nominal thickness of bare metal should apply to the stripped tape.

Table 4-15
Thickness of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Thickness			
		Ambrac, Brass, Steel, Stainless Steel, Bronze, and Monel Tape		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

4.5.7.5 NONMAGNETIC TAPE

When nonmagnetic tapes, such as aluminum, brass, bronze, zinc, or stainless steel tapes are used, the widths shall be in accordance with 4.5.7.3 and the thicknesses in accordance with 4.5.7.4.

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

4.5.7a Continuously Corrugated Metal Armor

4.5.7a.1 SCOPE

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

4.5.7a.2 TYPE OF METAL

4.5.7a.2.1 When metal armor is formed by a flat metal tape, the tapes used shall be aluminum, copper, steel, or alloys thereof.

4.5.7a.2.2 When metal armor is formed by applying a seamless sheath or tube, the metal shall be aluminum or an aluminum alloy.

4.5.7a.2.3 The minimum thickness of tape or of the sheath or tube before corrugation shall be as shown in Table 4-14a.

4.5.7a.3 FLEXIBILITY

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

4.5.7a.4 CORROSION PROTECTION

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

4.5.8 Galvanized Steel Wire Armor

4.5.8.1 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 Division II and III (4.5.17 through

Table 4-14a
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	0.4
1.906–3.05	48.41– 72.39	...	...	...	...	20	0.5
3.051–4.200	72.42–106.7	...	...	...	...	24	0.6

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4.5.26). All tests shall be made prior to application of the wire to the cable.

4.5.8.2 TENSILE STRENGTH, ELONGATION, AND TORSION

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

4.5.8.2.1 TENSILE STRENGTH

The zinc-coated wire shall have a tensile strength of not less than 50000 psi (35.2 kgf/mm^2) and not more than 70000 psi (49.2 kgf/mm^2). The tensile strength shall be tested in accordance with ASTM E8.

4.5.8.2.2 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.

4.5.8.2.3 TORSION TEST

The zinc-coated wire shall withstand, without fracture, the minimum number of twists specified in Table 4-16. 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 4-16
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

4.5.8.3 GALVANIZING TESTS

4.5.8.3.1 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 4-17. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A90.

4.5.8.3.2 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 4-18. The zinc coating shall be considered as meeting this requirement if, when the wire is wrapped about the specified mandrel, the coating does not flake and none of it can be removed from the wire by rubbing it with the fingers.

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

Table 4-18
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

4.5.8.4 SIZE OF ARMOR

The sizes of armor wire for submarine cables are given in Table 4-19.

If the service requirements are exceptionally severe, larger sizes of armor wire may be required. (This sen-

Table 4-17
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^2 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

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Table 4-19
Size of Galvanized Steel Armor Wire for Submarine 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

tence has been approved by NEMA as Authorized Engineering Information.)

The tolerance in diameter for galvanized steel wire shall be as shown in Table 4-20.

Table 4-20
Tolerances of 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

4.5.8.5 LAY

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter for all constructions except for dredge cable. For dredge cable, see 4.5.20.

"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."

4.5.8.6 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 birdcaging of the cable being armored shall be reduced to a minimum.

4.5.9 Jute Bedding for Armored Cable

See 4.5.11 for Interlocked Armored Cable.

4.5.9.1 APPLICATION

Metallic-sheathed cable to be armored shall be run through hot asphalt or tar compound before being served with a bedding of impregnated jute yarn or roving, each layer of which shall be run through hot asphalt or tar compound. If the cable is without metallic sheath, the core shall be covered as specified in 4.5.12.1 before it is run through the first application of compound.

4.5.9.2 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 4.5.8.6. Adjacent layers of jute shall be applied with opposite directions of lay.

4.5.9.3 THICKNESS

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

4.5.10 Jute Serving Overall for Armored Cable

See 4.5.11 for Interlocked Armored Cable.

4.5.10.1 APPLICATION

When an outer jute serving is required, the armored cable shall be run first through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 16/3) 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 that will prevent sticking of adjacent turns of the cable when wound in a reel.

4.5.10.2 DIRECTION OF LAY

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

4.5.11 Jute for Interlocked Armored Cable

4.5.11.1 JUTE BEDDING

If jute bedding is required, the application and direction of lay shall be in accordance with 4.5.9.1 and 4.5.9.2. The thickness shall be as specified for metal taped cable in Table 4-21.

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Table 4-21
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	1.45	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.

4.5.11.2 JUTE SERVING OVERALL

If jute serving overall is required, it shall be in accordance with 4.5.10.

4.5.12 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.

4.5.13 Core Covering for Jacketed Cable Under Armor

4.5.13.1 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 4-21 (see 6.9).

4.5.13.2 INTERLOCKED ARMOR

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

4.5.13.3 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 4-21 (see 6.9).

4.5.14 Cross-Linked Jackets Over Metallic Sheath

4.5.14.1 REINFORCED CROSS-LINKED JACKET

A reinforced cross-linked jacket over a metallic sheath shall consist of a combination of treated fibrous reinforcing tapes and a chloroprene rubber jacket compound.

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

Physical Requirements	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements	
After air oven test at 70°C±1°C for 168 hours—tensile strength, minimum	
psi	1000
MPa	6.89
Elongation at rupture, minimum, percent	200
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	60

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

4.5.14.2 THICKNESS

The average thickness of the cross-linked jacket shall be not less than that specified in Table 4-22. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the jacket.

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The minimum thickness shall be not less than 80 percent of the thickness specified in Table 4-22.

Table 4-22
Thickness of Cross-linked Jacket over Metallic Sheaths

Calculated Diameter Over Sheath		Thickness	
inches	mm	mils	mm
1.500 or less	38.10 or less	65	1.65
1.501–3.000	38.13–76.20	95	2.41
3.001 and larger	76.23 and larger	125	3.18

4.5.14.3 THICKNESS OF LEAD SHEATH

When a cross-linked jacket is applied over a lead sheath, the average thickness of the lead sheath shall be in accordance with Table 4-23. The minimum thickness shall be not less than 90 percent of the values given in the table (see 6.8).

Table 4-23
Thickness of Lead Sheath for Cables Having a Jacket over the Lead Sheath

Calculated Diameter of Core*		Thickness of Sheath	
inches	mm	mils	mm
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).

4.5.14.4 THICKNESS OF ALUMINUM SHEATH

When a cross-linked jacket is applied over an aluminum sheath, the average thickness of the aluminum sheath shall be the same as that given in Table 4-10 (see 6.8).

4.5.15 Thermoplastic Jacket over Metallic Sheath

4.5.15.1 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 4.4, except that the cold bend requirements shall be as given in 4.5.15.4, or
2. Black polyethylene meeting the requirements given in 4.4, or
3. Black chlorinated polyethylene meeting the requirements given in 4.4.3 except that the cold bend requirements shall be as given in 4.5.15.4.

4.5.15.2 THICKNESS

The average thickness of the thermoplastic jacket shall be not less than that specified in Table 4-24. The minimum thickness shall be not less than 70 percent of the values given in the table. The average thickness of the jacket shall be taken as one-half the difference in diameters over and under the jacket as determined by circumference measurements (see Section 6). The minimum thickness of the jacket shall be determined by direct measurements with a micrometer, a steel scale with pocket glass, or a micrometer microscope on a ring of jacket removed from the cable.

Table 4-24
Thickness of Thermoplastic Jacket over Metallic Sheath

Calculated Diameter Over Sheath		Thickness of Jacket	
inches	mm	mils	mm
0–0.750	0–19.05	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

4.5.15.3 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 that 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.

4.5.15.4 COLD BEND

When required, the manufacturer shall submit evidence that the jacket has been tested on similar cable

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and meets the following requiements. The jacketed cable shall be subjected to the sme bend tests an with the same frequency as requied for the underlying core. The test temperature shall be -10°C or colder. After the final bend, the jacket shall show no cracks visible to the normal unaided eye (see Section 6).

4.5.15.5 IRREGULARITY INSPECTION

Jackets shall not have irregularities as determined by the procedure of paragraph 3.8 of ICEA T-27-581 (NEMA WC 53). The methods to be used are:

Method B	Method C
Chlorinated Polyethylene Thermoplastic	Polyvinyl Chloride Polyethylene

4.5.15.6 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 4.5.14.3 (see Section 6).

4.5.15.7 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 4-10 (see Section 6).

4.5.16 Jackets over Metallic Armor

Jackets, when used, shall be either thermoplastic as described in 4.5.16.1 or cross-linked as described in 4.5.16.2

4.5.16.1 THERMOPLASTIC TYPES

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

1. Polyvinyl chloride meting the requirements of 4.4.1 except that the cold bend requirements shall be given in 4.5.15.4, or
2. Black polyethylene meeting the requirements of 4.4.2, or
3. Chlorinated polyethylene meeting the requirements of 7.3.7.4
4. (Table 4-25 was deleted July 22, 1987.)

4.5.16.2 CROSSLINKED TYPES

Crosslinked jackets, when used, shall be extruded over the metallic armor and shall fit tightly thereto. A separator shall be permitted to be used over the armor. The coverings shall be either:

1. Neoprene meeting the requirements of 4.4.3, or
2. Chlorosulfonated polyethylene meeting the requirements of 4.4.10 or
3. Chlorinated polyethylene meeting the requirements of 4.4.11.

4.5.16.3 THICKNESS

The average thickness of the jacket shall be not less than that specified in Table 4-26. 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.

4.5.16.4 IRREGULARITY INSPECTION

Jackets shall not have irregularities as determined by the procedure of paragraph 3.8 of ICEA T-27-581. The methods to be used are:

Method A	Method B	Method C
Neoprene (7.3.7.1)	Chlorinated polyethylene, theromplastic (4.4.43)	Polyethylene chloride (4.4.1)
	Chlorosulfonated polyethylene (7.3.7.3)	Polyethylene (4.4.2)
		Chlorinated polyethylene, cross-linked (7.3.7.4)

Table 4-26
Thickness of Jacket Over Metallic Armor

Calculated Diameter of Cble Under Jacket		Thickness			
		All Cables (Except Interlocked or Corrugated Armor)		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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DIVISION II
Round Wire Armor for Borehole, Dredge, Shaft, and Vertical Riser Cable

4.5.17 Scope

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

4.5.18 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.

4.5.19 Borehole Cable (Suspended at One End Only)

4.5.19.1 Armor

Galvanized round steel wire shall be used for borehole cable.

4.5.19.2 Size of Armor Wire

The size of the armor wire shall be as given in Table 4-27.

Table 4-27
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.

4.5.19.3 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."

4.5.20 Dredge Cable

4.5.20.1 Armor

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

4.5.20.2 Size of Armor Wire

The size of the armor wires shall be as given in Table 4-28.

Table 4-28
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

4.5.20.3 Pitch Ratio

The pitch ratio limits shall be in accordance with Table 4-29.

The pitch ratio is taken as the quotient resulting from dividing the length 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.

Table 4-29
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

4.5.21 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 4.5.3 through 4.5.16. 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 4-30, but the tensile safety factor shall be not less than five.

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Table 4-30
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

4.5.22 Vertical Riser Cable (Suspended at One End Only)

4.5.22.1 Nonsheathed Cable for Installation within Buildings

4.5.22.1.1 Armor

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

4.5.22.1.2 Size of Armor Wire

The size of the armor wires shall be as given in Table 4-30.

The tensile safety factor [based on 50000 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.

4.5.22.2 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 4.5.19.2 for borehole cable, but with a tensile safety factor of not less than four.

4.5.23 Wire Band Serving

Where wire band servings directly over the armor are required for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be used. The length of the serving band and the spacing of the band throughout the length of the cable shall be in accordance with Table 4-31.

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 4-31
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

Table 4-32
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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DIVISION III
Round Wire Armor for Buried Cable

4.5.24 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.

4.5.25 General

The requirements of Division I (4.5.3 through 4.5.16) 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.

4.5.26 Armor Wire and Jute Servings (Sheathed and Nonsheathed Cables)

The size of armor wire and thickness of jute bedding shall be in accordance with Table 4-32.

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 4.5.10 shall be applied over the armor.

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Section 5
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

5.1 ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES

Multiple-conductor cables shall be assembled in accordance with Section 5 unless otherwise modified by Section 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 not exceed 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 Section 7.

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Section 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 Section 2, 3, 4, 5, and 7. When there is a conflict between the test methods given in Section 6 and publications of other organizations to which reference is made, the requirements given in Section 6 shall apply.

Tests shall consist of the following, as required, namely, (1) tests on samples—see 6.2 to 6.13, inclusive, and 6.17 and 6.18, (2) tests on entire lengths of completed cables—see 6.14 to 6.16 inclusive, and 6.19, and (3 conductor resistance tests—see 6.3—on samples or on entire lengths of completed cables.

The test methods described in Section 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 and cable. To determine which tests are to be made, refer to the parts of this publication that 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 NEMA Standards Publication No. WC 54/ICEA T-26-465, Plan A.

6.3.1 Method for DC Resistance Determination

Measurements shall be made either on a sample at least 12 inches (305 mm) 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 ensure 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 specimens 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.

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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:

$$A = 10^{-3} \sum_{i=1}^{n} d_i^2$$

Where:

A = cross-sectional area in kcmil

d_i = diameter of the ith wire in mils determined according to 6.3.3.1

n = total number of wires in conductor

6.3.2.2 Cross-Sectional Area by Weight

The cross-sectional area shall be determined in accordance with ASTM B 263.

6.3.3 Methods for Diameter Determination

6.3.3.1 Diameter by Micrometer Measurement

Diameter measurements shall be made with a micrometer or other suitable instrument readable to at least 0.0001 inch. Round wires shall be measured at each end of the sample and near the middle of the sample. The average of the three measurements shall be taken as the diameter.

Stranded conductors shall be measured around the circumference of the conductor perpendicular to the axis of the conductor and on the extensions of a line through the center of the conductor and through the center of two wires in the outer layer that are 180 degrees apart. The average of three measurements shall be taken as the diameter.

6.3.3.2 Diameter by Tape Measurement

A diameter tape readable to at least 0.005 inch shall be wrapped one turn (360°) around the circumference of the conductor, tightly and perpendicular to the axis of the conductor. The average diameter of the conductor shall be read directly from the diameter tape.

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:

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

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

Where:

R_1 = Resistance at 25°C

R_2 = Measured resistance at test temperature T_2

For more accurate determination of resistance, allow for different conductivities, see Copper Wire Tables, *National Bureau of Standards Handbook 100* or Aluminum Wire Tables, *National Bureau of Standards*

Table 6-2
NUMBER OF SAMPLES
deleted

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Handbook 109 and ASTM B 193. (This paragraph is approved by NEMA as Authorized Engineering Information.)

6.4 TEST SAMPLES AND SPECIMENS FOR PHYSICAL AND AGING TESTS

6.4.1 General

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

6.4.2 Number of Thickness Measurements

When the lot of wire to be inspected consists of two coils or reels, or less, at least one determination of the thickness shall be made on each coil or reel. When the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, not less than 10 percent of the coils or reels shall be selected at random and at least one determination of the thickness shall be made on each coil or reel so selected. In the case of multiple-conductor cables, the measurements shall be made on the individual conductors before they are cabled.

6.4.3 Measurement of Thickness

The measurement of thickness for cables with unbonded components shall be made with either a micrometer or microscope but, for cables with bonded components, shall be made only with a microscope. The micrometer and microscope shall be capable of making measurements accurate to at least 0.001 inch.

6.4.3.1 MICROMETER MEASUREMENTS

When a micrometer is used, the average thickness of the insulation shall be taken as one-half of the difference between the mean of the maximum and minimum diameters over the insulation at one point and the average diameter over the conductor or any separator measured at the same point. The minimum thickness of the insulation shall be taken as the difference between a measurement made over the conductor or any separator plus the thinnest insulation wall, and the diameter over the conductor or any separator. The first measurement shall be made after slicing off the thicker side of the insulation. The thickness of any separator shall not be included in the thickness of insulation.

If the wire or cable has a jacket, the jacket shall be removed and the minimum and maximum thickness of the jacket determined directly with a micrometer. The average of these determinations shall be taken as the average thickness of the jacket.

6.4.3.2 MICROSCOPE MEASUREMENTS

When a microscope is used, the maximum and minimum thickness shall be determined from a specimen cut perpendicular to the axis of the sample so as to expose the full cross-section. The average of these determinations shall be taken as the average thickness.

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 6-4, except that samples for the solvent extraction test shall be selected in accordance with 6.4.13.

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 6-5. 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 6-6.

Table 6-6

	Total Number of Test Specimens
For determination of unaged properties	
Tensile strength and ultimate elongation	3†
Permanent set	3†
For accelerated aging tests	3†
For oil immersion	3†
Heat shock	1*
Heat distortion	3†
Cold bend	1*
Environmental cracking	see 6.10.4
Absorption coefficient	see 6.10.5
Stripping	1*

*For the heat-shock, cold-bend, and stripping 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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Table 6-4
Number and Length of Samples

Quantity of Completed Cable Ordered		Size of Conductor		Number of Samples	Minimum Length of Each Sample	
feet	meters	kcmil	mm^2		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 6-5
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	...	...
2000–50,000	610–15,240	Less than 1.0	Less than 25.4	1	6	1.8
1000–25,000	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 50,000	More than 15,240					
First 50,000	First 15,240	Less than 1.0	Less than 25.4	1	6	1.8
Each additional 50,000	Each additional 15,240	Less than 1.0	Less than 25.4	1	6	1.8
More than 25,000	More than 7,620					
First 25,000	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 25,000	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 25,000	More than 7620					
First 25,000	First 7620	2.0 and larger	50.8 and larger	1	2	0.6
Each additional 25,000	Each additional 7620	2.0 and larger	50.8 and larger	1	2	0.6

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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 a 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, and such, 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.

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

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

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 D412.

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 (50.8 mm) when using 6 inch (152.4 mm) specimens and 1 inch (25.4 mm) apart when using 4.5 inch (114.3 mm) specimens except that 1 inch (25.4 mm) gauge marks shall be used for polyethylene regardless of specimen length. Specimens shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (101.6 mm) except 2.5 inches (63.5 mm) for polyethylene. The

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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/m^3 or greater), or total base polyethylene resin content (having a density of 0.926 Mg/m^3 or greater), or total base polyethylene resin content (having a density of 0.926 Mg/m^3 or greater), shall be permitted to be tested at a jaw separation rate of 2 inches (51 mm) per minute as an alternate to 20 inches (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 Set Test

The set test shall be made on an unstretched test specimen having a length of not less than 6 inches (152 mm) and marked with gauge marks 2 inches (50.8 mm) apart. The specimen shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (102 mm) and shall be stretched at the rate of 20 inches (508 mm) per minute (jaw speed) until the gauge marks are 6 inches (152 mm) apart. The test specimen shall be held in the stretched position for 5 seconds, and the distance between gauge marks shall be determined 1 minute after the release of tension. The set is the difference between this distance and the original 2 inch (50.8 mm) gauge length, expressed as a percentage.

6.4.11.5 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 gauge marks and rupture less 2 inches (50.8 mm), except 1 inch (25.4 mm) for polyethylene (the original gauge length of the test specimen). The percentage of elongation at rupture is the elongation in inches divided by the original gauge length and multiplied by 100. Specimen length, gauge mark distance, and jaw speed shall be reported with results.

6.4.11.6 Tensile Stress Test

The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the gauge marks indicate that the specimen is at its prescribed elongation. The tensile stress shall be calculated in accordance with ASTM D412. The tensile stress shall be calculated on the area of the unstretched specimen.

6.4.12 Aging Tests

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.

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

In the case of wire and cable 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 smoothed 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. (This sentence 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 side 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 Oxygen Pressure Test

Paragraph deleted.

6.4.12.3 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.

6.4.12.4 Oil Immersion Test for Cross-Linked (Thermoset) Jacket

The test specimens shall be completely immersed in ASTM Oil No. 2, described in Table 1 of ASTM D471, at 121°C±1°C for 18 hours. The specimens shall then be removed from the oil, blotted lightly to remove excess

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oil, and suspended in air at room temperature for 4 hours, ±½ hour, after which they shall be tested for tensile strength and elongation.

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

6.4.12.5 Oil Immersion Test for Polyvinyl Chloride Jacket

The test specimens shall be immersed in ASTM Oil No. 2, described in Table 1 of ASTM D 471, at 70°C ±1°C for 4 hours. 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 Hot Creep Test

The hot creep test shall be determined in accordance with ICEA Publication T-28-562. When samples are measured, they shall be selected in accordance with NEMA Standards Publication No. WC 54/ICEA T-26-465, Plan D.

6.4.14 Solvent Extraction

The solvent extraction shall be determined in accordance with ASTM D2765.

6.4.15 Physical Test for Semiconducting Material Intended for Extrusion

6.4.15.1 Test Sample

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

6.4.15.2 Test Specimens

For each test, three test specimens, each approximately 6 inches (152 mm) long and not greater than 0.025 square inch (16 mm^2) 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.

6.4.15.3 Elongation

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

6.4.15.4 Brittleness Test

This test shall be conducted in accordance with ASTM D746, using Specimen A.

6.4.16 Retests for Physical and Aging Properties and Thickness

If any test specimen fails to meet the requirements of any test, either before or after aging, that test shall be repeated on two additional specimens taken from the same sample. Failure of either of the additional specimens shall indicate failure of the sample to conform to this standard.

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 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.

6.5 CAPACITY AND POWER FACTOR TESTS

6.5.1 This test is applicable only to power cables rated 5001 volts and above. The test sample shall be taken from the insulated conductor prior to the application of any coverings. When samples are measured, they shall be selected in accordance with NEMA Standards Publication No. WC 54/ICEA T-26-465, Plan E. The gross length of each sample shall be 13 feet (3.96 meters) for cables rated 15,000 volts and less an 17 feet (5.18 meters) for cables rated above 15,000 volts.

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6.5.2 The capacity and power factor shall be measured on suitable 60 Hz equipment after the test sample has been immersed in water at room temperature for at least 24 hours. The measurements shall be made at the rated voltage to ground of the cable under test.

6.6 ACCELERATED WATER ABSORPTION TESTS

Deleted.

6.7 THICKNESS OF TAPES

6.7.1 Compound-Filled Tape

Compound-filled tape, when not bonded to the insulation, shall be removed from no 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 (2.54 mm) 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.

6.7.2 Metallic Shielding Tape or Steel Tape

Metallic shielding tape or steel tape shall be removed from no 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 the thickness of the tape.

6.8 THICKNESS OF 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.

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.

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6.9 THICKNESS OF 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 ½ 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.

6.10 TESTS FOR THERMOPLASTIC JACKETS

6.10.1 Heat Shock

Samples (see 6.4.5) of polyvinyl-chloride-jacketed wire or cable shall be wound tightly around a mandrel having a diameter in accordance with Table 6-8, held firmly in place, and subjected to a temperature of 121°C±1°C for 1 hour.

6.10.2 Heat Distortion

6.10.2.1 TEST SPECIMEN

A sample of the jacket approximately 8 inches (203 mm) long shall be prepared to have a thickness of 50 ±10 mils (1.27 ± 0.254 mm) and smooth surfaces. From this sample, test specimens (see 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 gauge, or equivalent, having a 3/8 inch (9.5 mm) foot with no loading other than the 85 grams of the gauge.

6.10.2.2 TEST PROCEDURE

The following steps shall be completed in three hours.

The Randell & Stickney gauge, or equivalent, with a load of 2000 grams 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 thickness, T_2, shall be read on the dial of the gauge. The distortion shall be calculated as follows:

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

6.10.3 Cold Bend

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 6-9 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 6-9

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 over	20.35 and over	10

6.10.4 Environmental Cracking

Except as otherwise specified in 6.10.4.1 and 6.10.4.2, this test shall be made in accordance with ASTM D1693.

6.10.4.1 TEST SPECIMEN

The number and length of samples shall be selected in accordance with 6.4.5. Three test specimens approximately 1.5 inches (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 by 0.5 inch (38.1 by 12.7 mm) surfaces.

6.10.4.2 TEST PROCEDURE

The specimens shall be bent with the slit on the outside and placed in a test tube 200 mm long and 32 mm 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,

Table 6-8

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

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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.

6.10.5 Absorption Coefficient Test for Jackets

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 jacket compounds shall be determined in accordance with ASTM D 3349.

6.11 TESTS FOR DISCHARGE RESISTANCE

6.11.1 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).

6.11.2 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 dc 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.

6.11.3 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 6-10.

Table 6-10

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 Hz ac 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.

6.11.4 Track Resistance

6.11.4.1 METHOD A

The track resistance shall be determined in accordance with ASTM D2132 modified as follows:

1. Three test specimens of insulated conductor, each 5½ inches (140 mm) long, shall be used.
2. Seven electrodes shall be applied to each test specimen, with a ¾ inch (19 mm) minimum space between each electrode. Each electrode shall consist of at least one turn of a 12 AWG coated copper wire wrapped tightly around the insulated conductor.
3. Three test specimens shall be placed horizontally in the test chamber at right angles to the axis of the spray and equidistant from the nozzle. The upper half of each specimen shall be dusted. The dust shall then be removed for approximately a 1/32-inch (0.79-mm) width immediately adjacent to both sides of the three electrodes that are to be energized.
4. The end electrodes, each alternate electrode and the conductor in each test specimen shall be grounded. A 60 Hz potential shall be applied to the remaining three electrodes of each specimen.
5. The test potential shall be raised to 1500 volts and the fog deposits adjusted to give a current between 4 and 10 milliamperes. Failure occurs when the circuit breaker trips.

NOTE–For further information, see IEEE Transactions on Power Apparatus and Systems, Volume 84, 1965, p. 815 (paper 31 TP6), Discharge Resistant Characteristics of Polyethylenes for Wire and Cable by E. K. Duffy, S. Jovanovitch, and I.J. Marwick. (For the purposes of NEMA, this note is approved as Authorized Engineering Information).

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6.11.4.2 METHOD B

The track resistance shall be determined in accordance with the following:

1. The test specimen shall be a strip approximately 2 inches (50.8 mm) long and at least 60 mils (1.52 mm) thick and shall be taken from the outside of the insulation. The conductor shield shall be removed.
2. An electrode shall be attached near one end of the specimen and to the surface that was the outside surface of the insulation.
3. The specimen shall be immersed in an 0.1 percent solution of ammonium chloride at ground potential until the electrode contacts the surface of the solution and then withdrawn 1 inch (25.4 mm) of its immersed length. This procedure shall be repeated four times per minute for a minimum of ten cycles and a maximum of fifty cycles or until failure occurs. Failure occurs when an arc is maintained for two successive cycles between the electrode and solution across 1 inch of specimen.
4. A 60 Hz test potential shall be applied to the electrode attached to the specimen. The tracking voltage is the voltage at which no failures occur on five consecutive test specimens.

NOTE – For further information, see IEEE Transactions on Electrical Insulation, December 1967, Vol. EI-2, No.3, p. 137 (Paper 31 TP66-360), Dip-Track Test by C.F. Wallace and C.A. Bailey. (For the purposes of NEMA, this note is approved as Authorized Engineering Information).

6.12 VOLUME RESISTIVITY

6.12.1 Test Sample

One sample shall be taken from each lot or from each 25,000 feet of completed cable, whichever is less.

6.12.2 Conductor Stress Control

The samples 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 ac or dc voltage.

The volume resistivity shall be calculated as follows:

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

Where –

P = Volume resistivity in ohms-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.

6.12.3 Insulation Shield

Four silver-painted annular-ring electrodes shall be applied to the surface of the insulation 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 ac or dc voltage.

The voltage resistivity shall be calculated as follows:

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

Where –

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

6.12.4 Stripping Test

Test samples and specimens shall be selected in accordance with Tables 6-5 and 6-6. The test specimen shall be approximately 15 inches (381 mm) long, and all coverings over the extruded insulation shield shall be removed.

Starting at one end, two parallel longitudinal cuts ½ 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 ½ 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 ½ 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.

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

6.12.5 Flame Test

Paragraph deleted.

6.12.5.1

Paragraph deleted.

6.12.5.2

Paragraph deleted.

6.12.5.3

Paragraph deleted.

6.13 RETESTS FOR TESTS ON SAMPLES

Except physical and aging tests—see 6.4.16.

6.13.1 If all of the samples pass the applicable tests described in 6.5 through 6.12 and 6.17 and 6.18, the lot of cable that they represent shall be considered as meeting the requirements of this standard.

6.13.2 If any sample fails to pass these tests, the length of cable from which the sample was taken shall be considered as not meeting the requirements of this standard and another sample shall be taken from each of the two other lengths of the 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 as meeting the requirements of this standard.

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

6.13a TEAR TEST

The tear test shall be made on a minimum of six individual test specimens prepared as follows:

Each specimen shall be cut with a sharp knife or die. After irregulars, corrugations, and reinforcing cords or wires have been removed each test specimen shall have the dimensions shown in Figure 6-1, shall be not more than 0.150 inch (3.81 mm) and not less than 0.040 inch (1.02 mm) thick. Specimens shall be cut longitudinally with a new razor blade to a point 0.150 inch (3.81 mm) from the wider end.

The two halves of the split end of the test specimen shall be placed in the jaws of the testing machine and the jaws separated at a rate of 20 inches (508 mm) ±10 percent per minute. The tear resistance shall be determined by dividing the load in pounds required to tear the section by the thickness of the test specimen in inches. The average of the results obtained on all test specimens shall be considered as the value of the tear resistance.

Figure 6-1
TEST SPECIMEN FOR TEAR TEST

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6.13a.1 Retests

When the tear resistance of the first set of six specimens fails to meet the requirements, two additional sets of six specimens shall be tested. Failure of either of the additional sets of specimens shall indicate failure of the sample to conform with this standard.

ELECTRICAL TESTS ON COMPLETED CABLES

6.14 VOLTAGE TESTS

6.14.1 General

These tests consist of voltage tests on each length of completed cable. Except for the dc spark test and the ac 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.

6.14.2 AC Voltage Test

This test shall be made with an alternating potential from a transformer and generator of ample capacity but in no case less than 5 kva. The frequency of the test voltage shall be nominally between 25 and 60 Hz and shall have a wave shape approximating a sine wave as closely as possible.

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

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

6.14.3 DC 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 6.15. The equipment for the dc voltage test shall consist of a battery, generator or suitable rectifying equipment and shall be of ample capacity.

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

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

6.14.4 AC Spark Test

6.14.4.1 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:

1. Multiconductor cables other than assemblies of single-conductor cables;
2. Cables with insulation shield;
3. Cables with metallic sheath or armor;
4. Assemblies containing uninsulated conductors; and/or
5. Cables rated above 2000 volts.

6.14.4.2 TEST APPARATUS

The test apparatus shall consist of:

1. A source of single-phase ac potential capable of maintaining the required voltage under all normal leakage current conditions;
2. An electrode capable of maintaining contact, throughout its length, with the periphery of the cable under test;
3. A means of measuring voltage between electrode and ground; and/or
4. A means of indicating a fault (failure).

6.14.4.3 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 (This paragraph has been approved by NEMA as Authorized Engineering Information.):

1. 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.

2. 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.

6.14.4.4 FAILURE

Any indication by the fault indicator shall constitute a failure.

6.14.5 DC 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 dc spark test shall consist of a dc 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 dc spark test, the individual conductors shall be similarly tested prior to assembly.

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

6.14.6.1 SINGLE CONDUCTOR CABLE AND ASSEMBLIES WITHOUT AN OVERALL JACKET

Single conductor cable and assemblies of single conductor cables shall be tested by either the alternating current voltage test in water (see 6.14.2), the direct current voltage test in water (see 6.14.3), the alternating current spark test (see 6.14.4) or the direct current spark test (see 6.14.5). When west testing is utilized, the following shall apply:

1. Single conductor cable and parallel assemblies of single conductor cable shall be immersed in water for at least 6 hours and tested while still immersed.
2. Twisted assemblies of two or more conductors without an overall jacket or covering, shall be immersed in water for at least 1 hour and tested while still immersed.

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

6.14.6.2 MULTIPLE-CONDUCTOR CABLE WITH AN OVERALL JACKET

Multiple-conductor cables shall be tested prior to application of the jacket by either spark testing or wet testing (see 6.14.6.1). After the overall jacket is applied, each insulated conductor shall be tested against all other conductors connected to ground. Immersion in water is not required.

6.14.7 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.

6.14.8 Voltage Tests after Installation

If voltage tests are made after installation, they shall be made immediately. The test voltage shall be a dc voltage as given in Table 6-11 and shall be applied in accordance with 6.14.1 and 6.14.3.

Table 6-11
DC Test Voltage After Installation, kV

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	1/0–100	100	...

6.15 INSULATION RESISTANCE

6.15.1 Test Apparatus

The test apparatus shall consist of a source of constant potential of 100 to 4500 volts and such other apparatus as is listed in ASTM D-257

6.15.2 Test Procedure

The insulation resistance shall be measured after the completed cable alternating current voltage test or before any direct current voltage tests specified in 6.14 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 the metallic sheath or water. Multiple-conductor cables with non-shielded conductors and no overall jacket shall be tested between each conductor and all other conductors and metallic sheath or water. Multiple-conductor cables with non-shielded conductors and an overall jacket shall be tested between each conductor and all other conductors and any metallic sheath and water if utilized. 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) or 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 grade of insulation (see Part 3)
D = Diameter over the insulation in inches.
d = Diameter under the insulation in inches.

If the temperature at the time of measurement differs from 15.6°C (60°F), the 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 6.15.3) for the particular insulation and temperature in question. The temperature of the water shall not be less than 10°C (50°F) nor more than 29.4°C (85°F).

6.15.3 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 dkdkdkd

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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	10.8
82	27.8	1.92	2.37	2.94	3.60	4.43	5.45	6.69	8.18	9.92	12.1
83	28.3	1.98	2.47	3.08	3.82	4.72	5.89	7.28	9.00	11.0	13.6
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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length to yield insulation resistance values under 25000 meg/ohms 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 6.15.2.

Each of the three samples shall be exposed to successive water temperatures of 10, 16, 22, 28, and 35°C and returning 28, 22, 16, 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).

6.16 Deleted.

6.17 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 but 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.

6.18 METHOD FOR DETERMINING PERMITTIVITY (S.I.C.) AND DIELECTRIC STRENGTH OF EXTRUDED NONCONDUCTING POLYMERIC STRESS CONTROL LAYERS

The test specimen shall be an 18 inch (45.7 mm) length of conductor over which 0.015–0.030 inch (0.038–0.076 mm) of nonconducting stress control material has been extruded.

The central 12 inch (30.5 mm) length shall be shielded using a silver-painted electrode or equivalent applied to the surface of the stress control material.

$$C_o = 7.354 / \log_{10} \frac{D}{d}$$

The capacity C_o, in picofarads, shall be measured at the required temperature using a suitable bridge and a 60 Hz potential. The specimen shall be held at the required temperature for at least 15 minutes prior to measurements.

The geometric capacitance, C, in picofarads, shall be calculated for the 12 inch (30.5 mm) specimen as follows:

The ratio of measured capacitance divided by the geometric capacitance, C/Co, shall be the permittivity (S.I.C.) of the stress control material.

Following the capacitance measurement and while

$$S = 2V / (D - d)1000$$

the specimen is held at the required temperature, a 60 Hz ac potential shall be applied between the conductor and the grounded shield (painted electrode) with an increasing rate of rise not in excess of 100 volts per second until dielectric failure occurs. The dielectric withstand stress, in volts per mil* shall be calculated as follows:

D and d in inches
V in volts, actual breakdown level.

*S (V/mil) shall be expressed as M V/m by dividing by 25.4.

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Section 7
CONSTRUCTIONS OF SPECIFIC TYPES

(The requirements of Sections 1 through 6 shall be met except as otherwise modified in Section 7.)

7.1 CONCENTRIC-NEUTRAL UNDERGROUND DISTRIBUTION CABLES

7.1.1 Scope

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

7.1.2 Central Conductor

Central conductors shall be annealed copper, or aluminum. The minimum conductor size shall be in accordance with Table 7-1.

Table 7-1
Minimum Conductor Size

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

7.1.2.1 COPPER

The conductor shall be annealed uncoated copper or annealed coated copper either Class B or C stranded or, for uncoated copper, compact stranded in accordance with Section 2.

7.1.2.2 ALUMINUM

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

7.1.2.3 CONDUCTOR STRESS CONTROL LAYER

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

7.1.3 Insulation

The shielded central conductor shall be insulated with a cross-linked-thermosetting-polyethylene compound that meets the requirements of 3.7. The average thickness of the insulation shall be not less than that given in Table 3-1 for the 100 percent insulation level. The minimum thickness shall be not less than 90 percent of the values given in the table.

7.1.4 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 7-2.

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

Temperatures lower than 130°C (266°F) may be required for emergency overload conditions because of the type of material used in the cable, joints, and terminations or because of cable environmental conditions. (This paragraph is approved by NEMA as Authorized Engineering Information.)

Table 7-2 ■
For Cable With or Without an Overall Jacket

Calculated Insulation Diameter		Insulation Shield Thickness	
Inches	Minimum Point Inch	Maxmum Point Inch	Maxmum Point 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.

7.1.5 Concentric Conductor

The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B5 and the 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 7-3 for cables used in single-phase systems and in either Table 7-5 or Table 7-6 for three-phase systems.

The nominal diameters and circular mil areas of the wires in Tables 7-3, 7-5, and 7-6 shall be as follows:

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AWG Size	Diameter, Inch	Area, kcmil
14	0.0641	4.11
12	0.0808	6.53
10	0.1019	10.38
9	0.1144	13.09
8	0.1285	16.51

The individual wires comprising a given concentric conductor may vary ±5 percent in diameter from the appropriate nominal value given above, but the total circular mil area of the specified concentric conductor shall be as follows:

1. For single-phase systems, at least 98 percent of the product of the appropriate number of wires given in Table 7-3 times the appropriate nominal circular mil area tabulated above.
2. For three-phase systems at least 98 percent of the product of the appropriate number of wires given in Tables 7-5 or 7-6 times the appropriate nominal circular mil area tabulated above.

NOTE: This is for a one-third neutral.

The wires of the concentric conductor shall be applied directly over the conductor material given in 7.1.4 with a lay not less than six nor more than ten times the diameter over the concentric wires.

Table 7-3
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 7-4
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

7.1.6 Optional Jackets Applied over a Concentric Conductor

The jackets shall be either nonconducting or conducting depending upon installation requirements. If nonconducting compound is used, it shall meet the physical and aging requirements of 4.4.1 through 4.4.3 as applicable.

If conducting compound is used, it shall be either Type I or II compound meeting the physical and aging requirements of Table 7-6A.

A Type II jacket provides more heat and deformation resistance than Type I.

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

7.1.6.1 EXTRUDED-TO-FILL 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 7.4A.

■ Table 7.4A
Jacket Thickness and Test Voltage

Calculated Diameter Conductor	Average Jacket Thickness	AC Spark Test Voltage (kV) for Nonconducting	
Inches	Inch	Cross-linked Jackets	Thermoplastic Jackets
0–1.500	.050	2.0	4.5
Over 1.500	.080	3.0	7.0

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Table 7-5
One-third Neutral Concentric Conductor for Copper Central Conductor

Copper Insulated Conductor Size, AWG or kcmil	Concentric Conductor Minimum Number of Wires				
	14 AWG	12 AWG	10 AWG	9 AWG	8 AWG
4–2	6	...	...	...	...
1	7	6*	...	...	...
1/0	9	6*	...	...	...
2/0	11	7*	6*	...	...
3/0	14	9*	6*	6*	...
4/0	18	11*	7*	6*	...
250	21*	13	9*	7*	...
350	...	18	12*	9*	...
500	...	26*	17	13*	10*
750	...	...	25*	20*	15
1000	...	...	...	26*	20

*Alternate constructions.

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 casued by the metallic shield shall not be more than the specified maximum indent value found in Table 7-2.

7.1.6.2 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 4-8. 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 7-2.

7.1.6.3 Identification

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

7.1.6.4 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 7-4A. The voltage for overlaying type jackets is in accordance with 4.4.7. The voltage shall be applied between an electrode at the outside surface of the jacket and the concentric neutral conductor. The neutral conductor shall be connected to ground during the test. The spark test shall be conducted in accordance with 6.14.4.3 and 6.14.4.4.

7.1.7 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.1. The partial-discharge extinction level shall be in accordance with Table 7-4. The electrical requirement tests shall be made without immersion in water.

Table 7-6
One-third Neutral Concentric Conductor for Aluminum Central Conductor

Aluminum Insulated Conductor Size, AWG or kcmil	Concentric Conductor Minimum Number of Wires				
	14 AWG	12 AWG	10 AWG	9 AWG	8 AWG
4–1/0	6	...	...	...	...
2/0	7	6*	...	...	...
3/0	9	6*	...	...	...
4/0	11	7*	6*	...	...
250	13	8*	6*	6*	...
300	15	10*	6*	6*	...
350	18	11*	7*	6*	...
500	25*	16	10*	8*	...
750	...	24*	15	12*	...
1000	...	...	20*	16	12*

*Alternate constructions.

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Table 7-6A ■
Properties of Thermoplastic Conducting Jackets

	Type I	Type II
Physical Requirements		
Tensile strength, minimum		
psi	1200	1500
Elongation at rupture, minimum percent	100	150
Aging Requirements		
After air oven aging at 100°C±1°C for 48 hours		
Tensile strength, minimum percentage of unaged value	75	
Elongation at rupture, minimum percentage of unaged value	100	
After air oven aging at 121°C±1°C for 168 hours		
Tensile strength, minimum percentage of unaged value		75
Elongation at rupture, minimum percentage		75
Heat Distortion, Maximum, Percent		
Air oven at 90°C±1°C	25	
Air oven at 121°C±1°C		25
Volume resistivity at room temperature (23°C±2°C) and 90°C±1°C, max, meter-ohms	100	100
Brittleness Temperature, °C, not warmer than	–10	–15

7.2 NEUTRAL-SUPPORTED SECONDARY AND SERVICE DROP CABLES

7.2.1 Scope

This section covers secondary and service drop cables composed of one or more 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 90°C (194°F).

7.2.2 Conductors

7.2.2.1 Insulated Conductors

7.2.2.1.1 Copper

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

7.2.2.1.2 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 B230 or ASTM B609 before insulating and with Table 2-7, Class A or B stranded in accordance with ASTM B231, or compact round stranded in accordance with ASTM B400. Sizes larger than 4 AWG shall be Class A or B stranded in accordance with ASTM B231 or compact round stranded in accordance with ASTM B400.

7.2.2.1.3 Direction of Lay

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

7.2.2.2 Neutral Conductors

Neutral conductors shall be uncovered or covered and the sizes and composition shall be in accordance with Table 7-7 and 7-8.

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7.2.2.2.1 Copper

Conductors shall be hard drawn uncoated copper and shall meet the requirements of ASTM B1 and B8. Sizes 2 AWG and smaller shall be solid or shall be 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.

7.2.2.2.2 Aluminum

Conductors shall be hard drawn aluminum 1350. The stranding shall be in accordance with Class A Table 2 or ASTM B231 for sizes up through 2/0 AWG and in accordance with Class B Table 3 of ASTM B231 for sizes 3/0 AWG and larger. The direction of lay of the outer layer shall be right hand.

7.2.2.2.3 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 B229.

7.2.2.2.4 Aluminum Conductors—Steel Reinforced

Aluminum conductors—steel reinforced (ACSR) shall meet the requirements of ASTM B232.

The stranding shall be as follows:

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

7.2.2.2.5 Aluminum Alloy Conductors —5005-H19

Conductors shall meet the requirements of ASTM B397. 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.

7.2.2.2.6 Aluminum Alloy Conductors —6201-T81

Conductors shall meet the requirements of ASTM B399. 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.

7.2.3 Insulation

7.2.3.1 Physical and Aging Requirements

The insulation shall be black and, when tested in accordance with Section 6, shall meet the following requirements:

Physical Requirements	
Tensile strength, minimum	
psi	1700
MPa	11.7
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	75
Elongation at rupture, minimum, percentage of unaged value	65
After hot creep test at 150°C±2°C	

	Unfilled	Filled
*Hot creep elongation, maximum, percent	175	100
*Hot creep set, maximum, percent	10	5

*If this value is exceeded, the Solvent Extraction Test may be performed and will serve as a referee method to determine compliance (maximum percent after 20 hours drying time—30). (This note is approved by NEMA as Authorized Engineering Information.)

7.2.3.2 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 these values.

7.2.4 Assembly

7.2.4.1 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.

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7.2.4.2 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 (68.04 kg) and applied with a lay of 3 to 6 inches (76.2 to 152.4 mm).

7.2.4.3 Neutral Conductor

The size of the neutral conductor shall be in accordance with Table 7-7 for copper insulated power conductors and Table 7-8 for aluminum insulated power conductors.

7.2.5 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.2 except that each length of completed cable shall successfully withstand, after one hour's immersion in water, an ac voltage of 2500 volts applied for 1 minute between each insulated power conductor and ground.

7.3 MINE POWER CABLES

7.3.1 Scope

This section covers cross-linked-thermosetting-polyethylene-insulated shielded thermosetting or thermoplastic jacketed cables in sizes 6 AWG through 500 kcmil for use as connections between units of mine distribution systems at nominal ac voltages of 2001 to 15000 volts at 100 or 133 percent insulation level. These cables shall be one of the following types:

Type MP – three power conductors and three grounding conductors.

Type MP-GC – three power conductors and two grounding conductors and one ground check conductor.

The insulation shall be suitable for operation at a maximum conductor temperature of 90°C (194°F).

Ampacities are given in Appendix I. Recommended minimum bending radii are given in Appendix H. (This sentence is approved by NEMA as Authorized Engineering Information.)

7.3.2 Conductors

7.3.2.1 Power Conductors

Power conductors shall be Class B or C stranded annealed coated or uncoated copper or 3/4 hard drawn aluminum 1350 and shall meet the requirements given in Section 2.

Table 7-7
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 B229 (see Appendix E) for letter designations and construction.

In addition, those power conductors used for borehole and shaft cables shall have a minimum factor of safety of 7 when calculated by the formula $F = AT/W$. If the minimum factor of safety as calculated by the formula is less than 7, medium hard-drawn copper in accordance with ASTM B 2 or B 246 before stranding shall be used. In no case shall the factor of safety be less than 7.

Where –

F = Factor of safety.

A = Area of the three power conductors in square inches.

T = Tensile strength of conductor in pounds per square inch shall be as tabulated below:

	psi
Annealed copper	24,000
Medium hard copper	40,000
1350 aluminum	17,000

W = Weight of the cable in pounds.

The conductor size shall be in accordance with Table 7-9 and shall meet the requirements given in Section 2. When the size of medium hard-drawn copper power conductors is determined in accordance with 6.3.1, the dc resistance shall not exceed by more than 2 percent the values given in Table 7-13.

Conductor stress control layer in accordance with 2.7 shall be applied over each power conductor.

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7.3.2.2 Grounding Conductors

Grounding conductors shall be Class B or C stranded annealed coated copper wire and shall meet the requirements given in Section 2. The size of each grounding conductor shall be in accordance with Table 7-9.

7.3.2.3 Ground Check Conductors

The ground check conductor shall be Class B or C stranded annealed coated or uncoated copper of the minimum size shown in Table 7-9 and shall meet the requirements given in Section 2.

7.3.3 Insulation

Insulation shall meet the requirements given in Section 3.

The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7-10 and 7-11. The average thickness of the insulation on ground check conductors shall be not less than 45 mils (1.14 mm) for 8 AWG and not less than 30 mils (0.76 mm) for 10 AWG. The minimum thickness shall be not less than 90 percent of these values.

7.3.4 Insulation Shielding

Each power conductor shall be shielded in accordance with 4.1.

7.3.5 Identification

Power conductors shall be identified as black, white, and red.

The ground check conductor shall be covered with a closely woven cotton or rayon braid which is colored yellow or with a yellow colored insulation.

7.3.6 Conductor Assembly

The conductor assembly shall have a left-hand lay. A grounding conductor shall be placed in continuous contact with the metallic shields in each interstice of Type MP cables and in two interstices of Type MP-GC cables. The ground check conductor of Type MP-GC cables shall be placed between the black and white conductors. Fillers of suitable material shall be used to produce an essentially round cross-section in the completed cable. When required, a binder tape and/or threads shall be used over the conductor assembly.

Table 7-8
Neutral Conductors for Use with Aluminum Power Conductors

Aluminum Insulated Power Conductor Sizes AWG or kcmil	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
336.4	...	...	336.4	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 B229 (see Appendix E) for letter designations and construction.

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Table 7-9
Conductor Sizes

Size of Power Conductors, AWG or kcmil		Copper Grounding Conductors		Copper Ground Check Conductor, Minimum Size, AWG
Copper	Aluminum	Type MP Cables, Size in Each, Interstice, AWG	Type MP-GC Cables, Size in Each of Two Interstices, AWG	
6	4	10	10	10
4	2	8	8	8
2	1/0	8	6	8
1	2/0	7	5	8
1/0	3/0	6	4	8
2/0	4/0	5	3	8
3/0	250	4	2	8
4/0	350	3	1	8
250	400	2	1/0	8
300	450	1	1/0	8
350	500	1	2/0	8
400	...	1/0	3/0	8
450	...	1/0	3/0	8
500	...	2/0	4/0	8

Table 7-10
Insulation Thicknesses and Outside Diameters— 2001 to 5000 Volts*— 100 and 133 Percent Insulation Level

Conductor Size, AWG or kcmil	Insulation Thickness		Outside Diameter		AC Test Voltage, kV	Minimum Partial-discharge Extinction Level, kV†	
						Insulation Level	
	mils	mm	inches	mm		100 percent	133 percent
6	90	2.29	1.21	30.7	13	4	5
4	90	2.29	1.32	33.5	13	4	5
2	90	2.29	1.45	36.8	13	4	5
1	90	2.29	1.53	38.9	13	4	5
1/0	90	2.29	1.63	41.4	13	4	5
2/0	90	2.29	1.74	44.2	13	4	5
3/0	90	2.29	1.88	47.8	13	4	5
4/0	90	2.29	2.00	50.8	13	4	5
250	90	2.29	2.13	54.1	13	4	5
300	90	2.29	2.25	57.2	13	4	5
350	90	2.29	2.35	59.7	13	4	5
400	90	2.29	2.45	62.2	13	4	5
450	90	2.29	2.55	64.8	13	4	5
500	90	2.29	2.64	67.0	13	4	5

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

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

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Table 7-11
Insulation Thicknesses and Outside Diameters

Conductor Size, AWG or kcmil	100 Percent Insulation Level							133 Percent Insulation Level						
	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV
	mils	mm	inches	mm	AC	DC		mils	mm	inches	mm	AC	DC	
5001 TO 8000 VOLTS*														
6	115	2.92	1.33	33.8	18	45	6	140	3.56	1.45	36.8	22	45	8
4	115	2.92	1.43	36.3	18	45	6	140	3.56	1.54	39.1	22	45	8
2	115	2.92	1.55	39.4	18	45	6	140	3.56	1.68	42.7	22	45	8
1	115	2.92	1.65	41.9	18	45	6	140	3.56	1.78	45.2	22	45	8
1/0	115	2.92	1.75	44.5	18	45	6	140	3.56	1.90	48.3	22	45	8
2/0	115	2.92	1.88	47.7	18	45	6	140	3.56	2.00	50.8	22	45	8
3/0	115	2.92	2.00	50.8	18	45	6	140	3.56	2.12	53.8	22	45	8
4/0	115	2.92	2.12	53.8	18	45	6	140	3.56	2.25	57.1	22	45	8
250	115	2.92	2.25	57.2	18	45	6	140	3.56	2.35	59.7	22	45	8
300	115	2.92	2.35	59.7	18	45	6	140	3.56	2.48	63.0	22	45	8
350	115	2.92	2.46	62.5	18	45	6	140	3.56	2.58	65.5	22	45	8
400	115	2.92	2.57	65.3	18	45	6	140	3.56	2.70	68.6	22	45	8
450	115	2.92	2.66	67.6	18	45	6	140	3.56	2.85	72.4	22	45	8
500	115	2.92	2.75	69.9	18	45	6	140	3.56	2.93	74.4	22	45	8
8001 TO 15000 VOLTS*														
2	175	4.44	1.88	47.8	27	70	11	...	...	...	...	...	...	...
1	175	4.44	1.98	50.3	27	70	11	215	5.46	2.20	55.9	33	80	15
1/0	175	4.44	2.05	52.0	27	70	11	215	5.46	2.30	58.4	33	80	15
2/0	175	4.44	2.15	54.6	27	70	11	215	5.46	2.42	61.5	33	80	15
3/0	175	4.44	2.26	57.4	27	70	11	215	5.46	2.53	64.3	33	80	15
4/0	175	4.44	2.40	61.0	27	70	11	215	5.46	2.65	67.3	33	80	15
250	175	4.44	2.50	63.5	27	70	11	...	...	...	...	...	...	...
300	175	4.44	2.64	67.0	27	70	11	...	...	...	...	...	...	...
350	175	4.44	2.75	69.9	27	70	11	...	...	...	...	...	...	...
400	175	4.44	2.92	74.2	27	70	11	...	...	...	...	...	...	...
450	175	4.44	3.00	76.2	27	70	11	...	...	...	...	...	...	...
500	175	4.44	3.10	78.4	27	70	11	...	...	...	...	...	...	...

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

Table 7-12
Overall Jacket Thickness

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
1.500 or less	38.10 or less	110	2.79
1.501–2.500	38.13–63.50	140	3.56
2.501–3.500	63.53–88.90	170	4.32

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Table 7-13
Nominal DC Resistance of Medium Hard-Drawn Coated and Uncoated Copper Conductors Concentric Stranded, Class B and C

Conductor Size, AWG or kcmil	Class of Stranding	Coated Copper				Uncoated 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
6	B and C	0.436	1.43	0.444	1.46	0.417	1.37	0.425	1.40
4	B and C	0.274	0.899	0.279	0.917	0.262	0.860	0.267	0.877
2	B and C	0.172	0.565	0.176	0.577	0.165	0.541	0.168	0.552
1	B and C	0.137	0.448	0.139	0.457	0.131	0.429	0.133	0.437
1/0	B and C	0.108	0.355	0.110	0.362	0.104	0.340	0.106	0.347
2/0	B and C	0.0859	0.282	0.0876	0.287	0.0822	0.270	0.0838	0.275
3/0	B and C	0.0681	0.224	0.0695	0.228	0.0652	0.214	0.0665	0.218
4/0	B	0.0536	0.176	0.0547	0.179	0.0517	0.170	0.0527	0.173
4/0	C	0.0540	0.177	0.551	0.181	0.0517	0.170	0.0527	0.173
250	B and C	0.0457	0.150	0.0466	0.153	0.0438	0.144	0.0446	0.146
300	B and C	0.0381	0.125	0.0389	0.128	0.0365	0.120	0.0372	0.122
350	B and C	0.0327	0.107	0.0333	0.109	0.0313	0.103	0.0319	0.105
400	B	0.0284	0.0931	0.0289	0.0949	0.0274	0.0898	0.0279	0.0915
400	C	0.0286	0.0938	0.0292	0.0956	0.0274	0.0898	0.0279	0.0915
450	B	0.0252	0.0827	0.0257	0.0844	0.0243	0.0798	0.0248	0.0813
450	C	0.0254	0.0834	0.0259	0.0850	0.0243	0.0798	0.0248	0.0813
500	B	0.0227	0.0745	0.0231	0.0759	0.0219	0.0718	0.0223	0.0732
500	C	0.0229	0.0750	0.0233	0.0765	0.0219	0.0718	0.0223	0.0732

7.3.7 Jacket

A thermosetting jacket that meets the requirements of 7.3.7.1, 7.3.7.2, 7.3.7.3, or 7.3.7.4 or a thermoplastic jacket that meets the requirements of 4.4.1 or 4.4.3 shall be applied over the conductor assembly. The average thickness of the jacket shall be not less than that given in Table 7-12 and the minimum thickness of the jacket shall be not less than 80 percent of these values.

7.3.7.1 Neoprene, Heavy Duty, Black

This jacket shall consist of a vulcanized black neoprene compound. When tested in accordance with 6.4, the jacket shall meet the following requirements, and when applicable, the requirements given in 4.4.5:

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.3.7.2 Nitrile-Butadiene/Polyvinyl-Chloride, Heavy Duty

This jacket shall consist of a vulcanized acrylonitrile-butadiene/polyvinyl-chloride compound suitable for a minimum installing temperature of –25°C (–13°F). It shall be based on a fluxed blend of acrylonitrile-butadiene synthetic rubber and polyvinyl-chloride resin. When tested in accordance with 6.4, the jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.6:

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Physical requirements	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.3.7.3 Chlorosulfonated Polyethylene, Heavy Duty

This jacket shall consist of a vulcanized chloro-sulfonated-polyethylene compound. When tested in accordance with 6.4, the jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.6:

Physical requirements	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	65
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	60

7.3.7.4 Chlorinated Polyethylene, Heavy Duty, Cross-Linked (Thermoset)

This jacket shall consist of a cross-linked chlorinated polyethylene compound. When tested in accordance with 6.4, the jacket shall meet the following requirements and, when applicable, the requirements in 4.4.6:

Physical requirements	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	65
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	60

7.3.8 Outside Diameters

The outside diameter of the completed cable shall be within plus 8 and minus 5 percent of the values given in Tables 7-10 and 7-11.

7.3.9 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.3.

The insulated power conductors shall meet the test voltage and partial-discharge requirements given in Table 7-10 or 7-11.

The voltage test on the insulated ground check conductor shall be made between that conductor and the grounding conductors by applying an ac voltage of 3.0 kV for 15 seconds. The insulation resistance test is not required.

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7.4 PORTABLE SINGLE- AND MULTIPLE-CONDUCTOR POWER CABLES

7.4.1 Scope

This section covers cross-linked-thermosetting-polyethylene-insulated portable cables with copper conductors in sizes 8 AWG and larger for use on mining machines, dredges, shovels, and in similar applications. These cables are distinguished by the requirements for the jackets given in 7.4.18.

Extra-heavy-duty jackets are required for cables having a nominal outside diameter of more than 2.00 inches (50.8 mm) and for shielded cables and single-conductor hard-service cables.

Details of construction and dimensions for the voltages at which these cables may be used are given in Tables 7-14 through 7-27. Recommended ampacities and voltage ratings are given in Appendix J. Recommended bending radii are given in Appendix H.

GENERAL DESCRIPTION OF COMPLETED CABLE

7.4.2 Single-Conductor Cables, Nonshielded, 0–2000 Volts

These cables shall consist of an insulated conductor covered with a jacket that meets the requirements of 7.4.18 and shall be in accordance with Table 7-15. Normal-service cables shall be covered with heavy-duty jackets and hard-service cables shall be covered with extra-heavy-duty jackets.

7.4.3 Type W and G Two-Conductor Round Cables, 0-2000 Volts

7.4.3.1 Type W, without Grounding Conductors

These cables shall consist of two conductors which are separately covered with insulation. In addition, each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-16.

7.4.3.2 Type G, with Grounding Conductors

These cables shall consist of two power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The power conductors, together with two grounding conductors (see 7.4.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-16.

Table 7-14
Maximum Length of Lay

Number of Power Conductors	Factors for Maximum Length of Lay*
2	20×d
3	21×d
4	23×d
5	27×d
6	30×d

*d = diameter of individual power conductor.

7.4.4 Type W, G, and G-GC Three- and Four-Conductor Cables, 0–2000 Volts

Three-conductor cables shall be one of three types: (1) Type W, round construction, without grounding conductors, (2) Type G, round construction, with grounding conductors, and (3) Type G-GC, round construction, with grounding conductors and a ground check conductor. Four-conductor cables shall be one of two types: (1) Type W, round construction, without grounding conductors and (2) Type G, round construction, with grounding conductors.

7.4.4.1 Type W, Round, without Grounding Conductors

These cables shall consist of three or four conductors that are separately covered in insulation. Each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. Three-conductor cables shall be in accordance with Table 7-17, and four-conductor cables shall be in accordance with Table 7-18.

7.4.4.2 Type G, Round, with Grounding Conductors

These cables shall consist of three or four power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The power conductors, together with the grounding conductors (see 7.4.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. Three-conductor

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Table 7-15
0 to 2000 Volts
Single-Conductor Portable Power Cable

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter				Test Voltage, kV	
			Normal Service		Hard Service			
	mils	mm	inches	mm	inches	mm	AC	DC
8	60	1.52	0.44	11.2	0.51	13.0	7.0	21.0
6	60	1.52	0.51	13.0	0.59	15.0	7.0	21.0
4	60	1.52	0.57	14.5	0.64	16.3	7.0	21.0
3	60	1.52	0.63	16.0	0.68	17.3	7.0	21.0
2	60	1.52	0.66	16.8	0.71	18.0	7.0	21.0
1	80	2.03	0.74	18.8	0.82	20.8	8.0	24.0
1/0	80	2.03	0.77	19.6	0.87	22.1	8.0	24.0
2/0	80	2.03	0.82	20.8	0.95	24.1	8.0	24.0
3/0	80	2.03	0.87	22.1	1.04	26.4	8.0	24.0
4/0	80	2.03	0.93	23.6	1.11	28.2	8.0	24.0
250	95	2.41	1.03	25.2	1.18	29.5	9.5	28.5
300	95	2.41	1.09	27.7	1.25	31.0	9.5	28.5
350	95	2.41	1.15	29.2	1.30	32.5	9.5	28.5
400	95	2.41	1.20	30.5	1.36	33.8	9.5	28.5
450	95	2.41	1.26	32.0	1.41	34.8	9.5	28.5
500	95	2.41	1.31	33.3	1.45	35.8	9.5	28.5
550	110	2.79	1.42	36.1	...	...	11.5	34.5
600	110	2.79	1.46	37.1	...	...	11.5	34.5
650	110	2.79	1.50	38.1	...	...	11.5	34.5
700	110	2.79	1.54	39.1	...	...	11.5	34.5
750	110	2.79	1.58	40.1	...	...	11.5	34.5
800	110	2.79	1.62	41.0	...	...	11.5	34.5
900	110	2.79	1.69	43.0	...	...	11.5	34.5
1000	110	2.79	1.76	44.7	...	...	11.5	34.5

†See Table 7-28.

cables shall be in accordance with Table 7-17, and four-conductor cables shall be in accordance with Table 7-18.

7.4.4.3 Type G-GC, Three-conductor Round, with Grounding Conductors and Ground Check Conductor

These cables shall consist of three power conductors that are separately covered with insulation, two grounding conductors (see 7.4.12), and one ground check conductor (see 7.4.11). Each power and ground check conductor shall be separately covered with a colored tape or braid which may be omitted if colored insulation is used (see 7.4.15). All power, grounding, and ground check conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7-19.

7.4.5 Type W and G, Five- and Six-Conductor, 0–2000 Volt Cables

Five-conductor cables shall be of one of two types: (1) Type W, without a grounding conductor and (2) Type G, with a grounding conductor. Six-conductor cables shall be Type W only.

7.4.5.1 Type W, without Grounding Conductor

These cables shall consist of five or six conductors which are separately covered with insulation. Each conductor shall be separately covered with colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that

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Table 7-16
0 to 2000 Volts—Type W and G Two-Conductor Round Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.81	20.5	7.0	21.0
6	60	1.52	0.93	23.6	7.0	21.0
4	60	1.52	1.08	27.4	7.0	21.0
3	60	1.52	1.17	29.7	7.0	21.0
2	60	1.52	1.27	32.3	7.0	21.0
1	80	2.03	1.44	36.6	8.0	24.0
1/0	80	2.03	1.52	38.6	8.0	24.0
2/0	80	2.03	1.65	41.9	8.0	24.0
3/0	80	2.03	1.77	45.0	8.0	24.0
4/0	80	2.03	1.92	48.8	8.0	24.0
250	95	2.41	2.10*	53.3*	9.5	28.5
300	95	2.41	2.22*	56.3*	9.5	28.5
350	95	2.41	2.36*	59.9*	9.5	28.5
400	95	2.41	2.47*	62.7*	9.5	28.5
450	95	2.41	2.60*	66.0*	9.5	28.5
500	95	2.41	2.70*	68.5*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

Table 7-17
0 to 2000 Volts—Type W and G Three-Conductor Round Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.91	23.1	7.0	21.0
6	60	1.52	1.01	25.7	7.0	21.0
4	60	1.52	1.17	29.7	7.0	21.0
3	60	1.52	1.24	31.5	7.0	21.0
2	60	1.52	1.34	34.3	7.0	21.0
1	80	2.03	1.51	38.4	8.0	24.0
1/0	80	2.03	1.65	42.0	8.0	24.0
2/0	80	2.03	1.75	44.0	8.0	24.0
3/0	80	2.03	1.89	48.0	8.0	24.0
4/0	80	2.03	2.04*	51.8*	8.0	24.0
250	95	2.41	2.39*	60.7*	9.5	28.5
300	95	2.41	2.56*	65.0*	9.5	28.5
350	95	2.41	2.68*	68.1*	9.5	28.5
400	95	2.41	2.82*	71.6*	9.5	28.5
450	95	2.41	2.94*	74.7*	9.5	28.5
500	95	2.41	3.03*	77.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

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Table 7-18
0 to 2000 Volts
Type W and G Four-Conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.99	25.1	7.0	21.0
6	60	1.52	1.10	27.9	7.0	21.0
4	60	1.52	1.27	32.3	7.0	21.0
3	60	1.52	1.34	34.0	7.0	21.0
2	60	1.52	1.48	37.6	7.0	21.0
1	80	2.03	1.68	42.7	8.0	24.0
1/0	80	2.03	1.79	45.5	8.0	24.0
2/0	80	2.03	1.93	49.0	8.0	24.0
3/0	80	2.03	2.07*	52.6*	8.0	24.0
4/0	80	2.03	2.26*	57.4*	8.0	24.0
250	95	2.41	2.66*	67.6*	9.5	28.5
300	95	2.41	2.84*	72.1*	9.5	28.5
350	95	2.41	2.98*	75.7*	9.5	28.5
400	95	2.41	3.14*	79.8*	9.5	28.5
450	95	2.41	3.26*	82.8*	9.5	28.5
500	95	2.41	3.40*	86.4*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

Table 7-19
0 to 2000 Volts
Type G-GC Three-Conductor Round Portable Power Cables with Two Grounding Conductors and One Ground Check Conductor

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Each Grounding Conductor		Ground Check Conductor		Outside Diameter		Test Voltage, kV	
	mils	mm	Size, AWG	Number of Wires per Conductor	Minimum Size, AWG	Insulation Thickness, mils	inches	mm	AC	DC
8	60	1.52	10	49	10	30	0.97	24.6	7.0	21.0
6	60	1.52	10	49	10	30	1.05	26.6	7.0	21.0
4	60	1.52	8	49	10	30	1.19	30.2	7.0	21.0
3	60	1.52	8	49	10	30	1.25	31.7	7.0	21.0
2	60	1.52	7	49	10	30	1.34	34.3	7.0	21.0
1	80	2.03	6	133	8	45	1.51	38.4	8.0	24.0
1/0	80	2.03	5	133	8	45	1.65	42.0	8.0	24.0
2/0	80	2.03	4	133	8	45	1.75	44.0	8.0	24.0
3/0	80	2.03	3	133	8	45	1.89	48.0	8.0	24.0
4/0	80	2.03	2	133	8	45	2.04*	51.8*	8.0	24.0
250	95	2.41	2	133	8	45	2.39*	60.7*	9.5	28.5
300	95	2.41	1	133	8	45	2.56*	65.0*	9.5	28.5
350	95	2.41	1/0	259	8	45	2.68*	68.1*	9.5	28.5
400	95	2.41	1/0	259	8	45	2.82*	71.6*	9.5	28.5
450	95	2.41	2/0	259	8	45	2.94*	74.7*	9.5	28.5
500	95	2.41	2/0	259	8	45	3.03*	77.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

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meets the requirements of 7.4.18. These cables shall be in accordance with Table 7-20. These cables shall be used for the internal wiring of equipment only.

7.4.6 Type PG, Two- and Three-Power Conductors with Single Grounding Conductor, 0–2000 Volts

These cables shall consist of two or three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The power conductors, together with a single grounding conductor (see 7.4.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. These cables shall be in accordance with Table 7-21.

7.4.7 Type PCG, Two- and Three- Power Conductors with Control Conductors and Single Grounding Conductor, 0–2000 Volts

These cables shall consist of two or three power conductors and two No. 10 AWG control conductors all of which are separately covered with insulation. Each power and control conductor shall be separately covered with a tape or braid, except that on power conductors this tape or braid may be omitted if colored insulation is used (see 7.4.15). The power conductors, together with two control conductors and a single grounding conductor, shall be cabled together with a left-hand lay in accordance with Table 7-14. Each control conductor shall be in a separate interstice between the power conductors: the black control conductor shall be between the black and white power conductors, and the white control conductor adjacent to the white power conductor. The assembly shall be covered with a jacket that meets the requirements of 7.4.18. These cables shall be in accordance with Table 7-22.

7.4.8 Type G, Three-conductor Round with Grounding Conductors, 2001-5000 Volts

These cables shall consist of three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape (see 7.4.15). The power conductors, together with the grounding conductors (see 7.4.12), and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-23.

7.4.9 Type SH, SHC-GC, SHD, and SHD-GC Shielded Cables, 0-25,000 Volts

7.4.9.1 Type SH Single-conductor Cables, 2001–25000 Volts

These cables shall consist of an insulated conductor covered with a tape, a shield that meets the requirements of 7.4.16 with or without a tape over the shield, and a jacket that meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-24.

7.4.9.2 Type SHC-GC Three-conductor Cables 2000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.4.15). The power conductors, together with two grounding conductors (see 7.4.12), one ground

Table 7-20
0 to 2000 Volts
Type W and G, Five- and Six-conductor Portable Power Cables

Power Conductor Size, AWG†	Insulation Thickness		Grounding Conductor (Type G)		Outside Diameter				Test Voltage, kV	
			Size, AWG	Minimum Number of strands	Five-conductor Type W and G		Six-conductor Type W			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	1.07	27.2	1.18	30.0	7.0	21.0
6	60	1.52	7	49	1.21	30.7	1.31	33.3	7.0	21.0
4	60	1.52	5	133	1.40	35.6	1.52	38.6	7.0	21.0
3	60	1.52	4	133	1.48	37.6	1.61	40.9	7.0	21.0
2	60	1.52	3	133	1.61	40.9	1.75	44.4	7.0	21.0
1	80	2.03	2	133	1.88	47.8	2.05*	52.1*	8.0	24.0

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

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Table 7-21
0 to 2000 Volts, Type PG Two- and Three-Conductor Power Cables

Power Conductor Size, AWG or kcmil†	Power Conductor-Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
			Strands, AWG	Minimum Number of Strands	Two-conductor Cables		Three-conductor Cables			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	0.84	21.3	0.93	23.6	7.0	21.0
6	60	1.52	8	49	0.93	23.6	1.03	26.2	7.0	21.0
4	60	1.52	6	49	1.08	27.4	1.20	30.5	7.0	21.0
3	60	1.52	6	49	1.17	29.7	1.27	32.3	7.0	21.0
2	60	1.52	5	133	1.27	32.3	1.34	34.0	7.0	21.0
1	80	2.03	4	133	1.44	36.6	1.52	38.6	8.0	24.0
1/0	80	2.03	3	133	1.52	38.6	1.68	42.7	8.0	24.0
2/0	80	2.03	2	133	1.65	41.9	1.79	45.5	8.0	24.0
3/0	80	2.03	1	133	1.77	45.0	1.93	49.0	8.0	24.0
4/0	80	2.03	1/0	259	1.92	48.8	2.13*	54.1*	8.0	24.0
250	95	2.41	2/0	259	2.16*	54.9*	2.39*	60.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

Table 7-22
0 to 2000 Volts, Type PCG‡ Two- and Three-Conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Power Conductor-Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
			Strands, AWG	Minimum Number of Strands	Two-conductor Cables		Three-conductor Cables			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	0.94	23.9	1.03	26.2	7.0	21.0
6	60	1.52	8	49	0.98	24.9	1.18	30.0	7.0	21.0
4	60	1.52	6	49	1.10	27.9	1.29	32.8	7.0	21.0
3	60	1.52	6	49	1.20	30.5	1.31	33.3	7.0	21.0
2	60	1.52	5	133	1.29	32.8	1.39	35.3	7.0	21.0
1	80	2.03	4	133	1.44	36.6	1.52	38.6	8.0	24.0
1/0	80	2.03	3	133	1.52	38.6	1.68	42.7	8.0	24.0
2/0	80	2.03	2	133	1.65	41.9	1.79	45.5	8.0	24.0
3/0	80	2.03	1	133	1.77	45.0	1.93	49.0	8.0	24.0
4/0	80	2.03	1/0	259	1.92	48.8	2.13*	54.1*	8.0	24.0
250	95	2.41	2/0	259	2.16	54.9*	2.39*	60.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

‡Control conductors for all PCG cables shall be size 10 AWG, with a minimum of 49 strands and 30 mils (0.76 mm) insulation and, if necessary, a braid covering. The ac test voltage shall be 3.0 kV for 15 seconds.

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Table 7-23
2001 to 5000 Volts Type G Three-conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Jacket Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	mils	mm	inches	mm	AC	DC
6	110	2.79	155	3.94	1.37	34.8	13.0	35.0
4	110	2.79	170	4.32	1.55	39.3	13.0	35.0
3	110	2.79	170	4.32	1.62	41.1	13.0	35.0
2	110	2.79	190	4.83	1.75	44.4	13.0	35.0
1	110	2.79	190	4.83	1.84	46.7	13.0	35.0
1/0	110	2.79	205	5.21	1.96	49.7	13.0	35.0
2/0	110	2.79	205	5.21	2.08*	52.8*	13.0	35.0
3/0	110	2.79	205	5.21	2.20*	55.9*	13.0	35.0
4/0	110	2.79	220	5.59	2.38*	60.4*	13.0	35.0

*These cables require extra-heavy-duty jackets (see 7.4.1).

†See Table 7-28.

check conductor (see 7.4.11), and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7-14. The ground check conductor shall be laid between the black and white power conductors. The assembly shall be covered with a shield that meets the requirements of 7.4.16 and a jacket that meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-25.

7.4.9.3 Type SHD Three-Conductor Cables, 25,000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation, a colored tape (see 7.4.15), and a shield that meets the requirements of 7.4.16, and three grounding conductors (see Table 7-28), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. These cables shall be in accordance with Table 7-26.

7.4.9.4 Type SHD-GC Three-conductor Cables, 25,000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation, a colored tape (see 7.4.15) and a shield that meets the requirements of 7.4.16, and two grounding conductors (see Table 7-28) and one ground check conductor (see 7.4.11).

All power conductors, grounding conductors, the ground check conductor, and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7-14 and covered with a jacket that meets the requirements of 7.4.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7-26.

7.4.10 Power Conductors

7.4.10.1 Power conductors shall be made of annealed coated or uncoated copper wires in accordance with Section 2. A separator may be used.

7.4.10.2 The sizes, strandings, and nominal diameters of the conductors shall be in accordance with Table 7-28.

7.4.10.3 Conductor stress control shall be in accordance with 2.7.

7.4.11 Control and Ground Check Conductors

The control conductors for Type PCG shall be no smaller than No. 10 AWG. The ground check conductor for Types G-GC, SHC-GC, and SHD-GC shall be given in Tables 7-19, 7-25, and 7-26.

A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. A separator may be used. In all other characteristics, the conductors shall meet the requirements of 7.4.10.

7.4.12 Grounding Conductors

7.4.12.1 The grounding conductors for two-, three- and four-conductor round Type G, SHC-GC, SHD, and SHD-GC shall be annealed copper of not less than the size and number of wires in Table 7-28 for the corresponding power conductor sizes. In all other characteristics they shall meet the requirements of 7.4.10.

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Table 7-24
Type SH Single-conductor Portable Power Cables for 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Jacket Thickness		Outside Diameter*		Test Voltage, kV	
	mils	mm	mils	mm	inches	mm	AC	DC
2001 to 5000 Volts								
6	110	2.79	110	2.79	0.77	19.5	13.0	...
4	110	2.79	110	2.79	0.82	20.8	13.0	...
3	110	2.79	110	2.79	0.85	21.5	13.0	...
2	110	2.79	125	3.18	0.92	23.3	13.0	...
1	110	2.79	125	3.18	0.96	24.3	13.0	...
1/0	110	2.79	140	3.56	1.04	26.4	13.0	...
2/0	110	2.79	140	3.56	1.07	27.1	13.0	...
3/0	110	2.79	155	3.94	1.18	29.9	13.0	...
4/0	110	2.79	155	3.94	1.24	31.5	13.0	...
250	120	3.05	155	3.94	1.32	33.5	13.0	...
300	120	3.05	170	4.32	1.37	34.8	13.0	...
350	120	3.05	170	4.32	1.47	37.3	13.0	...
500	120	3.05	190	4.83	1.62	41.1	13.0	...
5001 to 8000 Volts								
4	150	3.81	125	3.18	0.97	24.6	18.0	45.0
3	150	3.81	140	3.56	1.03	26.1	18.0	45.0
2	150	3.81	140	3.56	1.07	27.1	18.0	45.0
1	150	3.81	140	3.56	1.12	28.4	18.0	45.0
1/0	150	3.81	155	3.94	1.19	30.2	18.0	45.0
2/0	150	3.81	155	3.94	1.24	31.5	18.0	45.0
3/0	150	3.81	155	3.94	1.30	33.0	18.0	45.0
4/0	150	3.81	155	3.94	1.37	34.8	18.0	45.0
250	150	3.81	170	4.32	1.45	36.8	18.0	45.0
300	150	3.81	170	4.32	1.52	38.6	18.0	45.0
350	150	3.81	170	4.32	1.57	39.9	18.0	45.0
500	150	3.81	190	4.83	1.76	44.7	18.0	45.0
8001 to 15,000 Volts								
2	210	5.33	155	3.94	1.22	30.9	27.0	70.0
1	210	5.33	155	3.94	1.26	32.0	27.0	70.0
1/0	210	5.33	155	3.94	1.31	33.2	27.0	70.0
2/0	210	5.33	155	3.94	1.36	34.5	27.0	70.0
3/0	210	5.33	170	4.32	1.46	37.0	27.0	70.0
4/0	210	5.33	170	4.32	1.52	38.6	27.0	70.0
250	210	5.33	170	4.32	1.57	39.9	27.0	70.0
300	210	5.33	170	4.32	1.64	41.6	27.0	70.0
350	210	5.33	190	4.83	1.73	43.9	27.0	70.0
500	210	5.33	190	4.83	1.88	47.7	27.0	70.0
15001 to 25,000 Volts								
1	295	7.49	170	4.32	1.49	37.8	38.0	100.0
1/0	295	7.49	170	4.32	1.54	39.1	38.0	100.0
2/0	295	7.49	170	4.32	1.59	40.4	38.0	100.0
3/0	295	7.49	170	4.32	1.64	41.6	38.0	100.0
4/0	295	7.49	190	4.83	1.74	44.2	38.0	100.0
250	295	7.49	190	4.83	1.79	45.5	38.0	100.0
300	295	7.49	190	4.83	1.86	47.2	38.0	100.0
350	295	7.49	190	4.83	1.91	48.5	38.0	100.0
500	295	7.49	205	5.21	2.10	53.3	38.0	100.0

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

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Table 7-25
0 to 2000 Volts
Type SHC-GC Three-conductor Portable Power Cable for 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Ground Check Conductor Size, AWG	Jacket Thickness		Outside Diameter*		AC Test Voltage, kV
	mils	mm		mils	mm	inches	mm	
6	70	1.78	10	155	3.94	1.27	32.2	7.0
4	70	1.78	10	155	3.94	1.39	35.3	7.0
3	70	1.78	10	170	4.32	1.49	37.8	7.0
2	70	1.78	10	170	4.32	1.57	39.9	7.0
1	80	1.78	8	190	4.83	1.75	44.4	8.0
1/0	80	2.03	8	190	4.83	1.85	47.0	8.0
2/0	80	2.03	8	205	5.21	1.99	50.5	8.0
3/0	80	2.03	8	205	5.21	2.11	53.6	8.0
4/0	80	2.03	8	220	5.59	2.29	58.2	8.0
250	95	2.41	8	220	5.59	2.46	62.5	9.5
300	95	2.41	8	235	5.97	2.63	66.8	9.5
350	95	2.41	8	235	5.97	2.75	69.8	9.5
500	95	2.41	8	265	6.73	3.14	79.8	9.5

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

7.4.12.2 The grounding conductors for three conductor round Type G-GC shall meet the requirements of 7.4.10 and shall be of the size and stranding given in Table 7-19.

7.4.12.3 The single grounding conductor for five conductor Type G and for Type PG and PCG cables shall meet the requirements of 7.4.10 and shall be of the size and stranding given in Tables 7-20, 7-21, and 7-22.

7.4.12.4 The grounding conductors for Types G, G-GC, PG, PCG, and SHC-GC cables shall be covered or uncovered. The grounding conductors for Types SHD and SHD-GC shall be uncovered. When used, the outer covering over the grounding conductor shall be green in color.

7.4.13 Insulation

7.4.13.1 Classes

The insulation shall meet the requirements given in Section 3.

7.4.13.2 Thickness of Insulation

The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7-15 through 7-26. In these tables, the highest rated circuit voltage given in the titles, represents the maximum operating voltage recommended for that thickness of insulation. The average thickness of insulation shall be not less than 30 mils (0.76 mm) on the 10 AWG control and ground check conductors and not less than 45 mils (1.14 mm) on the 8 AWG ground check conductors. The minimum thickness shall not be less than 90 percent of the specified average values.

7.4.14 Tapes and Braids

Tapes and braids if used over the insulation shall be suitable for the intended purpose.

7.4.15 Conductor or Circuit Identification

Identification shall be by any suitable means in accordance with the color sequence given in 7.4.15.1 and 7.4.15.2. When a conducting nonmetallic tape is used over the insulated conductors, it shall be plainly identified as being conducting.

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Table 7-26
Type SHD and SHD-GC Three-conductor Portable Power Cables for 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Ground Check Conductor Size, AWG (Type SHD-GC)	Jacket Thickness		Outside Diameter*		Test Voltage, kV	
	mils	mm		mils	mm	inches	mm	AC	DC
0 to 2000 Volts									
6	70	1.78	10	155	3.94	1.29	32.8	7.0	...
4	70	1.78	10	155	3.94	1.40	35.6	7.0	...
3	70	1.78	10	170	4.32	1.51	38.3	7.0	...
2	70	1.78	8	170	4.32	1.59	40.4	7.0	...
1	80	2.03	8	190	4.83	1.76	44.7	8.0	...
1/0	80	2.03	8	190	4.83	1.86	47.2	8.0	...
2/0	80	2.03	8	205	5.21	2.00	50.8	8.0	...
3/0	80	2.03	8	205	5.21	2.13	54.1	8.0	...
4/0	80	2.03	8	220	5.59	2.31	58.7	8.0	...
250	95	2.41	8	220	5.59	2.51	63.8	9.5	...
300	95	2.41	8	235	5.97	2.68	68.1	9.5	...
350	95	2.41	8	235	5.97	2.81	71.4	9.5	...
500	95	2.41	8	265	6.73	3.19	81.0	9.5	...
2001 to 5000 Volts									
6	110	2.79	8	185	4.70	1.56	39.6	13.0	...
4	110	2.79	8	185	4.70	1.68	42.6	13.0	...
3	110	2.79	8	205	5.21	1.78	45.2	13.0	...
2	110	2.79	8	205	5.21	1.87	47.5	13.0	...
1	110	2.79	8	205	5.21	1.95	49.5	13.0	...
1/0	110	2.79	8	220	5.59	2.08	52.8	13.0	...
2/0	110	2.79	8	220	5.59	2.20	55.8	13.0	...
3/0	110	2.79	8	235	5.97	2.36	59.9	13.0	...
4/0	110	2.79	8	235	5.97	2.50	63.5	13.0	...
250	120	3.05	8	250	6.35	2.69	68.3	13.0	...
300	120	3.05	8	250	6.35	2.81	71.4	13.0	...
350	120	3.05	8	265	6.73	2.95	74.9	13.0	...
500	120	3.05	8	280	7.11	3.31	84.0	13.0	...
5001 to 8000 Volts									
4	150	3.81	8	205	5.21	1.94	49.3	18.0	45.0
3	150	3.81	8	205	5.21	2.02	51.3	18.0	45.0
2	150	3.81	8	220	5.59	2.12	53.8	18.0	45.0
1	150	3.81	8	220	5.59	2.21	56.1	18.0	45.0
1/0	150	3.81	8	220	5.59	2.32	58.9	18.0	45.0
2/0	150	3.81	8	235	5.97	2.46	62.5	18.0	45.0
3/0	150	3.81	8	250	6.35	2.62	66.5	18.0	45.0
4/0	150	3.81	8	250	6.35	2.75	69.8	18.0	45.0
250	150	3.81	8	250	6.35	2.89	73.4	18.0	45.0
300	150	3.81	8	265	6.73	3.04	77.2	18.0	45.0
350	150	3.81	8	280	7.11	3.20	81.3	18.0	45.0
500	150	3.81	8	295	7.49	3.56	90.4	18.0	45.0
8001 to 15000 Volts									
2	210	5.33	8	235	5.97	2.41	61.2	27.0	70.0
1	210	5.33	8	235	5.97	2.52	64.0	27.0	70.0
1/0	210	5.33	8	250	6.35	2.64	67.0	27.0	70.0
2/0	210	5.33	8	250	6.35	2.73	69.8	27.0	70.0
3/0	210	5.33	8	265	6.73	2.90	73.6	27.0	70.0
4/0	210	5.33	8	265	6.73	3.05	77.4	27.0	70.0
15001 to 25000 Volts									
1	295	7.49	8	265	6.62	2.95	74.9	38.0	100.0
1/0	295	7.49	8	265	6.62	3.05	77.4	38.0	100.0
2/0	295	7.49	8	280	6.90	3.20	81.2	38.0	100.0
3/0	295	7.49	8	280	6.90	3.33	84.5	38.0	100.0
4/0	295	7.49	8	295	7.49	3.50	88.9	38.0	100.0

*These cables require extra-heavy-duty jackets (see 7.5.1).

†See Table 7-28.

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7.4.15.1 POWER CONDUCTORS

Two-conductor cables	
All types	black, white
Three-conductor cables	
Type G	black, white, red
Types PCG, PG, G-GC, SHD*, SHD-GC*, and SHC-GC	black, white, red
Type W	black, white, green
Four-conductor cables	
Type G	black, white, red, orange
Type W	black, white, red, green
Five-conductor cables	
Type G	black, white, red, orange, blue
Type W	black, white, red, green, orange
Six-conductor cables	
Type W	black, white, red, green, orange, blue

*When conducting nonmetallic tapes are used, identification may be by means of stripes or printing in a contrasting color.

7.4.15.2 CONTROL AND GROUND CHECK CONDUCTORS

Control conductors, Type PCG	black, white
Ground check conductor, Type G-GC, Type SHD-GC, and Type SHC-GC	yellow

7.4.16 Shielding

7.4.16.1 The shielding for Types SH, SHD, SHC-GC and SHD-GC cables shall consist of non-magnetic wires.

Where copper or copper alloy wires are used, they shall be coated in accordance with 2.1.1.

7.4.16.2 METAL BRAID SHIELDS

When shielding is applied in the form of a metal braid, the coverage shall be not less than 84 percent as determined by the following formula:

$$\text{Percent coverage} = 100\,(2F - F^2)$$

Where –

$F = \dfrac{NPd}{\sin a}$

a = Angle of braid with axis of cable

$\text{Tan } a = \dfrac{2\pi DP}{C}$

d = Diameter of individual braid wires in inches
C = Number of carriers
D = Diameter under shield in inches
N = Number of wires per carrier
P = Picks per inch

7.4.16.3 METAL WIRE SHIELDS

Where the shielding is applied in the form of a serving or wrap, the coverage shall be not less than 60 percent as determined by the following formula:

$$\text{Percent coverage} = \frac{Nd}{W} \times 100$$

Where –
N = Number of parallel wires
d = Diameter of individual wires in inches
$W = \pi D \cos a$
D = Diameter under shield in inches
a = Angle between serving wires and axis of cable

$\text{Tan } a = \pi \dfrac{D}{C}$

C = Pitch of serving in inches

7.4.17 Conductor Assembly

For round cables, the insulated conductors, together with grounding conductors and ground check conductor when required and any necessary fillers, shall be

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Table 7-27
Jacket Thicknesses for Types and Sizes of Portable Cables Not Covered by Tables 7-15 through 7-26

Calculated Diameter Under Jacket		Jacket Thickness		Calculated Diameter Under Jacket		Jacket Thickness	
inches	mm	mils	mm	inches	mm	mils	mm
				1.551–1.820	39.40–46.23	205	5.21
0.325 and less	8.26 and less	60	1.52	1.821–2.050	46.25–52.07	220	5.59
0.326–0.430	8.28–10.92	80	2.03	2.051–2.300	52.10–58.42	235	5.97
0.431–0.540	10.95–13.72	95	2.41	2.301–2.550	58.45–64.77	250	6.35
0.541–0.640	13.74–16.26	110	2.79	2.551–2.800	64.80–71.12	265	6.73
0.641–0.740	16.28–18.80	125	3.18	2.801–3.100	71.15–78.74	280	7.11
0.741–0.850	18.82–21.59	140	3.56	3.101–3.500	78.77–88.90	295	7.49
0.851–1.100	21.62–27.94	155	3.94	3.501–3.950	88.93–100.33	310	7.87
1.101–1.320	27.97–33.53	170	4.32	3.951–4.450	100.36–113.03	330	8.38
1.321–1.550	33.55–39.37	190	4.82	4.451–5.000	113.06–127.00	345	8.76

Table 7-28
Conductors

Power Conductors						Grounding Conductors (Round Cables)							
		Diameter of Each Wire		Conductor Diameter		Two-conductor Type G Cables		Three-conductor Type SHD-GC and Type SHC-GC Cables		Three-conductor Type G Cables		Four-conductor Type G Cables	
Conductor Size, AWG or kcmil	Minimum Number of Wires per Conductor	mils	mm	inches	mm	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor
8	49	18.4	0.467	0.166	4.22	10	19	...	...	12	19	12	19
6	49	23.1	0.587	0.208	5.28	10	19	10	19	10	19	12	19
4	49	29.2	0.742	0.263	6.68	8	49	8	49	8	49	10	19
3	49	32.8	0.833	0.295	7.49	6	49	7	49	8	49	10	19
2	133	22.3	0.566	0.335	8.51	6	133	6	133	8	49	9	49
1	133	25.1	0.638	0.377	9.58	5	133	5	133	7	49	8	49
1/0	133	28.2	0.716	0.423	10.74	4	133	4	133	6	133	7	49
2/0	133	31.6	0.803	0.474	12.04	3	133	3	133	5	133	6	133
3/0	259	25.5	0.648	0.536	13.61	2	259	2	133	4	133	5	133
4/0	259	28.6	0.726	0.601	15.27	1	259	1	133	3	133	4	133
250	259	31.1	0.790	0.653	16.59	1/0	259	1/0	259	2	259	3	133
300	259	34.0	0.864	0.714	18.14	1/0	259	1/0	259	1	259	3	133
350	259	36.8	0.934	0.773	19.63	2/0	259	2/0	259	1	259	2	259
400	259	39.3	0.998	0.825	20.96	3/0	259	3/0	259	1/0	259	1	259
450	259	41.7	1.060	0.876	22.25	3/0	259	3/0	259	1/0	259	1	259
500	259	43.9	1.115	0.922	23.42	4/0	259	4/0	259	2/0	259	1/0	259
550	427	35.9	0.912	0.969	24.61	...	...	...	...	...	...	...	...
600	427	37.5	0.952	1.013	25.73	...	...	...	...	...	...	...	...
650	427	39.0	0.991	1.053	26.75	...	...	...	...	...	...	...	...
700	427	40.5	1.029	1.094	27.79	...	...	...	...	...	...	...	...
750	427	41.9	1.064	1.131	28.73	...	...	...	...	...	...	...	...
800	427	43.3	1.100	1.169	29.69	...	...	...	...	...	...	...	...
900	427	45.9	1.166	1.239	31.47	...	...	...	...	...	...	...	...
1000	427	48.4	1.229	1.307	33.20	...	...	...	...	...	...	...	...

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cabled with a left-hand lay. For Types SHD and SHD-GC cables, the grounding conductors shall be in contact with the metallic shields. Suitable fillers shall be used to produce an essentially round cross-section in the completed cable. When required, a binder tape and/or threads shall be used over the conductor assembly.

7.4.18 Jackets

7.4.18.1 GENERAL

The jacket shall be applied in one or two layers. If applied in two layers, the outer jacket shall constitute at least 50 percent of the total thickness of jacket. The single-layer jacket and the outer layer of a two-layer jacket shall meet the applicable requirements of 7.4.18.1.1, 7.4.18.1.2, 7.4.18.1.3, 7.4.18.1.4, 7.4.18.1.5, 7.4.18.1.6, 7.4.18.1.7, or 7.4.18.1.8.

Single- or two-layer jackets shall be reinforced by two servings or a braid of a suitable natural or synthetic material. The diameter of the reinforcing material shall be not greater than 35 mils (0.89 mm). If two servings are used, they shall be applied in opposite directions of lay. The reinforcing shall be under the single-layer jacket and under or between the layers of the two-layer construction.

7.4.18.1.1 EXTRA-HEAVY-DUTY-NEOPRENE JACKET

Physical requirements	
Tensile strength, minimum	
psi	2400
kgf/mm^2	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm^2	0.49
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Tear, minimum	
pounds per inch	40
kgf/mm	0.71
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.4.18.1.2 HEAVY-DUTY NEOPRENE JACKET

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.4.18.1.3 EXTRA-HEAVY-DUTY NITRILE-BUTADIENE/POLYVINYL-CHLORIDE JACKET*

Physical requirements	
Tensile strength, minimum	
psi	2400
kgf/mm^2	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm^2	0.49
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Tear, minimum	
pounds per inch	40
kgf/mm	0.71
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

*Suitable for a minimum temperature of –10°C (14°F).

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7.4.18.1.4 HEAVY-DUTY NITRILE-BUTADIENE/POLYVINYL-CHLORIDE JACKET*

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

*Suitable for a minimum temperature of –10°C (14°F).

7.4.18.1.5 HEAVY-DUTY CHLOROSULFONATED POLYETHYLENE

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	65
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.4.18.1.6 EXTRA-HEAVY-DUTY CHLOROSULFONATED POLYETHYLENE

Physical requirements	
Tensile strength, minimum	
psi	2400
MPa	16.55
Tensile stress at 200 percent elongation, minimum	
psi	700
MPa	4.83
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Tear, minimum	
pounds per inch	40
KN/m	7.01
Aging requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	70
Elongation at rupture, minimum, percentage of unaged value	60
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.4.18.1.7 CHLORINATED POLYETHYLENE, HEAVY DUTY, CROSS-LINKED

Physical requirements	
Tensile strength, minimum	
psi	1800
MPa	12.41
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85

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Elongation at rupture, minimum, percentage of unaged value	55
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	60

7.4.18.1.8–7.4.2.1

Text deleted.

7.5 NONSHIELDED SINGLE-CONDUCTOR POWER CABLE

7.5.1 Scope

This section covers nonshielded single-conductor nonjacketed and jacketed power cable with cross-linked-thermosetting-polyethylene insulation intended for use at 2001 to 5000 volts at 100 percent insulation level and 2001 to 3000 volts at 133 percent insulation level under conditions where shields cannot be adequately grounded or where space is inadequate for proper termination of the shielding, as follows (see 4.2 and Appendix G):

1. Single Conductors
   a. Unspliced cables in random lay in grounded metal conduit indoors above grade in dry location.
   b. Mounted on insulators in free air.
2. Triplexed Single Conductors (Factory Assembled)—In conduit or cable trays indoors above grade in dry locations.
3. Single and Triplexed Conductors—Aerially, field spun to a grounded messenger.

NOTE 1—Care should be taken at joint and terminal locations to have a minimum length of separated conductors. Where field splices

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permitted, they should be bound together to keep the phase conductors in contact with each other.

NOTE 2—Pulling compounds should be nonconducting. (For the purposes of NEMA, these notes are approved as Authorized Engineering Information.)

7.5.2 Conductors

The conductors shall be copper or aluminum in accordance with Section 2. The conductor sizes shall be as given in Table 7-29.

7.5.3 Insulation

The insulation shall be cross-linked-thermosetting polyethylene which meets the requirements of 3.7.

7.5.3.1 Nonjacketed cables shall have a carbon-black pigmented insulation to provide resistance to sunlight. The average thickness of the insulation shall be not less than that given in Table 7-29. The minimum thickness shall be not less than 90 percent of the value in the table. Where installation conditions require additional mechanical protection, the average insulation thickness shall be increased by 30 mils (0.76 mm) or a jacketed cable shall be used.

7.5.3.2 The average thickness of the insulation for jacketed cables shall be not less than 90 mils (2.29 mm) and the minimum thickness shall be not less than 81 mils (2.06 mm).

7.5.4 Jacket

For jacketed cables, a jacket that meets the requirements of 4.4.1 polyvinyl chloride, 4.4.3 chlorinated polyethylene (thermoplastic), 7.3.7.1 neoprene, 7.3.7.2 nitrile-butadiene/polyvinyl chloride, 7.3.7.3 chlorosulfonated polyethylene, or 7.3.7.4 chlorinated polyethylene (cross-linked) shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7-30, and the minimum thickness shall be not less than 80 percent of these values.

7.5.5 Length of Lay

Triplexed cables shall have a maximum length of lay of 35 times the diameter of the single-conductor cable.

7.5.6 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.5 except as otherwise specified in 7.5.6.1 and 7.5.6.2.

7.5.6.1 Electrical Requirements

Each insulated and/or insulated and jacketed conductor in the completed cable shall be tested in accordance with 6.14 and 6.15 and shall meet the following requirements.

Table 7-29
Nonjacketed Cable

Conductor Size, AWG or kcmil	Insulation Thickness		Test Voltage, kV	
	mils	mm	AC	DC
8–4/0	110	2.79	13	35
225–500	120	3.05	13	35
525–1000	130	3.30	13	35

Table 7-30
Cables with Jackets

Conductor Size, AWG or kcmil	Insulation Thickness		Jacket Thickness		Test Voltage, kV	
	mils	mm	mils	mm	AC	DC
8–6	90	2.29	30	0.76	13	35
4–2/0	90	2.29	45	1.14	13	35
3/0–1000	90	2.29	65	1.65	13	35

7.5.6.1.1 AC Voltage Test

(See 6.14.) The conductor shall withstand the ac test voltage given in Table 7-29 or 7-30 for 5 minutes, except that the dc voltage test may be substituted.

7.5.6.1.2 Insulation Resistance

(See 6.15.) The conductor shall have an insulation resistance not less than that corresponding to a constant of 20,000 at 15.6°C (60°F).

7.5.6.1.3 DC Voltage Test

(See 6.14.) Upon completion of the insulation resistance test, the conductor shall withstand for 5 minutes the dc test voltage given in Table 7-29 or 7-30, unless the ac voltage test is performed.

7.5.6.2 Tests for Discharge Resistance

The samples shall be taken in accordance with 6.11.1.

7.5.6.2.1 Surface Resistivity

The surface resistivity shall be measured in accordance with 6.11.2 and shall be not less than 200,000 megohms.

7.5.6.2.2 U-Bend Discharge

The sample shall be tested in accordance with 6.11.3 except that the ac potential shall be 13 kV. There shall be no voltage breakdown or surface cracking.

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7.5.6.2.3 TRACK RESISTANCE OF NONJACKETED CABLES

The track resistance shall be determined in accordance with Method A or Method B of 6.11.4.

7.5.6.2.3.1 METHOD A

The average time to failure shall be not less than 200 hours.

7.5.6.2.3.2 METHOD B

The minimum tracking voltage shall be 2000 volts.

7.6 NONSHIELDED SINGLE-CONDUCTOR CABLE FOR SERIES-LIGHTING CIRCUITS

7.6.1 Scope

This section covers nonshielded single-conductor nonjacketed cable with cross-linked-thermosetting-polyethylene insulation intended for use in series lighting circuits at 0 to 5000 volts.

7.6.2 Conductors

The conductors shall be copper in accordance with Section 2 and of the sizes as given in Table 7-31.

7.6.3 Insulation

The insulation shall meet the requirements of 3.7 for all voltage ratings.

The cable shall have a carbon-black pigmented insulation which is resistant to sunlight. The average thickness of the insulation shall be not less than that given in Table 7-31, and the minimum thickness shall be not less than 90 percent of this value.

7.6.4 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.6 except as otherwise specified in 7.6.4.1 through 7.6.4.3.

7.6.4.1 VOLTAGE TESTS

(See 6.14.) The completed cable shall be tested in accordance with the following paragraphs at the test voltages specified in Table 7-31:

0 to 2000 volts—6.14.2 or 6.14.3 or 6.14.4
2001 to 5000 volts—6.14.2 or 6.14.3

7.6.4.2 INSULATION RESISTANCE

(See 6.15.) The completed cable shall have an insulation resistance not less than that corresponding to the constant of 20,000 at 15.6°C (60°F).

Table 7-31
Insulation Thickness for Series Lighting Cable

Circuit Voltage, Volts*	Conductor Size, AWG	Insulation Thickness†		Test Voltage, kV		
		mils	mm	AC	DC	DC Spark
0–1000	12–4	60	1.52	5.0	15.0	21.0
1001–2000	8–4	75	1.91	7.5	22.5	26.5
2001–5000	8–4	110	2.79	13.0	35.0	...

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

†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 following tabulation of series lighting transformer ratings is representative of those in common use.‡

	6.6 Ampere Secondary		20 Ampere Secondary	
Ratings, kW	Full-load Voltage, Volts, With Protectors	Open-circuit Voltage, Volts, Without Protectors	Full-load Voltage, Volts, With Protectors	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

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7.6.4.3 TESTS FOR DISCHARGE RESISTANCE

These tests shall be made on cables rated 2001 volts and higher. The samples shall be taken in accordance with 6.11.1.

7.6.4.3.1 Surface Resistivity

The surface resistivity shall be measured in accordance with 6.11.2 and shall be not less than 200,000 megohms.

7.6.4.3.2 U-Bend Discharge

The sample shall be tested in accordance with 6.11.3 with an ac potential of 13 kV. There shall be no voltage breakdown or surface cracking.

7.6.4.3.3 Track Resistance

The track resistance shall be determined in accordance with Method A or Method B or 6.11.4.

7.6.4.3.3.1 METHOD A

The average time to failure shall be not less than 200 hours.

7.6.4.3.3.2 METHOD B

The minimum tracking voltage shall be 2000 volts.

7.7 CONTROL CABLES

See NEMA Pub No. WC 57, ICEA Pub No. S-73-532.

7.7.1 Scope

Paragraph deleted.

7.7.2 Conductors

Paragraph deleted.

7.7.3 Insulation

Paragraph deleted.

7.7.4 Covering over Insulation

Paragraph deleted.

7.7.5 Conductor Identification

Paragraph deleted.

7.7.6 Assembly

Paragraph deleted.

7.7.7 Overall Jackets

7.7.8 Type D Cables

Paragraph deleted.

7.7.9 Tests

Paragraph deleted.

7.8 METAL-CLAD CABLES WITH GROUNDING CONDUCTOR

7.8.1 Scope

This section covers two-, three-, and four-conductor cross-linked-thermosetting-polyethylene-insulated interlocked armored metal-clad cables with a grounding conductor. Power conductors shall be size 14 AWG through 1000 kcmil if of copper and size 12 AWG through 1000 kcmil if of aluminum.

7.8.2 Conductors

Insulated power conductors and insulated or uninsulated grounding conductors shall be made of copper or aluminum and shall meet the requirements given in Section 2. The grounding conductor shall be cabled with the insulated power conductors in one or more sections.

7.8.2.1 CABLES RATED 2000 VOLTS OR LESS

The minimum size of the grounding conductor shall be as given in Table 7-32.

Table 7-32
Grounding Conductor Size for Cables Rated 2000 Volts or Less

Power Conductor Size, AWG or kcmil		Minimum Grounding Conductor Size, AWG	
Copper	Aluminum	Copper	Aluminum
14	12	14	12
12	10	12	10
10–8	8–6	10	8
6–4	4–2	8	6
3–2/0	1–4/0	6	4
3/0–400	...	3	1
...	250–700	3	1
500–1000	750–1000	1	2/0

7.8.2.2 CABLES RATED 2001 VOLTS AND ABOVE

The minimum size of the grounding conductor shall be as given in Table 7-33.

7.8.3 Conductor Stress Control Layer

Conductor stress control layer shall be used on conductors having rated circuit voltages above 2000 volts.

7.8.4 Insulation

The insulation shall meet the requirements given in Section 3.

7.8.5 Insulation Shielding

Insulation shielding shall comply with 4.1 and 4.2.

7.8.6 Covering

If a nonmetallic covering is used over the individual insulated conductor, it shall be a tape, braid, or jacket. The jacket shall comply with 4.4.

7.8.7 Assembly

The insulated power conductor and the grounding conductor shall be cabled together with or without fillers. The direction of lay shall be left-hand. The maximum length of

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Table 7-33
Grounding Conductor Size for Cables Rated 2001 Volts and Above

Power Conductor Size, AWG or kcmil		Minimum Grounding Conductor Size, AWG	
Copper	Aluminum	Copper	Aluminum
8 AWG	8–6 AWG	8	6
6–2	4–1/0	6	4
1–2/0	2/0 AWG–250 kcmil	4	2
3/0 AWG–250 kcmil	300–400	3	1
300–400	450–600	2	1/0
450–600	750–900	1	2/0
750–1000	1000	1/0	3/0

lay shall be in accordance with Section 5 and shall be based on the calculated diameter of the individual power conductor. A suitable binder shall be applied over the assembly.

7.8.8 Armor

An interlocked metal tape armor meeting the requirements of 4.5.7 shall be applied over the assembly.

7.8.9 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in Section 7.8.

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Section 8
APPENDICES

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Appendix A
ABBREVIATIONS AND SYMBOLS

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

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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

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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.

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Appendix D
EMERGENCY OVERLOADS

Operation at the emergency overload temperature of 130°C (266°F) shall not exceed 100 hours in any twelve consecutive months nor more than 500 hours during the lifetime of the cable.

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

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Appendix E
REFERENCED PUBLICATIONS AND STANDARDS

E1 NEMA PUBLICATIONS

NEMA WC 26-1984*	*Wire and Cable Packaging*

E2 ICEA PUBLICATIONS

T-24-380, rev. 12/80	*Guide for Partial-Discharge Test Procedure*†
T-27-581/NEMA WC 53-1983	*Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation and Portable Cables*
P-46-426/IEEE #S-135 (SH007096)	Power Cable Ampacities**
P-53-426, 2nd Ed./NEMA WC 50-1976 (R1982, 1988)	*Ampacities, Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable, 15 kV through 69 kV**

E3 ASTM STANDARDS‡

E3.1.1 ASTM Standards to which reference is made in this standard, but not in all of the other three: S-19-81, WC 3; S-61-402, WC 5; and S-68-516, WC 8.

B 232-86	*Concentric-Lay-Stranded Aluminum Conductors, Coated Steel-Reinforced (ACSR), Specification for*
B 233-85	*Aluminum-Alloy 1350 Drawing Stock for Electrical Purposes, Specifications for*
B 246-88	*Tinned Hard-Drawn and Medium-Hard Drawn Copper Wire for Electrical Purposes, Specifications for*
B 397-85	*Concentric-Lay-Stranded Aluminum-Alloy 5005-H19 Conductors, Specification for*
B 557-84	*Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products*
D 1248-84 (R 1989)	*Polyethylene Plastics Molding and Extrusion Materials, Specification for*
D 2132-85	*Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials, Test for*
D 2765-84	*Degree of Crosslinking in Crosslinked Ethylene Plastics as Determined by Solvent Extraction Tests for*

E3.1.2 ASTM Standards to which reference is made in each of the following four standards: S-19-81, WC 3; S-61-402, WC 5, S-66-524, WC 7; and S-68-516, WC 8.

A 90-81 (R 1987)	*Weight of Coating on Zinc Coating (Galvanized) Iron or Steel Articles, Test Method for*
B 1-85	*Hard-Drawn Copper Wire, Specification for*
B 2-88	*Medium-Hard Drawn Copper Wire, Specification for*
B 3-74 (R 1980, 1985)	*Soft or Annealed Copper Wire, Specification for*
B 5-89	*Tough-Pitch Electrolytic Copper Refinery Shapes, Specification for*
B 8-86	*Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Specification for*

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B 29-79 (R 1984)	*Pig Lead, Specification for*
B 33-81 (R 1985)	*Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for*
B 172-71 (R 1980, 1985)	*Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, Specification for*
B 173-71 (R 1980, 1985)	*Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors*
B 174-71 (R 1980, 1985)	*Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors*
B 189-85	*Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes*
B 193-87	*Standard Test Method for Resistivity of Electrical Conductor Materials*
B 229-85	*Standard Specification for Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors*
B 230-85	*Standard Specification for Aluminum-Alloy 1350-H19 Wire, for Electrical Purposes*
B 231-85	*Standard Specification for Concentric Lay-Stranded Aluminum Alloy 1350 Conductors*
B 243-88	*Cross-Sectional Area of Stranded Conductors, Determination of*
B 399-86	*Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors*
B 400-86	*Compact-Round Concentric-Lay-Stranded Aluminum 1350 Conductors*
B 496-81 (R 1984)	*Compact-Round Concentric-Lay-Stranded Copper Conductors*
B 609-85	*Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes*
D 257-78 (R 1983)	*Standard Test Method for DC Resistance or Conductance of Insulating Materials*
D 412-87	*Standard Test Method for Rubber Properties in Tension*
D 471-79	*Standard Test Method for Rubber Property—Effect of Liquids*
D 746-79 (R 1987)	*Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact*
D 1693-70 (R 1980, 1988)	*Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics*
D 3349-86	*Standard Test Method for Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic Film*
E 8-88	*Standard Methods of Tension Testing of Metallic Materials*

† Copies may be obtained from IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331
* Copies may be obtained from NEMA, National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209
** Copies may be obtained from ICEA, P.O. Box 440, South Yarmouth, MA 02664
‡ Copies may be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428

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E3.3 Method 3–Neutral of Single-Color Compounds with Surface Printing of Numbers and Color Designations or Only Color Designations

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

For example, using Table E-2 for conductors 1 to 2, inclusive:

1 – Black	1 – Black	1 – Black, and such
2 – Red	2 – Red	2 – Red, and such
3 – Blue	3 – Blue	3 – Blue, and such

Note: When color only designation is used, numbers are deleted.

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Appendix F
AMPACITIES FOR TWO-CONDUCTOR CONCENTRIC-NEUTRAL SINGLE-PHASE PRIMARY UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES (SEE 7.1.)

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:

	Correction Factors			
	75 Percent Load Factor		50 Percent Load Factor	
Rating of Cable, kV	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.

Appendix F-1
AMPACITIES FOR THREE-PHASE UNDERGROUND DISTRIBUTION CABLES

For ampacities see the ICEA/NEMA Standards Publication No. WC 50, *Ampacities Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cables 15 kV through 69 kV,* (ICEA P-53-426).

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Appendix G
SHIELDING

G1.1 DEFINITION OF SHIELDING

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.

G2.1 FUNCTIONS OF SHIELDING

G2.1.1 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.

G2.1.2 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.

G3.1 USE OF INSULATION SHIELDING

G3.1.1 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.

G3.1.2 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 that exceeds the dielectric strength of air, a discharge will occur, causing ozone formation.

G3.1.3 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.

G3.1.4 Where nonshielded cables are used in underground ducts containing several circuits that 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.

G4.1 GROUNDING OF THE INSULATION SHIELD

G4.1.1 The insulation shield must be grounded at least at one end and preferably to 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.

G4.1.2 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.

G5.1 SHIELD MATERIALS

G5.1.1 Two distinct types of materials are employed in constructing cable shields.

G5.1.1.1 Nonmetallic shields may consist of a conducting tape or a layer of conducting compound. The tape may be conducting compound, fibrous tape faced

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or filled with conducting compound, or conducting fibrous tape.

G5.1.1.2 Metallic shields should be nonmagnetic and may consist of tape, braid, concentric serving of wires, or a sheath.

G6.1 SPLICES AND TERMINATIONS

G6.1.1 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.

G6.1.2 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.

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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. 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 SHEATH, SHIELDING OR ARMOR

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

H3.1 POWER CABLES WITH METALLIC SHIELDING SHEATHS OR ARMOR

H3.1.1 Interlocked Armored and Metallic Sheathed Cables

The minimum bending radius for interlocked armored cables smooth or corrugated aluminum sheath or lead sheath shall be in accordance with Table H-2.

H3.1.2 Flat Tape Armored or 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, Without Armor

H3.1.3.1 Tape Shielded Cables

The minimum bending radius for tape shielded cables given below applies to helically applied flat or corrugated tape or longitudinally applied corrugated tape shielded cables.

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

For multiple-conductor or multiplexed single conductor 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 multiple-conductor cables having an overall tape shield over the assembly, the minimum bending radius is twelve times the overall diameter of the cable.

H3.1.3.2 Wire Shielded Cables

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

For multiple-conductor or multiplexed single conductor cables having wire shielded individual conductors, the minimum bending radius is eight times the diameter of the individual conductors or five times the overall diameter, whichever is greater.

For multiple-conductor cables having a wire shield over the assembly, the minimum bending radius is eight times the overall diameter of the cable.

H4.1 DRUM DIAMETERS OF REELS

See NEMA Pub. No. WC26-1984,* *Wire and Cable Packaging,* which is quoted in Table H-3.

Table H-1
MINIMUM BENDING RADII FOR POWER CABLE
SINGLE & MULTIPLE CONDUCTOR CABLES
WITHOUT METALLIC SHEATH, METALLIC SHIELDING OR ARMOR

Thickness of Conductor Insulation		Overall Diameter of Cable					
		inches	mm	inches	mm	inches	mm
		1.000 and less	25.4 and less	1.001–2.000	25.4–50.8	2.001 and more	50.8 and more
inches	mm	Minimum Bending Radius as a Multiple of Cable Diameter					
0.169 and less	4.31 and less	4		5		6	
0.170–0.310	4.32–7.87	5		6		7	
0.311 and over	7.88 and over	...		7		8	

* Editorially revised on July 22, 1987.
■ Revised 1-30-1991.

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Table H-2 ■
MINIMUM RADII FOR POWER CABLE
SINGLE & MULTIPLE CONDUCTOR CABLES WITH INTERLOCKED ARMOR, SMOOTH OR CORRUGATED ALUMINUM SHEATH OR LEAD SHEATH

	Overall Diameter of Cable					
	inches	mm	inches	mm	inches	mm
	0.75 & less	190 & less	0.76 to 1.50	191 to 381	1.51 & larger	382 & larger
	Minimum Bending Radius as a Multiple of Cable Diameter					
Smooth Aluminum Sheath						
Single Conductor Nonshielded, Multiple Conductor or Multiplexed, with Individually Shielded Conductors	10		12		15	
Single Conductor Shielded	12		12		15	
Multiple Conductor or Multiplexed, with Overall Shield	12		12		15	
Interlocked Armor or Corrugated Aluminum Sheath						
Nonshielded	7		7		7	
Multiple Conductor with Individually Shielded Conductor	12/7*		12/7*		12/7*	
Multiple Conductor with Overall Shield	12		12		12	
Lead Sheath	12		12		12	

*12 x individual shielded conductor diameter, or 7 x overall cable diameter, whichever is the greater.

■ Table added 1-30-1991.

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Table H-3
EXCERPT FROM NEMA STANDARDS PUBLICATION WC 26-1984, *WIRE AND CABLE PACKAGING* *

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. More than 2000 Volts	
1. Nonjacked 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 coilable nonmetallic duct	
Outside diameter of duct, inches— 0.0–0.5026	26
0.51–1.0024	24
1.01–1.2522	22
1.26–1.5021	21
More than1.5021	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.

* Editorially revised on 7-22-1987.

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Appendix I
AMPACITIES FOR THREE-CONDUCTOR MINE POWER CABLES

2001 TO 15000 VOLTS
COPPER AND ALUMINUM

Conductor Size, AWG or kcmil		Ampacities*			
		2001 to 8000 Volts		8001 to 15000 Volts	
Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
6	4	93	95	...	...
4	2	122	124	...	...
2	1/0	159	165	164	168
1	2/0	184	189	187	192
1/0	3/0	211	218	215	221
2/0	4/0	243	251	246	254
3/0	250	279	278	283	281
4/0	350	321	342	325	344
250	400	355	360	359	367
300	450	398	395	401	393
350	500	435	425	438	424
400	...	470	...	473	...
450	...	502	...	504	...
500	...	536	...	536	...

* Ampacities are based on an ambient temperature of 40°C and a conductor temperature of 90°C taken from "Power Cable Ampacities," ICEA Publication No. P-46-426 (IEEE Publication No. S-135), Vol. 1 for Copper Conductors and Vol. 2 for Aluminum Conductors, page 309.

Correction factors for ampacities at various ambient temperatures are as follow:

Ambient Temperature, Degrees C	Correction Factors
10	1.26
20	1.18
30	1.10
40	1.00
50	0.90

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Appendix J
AMPACITIES AND VOLTAGE RATINGS OF PORTABLE CABLES

J1.1 AMPACITIES (CURRENT-CARRYING CAPACITY IN AMPERES)

The recommended ampacities for portable cables are given in Table K-1. These values are based on an ambient temperature of 40°C (104°F). Correction factors for ampacities at various ambient temperatures are as follows:

Ambient Temperature, Degrees C	Correction Factors
10	1.26
20	1.18
30	1.10
40	1.00
50	0.90

When the cables are used with one or more layers wound on a reel, the ampacities shall be corrected as follows:

Number of Layers	Multiplying Correction Factors
1	0.85
2	0.65
3	0.45
4	0.35

J1.2 VOLTAGE RATINGS

It is recommended that the various types of portable cables be limited to the following maximum circuit voltages:

2000 Volts

Single-conductor nonshielded
Type W and G – two conductor
Type W – three, four, five, and six conductor
Type G – four and five conductor
Type G-GC – three conductor
Type PG – two and three conductor
Type PCG – two and three conductor
Type SHC-GC – three conductor

5000 Volts

Type G* – three conductor

25000 Volts

Type SH – single conductor
Types SHD and SHD-GC

*Shielded cables provide a higher level of safety at ratings over 2000 volts.

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Table J-1
Ampacities For Portable Power Cables, Amperes Per Conductor

Power Conductor Size, AWG or kcmil	Single Conductor				Two Conductor	Three Conductor				Four Conductor	Five Conductor	Six Conductor
	2000 Volts or less Non-shielded	2001–8000 Volts* Shielded	8001–15000 Volts* Shielded	15001–25000 Volts* Shielded	Up to 2000 Volts	Up to 5000 Volts Non-shielded	Up to 8000 Volts Shielded	8001–15000 Volts Shielded	15001–25000 Volts Shielded	Up to 2000 Volts	Up to 2000 Volts	Up to 2000 Volts
8	83	...	...	...	72	59	...	...	...	54	50	48
6	109	112	...	...	95	79	93	...	...	72	68	64
4	145	148	...	...	127	104	122	...	...	93	88	83
3	167	171	...	...	145	120	140	...	...	106	100	95
2	192	195	195	...	167	138	159	164	178	122	116	110
1	223	225	225	222	191	161	184	187	191	143	136	129
1/0	258	260	259	255	217	186	211	215	218	165	...	...
2/0	298	299	298	293	250	215	243	246	249	192	...	...
3/0	345	345	343	337	286	249	279	283	286	221	...	...
4/0	400	400	397	389	328	287	321	325	327	255	...	...
250	445	444	440	430	363	320	355	359	360	280	...	...
300	500	496	491	480	400	357	398	...	...	310	...	...
350	552	549	543	529	436	394	435	...	...	335	...	...
400	600	596	590	572	470	430	470	...	...	356	...	...
450	650	640	633	615	497	460	503	...	...	377	...	...
500	695	688	678	659	524	487	536	...	...	395	...	...
550	737	732	...	...	...	...	...	...	...	...	...	...
600	780	779	...	...	...	...	...	...	...	...	...	...
650	820	817	...	...	...	...	...	...	...	...	...	...
700	855	845	...	...	...	...	...	...	...	...	...	...
750	898	889	...	...	...	...	...	...	...	...	...	...
800	925	925	...	...	...	...	...	...	...	...	...	...
900	1010	998	...	...	...	...	...	...	...	...	...	...
1000	1076	1061	...	...	...	...	...	...	...	...	...	...

*These ampacities are based on single isolated cable in air operated with open-circuited shield.

NOTE—These ampacities are based on a conductor temperature of 90°C and an ambient air temperature of 40°C.

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	...	...

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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 N-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	Approximate 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	110	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 per1000 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 Outside 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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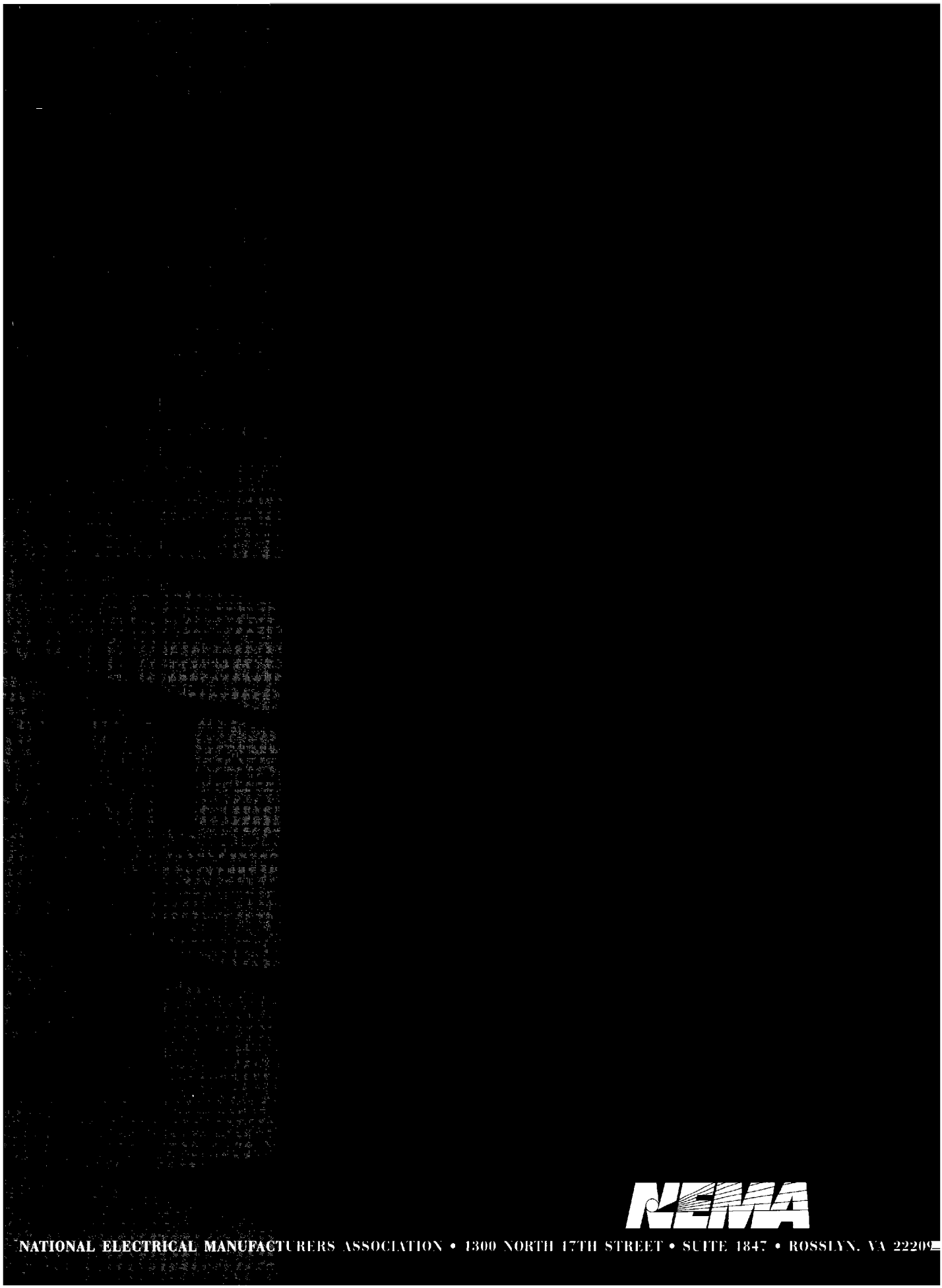

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