A-33-01

National Electrical Manufacturers Association
2101 L Street, N.W. Suite 300
Washington, D.C. 20037 (202) 457-8400

PROPOSED, NEW AND REVISED STANDARDS

VRS Page 131
March 18, 1988

TO ALL REPRESENTATIVES OF MEMBER COMPANIES IN THE
POWER AND CONTROL CABLE SECTION

Subject: Revision No. **4** to NEMA Standards Publication for *Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* NEMA Pub. No. **WC 7-1982** , ICEA Pub. No. **S-66-524**.

Dear Representative:

Revision No. **4**, consisting of printed pages dated JULY and NOVEMBER 1987 is enclosed for insertion into your copy of the subject publication. Also enclosed is a new title page to indicate that your book now contains Revision Nos. **1**–**4** as dated on the title page.

To bring your copy of ICEA Publication No. S-66-524, WC 7 up to date, please insert the attached revised pages in their proper place and delete the pages they replace. Note that pages 79–86 are enclosed for repagination and include an updated reference to WC 26-1984 in place of rescinded document WC 6-1975 (R 1980).

Sincerely,

Krystyna McIver

Krystyna McIver
Standards Publications Editor
NEMA

Encl: Revision No. 4 to ICEA S-66-524, WC 7-1982.
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PROPOSED, NEW AND REVISED STANDARDS

VRS Page 127
March 31, 1987

TO ALL REPRESENTATIVES OF MEMBER COMPANIES IN THE POWER AND CONTROL CABLE SECTION

Subject: Revision No. **3** to NEMA Standards Publication for *Cross-Linked Thermosetting Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* NEMA Pub. No. **WC 7-1982, ICEA No. S-66-524**

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Sincerely,

Krystyna Bagnato

Krystyna Bagnato
Standards Publications Editor
NEMA

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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

2101 L STREET N.W. WASHINGTON, D.C. 20037

Proposed, New and Revised Standards

March 27, 1985

TO ALL REPRESENTATIVES OF MEMBER COMPANIES
IN THE POWER AND CONTROL CABLE SECTION

Subject: Editorial Revision No. **2** to the ICEA/NEMA Standards Publication for *Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* ICEA Publication No. **S-66-524,** NEMA Publication No. **WC 7-1982**

Dear Representative:

For your convenience, the back of this letter contains a checklist of pages which now comprise ICEA S-66-524, NEMA WC 7-1982.

Sincerely Yours,

Carol Cross

Carol Cross
Standards Publications Editor

Copies to: All known holders of WC 7-1982
Technical Committee

CSC/mbh

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MARCH 1985

The following pages now comprise the ICEA/NEMA Standards Publication on *Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* ICEA Publication No. S-66-524 (Second Edition), NEMA Publication No. WC 7-1982.

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	Foreword	Undated
	i through v	December 1984
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2	2 and 3	December 1984
	4	Undated
	5 and 6	December 1984
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	21 through 28	Undated
	29 through 32	December 1984
	33	Undated
5	34	December 1984
6	35 through 37	December 1984
	38 through 40	Undated
	41 through 44	December 1984
	45 and 46	Undated
	47 through 53	December 1984
7	54 through 57	December 1984
	58	Undated
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	61 and 62	December 1984
	63 through 67	Undated
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	72 through 74a* and 75	December 1984
	76 and 77	Undated
	78 and 79	December 1984
	80	Undated
8	81 through 85	December 1984
	86	Undated
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Proposed, New and Revised Standards

VRS Page 118
January 9, 1985

TO ALL REPRESENTATIVES OF MEMBER COMPANIES
IN THE POWER AND CONTROL CABLE SECTION

Subject: Revision No. **1** to the ICEA/NEMA Standards Publication for **Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,** ICEA Publication No. **S-66-524** NEMA Publication No. **WC 7-1982**

Dear Representative:

The first set of revised printed pages, dated December 1984, is enclosed for insertion in your copy of the subject publication. These pages will bring your book completely up to date.

A new cover, indicating that your book now includes Revision 1 is enclosed. Also, enclosed are the revised pages of the detailed table of contents.

Please insert the revised pages carefully as extra copies are not available.

Sincerely yours,

Carol Cross

Carol Cross
Standards Publications Editor

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ICEA PUBLICATION NO. S-66-524
NEMA STANDARD PUBLICATION NO. WC 7

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

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ICEA PUB. NO. S-66-524
NEMA WC 7-1982

WC 7

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

Revision No. 1—December 1984
Revision No. 2—March 1985
Revision No. 3—August 1986
Revision No. 4—November 1987

Approved by Insulated Cable Engineers Association, Inc.

Prior to publication, all NEMA Standards and Authorized Engineering Information which appear in this publication unchanged since their appearance in WC 7-1971 (R 1976) (or in interim revisions 1 through 9) were reaffirmed by the National Electrical Manufacturers Association on May 12, 1982. Revisions appearing for the first time in this 1982 edition of WC 7 were approved by NEMA on July 16, 1981, and May 12, 1982. Publication of the 1982 edition occasioned the renumbering of some paragraphs, tables, and appendices; but the substantive content of the text remains unchanged.

Approved as an ICEA/NEMA Publication on May 12, 1982.

Published by:

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037
(202) 457-8400

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Section 1
GENERAL

1.1 SCOPE

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

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:

1.3.1 Characteristics of System on Which Cable is to be Used

1. Current—alternating or direct.
2. Frequency—hertz.
3. Normal operating voltage between phases or, if direct current, between conductors.
4. Number of phases and conductors. If series lighting, give open-circuit voltage and state whether system is operated with or without protectors.
5. Cable insulation level (see 3.2).
6. Minimum temperature at which cable will be installed.
7. Description of installation.
   a. In buildings.
   b. In underground ducts.
   c. Aerial.
      (1) On messenger in metal rings.
      (2) On messenger with marlin ties.
      (3) Preassembled.
      (4) Field spun.
   d. Direct burial in ground.
   e. Submarine.
   f. Descriptions other than the foregoing.
8. Conditions of installations.
   a. Ambient temperature.
   b. Number of loaded cables in duct bank or conduit. If in conduit, give type of conduit (metallic or nonmetallic), number of loaded conduits, enclosed or exposed, and spacing between conduits.
   c. Load factor.
   d. Method of bonding and grounding of metallic coverings (including shields).
   e. Wet or dry location.
   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 2-6.

c. Approximate conductor weights.

Authorized Engineering Information 7-14-1982.

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.

2.3 STRANDED CONDUCTORS

Stranded conductors shall consist of a number of wires individually meeting the appropriate requirements of 2.1. All wires in a stranded conductor shall be of the same material and temper.

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Table 2-1
Solid Aluminum 1350 and Aluminum Alloy Conductors

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

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

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

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

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

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

2.4 CONDUCTOR SIZE UNITS

Conductor size shall be expressed by cross-sectional area in thousand circular mils (kcmil). The AWG equivalents for small sizes shall be found in Table 2-7.

2.5 CONDUCTOR DC RESISTANCE PER UNIT LENGTH

The dc resistance per unit length of each conductor in a production or shipping length of completed cable shall not exceed the value determined from the schedule of maximum dc resistances specified in Table 2-3 when using the appropriate nominal value specified in Table 2-4, Table 2-5 and Table 2-6. The dc resistance shall be determined in accordance with 2.5.1 or 2.5.2. ▲

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

2.5.1 Direct Measurement of dc Resistance Per Unit Length

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

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

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 foot (30.5 cm) long shall be cut from that reel length, and the direct-current resistance of each conductor shall be measured using a Kelvin-type bridge or a potentiometer.

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

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

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

Authorized Engineering Information 7-14-1982.

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
Over 427 wires	1.06
Bunched Strand, single bunches	
All sizes	1.02
Rope-lay Strand Having Bunch-stranded Members, Classes I, K and M	
7 bunch stranded members	1.04
19	1.05
37	1.05
61	1.05
7 × 7 bunch stranded members	1.06
19 × 7	1.07
37 × 7	1.07
61 × 7	1.07

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

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

2.7 STRESS CONTROL LAYER

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

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

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.

▲

▲ Para. 2.7.1.2 deleted.

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Table 2-3 ▲
Schedule for Establishing Maximum Direct Current 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 Cables and Flat Parallel Cables	Table 2-5[a] or 2-6[a] Value Plus 2%[b] (R max = R × 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-5[a] or 2-6[a] Value Plus 2%[b] Plus 5% (R max = R × 1.02 × 1.05)

[a] For conductor strandings or sizes not listed in Tables 2-4 through 2-6 the nominal direct current resistance per unit length of a completed single conductor cable shall be calculated from the factors given in Table 2-8 using the following formula:

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

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

See 2.5.2 for cross-sectional area determination

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

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Table 2-4
Nominal Direct Current Resistance in Ohms Per 1000 Feet** at 25°C (77°F) of Solid and Concentric Lay stranded Conductor

Conductor Size	Solid			Concentric Lay Stranded*				
	Aluminum	Copper		Aluminum	Copper			
AWG or kcmil		Uncoated	Coated	Class, B, C, D	Uncoated	Coated		
					Class B, C, D	Class B	Class C	Class D
22	27.1	16.5	17.2	27.4	16.7	17.9	...	...
20	16.9	10.3	10.7	17.3	10.5	11.1	...	...
19	13.5	8.20	8.52	13.7	8.33	8.83	...	...
18	10.7	6.51	6.76	10.9	6.67	7.07	...	...
17	8.45	5.15	5.35	8.54	5.21	5.52	...	...
16	6.72	4.10	4.26	6.85	4.18	4.43	...	...
15	5.32	3.24	3.37	5.41	3.30	3.43	...	...
14	4.22	2.57	2.67	4.31	2.63	2.73	2.79	2.83
13	3.34	2.04	2.12	3.41	2.08	2.16	2.21	2.22
12	2.66	1.62	1.68	2.72	1.66	1.72	1.75	1.75
11	2.11	1.29	1.34	2.15	1.31	1.36	1.36	1.39
10	1.67	1.02	1.06	1.70	1.04	1.08	1.08	1.11
9	1.32	0.808	0.831	1.35	0.825	0.856	0.856	0.874
8	1.05	0.640	0.659	1.07	0.652	0.678	0.678	0.680
7	0.833	0.508	0.522	0.851	0.519	0.538	0.538	0.538
6	0.661	0.403	0.414	0.675	0.411	0.427	0.427	0.427
5	0.524	0.319	0.329	0.534	0.325	0.338	0.339	0.339
4	0.415	0.253	0.261	0.424	0.258	0.269	0.269	0.269
3	0.329	0.201	0.207	0.336	0.205	0.213	0.213	0.213
2	0.261	0.159	0.164	0.266	0.162	0.169	0.169	0.169
1	0.207	0.126	0.130	0.211	0.129	0.134	0.134	0.134
1/0	0.164	0.100	0.102	0.168	0.102	0.106	0.106	0.106
2/0	0.130	0.0794	0.0813	0.133	0.0810	0.0842	0.0842	0.0842
3/0	0.103	0.0630	0.0645	0.105	0.0642	0.0667	0.0669	0.0669
4/0	0.0819	0.0500	0.0511	0.0836	0.0510	0.0524	0.0530	0.0530
250	0.0694	...	...	0.0707	0.0431	0.0448	0.0448	0.0448
300	0.0578	...	...	0.0590	0.0360	0.0374	0.0374	0.0374
350	0.0495	...	...	0.0505	0.0308	0.0320	0.0320	0.0320
400	0.0433	...	...	0.0442	0.0269	0.0277	0.0280	0.0280
450	0.0385	...	...	0.0393	0.0240	0.0246	0.0249	0.0249
500	0.0347	...	...	0.0354	0.0216	0.0222	0.0224	0.0224
550	...	...	...	0.0321	0.0196	0.0204	0.0204	0.0204
600	...	...	...	0.0295	0.0180	0.0187	0.0187	0.0187
650	...	...	...	0.0272	0.0166	0.0171	0.0172	0.0173
700	...	...	...	0.0253	0.0154	0.0159	0.0160	0.0160
750	...	...	...	0.0236	0.0144	0.0148	0.0149	0.0150
800	...	...	...	0.0221	0.0135	0.0139	0.0140	0.0140
900	...	...	...	0.0196	0.0120	0.0123	0.0126	0.0126
1000	...	...	...	0.0177	0.0108	0.0111	0.0111	0.0112
1100	...	...	...	0.0161	0.00981	0.0101	0.0102	0.0102
1200	...	...	..	0.0147	0.00899	0.00925	0.00934	0.00934
1250	...	...	...	0.0141	0.00863	0.00888	0.00897	0.00897
1300	...	...	...	0.0136	0.00830	0.00854	0.00861	0.00862
1400	...	...	...	0.0126	0.00771	0.00793	0.00793	0.00801
1500	...	...	...	0.0118	0.00719	0.00740	0.00740	0.00747
1600	...	...	...	0.0111	0.00674	0.00694	0.00700	0.00700
1700	...	...	...	0.0104	0.00634	0.00653	0.00659	0.00659
1750	...	...	...	0.0101	0.00616	0.00634	0.00640	0.00640
1800	...	...	...	0.00982	0.00599	0.00616	0.00616	0.00622
1900	...	...	...	0.00931	0.00568	0.00584	0.00584	0.00589
2000	...	...	...	0.00885	0.00539	0.00555	0.00555	0.00560
2500	...	...	...	0.00715	0.00436	0.00448	...	...
3000	...	...	...	0.00596	0.00363	0.00374	...	...
3500	...	...	...	0.00515	0.00314	0.00323	...	...
4000	...	...	...	0.00451	0.00275	0.00283	...	...
4500	...	...	...	0.00405	0.00247	0.00254	...	...
5000	...	...	...	0.00364	0.00222	0.00229	...	...

* Concentric lay stranded includes compressed and compact conductors.

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

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Table 2-5
Nominal Direct Current Resistance in Ohms Per 1000 Feet* At 25°C (77°F) For Flexible Aluminum Conductors

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

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

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Table 2-6
Nominal Direct Current Resistance in Ohms Per 1000 Feet* At 25°C (77°F) For Flexible Annealed Copper Conductors

Conductor Size	Uncoated					Coated				
	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
AWG or kcmil										
20	...	...	...	10.6	10.6	...	...	...	11.4	11.4
18	...	...	...	6.66	6.66	...	...	...	7.15	7.15
16	...	...	...	4.18	4.18	...	...	...	4.49	4.49
14	2.65	...	...	2.62	2.62	2.81	...	...	2.82	2.82
12	1.67	...	...	1.65	1.68	1.77	...	...	1.77	1.81
10	1.05	...	1.04	1.04	1.06	1.11	...	1.08	1.12	1.14
9	0.832	...	0.824	0.840	0.840	0.884	...	0.857	0.902	0.902
8	0.660	0.666	0.653	0.666	0.666	0.701	0.708	0.679	0.715	0.715
7	0.523	0.528	0.518	0.528	0.533	0.544	0.561	0.539	0.567	0.573
6	0.415	0.419	0.419	0.419	0.423	0.432	0.445	0.436	0.450	0.454
5	0.329	0.332	0.332	0.332	0.336	0.342	0.353	0.346	0.357	0.360
4	0.261	0.263	0.263	0.263	0.266	0.271	0.280	0.274	0.283	0.286
3	0.207	0.209	0.209	0.211	0.213	0.215	0.222	0.217	0.227	0.227
2	0.164	0.166	0.166	0.167	0.169	0.171	0.172	0.172	0.180	0.181
1	0.131	0.132	0.131	0.133	0.134	0.137	0.140	0.137	0.142	0.144
1/0	0.104	0.105	0.105	0.105	0.106	0.108	0.109	0.109	0.113	0.114
2/0	0.0826	0.0830	0.0834	0.0842	0.0850	0.0859	0.0863	0.0868	0.0904	0.0913
3/0	0.0655	0.0659	0.0662	0.0668	0.0674	0.0682	0.0685	0.0688	0.0717	0.0724
4/0	0.0520	0.0522	0.0525	0.0530	0.0535	0.0541	0.0543	0.0546	0.0569	0.0574
250	0.0442	0.0444	0.0448	0.0448	0.0453	0.0460	0.0462	0.0466	0.0481	0.0486
300	0.0368	0.0370	0.0374	0.0374	0.0377	0.0383	0.0385	0.0389	0.0401	0.0405
350	0.0316	0.0317	0.0320	0.0323	0.0323	0.0328	0.0330	0.0333	0.0347	0.0347
400	0.0276	0.0278	0.0280	0.0283	0.0283	0.0287	0.0289	0.0291	0.0304	0.0304
450	0.0246	0.0247	0.0249	0.0251	0.0251	0.0255	0.0257	0.0259	0.0270	0.0262
500	0.0221	0.0222	0.0224	0.0226	0.0226	0.0230	0.0231	0.0233	0.0243	0.0243
550	0.0202	0.0204	0.0204	0.0206	0.0206	0.0210	0.0212	0.0212	0.0221	0.0221
600	0.0185	0.0187	0.0187	0.0189	0.0189	0.0192	0.0194	0.0194	0.0203	0.0202
650	0.0171	0.0172	0.0174	0.0174	0.0174	0.0178	0.0179	0.0181	0.0187	0.0187
700	0.0159	0.0168	0.0162	0.0162	0.0162	0.0165	0.0167	0.0168	0.0174	0.0174
750	0.0148	0.0149	0.0151	0.0151	0.0151	0.0154	0.0155	0.0157	0.0162	0.0162
800	0.0139	0.0140	0.0141	0.0141	0.0141	0.0144	0.0146	0.0147	0.0152	0.0152
900	0.0123	0.0125	0.0126	0.0126	0.0126	0.0128	0.0130	0.0131	0.0135	0.0135
1000	0.0111	0.0112	0.0113	0.0113	0.0113	0.0115	0.0117	0.0118	0.0122	0.0121
1100	0.0101	0.0102	0.0103	...	...	0.0105	0.0106	0.0107	...	...
1200	0.00925	0.00934	0.00943	...	...	0.00962	0.00971	0.00981	...	...
1250	0.00888	0.00897	0.00905	...	...	0.00924	0.00933	0.00941	...	...
1300	0.00854	0.00862	0.00870	...	...	0.00888	0.00897	0.00905	...	...
1400	0.00793	0.00801	0.00808	...	...	0.00825	0.00833	0.00841	...	...
1500	0.00740	0.00747	0.00754	...	...	0.00770	0.00777	0.00785	...	...
1600	0.00701	0.00701	0.00707	...	...	0.00729	0.00729	0.00735	...	...
1700	0.00659	0.00659	0.00666	...	...	0.00686	0.00686	0.00692	...	...
1750	0.00641	0.00641	0.00647	...	...	0.00666	0.00666	0.00672	...	...
1800	0.00623	0.00623	0.00629	...	...	0.00648	0.00648	0.00654	...	...
1900	0.00590	0.00590	0.00596	...	...	0.00614	0.00614	0.00619	...	...
2000	0.00561	0.00561	0.00566	...	...	0.00583	0.00583	0.00588	...	...

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

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Table 2-7
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters*					
			Concentric Lay Stranded				
		Solid	Compact	Compressed	Class B	Class C	Class D
AWG	kcmil	Inch	Inch	Inch	Inch	Inch	Inch
22	0.812	0.0253	...	...	...	...	...
20	1.02	0.0320	...	...	...	...	...
19	1.29	0.0359	...	...	...	...	...
18	1.62	0.0403	...	...	...	...	...
17	2.05	0.0453	...	...	...	...	...
16	2.58	0.0508	...	...	...	...	...
15	3.26	0.0571	...	0.0629	0.0648	...	...
14	4.11	0.0641	...	0.0704	0.0727	0.0735	0.0735
13	5.18	0.0720	...	0.0792	0.0816	0.0825	0.0826
12	6.53	0.0808	...	0.0888	0.0915	0.0925	0.0931
11	8.23	0.0907	...	0.0998	0.103	0.104	0.104
10	10.38	0.1019	...	0.112	0.116	0.117	0.117
9	13.09	0.1144	...	0.126	0.130	0.131	0.132
8	16.51	0.1285	0.134	0.141	0.146	0.148	0.148
7	20.82	0.1443	...	0.158	0.164	0.166	0.166
6	26.24	0.1620	0.169	0.178	0.184	0.186	0.186
5	33.09	0.1819	...	0.200	0.206	0.208	0.209
4	41.74	0.2043	0.213	0.225	0.232	0.234	0.235
3	52.62	0.2294	0.238	0.252	0.260	0.263	0.264
2	66.36	0.2576	0.268	0.283	0.292	0.296	0.297
1	83.69	0.2893	0.299	0.322	0.332	0.333	0.333
1/0	105.6	0.3249	0.336	0.361	0.372	0.374	0.374
2/0	133.1	0.3648	0.376	0.406	0.418	0.420	0.420
3/0	167.8	0.4096	0.423	0.456	0.470	0.471	0.472
4/0	211.6	0.4600	0.475	0.512	0.528	0.529	0.530
	250	0.5000	0.520	0.558	0.575	0.576	0.576
	300	0.5477	0.570	0.611	0.630	0.631	0.631
	350	0.5916	0.616	0.661	0.681	0.681	0.682
	400	0.6325	0.659	0.706	0.728	0.729	0.729
	450	0.6708	0.700	0.749	0.772	0.773	0.773
	500	0.7071	0.736	0.789	0.813	0.814	0.815
	550	...	0.775	0.829	0.855	0.855	0.855
	600	...	0.813	0.866	0.893	0.893	0.893
	650	...	0.845	0.901	0.929	0.930	0.930
	700	...	0.877	0.935	0.964	0.965	0.965
	750	...	0.908	0.968	0.998	0.999	0.998
	800	...	0.938	1.000	1.030	1.032	1.032
	900	...	0.999	1.061	1.094	1.093	1.095
	1000	...	1.060	1.117	1.152	1.153	1.153
	1100	...	...	1.173	1.209	1.210	1.211
	1200	...	...	1.225	1.263	1.264	1.264
	1250	...	...	1.251	1.289	1.290	1.290
	1300	...	...	1.275	1.314	1.316	1.316
	1400	...	...	1.323	1.365	1.365	1.365
	1500	...	...	1.370	1.412	1.413	1.413
	1600	...	...	1.415	1.459	1.460	1.460
	1700	...	...	1.459	1.504	1.504	1.504
	1750	...	...	1.480	1.526	1.527	1.527
	1800	...	...	1.502	1.548	1.548	1.549
	1900	...	...	1.542	1.590	1.590	1.591
	2000	...	...	1.583	1.632	1.632	1.632

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

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Table 2-8*
Factors** for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet

Conductivity, Percent	All Sizes, Uncoated		Diameter of Individual Coated Copper Wires in Inches for Stranded Conductors				
	Aluminum	Copper	0.460 to 0.290, Inclusive	Under 0.290 to 0.103, Inclusive	Under 0.103 to 0.0201, Inclusive	Under 0.0201 to 0.0111, Inclusive	Under 0.0111 to 0.0010, Inclusive
	61	100	97.66	97.16	96.16	94.16	93.15
	25 °C	25 °C	25 °C	25 °C	25 °C	25 °C	25 °C
Rope Stranded							
49 strands	17865	10892	11153	11210	11327	11568	...
133 strands	18038	10998	11261	11319	11437	11681	...
259 strands	18125	11051	11315	11374	11492	11737	...
427 strands	18212	11104	11370	11428	11547	11793	...
Over 427 strands	18385	11209	11478	11537	11657	11905	...
Bunch Stranded							
All sizes	17691	10786	...	...	11217	11456	11579
Rope-stranded Bunches							
7 ropes of bunched strand	18038	10998	...	...	11437	11681	11806
19, 37, or 61 ropes of bunched strand	18212	11104	...	...	11547	11793	11920
7 × 7 ropes of bunched strand	18385	11209	...	...	11657	11905	12033
19, 37, or 61 × 7 ropes of bunched strand	18559	11315	...	...	11767	12018	12147
Concentric Stranded							
Up to 2000 kcmil	17692	10786	11045	11102	11217	11456	11580
> 2000 to 3000 kcmil	17865	10892	11153	11211	11327	11568	11694
> 3000 to 4000 kcmil	18039	10998	11261	11319	11437	11680	11807
> 4000 to 5000 kcmil	18212	11104	11369	11428	11547	11792	11921

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

A. Resistivity
1. A volume resistivity of 10.575 Ω·cmil/ft (100 % conductivity) at 25 °C for uncoated (bare) copper.
2. A 25 °C volume resistivity converted from the 20 °C values specified in ASTM B 33 or ASTM B 189 for coated copper.
3. A volume resistivity of 17.345 Ω·cmil/ft (61.0% conductivity) at 25 °C for aluminum.

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

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

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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 which contains 10 percent or more of carbon black and/or mineral fillers by weight. An unfilled cross-linked-polyethylene insulation is one which contains up to 2½ 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 not 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. There shall be no water in the stranded conductor of the cable as shipped.

3.2 INSULATION THICKNESSES

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

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

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

3.2.1.1 *For Three-Phase Systems with 100 or 133 Percent Insulation Level (Grounded or Ungrounded Neutral).* Use the thickness values given in the respective columns of Table 3-1.

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

3.2.1.3 *For Single- and Two-Phase Systems With 100 Percent Insulation Level (Grounded).* Multiply the voltage to ground by 1.73 and use the resulting voltage value to select the corresponding insulation thickness in the 100 percent insulation level column of Table 3-1.

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

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

3.3 INSULATION THICKNESS FOR FOR SUBMARINE CABLES

For submarine power cables, the average insulation thickness shall be as given in Table 3-1, except that for cables without a jacket or a sheath, it shall be not less than 60 mils.

3.4 REPAIRS

Repairs or joints in the insulation shall conform to the limitations on insulation thickness given in 3.2. Each length of insulated conductor containing repairs or joints shall meet the electrical requirements of 3.6 or 3.7, as applicable.

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Table 3-1
Conductor Sizes, Insulation Thicknesses and Test Voltages

Rated Circuit Voltage, Phase to Phase Volts*	Conductor Size, AWG or kcmil ▲	Insulation Thickness‡‡ for 100 and 133 Percent Insulation Levels† Column A mils▲	Column A mm	Column B mils	Column B mm	a-c Test Voltage, kV for 100 and 133 Percent Insulation Levels† Column A	Column B	d-c Test Voltage, kV for 100 and 133 Percent Insulation Levels† Column A	Column B	d-c Spark Test Voltage, kV for 100 and 133 Percent Insulation Levels Column A	Column B	a-c Spark Test Voltage, kV for 100 and 133 Percent Insulation Levels Column A	Column B
0 600	14 9‡	45	1.14	30	0.76	4.0	3.5	12.0	10.5	16.0	10.5	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
601 2000	14 9‡	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
2001 5000	Nonshield. See Note 3.	100 Percent Insulation Level**		133 Percent Insulation Level		100 Percent Insulation Level**	133 Percent Insulation Level	100 Percent Insulation Level	133 Percent Insulation Level				
					Shielded								
2001 5000	8 1000	90	2.29	90	2.29	13	13	...	...	...	...	...	...
5001 8000	6 1000	115	2.92	140	3.56	18	22	45	45	...	...	...	...
8001 15000	2 1000	175	4.45	215	5.46	27	33	70	80	...	...	...	...
15001 25000	1 1000	260	6.60	345	8.76	38	49	100	125	...	...	...	...
25001 28000	1 1000	280	7.11	...	...	42	...	105	...	...	...	...	...
28001 35000	1/0 1000	345	8.76	...	...	49	...	125	...	...	...	...	...

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

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

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

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

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

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

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

‡‡ Column A thicknesses (2000 volts or less) apply to single-conductor power cables for general application when a carbon-black pigmented insulation is used without a 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 with a carbon-black pigmented insulation without further covering for applications where installation and service conditions are such that the additional thickness for mechanical protection is not considered necessary for satisfactory operation. ▲

NOTE 1—Nonshielded cables without supplementary protective coverings shall have a carbon-black pigmented insulation which is resistant to sunlight.

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

NOTE 3—For single-conductor nonshielded cables with and without metallic jacket, see 7.5 and 7.6. For single- and multiple-conductor nonshielded cables with a metallic sheath or armor and for multiple-conductor nonshielded cables with a discharge-resistant jacket (see Table 4-1), the insulation thickness shall be 90 mils (2.29 mm) and the test voltage shall be 13 kV a-c or 35 kV d-c (see 3.5.2). ▲

NOTE 4—a-c voltages are rms values.*** ▲

NOTE 5—Column B a-c spart test voltages are taken from 71.1 of UL Standard 44, *Rubber Insulated Wires and Cables, 10th edition.*** ▲

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

*** Approved by NEMA as Authorized Engineering Information.

▲ Editorially revised.

3.5 INSULATION CLASSES AND REQUIREMENTS

3.5.1 The classes of insulation shall be as follows:

1. 2000 volts or less (see 3.6). ▲
2. 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 3-1.

The test voltages shall be based on the rated voltage of the cable and the size of the conductor and not on the apparent thickness of the insulation.

3.5.3 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 TEST

Each insulated conductor in the completed cable shall be tested in accordance with 6.15 and shall have an insulation resistance not less than that corresponding to a constant of 10000 at 15.6 °C (60 °F). The insulation resistance test is not required when the direct-current spark test or the alternating-current spark test is performed (see 3.5.2).

3.6.3 Accelerated Water Absorption Requirements (See 6.6)

The insulation shall meet the following requirements when tested in accordance with the electrical (EM-60) method as specified in 6.6.2.

Electrical Method	
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 TEST

Each insulated conductor in the completed cable shall be tested in accordance with 6.15 and shall have an insulation resistance not less than that corresponding to a constant of 20000 at 15.6 °C (60 °F).

3.7.2.3 PARTIAL-DISCHARGE EXTINCTION LEVEL (SEE 6.16)

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:

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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 (See 6.6)

The insulation shall meet the following requirements when tested in accordance with 6.6.

Dielectric constant after 24 hours, maximum	3.5
Increase in capacitance	
1–14 days, maximum, percent	3.0
7–14 days, maximum, percent	1.5
Stability factor after 14 days, maximum*	1.0
Alternate to stability factor—stability factor difference, 1–14 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. ▲

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. 0–5000 Volts	6.14.2	6.14.2	6.14.2	6.14.2
b. 5001 volts and over	6.14.2 and 6.14.3	6.14.2 and 6.14.3	6.14.2 and 6.14.3	6.14.2 and 6.14.3

* See Section 6 for:
6.14.2 alternating-current voltage test.
6.14.3 direct-current voltage test.
6.14.4 alternating-current spark test.
6.14.5 direct-current 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 which 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 (13.3N) for cables rated 2001 through 25000 volts and not less than 4 pounds (17.8N) for cables rated 25001 through 35000 volts (see 6.12.4).

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

This sentence is approved by NEMA as Authorized Engineering Information.

4.1.1.2 METAL COMPONENT

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

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

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

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

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

This paragraph is approved by NEMA as Authorized Engineering Information.

4.1.2 Multiple-Conductor Cables (See 4.2) ▲

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

4.1.3 Conductor Identification (See 5.5) ▲

4.2 SHIELDING LIMITS FOR POWER CABLE FOR FIXED LOCATIONS

4.2.1 Insulation shielding shall be used on power cables for fixed locations when intended for operation above the three-phase (line-to-line) operating voltages given in Table 4-3. To obtain the equivalent three-phase voltage for single-phase or two-phase alternating-current systems or for direct-current systems, multiply the line-to-line voltage by the factors given in Table 4-3.

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.
5. Damp conduits.

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JACKETS ▲

4.3 GENERAL

Jackets shall be of one of the types covered in 4.4 except that, for cable with an embedded metal component, the jacket shall be a non-metallic 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

4.4.2 Polyethylene, Black

This jacket shall consist of a black polyethylene compound suitable for exposure to sunlight and other atmospheric environments at temperatures between −55°C (−67°F) through +75°C (+167°C) 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.

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

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

●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 requirements in 4.4.6.

Physical requirements	
Tensile strength, minimun	
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

▲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 which is compatible with the other components of the cable.

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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 component	
mils	5
mm	0.127
Physical Requirements (see 6.4)	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	100
Aging Requirements (see 6.4)—after air oven test at 121°C ± 1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percent	100
Brittleness Temperature (see 6.4.15), not warmer than	−10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C (see 6.12), ohm-meters ▲	500 ▲

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. 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 Voltages for Single- or Two-phase a-c Systems or for d-c Systems

Single- and Two-phase a-c Systems ✲ and d-c Systems 5 000 Volts or Less	Single- and Two-phase a-c Systems ✲ Over 5 000 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.

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▲4.4.6 Discharge-Resisting Jackets (See Table 4-1)

For single-conductor non-shielded cables rated 2001-5000 volts phase to phase, see 7.6 and 7.7.

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 of Jackets Over Metallic Shielded Power Cable

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

Table 4-4

Jacket Thickness for Single-Conductor Nonshielded Cable—2000 Volts or Less (For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial and Direct Burial†)▲

Size, AWG or MCM	600 Volts or Less▲		601–2000 Volts	
	mils	mm	mils	mm
14	15	0.38	15	0.38
12	15	0.38	15	0.38
10	15	0.38	15	0.38
9	15	0.38	15	0.38
8	15	0.38	15	0.38
6	30	0.76	30	0.76
4	30	0.76	30	0.76
2	30	0.76	30	0.76
1	45	1.14	45	1.14
1/0	45	1.14	45	1.14
2/0	45	1.14	45	1.14
3/0	45	1.14	45	1.14
4/0	45	1.14	45	1.14
250	65	1.65	65	1.65
300	65	1.65	65	1.65
350	65	1.65	65	1.65
400	65	1.65	65	1.65
450	65	1.65	65	1.65
500	65	1.65	65	1.65
600	65	1.65	65	1.65
750	65	1.65	65	1.65
1000	65	1.65	65	1.65

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

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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 ▲ 100 and 133 Percent Insulation Level		5001–8000 Volts 100 Percent Insulation Level		5001–8000 Volts 133 Percent Insulation Level		8001–15000 Volts 100 Percent Insulation Level		8001–15000 Volts 133 Percent Insulation Level	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
8	45	1.14	...	...	...	...	...	...	...	...
6	60	1.52	60	1.52	60	1.52	...	...	...	...
4	60	1.52	60	1.52	60	1.52	...	...	...	...
2	60	1.52	60	1.52	60	1.52	80	2.03	...	...
1	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
1/0	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
2/0	60	1.52	80	2.03	80	2.03	80	2.03	80	2.03
3/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
4/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
250	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
300	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
350	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
400	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
450	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
500	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
600	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
750	80	2.03	80	2.03	80	2.03	80	2.03	110	2.79
1000	80	2.03	80	2.03	110	2.79	110	2.79	110	2.79

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

For all other sizes and voltages not tabulated above see Table 4-8, 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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4.5 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 borehold, 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 Divisions 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 nonmetallic 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-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.
4. Galvanized steel wire armor.
   a. Submarine cable.
   b. Dredge cable.
   c. Vertical riser, borehole, and shaft cable for end suspension.
   d. Direct burial in trenches and subjected to unusual longitudinal stress.

   Jute 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.†

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

* 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.

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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 cable, if several cables are to be pulled in together in one duct; if the sections are extra long; or if the handling is severe or awkward during installation as in some transformer vaults. **

4.5.4.3 MEASUREMENT OF THICKNESS OF LEAD

The thickness shall be measured in accordance with 6.8.

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

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.

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).

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.

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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 approved by NEMA as Authorized Engineering Information.)

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
0-1.000	0-25.4	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. 1⅝ 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 which shall be run through hot asphalt or tar compound before the application of the outer serving which shall be No. 1⅝ 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 which 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 the hot-dip or the electro-galvanizing process.

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 (28.1 kgf/mm²) nor more than 70000 psi (49.2 kgf/mm²). 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/meter²) of exposed surface. The weight of coating 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 ¼ inch (3.18 mm) in diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake and none of it can be removed from the strip by rubbing with the fingers.

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

4.5.6.4 Width

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

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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
0–0.450	0–11.43	0.750	19.0
0.451–1.000	11.46–25.40	1.000	25.4
1.001–1.400	25.43–35.56	1.250	31.8
1.401–2.000	35.59–50.80	1.500	38.1
2.001–3.500	50.83–88.90	2.000	50.8
3.501 and larger	88.93 and larger	3.000	76.2

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

4.5.6.5 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.

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
0–1.000	0–25.40	20	0.51
1.001 and larger	25.43 and larger	30	0.76

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

4.5.6.6 APPLICATION, LAY, AND SPACING

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

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

4.5.7 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. 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
0–0.500	0–12.70	0.500	12.7
0.501–1.000	12.73–25.40	0.750	19.0
1.001–2.000	25.43–50.80	0.875	22.2
2.001 and larger	50.83 and larger	1.000	25.4

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.

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

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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		Nominal Thickness: Aluminum and Zinc Tape	
inches	mm	mils	mm	mils	mm
0-1.500	0-38.10	20	0.51	25	0.64
1.501 & larger	38.13 & larger	25	0.64	30	0.76

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

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 which is longitudinally folded around the cable core, seam welded, and corrugated or by applying over the cable core a seamless sheath or tube which is then corrugated.

4.5.7a.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

4.5.7a.3.1 The armored cable shall be capable of being bent around a mandrel having a diameter of 14 times the cable diameter. The armor shall show no evidence of fracture visible to the unaided eye. The test shall be conducted in accordance with the procedure given in Section 6.

4.5.7a.4 CORROSION PROTECTION

4.5.7a.4.1 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 Divisions II and III (4.5.17 through 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/mm²) and not more than 70000 psi (49.2 kgf/

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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mm²). 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.

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

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

Table 4-17
Minimum Weights of Zinc Coating

Nominal Diameter of Coated Wire			Minimum Weight of Zinc Coating	
mils	mm	Size, BWG	Ounces per Square Foot of Exposed Wire Surface	Grams per Meter² of Exposed Wire Surface
238	6.05	4	1.00	305
220	5.59	5	1.00	305
203	5.16	6	1.00	305
165	4.19	8	0.90	275
134	3.40	10	0.80	244
109	2.77	12	0.80	244
83	2.11	14	0.60	183

Table 4-18
Mandrell Diameter for
Adherence of Coating Tests

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

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Table 4-19

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

Table 4-20

Tolerances in Diameter

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

4.5.8.5 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 bird-caging 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 first be run through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 1⅔) impregnated jute yarn applied with a short close lay, again run through hot asphalt or tar compound and finished by running through some suitable material which will prevent sticking of adjacent turns of the cable when wound on a reel.

4.5.10.2 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	1.14	80	2.03
0.751–1.000	19.08–25.40	45	1.14	65	1.65	95	2.41
1.001–2.500	25.43–63.50	65	1.65	80	2.03	110	2.79
2.501 and larger	63.53 and larger	65	1.65	95	2.41	125	3.18

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

4.5.11.2 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 which is identical with that on the cable and which 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. ▲

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

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.) ▲

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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.) ▲

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

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).

4.5.15 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. ▲

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 which is at least 10 mils (0.254 mm) larger than the diameter over the sheath but not over 40 mils (1.02 mm) larger. No movement of the 2-inch (50.8-mm) ring shall take place within a period of 1 minute when weight is applied to the upper end of the sample. The weight to be applied shall be equal to 10 pounds per inch (1.77 kn/m) of outside diameter of the metallic sheath minus the weight of the prepared sample, rounded off to the nearer half pound. ▲

4.5.15.4 COLD BEND

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

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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

4.5.16 Jackets Over Metallic Armor

Jackets, when used, shall be either thermoplastic as described in 4.5.16.1 or crosslinked 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 tightly thereto. They shall be either:

1. Polyvinyl chloride meeting the requirements of 4.4.1 except that the cold bend requirements shall be as given in 4.5.15.4, or
2. Black polyethylene meeting the requirements of 4.4.2, or
3. 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.

4.5.16.2 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 7.3.7.1, or
2. Chlorosulfonated polyethylene meeting the requirements of 7.3.7.3, or
3. Chlorinated polyethylene meeting the requirements of 7.3.7.4.

(Table 4-25 has been deleted on July 22, 1987.)

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, thermoplastic (4.4.3) Chlorosulfonated polyethylene (7.3.7.3)	Polyvinyl chloride (4.4.1) Polyethylene (4.4.2) Chlorinated polyethylene, crosslinked (7.3.7.4)

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. ▲

Table 4-26
Thickness of Jacket Over Metallic Armor

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

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● Added.

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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 50000 psi (35.2 kgf/mm²)] 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.

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.

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.

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/mm²)] 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.

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

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

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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

4.5.22.2 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.

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.

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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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 be 60 times the diameter of the largest insulated conductor.

5.3 FLAT TWIN CABLES

For flat twin cables with diameters over the individual conductor of 0.500 inch (12.70 mm) or less, filling is not required. For flat twin cables with diameters over the individual conductor of more than 0.500 inch (12.70 mm), filling shall be used to give a substantially flat surface parallel to the plane of the major axis.

Flat twin cables are not recommended where the diameter over the conductor insulation exceeds 1 inch (25.4 mm).

5.4 FILLERS

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

▲ 5.5 CONDUCTOR IDENTIFICATION

5.5.1 Power Cables

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

5.5.2 Control Cables

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

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) electrical tests on entire lengths of completed cables—see 6.14 to 6.16, inclusive, 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 or cable. To determine which tests are to be made, refer to the parts in this publication which set forth the requirements to be met by the particular material or type of cable.

6.2 TESTS ON SAMPLES

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

6.3 CONDUCTOR TEST METHODS

When samples are measured, they shall be selected in accordance with Table 6-2. ●

6.3.1 Method for Direct Current Resistance Determination

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

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

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

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

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

4. Resistance measurements shall be made to an accuracy of ± 0.15 percent. To 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 specimen at reference temperatures other than room temperature.)

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

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

6.3.2 Methods for Cross-Sectional Area Determination

6.3.2.1 Cross-sectional area by diameter measurement. The cross-sectional area shall be calculated as follows:

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

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 which 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 d-c Resistance to 25°C (77°F)

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

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

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

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

Where:

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

For more accurate determination of resistance, allowing for different conductivities, see *Copper Wire Tables,* National Bureau of Standards Handbook 100 or *Aluminum Wire Tables,* National Bureau of Standards Handbook 109 and ASTM B 193. (This paragraph is approved by NEMA as Authorized Engineering Information.)

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● Table 6-2
Number of Samples

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

▲

▲ Table 6-3 deleted.
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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.

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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	mm²		conductor feet	conductor meters
Less than 2000	Less than 610	Less than 250	Less than 127	none	...	...
Less than 1000	Less than 305	250 and larger	127 and larger	none	...	...
2000–50,000	610–15,240	Less than 250	Less than 127	1	6	1.8
1000–25,000	305–7620	250 and larger	127 and larger	1	3	0.9
More than 25,000	More than 7620					
First 25,000	First 7620	250 and larger	127 and larger	1	3	0.9
Each additional 25,000	Each additional 7620	250 and larger	127 and larger	1	3	0.9
More than 50,000	More than 15,240					
First 50,000	First 15,240	Less than 250	Less than 127	1	6	1.8
Each additional 50,000	Each additional 15,240	Less than 250	Less than 127	1	6	1.8

Table 6-5
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	...	...
2000-50000	610-15240	Less than 1.0	Less than 25.4	1	6	1.8
1000-25000	305-7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
		2.0 and larger	50.8 and larger	1	2	0.6
More than 50000	More than 15240					
First 50000	First 15240	Less than 1.0	Less than 25.4	1	6	1.8
Each additional 50000	Each additional 15240	Less than 1.0	Less than 25.4	1	6	1.8
More than 25000	More than 7620					
First 25000	First 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
Each additional 25000	Each additional 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
More than 25000	More than 7620					
First 25000	First 7620	2.0 and larger	50.8 and larger	1	2	0.6
Each additional 25000	Each additional 7620	2.0 and larger	50.8 and larger	1	2	0.6

6.4.4 Sampling of Insulation for Physical and Aging Tests

Samples of insulated conductors for the unaged and aged physical tests shall be selected in accordance with Table 6-4, 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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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, etc., shall be removed so that the test specimen will be smooth and of uniform thickness.

6.4.9 Specimen for Accelerated Aging Test

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

6.4.10 Calculation of Area of Test Specimens

6.4.10.1 Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be calculated from its maximum diameter.

6.4.10.2 Where a slice cut from the insulation by a knife held tangent to the wire is used and when the cross-section of the slice is the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken.

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

The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.*

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

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

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

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

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

6.4.11.1 Test Temperature

Physical tests shall be made at a room temperature note 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.

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6.4.11.3 TENSILE STRENGTH TEST

The tensile strength test shall be made with specimens prepared in accordance with 6.4.6 and 6.4.7. The length of all of the specimens for the test shall be equal. Gauge marks shall be 2 inches (51 mm) when using 6 inch (152 mm) specimens and 1 inch (25 mm) apart when using 4.5 inch (114 mm) specimens except that 1 inch (25 mm) gauge marks shall be used for polyethylene regardless of specimen length. Specimens shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (102 mm) except 2.5 inches (63.5 mm) for polyethylene. The specimen shall be stretched at the rate of 20 inches (508 mm) per minute jaw speed until it breaks. ▲

The tensile and elongation determinations for compounds for which the compound manufacturer certifies that the base resin content is more than 50 percent by weight of high density polyethylene (having a density of 0.926 Mg/m³ or greater), or total base polyethylene resin content (having a density of 0.926 Mg/m³ or greater), shall be permitted to be tested at a jaw separation rate of 2 inches per minute (51 mm per minute) as an alternate to 20 inches per minute (508 mm per minute).

Specimens shall break between the gauge marks and the tensile strength shall be calculated on the area of the unstretched specimen. Specimen length, gauge mark distance and jaw speed shall be recorded with the results.

▲ 6.4.11.4 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 at 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 gage 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 mm²).

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 as Authorized Engineering Information.) ▲

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

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

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6.4.12.2 Oxygen Pressure Test *

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 Crosslinked (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 oil, and suspended in air at room temperature for 4, ±½, hours, 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.

For all cables with conductors larger than 500 kcmil and for all cables rated 28,000 volts or over, one sample shall be taken for orders of between 10 000 and 40 000 feet (3048 and 12192 meters). One additional sample shall be tested for each additional 30 000 feet (9144 meters) or major fraction thereof.

For all cables rated 2001-25000 volts with conductor sizes 500 kcmil and less, one sample shall be taken for orders of between 25 000 and 100 000 feet (7620 and 30480 meters). One additional sample shall be tested for each additional 100 000 feet (30480 meters) or major fraction thereof.

For all cables rated 0 to 2000 volts with conductor sizes 500 kcmil and less, one sample shall be taken for orders of between 100 000 and 10 00000 feet (304800 meters) or major fraction thereof.

▲6.4.14 Solvent Extraction

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

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● Added.

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6.4.15 Physical Tests 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 square mm) in cross-section, shall be cut out of the test sample with a die. All three test specimens shall be tested and the results averaged.

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. One test sample shall be taken for the first 5000 to 20 000 feet (1524 to 6096 meters) of each cable construction and one additional sample for each additional 100 000 feet (30 480 meters). The gross length of each sample shall be 13 feet (3.96 meters) for cables rated 15 000 volts and less and 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-hertz 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

6.6.1 Test Sample

The test sample shall be taken from the insulated conductor prior to the application of any covering. One test sample for each test shall be taken for the first 5000 to 20000 feet (1524 to 6096 meters) of each cable construction and one additional sample for each additional 100000 feet (30 480 meters). The gross length of each sample shall be 15 feet (4.57 meters).

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

6.6.2 Electrical Method (EM-60)

A 15-foot (4.57-meter) test specimen of the insulated conductor shall be taken after vulcanization. Not earlier than 48 hours after vulcanization, the specimen shall be immersed in water.

The middle 10 feet (3.05 meters) of the test specimen shall be immersed in tap water which is maintained at 75°C ± 1°C for a period of 14 days, keeping the 2½ foot (0.76-meter) portion of each end above water as leakage insulation. A tightly fitting cover shall be placed directly above the water surface, with suitable watertight bushings for the ends of the specimen. The water level shall be kept constant.

The capacitance of the insulation shall be determined at an average stress of 80 volts per mil at a frequency of approximately 60 hertz after 1, 7 and 14 days' immersion. The power factor of the insulation at average stresses of 80 and 40 volts per mil shall be determined after 1 and 14 days' immersion. The increase in capacitance from 1 to 14 days and from 7 to 14 days shall be expressed as a percentage of the 1- and 7-day values, respectively. The power factor shall be expressed to the nearest 0.1 percent.

Stability Factor. The stability factor is the difference between the percentage power factor at 80 and at 40 volts per mil after the test specimen has been immersed in water at 75°C ± 1°C for the specified time. The alternate to stability factor is the 14-day stability factor minus the 1-day stability factor.

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

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

where—

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

6.7 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 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 measured by means of a micrometer caliper having flat surfaces on both the anvil and the end of spindle and graduated to read directly at least to mils, and preferably to tenths of a mil. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

6.8 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

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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.

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 mils (1.27 mm) ± 10 mils and smooth surfaces. From this sample, test specimens (see 6.4.5) 1 inch (25.4 mm) long and 5/16 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 5/16 inch (14.3 mm) wide, a molded sheet of the same compound may be used.

The thickness of the specimen, T_1, shall be measured with a Randall & Stickney, or equivalent, gauge having a ⅜-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, or equivalent, gauge 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

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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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 inch (38.1 mm) long, 0.5 inch (12.7 mm) wide, and 0.125 inch (3.18 mm) thick from each sample shall be molded from material taken from the completed cable. The temperature of the molded specimens shall be lowered at any suitable rate. A slit made with a razor blade, approximately 0.75 inch (19.0 mm) long and from 0.020 to 0.025 inch (0.51 to 0.64 mm) deep, shall be centrally located on one of the 1.5 inch 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 millimeters long and 32 millimeters in outside diameter. The cracking agent (Igepal CO-630, made by the GAF Corporation, or its equivalent) shall be added to completely cover the specimen. The test tube, suitably closed by means such as foil-covered cork, shall be placed in an oven at 50°C ± 1°C for 48 hours. At the end of this period, the specimens shall be removed, allowed to cool to room temperature, and inspected for cracking.

6.10.5 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 direct-current potential shall be applied between the two electrodes and the resistance shall be measured in accordance with ASTM D 257. The specific surface resistivity shall be calculated by the following formula:

$$P = 0.524\,RD$$

where—

P = Specific surface resistivity.
R = Surface resistance in megohms per 6-inch spacing.
D = Cable diameter in inches.

6.11.3 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 MCM	Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
8–2	6
1–3/0	8
4/0–500	10
Over 500	12

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

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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 which are to be energized.
4. The end electrodes, each alternate electrode and the conductor in each test specimen shall be grounded. A 60-hertz 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 deposit 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.)

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 which 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-hertz 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 25000 feet of completed cable, whichever is less.

6.12.2 Conductor Stress Control ▲

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

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

The volume resistivity shall be calculated as follows:

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

where—

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

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)

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beyond each potential electrode. When a high degree of accuracy is not required, this test may be made with only two electrodes spaced at least 2 inches (50.8 mm) apart. ▲

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

The volume resistivity shall be calculated as follows.

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

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 long, and all coverings over the extruded insulation shield shall be removed. ▲

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

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

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

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

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

6.12.5 Flame Test

6.12.5.1 The test apparatus shall consist of the following:

1. Test chamber of sheet metal 12 inches (305 mm) wide, 14 inches (356 mm) deep and 24 inches (610 mm) high, which is open at the top, and which is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.
2. Means for adjusting the position of the test specimen.
3. A 4-pound (1.8-kg) weight (for 8 AWG and smaller sizes) to be attached to the lower end of the test specimen to keep it taut.
4. Tirrill burner with an attached pilot light and mounted on a 20-degree angle block. The burner shall have a nominal bore of 3/8 inch (9.5 mm) and a length of aproximately 4 inches (102 mm) above the primary air inlets.
5. An adjustable steel angle (jig) attached to the bottom of the chamber to insure the correct location of the burner with relation to the test specimen.
6. Gas (a supply of ordinary illuminating gas at normal pressure).
7. Watch or clock with a hand which makes one complete revolution per minute.
8. Flame indicators consisting of strips of gummed kraft paper having a nominal thickness of 5 mils (0.127 mm) and a width of 1/2 inch (12.7 mm).*
9. Untreated surgical cotton.

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

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

6.12.5.2 The test shall be made in a room which is generally free from drafts of air, although a ventilated hood may be used if air currents do not affect the flame. One end of the test specimen approximately 22 inches (559 mm) in length shall be clamped in position at the upper end of the chamber, and (for 8 AWG and smaller) the 4-pound (1.8-kg) weight attached to keep the specimen taut. A paper indicator shall be applied to the specimen so that the lower edge is 10 inches (254 mm) above the point at which the inner blue cone of the test flame is to be applied. The indicator shall be wrapped once around the specimen, with the gummed side toward the conductor. The ends shall be pasted evenly together and shall project ¾ inch (19.0 mm) from the specimen on the opposite side of the specimen to that to which the flame is to be

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applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches (127 mm), with an inner blue cone 1½ inches (38.1 mm) high.

The temperature at the tip of the inner blue cone shall be not less than 836 °C (1500 °F).

A flat horizontal layer of untreated surgical cotton shall be placed on the floor of the chamber and centered directly under the specimen. The upper surface of the cotton shall be no more than 9½ inches from the point at which the inner blue cone touches the cable surface.

6.12.5.3 The burner, with only the pilot lighted, shall be placed in front of the sample so that the vertical plane through the stem of the burner includes the axis of the wire or cable. The angle block shall rest against the jig, which shall be adjusted so that there is a distance of 1½ inches (38.1 mm) along the axis of the burner stem between the tip of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for no less than 15 seconds, then reopened for 15 seconds, closed for no less than 15 seconds, etc., for a total of five 15-second flame applications. The flame shall not be reapplied until flaming of the specimen ceases of its own accord. During each application of flame, the position of the burner or specimen shall be adjusted, as necessary, so that the tip of the inner blue cone just touches the surface of the specimen.

The time intervals between flame applications and the duration of specimen burning after the final flame application shall be recorded.

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 which they represent shall be considered as meeting the requirements of this standards.▲

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 irregularities, 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 the 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.

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.

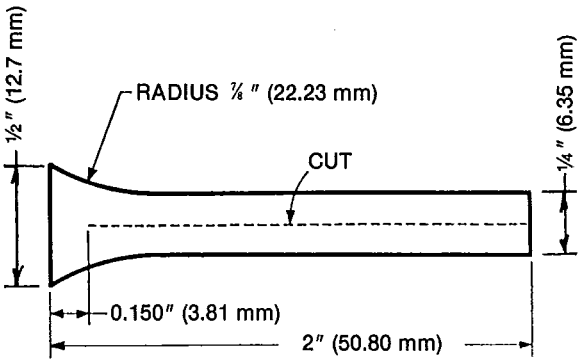

Figure 6-1
Test Specimen for Tear Test

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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 direct-current spark test and the alternating current spark test, the voltage shall be applied between the conductor or conductors and the metallic sheath, metallic shield, metallic armor, or water, and the rate of increase from the initially applied voltage to the specified test voltage shall be approximately uniform and shall be not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds. ▲

6.14.2 Alternating-Current Voltage Test

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

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

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

6.14.3 Direct-Current Voltage Test

This test is applicable to cables without insulation shield rated up through 5000 volts and to all cables rated 5001 volts and above and shall be made after the insulation resistance test described in 6.15. The equipment for the direct-current voltage test shall consist of a battery, generator or suitable rectifying equipment and shall be of ample capacity.

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

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

6.14.4 Alternating-Current 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.
5. Cables rated above 2000 volts.

6.14.4.2 TEST APPARATUS

The test apparatus shall consist of:

1. A source of single-phase alternating-current potential capable of maintaining the required voltage under all normal leakage current conditions.
2. An electrode capable of maintaining contact, throughout its length, with the periphery of the cable under test.
3. A means of measuring voltage between electrode and ground.
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:†

1. U.S. Customary Units Formula for Determining Maximum Speed of Cable

$$MS = \tfrac{5}{8} \times F \times EL$$

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

$$MS = \tfrac{1}{150} \times F \times EL$$

where—

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

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revised.

6.14.4.4 FAILURE

Any indication by the fault indicator shall constitute a failure.

6.14.5 Direct-Current Spark Test

This test is applicable to single-conductor cables and assemblies of insulated single-conductor cables without insulation shield, and without metallic sheath or metallic armor, rated 0 through 2000 volts. The equipment for the direct-current spark test shall consist of a direct-current sparker of ample voltage and a suitable electrode. The sparker shall be capable of maintaining the specified test voltage under all normal conditions of leakage current. The voltage shall be applied between the outside surface of the cable and the conductor(s) for not less than 0.05 second. The conductor(s) shall be grounded.

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

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

6.14.6 Cables Without Metallic Sheath, Metallic Shield or Metallic Armor

Except for the direct-current spark test (see 6.14.5) and the alternating current spark test (see 6.14.4), single-conductor cables of this type which are twisted together into an assembly of two or more conductors without an overall jacket or covering shall be immersed in water for at least 1 hour and tested while still immersed; all other single-conductor and multiple-conductor cables of this type shall be immersed in water for at least 6 hours and tested while still immersed. Each insulated conductor shall be tested against all other conductors connected to the grounded water tank. ▲

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 direct-current 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 Voltages 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	1/0–1000	100	...

6.15 INSULATION RESISTANCE

6.15.1 Test Apparatus

The test apparatus shall consist of a source of constant potential of from 100 to 500 volts and such other apparatus as is listed in ASTM D257.

6.15.2 Test Procedure

The insulation resistance shall be measured after the completed cable alternating-current voltage tests or before any direct-current voltage tests specified in 6.14. 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 shield, metallic sheath or water. Multiple-conductor cables without shielding over the individual insulated conductors shall be tested between each conductor and all other conductors and sheath or water. Multiple-conductor cables with shielded conductors shall be tested between the conductor and shield.

The conductor under test shall be connected to the negative terminal of the test equipment and readings shall be taken after an electrification of 1 minute.

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

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

where—

R = Insulation resistance in megohms-1000 feet.
K = Constant for the insulation. (See Part 3.)
D = Diameter over the insulation.
d = Diameter under the insulation.

If the temperature at the time of measurement differs from 15.6°C (60°F), the 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 be not 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 length to yield insulation resistance values under 25000 megohms at the lowest water bath temperature. ▲

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

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

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

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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 reading 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 PARTIAL-DISCHARGE TEST PROCEDURE

Refer to ICEA Publication T-24-380.

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 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 .015–.030 inch (.038–.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.

The capacity C, 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 measurement.

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

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

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

Following the capacitance measurement and while the specimen is held at the required temperature, a 60 Hz alternating current 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:

$$S = 2\,V/(D\text{-}d)\,1000$$

D and d in inches

V in volts, actual breakdown level

* S (V/mil) shall be expressed as MV/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 which 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 average thickness of this layer shall be not less than that shown in Table 7-2, and the minimum thickness at any point shall be not less than 80 percent of the values given in the table.

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
Insulation Shielding Thickness ▲

Calculated Insulation Diameter		Average Thickness	
inches	mm	mils	mm
Up through 1.000	Up through 25.40	30	0.76
1.001–1.500	25.43–38.10	50	1.27
1.501–2.000	38.13–50.80	70	1.78

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 (6) nor more than ten (10) 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 the 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 stated as follows:

Calculated Diameter Conductor		Average Jacket Thickness		a-c Spark Test Voltage (kV) for Nonconducting	
Inches	(mm)	Mils	(mm)	Crosslinked Jackets	Thermoplastic Jackets
0–1.500	0–38.0	50	1.27	2.0	4.5
Over 1.500	Over 38.0	80	2.03	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 minimum thickness of the extruded insulation shielding shall not be less than 70 percent of the specified average thickness 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 minimum thickness of the extruded insulation shielding shall be not less than 70 percent of the specified average thickness 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 conducting.

7.1.6.4 Spark Test for Nonconducting Jackets

A nonconducting jacket over concentric neutral conductors shall withstand the alternating current spark test voltage given in 7.1.6.1. 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

Physical Requirements	Type I	Type II
Tensile strength, minimum		
psi	1200	1500
MPa	8.27	10.34
Elongation at rupture, minimum percent of unaged value	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 of unaged value		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

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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 17000 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 4AWG 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.

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 than 4/0 AWG—19-wire strand (18 aluminum around 1 steel) or, where

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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 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	Thickness 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.

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 alternating-current 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 alternating-current voltages of 2001 to 15000 volts at 100 or 133 percent insulation level. These cables shall be of 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.▲ **

7.3.2 Conductors

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▲ Editorially revised.

† Editorially revised on July 22, 1987.

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7.3.2.1 POWER CONDUCTORS

Power conductors shall be Class B or C stranded annealed coated or uncoated copper or ¾ 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	1F
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.

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

Aluminum Insulated Power Conductor Sizes AWG or MCM	Neutral Conductor Sizes, AWG				
	Copper	Copper Covered Steel*	Aluminum 1350	ACSR	Aluminum Alloy 5005-H19 6201-T81
6	8	8C	6	6	6
4	6	6C	4	4	4
4	8	8C	...	6	6
2	4	4A	2	2	2
2	6	6C	...	4	4
1/0	2	2F	1/0	1/0	1/0
1/0	4	4A	...	2	2
2/0	1	1F	2/0	2/0	2/0
2/0	3	3A	...	1	1
3/0	1/0	1/0F	3/0	3/0	3/0
3/0	2	2F	...	1/0	1/0
4/0	2/0	2/0F	4/0	4/0	4/0
4/0	1	1F	...	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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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	24000
Medium hard copper	40000
1350 aluminum	17000

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 direct-current 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. ▲

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.

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

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

Conductor Size, AWG or MCM	Insulation Thickness		Outside Diameter		a-c 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 voltages by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.
†Unless otherwise indicated, the cable will be rated at 100 percent insulation level.

Table 7-11
Insulation Thicknesses and Outside Diameters

Conductor Size, AWG or MCM	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	a-c	d-c		mils	mm	inches	mm	a-c	d-c	
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.

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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

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

Conductor Size, AWG or MCM	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	0.0551	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

7.3.6 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.

▲ 7.3.7 Jacket

A thermosetting jacket which 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 which 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/mm²	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm²	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 chlorosulfonated-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, CROSSLINKED (THERMOSET)

This jacket shall consist of a crosslinked 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

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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 Section 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 alternating-current voltage of 3.0 kV for 15 seconds. The insulation resistance test is not required.

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 which 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

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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 which 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 X d
3	21 X d
4	23 X d
5	27 X d
6	30 X d

* d = diameter of individual power conductor.

7.4.3.2 TYPE G, WITH GROUNDING CONDUCTORS

These cables shall consist of two power conductors which 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 which meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-16.

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 which are separately covered with 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 which 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.

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

Power Conductor Size, AWG or MCM†	Insulation Thickness		Outside Diameter				Test Voltage, kV	
			Normal Service		Hard Service			
	mils	mm	inches	mm	inches	mm	a-c	d-c
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.

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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 MCM†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	a-c	d-c
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 MCM†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	a-c	d-c
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.

7.4.4.2 Type G, Round, With Grounding Conductors

These cables shall consist of three or four power conductors which 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 which 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.

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

These cables shall consist of three power conductors which 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 which 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.

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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 MCM†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	a-c	d-c
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 MCM†	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	a-c	d-c
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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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 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 which meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-20.

7.4.5.2 Type G, With Grounding Conductor (Five-Conductor Cables Only)

These cables shall consist of five power conductors which are separately covered with 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 power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7-14 around a single grounding conductor and covered with a jacket which 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 which 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 which 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 which meets the requirements of 7.4.18. These cables shall be in accordance with Table 7-22.

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	
					Five-conductor Type W and G		Six-conductor Type W			
	mils	mm	Size, AWG	Minimum Number of Strands	inches	mm	inches	mm	a-c	d-c
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 MCM†	Power Conductor Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
					Two-conductor Cables		Three-conductor Cables			
	mils	mm	Size AWG	Minimum Number of Strands	inches	mm	inches	mm	a-c	d-c
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 MCM†	Power Conductor Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
					Two-conductor Cables		Three-conductor Cables			
	mils	mm	Size AWG	Minimum Number of Strands	inches	mm	inches	mm	a-c	d-c
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.

7.4.8 Type G, Three-Conductor Round, With Grounding Conductors, 2001-5000 Volts

These cables shall consist of three power conductors which 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 which 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 0-25000 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 which meets the requirements of 7.4.16 with or without a tape over the shield, and a jacket which meets the requirements of 7.4.18. The cables shall be in accordance with Table 7-24.

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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	a-c	d-c
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.

7.4.9.2 Type SHC-GC Three-Conductor Cables 2000 Volts or Less ▲

These cables shall consist of three power conductors which 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 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 which meets the requirements of 7.4.16 and a jacket which 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, 25000 Volts or Less ▲

These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.4.15), and a shield which 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 which 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 25000 Volts or Less ▲

These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.4.15) and a shield which 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 which 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 not smaller than No. 10 AWG. The ground check conductor for Types G-GC, SHC-GC and SHD-GC shall be as 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 conductor 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 MCM†	Insulation Thickness		Jacket Thickness		Outside Diameter*		Test Voltage, kV	
	mils	mm	mils	mm	inches	mm	a-c	d-c
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 15000 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 25000 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*		a-c 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 be not 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.

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

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

(continued)

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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 MCM†	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	a-c	d-c
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 *(continued)*

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

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—

$$F = \frac{NP\,d}{\sin a}$$

a = Angle of braid with axis of cable

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

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 = π D cos a
D = Diameter under shield in inches
a = Angle between serving wires and axis of cable

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

C = Pitch of serving in inches

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

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Table 7-28
Conductors

Power Conductors						Grounding Conductors (Round Cables)							
						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 MCM	Minimum Number of Wires per Conductor	Diameter of Each Wire, mils	Diameter of Each Wire, mm	Conductor Diameter, inches	Conductor Diameter, 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	...	...	...	...	...	...	...	...

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 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/mm²	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm²	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

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7.4.18.1.2 HEAVY-DUTY NEOPRENE JACKET

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm²	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm²	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/mm²	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm²	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).

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

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm²	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm²	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/mm²	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm²	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30

(continued)

7.4.18.1.5 *(continued)*

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, CROSSLINKED

Physical requirements	
Tensile Strength, a 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
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

● Added

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● **7.4.18.1.8** EXTRA-HEAVY-DUTY CHLORINATED POLYETHYLENE, CROSSLINKED

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	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

7.4.18.2 THICKNESS OF JACKET

The average thickness of the jacket shall be not less than that given in Tables 7-23 through 7-27. The minimum thickness shall be not less than 80 percent of the values given in the tables. The reinforcing specified in 7.4.18.1 shall be included in the measurement of the jacket thickness.

7.4.19 Completed Cable

7.4.19.1 OUTSIDE DIAMETERS

Nominal outside diameters of the completed cables shall be in accordance with Tables 7-15 through 7-26.

7.4.19.2 DIAMETER TOLERANCES

The tolerance for outside diameters shall be plus 8 percent and minus 5 percent, except for 0-2000 volt nonshielded cables. For all 0-2000 volt nonshielded cables, the tolerances shall be as follows:

Size, AWG or MCM	Outside Diameter Tolerances, Plus and Minus, Inches
8–1	0.03
1/0–2/0	0.04
3/0–4/0	0.05
250–1000	0.06

● Added.

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7.4.20 Marking

The cable shall be identified throughout its length to indicate the manufacturer.

7.4.21 Tests

The cable shall be tested in accordance with Section 6 and shall meet the requirements specified in 7.4.

The insulated power conductor shall meet the test voltage requirements given in Table 7-15 through 7-26. The partial-discharge extinction level test is not required.

The insulated ground check conductor shall withstand for 15 seconds an alternating-current voltage of 3000 volts. The insulation resistance test is not required.

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 must be taken at joint and terminal locations to have a minimum length of separated conductors. Where field splices are 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 which meets the requirements of 4.4.1 polyvinyl chloride, 4.4.3 chlorinated polyethylene (thermoplastic), 7.3.7.1 neoprene, 7.3.7.2 nitrilebutadiene/polyvinyl chloride, 7.3.7.3 chlorosulfonated polyethylene or 7.3.7.4 chlorinated polyethylene (crosslinked) 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.

Table 7-29
Nonjacketed Cable

Conductor Size, AWG or MCM	Insulation Thickness		Test Voltage, kV	
	mils	mm	a-c	d-c
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 MCM	Insulation Thickness		Jacket Thickness		Test Voltage, kV	
	mils	mm	mils	mm	a-c	d-c
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

7.5.5 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

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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.

7.5.6.1.1 ALTERNATING-CURRENT VOLTAGE TEST (SEE 6.14)

The conductor shall withstand the alternating-current test voltage given in Table 7-29 or 7-30 for 5 minutes, except that the direct-current 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 20000 at 15.6 °C (60 °F).

7.5.6.1.3 DIRECT-CURRENT VOLTAGE TEST (SEE 6.14)

Upon completion of the insulation resistance test, the conductor shall withstand for 5 minutes the direct-current test voltage given in Table 7-29 or 7-30, unless the alternating-current 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 200000 megohms.

7.5.6.2.2 U-BEND DISCHARGE

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

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 a constant of 20000 at 15.6 °C (60 °F).

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 200000 megohms.

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Table 7-31
Insulation Thickness for Series Lighting Cable

Circuit Voltage, Volts*	Conductor Size, AWG	Insulation Thickness†		Test Voltage, kV		
		mils	mm	a-c	d-c	d-c 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‡.

Rating, kW	6.6 Ampere Secondary		20 Ampere Secondary	
	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

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

7.6.4.3.2 U-Bend Discharge

The sample shall be tested in accordance with 6.11.3 with an alternating-current 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 of 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

7.7.1 Scope

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

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

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

TYPE C—Control cables for connection to circuits with heavy magnetic trip or break devices, where inductively induced overvoltages may occur—maximum circuit voltage rating 1000 volts.

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

7.7.2 Conductors

7.7.2.1 Conductors shall be made of annealed coated or uncoated copper in accordance with Section 2.

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

7.7.3 Insulation

The insulation shall meet the requirements of 3.6 or 7.7.3.1.

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7.7.3.1 FLAME-RETARDANT INSULATION

7.7.3.1.1 PHYSICAL AND AGING REQUIREMENTS

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

Physical Requirements	
Tensile strength, minimum	
psi	1800
▲MPa	12.4
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, minimum, percentage of unaged value	60
Heat distortion at 121 °C ± 1 °C, maximum, percentage of unaged value	30

7.7.3.1.2 ACCELERATED WATER ABSORPTION REQUIREMENTS (SEE 6.6)

The insulation shall be tested in accordance with 6.6.2 and shall meet the following requirements:

Electrical Method (EM-60)	
Dielectric constant after 24 hours, maximum	6.0
Increase in capacitance, maximum, percent	
1 to 14 days	4.0
7 to 14 days	2.0
Stability factor after 14 days, maximum	1.0
Alternate to stability factor—stability factor difference, 1 to 14 days, maximum	0.5

7.7.3.1.3 FLAME TEST REQUIREMENTS

Unaged samples of insulated conductors shall be selected in accordance with 6.4.4 and tested in accordance with 6.12.5. Specimens shall not burn longer than 1 minute after any flame application. Not more than 25 percent of the extended portion of the indicator shall be burned. The cotton under the specimen shall not be ignited by flaming particles or drippings from the specimen. Flameless charring of the cotton shall not constitute failure.

7.7.3.2 THICKNESS

The average thickness of insulation shall be not less than that given in Table 7-32. The minimum thickness at any point shall be not less than 90 percent of that given in the table.

7.7.4 Covering Over Insulation

The individual conductors need not have any covering over the insulation but, if a covering is used, it shall be one of the materials given in 7.7.7 and shall have an average thickness of not less than 15 mils (0.38 mm) and a minimum thickness at any point of not less than 12 mils (0.30 mm).

7.7.5 Conductor Identification ▲

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

7.7.6 Assembly

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

7.7.7 Overall Jackets

† **7.7.7.1** Type A, B, and C cables shall have a jacket in accordance with one of the following:

Polyvinyl chloride	4.4.1
Polyethylene, black	4.4.2*
Chlorinated polyethylene, thermoplastic	4.4.3
Neoprene, heavy duty black	7.3.7.1
Nitrile-butadiene/polyvinyl chloride, heavy duty	7.3.7.2
Chlorosulfonated polyethylene, heavy duty	7.3.7.3
Chlorinated polyethylene, heavy duty, crosslinked	7.3.7.4

* Shall not be used for cables with flame-retardant insulation. (See 7.7.3.1.)

Table 7-32
Conductor Sizes, Insulation Thicknesses and Test Voltages*

Conductor Size, AWG	300 Volts*				600 Volts*				1000 Volts*			
	Insulation Thickness		Test Voltages, kV		Insulation Thickness		Test Voltages, kV		Insulation Thickness		Test Voltages, kV	
	mils	mm	ac	dc	mils	mm	ac	dc	mils	mm	ac	dc
20–18	20	0.51	2.0	6.0	25	0.64	2.5	7.5	...	...	...	...
16	20	0.51	2.0	6.0	25	0.64	2.5	7.5	45	1.14	4.5	13.5
14	25	0.64	2.5	7.5	30	0.76	3.0	9.0	45	1.14	4.5	13.5
12–9	...	..	..	...	30	0.76	3.0	9.0	45	1.14	4.5	13.5

* Where the insulation thickness is increased for mechanical reasons, the test voltage shall be determined by the size of the conductor and the rated voltage of the cable and not by the apparent thickness of the insulation.

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7.7.7.2 The average thickness of the jacket shall be not less than that given in Table 7-33. The minimum thickness at any point shall be not less than 80 percent of that given in the table.

Table 7-33
Overall Jacket Thickness

Calculated Diameter of Cable Under 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

7.7.8 Type D Cables

The design of Type D cables will depend on conditions of use. Belt insulation, shielding and outer protection may be required. The manufacturer should be consulted for further information. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

7.7.9 Tests

7.7.9.1 The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.7. ▲

7.7.9.2 Electrical tests on completed cable shall be in accordance with 6.14 and 6.15 except that the tests may be made without immersion in water. The insulation resistance shall be not less than that corresponding to a constant of 10000 at 15.6 °C (60 °F).

7.7.9.3 The insulated conductors shall withstand for 5 minutes either the alternating-current or direct-current test voltage given in Table 7-32.

7.8 METAL-CLAD CABLES WITH GROUNDING CONDUCTOR

7.8.1 Scope

This section covers two-, three- and four-conductor cross - linked - thermosetting - poly - ethylene-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 7-34.

7.8.2.2 CABLES RATED 2001 VOLTS AND ABOVE

The minimum size of the grounding conductor shall be as given in Table 7-35.

Table 7-34
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

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

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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.

Table 7-35
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

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Section 8
APPENDICES

Section 8 is classified by NEMA as Authorized Engineering Information.

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

Appendix B
REPRESENTATIVE TENSILE STRENGTH AND ELONGATION OF NONMAGNETIC METALS

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

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

C1.1 MAXIMUM CONDUCTOR TEMPERATURE—OPERATING

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

C1.2 MAXIMUM CONDUCTOR TEMPERATURE—EMERGENCY OVERLOAD

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

C1.3 MAXIMUM CONDUCTOR TEMPERATURE—SHORT CIRCUIT

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

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.

▲ Editorially revised.
● Editorially added.

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Appendix E
NEMA, ICEA AND ASTM STANDARDS

Publication No. and Year	Title

E.1 NEMA Publications

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

E.2 ICEA Publications

T-24-380, rev. 12/80	*Guide for Partial-Discharge Test Procedure. See Note 1*
P-46-426/IEEE #S-135 (SH007096)	*Power Cable Ampacities. See Note 3.*
P-53-426, 2nd Ed./ NEMA WC 50-1976	*Ampacities, Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable, 15 kV through 69 kV. See Note 2.*

E.3 ASTM Standards. See Note 4.

E.3.1 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 232-81	*Concentric-Lay-Stranded Aluminum Conductors, Coated Steel-Reinforced (ACSR), Specification for*
B 233-78	*Aluminum-Alloy 1350 Redraw Rod for Electrical Purposes, Specification for*
B 246-64 (1980)	*Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes, Specification for*
B 397-81	*Concentric-Lay-Stranded 5005-H19 Aluminum-Alloy Conductors, Specification for*
B 557-81	*Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products*
D 1248-81a	*Polyethylene Plastics Molding and Extrusion Materials, Specification for*
D 2132-68 (1979)	*Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials, Test for*
D 2765-68 (1978)	*Degree of Crosslinking in Crosslinked Ethylene Plastics as Determined by Solvent Extraction, Tests for*

E.3.2 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	*Weight of Coating on Zinc Coated (Galvanized) Iron or Steel Articles, Tests for*
B 1-81	*Hard-Drawn Copper Wire, Specification for*
B 2-81	*Medium-Hard Drawn Copper Wire, Specification for*
B 3-74 (1980)	*Soft or Annealed Copper Wire, Specification for*
B 5-80	*Tough-Pitch Electrolytic Copper Refinery Shapes, Specification for*
B 8-81	*Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Specification for*
B 29-79	*Pig Lead, Specification for*
B 33-81	*Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for*
B 172-71 (1980)	*Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, Specification for*
B 173-71 (1980)	*Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors, Specification for*
B 174-71 (1980)	*Bunch Stranded Copper Conductors for Electrical Conductors, Specification for*
B 189-81	*Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, Specification for*
B 193-78	*Resistivity of Electrical Conductor Materials, Test for*
B 229-81	*Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors, Specification for*
B 230-82	*Aluminum-Alloy 1350-H19 Wire, for Electrical Purposes, Specification for*
B 231-81	*Concentric-Lay-Stranded Aluminum-Alloy 1350 Conductors, Specification for*
B 243-58 (1981)	*Cross-Sectional Area of Stranded Conductors, Determination of*
B 399-81	*Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors, Specification for*
B 400-81	*Compact-Round Concentric-Lay-Stranded 1350 Aluminum-Alloy Conductors, Specification for*
B 496-81	*Compact Round Concentric-Lay-Stranded Copper Conductors, Specification for*
B 609-81	*Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes, Specification for*
D 257-78	*D-C Resistance or Conductance of Insulating Materials, Tests for*
D 412-80	*Rubber Properties in Tension, Tests for*
D 471-79	*Rubber Property—Effect of Liquids, Test for*
D 746-79	*Brittleness Temperature of Plastics and Elastomers by Impact, Test for*
D 1693-70 (1980)	*Environmental Stress-Cracking of Ethylene Plastics, Test for*
D 3349-74 (1978)	*Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic, Tests for*
E 8-82	*Tension Testing of Metallic Materials*

NOTE 1: Copies may be obtained from the Insulated Cable Engineers Association, Inc., P.O. Box P, South Yarmouth, MA 02664, USA.

NOTE 2: Copies may be obtained from NEMA Sales Office, National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, DC 20037, USA.

NOTE 3: Copies may be obtained from IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854, USA.

NOTE 4: Copies may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

NOTE 5: Copies may be obtained from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA.

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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:

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

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

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

For ampacities see the ICEA/NEMA Standards Publication *Ampacities Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable 15 kV through 69 kV*, ICEA P-53-426, Second Edition; NEMA WC 50-1976 (R 1982). ▲

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Appendix G ▲
SHIELDING

G1 DEFINITION OF SHIELDING

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

G2 FUNCTIONS OF SHIELDING

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

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

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

G3 USE OF INSULATION SHIELDING

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

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

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

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

G4 GROUNDING OF THE INSULATION SHIELD

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

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

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G5 SHIELD MATERIALS

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

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

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

G6 SPLICES AND TERMINATIONS

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

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

Appendix H ▲
RECOMMENDED BENDING RADII FOR CABLES

H1.1 SCOPE

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

H2.1 POWER CABLES WITHOUT METALLIC SHIELDING OR ARMOR

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

H3.1 POWER CABLES WITH METALLIC SHIELDING OR ARMOR

H3.1.1 Interlocked Armored Cables

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

H3.1.2 Flat Tape and Wire Armored Cables

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

H3.1.3 Shielded Cables

H3.1.3.1 TAPE SHIELDED CABLES

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

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

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

H3.1.3.2 WIRE SHIELDED CABLES

The minimum bending radii for all cables with wire shielding, except portable cables and armored cables, are given in H2.1. For portable cables see H4.1. For armored cables, see H3.1.1 and H3.1.2.

H4.1 PORTABLE CABLES

The minimum bending radius for portable cables during installation and handling in service is six times the cable diameter for cables rated 5000 volts and less and eight times the cable diameter for cables rated over 5000 volts. For flat-twin cables, the minor diameter is used to determine the bending radius.

H5.1 DRUM DIAMETERS OF REELS

See NEMA Pub. No. WC 26-1984, which is quoted in Table H-2.

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Table H-1

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

Table H-2
Excerpt from NEMA Standards Publication, *Wire and Cable Packaging*, WC 26-1984†

Type of Cable	Minimum Drum Diameter as a Multiple of Outside Diameter† of Cable			
	Type of Insulation			
	Paper			
	Solid and Gas	Oil Filled	Varnished Cloth	Extruded
A. Single and multiple conductor nonmetallic covered cable				
1. Nonshielded and wire shielded, including cables with concentric wires:				
a. 0–2000 volts	14	—	14	10
b. Over 2000 volts;				
(1) Nonjacketed with concentric wires	—	—	—	14
(2) All others	14	—	14	12
2. Tape shielded	14	—	14	14
B. Single- and multiple-conductor metallic-covered cable:				
1. Tubular metallic sheathed;				
a. Lead	14	14*	14	14
b. Aluminum;				
(1) Outside diameter—1.750″ and less	25	25	25	25
(2) Outside diameter—1.751″ and larger	30	30	30	30
2. Wire armored	16	18	16	16
3. Flat tape armored	16	18	16	16
4. Corrugated metallic sheathed	16	18	14	14
5. Interlocked armor	14	18	14	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 at the right	0.85	—	0.85	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 –0.50	—	—	—	26
0.51–1.00	—	—	—	24
1.01–1.25	—	—	—	22
1.26–1.50	—	—	—	21
Over 1.50	—	—	—	20

†Outside Diameter—

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

*For single-conductor cables with more than 500 mils of insulation, this factor is 18.

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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", IPCEA 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 follows:

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

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 Nonshielded	2001–8000 Volts* Shielded	8001–15000 Volts* Shielded	15001–25000 Volts* Shielded	Up to 2000 Volts	Up to 5000 Volts Nonshielded	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.

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Appendix K▲
CONDUCTOR IDENTIFICATION FOR CONTROL CABLES

K1 SCOPE

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

K2 *NATIONAL ELECTRICAL CODE* APPLICATIONS

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

K3 METHODS OF CONDUCTOR IDENTIFICATION

K3.1 Method 1—Colored Compounds with Tracers

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

Base and tracer colors should be recognizably the color combinations given in the tables and should approximately, but not necessarily exactly, match the color shades given in Table K-6.

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

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

K3.2 Method 2—Neutral Colored Compounds with Tracers

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

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

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

For example, using Table K-2, for conductors 1 to 3, inclusive:

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

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

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

K3.5 Method 5—Individual Color Coding with Braids

This method uses colored braids over the insulated conductors in accordance with Table K-2 or K-5. The shades of the colors should approximately match those identified by the numbers given in Table K-6 as found in the "Color Card" of the Color Association of the U.S., Inc., Tenth Edition. (Available from C.A.U.S., 24 East 38th Street, New York, NY 10016.)

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

K3.6 Method 6—Layer Identification

This method uses a distinctively identified conductor in each layer.

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K3.7 Method 7—Paired Conductors

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

Table K-1
COLOR SEQUENCE

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

Table K-2
COLOR SEQUENCE

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

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

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Table K-3
COLOR SEQUENCE

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

Table K-4
COLOR SEQUENCE

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

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

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Table K-5
COLOR SEQUENCE

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

Table K-6 †
SHADES OF COLOR

Color	Color Card (10th Edition) Designation*	Number	10th Edition
Black	...	...	...
White	White	(70001)	80002
Red	Scarlet	(70080)	80080
Blue	Marine Corps	(70048)	80048
Green	Emerald	(70063)	80063
Orange	Orange	(70069)	80069
Yellow	Jasmine	(70067)	80067
Brown	Brown	(70119)	80167

* Parenthetical number corresponds to the obsolete 9th Edition cross-reference number.

† Revised.

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Appendix L ▲
ADDITIONAL CONDUCTOR INFORMATION

Table L-1
Solid Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Approximate Weight			
	Aluminum		Copper	
	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
22	...	...	1.94	2.88
20	...	...	3.10	4.61
19	...	...	3.90	5.81
18	...	...	4.92	7.32
17	...	...	6.21	9.24
16	...	...	7.81	11.6
15	...	...	9.87	14.7
14	...	...	12.4	18.5
13	...	...	15.7	23.4
12	6.01	8.94	19.8	29.4
11	7.57	11.3	24.9	37.1
10	9.56	14.22	31.43	46.77
9	12.04	17.92	39.62	58.95
8	15.20	22.62	49.98	74.38
7	19.16	28.52	63.03	93.80
6	24.15	35.94	79.44	118.2
5	30.45	45.32	100.2	149.0
4	38.41	57.17	126.3	188.0
3	48.43	72.08	159.3	237.1
2	61.07	90.89	200.9	298.9
1	77.03	114.6	253.3	377.0
1/0	97.15	144.6	319.5	475.5
2/0	122.5	182.3	402.8	599.5
3/0	154.4	229.8	507.8	755.8
4/0	194.7	289.8	640.5	953.2
250	230.1	342.4	...	...
300	276.1	410.9	...	...
350	322.1	479.4	...	...
400	368.2	547.9	...	...
450	414.4	616.3	...	...
500	460.2	648.8	...	...

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▲Editorially revised.

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

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

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

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

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

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

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

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

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

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

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