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PROPOSED, NEW AND REVISED STANDARDS

VRS Page 132
February 24, 1988

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

Subject: Revision No. **10** to NEMA Standards Publication for *Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* NEMA Pub. No. WC 8, ICEA No. S-68-516.

Dear Representative:

Revision No. **10**, 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. **1–10** as dated on the title page.

To bring your copy of ICEA Publication No. S-68-516, WC 8 up to date, please insert the attached revised pages in their proper place in the publication and delete the pages they replace.

Sincerely,

Krystyna McIver
Standards Publications Editor
NEMA

Encl: Revision No. **10** to ICEA S-68-516, NEMA WC 8-1976 (R 1982)
Copies to: All known holders of WC 8.

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ICEA PUB. NO. S-68-516
NEMA WC 8-1976 (R 1982)

WC 8

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 1—September 1977
Revision No. 2—January 1978
Revision No. 3—August 1978
Revision No. 4—January 1979
Revision No. 5—May 1980
Revision No. 6—January 1983
Revision No. 7—December 1984
Editorial Revision No. 8—March 1985
Revision No. 9—August 1986
Revision No. 10—July 1987

This publication includes and supersedes the following Interim Standards which were previously published for inclusion in ICEA Pub. No. S-68-516, NEMA Pub. No. WC 8.

#1	August 1973	*Cables Rated 0-35000 Volts and Having Ozone-resistant Ethylene-propylene Rubber Insulation*
#2	August 1973	*Cables Rated 2000 Volts and Less and Having Ozone-resistant Ethylene-propylene-rubber Integral Insulation and Jacket*
#3	July 1971	*Primary Underground Residential Distribution Cables with Ethylene-propylene-rubber Insulation*
#4	July 1971	*Concentric-neutral Underground Distribution Cables with Ethylene-propylene-rubber Insulation*
#5	September 1973	*Mine Power Cables with Ethylene-propylene-rubber Insulation*
#6	September 1973	*Portable Single- and Multiple-conductor Cables with Ethylene-propylene-rubber Insulation*
#7	August 1973	*Nonshielded Single-conductor Power Cable with Ethylene-propylene-rubber Insulation, 2001-5000 Volts*

Approved by Insulated Cable Engineers Association, Inc.

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Part 3
INSULATION

3.1 Material. The insulation shall be an ethylene-propylene rubber meeting the dimensional, electrical and physical requirements specified in Part 3.

This insulation is suitable for use on cables in wet or dry locations at not more than 35,000 volts between phases at the 100 percent insulation level and at not more than 25,000 volts at the 133 percent insulation level. The conductor temperature shall not exceed 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.

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. For exceptions see 3.3.

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 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. 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. 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. 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 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. Over 2000 volts—consult the manufacturer.

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Table 3-1
CONDUCTOR SIZES, INSULATION THICKNESS AND TEST VOLTAGE

Rated Circuit Voltage, Phase to Phase, Volts*	Conductor Size, AWG or MCM	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	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	Nonshielded. See Note 2.												

		100 Percent Insulation Level **†		133 Percent Insulation Level †		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	...	....	....

(Continued)

▲ Revised 1-28-1976.
*Editorially revised on November 19, 1987.

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▲4.4.12 Jacket Thickness (See 6.4)

The average thickness of jackets shall be not less than those given in Tables 4-2, 4-3, 4-4, or 4-5. For the jacket thicknesses of cables not shown in these tables, see Table 4-6. The minimum thickness shall be not less than 80 percent of the values given in these tables. The tables do not apply to communication and portable cables and portable cords.

▲4.4.13 Separator Under Jacket

If used, a separator shall consist of compatible material.

†4.4.14 Discharge-Resisting Jacket (See Table 4-1)

For single-conductor nonshielded cables rated 2001-5000 volts phase to phase, see 7.9 and 7.10.

For multiple-conductor nonshielded cables rated 2001-5000 volts phase to phase, the overall jacket shall meet the requirements of 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, 4.4.10, or 4.4.11 and, in addition, shall have a specific surface resistivity of not less than 200,000 megohms (see 6.23.1 and 6.23.2).

Table 4-2
Single-Conductor Nonshielded Cable 2000 volts or less ▲
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial†)

Size, AWG or kcmil ▲	Jacket Thickness			
	0-600 Volts		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.

▲ Editorially revised.
† Revised.

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4.4.15 Irregularity Inspection of Jackets Over Metallic Shielding 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 for the jackets specified in paragraphs 4.4.1 through 4.4.11 inclusive are:

Method A	Method B	Method C
Neoprene (4.4.3)	Natural Rubber(4.4.1)	Polyvinyl Chloride (4.4.5)
Neoprene (4.4.4)	SBR (4.4.2)	Polyethylene (4.4.6)
	Chlorinated Polyethylene Thermoplastic (4.4.7)	Chlorinated Polyethylene Thermoset (4.4.11)
	Nitrile-butadiene/ Polyvinyl Chloride (4.4.8)	
	Nitrile-butadiene/ Polyvinyl Chloride (4.4.9)	
	*Chlorosulfonated Polyethylene (4.4.10)	

*Also known as Chlorosulfonyl Polyethylene

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METALLIC AND ASSOCIATED COVERINGS

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 and lighting circuit wires and cables. It also covers submarine cables.

Division II. (See 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shafts, 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 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 and Conditions of Installation.

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

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

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

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

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

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

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

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

Jute covering is not required on dredge and vertical riser cable. It is required on submarine, borehole and shaft cable where severe installation and service conditions exist. It is required for direct burial cable.

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

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Division I
Metallic and Associated Coverings
for Use Under Normal Conditions

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

4.5.4.1.1 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 B 29.

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

4.5.4.1.2 Thickness of Lead. The average thickness of the lead sheath shall be not less than the values given in Table 4-7. The minimum thickness shall be not less than 90 percent of the values given in the table. If protective jackets are used over the lead sheath, see 4.5.14.3 and 4.5.15.6 for the thickness of the lead sheath.

Table 4-7
Thickness of Lead Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
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, these thicknesses shall be 80 mils (2.03 mm).

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. **

4.5.4.1.3 Measurement of Thickness of Lead. The thickness shall be measured in accordance with 6.15.

4.5.4.1.4 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.

The lead may be stripped from the entire length of cable and the cable releaded.**

4.5.4.2 Aluminum Sheath

4.5.4.2.1 Type of Aluminum. A smooth sheath of aluminum 1060 or 1350 or equivalent▲ shall be tightly formed around the core of the cable.

4.5.4.2.2 Thickness of Aluminum. The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

▲ Editorially revised on November 19, 1987.

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The neoprene compound shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1200
▲MPa	8.27
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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, minimum, percentage of unaged value	60

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

4.5.14.2 Thickness. The average thickness of the thermosetting jacket shall be not less than that given in Table 4-20. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the jacket. ▲

The minimum thickness shall be not less than 80 percent of the values given in Table 4-20.

Table 4-20
Thickness of Thermosetting Jacket Over Metallic Sheath ▲

Calculated Diameter over Sheath		Thickness	
inches	mm	mils	mm
0-1.500	0-38.10	65	1.65
1.501-3.000	38.13-76.20	95	2.41
3.001 and over	76.23 and over	125	3.18

▲ 4.5.14.3 Thickness of Lead Sheath (See 6.15)

If a cross-linked jacket is applied over a lead sheath, the average thickness of the lead sheath shall be not less than that given in Table 4-21. The minimum thickness shall be not less than 90 percent of the values given in the table.

Table 4-21
Thickness of Lead Sheath for Cables Having a Cross-Linked Jacket or Thermoplastic Jacket Over Lead Sheath ▲

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

* The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.
† For submarine cables, these thicknesses shall be 70 mils (1.78 mm).

4.5.14.4 Thickness of Aluminum Sheath (See 6.15). If a cross-linked jacket is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2. ▲

4.5.15 Thermoplastic Jacket over Metallic Sheath

4.5.15.1 Thermoplastic Jacket. If used, a thermoplastic jacket shall be extruded over the metallic sheath and shall fit tightly thereto. It shall be either:

(a) Polyvinyl chloride meeting the requirements of 4.4, except that the cold-bend requirements shall be as given in 4.5.15.4, or

(b) Black polyethylene meeting the requirements of 4.4, or

● (c) Black chlorinated polyethylene meeting the requirements given in 4.4 except that the cold bend requirements shall be as given in 4.5.15.4.

▲ 4.5.15.2 Thickness. The average thickness of jacket shall be taken as one-half the difference in diameters and under the jacket as determined by circumference measurements and shall be not less than that given in Table 4-22. The minimum thickness of the jacket shall be determined by direct

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measurements with a micrometer, a steel scale with pocket glass, or a microscope on a ring of jacket removed from the cable and shall be not less than 70 percent of the values given in Table 4-22.

Table 4-22
Thickness of Thermoplastic Jacket Over Metallic Sheath

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

4.5.15.3 Tightness 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. There shall be no movement of the cable in relation to the ring 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 (1770 N/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 (See 6.18). Polyvinyl-chloride-jacketed cable shall show no cracks at a test temperature of -10°C or colder. In lieu of this test the manufacturer may submit evidence that the jacket compound has been tested on similar cable and meets this requirement.

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

(Table 4-23 has been deleted on July 22, 1987.)

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 4.4.5 except that the cold bend requirements shall be as given in 4.5.15.4, or
2. Black polyethylene meeting the requirements of 4.4.6, or
3. Chlorinated polyethylene meeting the requirements given in 4.4.7 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 4.4.3, or
2. Chlorosulfonated polyethylene meeting the requirements of 4.4.10, or
3. Chlorinated polyethylene meeting the requirements of 4.4.11.

4.5.16.3 Thickness. The average thickness of the jacket shall be not less than that specified in Table 4-24. 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 (4.4.3)	Chlorinated polyethylene, thermoplastic (4.4.7) Chlorosulfonated polyethylene (4.4.10)	Polyvinyl chloride (4.4.5) Polyethylene (4.4.6) Chlorinated polyethlene, crosslinked (4.4.11)

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Table 4-24
Thickness of Jacket Over Metallic Armor

Calculated Diameter of Cable Under Jacket		Jacket Thickness: All Cables (Except Interlocked or Corrugated Armored)▲		Jacket Thickness: 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

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 (4.5.3 through 4.5.16) pertaining to quality of materials, design and construction, apply also to borehole, dredge, shaft, and vertical riser cable (which are designed for special uses), except as to the particular details expressly set forth in the following sections for the respective types of cable, or as otherwise modified.

4.5.19 Borehole Cable (Suspended at One End Only)

4.5.19.1 Armor. Galvanized round steel wire shall be used for borehole cable.

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

▲ The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

Table 4-25
Size of Galvanized Steel Armor Wires for Borehole Cable

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

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 Wires. The size of the armor wires shall be as given in Table 4-26.

Table 4-26
Size of Galvanized Steel Armor Wires for Dredge Cable

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

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4.5.20.3 Pitch Ratio. The minimum pitch ratio shall be as given in Table 4-27.

Table 4-27
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

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

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires.

Where unusual service conditions exist, it may be desirable to modify the above pitch ratio. If so, it should be defined before the cable design is finalized.

4.5.21 Shaft Cable. If shaft cable is to be clamped to the shaft structure or wall, the metallic covering (either tape or wire) shall comply with the requirements of 4.5.3 through 4.5.16. If the shaft cable is to be suspended from one end, galvanized round steel wire armor shall be used.

The size of the armor wires shall be in accordance with 4.5.22.2, but the tensile safety factor shall be not less than five.

4.5.22 Vertical Riser Cable (Suspended at One End Only) for Installation Within Buildings

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

4.5.22.2 Size of Armor Wires for Nonsheathed Cable. The size of the armor wires shall be as given in Table 4-28.

The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.▲

Table 4-28
Size of Galvanized Steel Armor Wires for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
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

4.5.22.3 Size of Armor Wires for Sheathed Vertical Cable Riser. The size of armor wires 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. If wire band servings are used for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be applied over the armor. The length of the serving band and the spacing of the band throughout the length of the cable shall be as given in Table 4-29.

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

Table 4-29
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
2.501 and larger	63.53 and larger	25	7.6	4	102

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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.)

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

When measured over the wires, the average jacket thickness shall be not less that the appropriate value stated as follows:

Calculated Diameter Over Concentric 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

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 be not less than 70 percent of the specified average thickness found in Table 7.6-2.

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

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

After a jacket has been applied, the minimum thickness of the extruded insulation shielding shall be not less than 70 percent of the specified average thickness found in Table 7.6-2.

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

7.6.6.4 SPARK TEST FOR NONCONDUCTING JACKETS. A nonconducting jacket over the concentric neutral conductors shall withstand the alternating current spark test voltage given in 7.6.6.1. The voltage shall be applied between an electrode at the outside surface of the jacket and the concentric neutral conductor. The netural conductor shall be connected to ground during the test. The spark test shall be conducted in accordance with 6.27.4a.3 and 6.27.4a.4.

7.6.7 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.6. The partial-discharge extinction level shall be in accordance with Table 7.6-4. The electrical requirement tests shall be made without immersion in water.

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Table 7.6-7
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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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,* Publication No. WC 26-1984 *

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

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PROPOSED, NEW AND REVISED STANDARDS

VRS Page 128
March 20, 1987

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

Subject: Revision No. **9** to NEMA Standards Publication for *Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* NEMA Pub. No. **WC 8-1976 (R 1982),** ICEA Pub. No. **S-68-516**

Dear Representative:

Revision No. **9**, consisting of printed pages dated JUNE and NOVEMBER 1985 and MAY and AUGUST 1986, is enclosed for insertion into your copy of the subject publication. Also enclosed is a revised table of contents and a new title page to indicate that your book now contains Revision Nos. **1–9** as dated on the title page.

Note also that pages 45A through 45C in Part 7 have been repaginated and are now 46, 46A and 46B; there are *no* changes to this text, and the date of previous approval remains the same.

To bring your copy of ICEA Publication No. S-68-516, WC 8 up to date, please insert the attached revised pages in their proper place in the publication and delete the pages they replace.

Sincerely,

Krystyna Bagnato

Krystyna Bagnato
Standards Publications Editor
NEMA

Encl: Revision No. **9** to ICEA S-68-516, NEMA WC 8-1976 (R 1982)
Copies to: All known holders of WC 8.

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ICEA PUB. NO. S-68-516
NEMA WC 8-1976 (R 1982)

WC 8

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 1—September 1977
Revision No. 2—January 1978
Revision No. 3—August 1978
Revision No. 4—January 1979
Revision No. 5—May 1980
Revision No. 6—January 1983
Revision No. 7—December 1984
Editorial Revision No. 8—March 1985
Revision No. **9**—August 1986

This publication includes and supersedes the following interim Standards which were previously published for inclusion in ICEA Publication No. S-68-516, NEMA Publication No. WC 8:

1—August 1973	*Cables Rated 0-35000 Volts and Having Ozone-resistant Ethylene-Propylene Rubber Insulation*
2—August 1973	*Cables Rated 2000 Volts and Less and Having Ozone-resistant Ethylene-Propylene-Rubber Integral Insulation and Jacket*
3—July 1971	*Primary Underground Residential Distribution Cables with Ethylene-Propylene-Rubber Insulation*
4—July 1971	*Concentric-neutral Underground Distribution Cables with Ethylene-Propylene-Rubber Insulation*
5—September 1973	*Mine Power Cables with Ethylene-Propylene-Rubber Insulation*
6—September 1973	*Portable Single- and Multiple-Conductor Cables with Ethylene-Propylene-Rubber Insulation*
7—August 1973	*Nonshielded Single-Conductor Power Cable with Ethylene-Propylene-Rubber Insulation, 2001-5000 Volts*

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Foreword ▲

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

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

Requests for interpretation of this Standard must be submitted in writing to the Insulated Cable Engineers Association, P.O. Box P, South Yarmouth, Massachusetts 02664. An official written interpretation will be provided. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

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*A more detailed table of contents follows.

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

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

▲ Editorially revised.
● Editorially added.

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Part 1
GENERAL

1.1 Scope. These standards apply to materials, constructions and testing of ethylene-propylene-rubber-insulated wires and cables which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, such as indoor and outdoor installations, above and below grade, and submarine.

1.2 General Information. This publication is so arranged that cables can be designed for a broad range of installation and service conditions. Parts 2 to 4 cover the three major components of cables:

Part 2 - Conductors
Part 3 - Insulation
Part 4 - Shielding and Coverings

Each of these parts designates the materials, material characteristics, dimensions, and tests applicable to the particular component.

Specific attention is directed to 4.2 "Shielding Practice." A thorough understanding of these requirements is necessary to secure safe and reliable cable operation at voltages over 2 kV.

Part 5 deals with the assembly, cabling and identification of two or more conductors.

Part 6 covers the test procedures applicable to cable component materials and to completed cables.

Part 7 covers cables for specific service and installation conditions and gives construction details and additional or modified tests applicable to these particular types. If there is a conflict between Parts 1 through 6 and Part 7, the provisions of Part 7 apply.

Part 8 contains reference data such as definitions, abbreviations, cross-references to other standards, and application and installation information.

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

Units in these standards 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 describe the cable desired by reference to pertinent provisions of these standards. To help avoid misunderstandings and possible misapplication of the cables, he should also furnish the following information:

1.3.1 Characteristics of System on which Cable Is to Be Used

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

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1.3.2 Quantities and Description of Cable

(a) Total number of feet, including test lengths, and lengths if specific lengths are required.
(b) Type of cable. Describe as single conductor, two-conductor flat, two-conductor round, etc.
(c) Rated circuit voltage, phase to phase.
(d) Type of conductor—copper or aluminum.
(e) Size of conductors—AWG or circular mils. If conditions require other than standard stranding, a complete description should be given.
(f) Grade of insulation.
(g) Thickness of insulation in mils.
(h) Type of outer covering.
(i) Maximum allowable overall diameter in inches. When duct space is not limited, it is desirable not to restrict the overall diameter.
(j) Method of conductor identification.

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

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

$$R = K\rho/A$$

Where:

R = Conductor resistance in Ω/1000 ft.

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

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

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

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

Table 2-2

Weight Increment Factors*, K

Solid Conductors	1
Concentric-lay Strand, 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 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.▲

NEMA Authorized Engineering Information 7-14-1982.

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

2.7 Stress Control Layer (Conductor Shield). 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 6.11 shall meet the following requirements:

Elongation after air oven test at at 100 °C ± 1 °C for 48 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 6.24 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

2.7.1.2 An extruded nonconducting stress controlling material, when measured according to 6.31, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Permittivity (SIC), range	10—1000
60 hz ac voltage withstand stress, volts per mil, minimum	1500/permittivity

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Part 3
INSULATION

3.1 Material. The insulation shall be an ethylene-propylene rubber meeting the dimensional, electrical and physical requirements specified in Part 3.

This insulation is suitable for use on cables in wet or dry locations at not more than 35,000 volts between phases at the 100 percent insulation level and at not more than 35,000 volts at the 133 percent insulation level. The conductor temperature shall not exceed 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.

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. For exceptions see 3.3.

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 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. 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. 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. 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 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. Over 2000 volts—consult the manufacturer.

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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 MCM	Insulation Thickness## for 100 and 133 Percent Insulation Levels†				a-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels†		d-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels †		d-c Spark Test Voltage, kV for 100 and 133 Percent Insulation Levels	
		Column A		Column B							
		mils	mm	mils	mm	Column A	Column B	Column A	Column B	Column A	Column B
0-600	14-9‡	45	1.14	30	0.76	4.0	3.5▲	12.0	10.5▲	16.0	10.5▲
	8-2	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5
	1-4/0	80	2.03	55	1.40	7.0	7.0	21.0	21.0	28.0	21.0
	225-500	95	2.41	65	1.65	8.0	8.0	24.0	24.0	33.5	24.0
	525-1 000	110	2.79	80	2.03	10.0	10.0	30.0	30.0	38.5	30.0
601-2 000	14-9 ‡	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5
	8-2	70	1.78	55	1.40	7.0	7.0	21.0	21.0	24.5	21.0
	1-4/0	90	2.29	65	1.65	8.0	8.0	24.0	24.0	31.5	24.0
	225-500	105	2.67	75	1.90	9.5	9.5	28.5	28.5	37.0	28.5
	525-1 000	120	3.05	90	2.29	11.5	11.5	34.5	34.5	42.0	34.5
2 001-5 000	Nonshielded. See Note 2.										

		100 Percent Insulation Level **†		133 Percent Insulation Level †		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					
2 001-5 000	8-1 000	90	2.29	90	2.29	13	13	..	..	....	....
5 001-8 000	6-1 000	115	2.92	140	3.56	18	22	45	45	....	....
8 001-15 000	2-1 000	175	4.45	215	5.46	27	33	70	80	....	....
15 001-25 000	1-1 000	260	6.60	345	8.76	38	49	100	125	....	....
25 001-28 000	1-1 000	280	7.11	...	....	42	..	105	...	....	....
28 001-35 000	1/0-1 000	345	8.76	...	....	49	..	125	...	....	....

(Continued)

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*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.

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

100 Percent Level—Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within 1 minute. While these cables are applicable to the great majority of cable installations which are on grounded systems, they may be used also on other systems for which the application of cables is acceptable provided the above clearing requirements are met in completely de-energizing the faulting 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 covering. In this construction, the insulation shall be in accordance with 3.7. Column B thicknesses (2000 volts or less) apply to single-conductor cables having a covering over the insulation and to the individual conductors of multiple-conductor cables having an overall covering.▲

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

NOTE 2—For single-conductor nonshielded cables with nonmetallic jacket, see 7.9 and 7.10. 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 ac or 35 kV dc (see 3.5.2).▲

● NOTE 3—a-c voltages are r.m.s. values. ‡‡

● NOTE 4—Column B a-c spark test voltages are taken from Table 71.1, UL Standard 44, Rubber Insulated Wires and Cables, 10th Edition. ‡‡

‡‡ Approved by NEMA as Authorized Engineering Information.
● Added 10-29-1979.
▲ Editorially revised.

3.3 Insulation Thickness for Submarine Power Cable

The insulation thickness shall be as given in Table 3-1, except that for voltage classifications up through 5 kV:

(a) When Type I insulation (see 3.6) is used, the thickness of insulation in cables without a metallic sheath shall be increased by 30 mils (0.76 mm);

(b) When Type II insulation (see 3.7) is used, the thickness of insulation 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 (1.52 mm).

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.

3.5 Insulation Types and Requirements.

3.5.1 Insulation Types. The insulation shall be either Type I (see 3.6) or Type II (see 3.7).▲

3.5.2 Voltage Tests (See 6.27). Each length of completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-1.

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 (See 6.28). The insulation resistance constants of insulations shall be in accordance with 3.6 or 3.7, as applicable.

3.6 Type I Insulation. This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

3.6.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength, Minimum	
psi	700
▲MPa	4.8
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	
Hot Creep Elongation, Maximum Percent	50
Hot Creep Set, Maximum Percent	5

3.6.2 Electrical Requirements.

3.6.2.1 Voltage Tests. See 3.5.2.

3.6.2.2 Insulation Resistance Test (See 6.28). Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20 000 at 15.6°C (60°F). 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).

Where a nonconducting separator is applied between the conductor and the insulation, or where an insulated conductor is covered with a nonmetallic jacket, the insulation resistance shall be not less than 60 percent of that required for the primary insulation, based on the thickness of that insulation.

3.6.2.3 Partial-discharge Extinction Level (See 6.29). Each length of completed power cable rated at 2 001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

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

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

▲ Editorially revised.

● Added.

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METALLIC AND ASSOCIATED COVERINGS

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 and lighting circuit wires and cables. It also covers submarine cables.

Division II. (See 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shafts, 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 and Conditions of Installation.

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

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

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

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

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

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

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

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

Jute covering is not required on dredge and vertical riser cable. It is required on submarine, borehole and shaft cable where severe installation and service conditions exist. It is required for direct burial cable.

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

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Division I
Metallic and Associated Coverings
for Use Under Normal Conditions

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

4.5.4.1.1 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 B 29.

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

4.5.4.1.2 Thickness of Lead. The average thickness of the lead sheath shall be not less than the values given in Table 4-7. The minimum thickness shall be not less than 90 percent of the values given in the table. If protective jackets are used over the lead sheath, see 4.5.14.3 and 4.5.15.6 for the thickness of the lead sheath.

Table 4-7
Thickness of Lead Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
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, these thicknesses shall be 80 mils (2.03 mm).

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. **

4.5.4.1.3 Measurement of Thickness of Lead. The thickness shall be measured in accordance with 6.15.

4.5.4.1.4 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.

The lead may be stripped from the entire length of cable and the cable releaded.**

4.5.4.2 Aluminum Sheath

4.5.4.2.1 Type of Aluminum. A smooth sheath of aluminum 1060 or 1350 or equivalent shall be tightly formed around the core of the cable.

4.5.4.2.2 Thickness of Aluminum. The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

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Table 4-8
Thickness of Aluminum Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
inches	mm	mils	mm
0-0.400	0- 10.16	35	0.89
0.401-0.740	10.19- 18.80	45	1.14
0.741-1.050	18.82- 26.67	55	1.40
1.051-1.300	26.70- 33.02	65	1.65
1.301-1.550	33.05- 39.37	75	1.90
1.551-1.800	39.40- 45.72	85	2.16
1.801-2.050	45.75- 52.07	95	2.41
2.051-2.300	52.10- 58.42	105	2.67
2.301-2.550	58.45- 64.77	115	2.92
2.551-2.800	64.80- 71.12	125	3.18
2.801-3.050	71.15- 77.47	135	3.43
3.051-3.300	77.50- 83.82	145	3.68
3.301-3.550	83.85- 90.17	155	3.94
3.551-3.800	90.20- 96.52	165	4.19
3.801-4.050	96.55-102.9	175	4.45

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

4.5.4.2.3 Measurement of Thickness of Aluminum. The thickness shall be measured in accordance with 6.15.

4.5.4.2.4 Reapplication of Aluminum Sheaths. When the sheath does not meet the requirements of these standards, it shall not be repaired.

The aluminum may be stripped from the entire length of cable and the cable resheathed.**

4.5.5 Jute Serving over Metallic Sheath without Metallic Armor

4.5.5.1 Jute Servings (See 6.13). The average thickness of one serving (or two servings) of jute applied over metallic-sheathed cable for mechanical protection shall be not less than that given in Table 4-9.

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

For either one or two servings, the outer serving shall be run through hot asphalt or tar compound and coated with some suitable material 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.

Table 4-9
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	0-25.40	65	1.65	95	2.41
1.001-2.500	25.43-63.50	65	1.65	110	2.79
2.501 and larger	63.52 and 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.

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4.5.6.2 Tensile Strength and Elongation. The plain and zinc-coated strip shall have a tensile strength of not less than 40,000 psi (28.1 kgf/mm^2) nor more than 70,000 psi (49.2 kgf/mm^2). The tensile strength shall be determined on longitudinal specimens consisting of the full width of the strip when practical or on a straight specimen slit from the center of the strip. The strip shall have an elongation of not less than 10 percent in 10 inches (254 mm). The elongation shall be the permanent increase in length of a marked section of the strip, originally 10 inches (254 mm) in length, and shall be determined after the specimen has fractured. All tests shall be made prior to application of the strip to the cable.

4.5.6.3 Galvanizing Test

4.5.6.3.1 Weight of Zinc Coating. The weight of zinc coating shall be determined before application of the strip to the cable. The strip shall have a minimum weight of coating of 0.35 ounce per square foot (106.8 grams/meter^2) of exposed surface. The weight of coating shall be determined in accordance with the method described in ASTM A 90.

4.5.6.3.2 Adherence of Coating. The zinc coating shall remain adherent without flaking or spalling when the strip is subjected to a 180-degree bend over a mandrel 1/8 inch (3.18 mm) in diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake 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 tape may be less than but shall not be greater than that given in Table 4-10.

Table 4-10
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.

For nominal widths 1,000 inch (25.4 mm) or less, the tolerance in width shall be ± 30 mils. For nominal widths greater than 1.000 inch (25.4 mm), the tolerance in width shall be ± 45 mils.

4.5.6.5 Thickness (See 6.14). The average thickness of metal tape shall be not less than that given in Table 4-11.

Table 4-11
Thickness of Metal Tape for Flat Armor
(Plain or Zinc Coated)

Calculated Diameter of Cable Under Jute Bedding*		Average 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 average thickness shall be based on the calculated major core diameter.

The tolerance in the thickness of an individual 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 average thickness of bare metal.

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

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7.2.18.1.3 Extra - heavy - duty Nitrile - butadiene/polyvinyl-chloride Jacket *

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

7.2.18.1.4 Heavy-duty Nitrile-butadiene/-polyvinyl-chloride Jacket *

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30

(Continued)

(Continued)

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

7.2.18.1.5 Heavy - duty Chlorosulfonated Polyethylene Jacket

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C ± 1°C for 168 hours—tensile strength, 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

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

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7.2.18.1.6 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

●7.2.18.1.7 **Heavy-Duty Chlorinated Polyethylene, Cross-Linked**

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

●7.2.18.1.8 **Extra-Heavy-Duty Chlorinated Polyethylene, Cross-Linked**

Physical requirments	
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, minimum, percentage of unaged value	60

7.2.18.2 Thickness of Jacket. The average thickness of the jacket shall be not less than that given in Tables 7.2-13 through 7.2-17. The minimum thickness shall be not less than 80 percent of the values given in the tables. The reinforcing specified in 7.2.18.1 shall be included in the measurement of the jacket thickness.

7.2.19 Completed Cable

7.2.19.1 Outside Diameters. Nominal outside diameters of the completed cables shall be in accordance with Tables 7.2-2 through 7.2-16.

7.2.19.2 Diameter Tolerances. The tolerance for outside diameters shall be plus 8 percent and minus 5 percent, except for 0-2000 volt SHD and SHD-GC cables, and 0-2000 volt non-shielded cables. For 0-2000 volt SHD and SHD-GC cables, the tolerance for outside diameters shall be plus or minus 5 percent. For 0-2000 volt flat twin cables, the tolerance shall be ±0.04 inch for the major and ±0.03 inch for the minor diameter. For 0-2000 volt flat three-conductor cables, the tolerance shall be ±0.08 inch for the major and ±0.05 inch for the minor diameter. For all other 0-2000 volt non-shielded cables, the tolerances shall be as follows:

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Size, AWG or kcmil ▲	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

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

7.2.21 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.2.

The insulated power conductors shall meet the test voltage requirements given in Table 7.2-2 through 7.2-16. 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.

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7.5 Control Cables

7.5.1 Scope. This section covers multiple conductor ethylene-propylene-rubber-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 coveyance 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 or control 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 over-voltages 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.

7.5.2 Conductors

7.5.2.1 Conductors shall be made of annealed coated or uncoated copper in accordance with Part 2.

7.5.2.2 Sizes 16 AWG and smaller shall be solid or stranded. Sizes larger than 16 AWG shall be stranded. Stranding shall be in accordance with 2.3, Class B or C.

7.5.3 Insulation

7.5.3.1 The insulation shall be of one of the following types:

a. Type I (see 3.6).

b. Type II (see 3.7).

c. A composite insulation consisting of a layer of insulating neoprene or chlorosulfonated polyethylene over a layer of Type I or Type II insulation without any further covering (see 7.5.9.3 and 7.5.9.4).

7.5.3.2 The minimum average thickness of insulation shall be not less than that given in Table 7.5-1. The minimum thickness at any point shall be not less than 90 percent of that given in the table. For composites, the minimum thickness at any point of each layer of material shall not be less than 90 percent of the value specified in Table 7.5-1.

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7.5.4 Jacket Over Insulation. Jackets shall not be required over the individual conductors. However, if a jacket is used, it shall be of one of the materials given in 7.5.7 and shall have a minimum average thickness of not less that 15 mils (0.38 mm) and a minimum thickness at any point of not less than 12 mils (0.30 mm).

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

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

7.5.7 Overall Jacket

7.5.7.1 Type A, B and C cables shall have an overall jacket in accordance with one of the following:

Thermoplastic

Polyvinyl chloride.....4.4.5
Polyethylene, black.....4.4.6
Chlorinated polyethylene.....4.4.7

Thermoset

Neoprene, heavy-duty black.....4.4.3
Nitrile-butadiene/polyvinyl-chloride, heavy-duty.....4.4.8
Chlorosulphonated polyethylene, heavy-duty.....4.4.10
Chlorinated polyethylene, heavy-duty.....4.4.11

7.5.7.2 The minimum average thickness of the jacket shall be not less than that given in Table 7.5-2. The minimum thickness at any point shall be not less than 80 percent of that given in the table.

7.5.8 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.*

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Table 7.5-1
Conductor Sizes, Insulation Thicknesses, and Test Voltages

Conductor Size AWG	Voltage Rating-300V or 600V						Voltage Rating-1000V					
	Insulation Thickness				Test Voltage kV		Insulation Thickness				Test Voltage kV	
	Single Layer		Composite†				Single Layer		Composite†			
	mils	mm	mils	mm	a-c	d-c	mils	mm	mils	mm	a-c	d-c
20-18	25	0.64	20/10	0.51/0.25	2.5	7.5	...	...	...	...	...	...
16	25	0.64	20/10	0.51/0.25	2.5	7.5	45	1.14	30/15	0.76/0.38	4.5	13.5
14-9	30	0.76	20/10	0.51/0.25	3.0	9.0	45	1.14	30/15	0.76/0.38	4.5	13.5

The voltages shall be determined by the size of the conductor and the rated voltage of the cable and not the apparent thickness of the insulation.

† Composite Thicknesses - Inner Layer/Outer Layer

7.5.9 Tests

7.5.9.1 The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.5.

7.5.9.2 Electrical tests on completed cable shall be in accordance with 6.27 and 6.28, except that the tests may be made without immersion in water. The dielectric withstand voltage level shall be as specified in Table 7.5-1.

7.5.9.3 Physical and Aging Requirements For Composite Insulations. (See 6.5) Composite insulation shall meet the requirements specified in either 7.5.9.3.1 or 7.5.9.3.2.

7.5.9.3.1 If the layers cannot be separated, they shall be tested as a unit construction and shall meet the following requirements:

Physical Requirements
- Tensile strength, minimum
  - psi 1000
  - MPa 6.90
- Elongation at rupture, minimum, percent 250

Aging Requirements
- After air oven test at 121 °C ± 1°C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 50

7.5.9.3.2 If the layers can be separated, they shall be tested separately and shall meet the following requirements:

Inner Insulating Layer-Type I

Physical requirements
- Tensile strength, minimum
  - psi 700
  - MPa 4.83
- Elongation at rupture, minimum, percent 250

Aging Requirements
- After air oven test at 121 °C ± 1 °C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 75

Inner Insulating Layer-Type II

Physical requirements
- Tensile strength, minimum
  - psi 1200
  - MPa 8.27
- Elongation at rupture, minimum, percent 150
- Tensile Strength at 100 percent elongation, minimum
  - psi 500
  - MPa 3.45

Aging Requirements
- After air oven test at 121 °C ± 1 °C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 75

Outer Insulating Layer
- Tensile strength, minimum
  - psi 1500
  - MPa 10.34
- Elongation at rupture, minimum, percent 300

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Table 7.5-2
Overall Jacket Thickness

Calculated Diameter of Cable Under Jacket inches	mm	Thickness 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

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 40

7.5.9.4 Electrical Requirements For Composite Insulations:

Specific surface resistivity, minimum megohms (see 6.23.2) 200,000

Accelerated water absorption (see 6.21*)
Electrical method (EM-60)
Dielectric constant after 24 hours, maximum 4.5
Increase in capacitance, maximum, percent
1 to 14 days 3.5
7 to 14 days 2.0
Stability Factor after 14 days, maximum 1.0

Gravimetric method
Water absorption, maximum, mg/in^2 35

Insulation resistance constant (K) at 15.6 °C (60 °F) (see 7.5.9.2) 12,000

7.5.10 Optional Flame Test Requirement. This section describes optional flame test requirements for insulated conductors (Tests A and B) and finished cable described within this standard. These tests shall not be applicable unless specifically requested.

▲ **7.5.10.1** Flame Test A-Insulated Conductor
The test apparatus shall consist of the following:
a. Test chamber of sheet metal 12 inches (305 mm) wide, 14 inches (356 mm) deep and 24 inches (610 mm) high, which is open at the top, and which is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.
b. Means for adjusting the position of the test specimen.
c. A 4-pound (1.8-kg) weight for 9AWG and smaller conductor sizes to be attached to the lower end of the test specimen to keep it taut.
d. Tirrill burner with an attached pilot light and mounted on a 20-degree angle block. The burner shall have a nominal bore of ⅛ inch (9.5 mm) and a length of approximately 4 inches (102 mm) above the primary air inlets.
e. 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.
f. Gas - a supply of ordinary illuminating gas at normal pressure.
g. Watch or clock with a hand which makes one complete revolution per minute.
h. Flame indicators consisting of strips of gummed kraft paper having a nominal thickness of 5 mils (0.127 mm) and a width of ½ inch (12.7 mm)**.

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 9 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 test shall be performed on a sample having a 30 or 45 mil composite wall (inner layer plus outer layer), as specified in Table 7.5-1.

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

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the flame is to be applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches (127 mm) with an inner blue cone 1 ½ inches (38.1 mm) high. The temperature at the tip of the inner blue cone shall be not less than 836 °C (1500 °F).

The burner, with only the pilot lighted, shall be placed in front of the samples 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 burner stem between the tip of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for 15 seconds. This process shall be repeated four times. During each application of the flame the specimen shall be adjusted, if necessary, so that the top of the inner blue cone touches the surface of the specimen. The duration of burning of this specimen after the fifth application of the flame shall be recorded.

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.
2. The specimen continues to burn for more than one minute after the fifth application of flame.

7.5.10.2 Flame Resisting Test B - Insulated Conductor

This test shall be the same as in 7.5.10.1, except for the following:

a. 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 9 ½ inches from the point at which the inner blue cone touches the cable surface.

b. The valve supplying the gas to the burner proper shall 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.

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

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.
2. The specimen continues to burn for more than one minute after any of the flame applications.
3. The surgical cotton is burned.

▲ **7.5.10.3** Flame Test-Finished Cable

This test shall be a type test to demonstrate flame resistance of a cable construction. (i.e. insulation and jacket type). The test shall be performed as described in IEEE Standard 383-1974, paragraph 2.5 with the following exceptions:

1. The standards sample to be tested shall be a 7 or 9 conductor, No. 12 AWG rated at 600 volts.
2. Only the ribbon gas burner shall be used as the flame source.
3. Ribbon Gas Burner, American Gas Furnace Company (Cat. No. 10L 11-55 formerly specified as Cat. No. 10X 11-55), or equivalent.

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7.6 Concentric-neutral Underground Distribution Cables

7.6.1 Scope. This section covers two-conductor concentric-neutral power cables consisting of one ethylene-propylene-rubber-insulated central conductor and one copper concentric neutral conductor applied helically overall. These cables are intended for use on single-phase and three phase primary underground distribution systems operating at 2001 to 35,000 volts phase-to-phase at 100 percent insulation level. For ampacities, see Appendix F.

Central Conductor. Central conductors shall be annealed copper or aluminum. The minimum conductor size shall be in accordance with Table 7.6-1.

Table 7.6-1
Minimum Conductor Size

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

7.6.2.1 Copper. Conductors shall be (1) annealed uncoated copper or annealed coated copper either Class B or C stranded or (2) uncoated copper, compact stranded, and shall meet the requirements of Part 2.

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

▲7.6.2.3 Conductor (Stress Control Layer) The conductors shall be covered with a stress control layer in accordance with Part 2.

7.6.3 Insulation. The shielded central conductor shall be insulated with an ethylene-propylene-rubber compound which meets the requirements given in Part 3. 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 that table.

7.6.4 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 7.6-2, and the minimum thickness at any point shall be not less than 80 percent of the values given in this 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.

Table 7.6-2
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

7.6.5 Concentric Conductor. The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B 5 and the resistivity, tensile, and elongation requirements of ASTM B 3 for uncoated wires, ASTM B 33 for tin coated wires or ASTM B 189 for lead-alloy-coated wires. The number of wires of a specified size shall be not less than that given in Table 7.6-3 for cables used in single phase systems and in either Table 7.6-5 or Table 7.6-6 for three phase system.

The nominal diameters and circular mil areas of the wires in Tables 7.6-3, 7.6-5 and 7.6-6 shall be as follows:

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

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

1. For single phase systems, at least 98% of the product of the appropriate number of wires given in Table 7.6-3 times the appropriate nominal circular mil area tabulated above.
2. For three phase systems at least 98% of the product of the appropriate number of wires given in Tables 7.6-5 or 7.6-6 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 conducting material given in 7.6.4 with a lay not less than six nor more than ten times the diameter over the concentric wires.

7.6.6 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 4.4.3 through 4.4.11 as applicable.

If conducting compound is used, it shall be either Type I or II compound meeting the physical and aging requirements of Table 7.6-7.

Table 7.6-3

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 7.6-4

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

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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.)

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

After a jacket has been applied, the minimum thickness of the extruded insulation shielding shall be not less than 70 percent of the specified average thickness found in Table 7.6-2.

Calculated Diameter Over Concentric 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

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

When measured over the wires, the average jacket thickness shall be not less that the appropriate value stated as follows:

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 be not less than 70 percent of the specified average thickness found in Table 7.6-2.

7.6.6.2 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.

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

7.6.6.4 SPARK TEST FOR NONCONDUCTING JACKETS. A nonconducting jacket over the concentric neutral conductors shall withstand the alternating current spark test voltage given in 7.6.6.1. The voltage shall be applied between an electrode at the outside surface of the jacket and the concentric neutral conductor. The netural conductor shall be connected to ground during the test. The spark test shall be conducted in accordance with 6.27.4a.3 and 6.27.4a.4.

7.6.7 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.6. The partial-discharge extinction level shall be in accordance with Table 7.6-4. The electrical requirement tests shall be made without immersion in water.

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Table 7.6-7
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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7.8 Metal-clad Cables with Grounding Conductor

7.8.1 Scope. This section covers two-, three-, and four-conductor ethylene-propylene-rubber-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 Part 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 7.8-1.▲

▲ 7.8.2.2 Cables Rated 2001 Volts and Above. The minimum size of the grounding conductor shall be in accordance with Table 7.8-2.

7.8.3 Conductor Stress Control Layer. A conductor stress control layer shall be used on conductors having rated circuit voltages above 2000 volts.▲

Table 7.8-1
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

7.8.4 Insulation. The insulation shall meet the requirements given in Part 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 Part 5 and shall be based on the calculated diameter of the individual power conductor. A suitable binder shall be applied over the assembly.

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

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

Table 7.8-2 ●
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	2/0-250 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

▲ Editorially revised.
● Added 1-17-1980.

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

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

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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. **8** to the ICEA/NEMA Standards Publication for *Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* ICEA Publication No. **S-68-516,** NEMA Publication No. **WC 8-1976 (R1982)**

Dear Representative:

For your convenience, the back of this letter contains a checklist of pages which now comprise ICEA S-68-516, NEMA WC 8-1976 (R1982).

Sincerely yours,

Carol Cross

Carol Cross
Standards Publications Editor

Copies to: All known holders of WC 8-1976 (R1982)
Technical Committee

CSC/mbh

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MARCH 1985

The following pages now comprise the ICEA/NEMA Standards Publication on *Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy,* ICEA Publication No. S-68-516, NEMA Publication No. WC 8-1976 (R1982).

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2	1 through 4	December 1984
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	11	January 1983
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	13A	December 1984
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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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

Proposed, New and Revised Standards

January 9, 1985

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

Subject: Revision No. 7 to the ICEA/NEMA Standards Publication for *Ethylene-Propylene-Rubber-Insulated Wire and and Cable for the Transmission and Distribution of Electrical Energy,* ICEA Publication No. **S-68-516,** NEMA Publication No. **WC 8-1976 (R 1982)**

Gentlemen:

The seventh 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 Revisions 1 through 7, is enclosed. Also, enclosed are 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

Copies to: All known holders of WC 8-1976
Technical Committee

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ICEA PUB. NO. S-68-516
NEMA PUB. NO. WC 8-1976 (R 1982)
JANUARY 1983

ICEA-NEMA Standards Publication

Ethylene-propylene-rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

This publication includes and supersedes the following Interim Standards which were previously published for inclusion in ICEA Pub. No. S-68-516, NEMA Pub. No. WC 8.

#1 August 1973	Cables Rated 0-35000 Volts and Having Ozone-resistant Ethylene-propylene Rubber Insulation
#2 August 1973	Cables Rated 2000 Volts and Less and Having Ozone-resistant Ethylene-propylene-rubber Integral Insulation and Jacket
#3 July 1971	Primary Underground Residential Distribution Cables with Ethylene-propylene-rubber Insulation
#4 July 1971	Concentric-neutral Underground Distribution Cables with Ethylene-propylene-rubber Insulation
#5 September 1973	Mine Power Cables with Ethylene-propylene-rubber Insulation
#6 September 1973	Portable Single- and Multiple-conductor Cables with Ethylene-propylene-rubber Insulation
#7 August 1973	Nonshielded Single-conductor Power Cable with Ethylene-propylene-rubber Insulation, 2001-5000 Volts

Approved by Insulated Cable Engineers Association
September 25, 1975

Approved as a NEMA Standard September 25, 1975
National Electrical Manufacturers Association

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Foreword ▲

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

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

Requests for interpretation of this Standard must be submitted in writing to the Insulated Cable Engineers Association, P.O. Box P, South Yarmouth, Massachusetts 02664. An official written interpretation will be provided. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

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*A more detailed table of contents follows.

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

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

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Part 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 B 230. Tensile strength of aluminum 1350 and aluminum alloy conductors and elongation of aluminum alloy conductors shall be determined according to ASTM B 230.

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

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

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

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

$$R = K\rho/A$$

Where:

R = Conductor resistance in Ω/1000 ft.

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

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

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

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

Table 2-2

Weight Increment Factors*, K

Solid Conductors	1
Concentric-lay Strand, 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 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.▲

NEMA Authorized Engineering Information 7-14-1982.

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

2.7 Stress Control Layer (Conductor Shield). 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 6.11 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 6.24 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

2.7.1.2 An extruded nonconducting stress controlling material, when measured according to 6.31, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Permittivity (SIC), range	10—1000
60 hz ac voltage withstand stress, volts per mil, minimum	1500▲

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*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.

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

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

†† For 133 percent insulation level (ungrounded neutral), the minimum conductor size is 1 AWG.

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 covering. In this construction, the insulation shall be in accordance with 3.7. Column B thicknesses (2000 volts or less) apply to single-conductor cables having a covering over the insulation and to the individual conductors of multiple-conductor cables having an overall covering.▲

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

NOTE 2—For single-conductor nonshielded cables with nonmetallic jacket, see 7.9 and 7.10. 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 ac or 35 kV dc (see 3.5.2).▲

● NOTE 3—a-c voltages are r.m.s. values. ‡‡

● NOTE 4—Column B a-c spark test voltages are taken from Table 71.1, UL Standard 44, Rubber Insulated Wires and Cables, 10th Edition. ‡‡

‡‡ Approved by NEMA as Authorized Engineering Information.
● Added 10-29-1979.
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3.3 Insulation Thickness for Submarine Power Cable

The insulation thickness shall be as given in Table 3-1, except that for voltage classifications up through 5 kV:

(a) When Type I insulation (see 3.6) is used, the thickness of insulation in cables without a metallic sheath shall be increased by 30 mils (0.76 mm);

(b) When Type II insulation (see 3.7) is used, the thickness of insulation 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 (1.52 mm).

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.

3.5 Insulation Types and Requirements.

3.5.1 Insulation Types. The insulation shall be either Type I (see 3.6) or Type II (see 3.7).▲

3.5.2 Voltage Tests (See 6.27). Each length of completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-1.

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 (See 6.28). The insulation resistance constants of insulations shall be in accordance with 3.6 or 3.7, as applicable.

3.6 Type I Insulation. This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

3.6.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength, Minimum	
psi	700
▲MPa	4.8
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	
Hot Creep Elongation, Maximum Percent	50
Hot Creep Set, Maximum Percent	5

3.6.2 Electrical Requirements.

3.6.2.1 Voltage Tests. See 3.5.2.

3.6.2.2 Insulation Resistance Test (See 6.28). Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20 000 at 15.6°C (60°F). 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).

Where a nonconducting separator is applied between the conductor and the insulation, or where an insulated conductor is covered with a nonmetallic jacket, the insulation resistance shall be not less than 60 percent of that required for the primary insulation, based on the thickness of that insulation.

3.6.2.3 Partial-discharge Extinction Level (See 6.29). Each length of completed power cable rated at 2 001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

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

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

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● Added.

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Table 3-2

	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. 0-2 000 Volts				
▲ (1) Without metallic sheath or armor	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3	6.27.2 or 6.27.3
(2) With metallic sheath or armor	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
b. 2 001-5 000 Volts	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
2. Cables With Insulation Shield				
a. 0-5 000 Volts	6.27.2	6.27.2	6.27.2	6.27.2
b. 5 001 volts and over	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3

● See Part 6 for:

6.27.2 alternating-current voltage test
6.27.3 direct-current voltage test
6.27.4a alternating-current spark test
6.27.4b direct-current spark test

▲ Revised 10-29-1979.

3.6.3 Additional Requirements.

3.6.3.1 Capacity and Power Factor (See 6.22). The insulation on cables rated at 5 001 volts and above shall have a specific inductive capacity not exceeding 4.0 and a power factor not exceeding 2.0 percent.

3.6.3.2 Accelerated Water Absorption (See 6.21). The insulation shall meet the following requirements:

Electrical Method	
Dielectric constant after 24 hours, maximum	4.0
Increase in capacitance, maximum, percent	
1 to 14 days	3.5
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 Type II Insulation. This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering. Also, it is suitable for use on single-conductor cables, without covering, rated at voltages up through 2000 volts. When used without a covering, the insulation shall be carbon-black pigmented to provide resistance to sunlight.

3.7.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength, Minimum	
psi	1200
▲MPa	8.2
Elongation at Rupture, Minimum, Percent	150
Tensile Stress at 100 percent Elongation, Minimum	
psi	500
▲MPa	3.4
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	
Hot Creep Elongation, Maximum Percent	50
Hot Creep Set, Maximum Percent	5

3.7.2 Electrical Requirements. Each insulated conductor in the completed cable shall meet the requirements of 3.6.2, except that the insulation resistance constants shall be:

0-2000 volts	10,000
2001-35000 volts	20,000

3.7.3 Additional Requirements.

3.7.3.1 Capacity and Power Factor (See 6.22). The insulation on cables rated at 5 001 volts and above shall have a specific inductive capacity not exceeding 4.0 and a power factor not exceeding 2.0 percent.

3.7.3.2 Accelerated Water Absorption (See 6.21). The insulation shall meet the requirements given in Table 3-3.

Table 3-3
Water Absorption Requirements for Type II Insulations▲

	0-2000 Volts	2001-35000 Volts
Electrical Method		
Dielectric constant after 24 hours, maximum	6.0	4.0
Increase in capacitance, maximum, percent		
1 to 14 days	5.0	3.5
7 to 14 days	3.0	1.5
Stability factor after 14 days, maximum*	1.0	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.

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● Added.

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Part 4
SHIELDING AND COVERINGS

SHIELDING (SEE APPENDIX G) ▲

4.1 SHIELDING OF INSULATED CABLE ▲

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

4.1.1 Insulation Shield ▲

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 4a or 4b 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 25,000 volts and not less than 4 pounds (17.8N) for cables rated 25,001 through 35,000 volts (see Part 6).▲

For removability of insulation shields, see Appendix G, par, G6. (This sentence is approved by NEMA as Authorized Engineering Information.)

4.1.1.2 Metal Component

A nonmagnetic metal component consisting of a tape or tapes, wires, straps, or sheaths shall be applied over or embedded in the conducting nonmetallic covering. The metal components shall be electrically continuous throughout each cable length and shall be in contact with the nonmetallic covering. Metal components shall be applied in such a manner that electrical continuity or continguity 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 mm^2/mm) of insulated conductor diameter, or of other nonmagnetic metals having equivalent conductance.

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

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

NOTE—Additional conductance may be required in the metal component depending upon installation and electrical system characteristics, particularly in regard to the functioning of overcurrent protective devices, available fault current, and the manner in which the system may be grounded. (This paragraph is approved by NEMA as Authorized Engineering Information.)

4.1.2 Multiple—Conductor Cables

When shielding is required on multiple-conductor cables (see 4.2), the shields shall be applied over the individual conductors.

4.1.3 Conductor Identification ▲

See 5.3.

4.2 SHIELDING LIMITS FOR POWER CABLE FOR FIXED LOCATIONS

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

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Table 4a ●

Requirements for Nonmetallic Conducting Coverings using Nonembedded Metal Components

	Thermoplastic	Cross-Linked ▲
Aging Requirements (see Part 6)▲		
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, not warmer than	-10°C*	-10°C*
Volume Resistivity, maximum at room temperature and at rated ▲temperature ± 1°C, ohm-meters	500	500

*For extruded coverings only.

Table 4b ●

Requirements for Extruded Nonmetallic Conducting Coverings using Embedded Metal Components

Thickness, Minimum (see Part 6)▲	
Total	in accordance with 4.4.12▲
Between insulation and metal component	
mils	5
mm	0.127
▲Physical Requirements	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	100
▲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, percent	100
▲Brittleness Temperature, not warmer than	-10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C ▲ohm-meters	500

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

(a) Connections to aerial lines
(b) Transition from conducting to nonconducting environment
(c) Transition from moist to dry earth
(d) Dry soil, such as in the desert
(e) Damp conduits.

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

Table 4-1 ▲

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 5000 Volts or Less	Single- and Two-phase a-c Systems* Over 5000 Volts	
	One Side Grounded	Ungrounded and Midpoint Grounded
1	1.73	0.866

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

JACKETS ▲

4.3 GENERAL ▲

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

† 4.4 RUBBER OR THERMOPLASTIC JACKETS

These jackets consist of a durable moisture-resisting cross-linked natural- or synthetic-rubber compound or a 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 4.4.15. The tests shall be made only on jackets having a nominal wall thickness of 30 mils (0.76 mm) or greater.

4.4.1 Natural Rubber

This jacket shall consist of a vulcanized rubber compound containing not less than 60 percent of natural rubber and shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	3500
MPa	24.1 ▲
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45 ▲
Elongation at rupture, minimum, percent	500
Set, maximum, percent	15
Aging Requirements (see 6.5)	
After oxygen pressure test at 70°C ± 1°C for 96 hours	
Tensile strength, minimum	
psi	2500
MPa	17.2 ▲
Elongation at rupture, minimum, percent	400
Tear resistance, minimum (see 6.12)	
pounds per inch	40
N/m	7000 ▲

4.4.2 Synthetic Rubber

This jacket shall consist of a vulcanized SBR synthetic rubber compound and shall meet the following requirements:

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Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 70°C ± 1°C for 168 hours	
Tensile strength, minimum	
psi	1600
kgf/mm^2	1.12
Elongation at rupture, minimum, percent	250
After oxygen pressure test at 70°C ± 1°C for 96 hours	
Tensile strength, minimum	
psi	1600
kgf/mm^2	1.12
Elongation at rupture, minimum, percent	250

4.4.3 Neoprene, Heavy-duty Black. This jacket shall consist of a vulcanized black neoprene compound and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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

4.4.4 Neoprene, General Purpose. This jacket shall consist of a vulcanized neoprene compound, and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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

4.4.5 Polyvinyl Chloride. This jacket shall consist of a polyvinyl chloride compound suitable for a minimum installing temperature of -10°C (+14°F), and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	100
Aging Requirements (see 6.5)	
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 (see 6.17)	50
Heat shock, 121°C ± 1°C (see 6.16)	No cracks
Cold bend, minus 35 ± 1°C (see 6.18)	No cracks

4.4.6 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°F) and a minimum installing tempera-

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ture of -40°C (-40°F). The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1400
▲MPa	9.65
Elongation at rupture, minimum, percent	350
Aging Requirements (see 6.5)	
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 (see 6.17)	25
Absorption coefficient, minimum milli(absorbance/meter) (see 6.20)	320*
Environmental cracking (see 6.19)	No cracks

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

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4.4.7 Chlorinated Polyethylene, Thermoplastic●

This jacket shall consist of a thermoplastic chlorinated polyethylene compound. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical requirements	
Tensile strength, minimum	
psi	1400
MPa	9.65
Tensile stress at 100 percent elongation, minimum	
psi	1000
MPa	6.9
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, minimun, percentage of unaged value	50
After oil immersion test at 100 °C ± 1 °C for 18 hours	
Tensile strength and elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121 °C ± 1 °C, maximum percent	25
Cold bend, minus 35 °C ± 1 °C	No cracks

▲4.4.8 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. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements (see 6.5)	
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 (see 6.5)	
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

▲4.4.9 Nitrile-Butadiene/Polyvinyl-Chloride, General-Purpose 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. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
▲MPa	10.3
Elongation at rupture, minimum, percent	250
Set, maximum, percent	30
Aging Requirements (see 6.5)	
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

▲4.4.10 Chlorosulfonated Polyethylene, Heavy Duty

This jacket shall consist of a vulcanized chlorosulfonated-polyethylene compound, shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

(Continued)

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Physical Requirements (see 6.5)	
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 (see 6.5)	
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

4.4.11 Chlorinated Polyethylene, Heavy-Duty Cross-Linked (Thermoset)●

This jacket shall consist of a cross-linked chlorinated polyethylene compound. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

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	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

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● Added.

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▲4.4.12 Jacket Thickness (See 6.4)

The average thickness of jackets shall be not less than those given in Tables 4-2, 4-3, 4-4, or 4-5. For the jacket thicknesses of cables not shown in these tables, see Table 4-6. The minimum thickness shall be not less than 80 percent of the values given in these tables. The tables do not apply to communication and portable cables and portable cords.

▲4.4.13 Separator Under Jacket

If used, a separator shall consist of compatible material.

†4.4.14 Discharge-Resisting Jacket (See Table 4-1)

For single-conductor nonshielded cables rated 2001-5000 volts phase to phase, see 7.9 and 7.10.

For multiple-conductor nonshielded cables rated 2001-5000 volts phase to phase, the overall jacket shall meet the requirements of 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, 4.4.10, or 4.4.11 and, in addition, shall have a specific surface resistivity of not less than 200,000 megohms (see 6.23.1 and 6.23.2).

Table 4-2
Single-Conductor Nonshielded Cable 2000 volts or less ▲
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial†)

Size, AWG or kcmil ▲	Jacket Thickness			
	0-600 Volts		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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† Revised.

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† 4.4.15 Spark Test of Jackets Over Metallic Shielded Power Cable. The jackets (see par. 4.4.1 through 4.4.11 inclusive) over each length of shielded power cable (see par. 4.1) shall withstand without failure the alternating-current spark-test voltage given in the following table. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic shield for not less than 0.15 second. ●

Thickness of Jacket		a-c Spark-test Voltage kV	
mils	mm	For ▲ Cross-Linked Jackets*	For Thermoplastic Jackets**
45	1.14	2.0	4.0
60	1.52	2.5	5.5
80	2.03	3.0	7.0
110	2.79	4.5	10.0
140	3.56	5.5	12.5

* See par. 4.4.1 through 4.4.4 and 4.4.8 through 4.4.11.▲
**See par. 4.4.5 through 4.4.7.▲

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† Revised.

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METALLIC AND ASSOCIATED COVERINGS

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 and lighting circuit wires and cables. It also covers submarine cables.

Division II. (See 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shafts, 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 and Conditions of Installation.

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

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

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

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

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

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

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

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

Jute covering is not required on dredge and vertical riser cable. It is required on submarine, borehole and shaft cable where severe installation and service conditions exist. It is required for direct burial cable.

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

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Division I
Metallic and Associated Coverings
for Use Under Normal Conditions

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

4.5.4.1.1 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 B 29. The types of lead used shall be as follows:

Corroding

Desilverized A

Soft, undesilverized

Chemical

Acid

Copper (copper bearing)

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

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

4.5.4.1.2 Thickness of Lead. The average thickness of the lead sheath shall be not less than the values given in Table 4-7. The minimum thickness shall be not less than 90 percent of the values given in the table. If protective jackets are used over the lead sheath, see 4.5.14.3 and 4.5.15.6 for the thickness of the lead sheath.

Table 4-7
Thickness of Lead Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
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, these thicknesses shall be 80 mils (2.03 mm).

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.

4.5.4.1.3 Measurement of Thickness of Lead. The thickness shall be measured in accordance with 6.15.

4.5.4.1.4 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.

4.5.4.2 Aluminum Sheath

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

4.5.4.2.2 Thickness of Aluminum. The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

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4.5.7a Continuously Corrugated Metal Armor

4.5.7a.1 Scope. This section covers the equirements 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 4-13A.

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 Part 6.

4.5.7a.4 Corrosion Protection

4.5.7a.4.1 When required a corrosion protective covering shall be applied over the armor.

Table 4-13A
Minimum Thickness of Metal for Corrugated Armor

Calculated Diameter of Cable Under Armor		Aluminum		Copper		Steel	
inches	mm	mils	mm	mils	mm	mils	mm
0—2.180	0— 55.37	22	0.56	...	...	...	...
2.181—3.190	55.40— 81.03	29	0.74	...	...	...	...
3.190—4.200	81.05—106.7	34	0.86	...	...	...	...
0—2.365	0— 60.7	...	...	17	0.43	...	...
2.366—3.545	60.10— 90.4	...	...	21	0.53	...	...
3.546—4.200	90.07—106.7	...	...	25	0.64	...	...
0—1.905	0— 48.39	...	...	...	...	16	0.41
1.906—3.05	48.41— 72.39	...	...	...	...	20	0.51
3.051—4.200	72.42—106.7	...	...	...	...	24	0.61

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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 Division II and III applications, see 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.

▲ 4.5.8.2.1 Tensile Strength. The zinc-coated wire shall have a tensile strength of not less than 50,000 psi (345 MPa) and not more than 70,000 psi (482 MPa). The tensile strength shall be tested in accordance with ASTM E 8. (See Appendix E.)

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 4-14. This test shall be made on a sample of wire having an initial length of 6 inches (152 mm) between jaws of a standard torsion machine or equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 4-14
Number of Twists (Torsion Test)

▲ Nominal Diameter of Coated Wire		Minimum Number
mils	mm	of Twists
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 4-15. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90. (See Appendix E.)▲

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

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

4.5.8.4 Size of armor. The sizes of armor wire for Division I applications, including submarine cables, shall be as given in Table 4-17.

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

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

The tolerance in diameter for galvanized steel wire shall be as given in Table 4-18.

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

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

4.5.8.6 Direction of Lay. Successive layers of jute and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen that birdcaging of the armor will 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 before it is run through the first application of compound.

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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 (See 6.13). The average thickness of jute bedding under the armor in the finished cable shall be not less than that given in Table 4-19.

4.5.10 Jute Serving Overall for Armored Cable (See 4.5.11 for Interlocked Armored Cable

4.5.10.1 Application. When an outer jute serving is required, the armored cable shall be run through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 16/3) impregnated jute yarn applied with a short close lay, again run through hot asphalt or tar compound and finished by running through some suitable material 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 (See 6.13). 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 4-19.

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, saturated cotton braid, 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 Thermosetting and Thermoplastic Jacketed Cable Under Armor

4.5.13.1 Flat Steel Tape Armor. If 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 as given in Table 4-19 (see 6.13).

4.5.13.2 Interlocked Armor. Interlocked armor shall be applied directly over the jacket or tape in which it is vulcanized, no bedding being necessary.

4.5.13.3 Round Wire Armor. If 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 as given in Table 4-19 (see 6.13).

4.5.14 Thermosetting Coverings over Metallic Sheath

4.5.14.1 Thermosetting Covering. A thermosetting covering over a metallic sheath shall consist of a combination of treated fibrous reinforcing tapes and a neoprene compound.

Table 4-19
Thickness of Jute Bedding for Armored Cable

Calculated Diameter of Cable Under Jute Bedding*		Thickness of Jute Bedding					
				Round Wire Armored Cable			
		Metal Taped		Sheathed or Jacketed		Nonsheathed or Nonjacketed	
inches	mm	mils	mm	mils	mm	mils	mm
0-0.450	0-11.43	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.

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The neoprene compound shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1200
▲MPa	8.27
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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, minimum, percentage of unaged value	60

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

4.5.14.2 Thickness. The average thickness of the thermosetting jacket shall be not less than that given in Table 4-20. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the jacket. ▲

The minimum thickness shall be not less than 80 percent of the values given in Table 4-20.

Table 4-20
Thickness of Thermosetting Jacket Over Metallic Sheath ▲

Calculated Diameter over Sheath		Thickness	
inches	mm	mils	mm
0-1.500	0-38.10	65	1.65
1.501-3.000	38.13-76.20	95	2.41
3.001 and over	76.23 and over	125	3.18

▲ 4.5.14.3 Thickness of Lead Sheath (See 6.15)

If a cross-linked jacket is applied over a lead sheath, the average thickness of the lead sheath shall be not less than that given in Table 4-21. The minimum thickness shall be not less than 90 percent of the values given in the table.

Table 4-21
Thickness of Lead Sheath for Cables Having a Cross-Linked Jacket or Thermoplastic Jacket Over Lead Sheath ▲

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

* The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.
† For submarine cables, these thicknesses shall be 70 mils (1.78 mm).

4.5.14.4 Thickness of Aluminum Sheath (See 6.15). If a cross-linked jacket is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2. ▲

4.5.15 Thermoplastic Jacket over Metallic Sheath

4.5.15.1 Thermoplastic Jacket. If used, a thermoplastic jacket shall be extruded over the metallic sheath and shall fit tightly thereto. It shall be either:

(a) Polyvinyl chloride meeting the requirements of 4.4, except that the cold-bend requirements shall be as given in 4.5.15.4, or

(b) Black polyethylene meeting the requirements of 4.4, or

● (c) Black chlorinated polyethylene meeting the requirements given in 4.4 except that the cold bend requirements shall be as given in 4.5.15.4.

▲ 4.5.15.2 Thickness. The average thickness of jacket shall be taken as one-half the difference in diameters and under the jacket as determined by circumference measurements and shall be not less than that given in Table 4-22. The minimum thickness of the jacket shall be determined by direct

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measurements with a micrometer, a steel scale with pocket glass, or a microscope on a ring of jacket removed from the cable and shall be not less than 70 percent of the values given in Table 4-22.

Table 4-22
Thickness of Thermoplastic Jacket Over Metallic Sheath

Calculated Diameter Over Sheath		Jacket Thickness	
inches	mm	mils	mm
0-0.750	0-19.05	50	1.27
0.751-1.500	19.08-38.10	65	1.65
1.501-2.250	38.13-57.15	80	2.03
2.251-3.000	57.18-76.20	95	2.41
3.001 and larger	76.23 and larger	110	2.79

4.5.15.3 Tightness of 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. There shall be no movement of the cable in relation to the ring 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 (1770 N/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 (See 6.18). Polyvinyl-chloride-jacketed cable shall show no cracks at a test temperature of -10°C or colder. In lieu of this test the manufacturer may submit evidence that the jacket compound has been tested on similar cable and meets this requirement.

4.5.15.5 Spark Test. The jacket on each length of cable shall withstand the alternating current spark-test voltage given in Table 4-23. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic sheath for not less than 0.15 second. ▲

Table 4-23
Spark-test Voltage for Thermoplastic Jacket

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

4.5.15.6 Thickness of Lead Sheath. If a thermoplastic jacket is applied over a lead sheath, the thicknesses of the lead sheath shall be in accordance with 4.5.14.3.

4.5.15.7 Thickness of Aluminum Sheath (See 6.15). If a thermoplastic jacket is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2.

4.5.16 Thermoplastic Jacket over Metallic Armor. If used, a thermoplastic jacket shall be extruded over the metallic armor and shall fit tightly thereto. It shall be either:

▲(a) Polyvinyl chloride meeting the requirements given in 4.4, except that the cold bend requirments shall be as given in 4.5.15.4, or

▲(b) Black polyethylene meeting the requirements given in 4.4, or

●(c) Black chlorinated polyethylene meeting the requirements given in 4.4 except that the cold bend requirements shall be as given in 4.5.15.4.

4.5.16.1 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 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 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.

4.5.16.2 Spark Test. The jacket on each length of cable shall withstand the alternating current spark-test voltage given in Table 4-23. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic armor for not less than 0.15 second. ▲

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● Added

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Table 4-24
Thickness of Thermoplastic Jacket Over Metallic Armor

Calculated Diameter of Cable Under Thermoplastic Jacket		Jacket Thickness			
		All Cables (Except Interlocked or Corrugated Armored) ▲		Cables With Interlocked or Corrugated Armor ▲	
inches	mm	mils	mm	mils	mm
0-0.750	0-19.05	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

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 (4.5.3 through 4.5.16) pertaining to quality of materials, design and construction, apply also to borehole, dredge, shaft, and vertical riser cable (which are designed for special uses), except as to the particular details expressly set forth in the following sections for the respective types of cable, or as otherwise modified.

4.5.19 Borehole Cable (Suspended at One End Only)

4.5.19.1 Armor. Galvanized round steel wire shall be used for borehole cable.

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

▲ The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

Table 4-25
Size of Galvanized Steel Armor Wires for Borehole Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
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

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 Wires. The size of the armor wires shall be as given in Table 4-26.

Table 4-26
Size of Galvanized Steel Armor Wires for Dredge Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
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

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4.5.20.3 Pitch Ratio. The minimum pitch ratio shall be as given in Table 4-27.

Table 4-27
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

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

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires.

Where unusual service conditions exist, it may be desirable to modify the above pitch ratio. If so, it should be defined before the cable design is finalized.

4.5.21 Shaft Cable. If shaft cable is to be clamped to the shaft structure or wall, the metallic covering (either tape or wire) shall comply with the requirements of 4.5.3 through 4.5.16. If the shaft cable is to be suspended from one end, galvanized round steel wire armor shall be used.

The size of the armor wires shall be in accordance with 4.5.22.2, but the tensile safety factor shall be not less than five.

4.5.22 Vertical Riser Cable (Suspended at One End Only) for Installation Within Buildings

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

4.5.22.2 Size of Armor Wires for Nonsheathed Cable. The size of the armor wires shall be as given in Table 4-28.

The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.▲

Table 4-28
Size of Galvanized Steel Armor Wires for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
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

4.5.22.3 Size of Armor Wires for Sheathed Vertical Cable Riser. The size of armor wires 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. If wire band servings are used for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be applied over the armor. The length of the serving band and the spacing of the band throughout the length of the cable shall be as given in Table 4-29.

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

Table 4-29
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
2.501 and larger	63.53 and larger	25	7.6	4	102

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Division III
Round Wire Armor for Buried Cable

4.5.24. Scope. Division III gives details of construction of armor for buried land cables where greater longitudinal strength than that provided by flat tape armor is required, but not the strength of the regular armor required for submarine service. ▲

4.5.25 General. The requirements of Division I (4.5.3 through 4.5.16) pertaining to quality of materials, design and construction apply also to buried round wire armored cables, except as to particular details expressly set forth in 4.5.26.

4.5.26 Armor Wire and Jute Beddings and Servings (Sheathed and Nonsheathed Cables). The size of armor wire and thickness of jute bedding shall be as given in Table 4-30. (See 6.13.) ▲

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

A jute serving in accordance with 4.5.10 shall be applied over the armor.

Table 4-30
Thickness of Jute Bedding and Size of Armor Wires

Calculated Diameter of Cable Under Jute Bedding		▲ Minimum Thickness of Jute Bedding		▲ Nominal Size of Armor Wires		
inches	mm	mils	mm	BWG	mils	mm
0-0.750	0-19.05	45	1.14	14	83	2.11
1.751-1.000	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 is obtainable with No. 6 BWG (203 mils) (5.16 mm) or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils) (6.05 mm) wire may be used.

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Part 5
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

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

5.1.1 Multiple-conductor Round Cables. Where cables consist of one layer of conductors that layer shall have a left-hand lay; where there is more than one layer, the outer layer shall have a left-hand lay. A left-hand lay is defined as a counterclockwise twist away from the observer.

The length of lay of the individual conductors in the outer layer of cables with a common covering shall not exceed the value calculated from the factor given in Table 5-1. Where there is more than one layer of conductors, the conductors in the inner layers shall have a length of lay not greater than those in the outer layer unless the inner layer consists of a single conductor.

The length of lay of the individual conductors in 2, 3- or 4- conductor cables without a common covering shall not exceed 60 times the largest conductor* diameter.

Table 5-1

Number of Conductors in Cable	Multiplying Factors* Based on Calculated Diameter
2	30 times largest conductor
3	35 times largest conductor
4	40 times largest conductor
5 or more	15 times assembled cable diameter

*The "largest conductor" is the insulated or uninsulated conductor having the largest calculated overall diameter.

5.1.2 Flat Twin Cables. Flat twin cables shall consist of two insulated conductors laid parallel under a common covering. The diameter over the insulation of each conductor shall not exceed 1 inch (25.4 mm).

5.2 Fillers. Fillers shall be used in the interstices of multiple-conductor round cable with a common covering where necessary to give the completed cable a substantially circular cross section.

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

Fillers shall be of suitable material which is separate or integral with the jacket.

5.3 Conductor Identification

5.3.1 Power Cables. When required, insulated conductors shall be identified by any suitable means.

▲ 5.3.2 Control Cables

See Part 7.

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Part 6

TESTING AND TEST METHODS

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

Tests shall consist of the following, as required, namely, (1) tests on samples (see 6.4 to 6.26, inclusive and 6.30 and 6.31), (2) electrical tests on entire lengths of completed cables (see 6.27 to 6.29, inclusive), and (3) conductor tests (see 6.3) on samples or on entire lengths of completed cables. ▲

6.2 Selection of Samples. Tests shall be made on samples selected at random. Each test sample shall be taken from an 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 shall be permitted to 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:

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

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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 DC Resistance to 25°C (77°F)

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

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

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

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

Where:

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

For more accurate determination of resistance, allowing for different conductivities, see "Copper Wire Tables", National Bureau of Standards Handbook 100 or "Aluminum Wire Tables", National Bureau of Standards Handbook 109 and ASTM 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 2 000	Less than 610	0
2 000-10 000	610-3 048	1
Each 10 000 or fraction thereof from 10 000-50 000	Each 3 048 or fraction thereof from 3 048-15 240	1
Each additional 50 000 or fraction thereof	Each additional 15 240 or fraction thereof	1

Table 6-4
Number and Length of Samples

Quantity of Completed Cable Ordered		Size of Conductor		Number of Samples	Minimum Length of Each Sample	
feet	meters	kcmil ▲	mm^2		conductor feet	conductor meters
Less than 2 000	Less than 610	Less than 250	Less than 127	none	..	...
Less than 1 000	Less than 305	250 and larger	127 and larger	none	..	...
2 000-50 000	610-15 240	Less than 250	Less than 127	1	6	1.8
1 000-25 000	305-7 620	250 and larger	127 and larger	1	3	0.9
More than 25 000	More than 7 620					
First 25 000	First 7 620	250 and larger	127 and larger	1	3	0.9
Each additional 25 000	Each additional 7 620	250 and larger	127 and larger	1	3	0.9
More than 50 000	More than 15 240					
First 50 000	First 15 240	Less than 250	Less than 127	1	6	1.8
Each additional 50 000	Each additional 15 240	Less than 250	Less than 127	1	6	1.8

Table 6-3 deleted.

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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 Thickness Measurements for Insulations and Nonmetallic Jackets.

6.4.1 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. Measurements on the individual conductors of multiple-conductor cables shall be made before they are cabled.

6.4.2 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.

6.4.2.1 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 opposite 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.

6.4.2.2 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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6.4.3 Thickness Conformance. If the thickness is found to be less than the specified value, the coil or reel from which the sample was taken shall be considered as not conforming to this standard, and a thickness measurement shall be made on each of the remaining coils or reels.

6.5 Physical and Aging Tests for Insulations, Jackets and Nonmetallic Conducting Materials. (See 6.6 through 6.11).

6.5.1 Sampling

6.5.1.1 Insulations. Samples of insulated conductors for the unaged and aged physical tests shall be selected in accordance with Table 6-4.▲

Samples shall be taken after vulcanization and prior to the application of any covering except those applied before vulcanization. Cable tapes applied prior to vulcanization shall be removed from the samples prior to testing.

6.5.1.2 Jackets. 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.▲

6.5.1.3 Nonmetallic Conducting Materials. One test sample shall be molded from each lot of material intended for extrusion on cable.

6.5.2 Number of Test Specimens. Three test specimens shall be prepared from each of the samples selected in accordance with 6.5.1.

When one sample is selected in accordance with 6.5.1, all three test specimens shall be tested and the results averaged. When additional samples are required, only one test specimen out of three for each additional sample shall be tested and the other two specimens held in reserve.

6.5.3 Size and Preparation 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). The specimens shall be free of surface incisions and shall be as free as possible from other imperfections. For wire and cable smaller than 6 AWG having an insulation thickness of 90 mils (2.29 mm) or less, the test specimen may be the entire section of the insulation. When the full cross-section is used, the specimens shall not be cut longitudinally. For wire and cable 6 AWG and larger, or for wire and cable smaller than 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 mm²) shall be cut from the insulation. (In extreme cases, it may be necessary to use a segmental specimen.)* Except when a full cross-section is used, surface irregularities such as corrugations due to stranding, and so forth, shall be removed so that the test specimen will be smooth and of uniform thickness.▲

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

Where jackets are bonded to the insulation, separate smoothed samples of the insulation and jacket shall be prepared. Test specimens shall be die-cut from the samples after they have been allowed to recover for at least 30 minutes.

6.5.4 Calculation of Area of Test Specimens

6.5.4.1 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.

6.5.4.2 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. (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. *)

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.

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

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

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

6.5.4.4 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.

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

6.5.5 Physical Test Procedures. Physical tests on both the unaged and aged test specimens shall be made at approximately the same time. Tests shall be made not earlier than 24 hours nor later than 60 days after vulcanization.

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

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

6.5.6 Retests. If any 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.

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. 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.

6.6 Tensile Strength Test. The tensile strength test shall be made with specimens prepared in accordance with 6.5.2 and 6.5.3. The length of all of the specimens for the test shall be equal. Gauge marks shall be 2 inches (51 mm) when using 6 inch (152 mm) specimens and 1 inch (25 mm) apart when using 4.5 inch (114 mm) specimens except that 1 inch (25 mm) shall be used for polyethylene regardless of specimen length and shall have its cross-sectional area between gauge marks determined in accordance with 6.5.4. Each specimen 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. Each specimen shall be stretched at the rate of 20 inches (508 mm) ± 10 percent per minute (jaw speed) until it breaks. The tensile strength shall be calculated in accordance with ASTM D 412, using only those specimens which break between the gauge marks. The tensile strength shall be calculated on the area of the unstretched specimen.

The tensile and elongation determinations for compounds for which the compound manufacturer certifies that the base resin content is more than 50% 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).▲

Specimen length gauge mark distance and jaw speed shall be recorded with the results.

6.7 Tensile Stress Test. The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the gauge marks indicate that the specimen is at its prescribed elongation. The tensile stress shall be calculated in accordance with ASTM D 412. The tensile stress shall be calculated on the area of the unstretched specimen.▲

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

The elongation shall be taken as the distance between the gauge marks at rupture less the original gauge length marked on the specimen. The percentage of elongation at rupture is the elongation divided by the original gauge length and multiplied by 100. Specimen length, gauge mark distance and jaw speed shall be reported with the results.

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6.9 Set Test. The set test shall be made on test specimens which have been prepared, marked and stretched in accordance with 6.6 until the gauge marks are 6 inches (152 mm) apart. The test specimen shall be held in the stretched position for 5 seconds and then released. 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 of the original gauge length.

6.10 Aging Tests

6.10.1 Test Specimens. Test specimens of similar size and shape shall be prepared from each sample selected in accordance with 6.5.1 through 6.5.3, three for the determination of the initial or unaged properties, and three for each aging test required for the insulation or jacket being tested.

When the entire cross-section of insulation is used, the insulation shall be subjected to the aging condition with the conductor removed and each end of the specimen suitably plugged.

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

Simultaneous aging of different compounds should be avoided. (This paragraph is approved by NEMA as Authorized Engineering Information.)

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

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 rests and the determination of tensile strength and elongation.

6.10.2 Oxygen Pressure Test. The test specimens shall be heated in an atmosphere of oxygen at a pressure of 290 to 310 pounds per square inch (0.204 to 0.218 kgf/mm^2) at the temperature and for the period specified. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ± 1°C and recorded continuously.

6.10.3 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 controlled to within ± 1°C and recorded continuously.

6.10.4 Air Pressure Heat Test. The test specimens shall be heated in air at a pressure of 77 to 83 pounds per square inch (0.054 to 0.058 kgf/mm^2) at the temperature and for the period specified. This test shall be conducted in a steam-jacketed bomb or other suitable and uniformly heated chamber. The bomb shall be so regulated that the temperature inside the chamber will reach the test temperature within 15 minutes after inserting the test specimens. The air shall be substantially free from oil and moisture. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ± 1°C and recorded continuously.

6.10.5 Oil Immersion Test for Polyvinyl Chloride Jacket. The test specimens shall be immersed in ASTM Oil No. 2, described in Table I of ASTM D 471, at 70°C ± 1°C for 4 hours. At the end of this time, the specimens shall be removed from the oil and blotted.

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

6.10.6 Oil Immersion Test for Thermosetting Jacket. The test specimens shall be completely immersed in ASTM Oil No. 2, described in Table I of ASTM D 471, at 121°C ± 1°C for 18 hours. The specimens shall then be removed from the oil, blotted lightly, and suspended in air at room temperature for only 4 hours ± 1/2 hour before being 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. The elongation shall be based on the gauge marks applied to the specimen before immersion in the oil.

6.11 Physical Tests for Nonmetallic Conducting Materials Intended for Extrusion

6.11.1 Test Sample. See 6.5.1.3.

6.11.2 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 die-cut from the test sample. All three specimens shall be tested and the results averaged.▲

6.11.3 Elongation. Elongation shall be determined in accordance with 6.8 and 6.10.3.

6.11.4 Brittleness. Brittleness shall be determined in accordance with ASTM D 746, using Specimen A.

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6.20 Absorption Coefficient. Test specimens (see 6.5.2) shall be prepared from test samples selected in accordance with Table 6-5. The absorption coefficient of jacket compounds shall be determined in accordance with ASTM D 3349. ▲

6.21 Accelerated Water Absorption

6.21.1 General. No test sample shall be taken for 5 000 feet (1 524 meters) or less. One test sample for each test shall be taken for the first 5 001 to 20 000 feet (1 524 to 6 096 meters) of each cable construction and one additional sample for each additional 100 000 feet (30 480 meters). The gross length of each sample required by the electrical method shall be 15 feet (4.57 meters) and, by the gravimetric method, 11 inches (279 mm).

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

Test samples of the insulated conductor shall be taken after vulcanization and prior to the application of any covering except that which may have been applied before vulcanization. Such coverings shall be removed before the test is made.

6.21.2 Electrical Method (EM-60). The test shall be made at least 48 hours after vulcanization.

The middle 10 feet (3.05 meters) of the test sample shall be immersed in tap water which is maintained at 75°C ± 1°C for a period of 14 days, keeping the 2 1/2 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 sample. The water level shall be kept constant.

The capacitance of the insulation shall be determined at an average stress of 80 volts per mil at approximately 60 hertz after 1, 7 and 14 days' immersion. The power factor of the insulation at average stresses of 80 and 40 volts per mil shall be determined after 1 and 14 day's 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 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.

▲ 6.21.3 Gravimetric Method. An 11-inch (279-mm) test sample of the insulated conductor shall be taken if the weight of the sample is less than 100 grams. For heavier samples, a segment of the insulation 4 inches (102 mm) long shall be cut from the insulated conductor and smoothed to remove all corrugations. The surface of the test sample or segment shall be cleaned by scrubbing with a lintless cloth moistened with water, dried for 48 hours in a vacuum of 5 mm of mercury or less over calcium chloride at 70°C ± 2°C, and then weighed to the nearest milligram, Weight A. The area, S, shall be the number of square inches in a 10-inch (254-mm) length of the insulated wire or the total area in square inches of the segment.

The insulated wire sample shall be bent in the shape of a U around a mandrel having a diameter not less than three times the diameter of the sample, and the ends shall be inserted in tightly fitting holes in the cover of a 1-pint glass jar so that 10 inches (245 mm) of the sample will be immersed when the jar is completely filled with water and the cover applied.

The test segment shall be completely immersed.

The test sample or segment shall be immersed for 168 hours in freshly boiled distilled water which is maintained at 70°C ± 1°C. The level of the water shall be maintained flush with the undersurface of the cover during the soaking period. After 168 hours, the water shall be cooled to room temperature. The sample or segment shall be removed and the adhering water shaken off. It shall be blotted lightly with lintless cloth and weighed within 3 minutes to the nearest milligram, Weight B.

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The sample or segment shall be dried in a vacuum of 5 millimeters of mercury or less over calcium chloride at 70°C ± 2°C for 48 hours and then weighed to the nearest milligram, Weight C. The water absorption shall be calculated in terms of milligrams per square inch of surface as follows:

Water absorption (if C is less than A) $\frac{B - C}{S}$

Water absorption (if C is greater than A) $= \frac{B - A}{S}$

Where—

A = Weight of the sample or segment in milligrams before immersion.
B = Weight of the sample or segment in milligrams after immersion.
C = Weight of the sample or segment in milligrams after drying in vacuum.
S = Total area in square inches of the sample or segment.

6.22 Capacity and Power Factor. This test is applicable only to power cables rated 5 001 volts and above. One test sample shall be taken for the first 5 000 to 20 000 feet (1 524 to 6 096 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. The test sample shall be taken from the insulated conductor prior to the application of any covering except that which may have been applied before vulcanization. Such coverings shall be removed before the test is made.

The capacity and power factor shall be measured at approximately 60 hertz 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.

6.23 Tests for Discharge Resistance

6.23.1 Test Samples. The samples shall be taken from the completed cable. No sample shall be taken from the first 5 000 feet (1 524 meters). One sample shall be taken from the first 5 001 to 20 000 feet (1 524 to 6 096 meters) of each cable construction and one additional sample for each additional 100 000 feet (30 480 meters).

6.23.2 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, blotted and allowed to remain at room temperature for 10 minutes. Two 1-inch- (25.4-mm-) wide foil electrodes spaced 6 inches (152 mm) apart shall be wound around the cable surface which was immersed. 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 as follows:

$$P = 0.524\ RD$$

Where—

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

6.23.3 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 6-8.

Table 6-8

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 shall be applied between the conductor and the metal plate continuously for at least 6 hours. This test shall be made at room temperature.

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6.24 Volume Resistivity

6.24.1 Test Samples. One sample shall be taken from each 25 000 feet (7 620 meters) or major fraction thereof for each cable construction.

▲**6.24.2 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. Where a high degree of accuracy is not required, the 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:

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

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.

▲**6.24.3 Insulation Shield.** Four silver-painted annular-ring electrodes shall be applied to the surface of the insulation shield layer. The two potential electrodes shall be at least 2 inches (50.8 mm) apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode. Where a high degree of accuracy is not required, the 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.

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6.25 Stripping Test. Test samples shall be selected in accordance with Table 6-5, page 4. One test specimen shall be prepared from each sample. The test specimen shall be approximately 15 inches long, and all coverings over the extruded insulation 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.

6.26 Retests for Tests Covered by 6.13 through 6.25 and 6.30 and 6.31 ▲

6.26.1 If all of the samples pass the applicable tests described in 6.13 through 6.25 and 6.30 and 6.31, the quantity of cable which they represent shall be considered as meeting the requirements of this standard. ▲

6.26.2 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 two other lengths of cable in the quantity of cable under test. If either of the second samples fails to pass the test, the quantity of cable shall be considered as not meeting the requirements of this standard. If both such second samples pass the test, the quantity of cable (except the length represented by the first sample) shall be considered as meeting the requirements of this standard.

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

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ELECTRICAL TESTS ON COMPLETED CABLES

6.27 Voltage Tests

6.27.1 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.▲

6.27.1.1 Cables Without Metallic Sheath, Metallic Shield, or Metallic Armor. Except for the direct current spark test (see 6.27.4b) and the alternating current spark test (see 6.27.4a), single-conductor cables of this type which are twisted together into an assembly of two or more conductors without an overall jacket or covering shall be immersed in water for at least 1 hour and tested while still immersed; all other single-conductor and multiple-conductor cables of this type shall be immersed in water for at least 6 hours and tested while still immersed. Each insulated conductor shall be tested against all other conductors connected to the grounded water tank.▲

6.27.1.2 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.

6.27.2 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.

6.27.3 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 6.28. 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.

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● 6.27.4a Alternating-current Spark Test

6.27.4a.1 Application. This test shall apply to single-conductor cable and assemblies of single-conductor cables rated 0 through 2000 volts.

This test shall not apply to:
(a) Multiconductor cables other than assemblies of single-conductor cables.
(b) Cables with insulation shield.
(c) Cables with metallic sheath or armor.
(d) Assemblies containing uninsulated conductors.
(e) Cables rated above 2000 volts.

6.27.4a.2 Test Apparatus. Test apparatus shall consist of:
(a) A source of single-phase alternating-current potential capable of maintaining the required voltage under all normal leakage current conditions.
(b) An electrode capable of maintaining contact, throughout its length, with the periphery of the cable under test.
(c) A means of measuring voltage between electrode and ground.
(d) A means of indicating a fault (failure).

6.27.4a.3 Test Procedure. One side of the potential source shall be connected to the electrode and the other side of the potential source shall be connected to ground. The conductor(s) in the cable shall be tested to assure continuity when grounded at one or both ends. All ground connections shall be bonded (common). The fault indicator shall be connected to indicate abnormal current between electrode and ground.

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

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

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

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

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

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

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

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

6.27.4a.4 Failure. Any indication by the fault indicator shall constitute a failure.

▲ 6.27.4b Direct-current Spark Test. This test is applicable to single-conductor cables and assemblies of insulated single-conductor cables without insulation shield, and without metallic sheath or metallic armor, rated 0 through 2000 volts. The equipment for the direct-current spark test shall consist of a direct-current sparker of ample voltage and a suitable electrode. The sparker shall be capable of

† This paragraph is approved by NEMA as Authorized Engineering Information.
● Added 10-29-1979.
▲ Formerly par. 6.27.4.

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6.29 Partial-discharge Test Procedure ▲

Refer to ICEA Publication T-24-380.

6.30 Method for Flexibility Test for Continously Corrugated Armor.

6.30.1 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.

6.31 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:

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

D and d in inches

V in volts, actual breakdown level

● 6.32 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 MCM 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 12,192 meters). One additional sample shall be tested for each additional 30,000 feet (9144 meters) or major fraction thereof.

For all cables rated 2001-25,000 volts with conductor sizes 500 MCM and less, one sample shall be taken for orders of between 25,000 and 100,000 feet (7620 and 30,480 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 MCM and less, one sample shall be taken for orders of between 100,000 and 1,000,000 feet (304800 meters) or major fraction thereof.

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

▲ Deleted 7-16-1981.
● Added.

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Part 7
CONSTRUCTIONS OF SPECIFIC TYPES

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

7.1 Mine Power Cables

7.1.1 Scope. This section covers ethylene-propylene-rubber-insulated shielded cross-linked 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 15,000 volts at 100 or 133 percent insulation level. These cables shall be one of the following types: ▲

Type MP —three power conductors and three grounding conductors.

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

Ampacities are given in Appendix I. ▲

Recommended minimum bending radii are given in Appendix H. ▲

7.1.2 Conductors

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

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 B2 or B246 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 shall be as tabulated below. ▲

▲

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

W = Weight of cable in pounds. ▲

The conductor size shall be in accordance with Table 7.1-1 and shall meet the requirements given in Part 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 7.1-5. ▲

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

7.1.2.2 Grounding Conductors. Grounding conductors shall be Class B or C stranded annealed coated copper and shall meet the requirements given in Part 2. The size of each grounding conductor shall be in accordance with Table 7.1-1.

7.1.2.3 Ground Check Conductor. The ground check conductor shall be Class B or C stranded annealed coated or uncoated copper of the minimum size shown in Table 7.1-1 and shall meet the requirements given in Part 2.

7.1.3 Insulation. The insulation shall meet the requirements given in Part 3.

The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.1-2 and 7.1-3. 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.

7.1.4 Insulation Shielding. Each power conductor shall be shielded in accordance with 4.1.

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

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

7.1.6 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.

† **7.1.7 Jacket.** A cross-linked jacket which meets the requirements of 4.4.3, 4.4.8, 4.4.10, or 4.4.11 or a thermoplastic jacket which meets the requirements of 4.4.5 or 4.4.7 shall be applied over the conductor assembly. The average thickness of the jacket shall be not less than that given in Table 7.1-4, and the minimum thickness shall be not less than 80 percent of these values.

7.1.8 Outside Diameters. The outside diameter of the completed cable shall be within plus 8 and minus 5 percent of the values given in Tables 7.1-2 and 7.1-3.

7.1.9 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.1.

The insulated power conductors shall meet the test voltage and partial-discharge requirements given in Table 7.1-2 or 7.1-3.

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.

Table 7.1-1
Conductor Sizes

Size of Power Conductors, AWG or kcmil ▲		Copper Grounding Conductors		Copper
		Type MP Cables, Size in Each Interstice,	Type MP-GC Cables, Size in Each of Two Interstices,	Ground Check Conductor, Minimum Size,
Copper	Aluminum	AWG	AWG	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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7.2 Portable Single- and Multiple-conductor Power Cables

7.2.1 Scope. This section covers ethylene-propylene-rubber-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 7.2.18.

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 7.2-1 through 7.2-18. Recommended ampacities and voltage ratings are given in Appendix J. Recommended bending radii are given in Appendix H. ▲

GENERAL DESCRIPTION OF COMPLETED CABLE

7.2.2 Single-conductor Cables, Nonshielded, 0-2000 Volts. These cables shall consist of an insulated conductor with a jacket which meets the requirements of 7.2.18 and shall be in accordance with Table 7.2-2. Normal-service cables shall have a heavy-duty jacket, and hard-service cables shall have an extra-heavy-duty jacket.

7.2.3 Type W and G Two-conductor Cables, 0-2000 Volts. These cables shall be one of two types: (1) flat twin or (2) two-conductor round.

7.2.3.1 Two-conductor Flat Twin Cables

7.2.3.1.1 Type W, Without Grounding Conductor. These cables shall consist of two conductors which are separately covered with insulation and, in addition, may be separately covered with a tape, braid or serving, and then laid parallel under a jacket which meets the requirements of 7.2.18. The conductor shall be separated by a web of the jacket or other material. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.1.2 Type G, With Grounding Conductor. These cables shall consist of two power conductors which are separately covered with insulation and, in addition, may be separately covered with a tape, braid or serving. The two power conductors shall then be laid parallel with a grounding conductor (see 7.2.12) between them under a jacket which meets the requirements of 7.2.18. If the protective covering on the power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductor or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.2 Two-conductor Round Cables

7.2.3.2.1 Type W, Without Grounding Conductors. These cables shall consist of two conductors which are separately covered with insulation. In addition, each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.3.2.2 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 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.4 Type W, G and G-GC Three- and Four-conductor Cables, 0-2000 Volts. Three-conductor cables shall be one of five types: (1) Type W, round construction, without grounding conductors, (2) Type G, round construction, with grounding conductors, (3) Type G, flat construction, with grounding conductors, (4) Type G-GC, round construction, with

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grounding conductors and a ground check conductor and (5) Type G-GC, flat construction, with a grounding conductor 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.

7.2.4.1 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 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.2 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 7.2.15). The power conductors, together with the grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.3 Type G, Three-conductor Flat, With Grounding Conductors. These cables shall consist of three power conductors which are separately covered with insulation and may be separately covered with a tape, braid or serving. The three power conductors shall then be laid parallel with one of two flat grounding conductors (see 7.2.12) in a vertical position between each of them and under a jacket which meets the requirements of 7.2.18. If the protective covering on the individual power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductors or within the jacket. The cables shall be in accordance with Table 7.2-7.

7.2.4.4 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 7.2.12) and one ground check conductor (see 7.2.11). 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 7.2.15). All power grounding and ground check conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-8.

7.2.4.5 Type G-GC, Three-conductor Flat, With Grounding Conductor and Ground Check Conductor. These cables shall consist of three power conductors which are separately covered with insulation and may be separately covered with a tape, braid or serving. The three power conductors shall be laid parallel with the flat ground check conductor (see 7.2.11) in a vertical position between the black and white power conductors and with the flat grounding conductor (see 7.2.12) in a vertical position between the white and red power conductors under a jacket which meets the requirements of 7.2.18. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors, grounding conductor and ground check conductor or within the jacket. The cables shall be in accordance with Table 7.2-9.

7.2.5 Type W and G, Five- and Six-conductor 0-2000 Volts. Five-conductor cables shall be 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.

7.2.5.1 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 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-10.

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7.2.5.2 Type G, With Grounding Conductor (Five-conductor Cables Only). These cables shall consist of five power conductors which are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 around a single grounding conductor and covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-10. These cables shall be used for the internal wiring of equipment only.

7.2.6 Type PG, Two and Three Power Conductor 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 7.2.15). The power conductors, together with a single grounding conductor (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-11.▲

7.2.7 Type PCG, Two and Three Power Conductor 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 7.2.15). 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 7.2-1. 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 7.2.18. These cables shall be in accordance with Table 7.2-12.

7.2.8 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 7.2.15). The power conductors, together with the grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-13.

7.2.9 Type SH, SHC-GC, SHD, and SHD-GC, Shielded Cables, 0-25 000 Volts at 100 Percent Insulation Level Only

7.2.9.1 Type SH Single-conductor Cables, 2001-25 000 Volts. These cables shall consist of an insulated conductor covered with a tape, a shield which meets the requirements of 7.2.16 with or without a tape over the shield, and a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-14.

7.2.9.2 Type SHC-GC Three-conductor Cables, 0-2000 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 or braid which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12), one ground check conductor (see 7.2.11), and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1. 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 7.2.16 and a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-15.

7.2.9.3 Type SHD Three-conductor Cables, 0-25 000 Volts. These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.2.15) and a shield which meets the requirements of 7.2.16, and three grounding conductors (see Table 7.2-18), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 7.2-1 and

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covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-16.

7.2.9.4 Type SHD-GC Three-conductor Cables, 0-25 000 Volts. These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.2.15) and a shield which meets the requirements of 7.2.16 and two grounding conductors (see Table 7.2-18) and one ground check conductor (see 7.2.11).

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 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-16.

7.2.10 Power Conductors

7.2.10.1 Power conductors shall be made of annealed coated or uncoated copper wires in accordance with Part 2. A nonconducting separator may be used for cables rated 0-2000 volts.

7.2.10.2 The sizes, strandings, and nominal diameters of the conductors shall be in accordance with Table 7.2-18.

7.2.10.3 A Conductor stress control layer shall be in accordance with 2.7.▲

7.2.11 Control and Ground Check Conductors. The control conductors for Type PCG shall be not smaller than 10 AWG. The ground check conductor for Types G-GC, SHC-GC and SHD-GC shall be as given in Tables 7.2-8, 7.2-9, 7.2-15 and 7.2-16. 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 7.2.10.

7.2.12 Grounding Conductors

7.2.12.1 The grounding conductors for two, three and four conductor round Type G, SHC-GC, SHD and SHD-GC shall be annealed copper of not less than the size and number of wires in Table 7.2-18 for the corresponding power conductor sizes. In all other characteristics, they shall meet the requirements of 7.2.10.

7.2.12.2 The single grounding conductor for flat twin Type G cables shall be composed of either coated or uncoated copper and shall have a minimum cross-sectional area of 50 percent of the power conductor but not less than the cross-sectional area for a No. 8 AWG conductor as given in Table 7.2-3. A separator may be used. The grounding conductor wires shall meet the requirements of 2.1.1.

7.2.12.3 The two grounding conductors for flat three-conductor Type G cables shall be flat, rectangular or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-7. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.4 The grounding conductors for three-conductor round Type G-GC shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Table 7.2-8.

7.2.12.5 The grounding conductor for flat three-conductor Type G-GC cables shall be flat, rectangular or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-9. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.6 The single grounding conductor for five-conductor Type G and for Type PG and PCG cables shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Tables 7.2-10, 7.2-11 and 7.2-12.

7.2.12.7 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.

7.2.13 Insulation. The insulation shall meet the requirements given in Part 3. The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.2-2 through 7.2-16. In these tables, the highest rated circuit voltage given in the titles represents the maximum operating volt-

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age 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 8 AWG ground check conductors. The minimum thickness shall be not less than 90 percent of the specified average values.

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

▲ **7.2.15 Conductor Identification.** Identification shall be by any suitable means in accordance with the color sequence given in 7.2.15.1 and 7.2.15.2. If a conducting nonmetallic tape is used over the insulated conductor, it shall be plainly identified as being conducting.

7.2.15.1 Power Conductors

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

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

7.2.15.2 Control and Ground Check Conductors

Control conductors, Type PCG	black, white
Ground check conductor, Type G-GC (round or flat), Type SHD-GC, and Type SHC-GC	yellow

▲ Editorially revised.

7.2.16 Shielding

7.2.16.1 The shielding for Types SH, SHD, SHC-GC and SHD-GC cables shall consist of nonmagnetic wires.

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

7.2.16.2 Metal Braid Shields. If 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

$$\tan a = \frac{2\pi DP}{C}$$

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

7.2.16.3 Metal Wire Shields. If the shielding is applied in the form of a serving or wrap, the coverage shall be not less than 60 percent as determined by the following formula:

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

Where—

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

$$\tan a = \pi \frac{D}{C}$$

C = Pitch of serving in inches

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7.2.17 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 Type 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. A binder tape and/or threads may be used over the assembly.

† 7.2.18 Jackets

7.2.18.1 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 requirements of 7.2.18.1.1, 7.2.18.1.2, 7.2.18.1.3, 7.2.18.1.4, 7.2.18.1.5, 7.2.18.1.6, 7.2.18.1.7, or 7.2.18.1.8.

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. ▲

7.2.18.1.1 Extra-heavy-duty Neoprene Jacket

Physical requirements	
Tensile strength, minimum	
psi	2400
MPa	16.5 ▲
Tensile stress at 200 percent elongation, minimum	
psi	700
MPa	4.83 ▲
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Tear, minimum	
pounds per inch	40
kN/m	7.01 ▲

(Continued)

(Continued)

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

7.2.18.1.2 Heavy-duty Neoprene Jacket

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	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

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† Revised.

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7.2.18.1.3 Extra - heavy - duty Nitrile - butadiene/polyvinyl-chloride Jacket *

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

7.2.18.1.4 Heavy-duty Nitrile-butadiene/-polyvinyl-chloride Jacket *

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30

(Continued)

(Continued)

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

7.2.18.1.5 Heavy - duty Chlorosulfonated Polyethylene Jacket

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C ± 1°C for 168 hours — tensile strength, 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

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

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7.2.18.1.6 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

●7.2.18.1.7 Heavy-Duty Chlorinated Polyethylene, Cross-Linked

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

●7.2.18.1.8 Extra-Heavy-Duty Chlorinated Polyethylene, Cross-Linked

Physical requirments	
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, minimum, percentage of unaged value	60

7.2.18.2 Thickness of Jacket. The average thickness of the jacket shall be not less than that given in Tables 7.2-13 through 7.2-17. The minimum thickness shall be not less than 80 percent of the values given in the tables. The reinforcing specified in 7.2.18.1 shall be included in the measurement of the jacket thickness.

7.2.19 Completed Cable

7.2.19.1 Outside Diameters. Nominal outside diameters of the completed cables shall be in accordance with Tables 7.2-2 through 7.2-16.

7.2.19.2 Diameter Tolerances. The tolerance for outside diameters shall be plus 8 percent and minus 5 percent, except for 0-2000 volt nonshielded cables. For 0-2000 volt flat twin cables, the tolerance shall be ± 0.04 inch for the major and ± 0.03 inch for the minor diameter. For 0-2000 volt flat three-conductor cables, the tolerance shall be ± 0.08 inch for the major and ± 0.05 inch for the minor diameter. For all other 0-2000 volt nonshielded cables, the tolerances shall be as follows:

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Size, AWG or kcmil ▲	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

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

7.2.21 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.2.

The insulated power conductors shall meet the test voltage requirements given in Table 7.2-2 through 7.2-16. 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.

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7.3 Preassembled Aerial Cables

7.3.1 Scope. This section covers preassembled aerial cables with one or more individually insulated ethylene-propylene-rubber conductors which are attached to a messenger to form self-supporting aerial cables for use on power transmission and distribution systems operating at 35 kV or less phase to phase.

The characteristics of the completed assembly shall be such that the cable can be installed at a minimum temperature of minus 10°C (14°F).

For ampacities see Appendix M.▲

7.3.2 Conductors. Conductors shall be either copper or aluminum in accordance with Part 2.

7.3.2.1 Copper. Copper conductors shall be sizes 6 AWG to 750 kcmil. The stranding will be Class B, Class C or compact except that, when required, size 6 AWG may be solid.▲

7.3.2.2 Aluminum. Aluminum conductors shall be sizes 6 AWG to 750 kcmil. The stranding shall be Class B, Class C, or compact.▲

7.3.2.3 Conductor Stress Control Layer. Conductor stress control layer shall be in accordance with 2.7.▲

7.3.3 Insulation. The insulation shall meet the requirements given in Part 3, except that, for Type I cable, the average insulation thickness shall be not less than that given in Table 7.3-1 and the minimum thickness shall be not less than 90 percent of this value.

7.3.4 Cable Types. The cable shall be one of the types given in Table 7.3-2.

7.3.4.1 Type I Nonshielded, Jacketed or Nonjacketed. Type I cables shall be in accordance with Tables 7.3-1 and 7.3-2, and cables rated 2001-5000 volts shall meet the requirements of 7.9.6.2.

Table 7.3-1
Type I Cables Only

Rated Circuit Voltage, Phase to Phase, Volts	Conductor Size, AWG or kcmil▲	Jacketed Cable: Insulation Thickness at 100 and 133 Percent Insulation Level		Jacket Thickness		Nonjacketed Cable: Insulation Thickness		Test Voltage, kV	
		mils	mm	mils	mm	mils	mm	a-c	d-c
0-600	6-2	45	1.14	30	0.76	60	1.52	5.5	16.5
	1-4/0	55	1.40	45	1.14	80	2.03	7	21
	225-500	65	1.65	65	1.65	95	2.41	8	24
	525-750	80	2.03	65	1.65	110	2.79	10	30
601-2000	6-2	55	1.40	30	0.76	70	1.78	7	21
	1-4/0	65	1.65	45	1.14	90	2.29	8	24
	225-500	75	1.90	65	1.65	105	2.67	9.5	28.5
	525-750	90	2.29	65	1.65	120	3.05	11.5	34.5
		100 Percent Insulation Level Only							
2001-5000	6	90	2.29	30	0.76	110	2.79	13	35
	4-2/0	90	2.29	45	1.14	110	2.79	13	35
	3/0-4/0	90	2.29	65	1.65	110	2.79	13	35
	225-500	90	2.29	65	1.65	120	3.05	13	35
	525-750	90	2.29	65	1.65	130	3.30	13	35

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7.3.4.2 Type II Shielded, Nonjacketed. Type II cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1 except that the metallic component shall be a helically wrapped nonmagnetic shielding tape having a thickness of at least 4.5 mils (0.114 mm) and shall be applied with a lap of not less than 15 percent of its width.

7.3.4.3 Type III Shielded, Jacketed Type III cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1. A separator tape may be applied over the shielding.

7.3.5 Jacket. Jackets for Type I and III cables shall be one of the following:

	See par.
Neoprene, heavy-duty black	4.4.3
Polyvinyl chloride	4.4.5
Polyethylene, black	4.4.6
● Chlorinated Polyethylene, Thermoplastic	4.4.7
▲ Nitrile-butadiene/polyvinyl-chloride, heavy duty	4.4.8
▲ Chlorosulfonated polyethylene, heavy duty	4.4.10
● Chlorinated Polyethylene, Heavy Duty, Cross-Linked	4.4.11

The average thickness of the jacket for Type I cables shall be not less than that given in Table 7.3-1 and, for Type III cables, not less than that given in Table 4-3. The minimum thickness shall be not less than 80 percent of these values.

7.3.6 Identification. Each insulated conductor of multiple-conductor cables shall be permanently marked so that circuit identification can be made without exposing the insulation. Single-conductor cables need not have circuit identification. Cables shall be identified to indicate the manufacturer.

7.3.7 Assembly. The insulated conductors shall be cabled together with a suitable lay. The messenger shall be laid parallel to the axis of a single conductor or the cabled conductors. The cabled conductors shall be bound to a copper type messenger by means of a copper binding strap or to an aluminum type messenger by means of an aluminum binding strap. The binding strap shall have a pitch of from 3 to 8 inches (76.2 to 203.2 mm), shall be rectangular with rounded edges, and shall have nominal dimensions not less than those shown in Table 7.3-3.

The messenger shall extend 5 feet (1.52 meters) beyond each end of the conductors for use in installing the cable.

7.3.8 Messenger Sizes. The messenger shall be either composite stranded copper and copper-clad steel in accordance with ASTM B 229, Grade 30 EHS stranded copper-clad steel in accordance with ASTM B 228, stranded aluminum-clad steel in accordance with ASTM B 416, stranded aluminum-alloy conductors (AAAC) in accordance with ASTM B 399, or composite stranded aluminum and aluminum-clad steel (ACSR/AW) in accordance with ASTM B 549. The 9/16-inch copper-clad steel size is based on the use of 19-wire construction rather than the 7-wire for added strength and flexibility.

The messenger sizes for copper-clad steel shall be as given in Table 7.3-4 and for ACSR/AW shall be as given in Table 7.3-5. For other types of messenger, consult the manufacturer.

7.3.9 Design Criteria*. The messenger size should be based on a normal stringing tension of 60°F(15.6°C) not exceeding 30 percent of the ultimate strength and a maximum tension not exceeding 50 percent of the ultimate strength at a heavy loading condition. For further information, see the National Electrical Safety Code, ANSI Standards Publication No. C2.

The messenger sizes given in Tables 7.3-4 and 7.3-5 are of sufficient strength, except for the 750 kcmil copper cable, to permit installation of the cables on the basis of a 150-foot (45.7-meter) ruling span with a maximum normal sag of 2.5 feet (0.76 meter) at 60°F (15.6°C) no ice, no wind, and without exceeding the tension limits given in Table 7.3-6. ▲

For the 750 kcmil copper cable, the span should be limited to 125 feet (38.1 meters) to satisfy this design criteria. ▲

For single-phase circuits using the messenger as the grounded neutral conductor, the resistance of the messenger should be not greater than that of the conductor.

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

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

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● Added.

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7.4 Single- and Multiple-conductor Flexible Cords

7.4.1 Scope. This section covers single, two-, three- and four-conductor flexible cords with conductor sizes 18 to 10 AWG, inclusive, with ethylene-propylene-rubber insulation and with heavy-duty or medium-duty jackets.

Multiple-conductor cords are intended for hard service (300 volts maximum) or extra hard service (600 volts maximum).

Single-conductor cords do not have a service designation. For single-conductor cords, sizes 18 and 16 AWG, the maximum voltage rating is 300 volts. For single-conductor cords, sizes 14, 12 and 10 AWG, the maximum voltage rating is 600 volts.

Ampacities, type designations and voltage ratings are given in Appendix N. ▲

Remote control and drill cords for use in underground coal mines in accordance with U. S. Bureau of Mines requirements for Electric Motor-Driven Mine Equipment and Accessories (Schedule 2G) are covered in Appendix N.

7.4.2 Conductors

7.4.2.1 The conductors shall be annealed uncoated or coated copper wire and shall meet the requirements given in Part 2 except the conductor resistance, as specified in paragraph 2.5, is not required.

The conductor size shall be determined by the method in paragraph 6.3.2.1 which specifies cross-sectional area by diameter measurement, or by paragraph 6.3.2.2 which specifies cross-sectional area by weight.

7.4.2.2 Sizes. The conductors shall be sizes 18 through 10 AWG. The cross-sectional area of the conductors shall be not more than 2.0 percent below the values given in Table 7.4-1, except that if only No. 30 AWG strands are employed on 18 AWG conductors, the cross-sectional area shall be not less than 3 percent below the values given in the table.

7.4.2.3 Stranding. The strands in the conductors shall be no smaller than 36 AWG and no larger than 30 AWG. The individual strands of the conductors shall be bunch stranded (twisted together) or rope stranded. The lay of twist shall not exceed the values given in Table 7.4-1.

7.4.2.4 Separator. A separator, if used, shall consist of a close covering of cotton, paper or other material. Where a separator is not used, the individual strands of the conductor shall be separately coated in accordance with 2.1.1.2.

Table 7.4-1
Conductor Requirements

Conductor Size, AWG	Cross-sectional Area, cmil ▲	Maximum Lay of Twist: Bunch Stranded (Lay of Strands) inches	mm	Rope Stranded (Lay of Ropes) inches	mm
18	1 620	1.00	25.4	1.88	47.8
16	2 580	1.25	31.8	2.13	54.1
14	4 110	1.63	41.4	2.50	63.5
12	6 530	2.00	50.8	3.13	79.5
10	10 380	2.50	63.5	3.13	79.5

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7.4.3 Insulation. The insulation shall meet the requirements given in Part 3, except that the thickness shall be in accordance with Table 7.4-2 and shall be measured as follows:

7.4.3.1 Average Thickness. The average thickness of the insulation shall be determined in accordance with 6.4.2.1.

7.4.3.2 Minimum Thickness. The minimum thickness of the insulation shall be determined by a pin-gauge dial micrometer which exerts a force of 25 plus or minus 2 grams on the specimen. The pin shall be 0.437 inch (11.1 mm) long and 0.043 inch (1.09 mm) in diameter, and the end of the presser foot which makes contact with the specimen shall be a flat rectangle 0.043 inch (1.09 mm) wide by 0.312 inch (7.92 mm) long.

The conductor and the separator, if any, shall be removed carefully. The specimen of insulation shall be placed carefully on the pin. The specimen shall be so located that the entire length of the presser foot will make contact with it. The presser foot shall be permitted to come to rest gently on the specimen, and the reading shall be taken immediately.

The specimen shall be rotated and several measurements taken in order to determine the actual minimum thickness. The presser foot shall not be in contact with the specimen when the latter is rotated.

7.4.4 Conductor Assembly

7.4.4.1 Circuit Identification. Circuit identification shall be obtained by means of colored insulating compounds, braids or tapes in the following sequence:

Two conductors —black, white
Three conductors—black, white, green, or
black, white, red
Four conductors —black, white, red, green

7.4.4.2 Length of Lay. The length of lay of insulated conductors shall not exceed the values given in Table 7.4-3.

7.4.4.3 Fillers. Fillers shall be placed in the interstices of the assembly (see 5.2).

7.4.4.4 Binder. A binder, if used, shall be a tape, braid, wrap of multiple ends of thread, or a combination of these, and shall be applied over the assembled conductors.

Table 7.4-2▲
Insulation Thicknesses

Conductor Size, AWG	Hard Service Multiple-conductor Cords				Extra Hard Service Multiple-conductor Cords and Single-conductor Cords			
	Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm
18-16	30	0.76	27 *	0.69	30	0.76	27 *	0.69
14	30	0.76	27 *	0.69	45	1.14	41 †	1.04
12	30	0.76	27 *	0.69	45	1.14	41 †	1.04
10	45	1.14	41 †	1.04	45	1.14	41 †	1.04

* The minimum thickness at the line of contact between conductors shall be not less than 25 mils (0.64 mm).
† The minimum thickness at the line of contact between conductors shall be not less than 39 mils (0.99 mm).

Table 7.4-3
Maximum Length of Lay

Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
	inches	mm	inches	mm	inches	mm
18	2.00	50.8	2.25	57.2	2.50	63.5
16	2.25	57.2	2.50	63.5	2.75	69.8
14	2.50	63.5	3.25	82.6	3.75	95.2
12	3.00	76.2	3.50	88.9	4.25	108.0
10	3.50	88.9	4.00	101.6	4.75	120.6

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7.4.5 Jackets

7.4.5.1 Heavy-Duty Jackets The jacket shall be a black compound of natural rubber, SBR synthetic rubber, or neoprene or a black or colored compound of nitrile-butadiene/polyvinyl-chloride, chlorosulfunated polyethylene, or cross-linked chlorinated polyethylene which meets the applicable requirements of Table 7.4-4.▲

Table 7.4-4▲
Heavy-duty Jackets

	Natural Rubber	SBR	Neoprene	Nitrile butadiene/ polyvinyl-chloride*	Chloro-sulfonated Poly-ethylene	Chlorinated Poly-ethylene, Cross-linked
Physical requirements						
Tensile strength, minimum						
psi	3500	1800	1800	1800	1800	1800
MPa	24.1	12.4	12.4	12.4	12.4	12.4
Tensile stress at 200 percent elongation, minimum						
psi	500	...	500	500	500	500
MPa	3.45	...	3.45	3.45	3.45	3.45
Elongation at rupture, minimum, percent	500	300	300	300	300	300
Set, maximum, percent	15	20	20	30	30	30
Tear resistance, 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	...	...	50	50	85	85
Elongation at rupture, minimum, percentage of unaged value	...	...	50	50	65	55
After air oven test at 70 °C ± 1 °C for 168 hours						
Tensile strength, minimum						
psi	...	1600	...	...	...	...
MPa	...	11.0	...	...	...	...
Elongation at rupture, minimum, percent	...	250	...	...	...	...
After oxygen pressure test at 70 °C ± 1 °C for 96 hours						
Tensile strength, minimum						
psi	2500	1600	...	...	...	...
MPa	17.2	11.0	...	...	...	...
Elongation at rupture, minimum, percent	400	250	...	...	...	...
After oil immersion test at 121 °C ± 1 °C for 18 hours—tensile strength and elongation. minimum, percentage of unaged value	...	...	60	60	60	60

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

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● Added

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7.4.5.2 Medium-duty Jackets. The jacket shall be a black or colored compound of natural rubber, SBR synthetic rubber, neoprene, nitrile-butadiene/polyvinyl-chloride, chlorosulphonated polyethylene, ethylene propylene rubber or polyvinyl-chloride, or thermoplastic chlorinated polyethylene which meets the applicable requirements of Table 7.4-5. ▲

7.4.5.3 Oil Resistance. The jacket of an oil-resistant cord shall be one of those meeting the requirements of 121 °C oil immersion test given in Table 7.4-4 or 7.4-5. ▲

7.4.5.4 Application. The jacket shall be applied over the insulation of a single-conductor cord or over the assembled conductors or binder of multiple-conductor cords.

7.4.5.5 Reinforcement. Reinforcement, if used, shall consist of a braid or a serving of fibrous material under the entire jacket or completely embedded in the jacket.

7.4.5.6 Thickness. The thickness of the jacket shall be in accordance with Table 7.4-6 and shall be determined in accordance with 7.4.3.1 and 7.4.3.2.

7.4.6 Overall Diameters. The minimum average overall diameter of the completed cord shall be in accordance with Table 7.4-7.

Table 7.4-6
Average and Minimum Thicknesses of Jackets

Conductor Size, AWG	Single-conductor Cords				Multiple-conductor Cords ▲							
					Hard Service Two to Four Conductors				Extra Hard Service Two to Four Conductors			
	Average		Minimum		Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
18	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
16	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
14	30	0.76	23	0.58	30	0.76	23	0.58	80	2.04	64	1.63
12	30	0.76	23	0.58	45	1.14	36	0.91	95	2.42	76	1.94
10	30	0.76	23	0.58	60	1.55	48	1.22	95	2.42	76	1.94

Table 7.4-7
Overall Diameters

Type of Cord	Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
		Minimum inches	Maximum inches	Minimum inches	Maximum inches	Minimum inches	Maximum inches
Hard service	18	0.280	0.315	0.300	0.335	0.325	0.365
	16	0.305	0.340	0.325	0.360	0.350	0.395
	14	0.335	0.375	0.360	0.395	0.390	0.435
	12	0.405	0.455	0.425	0.475	0.465	0.520
	10	0.540	0.606	0.565	0.635	0.625	0.700
Extra hard service	18	0.340	0.385	0.360	0.400	0.385	0.430
	16	0.365	0.410	0.385	0.430	0.410	0.460
	14	0.495	0.550	0.520	0.575	0.560	0.620
	12	0.565	0.625	0.590	0.655	0.640	0.710
	10	0.615	0.685	0.650	0.720	0.700	0.775

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Table 7.4-5
Medium-duty Jackets

	Natural Rubber or SBR	Neoprene	Nitrile-butadiene/ polyvinyl-chloride*	Chloro-sulphonated Polyethylene	Ethylene Propylene Rubber	● Chlorinated Polyethylene, Cross-linked	Polyvinyl Chloride*	● Chlorinated Polyethylene, Thermoplastic
Physical requirements								
Tensile strength, minimum								
psi	1500	1500	1500	1500	1500	1500	1600	1400
MPa	10.3	10.3	10.3	10.3	10.3	10.3	11.0	9.6
Elongation at rupture, minimum, percent	300	300	250	300	300	300	250	150
Set, maximum, percent	20	20	30	30	. . .	35	. . .	. . .
Aging requirements								
After air-oven test at 121 °C for 168 hours								
Tensile strength, minimum, percentage of unaged value	. . .	. . .	. . .	. . .	. . .	. . .	. . .	85
Elongation at rupture, minimum, percentage of unaged value	. . .	. . .	. . .	. . .	. . .	. . .	. . .	50
After air oven test at 100 °C ± 1 °C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	. . .	50	50	. . .	. . .	55	50	. . .
After oxygen pressure test at 70 °C ± 1 °C for 96 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	70	. . .	. . .	70	. . .	. . .	. . .	. . .
After oxygen pressure test at 80 °C ± 1 °C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	. . .	. . .	. . .	. . .	50	. . .	. . .	. . .
After air pressure heat test at 127 °C ± 1 °C for 20 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	60	. . .	. . .	60	50	. . .
After oil immersion test at 100 °C ± 1 °C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	. . .	. . .	. . .	. . .	. . .	. . .	. . .	60
After air oven test at 70 °C ± 1 °C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	. . .	. . .	. . .	70	. . .	. . .	. . .	. . .

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

● Added.

7.4.7 Strength of Completed Cord. The mechanical strength of completed two- and three-conductor cord, sizes 16 and 18 AWG, shall be determined by means of a freely hanging weight or a suitable testing machine and shall be such that no conductor will break when the test force given in Table 7.4-8 is applied for 1 minute.

7.4.8 Tests. The cord shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.4 except as otherwise specified in 7.4.8.1.

7.4.8.1 Electrical Tests. Each length of completed single-conductor cord shall withstand either the direct-current or the alternating-current spark test voltage given in Table 7.4-9. Each length of completed multiple-conductor cord shall withstand an alternating-current voltage test unless each individual insulated conductor, prior to assembly, has withstood either an alternating-current spark test or a direct-current spark test. The alternating-current voltage shall be applied for 15 seconds between conductors without immersing the cord in any liquid.

The alternating-current test and the alternating-current spark test shall be in accordance with Underwriters' Laboratories, Inc., "Standards for Flexible Cord and Fixture Wire", UL 62.

The direct current spark test shall be in accordance with 6.27.4b.▲

The test voltages shall be in accordance with Table 7.4-9.

Table 7.4-8
Strength of Completed Cord

Type of Cord	Conductor Size, AWG	Test Force, Two and Three Conductor, Pounds	Test Force, Two and Three Conductor, kg
Hard service	18	175	79.4
	16	200	90.7
Extra hard service	18	200	90.7
	16	225	102

Table 7.4-9
Test Voltages

Conductor Size, AWG	Test Voltages, kV: a-c Voltage Test	a-c Spark Test	d-c Spark Test
18	2.0	6.0	....
16	2.0	6.0	....
14	3.0	7.0	16.0
12	3.0	7.0	16.0
10	3.0	7.0	16.0

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7.5 Control Cables

7.5.1 Scope. This section covers multiple conductor ethylene-propylene-rubber-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 coveyance 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 or control 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 over-voltages 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.

7.5.2 Conductors

7.5.2.1 Conductors shall be made of annealed coated or uncoated copper in accordance with Part 2.

7.5.2.2 Sizes 16 AWG and smaller shall be solid or stranded. Sizes larger than 16 AWG shall be stranded. Stranding shall be in accordance with 2.3, Class B or C.

7.5.3 Insulation

7.5.3.1 The insulation shall be of one of the following types:

a. Type I (see 3.6).

b. Type II (see 3.7).

c. A composite insulation consisting of a layer of insulating neoprene or chlorosulfonated polyethylene over a layer of Type I or Type II insulation without any further covering (see 7.5.9.3 and 7.5.9.4).

7.5.3.2 The minimum average thickness of insulation shall be not less than that given in Table 7.5-1. The minimum thickness at any point shall be not less than 90 percent of that given in the table. For composites, the minimum thickness at any point of each layer of material shall not be less than 90 percent of the value specified in Table 7.5-1.

7.5.4 Jacket Over Insulation. Jackets shall not be required over the individual conductors. However, if a jacket is used, it shall be of one of the materials given in 7.5.7 and shall have a minimum average thickness of not less that 15 mils (0.38 mm) and a minimum thickness at any point of not less than 12 mils (0.30 mm).

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

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

7.5.7 Overall Jacket

7.5.7.1 Type A, B and C cables shall have an overall jacket in accordance with one of the following:

Thermoplastic

Polyvinyl chloride.....4.4.5
Polyethylene, black 4.4.6

Thermoset

Neoprene, heavy-duty black 4.4.3
Nitrile-butadiene/polyvinyl-chloride heavy-duty.....4.4.7
Chlorosulfonated polyethylene, heavy-duty.....4.4.9

7.5.7.2 The minimum average thickness of the jacket shall be not less than that given in Table 7.5-2. The minimum thickness at any point shall be not less than 80 percent of that given in the table.

7.5.8 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.*

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Table 7.5-1
Conductor Sizes, Insulation Thicknesses, and Test Voltages #

Conductor Size AWG	Voltage Rating-300V or 600V						Voltage Rating-1000V					
	Insulation Thickness				Test Voltage kV		Insulation Thickness				Test Voltage kV	
	Single Layer		Composite†				Single Layer		Composite†			
	mils	mm	mils	mm	a-c	d-c	mils	mm	mils	mm	a-c	d-c
20-18	25	0.64	20/10	0.51/0.25	2.5	7.5	...	...	...	...	...	...
16	25	0.64	20/10	0.51/0.25	2.5	7.5	45	1.14	30/15	0.76/0.38	4.5	13.5
14-9	30	0.76	20/10	0.51/0.25	3.0	9.0	45	1.14	30/15	0.76/0.38	4.5	13.5

The voltages shall be determined by the size of the conductor and the rated voltage of the cable and not the apparent thickness of the insulation.

† Composite Thicknesses - Inner Layer/Outer Layer

7.5.9 Tests

7.5.9.1 The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.5.

7.5.9.2 Electrical tests on completed cable shall be in accordance with 6.27 and 6.28, except that the tests may be made without immersion in water. The dielectric withstand voltage level shall be as specified in Table 7.5-1.

7.5.9.3 Physical and Aging Requirements For Composite Insulations. (See 6.5) Composite insulation shall meet the requirements specified in either 7.5.9.3.1 or 7.5.9.3.2.

7.5.9.3.1 If the layers cannot be separated, they shall be tested as a unit construction and shall meet the following requirements:

Physical Requirements
- Tensile strength, minimum
  - psi 1000
  - MPa 6.90
- Elongation at rupture, minimum, percent 250

Aging Requirements
- After air oven test at 121 °C ± 1°C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 50

7.5.9.3.2 If the layers can be separated, they shall be tested separately and shall meet the following requirements:

Inner Insulating Layer-Type I

Physical requirements
- Tensile strength, minimum
  - psi 700
  - MPa 4.83
- Elongation at rupture, minimum, percent 250

Aging Requirements
- After air oven test at 121 °C ± 1 °C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 75

Inner Insulating Layer-Type II

Physical requirements
- Tensile strength, minimum
  - psi 1200
  - MPa 8.27
- Elongation at rupture, minimum, percent 150
- Tensile Strength at 100 percent elongation, minimum
  - psi 500
  - MPa 3.45

Aging Requirements
- After air oven test at 121 °C ± 1 °C for 168 hours
- Tensile strength, minimum, percentage of unaged value 75
- Elongation, minimum, percentage of unaged value 75

Outer Insulating Layer
- Tensile strength, minimum
  - psi 1500
  - MPa 10.34
- Elongation at rupture, minimum, percent 300

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Table 7.5-2
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

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 40

7.5.9.4 Electrical Requirements For Composite Insulations:

Specific surface resistivity, minimum megohms (see 6.23.2) 200,000

Accelerated water absorption (see 6.21*)
Electrical method (EM-60)
Dielectric constant after 24 hours, maximum 4.5
Increase in capacitance, maximum, percent
1 to 14 days 3.5
7 to 14 days 2.0
Stability Factor after 14 days, maximum 1.0

Gravimetric method
Water absorption, maximum, mg/in^2 35

Insulation resistance constant (K) at 15.6 °C (60 °F) (see 7.5.9.2) 12,000

7.5.10 Optional Flame Test Requirement. This section describes optional flame test requirements for insulated conductors (Tests A and B) and finished cable described within this standard. These tests shall not be applicable unless specifically requested.

▲ **7.5.10.1** Flame Test A-Insulated Conductor
The test apparatus shall consist of the following:
a. Test chamber of sheet metal 12 inches (305 mm) wide, 14 inches (356 mm) deep and 24 inches (610 mm) high, which is open at the top, and which is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.
b. Means for adjusting the position of the test specimen.
c. A 4-pound (1.8-kg) weight for 9AWG and smaller conductor sizes to be attached to the lower end of the test specimen to keep it taut.
d. Tirrill burner with an attached pilot light and mounted on a 20-degree angle block. The burner shall have a nominal bore of ⅜ inch (9.5 mm) and a length of approximately 4 inches (102 mm) above the primary air inlets.
e. 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.
f. Gas - a supply of ordinary illuminating gas at normal pressure.
g. Watch or clock with a hand which makes one complete revolution per minute.
h. Flame indicators consisting of strips of gummed kraft paper having a nominal thickness of 5 mils (0.127 mm) and a width of ½ inch (12.7 mm)**.

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 9 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 test shall be performed on a sample having a 30 or 45 mil total composite wall (inner layer plus outer layer), as applicable and specified in Table 7.5-1.

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

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the flame is to be applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches (127 mm) with an inner blue cone 1 ½ inches (38.1 mm) high. The temperature at the tip of the inner blue cone shall be not less than 836 °C (1500 °F).

The burner, with only the pilot lighted, shall be placed in front of the samples 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 burner stem between the tip of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for 15 seconds. This process shall be repeated four times. During each application of the flame the specimen shall be adjusted, if necessary, so that the top of the inner blue cone touches the surface of the specimen. The duration of burning of this specimen after the fifth application of the flame shall be recorded.

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.
2. The specimen continues to burn for more than one minute after the fifth application of flame.

7.5.10.2 Flame Resisting Test B - Insulated Conductor

This test shall be the same as in 7.5.10.1, except for the following:

a. 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.

b. The valve supplying the gas to the burner proper shall 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.

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

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.
2. The specimen continues to burn for more than one minute after any of the flame applications.
3. The surgical cotton is burned.

▲ **7.5.10.3** Flame Test-Finished Cable

This test shall be a type test to demonstrate flame resistance of a cable construction. (i.e. insulation and jacket type). The test shall be performed as described in IEEE Standard 383-1974, paragraph 2.5 with the following exceptions:

1. The standards sample to be tested shall be a 7 or 9 conductor, No. 12 AWG rated at 600 volts.
2. Only the ribbon gas burner shall be used as the flame source.
3. Ribbon Gas Burner, American Gas Furnace Company (Cat. No. 10L 11-55 formerly specified as Cat. No. 10X 11-55), or equivalent.

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7.6 Concentric-neutral Underground Distribution Cables

▲**7.6.1 Scope.** This section covers two-conductor concentric-neutral power cables consisting of one ethylene-propylene-rubber-insulated central conductor and one copper concentric neutral conductor applied helically overall. These cables are intended for use on single-phase and three phase primary underground distribution systems operating at 2001 to 35,000 volts phase-to-phase at 100 percent insulation level. For ampacities, see Appendix F.

7.6.2 Central Conductor. Central conductors shall be annealed copper or aluminum. The minimum conductor size shall be in accordance with Table 7.6-1.

Table 7.6-1
Minimum Conductor Size

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

7.6.2.1 Copper. Conductors shall be (1) annealed uncoated copper or annealed coated copper either Class B or C stranded or (2) uncoated copper, compact stranded, and shall meet the requirements of Part 2.

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

▲**7.6.2.3 Conductor (Stress Control Layer)** The conductors shall be covered with a stress control layer in accordance with Part 2.

7.6.3 Insulation. The shielded central conductor shall be insulated with an ethylene-propylene-rubber compound which meets the requirements given in Part 3. 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 that table.

7.6.4 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 7.6-2, and the minimum thickness at any point shall be not less than 80 percent of the values given in this 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.

Table 7.6-2
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

7.6.5 Concentric Conductor. The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B 5 and the resistivity, tensile, and elongation requirements of ASTM B 3 for uncoated wires, ASTM B 33 for tin coated wires or ASTM B 189 for lead-alloy-coated wires. The number of wires of a specified size shall be not less than that given in Table 7.6-3 for cables used in single phase systems and in either Table 7.6-5 or Table 7.6-6 for three phase system.

The nominal diameters and circular mil areas of the wires in Tables 7.6-3, 7.6-5 and 7.6-6 shall be as follows:

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

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

1. For single phase systems, at least 98% of the product of the appropriate number of wires given in table 7.6-3 times the appropriate nominal circular mil area tabulated above.

2. For three phase systems at least 98% of the product of the appropriate number of wires given in Tables 7.6-5 or 7.6-6 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 conducting material given in 7.6.4 with a lay not less than six nor more than ten times the diameter over the concentric wires.

7.6.6 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.6. The partial-discharge extinction level shall be in accordance with Table 7.6-4. The electrical requirement tests shall be made without immersion in water.

Table 7.6-3

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 7.6-4

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

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7.8 Metal-clad Cables with Grounding Conductor

7.8.1 Scope. This section covers two-, three-, and four-conductor ethylene-propylene-rubber-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 Part 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 7.8-1.▲

7.8.3 Conductor Stress Control Layer. A conductor stress control layer shall be used on conductors having rated circuit voltages above 2000 volts.▲

7.8.3 Conductor Shielding. Conductor shielding shall be used on conductors having rated circuit voltages above 2000 volts.

Table 7.8-1
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

7.8.4 Insulation. The insulation shall meet the requirements given in Part 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 Part 5 and shall be based on the calculated diameter of the individual power conductor. A suitable binder shall be applied over the assembly.

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

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

Table 7.8-2 ●
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	8	10	8
6	6-4	8	6
4-1	2-2/0	6	4
1/0- 300	3/0- 400	3	1
350- 600	500- 800	1	2/0
650-1000	900-1000	1/0	3/0

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7.9 Nonshielded Single-conductor Power Cable

7.9.1 Scope. This section covers nonshielded single-conductor power cable with ethylene-propylene-rubber 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): ▲

(a) Single Conductors

(1) Unspliced cables in random lay in grounded metal conduit indoors above grade in dry locations.

(2) Mounted on insulators in free air.

(b) Triplexed Single Conductors (Factory Assembled)—In conduit or cable trays indoors above grade in dry locations.

(c) 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. *

7.9.2 Conductors. The conductors shall be copper or aluminum in accordance with Part 2. The conductor sizes shall be as given in Table 7.9-1.

7.9.3 Insulation. The insulation shall meet the requirements given in Part 3. The average thickness of the insulation shall be not less than 90 mils (2.29 mm) and the minimum thickness shall be not less than 81 mils (2.06 mm).

† **7.9.4 Jacket.** A jacket which meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyl chloride, 4.4.7 thermoplastic chlorinated polyethylene, 4.4.8 nitrile butadiene/polyvinyl chloride, 4.4.10 chlorosulfonated polyethylene, or 4.4.11 cross-linked chlorinated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.9-1, and the minimum thickness shall be not less than 80 percent of this value.

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

7.9.6 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.9, except as otherwise specified in 7.9.6.1 and 7.9.6.2.

7.9.6.1 Electrical Requirements. Each insulated and jacketed conductor in the completed cable shall be tested in accordance with 6.27 and 6.28 and shall meet the following requirements.

7.9.6.1.1 Alternating-current Voltage Test (See 6.27.2). The conductor shall withstand an alternating-current test voltage of 13 kV, except that the direct-current voltage test may be substituted.

7.9.6.1.2 Insulation Resistance (See 6.28). The conductor shall have an insulation resistance not less than that corresponding to a constant of 12 000 at 15.6°C (60°F).

7.9.6.1.3 Direct-current Voltage Test (See 6.27.3). Upon completion of the insulation resistance test, each conductor shall withstand a direct-current test voltage of 35 kV, unless the alternating-current voltage test is performed.

7.9.6.2 Tests for Discharge Resistance. The samples shall be taken in accordance with 6.23.1.

7.9.6.2.1 Surface Resistivity. The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 200 000 megohms.

7.9.6.2.2 U-bend Discharge. The sample shall be tested in accordance with 6.23.3 with an alternating-current potential of 13 kV. There shall be no voltage breakdown or surface cracking.

Table 7.9-1

Conductor Size, AWG or kcmil ▲	Jacket Thickness mils	mm
8-6	30	0.76
4-2/0	45	1.14
3/0-1000	65	1.65

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7.10 Nonshielded Single-conductor Cables for Series-lighting Circuits

7.10.1 Scope. This section covers nonshielded single-conductor cable with ethylene-propylene rubber insulation intended for use in series lighting circuits, as follows:

▲(a) Nonjacketed—2000 volts or less
▲(b) Jacketed —5000 volts or less

7.10.2 Conductors. The conductors shall be copper in accordance with Part 2 and of the sizes given in Table 7.10-1 or 7.10-2.

7.10.3 Insulation

7.10.3.1 Nonjacketed Cable. The insulation for nonjacketed cable shall meet the requirements of 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-1, and the minimum thickness at any point shall be not less than 90 percent of this value.

7.10.3.2 Jacketed Cable. The insulation for jacketed cables shall meet the requirements of 3.6 or 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-2, and the minimum thickness at any point shall be not less than 90 percent of this value.

‡ **7.10.4 Jacket.** For jacketed cables, a jacket which meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyle chloride, 4.4.7 thermoplastic chlorinated polyethylene, 4.4.8 nitrile butadiene/polyvinyl chloride, 4.4.10 chlorosulfonated polyethylene, or 4.4.11 cross-linked chlorinated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.10-2, and the minimum thickness shall be not less than 80 percent of this value.

7.10.5 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.10, except as otherwise specified in 7.10.5.1 through 7.10.5.3.

7.10.5.1 Voltage Tests (See 6.27). The completed cable shall be tested at the test voltages specified in Table 7.10-1 or 7.10-2 in accordance with the following: ▲

2000 volts or less—6.27.2 or 6.27.3 or 6.27.4
2001 to 5000 volts—6.27.2 or 6.27.3

7.10.5.2 Insulation Resistance (See 6.28). The completed cable shall have an insulation resistance not less than that corresponding to the following at 15.6°C (60°F).

Circuit Voltage, Volts	Insulation Resistance Constant	
	Nonjacketed	Jacketed
0-2000	10 000	6 000
2001-5000	....	12 000

7.10.5.3 Tests for Discharge Resistance. These tests shall be made on cable rated 2001 volts and higher; and the samples shall be taken in accordance with 6.23.1.

7.10.5.3.1 Surface Resistivity. The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 200 000 megohms.

7.10.5.3.2 U-bend Discharge. The sample shall be tested in accordance with 6.23.3 with an alternating-current potential of 13 kV. There shall be no voltage breakdown or surface cracking.

Table 7.10-1
Nonjacketed Cable

Circuit Voltage, Volts *	Conductor Size, AWG	Insulation Thickness †		Test Voltage, kV		d-c Spark Test Voltage, kV
		mils	mm	a-c	d-c	
1000 or less ▲	12-4	60	1.52	5.0	15.0	21.0
1001-2000	8-4	75	1.91	7.5	22.5	26.5

* 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.

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Table 7.10-2
Jacketed Cable

Circuit Voltage, Volts *	Conductor Size, AWG	Insulation Thickness †		Jacket Thickness		Test Voltage, kV		d-c Spark Test Voltage, kV
		mils	mm	mils	mm	a-c	d-c	
0-1000	12-4	45	1.14	30	0.76	5.0	15.0	16.0
1001-2000	8-4	60	1.52	30	0.76	7.5	22.5	22.5
2001-5000	8-6	90	2.29	30	0.76	13.0	35.0	...
	4	90	2.29	45	1.14	13.0	35.0	...

The following tabulation of series lighting transformer ratings is representative of those in current 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

* 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.

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Part 8 *
APPENDICES

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 psi	Tensile Strength MPa▲	Elongation 2-inch (50.8 mm) Length, Percent
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.

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Appendix D

EMERGENCY OVERLOADS

Operations 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.

Appendix E ▲

ICEA PUBLICATIONS AND ASTM STANDARDS

E.1 ICEA Publications

T-24-380, rev. 12/80 *Guide for Partial-Discharge Test Procedure* See Note 1
A-9-428 2nd Ed./ NEMA WC 6-1975 *Minimum Drum Diameters of Reels for Cables* See Note 2
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.2 ASTM Standards See Note 4

E.2.1 ASTM Standards to which reference is made in this standard, but not in all of the other three: ICEA S-19-81, NEMA WC 3; ICEA S-61-402, NEMA WC 5; and ICEA S-66-524, NEMA WC 7

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 557-81	*Tension Testing Wrought and Cast Aluminum- and Magisium-Alloy Products*
D 1248-81a	*Polyethylene Plastics Molding and Extrusion Materials, Test for*
B 228-81	*Concentric-Lay, Stranded Copper-Clad Steel Conductors, Specification for*
B 416-81	*Concentric-Lay-Stranded Aluminum-Clad Steel Conductors, Specification for*
B 549-82	*Concentric-Lay-Stranded Aluminum Conductors, Aluminum-Clad Steel Reinforced (ACSR/AW), Specification for*

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Appendix E (continued)

E.2.2 ASTM Standards to which reference is made in each of the following four standards: ICEA 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, Speficiation for*
B 8-81	*Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Speficiation 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, Speficiation 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.

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Appendix F▲

AMPACITIES FOR TWO-CONDUCTOR CONCENTRIC-NEUTRAL SINGLE-PHASE PRIMARY UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES (SEE PART 7)

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

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

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

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

Continuous loading at maximum rating may result in moisture migration away from cables and increased thermal resistivity. See "Power Cable Ampacities," IPCEA 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 IPCEA-NEMA Standards Publication Ampacities Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable 15 kV through 69 kV, IPCEA P-53-426, 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 tráining 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 cables having individually taped shielded conductors, the minimum bending radius is twelve times the diameter of one of the individual conductors or seven times the overall diameter of the multiconductor or multiplex cable, whichever is greater. For multiconductor cables having an overall tape shield over the multiconductor assembly, the minimum bending radius is twelve times the overall diameter of the cable.

H3.1.3.2 WIRE SHIELDED CABLES

The minimum bending radii for all cables with wire shielding, except 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 ICEA Pub. No. A-9-428 (Second Edition), NEMA Pub. No. WC 6-1975 (R 1980), 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 ICEA/NEMA Standards Publication, *Drum Diameters of Reels for Wires and Cables*, ICEA Publication No. A-9-428 (Second Edition), NEMA Publication No. WC 6-1975 (R 1980)

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

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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	Alumi-num	Copper	Alumi-num	Copper	Alumi-num
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 J-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
	up to 2000 Volts 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

K.1 Scope. This appendix contains recommendations for identification of control conductors in cables if such identification is used.

K.2 "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.

K.3 Methods of Conductor Identification

K.3.1 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.

K.3.2 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.

K.3.3 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.

K.3.4 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.

K.3.5 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.
(C.A.U.S., 24 East 32nd 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.

K.3.6 Method 6—Layer Identification. This method uses a distinctively identified conductor in each layer.

K.3.7 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.

● Added 9-8-1976.

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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 Card		
Color	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.

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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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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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Appendix M▲
AMPACITIES FOR PREASSEMBLED AERIAL CABLES

For ampacities, see AIEE-IPCEA Power Cable Ampacities, IEEE Publications No. S-135, 1962, Vol. 1 for Copper Conductors or Vol. 2 for Aluminum Conductors, pages 258 through 261.

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Appendix N ▲
FLEXIBLE CORDS AND REMOTE CONTROL AND DRILL CORDS

N1.1 Ampacities of Flexible Cords Ampacities of flexible cords are based on the number of current-carrying conductors. The ampacities shown below are based on an ambient temperature of 30°C.

Conductor Size, AWG	Number of Current-carrying Conductors in Cord		
	2	3	4
18	10	7	6
16	13	10	8
14	18	15	12
12	25	20	16
10	30	25	20

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

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

N2.1 National Electrical Code Type Designations and Maximum Voltage Ratings of Multiple-Conductor Flexible Cords.

Conductor Size, AWG	Insulation Thickness		Jacket Thickness, 2, 3 and 4 Conductors		NEC Type Designations*		Maximum Voltage Ratings, Volts
	mils	mm	mils	mm			
18	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
18	30	0.76	60	1.53	S, ST	SO, STO	600
16	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
16	30	0.76	60	1.53	S, ST	SO, STO	600
14	45	1.14	80	2.04	S, ST	SO, STO	600
14	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
12	45	1.14	95	2.42	S, ST	SO, STO	600
10	45	1.14	95	2.42	S, ST	SO, STO	600

* S and SO designate extra hard service cords. SJ and SJO designate hard service cords. T designates a thermoplastic (polyvinyl chloride) jacket. O designates an oil-resistant jacket. ▲

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N3.1 Remote Control and Drill Cords Remote control and drill cords intended for use in underground mines in accordance with Schedule 2G of the U.S. Bureau of Mines comply with the constructions given in 7.4 in sizes 14 to 10 AWG, except for the jackets and number of conductors. The jackets shall be applied in two layers with a reinforcement between them and are approximately 50 mils (1.27 mm) thicker than those shown in Table 7.4-6. The cords shall comply with the flame resistance requirements of Schedule 2G. The outside diameters shall be in accordance with the following table:

Conductor Size, AWG	Number of Conductors	Outside Diameter Nominal inches	Outside Diameter Nominal mm	Outside Diameter Tolerances, Plus and Minus
14	2	0.64	16.3	0.02
	3	0.67	17.0	0.02
	4	0.71	18.0	0.02
	5	0.78	19.8	0.03
	6	0.83	21.1	0.03
	7	0.89	22.6	0.03
12	2	0.68	17.3	0.02
	3	0.72	18.3	0.03
	4	0.76	19.3	0.03
	5	0.83	21.1	0.03
	6	0.89	22.6	0.03
	7	0.98	24.9	0.03
10	2	0.73	18.5	0.03
	3	0.80	20.3	0.03
	4	0.84	21.3	0.03
	5	0.90	22.8	0.03
	6	1.00	25.4	0.03
	7	1.07	27.2	0.03

(Continued)

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Ethylene-propylene-rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

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SUPERSEDED

ICEA PUBLICATION NO. S-68-516

NEMA STANDARDS PUBLICATION NO. WC 8

nema

Ethylene-propylene-rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

NEMA

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

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WC 8

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 1—September 1977
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This publication includes and supersedes the following Interim Standards which were previously published for inclusion in ICEA Pub. No. S-68-516, NEMA Pub. No. WC 8.

#1	August 1973	*Cables Rated 0-35000 Volts and Having Ozone-resistant Ethylene-propylene Rubber Insulation*
#2	August 1973	*Cables Rated 2000 Volts and Less and Having Ozone-resistant Ehtylene-propylene-rubber Integral Insulation and Jacket*
#3	July 1971	*Primary Underground Residential Distribution Cables with Ethylene-propylene-rubber Insulation*
#4	July 1971	*Concentric-neutral Underground Distribution Cables with Ethylene-propylene-rubber Insulation*
#5	September 1973	*Mine Power Cables with Ethylene-propylene-rubber Insulation*
#6	September 1973	*Portable Single- and Multiple-conductor Cables with Ethylene-propylene-rubber Insulation*
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Foreword ▲

This Standards Publication for Ethylene-propylene-rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-68-516, NEMA WC 8-1976) was developed by the Insulated Cable Engineers Association and approved by the National Electrical Manufacturers Association.

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

Requests for interpretation of this Standard must be submitted in writing to the Insulated Cable Engineers Association, P.O. Box P, South Yarmouth, Massachusetts 02664. An official written interpretation will be provided. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

▲ Editorially revised.

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Part 1
GENERAL

1.1 Scope. These standards apply to materials, constructions and testing of ethylene-propylene-rubber-insulated wires and cables which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, such as indoor and outdoor installations, above and below grade, and submarine.

1.2 General Information. This publication is so arranged that cables can be designed for a broad range of installation and service conditions. Parts 2 to 4 cover the three major components of cables:

Part 2 - Conductors
Part 3 - Insulation
Part 4 - Shielding and Coverings

Each of these parts designates the materials, material characteristics, dimensions, and tests applicable to the particular component.

Specific attention is directed to 4.2 "Shielding Practice." A thorough understanding of these requirements is necessary to secure safe and reliable cable operation at voltages over 2 kV.

Part 5 deals with the assembly, cabling and identification of two or more conductors.

Part 6 covers the test procedures applicable to cable component materials and to completed cables.

Part 7 covers cables for specific service and installation conditions and gives construction details and additional or modified tests applicable to these particular types. If there is a conflict between Parts 1 through 6 and Part 7, the provisions of Part 7 apply.

Part 8 contains reference data such as definitions, abbreviations, cross-references to other standards, and application and installation information.

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

Units in these standards 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 describe the cable desired by reference to pertinent provisions of these standards. To help avoid misunderstandings and possible misapplication of the cables, he should also furnish the following information:

1.3.1 Characteristics of System on which Cable Is to Be Used

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

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1.3.2 Quantities and Description of Cable

(a) Total number of feet, including test lengths, and lengths if specific lengths are required.

(b) Type of cable. Describe as single conductor, two-conductor flat, two-conductor round, etc.

(c) Rated circuit voltage, phase to phase.

(d) Type of conductor—copper or aluminum.

(e) Size of conductors—AWG or circular mils. If conditions require other than standard stranding, a complete description should be given.

(f) Grade of insulation.

(g) Thickness of insulation in mils.

(h) Type of outer covering.

(i) Maximum allowable overall diameter in inches. When duct space is not limited, it is desirable not to restrict the overall diameter.

(j) Method of conductor identification.

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Part 2
CONDUCTORS

2.0 Requirements of a reference 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 O:

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 B 230. Tensile strength of aluminum 1350 and aluminum alloy conductors and elongation of aluminum alloy conductors shall be determined according to ASTM B 230.

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

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

2.3.1 Compact stranded aluminum conductors, is 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.

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

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

$$R = K\rho/A$$

Where:

R = Conductor resistance in Ω/1000 ft.

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

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

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

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

Table 2-2

Weight Increment Factors*, K

Solid Conductors	1
Concentric-lay Strand, 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 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 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.

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 (Conductor Shield). 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 6.11 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 6.24 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

2.7.1.2 An extruded nonconducting stress controlling material, when measured according to 6.31, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Permittivity (SIC), range	10—1000
60 hz ac voltage withstand stress, volts per mil, minimum	1500/permittivity

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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	
Flat Parallel Cable	Table 2-4[a] Value Plus 2% (R max = R × 1.02)
Multiple Conductor Cables	
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	
Flat Parallel Cables	Table 2-5[a] or 2-6[a] Value Plus 2%[b] (R max = R × 1.02)
Multiple Conductor Cables	
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.

** Values 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	Class G	Class H	Class I
AWG or kcmil			
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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Part 3
INSULATION

3.1 Material. The insulation shall be an ethylene-propylene rubber meeting the dimensional, electrical and physical requirements specified in Part 3.

This insulation is suitable for use on cables in wet or dry locations at not more than 35,000 volts between phases at the 100 percent insulation level and at not more than 25,000 volts at the 133 percent insulation level. The conductor temperature shall not exceed 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.

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. For exceptions see 3.3.

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 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. 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. 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. 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 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. Over 2000 volts—consult the manufacturer.

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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 MCM	Insulation Thickness ## for 100 and 133 Percent Insulation Levels† Col. A mils	Col. A mm	Col. B mils	Col. B mm	a-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels† Col. A	Col. B	d-c Test Voltage, kV, for 100 and 133 Percent Insulation Levels† Col. A	Col. B	d-c Spark Test Voltage, kV for 100 and 133 Percent Insulation Levels Col. A	Col. B	a-c Spark Test Voltage, kV for 100 and 133 Percent Insulation Levels● Col. A	Col. 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
	525-1 000	110	2.79	80	2.03	10.0	10.0	30.0	30.0	38.5	30.0	27.5	17.5
601-2 000	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
	525-1 000	120	3.05	90	2.29	11.5	11.5	34.5	34.5	42.0	34.5	30.0	20.0
2 001-5 000	Nonshielded.	See Note 2.											

		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							
2 001-5 000	8-1 000	90	2.29	90	2.29	13	13	...	...	...	...	...	...
5 001-8 000	6-1 000	115	2.92	140	3.56	18	22	45	45	...	...	...	...
8 001-15 000	2-1 000††	175	4.45	215	5.46	27	33	70	80	...	...	...	...
15 001-25 000	1-1 000	260	6.60	345	8.76	38	49	100	125	...	...	...	...
25 001-28 000	1-1 000	280	7.11	...	...	42	...	105	...	...	...	...	...
28 001-35 000	1/0-1 000	345	8.76	...	...	49	...	125	...	...	...	...	...

(Continued)

● Added 10-29-1979

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*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.

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

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

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

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

‡‡ Approved by NEMA as Authorized Engineering Information.
● Added 10-29-1979.

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.

‡ 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.

†† For 133 percent insulation level (ungrounded neutral), the minimum conductor size is 1 AWG.

Column A thicknesses (0-2000 volts) apply to single-conductor power cables for general application when a carbon-black pigmented insulation is used without a covering. In this construction, the insulation shall be in accordance with 3.7. Column B thicknesses (0-2000 volts) apply to single-conductor cables having a covering over the insulation and to the individual conductors of multiple-conductor cables having an overall covering.

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

NOTE 2—For single-conductor nonshielded cables with nonmetallic jacket, see 7.9. 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 3—a-c voltages are r.m.s. values. ‡‡

● NOTE 4—Column B a-c spark test voltages are taken from Table 71.1, UL Standard 44, Rubber Insulated Wires and Cables, 10th Edition. ‡‡

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3.3 Insulation Thickness for Submarine Power Cable

The insulation thickness shall be as given in Table 3-1, except that for voltage classifications up through 5 kV:

(a) When Type I insulation (see 3.6) is used, the thickness of insulation in cables without a metallic sheath shall be increased by 30 mils (0.76 mm);

(b) When Type II insulation (see 3.7) is used, the thickness of insulation 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 (1.52 mm).

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.

3.5 Insulation Types and Requirements.

3.5.1 The insulation shall be either Type I (see 3.6) or Type II (see 3.7).

3.5.2 Voltage Tests (See 6.27). Each length of completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-1.

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 (See 6.28). The insulation resistance constants of insulations shall be in accordance with 3.6 or 3.7, as applicable.

3.6 Type I Insulation. This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

3.6.1 Physical and Aging Requirements (See 6.5). The insulation shall meet the following requirements:

Physical Requirements	
Tensile strength, minimum	
psi	700
kgf/mm^2	0.49
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

3.6.2 Electrical Requirements.

3.6.2.1 Voltage Tests. See 3.5.2.

3.6.2.2 Insulation Resistance Test (See 6.28). Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20 000 at 15.6°C (60°F). 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).

Where a nonconducting separator is applied between the conductor and the insulation, or where an insulated conductor is covered with a nonmetallic jacket, the insulation resistance shall be not less than 60 percent of that required for the primary insulation, based on the thickness of that insulation.

3.6.2.3 Partial-discharge Extinction Level (See 6.29). Each length of completed power cable rated at 2 001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

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

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

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Table 3-2

	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	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3	6.27.2 or 6.27.3
(2) With metallic sheath or armor	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
b. 2001-5000 Volts	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
2. Cables With Insulation Shield				
a. 0-5000 Volts	6.27.2	6.27.2	6.27.2	6.27.2
b. 5001 volts and over	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3

▲ See Part 6 for:

6.27.2 alternating-current voltage test
6.27.3 direct-current voltage test
6.27.4a alternating-current spark test
6.27.4b direct-current spark test

▲ Revised 10-29-1979.

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3.6.3 Additional Requirements.

3.6.3.1 Capacity and Power Factor (See 6.22). The insulation on cables rated at 5 001 volts and above shall have a specific inductive capacity not exceeding 4.0 and a power factor not exceeding 2.0 percent.

3.6.3.2 Accelerated Water Absorption (See 6.21). The insulation shall meet the following requirements:

Electrical Method	
Dielectric constant after 24 hours, maximum	4.0
Increase in capacitance, maximum, percent	
1 to 14 days	3.5
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 part of these two requirements need be satisfied, not both.

3.7 Type II Insulation. This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering. Also, it is suitable for use on single-conductor cables, without covering, rated at voltages up through 2000 volts. When used without a covering, the insulation shall be carbon-black pigmented to provide resistance to sunlight.

3.7.1 Physical and Aging Requirements (See 6.5). The insulation shall meet the following requirements:

Physical Requirements	
Tensile strength, minimum,	
psi	1200
kgf/mm^2	0.84
Elongation at rupture, minimum, percent	150
Tensile stress at 100 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
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

3.7.2 Electrical Requirements. Each insulated conductor in the completed cable shall meet the requirements of 3.6.2, except that the insulation resistance constants shall be:

0-2000 volts	10,000
2001-35000 volts	20,000

3.7.3 Additional Requirements.

3.7.3.1 Capacity and Power Factor (See 6.22). The insulation on cables rated at 5 001 volts and above shall have a specific inductive capacity not exceeding 4.0 and a power factor not exceeding 2.0 percent.

3.7.3.2 Accelerated Water Absorption (See 6.21). The insulation shall meet the requirements given in Table 3-3.

Table 3-3

	0-2000 Volts	2001-35000 Volts
Electrical Method		
Dielectric constant after 24 hours, maximum	6.0	4.0
Increase in capacitance, maximum, percent		
1 to 14 days	5.0	3.5
7 to 14 days	3.0	1.5
Stability factor after 14 days, maximum*	1.0	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.

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Part 4
SHIELDING AND COVERINGS

SHIELDING (SEE APPENDIX K)

4.1 Shielding of Insulated Cable. Shielding of insulated cables shall consist of conductor shielding and insulation shielding. For conductor shielding, see 2.4. ▲

4.1.1 Insulation Shield. The insulation shield 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 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 4a or 4b 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 25 000 volts and not less than 4 pounds (17.8N) for cables rated 25 001 through 35 000 volts (see 6.25).

For removability of insulation shields, see Appendix K, par. K6. (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 L).

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 mm^2/mm) of insulated conductor diameter, or of other nonmagnetic metals having equivalent conductance.

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

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

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. When shielding is required on multiple-conductor cables (see 4.2), the shields shall be applied over the individual conductors.

4.1.3 Conductor or Circuit Identification. See 5.3.1.

4.2 Shielding Limits for Power Cable for Fixed Locations. ▲

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

▲ Sections 4.1 and 4.2 revised in their entirety 7-13-1977.

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

	Thermoplastic	Thermoset
Aging Requirements (see 6.11)		
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 6.11), not warmer than	-10°C*	-10°C*
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C (see 6.24), ohm-centimeters	50 000	50 000

*For extruded coverings only.

Table 4b ●
Requirements for Extruded Nonmetallic Conducting Coverings using Embedded Metal Components

Thickness, Minimum (see 6.4)	
Total	in accordance with 4.4.10
Between insulation and metal component	
mils	5
mm	0.127
Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	100
Aging Requirements (see 6.5)—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 6.11), not warmer than	-10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C (see 6.24), ohm-centimeters	50 000

● Added 7-13-1977.

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4.2.2 Shielding should be considered where any of the following conditions exists. (This section is approved by NEMA as Authorized Engineering Information.)

(a) Connections to aerial lines.
(b) Transition from conducting to nonconducting environment.
(c) Transition from moist to dry earth.
(d) Dry soil, such as in the desert.
(e) Damp conduits.

Table 4-1 ▲

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

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 5000 Volts or Less	Single- and Two-phase a-c Systems* Over 5000 Volts	
	One Side Grounded	Ungrounded and Midpoint Grounded
1	1.73	0.866

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

NONMETALLIC JACKETS

4.3 General. Nonmetallic 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 nonmetallic conducting covering meeting the requirements of Table 4b. For jackets over metallic coverings, see 4.5. ▲

4.4 Rubber or Thermoplastic Jackets. These jackets consist of a durable moisture-resisting thermosetting natural- or synthetic-rubber compound or a 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 4.4.11. The tests shall be made only on jackets having a nominal wall thickness of 30 mils (0.76 mm) or greater.

4.4.1 Natural Rubber. This jacket shall consist of a vulcanized rubber compound containing not less than 60 percent of natural rubber and shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	3500
kgf/mm^2	2.46
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	500
Set, maximum, percent	15
Aging Requirements (see 6.5)	
After oxygen pressure test at 70°C ± 1°C for 96 hours	
Tensile strength, minimum	
psi	2500
kgf/mm^2	1.76
Elongation at rupture, minimum, percent	400
Tear resistance, minimum (see 6.12)	
pounds per inch	40
kgf/mm	0.71

(Continued)

4.4.2 Synthetic Rubber. This jacket shall consist of a vulcanized SBR synthetic rubber compound and shall meet the following requirements:

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Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 70°C ± 1°C for 168 hours	
Tensile strength, minimum	
psi	1600
kgf/mm^2	1.12
Elongation at rupture, minimum, percent	250
After oxygen pressure test at 70°C ± 1°C for 96 hours	
Tensile strength, minimum	
psi	1600
kgf/mm^2	1.12
Elongation at rupture, minimum, percent	250

4.4.3 Neoprene, Heavy-duty Black. This jacket shall consist of a vulcanized black neoprene compound and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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

4.4.4 Neoprene, General Purpose. This jacket shall consist of a vulcanized neoprene compound, and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
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

4.4.5 Polyvinyl Chloride. This jacket shall consist of a polyvinyl chloride compound suitable for a minimum installing temperature of -10°C (+14°F), and shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	100
Aging Requirements (see 6.5)	
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 (see 6.17)	50
Heat shock, 121°C ± 1°C (see 6.16)	No cracks
Cold bend, minus 35 ± 1°C (see 6.18)	No cracks

4.4.6 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°F) and a minimum installing tempera-

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ture of -40°C (-40°F). The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1400
kgf/mm^2	0.98
Elongation at rupture, minimum, percent	350
Aging Requirements (see 6.5)	
After air oven test at 100°C ± 1°C for 48 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	75
H distortion, 90°C ± 1°C, maximum, at (see 6.17)	25
▲ tion coefficient, minimum (absorbance/meter) (see 6.20)	320*
E nmental cracking (see 6.19)	No cracks

*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.

4.4.7 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. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements (see 6.5)	
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

4.4.8 Nitrile-butadiene/Polyvinyl-chloride, General-purpose 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. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	250
Set, maximum, percent	30
Aging Requirements (see 6.5)	
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

4.4.9 Chlorosulfonated Polyethylene, Heavy Duty. This jacket shall consist of a vulcanized chlorosulfonated-polyethylene compound, shall meet the following requirements and, when applicable, the requirements given in 4.4.12:

(Continued)

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Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements (see 6.5)	
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

4.4.10 Jacket Thicknesses (See 6.4). The average thicknesses of jackets shall be not less than those given in Tables 4-2, 4-3, 4-4 or 4-5. For the jacket thicknesses of cables not shown in these tables, see Table 4-6. The minimum thickness shall be not less than 80 percent of the values given in these tables. The tables do not apply to communication and portable cables and portable cords.

4.4.11 Separator Under Jacket. If used, a separator shall consist of compatible material.

4.4.12 Discharge-resisting Jacket (See Table 4-1). For single-conductor nonshielded cables rated 2001-5 000 volts phase to phase, see 7.9 and 7.10.

For multiple-conductor nonshielded cables rated 2001-5000 volts phase to phase, the overall jacket shall meet the requirements of 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8 or 4.4.9 and, in addition, shall have a specific surface resistivity of not less than 200 000 megohms (see 6.23.1 and 6.23.2).

Table 4-2
Single-conductor Nonshielded Cable 0-2000 Volts
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial and Direct Burial†)

Size, AWG or MCM	Jacket Thickness			
	0-600 Volts		601-2000 Volts	
	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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4.4.13 Spark Test of Jackets Over Metallic Shielded Power Cable. The jackets (see par. 4.4.1 through 4.4.9 inclusive) over each length of shielded power cable (see par. 4.1) shall withstand without failure the alternating-current spark-test voltage given in the following table. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic shield for not less than 0.15 second. ●

Thickness of Jacket		a-c Spark-test Voltage kV	
mils	mm	For (Crosslength Thermoset) Jackets*	For Thermoplastic Jackets**
45	1.14	2.0	4.0
60	1.52	2.5	5.5
80	2.03	3.0	7.0
110	2.79	4.5	10.0
140	3.56	5.5	12.5

* See par. 4.4.1 through 4.4.4 and 4.4.7 through 4.4.9.
** See par. 4.4.5 and 4.4.6.

● Added 9-20-1978.

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

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

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

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

*See 4.1 and 4.2 for shielding requirements.

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

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

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

Table 4-5
Common Overall Jacket of Multiple-conductor Cables (For All Voltages and All Uses)

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

NOTE 1—Table 4-5 applies to all round multiple-conductor cables having a common overall jacket.

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

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

Calculated Diameter of Cable Under Jacket		Jacket Thickness							
		Single-conductor Cable				Multiple-conductor Cables*			
		(1) 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 4-3) 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 and lighting circuit wires and cables. It also covers submarine cables.

Division II. (See 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shafts, and vertical riser cable.

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

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 and Conditions of Installation.

(a) Metallic sheath, lead or aluminum

(1) Conduit, ducts, troughs or raceways.

(2) Suspended from aerial messenger.

(3) When protected by metal armor or nonmetallic coverings for other types of installation.

(b) Flat metal tape armor

(1) Direct burial in trenches.

(2) Suspended from aerial messenger.

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

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

(c) Interlocked metal tape armor.

(1) Direct burial in trenches.

(2) Troughs.

(3) Racks.

(4) Raceways.

(5) Suspended from aerial messenger.

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

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

(d) Galvanized steel wire armor.

(1) Submarine cable.

(2) Dredge cable.

(3) Vertical riser, borehole, and shaft cable for end suspension.

(4) Direct burial in trenches and subjected to unusual longitudinal stress.

Jute covering is not required on dredge and vertical riser cable. It is required on submarine, borehole and shaft cable where severe installation and service conditions exist. It is required for direct burial cable.

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

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

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Division I
Metallic and Associated Coverings
for Use Under Normal Conditions

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

4.5.4.1.1 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 B 29. The types of lead used shall be as follows:

Corroding

Desilverized A

Soft, undesilverized

Chemical

Acid

Copper (copper bearing)

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

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

4.5.4.1.2 Thickness of Lead. The average thickness of the lead sheath shall be not less than the values given in Table 4-7. The minimum thickness shall be not less than 90 percent of the values given in the table. If protective jackets are used over the lead sheath, see 4.5.14.3 and 4.5.15.6 for the thickness of the lead sheath.

Table 4-7
Thickness of Lead Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
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, these thicknesses shall be 80 mils (2.03 mm).

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.

4.5.4.1.3 Measurement of Thickness of Lead. The thickness shall be measured in accordance with 6.15.

4.5.4.1.4 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.

4.5.4.2 Aluminum Sheath

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

4.5.4.2.2 Thickness of Aluminum. The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

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Table 4-8
Thickness of Smooth Aluminum Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
inches	mm	mils	mm
0-0.400	0- 10.16	35	0.89
0.401-0.740	10.19- 18.80	45	1.14
0.741-1.050	18.82- 26.67	55	1.40
1.051-1.300	26.70- 33.02	65	1.65
1.301-1.550	33.05- 39.37	75	1.90
1.551-1.800	39.40- 45.72	85	2.16
1.801-2.050	45.75- 52.07	95	2.41
2.051-2.300	52.10- 58.42	105	2.67
2.301-2.550	58.45- 64.77	115	2.92
2.551-2.800	64.80- 71.12	125	3.18
2.801-3.050	71.15- 77.47	135	3.43
3.051-3.300	77.50- 83.82	145	3.68
3.301-3.550	83.85- 90.17	155	3.94
3.551-3.800	90.20- 96.52	165	4.19
3.801-4.050	96.55-102.9	175	4.45

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

4.5.4.2.3 Measurement of Thickness of Aluminum. The thickness shall be measured in accordance with 6.15.

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

4.5.5 Jute Serving over Metallic Sheath without Metallic Armor

4.5.5.1 Jute Servings (See 6.13). The average thickness of one serving (or two servings) of jute applied over metallic-sheathed cable for mechanical protection shall be not less than that given in Table 4-9.

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

For either one or two servings, the outer serving shall be run through hot asphalt or tar compound and coated with some suitable material 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 electrogalvanizing process.

Table 4-9
Thickness of Jute Servings over Metallic Sheath
(Without Metallic Armor)

Calculated Diameter of Cable Under Jute Serving*		Thickness of Jute Serving			
		One Serving		Two Servings	
inches	mm	mils	mm	mils	mm
0-1.000	0-25.40	65	1.65	95	2.41
1.001-2.500	25.43-63.50	65	1.65	110	2.79
2.501 and larger	63.52 and 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.

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4.5.6.2 Tensile Strength and Elongation. The plain and zinc-coated strip shall have a tensile strength of not less than 40,000 psi (28.1 kgf/mm^2) nor more than 70,000 psi (49.2 kgf/mm^2). The tensile strength shall be determined on longitudinal specimens consisting of the full width of the strip when practical or on a straight specimen slit from the center of the strip. The strip shall have an elongation of not less than 10 percent in 10 inches (254 mm). The elongation shall be the permanent increase in length of a marked section of the strip, originally 10 inches (254 mm) in length, and shall be determined after the specimen has fractured. All tests shall be made prior to application of the strip to the cable.

4.5.6.3 Galvanizing Test

4.5.6.3.1 Weight of Zinc Coating. The weight of zinc coating shall be determined before application of the strip to the cable. The strip shall have a minimum weight of coating of 0.35 ounce per square foot (106.8 grams/meter^2) of exposed surface. The weight of coating shall be determined in accordance with the method described in ASTM A 90.

4.5.6.3.2 Adherence of Coating. The zinc coating shall remain adherent without flaking or spalling when the strip is subjected to a 180-degree bend over a mandrel 1/8 inch (3.18 mm) in diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake 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 tape may be less than but shall not be greater than that given in Table 4-10.

Table 4-10
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.

For nominal widths 1,000 inch (25.4 mm) or less, the tolerance in width shall be ± 30 mils. For nominal widths greater than 1.000 inch (25.4 mm), the tolerance in width shall be ± 45 mils.

4.5.6.5 Thickness (See 6.14). The average thickness of metal tape shall be not less than that given in Table 4-11.

Table 4-11
Thickness of Metal Tape for Flat Armor
(Plain or Zinc Coated)

Calculated Diameter of Cable Under Jute Bedding*		Average 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 average thickness shall be based on the calculated major core diameter.

The tolerance in the thickness of an individual 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 average thickness of bare metal.

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

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4.5.6.6 Application, Lay and Spacing. Two metal tapes shall be applied helically in the same direction over the jute bedding except that they may be applied in opposite directions where the total area of the conductors is less than 50,000 circular mils (25.34 mm^2). The direction of lay of the inner tape shall be opposite to that of the jute bedding. When applied in the same direction as the inner tape, the outer tape shall be approximately centered over the spaces between the convolutions of the inner tape. The maximum space between turns shall not exceed 20 percent of the width of the tape or 0.200 inch (5.08 mm), whichever is the greater.

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

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 the cable has an outer jute or other protective covering, 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 given in Table 4-12.

Table 4-12
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 and -5 mils, except for aluminum which shall be ±10 mils.

4.5.7.4 Thickness (See 6.14). The average thickness of metal tape shall be not less than that given in Table 4-13.

The tolerance in the thickness of an individual 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 thickness for bare metal.

The tolerance for 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.

Table 4-13
Thickness of Metal Tape for Interlocked Armor

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

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4.5.7a Continuously Corrugated Metal Armor

4.5.7a.1 Scope. This section covers the equirements 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 armoris 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 4-13A.

4.5.7a.3 Flexibility

4.4.7a.3.1 The armored cable shall be capable of being bent around a mandrel having a diameter of 14 times the cable diameter. The armor shall show no evidence of fracture visible to the unaided eye. The test shall be conducted in accordance with the procedure given in Part 6.

4.5.7a.4 Corrosion Protection

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

Table 4-13A
Minimum Thickness of Metal for Corrugated Armor

Calculated Diameter of Cable Under Armor		Aluminum		Copper		Steel	
inches	mm	mils	mm	mils	mm	mils	mm
0—2.180	0— 55.37	22	0.56	...	...	...	...
2.181—3.190	55.40— 81.03	29	0.74	...	...	...	...
3.190—4.200	81.05—106.7	34	0.86	...	...	...	...
0—2.365	0— 60.7	...	...	17	0.43	...	...
2.366—3.545	60.10— 90.4	...	...	21	0.53	...	...
3.546—4.200	90.07—106.7	...	...	25	0.64	...	...
0—1.905	0— 48.39	...	...	...	...	16	0.41
1.906—3.05	48.41— 72.39	...	...	...	...	20	0.51
3.05 —4.200	72.42—106.7	...	...	...	...	24	0.61

● Added 5-12-1982.

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Table 4-15
Minimum Weights of Zinc Coating

Diameter of Coated Wire			Minimum Weight of Zinc Coating	
mils	mm	Size, BWG	Ounces per Square Foot of Exposed Wire Surface	Grams per Square Meter 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 4-16
Mandrel Diameter for Adherence of Coating Tests

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

Table 4-17
Size of Galvanized Steel Armor Wire for Cables for Division I Applications, Including Submarine Cables

Calculated Diameter of Cable Under Jute Bedding		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 4-18
Tolerances in Diameter

Diameter of Coated Wire		
mils	mm	Tolerances, mils
238-166	6.05-4.22	± 5
165-109	4.20-2.77	± 4
108- 65	2.74-1.65	± 3

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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 cables for power and lighting circuits. For wire armor for Division II and III applications, see 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.

4.5.8.2.1 Tensile Strength. The zinc-coated wire shall have a tensile strength of not less than 50,000 psi (35.2 kgf/mm^2) and not more than 70,000 psi (49.2 kgf/mm^2). The tensile strength shall be tested in accordance with ASTM E 8.

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 4-14. This test shall be made on a sample of wire having an initial length of 6 inches (152 mm) between jaws of a standard torsion machine or equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 4-14
Number of Twists (Torsion Test)

Diameter of Coated Wire		Minimum Number
mils	mm	of Twists
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 4-15. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90.

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

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

4.5.8.4 Size of armor. The sizes of armor wire for Division I applications, including submarine cables, shall be as given in Table 4-17.

If the service requirements are exceptionally severe, larger sizes of armor wire may be required*.

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

The tolerance in diameter for galvanized steel wire shall be as given in Table 4-18.

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

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

4.5.8.6 Direction of Lay. Successive layers of jute and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen that birdcaging of the armor will 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.

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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 (See 6.13). The average thickness of jute bedding under the armor in the finished cable shall be not less than that given in Table 4-19.

4.5.10 Jute Serving Overall for Armored Cable (See 4.5.11 for Interlocked Armored Cable

4.5.10.1 Application. When an outer jute serving is required, the armored cable shall be run through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 16/3) impregnated jute yarn applied with a short close lay, again run through hot asphalt or tar compound and finished by running through some suitable material 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 (See 6.13). 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 4-19.

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, saturated cotton braid, 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 Thermosetting and Thermoplastic Jacketed Cable Under Armor

4.5.13.1 Flat Steel Tape Armor. If 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 as given in Table 4-19 (see 6.13).

4.5.13.2 Interlocked Armor. Interlocked armor shall be applied directly over the jacket or tape in which it is vulcanized, no bedding being necessary.

4.5.13.3 Round Wire Armor. If 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 as given in Table 4-19 (see 6.13).

4.5.14 Thermosetting Coverings over Metallic Sheath

4.5.14.1 Thermosetting Covering. A thermosetting covering over a metallic sheath shall consist of a combination of treated fibrous reinforcing tapes and a neoprene compound.

Table 4-19
Thickness of Jute Bedding for Armored Cable

Calculated Diameter of Cable Under Jute Bedding*		Thickness of Jute Bedding					
				Round Wire Armored Cable			
		Metal Taped		Sheathed or Jacketed		Nonsheathed or Nonjacketed	
inches	mm	mils	mm	mils	mm	mils	mm
0-0.450	0-11.43	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.

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The neoprene compound shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1200
kgf/mm^2	0.84
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 70°C ± 1°C for 168 hours	
Tensile strength, minimum	
psi	1000
kgf/mm^2	0.70
Elongation at rupture, minimum, percent	200
After oil immersion test at 121°C ± 1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

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

4.5.14.2 Thickness. The average thickness of the thermosetting covering shall be not less than that given in Table 4-20. 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 covering.

The minimum thickness shall be not less than 80 percent of the values given in Table 4-20.

Table 4-20
Thickness of Thermosetting Covering Over Metallic Sheath

Calculated Diameter over Sheath		Thickness	
inches	mm	mils	mm
0-1.500	0-38.10	65	1.65
1.501-3.000	38.13-76.20	95	2.41
3.001 and over	76.23 and over	125	3.18

4.5.14.3 Thickness of Lead Sheath (Sec 6.15). If a thermosetting covering is applied over a lead sheath, the average thickness of the lead sheath shall be not less than that given in Table 4-21. The minimum thickness shall be not less than 90 percent of the values given in the table.

Table 4-21
Thickness of Lead Sheath for Cables Having a Thermosetting Covering or Thermoplastic Jacket Over Lead Sheath

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

* The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.
† For submarine cables, these thicknesses shall be 70 mils (1.78 mm).

4.5.14.4 Thickness of Aluminum Sheath (See 6.15). If a thermosetting covering is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2.

4.5.15 Thermoplastic Jacket over Metallic Sheath

4.5.15.1 Thermoplastic Jacket. If used, a thermoplastic jacket shall be extruded over the metallic sheath and shall fit tightly thereto. It shall be either:

(a) Polyvinyl chloride meeting the requirements given in 4.4.5, except that the cold bend requirements shall be as given in 4.5.15.4, or

(b) Black polyethylene meeting the requirements given in 4.4.6.

4.5.15.2 Thickness. The average thickness of jacket shall be taken as one-half the difference in diameters over and under the covering as determined by circumference measurements and shall be not less than that given in Table 4-22. The minimum thickness of the jacket shall be determined by direct

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measurements with a micrometer, a steel scale with pocket glass, or a microscope on a ring of jacket removed from the cable and shall be not less than 70 percent of the values given in Table 4-22.

Table 4-22
Thickness of Thermoplastic Jacket Over Metallic Sheath

Calculated Diameter Over Sheath		Jacket Thickness	
inches	mm	mils	mm
0-0.750	0-19.05	50	1.27
0.751-1.500	19.08-38.10	65	1.65
1.501-2.250	38.13-57.15	80	2.03
2.251-3.000	57.18-76.20	95	2.41
3.001 and larger	76.23 and larger	110	2.79

4.5.15.3 Tightness of 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. There shall be no movement of the cable in relation to the ring 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 (0.18 kg/mm) 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 (See 6.18). Polyvinyl-chloride-jacketed cable shall show no cracks at a test temperature of -10°C or colder. In lieu of this test the manufacturer may submit evidence that the jacket compound has been tested on similar cable and meets this requirement.

4.5.15.5 Spark Test. The jacket on each length of cable shall withstand without failure the alternating-current spark-test voltage given in Table 4-23. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic sheath for not less than 0.15 second.▲

Table 4-23
Spark-test Voltage for Thermoplastic Jacket

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

4.5.15.6 Thickness of Lead Sheath. If a thermoplastic jacket is applied over a lead sheath, the thicknesses of the lead sheath shall be in accordance with 4.5.14.3.

4.5.15.7 Thickness of Aluminum Sheath (See 6.15). If a thermoplastic jacket is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2.

4.5.16 Thermoplastic Jacket over Metallic Armor. If used, a thermoplastic jacket shall be extruded over the metallic armor and shall fit tightly thereto. It shall be either:

(a) Polyvinyl chloride meeting the requirements of 4.4.5, except that the cold-bend requirements shall be as given in 4.5.15.4, or
(b) Black polyethylene meeting the requirements of 4.4.6.

4.5.16.1 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 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 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.

4.5.16.2 Spark Test. The jacket on each length of cable shall withstand without failure the alternating-current spark-test voltage given in Table 4-23. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic armor for not less than 0.15 second. ▲

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Table 4-24
Thickness of Thermoplastic Jacket Over Metallic Armor

Calculated Diameter of Cable Under Thermoplastic Jacket		Jacket Thickness			
		All Cables (Except Interlocked Armored)		Cables With Interlocked Armor	
inches	mm	mils	mm	mils	mm
0-0.750	0-19.05	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

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 (4.5.3 through 4.5.16) pertaining to quality of materials, design and construction, apply also to borehole, dredge, shaft, and vertical riser cable, except as to the particular details expressly set forth in the following sections for the respective types of cable.

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

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

Table 4-25
Size of Galvanized Steel Armor Wires for Borehole Cable

Calculated Diameter of Cable Under Jute Bedding		Size of Armor Wires		
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

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 Wires. The size of the armor wires shall be as given in Table 4-26.

Table 4-26
Size of Galvanized Steel Armor Wires for Dredge Cable

Calculated Diameter of Cable Under Jute Bedding		Size of Armor Wires		
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

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4.5.20.3 Pitch Ratio. The minimum pitch ratio shall be as given in Table 4-27.

Table 4-27
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

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

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires.

Where unusual service conditions exist, it may be desirable to modify the above pitch ratio. If so, it should be defined before the cable design is finalized.

4.5.21 Shaft Cable. If shaft cable is to be clamped to the shaft structure or wall, the metallic covering (either tape or wire) shall comply with the requirements of 4.5.3 through 4.5.16. If the shaft cable is to be suspended from one end, galvanized round steel wire armor shall be used.

The size of the armor wires shall be in accordance with 4.5.22.2, but the tensile safety factor shall be not less than five.

4.5.22 Vertical Riser Cable (Suspended at One End Only) for Installation Within Buildings

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

4.5.22.2 Size of Armor Wires for Nonsheathed Cable. The size of the armor wires shall be as given in Table 4-28.

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

Table 4-28
Size of Galvanized Steel Armor Wires for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
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

4.5.22.3 Size of Armor Wires for Sheathed Vertical Riser Cable. The size of armor wires shall be in accordance with 4.5.19.2 for borehole cable, but the tensile safety factor shall be not less than four.

4.5.23 Wire-band Serving. If wire band servings are used for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be applied over the armor. The length of the serving band and the spacing of the band throughout the length of the cable shall be as given in Table 4-29.

The wire bands shall be applied tightly to prevent their movement along the cable during installation.

Table 4-29
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
2.501 and larger	63.53 and larger	25	7.6	4	102

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Division III
Round Wire Armor for Buried Cable

4.5.24 Scope. Division III gives details of construction of armor for buried land cables where greater longitudinal strength than that provided by flat tape armor is required, but not the strength of the 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 4.5.26.

4.5.26 Armor Wire and Jute Beddings and Servings (Sheathed and Nonsheathed Cables). The size of armor wire and thickness of jute bedding shall be as given in Table 4-30.

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

A jute serving in accordance with 4.5.10 shall be applied over the armor.

Table 4-30
Thickness of Jute Bedding and Size of Armor Wires

Calculated Diameter of Cable Under Jute Bedding		Average Thickness of Jute Bedding		Size of Armor Wires		
inches	mm	mils	mm	BWG	mils	mm
0-0.750	0-19.05	45	1.14	14	83	2.11
1.751-1.000	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 is obtainable with No. 6 BWG (203 mils) (5.16 mm) or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils) (6.05 mm) wire may be used.

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Part 5
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

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

5.1.1 Multiple-conductor Round Cables. Where cables consist of one layer of conductors that layer shall have a left-hand lay; where there is more than one layer, the outer layer shall have a left-hand lay. A left-hand lay is defined as a counterclockwise twist away from the observer.

The length of lay of the individual conductors in the outer layer of cables with a common covering shall not exceed the value calculated from the factor given in Table 5-1. Where there is more than one layer of conductors, the conductors in the inner layers shall have a length of lay not greater than those in the outer layer unless the inner layer consists of a single conductor.

The length of lay of the individual conductors in 2, 3- or 4- conductor cables without a common covering shall not exceed 60 times the largest conductor* diameter.

Table 5-1

Number of Conductors in Cable	Multiplying Factors* Based on Calculated Diameter
2	30 times largest conductor
3	35 times largest conductor
4	40 times largest conductor
5 or more	15 times assembled cable diameter

*The "largest conductor" is the insulated or uninsulated conductor having the largest calculated overall diameter.

5.1.2 Flat Twin Cables. Flat twin cables shall consist of two insulated conductors laid parallel under a common covering. The diameter over the insulation of each conductor shall not exceed 1 inch (25.4 mm).

5.2 Fillers. Fillers shall be used in the interstices of multiple-conductor round cable with a common covering where necessary to give the completed cable a substantially circular cross section.

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

Fillers shall be of suitable material which is separate or integral with the jacket.

5.3 Conductor Identification

5.3.1 Power Cables. When required, insulated conductors shall be identified by any suitable means.

5.3.2 Control Cables

5.3.2.1 Individual Color Coding of Braidless Conductors. Where color coding of individual conductors is required by other than colored marker braids or wraps, one of the following four methods, namely Method 1, 2, 3, or 4, shall be used.

5.3.2.1.1 Method 1—Colored Compounds with Tracers. The assembly of conductors in cables composed of 21 conductors or less shall be in accordance with the first 21 color combinations given in Table 5-2. For cables composed of more than 21 conductors, these 21 color combinations shall be repeated in regular sequence to the extent necessary to provide identification of all conductors.

When more than one color is required, the first color named in the table shall be the background or base color, and the second color named shall be the first tracer color.

Base and tracer colors shall be recognizably the first 21 color combinations given in Table 5-2 and shall approximately, but need not necessarily exactly, match the color shades specified in Method 5.

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

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Table 5-2
Color Sequence for Control Cables

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	...	...	46	Red	White	Blue
2	White	...	...	47	Green	Orange	Red
3	Red	...	...	48	Orange	Red	Blue
4	Green	...	...	49	Blue	Red	Orange
5	Orange	...	...	50	Black	Orange	Red
6	Blue	...	...	51	White	Black	Orange
7	White	Black	...	52	Red	Orange	Black
8	Red	Black	...	53	Green	Red	Blue
9	Green	Black	...	54	Orange	Black	Blue
10	Orange	Black	...	55	Blue	Black	Orange
11	Blue	Black	...	56	Black	Orange	Green
12	Black	White	...	57	White	Orange	Green
13	Red	White	...	58	Red	Orange	Green
14	Green	White	...	59	Green	Black	Blue
15	Blue	White	...	60	Orange	Green	Blue
16	Black	Red	...	61	Blue	Green	Orange
17	White	Red	...	62	Black	Red	Blue
18	Orange	Red	...	63	White	Orange	Blue
19	Blue	Red	...	64	Red	Black	Blue
20	Red	Green	...	65	Green	Orange	Blue
21	Orange	Green	...	66	Orange	White	Red
22	Black	White	Red	67	Blue	White	Red
23	White	Black	Red	68	Black	Green	Blue
24	Red	Black	White	69	White	Green	Blue
25	Green	Black	White	70	Red	Green	Blue
26	Orange	Black	White	71	Green	White	Red
27	Blue	Black	White	72	Orange	Red	Black
28	Black	Red	Green	73	Blue	Red	Black
29	White	Red	Green	74	Black	Orange	Blue
30	Red	Black	Green	75	Red	Orange	Blue
31	Green	Black	Orange	76	Green	Red	Black
32	Orange	Black	Green	77	Orange	White	Green
33	Blue	White	Orange	78	Blue	White	Green
34	Black	White	Orange	79	Red	White	Orange
35	White	Red	Orange	80	Green	White	Orange
36	Orange	White	Blue	81	Blue	Black	Green
37	White	Red	Blue	82	Orange	White	...
38	Black	White	Green	83	Green	Red	...
39	White	Black	Green	84	Black	Green	...
40	Red	White	Green	85	White	Green	...
41	Green	White	Blue	86	Blue	Green	...
42	Orange	Red	Green	87	Black	Orange	...
43	Blue	Red	Green	88	White	Orange	...
44	Black	White	Blue	89	Red	Orange	...
45	White	Black	Blue	90	Green	Orange	...

(Continued)

*This conductor is in the inside of the assembly.

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Table 5-2 (Continued)
Color Sequence for Control Cables

Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color
91	Blue	Orange	...
92	Black	Blue	...
93	White	Blue	...
94	Red	Blue	...
95	Green	Blue	...
96	Orange	Blue	...
97	Yellow	...	...
98	Yellow	Black	...
99	Yellow	White	...
100	Yellow	Red	...
101	Yellow	Green	...
102	Yellow	Orange	...
103	Yellow	Blue	...
104	Black	Yellow	...
105	White	Yellow	...
106	Red	Yellow	...
107	Green	Yellow	...
108	Orange	Yellow	...
109	Blue	Yellow	...
110	Black	Yellow	Red
111	White	Yellow	Red
112	Green	Yellow	Red
113	Orange	Yellow	Red
114	Blue	Yellow	Red
115	Black	Yellow	White
116	Red	Yellow	White
117	Green	Yellow	White
118	Orange	Yellow	White
119	Blue	Yellow	White
120	Black	Yellow	Green
121	White	Yellow	Green
122	Red	Yellow	Green
123	Orange	Yellow	Green
124	Blue	Yellow	Green
125	Black	Yellow	Blue
126	White	Yellow	Blue
127	Red	Yellow	Blue

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

5.3.2.1.2 Method 2—Neutral Colored Compounds with Tracers. This method uses a neutral colored compound, such as tan on all conductors, with tracers as defined in Method 1 and in accordance with Table 5-3. For cables composed of more than 21 conductors, these 21 color combinations shall be repeated in regular sequence to the extent necessary to provide such identifications of all conductors.

Table 5-3

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

*This conductor is in the inside of the assembly.

5.3.2.1.3 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 as given for the first 21 conductor numbers in Table 5-2. For cables composed of more than 21 conductors, these 21 color combinations shall be repeated in regular sequence to the extent necessary to provide such identification of all conductors.

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For example, for conductors 1 to 7, inclusive:

1—Black 1—Black 1—Black, etc.
2—White 2—White 2—White, etc.
3—Red 3—Red 3—Red, etc.
4—Green 4—Green 4—Green, etc.
5—Orange 5—Orange 5—Orange, etc.
6—Blue 6—Blue 6—Blue, etc.
7—White-black 7—White-black 7—White-black, etc.
etc.—(8 to 21 conductors)

5.3.2.1.4 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 printed conductor numbers only for the first 21 conductor numbers given in Table 5-2. For cables composed of more than 21 conductors, these 21 conductor numbers shall be repeated in regular sequence to the extent necessary to provide such identification of all conductors.

5.3.2.2 Method 5—Individual Color Coding with Braids. If colored marker braids are required, the color sequence of the conductors in the cable, beginning with black on the inside, shall be in accordance with Table 5-2. When more than one color is required, the first color named in the table shall be the background color. The shades of the colors shall approximately match those identified by the numbers given in Table 5-4 as found in the "Color Card" of the Color Association of the U. S., Inc., Ninth Edition.

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

Table 5-4

	Color Card	
Color	Designation	Number 9th Edition
Black	....	...
White	White	70001
Red	Scarlet	70080
Blue	Peking Blue	70047
Green	Emerald	70063
Orange	Orange	70069
Yellow	Jasmine	70067

5.3.2.3 Method 6—Layer Identification. For control cables having braidless or jacketed individual conductors requiring layer-tracer identification, one conductor of each layer of the cable shall be covered by a braid or tape, or shall be provided with a raised ridge or ridges to function as a tracer, or be otherwise distinctively marked or colored.

5.3.2.4 Color Coding of Paired Conductors. See 7.5.

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Part 6

TESTING AND TEST METHODS

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

Tests shall consist of the following, as required, namely, (1) tests on samples (see 6.4 to 6.26, inclusive), (2) electrical tests on entire lengths of completed cables (see 6.27 to 6.29, inclusive and (3) conductor tests (see 6.3) on samples or on entire lengths of completed cables.

6.2 Selection of Samples. Tests shall be made on samples selected at random. Each test sample shall be taken from an 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

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. ... 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 shall be permitted to 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:

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

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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°C) around the circumference of the conductor, tightly and perpendicular to the axis of the conductor. The average diameter of the conductor shall be read directly from the diameter tape.

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

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

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

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

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

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 6-4
Number and Length of Samples

Quantity of Completed Cable Ordered		Size of Conductor		Number of Samples	Minimum Length of Each Sample	
feet	meters	MCM	mm^2		conductor feet	conductor meters
Less than 2 000	Less than 610	Less than 250	Less than 127	none	..	...
Less than 1 000	Less than 305	250 and larger	127 and larger	none	..	...
2 000-50 000	610-15 240	Less than 250	Less than 127	1	6	1.8
1 000-25 000	305-7 620	250 and larger	127 and larger	1	3	0.9
More than 25 000	More than 7 620					
First 25 000	First 7 620	250 and larger	127 and larger	1	3	0.9
Each additional 25 000	Each additional 7 620	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

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6.4 Thickness Measurements for Insulations and Nonmetallic Jackets.

6.4.1 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. Measurements on the individual conductors of multiple-conductor cables shall be made before they are cabled.

6.4.2 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.

6.4.2.1 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 opposite 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.

6.4.2.2 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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6.4.3 Thickness Conformance. If the thickness is found to be less than the specified value, the coil or reel from which the sample was taken shall be considered as not conforming to this standard, and a thickness measurement shall be made on each of the remaining coils or reels.

6.5 Physical and Aging Tests for Insulations, Jackets and Nonmetallic Conducting Materials. (See 6.6 through 6.11).

6.5.1 Sampling

6.5.1.1 Insulations. Samples of insulated conductors for the unaged and aged physical tests shall be selected in accordance with Table 6-4, page 2.

Samples shall be taken after vulcanization and prior to the application of any covering except those applied before vulcanization. Cable tapes applied prior to vulcanization shall be removed from the samples prior to testing.

6.5.1.2 Jackets. Samples of jacketed cable for the unaged and aged physical tests shall be selected in accordance with Table 6-5. Page 4. No tests shall be made on jackets less than 30 mils (0.76 mm) in thickness.

6.5.1.3 Nonmetallic Conducting Materials. One test sample shall be molded from each lot of material intended for extrusion on cable.

6.5.2 Number of Test Specimens. Three test specimens shall be prepared from each of the samples selected in accordance with 6.5.1.

When one sample is selected in accordance with 6.5.1, all three test specimens shall be tested and the results averaged. When additional samples are required, only one test specimen out of three for each additional sample shall be tested and the other two specimens held in reserve.

6.5.3 Size and Preparation 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). The specimens shall be free of surface incisions and shall be as free as possible from other imperfections. For wire and cable smaller than 6 AWG having an insulation thickness of 90 mils (2.29 mm) or less, the test specimen may be the entire section of the insulation. When the full cross-section is used, the specimens shall not be cut longitudinally. For wire and cable 6 AWG and larger, or for wire and cable smaller than 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. Except when a full cross-section is used, surface irregularities such as corrugations due to stranding, etc., shall be removed so that the test specimen will be smooth and of uniform thickness.

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

Where jackets are bonded to the insulation, separate smoothed samples of the insulation and jacket shall be prepared. Test specimens shall be die-cut from the samples after they have been allowed to recover for at least 30 minutes.

6.5.4 Calculation of Area of Test Specimens

6.5.4.1 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.

6.5.4.2 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. (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. *)

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.

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

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

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

6.5.4.4 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.

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

6.5.5 Physical Test Procedures. Physical tests on both the unaged and aged test specimens shall be made at approximately the same time. Tests shall be made not earlier than 24 hours nor later than 60 days after vulcanization.

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

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

6.5.6 Retests. If any 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.

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. 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.

6.6 Tensile Strength Test. The tensile strength test shall be made with specimens prepared in accordance with 6.5.2 and 6.5.3. The length of all of the specimens for the test shall be equal. Gauge marks shall be 2 inches (51 mm) when using 6 inch (152 mm) specimens and 1 inch (25 mm) apart when using 4.5 inch (114 mm) specimens except that 1 inch (25 mm) shall be used for polyethylene regardless of specimen length and shall have its cross-sectional area between gauge marks determined in accordance with 6.5.4. Each specimen 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. Each specimen shall be stretched at the rate of 20 inches (508 mm) ± 10 percent per minute (jaw speed) until it breaks. The tensile strength shall be calculated in accordance with 6.11 of ASTM D 412, using only those specimens which break between the gauge marks.

The tensile and elongation determinations for compounds for which the compound manufacturer certifies that the base resin content is more than 50% by weight of high density polyethylene (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).

Specimen length gauge mark distance and jaw speed shall be recorded with the results.

6.7 Tensile Stress Test. The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the gauge marks indicate that the specimen is at its prescribed elongation. The tensile stress shall be calculated in accordance with 6.11 of ASTM D 412.

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

The elongation shall be taken as the distance between the gauge marks at rupture less the original gauge length marked on the specimen. The percentage of elongation at rupture is the elongation divided by the original gauge length and multiplied by 100. Specimen length, gauge mark distance and jaw speed shall be reported with the results.

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6.9 Set Test. The set test shall be made on test specimens which have been prepared, marked and stretched in accordance with 6.6 until the gauge marks are 6 inches (152 mm) apart. The test specimen shall be held in the stretched position for 5 seconds and then released. 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 of the original gauge length.

6.10 Aging Tests

6.10.1 Test Specimens. Test specimens of similar size and shape shall be prepared from each sample selected in accordance with 6.5.1 through 6.5.3, three for the determination of the initial or unaged properties, and three for each aging test required for the insulation or jacket being tested.

When the entire cross-section of insulation is used, the insulation shall be subjected to the aging condition with the conductor removed and each end of the specimen suitably plugged.

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

Simultaneous aging of different compounds should be avoided. (This paragraph is approved by NEMA as Authorized Engineering Information.)

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

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 rests and the determination of tensile strength and elongation.

6.10.2 Oxygen Pressure Test. The test specimens shall be heated in an atmosphere of oxygen at a pressure of 290 to 310 pounds per square inch (0.204 to 0.218 kgf/mm^2) at the temperature and for the period specified. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ± 1°C and recorded continuously.

6.10.3 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 controlled [illegible] recorded continuously.

6.10.4 Air Pressure Heat Test. The test specimens shall be heated in air at a pressure of 77 to 83 pounds per square inch (0.054 to 0.058 kgf/mm^2) at the temperature and for the period specified. This test shall be conducted in a steam-jacketed bomb or other suitable and uniformly heated chamber. The bomb shall be so regulated that the temperature inside the chamber will reach the test temperature within 15 minutes after inserting the test specimens. The air shall be substantially free from oil and moisture. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ± 1°C and recorded continuously.

6.10.5 Oil Immersion Test for Polyvinyl Chloride Jacket. The test specimens shall be immersed in ASTM Oil No. 2, described in Table I of ASTM D 471, at 70°C ± 1°C for 4 hours. At the end of this time, the specimens shall be removed from the oil and blotted.

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

6.10.6 Oil Immersion Test for Thermosetting Jacket. The test specimens shall be completely immersed in ASTM Oil No. 2, described in Table I of ASTM D 471, at 121°C ± 1°C for 18 hours. The specimens shall then be removed from the oil, blotted lightly, and suspended in air at room temperature for only 4 hours ± 1/2 hour before being 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. The elongation shall be based on the gauge marks applied to the specimen before immersion in the oil.

6.11 Physical Tests for Nonmetallic Conducting Materials Intended for Extrusion

6.11.1 Test Sample. See 6.5.1.3.

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

6.11.3 Elongation. Elongation shall be determined in accordance with 6.8 and 6.10.3.

6.11.4 Brittleness. Brittleness shall be determined in accordance with ASTM D 746, using Specimen A.

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6.12 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.

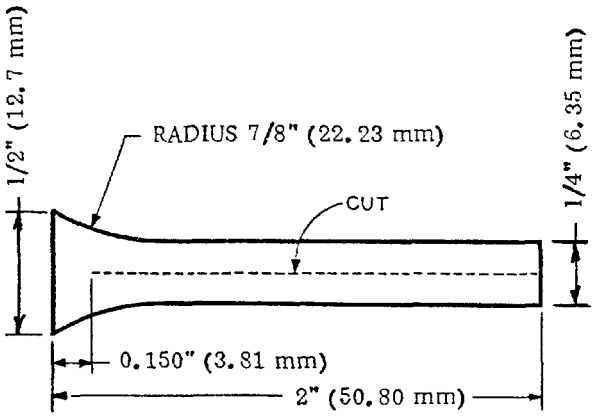

Fig. 6-1 TEST SPECIMEN FOR TEAR TEST

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 ± 10 percent (508 mm) 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.

6.12.1 Retests. When the tear resistance of the first set of six specimens fail 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.

6.13 Thickness of Jute Beddings and Servings. The thickness of jute beddings and servings shall be determined by the use of a diameter tape and shall be considered as 1/2 of the difference between the measurements under and over the jute. The measurement in each case shall be the average of five readings taken at different points along the cable.

6.14 Thickness of Metallic Tapes. Metallic 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.

6.15 Thickness of Metallic Sheaths. One 3-inch (76.2-mm) specimen of the sheath, free from external mechanical injury, shall be removed from each end of a reel length of cable. The ends of the specimens shall be cut perpendicular to the axis of the cable.

The thickness shall be determined by measurements made with a micrometer caliper having a rounded anvil. At least five separate measurements, approximately equally spaced around the circumference, shall be made on each specimen, and the average of all the measurements on the two specimens shall be considered as the average thickness of the sheath. The minimum of all of the measurements obtained shall be considered as the minimum thickness of the sheath.

6.16 Heat Shock. Each sample of jacketed cable selected in accordance with Table 6-5 shall be wound tightly around a mandrel having a diameter in accordance with Table 6-6 (Page 10), held firmly in place, and subjected to a temperature of 121°C ± 1°C for 1 hour.

6.17 Heat Distortion

6.17.1 Test Specimen. A sample (see 6.5.1.2) 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, three test specimens (see 6.5.2) each 1 inch (25.4 mm) long and 9/16 inch (14.3 mm) ± 1/16 inch wide shall be prepared. Where the diameter of the cable does not permit the preparation of a specimen 9/16 inch (14.3 mm) wide, the specimens shall be taken from a molded sheet of the same compound.

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

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6.17.2 Test Procedure. Each test shall be completed within 3 hours.

The Randall & Stickney, or equivalent, gauge with a load of 2 000 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:

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

6.18 Cold Bend. Each sample of completed cable selected in accordance with Table 6-5 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 6-7 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.

6.19 Environmental Cracking. Except as otherwise specified in 6.19.1 and 6.19.2, the test shall be made in accordance with ASTM D 1693.

6.19.1 Test Specimens. Test specimens (see 6.5.2) shall be prepared from test samples selected in accordance with Table 6-5. Three test specimens, each approximately 1.5 inch (38.1 mm) long, 0.5 inch (12.7 mm) wide and 0.125 inch (3.18 mm) thick, 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.

6.19.2 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 a 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.

Table 6-6

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

Table 6-7

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

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6.20 Absorption Coefficient. Test specimens (see 6.5.2) shall be prepared from test samples selected in accordance with Table 6-5. The absorption coefficient of jacket compounds shall be determined in accordance with ASTM D 3349.

6.21 Accelerated Water Absorption

6.21.1 General. No test sample shall be taken for 5 000 feet (1 524 meters) or less. One test sample for each test shall be taken for the first 5 001 to 20 000 feet (1 524 to 6 096 meters) of each cable construction and one additional sample for each additional 100 000 feet (30 480 meters). The gross length of each sample required by the electrical method shall be 15 feet (4.57 meters) and, by the gravimetric method, 11 inches (279 mm).

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

Test samples of the insulated conductor shall be taken after vulcanization and prior to the application of any covering except that which may have been applied before vulcanization. Such coverings shall be removed before the test is made.

6.21.2 Electrical Method (EM-60). The test shall be made at least 48 hours after vulcanization.

The middle 10 feet (3.05 meters) of the test sample shall be immersed in tap water which is maintained at 75°C ± 1°C for a period of 14 days, keeping the 2 1/2 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 sample. The water level shall be kept constant.

The capacitance of the insulation shall be determined at an average stress of 80 volts per mil at approximately 60 hertz after 1, 7 and 14 days' immersion. The power factor of the insulation at average stresses of 80 and 40 volts per mil shall be determined after 1 and 14 day's 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 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.

6.21.3 Gravimetric Method.▲

▲ 6.21.3 deleted.

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6.22 Capacity and Power Factor. This test is applicable only to power cables rated 5 001 volts and above. One test sample shall be taken for the first 5 000 to 20 000 feet (1 524 to 6 096 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. The test sample shall be taken from the insulated conductor prior to the application of any covering except that which may have been applied before vulcanization. Such coverings shall be removed before the test is made.

The capacity and power factor shall be measured at approximately 60 hertz 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.

6.23 Tests for Discharge Resistance

6.23.1 Test Samples. The samples shall be taken from the completed cable. No sample shall be taken from the first 5 000 feet (1 524 meters). One sample shall be taken from the first 5 001 to 20 000 feet (1 524 to 6 096 meters) of each cable construction and one additional sample for each additional 100 000 feet (30 480 meters).

6.23.2 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, blotted and allowed to remain at room temperature for 10 minutes. Two 1-inch- (25.4-mm-) wide foil electrodes spaced 6 inches (152 mm) apart shall be wound around the cable surface which was immersed. 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 as follows:

$$P = 0.524\ RD$$

Where—

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

6.23.3 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 6-8.

Table 6-8

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 shall be applied between the conductor and the metal plate continuously for at least 6 hours. This test shall be made at room temperature.

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6.24 Volume Resistivity

6.24.1 Test Samples. One sample shall be taken from each 25 000 feet (7 620 meters) or major fraction thereof for each cable construction.

6.24.2 Conductor Shielding. The sample shall be cut in half longitudinally and the conductor removed. Four silver-painted electrodes shall be applied to the conductor shielding. 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. Where a high degree of accuracy is not required, the 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:

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

Where—

P = Volume resistivity in ohm-centimeters.

R = Measured resistance in ohms.

D = Diameter over the conductor shielding in inches.

d = Diameter over the conductor in inches.

L = Distance between potential electrodes in inches.

6.24.3 Insulation Coverings. Four silver-painted annular-ring electrodes shall be applied to the surface of the insulation covering. 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. Where a high degree of accuracy is not required, the 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:

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

Where—

P = Volume resistivity in ohm-centimeters.

R = Measured resistance in ohms.

D = Diameter over the insulation covering in inches.

d = Diameter over the insulation in inches.

L = Distance between potential electrodes in inches.

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6.25 Stripping Test. Test samples shall be selected in accordance with Table 6-5, page 4. One test specimen shall be prepared from each sample. The test specimen shall be approximately 15 inches long, and all coverings over the extruded insulation 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.

6.26 Retests for Tests Covered by 6.13 through 6.25

6.26.1 If all of the samples pass the applicable tests described in 6.13 through 6.25, the quantity of cable which they represent shall be considered as meeting the requirements of this standard.

6.26.2 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 two other lengths of cable in the quantity of cable under test. If either of the second samples fails to pass the test, the quantity of cable shall be considered as not meeting the requirements of this standard. If both such second samples pass the test, the quantity of cable (except the length represented by the first sample) shall be considered as meeting the requirements of this standard.

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

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ELECTRICAL TESTS ON COMPLETED CABLES

6.27 Voltage Tests

6.27.1 General. These tests consist of voltage tests on each length of completed cable. Except for the direct-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.

6.27.1.1 Cables Without Metallic Sheath, Metallic Shield or Metallic Armor. Except for the direct-current spark test (see 6.27.4), 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.

6.27.1.2 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.

6.27.2 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.

6.27.3 Direct-current Voltage Test. This test is applicable to cables without insulation shield rated up through 5 000 volts and to all cables rated 5 001 volts and above and shall be made after the insulation resistance test described in 6.28. 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.

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● 6.27.4a Alternating-current Spark Test

6.27.4a.1 Application. This test shall apply to single-conductor cable and assemblies of single-conductor cables rated 0 through 2000 volts.

This test shall not apply to:

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

6.27.4a.2 Test Apparatus. Test apparatus shall consist of:

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

6.27.4a.3 Test Procedure. One side of the potential source shall be connected to the electrode and the other side of the potential source shall be connected to ground. The conductor(s) in the cable shall be tested to assure continuity when grounded at one or both ends. All ground connections shall be bonded (common). The fault indicator shall be connected to indicate abnormal current between electrode and ground.

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

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

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

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

Where—

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

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

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

Where—

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

6.27.4a.4 Failure. Any indication by the fault indicator shall constitute a failure.

▲ 6.27.4b Direct-current Spark Test. This test is applicable to single-conductor cables and assemblies of insulated single-conductor cables without insulation shield, and without metallic sheath or metallic armor, rated 0 through 2000 volts. The equipment for the direct-current spark test shall consist of a direct-current sparker of ample voltage and a suitable electrode. The sparker shall be capable of

† This paragraph is approved by NEMA as Authorized Engineering Information.
● Added 10-29-1979.
▲ Formerly par. 6.27.4.

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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.

6.27.5 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 6-9 and shall be applied in accordance with 6.27.1 and 6.27.3.

6.28 Insulation Resistance

6.28.1 Test Apparatus. The test apparatus shall be in accordance with ASTM D 257. The test potential shall be a steady source of 100 through 500 volts direct current.

6.28.2 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 6.27. Where the voltage tests are made on wire or cable immersed in water, the insulation resistance shall be measured while the cable is still immersed. Single-conductor cables shall be tested between the conductor and metallic sheath or water. Multiple-conductor cables with nonshielded conductors shall be tested between each conductor and all other conductors and sheath or water. Multiple-conductor cables with shielded conductors shall be tested between the conductor and shield. The conductor under test shall be connected to the negative terminal of the test equipment and readings shall be taken after an electrification of 1 minute.

Each coil, reel or length of wire or cable shall have an insulation resistance in megohms-1 000 feet at a temperature of 15.6°C (60°F) of not less than the value of R calculated as follows:

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

Where—

R = Insulation resistance in megohms-1 000 feet.

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

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 6-10 using the coefficient (see 6.28.3) for the particular grade of insulation and temperature in question. The temperature of the water shall be not less than 10°C (50°F) nor more than 29.4°C (85°F).

Table 6-9
d-c Test Voltages After Installation, kV

Rated Circuit Voltage, Phase to Phase, Volts	Conductor Size, AWG or MCM	Test Voltage, kV	
		100 Percent Insulation Level	133 Percent Insulation Level
2 001-5 000	8-1 000	25	25
5 001-8 000	6-1 000	35	35
8 001-15 000	2-1 000	55	65
15 001-25 000	1-1 000	80	100
25 001-28 000	1-1 000	85	...
28 001-35 000	1/0-1 000	100	...

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Table 6-10
Temperature Correction Factors for Insulation Resistance to 15.6°C (60°F)

Temperature		Coefficient for 1°F									
F	C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
50	10.0	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35	0.32
51	10.6	0.77	0.70	0.65	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.82	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.87	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60	0.57
56	13.3	0.89	0.86	0.82	0.76	0.76	0.74	0.71	0.69	0.66	0.64
57	13.9	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.71
58	14.4	0.94	0.93	0.91	0.90	0.88	0.86	0.85	0.83	0.82	0.80
59	15.0	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.24	1.27
63	17.2	1.09	1.13	1.16	1.19	1.23	1.26	1.30	1.34	1.38	1.42
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.47	1.53	1.58
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.62	1.70	1.78
66	18.9	1.20	1.27	1.35	1.42	1.50	1.59	1.69	1.78	1.88	1.98
67	19.4	1.23	1.32	1.41	1.51	1.62	1.72	1.84	1.96	2.09	2.21
68	20.0	1.27	1.37	1.48	1.60	1.72	1.85	1.99	2.15	2.31	2.48
69	20.6	1.31	1.43	1.55	1.69	1.84	2.00	2.18	2.36	2.57	2.77
70	21.1	1.35	1.48	1.63	1.79	1.97	2.17	2.38	2.60	2.85	3.10
71	21.7	1.39	1.54	1.72	1.90	2.11	2.34	2.59	2.87	3.17	3.46
72	22.2	1.43	1.60	1.80	2.02	2.26	2.53	2.82	3.15	3.52	3.90
73	22.8	1.47	1.67	1.89	2.14	2.42	2.72	3.08	3.46	3.90	4.37
74	23.3	1.52	1.74	1.98	2.27	2.58	2.94	3.35	3.81	4.31	4.88
75	23.9	1.56	1.80	2.08	2.40	2.76	3.18	3.65	4.19	4.78	5.47
76	24.4	1.61	1.87	2.19	2.54	2.96	3.43	3.98	4.61	5.30	6.12
77	25.0	1.66	1.95	2.30	2.70	3.17	3.70	4.34	5.08	5.88	6.85
78	25.6	1.71	2.02	2.41	2.86	3.39	4.00	4.73	5.59	6.51	7.68
79	26.1	1.76	2.11	2.53	3.03	3.62	4.33	5.16	6.14	7.27	8.59
80	26.7	1.81	2.19	2.66	3.21	3.87	4.67	5.61	6.72	8.07	9.65
81	27.2	1.87	2.28	2.80	3.40	4.15	5.04	6.12	7.43	8.98	10.8
82	27.8	1.92	2.37	2.94	3.60	4.43	5.45	6.69	8.18	9.92	12.1
83	28.3	1.98	2.47	3.08	3.82	4.72	5.89	7.28	9.00	11.0	13.6
84	28.9	2.04	2.57	3.23	4.05	5.04	6.35	7.92	9.90	12.2	15.2
85	29.4	2.10	2.67	3.40	4.30	5.42	6.84	8.67	10.8	13.5	17.0

6.28.3 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 25 000 megohms at the lowest water bath temperature.

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

The resistance of the conductor shall be measured at suitable intervals until it remains unchanged for at least 5 minutes. The insulation will then be at the temperature of the bath as read on the bath thermometer. Insulation resistance shall then be measured in accordance with 6.28.2.

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

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

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

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6.29 Partial-discharge Test Procedure ▲

Refer to ICEA Publication T-24-380 revised 1980.

6.30 Method for Flexibility Test for Continously Corrugated Armor.

6.30.1 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.

6.31 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:

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

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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Part 7
CONSTRUCTIONS OF SPECIFIC TYPES

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

7.1 Mine Power Cables

7.1.1 Scope. This section covers ethylene-propylene-rubber-insulated shielded thermosetting or thermoplastic jacketed cables in sizes 6 AWG through 500 MCM for use as connections between units of mine distribution systems at nominal alternating-current voltages of 2001 to 15 000 volts at 100 or 133 percent insulation level. These cables shall be one of the following types:

Type MP —three power conductors and three grounding conductors.

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

Ampacities are given in Appendix F.

Recommended minimum bending radii are given in Appendix L.

7.1.2 Conductors

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

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 (square millimeters).

T = Tensile strength of conductor in pounds per square inch (kgf/mm^2) =

	psi	MPa▲
Annealed copper	24 000	165
Medium hard copper	40 000	276
1350 aluminum	17 000	117

W = Weight of cable in pounds (kg).

The conductor size shall be in accordance with Table 7.1-1 and shall meet the requirements given in Part 2. When the size of medium hard-drawn copper power conductors is determined in accordance with 6.3.2.3, the direct-current resistance shall not exceed by more than 2 percent the values given in Table 7.1-5.

Conductor shielding in accordance with 2.4 shall be applied over each power conductor.

7.1.2.2 Grounding Conductors. Grounding conductors shall be Class B or C stranded annealed coated copper and shall meet the requirements given in Part 2. The size of each grounding conductor shall be in accordance with Table 7.1-1.

7.1.2.3 Ground Check Conductor. The ground check conductor shall be Class B or C stranded annealed coated or uncoated copper of the minimum size shown in Table 7.1-1 and shall meet the requirements given in Part 2.

7.1.3 Insulation. The insulation shall meet the requirements given in Part 3.

The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.1-2 and 7.1-3. 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.

7.1.4 Insulation Shielding. Each power conductor shall be shielded in accordance with 4.1.

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

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

7.1.6 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.

7.1.7 Jacket. A thermosetting jacket which meets the requirements of 4.4.3, 4.4.7 or 4.4.9 or a thermoplastic jacket which meets the requirements of 4.4.5 shall be applied over the conductor assembly. The average thickness of the jacket shall be not less than that given in Table 7.1-4, and the minimum thickness shall be not less than 80 percent of these values.

7.1.8 Outside Diameters. The outside diameter of the completed cable shall be within plus 8 and minus 5 percent of the values given in Tables 7.1-2 and 7.1-3.

7.1.9 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.1.

The insulated power conductors shall meet the test voltage and partial-discharge requirements given in Table 7.1-2 or 7.1-3.

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.

Table 7.1-1
Conductor Sizes

Size of Power Conductors, AWG or MCM		Copper Grounding Conductors		Copper
		Type MP Cables, Size in Each Interstice,	Type MP-GC Cables, Size in Each of Two Interstices,	Ground Check Conductor, Minimum Size,
Copper	Aluminum	AWG	AWG	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 7.1-2
Insulation Thicknesses and Outside Diameters—2001 to 5000 Volts *—
100 and 133 Percent Insulation Levels

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.

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Table 7.1-3

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

*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.

(Continued)

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Table 7.1-3 (Continued)
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	
8001 to 15000 Volts*														
2	175	4.44	1.88	47.8	27	70	11	...	....	....	....	..	..	..
1	175	4.44	1.98	50.3	27	70	11	215	5.46	2.20	55.9	33	80	15
1/0	175	4.44	2.05	52.0	27	70	11	215	5.46	2.30	58.4	33	80	15
2/0	175	4.44	2.15	54.6	27	70	11	215	5.46	2.42	61.5	33	80	15
3/0	175	4.44	2.26	57.4	27	70	11	215	5.46	2.53	64.3	33	80	15
4/0	175	4.44	2.40	61.0	27	70	11	215	5.46	2.65	67.3	33	80	15
250	175	4.44	2.50	63.5	27	70	11	...	....	....	....	..	..	..
300	175	4.44	2.64	67.0	27	70	11	...	....	....	....	..	..	..
350	175	4.44	2.75	69.9	27	70	11	...	....	....	....	..	..	..
400	175	4.44	2.92	74.2	27	70	11	...	....	....	....	..	..	..
450	175	4.44	3.00	76.2	27	70	11	...	....	....	....	..	..	..
500	175	4.44	3.10	78.4	27	70	11	...	....	....	....	..	..	..

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

Table 7.1-4
Overall Jacket Thickness

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

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Table 7.1-5
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

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7.2 Portable Single- and Multiple-conductor Power Cables

7.2.1 Scope. This section covers ethylene-propylene-rubber-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 7.2.18.

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 7.2-1 through 7.2-16. Recommended ampacities and voltage ratings are given in Appendix G. Recommended bending radii are given in Appendix L.

GENERAL DESCRIPTION OF COMPLETED CABLE

7.2.2 Single-conductor Cables, Nonshielded, 0-2000 Volts. These cables shall consist of an insulated conductor with a jacket which meets the requirements of 7.2.18 and shall be in accordance with Table 7.2-2. Normal-service cables shall have a heavy-duty jacket, and hard-service cables shall have an extra-heavy-duty jacket.

7.2.3 Type W and G Two-conductor Cables, 0-2000 Volts. These cables shall be one of two types: (1) flat twin or (2) two-conductor round.

7.2.3.1 Two-conductor Flat Twin Cables

7.2.3.1.1 Type W, Without Grounding Conductor. These cables shall consist of two conductors which are separately covered with insulation and, in addition, may be separately covered with a tape, braid or serving, and then laid parallel under a jacket which meets the requirements of 7.2.18. The conductor shall be separated by a web of the jacket or other material. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.1.2 Type G, With Grounding Conductor. These cables shall consist of two power conductors which are separately covered with insulation and, in addition, may be separately covered with a tape, braid or serving. The two power conductors shall then be laid parallel with a grounding conductor (see 7.2.12) between them under a jacket which meets the requirements of 7.2.18. If the protective covering on the power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductor or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.2 Two-conductor Round Cables

7.2.3.2.1 Type W, Without Grounding Conductors. These cables shall consist of two conductors which are separately covered with insulation. In addition, each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.3.2.2 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 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.4 Type W, G and G-GC Three- and Four-conductor Cables, 0-2000 Volts. Three-conductor cables shall be one of five types: (1) Type W, round construction, without grounding conductors, (2) Type G, round construction, with grounding conductors, (3) Type G, flat construction, with grounding conductors, (4) Type G-GC, round construction, with

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grounding conductors and a ground check conductor and (5) Type G-GC, flat construction, with a grounding conductor 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.

7.2.4.1 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 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.2 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 7.2.15). The power conductors, together with the grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.3 Type G, Three-conductor Flat, With Grounding Conductors. These cables shall consist of three power conductors which are separately covered with insulation and may be separately covered with a tape, braid or serving. The three power conductors shall then be laid parallel with one of two flat grounding conductors (see 7.2.12) in a vertical position between each of them and under a jacket which meets the requirements of 7.2.18. If the protective covering on the individual power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductors or within the jacket. The cables shall be in accordance with Table 7.2-7.

7.2.4.4 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 7.2.12) and one ground check conductor (see 7.2.11). 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 7.2.15). All power grounding and ground check conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-8.

7.2.4.5 Type G-GC, Three-conductor Flat, With Grounding Conductor and Ground Check Conductor. These cables shall consist of three power conductors which are separately covered with insulation and may be separately covered with a tape, braid or serving. The three power conductors shall be laid parallel with the flat ground check conductor (see 7.2.11) in a vertical position between the black and white power conductors and with the flat grounding conductor (see 7.2.12) in a vertical position between the white and red power conductors under a jacket which meets the requirements of 7.2.18. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors, grounding conductor and ground check conductor or within the jacket. The cables shall be in accordance with Table 7.2-9.

7.2.5 Type W and G, Five- and Six-conductor 0-2000 Volts. Five-conductor cables shall be 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.

7.2.5.1 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 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-10.

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7.2.5.2 Type G, With Grounding Conductor (Five-conductor Cables Only). These cables shall consist of five power conductors which are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 around a single grounding conductor and covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-10. These cables shall be used for the internal wiring of equipment only.

7.2.6 Type PG, Two and Three Power Conductor 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 7.2.15). The power conductors, together with a single grounding conductor (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2.11.

7.2.7 Type PCG, Two and Three Power Conductor 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 7.2.15). 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 7.2-1. 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 7.2.18. These cables shall be in accordance with Table 7.2-12.

7.2.8 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 7.2.15). The power conductors, together with the grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-13.

7.2.9 Type SH, SHC-GC, SHD, and SHD-GC, Shielded Cables, 0-25 000 Volts at 100 Percent Insulation Level Only

7.2.9.1 Type SH Single-conductor Cables, 2001-25 000 Volts. These cables shall consist of an insulated conductor covered with a tape, a shield which meets the requirements of 7.2.16 with or without a tape over the shield, and a jacket which meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-14.

7.2.9.2 Type SHC-GC Three-conductor Cables, 0-2000 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 or braid which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12), one ground check conductor (see 7.2.11), and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1. 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 7.2.16 and a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-15.

7.2.9.3 Type SHD Three-conductor Cables, 0-25 000 Volts. These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.2.15) and a shield which meets the requirements of 7.2.16, and three grounding conductors (see Table 7.2-18), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 7.2-1 and

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covered with a jacket which meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-16.

7.2.9.4 Type SHD-GC Three-conductor Cables, 0-25 000 Volts. These cables shall consist of three power conductors which are separately covered with insulation, a colored tape (see 7.2.15) and a shield which meets the requirements of 7.2.16 and two grounding conductors (see Table 7.2-18) and one ground check conductor (see 7.2.11).

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 7.2-1 and covered with a jacket which meets the requirements of 7.2.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-16.

7.2.10 Power Conductors

7.2.10.1 Power conductors shall be made of annealed coated or uncoated copper wires in accordance with Part 2. A nonconducting separator may be used for cables rated 0-2000 volts.

7.2.10.2 The sizes, strandings, and nominal diameters of the conductors shall be in accordance with Table 7.2-18.

7.2.10.3 Conductor shielding shall be in accordance with 2.4.

7.2.11 Control and Ground Check Conductors. The control conductors for Type PCG shall be not smaller than 10 AWG. The ground check conductor for Types G-GC, SHC-GC and SHD-GC shall be as given in Tables 7.2-8, 7.2-9, 7.2-15 and 7.2-16. 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 7.2.10.

7.2.12 Grounding Conductors

7.2.12.1 The grounding conductors for two, three and four conductor round Type G, SHC-GC, SHD and SHD-GC shall be annealed copper of not less than the size and number of wires in Table 7.2-18 for the corresponding power conductor sizes. In all other characteristics, they shall meet the requirements of 7.2.10.

7.2.12.2 The single grounding conductor for flat twin Type G cables shall be composed of either coated or uncoated copper and shall have a minimum cross-sectional area of 50 percent of the power conductor but not less than the cross-sectional area for a No. 8 AWG conductor as given in Table 7.2-3. A separator may be used. The grounding conductor wires shall meet the requirements of 2.1.1.

7.2.12.3 The two grounding conductors for flat three-conductor Type G cables shall be flat, rectangular or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-7. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.4 The grounding conductors for three-conductor round Type G-GC shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Table 7.2-8.

7.2.12.5 The grounding conductor for flat three-conductor Type G-GC cables shall be flat, rectangular or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-9. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.6 The single grounding conductor for five-conductor Type G and for Type PG and PCG cables shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Tables 7.2-10, 7.2-11 and 7.2-12.

7.2.12.7 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.

7.2.13 Insulation. The insulation shall meet the requirements given in Part 3. The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.2-2 through 7.2-16. In these tables, the highest rated circuit voltage given in the titles represents the maximum operating volt-

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age 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 8 AWG ground check conductors. The minimum thickness shall be not less than 90 percent of the specified average values.

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

7.2.15 Conductor or Circuit Identification. Identification shall be by any suitable means in accordance with the color sequence given in 7.2.15.1 and 7.2.15.2. If a conducting nonmetallic tape is used over the insulated conductor, it shall be plainly identified as being conducting.

7.2.15.1 Power Conductors

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

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

7.2.15.2 Control and Ground Check Conductors

Control conductors, Type PCG ... black, white
Ground check conductor, Type G-GC (round or flat), Type SHD-GC, and Type SHC-GC.. yellow

7.2.16 Shielding

7.2.16.1 The shielding for Types SH, SHD, SHC-GC and SHD-GC cables shall consist of nonmagnetic wires.

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

7.2.16.2 Metal Braid Shields. If shielding is applied in the form of a metal braid, the coverage shall be not less than 84 percent as determined by the following formula:

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

Where—

$F = \dfrac{NP\ d}{\sin a}$

a = Angle of braid with axis of cable

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

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

7.2.16.3 Metal Wire Shields. If the shielding is applied in the form of a serving or wrap, the coverage shall be not less than 60 percent as determined by the following formula:

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

Where—

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

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

C = Pitch of serving in inches

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7.2.17 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 Type 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. A binder tape and/or threads may be used over the assembly.

7.2.18 Jackets

7.2.18.1 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 requirements of 7.2.18.1.1, 7.2.18.1.2, 7.2.18.1.3, 7.2.18.1.4, 7.2.18.1.5, or 7.2.18.1.6.

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. ▲

7.2.18.1.1 Extra-heavy-duty Neoprene Jacket

Physical requirements	
Tensile strength, minimum	
psi	2400
kgf/mm^2	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm^2	0.49
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Tear, minimum	
pounds per inch	40
kgf/mm	0.71

(Continued)

(Continued)

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

7.2.18.1.2 Heavy-duty Neoprene Jacket

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

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7.2.18.1.3 Extra - heavy - duty Nitrile - butadiene/polyvinyl-chloride Jacket *

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

7.2.18.1.4 Heavy-duty Nitrile-butadiene/-polyvinyl-chloride Jacket *

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30

(Continued)

(Continued)

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

7.2.18.1.5 Heavy - duty Chlorosulfonated Polyethylene Jacket

Physical requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging requirements	
After air oven test at 100°C ± 1°C for 168 hours—tensile strength, 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

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

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7.2.18.1.6 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

7.2.18.2 Thickness of Jacket. The average thickness of the jacket shall be not less than that given in Tables 7.2-13 through 7.2-17. The minimum thickness shall be not less than 80 percent of the values given in the tables. The reinforcing specified in 7.2.18.1 shall be included in the measurement of the jacket thickness.

7.2.19 Completed Cable

7.2.19.1 Outside Diameters. Nominal outside diameters of the completed cables shall be in accordance with Tables 7.2-2 through 7.2-16.

7.2.19.2 Diameter Tolerances. The tolerance for outside diameters shall be plus 8 percent and minus 5 percent, except for 0-2000 volt nonshielded cables. For 0-2000 volt flat twin cables, the tolerance shall be ± 0.04 inch for the major and ± 0.03 inch for the minor diameter. For 0-2000 volt flat three-conductor cables, the tolerance shall be ± 0.08 inch for the major and ± 0.05 inch for the minor diameter. For all other 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

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

7.2.21 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.2.

The insulated power conductors shall meet the test voltage requirements given in Table 7.2-2 through 7.2-16. 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.

● Added 11-3-1977.

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Table 7.2-1
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.

Table 7.2-2
0 to 2000 Volts
Single-conductor Portable Power Cable

Power Conductor Size, AWG or MCM†	Insulation Thickness		Outside Diameter Normal Service		Outside Diameter Hard Service		Test Voltage, kV	
	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 7.2-18.

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Table 7.2-3
0 to 2000 Volts
Type W and G Two-conductor Flat Twin Portable Power Cables

Power Conductor Size, AWG or MCM†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Outside Diameter				Test Voltage, kV	
				Minor		Major			
	mils	mm		inches	mm	inches	mm	a-c	d-c
Type W (Without Grounding Conductor)									
8	60	1.52	...	0.51	12.9	0.84	21.3	7.0	21.0
6	60	1.52	...	0.56	14.2	0.93	23.6	7.0	21.0
4	60	1.52	...	0.61	15.5	1.05	26.7	7.0	21.0
3	60	1.52	...	0.68	17.3	1.14	28.9	7.0	21.0
2	60	1.52	...	0.73	18.5	1.24	31.5	7.0	21.0
1	80	2.03	...	0.81	20.6	1.40	35.6	8.0	24.0
1/0	80	2.03	...	0.93	23.6	1.51	38.3	8.0	24.0
2/0	80	2.03	...	0.99	25.1	1.63	41.4	8.0	24.0
3/0	80	2.03	...	1.03	26.1	1.77	45.0	8.0	24.0
4/0	80	2.03	...	1.10	27.9	1.89	48.0	8.0	24.0
Type G (With Grounding Conductors)									
6	60	1.52	8	0.56	14.2	1.02	25.9	7.0	21.0
4	60	1.52	7	0.61	15.5	1.15	29.2	7.0	21.0
3	60	1.52	6	0.68	17.3	1.26	32.0	7.0	21.0
2	60	1.52	5	0.73	18.5	1.35	34.3	7.0	21.0
1	80	2.03	4	0.81	20.6	1.55	39.4	8.0	24.0
1/0	80	2.03	3	0.93	23.6	1.67	42.4	8.0	24.0
2/0	80	2.03	2	0.99	25.1	1.85	47.5	8.0	24.0
3/0	80	2.03	1	1.03	26.1	2.00	50.8	8.0	24.0
4/0	80	2.03	1/0	1.10	27.9	2.10*	53.3 *	8.0	24.0

*This cable requires extra-heavy-duty jackets (see 7.2.1).

† See Table 7.2-18.

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Table 7.2-4
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-5
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-6
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-7
0 to 2000 Volts
Type G Three-conductor Flat Portable Power Cables With Two Grounding Conductors

Power Conductor Size, AWG†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Nominal Outside Diameter				Test Voltage, kV	
				Minor		Major			
	mils	mm	(each)	inches	mm	inches	mm	a-c	d-c
6	60	1.52	8	0.67	17.0	1.65	41.9	7.0	21.0
4	60	1.52	8	0.75	19.0	1.85	47.0	7.0	21.0
3	60	1.52	7	0.77	19.6	1.99	50.5	7.0	21.0
2	60	1.52	6	0.81	20.6	2.10*	53.3*	7.0	21.0
1	80	2.03	5	0.97	24.6	2.43*	61.7*	8.0	24.0
1/0	80	2.03	4	1.01	25.6	2.61*	66.3*	8.0	24.0
2/0	80	2.03	3	1.10	27.9	2.86*	72.6*	8.0	24.0
3/0	80	2.03	2	1.18	29.9	3.12*	79.2*	8.0	24.0
4/0	80	2.03	1	1.24	31.5	3.30*	83.8*	8.0	24.0

*These cables require extra-heavy-duty jackets (see 7.2.1).

† See Table 7.2-18.

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Table 7.2-8
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-9
0 to 2000 Volts
Type G-GC Three-conductor Flat Portable Power Cables With
One Grounding Conductor and One Ground Check Conductor

Power Conductor Size, AWG†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Ground Check Conductor, Minimum Size, AWG	Nominal Outside Diameter				Test Voltage, kV	
					Minor		Major			
	mils	mm			inches	mm	inches	mm	a-c	d-c
6	60	1.52	8	8	0.67	17.0	1.69	42.9	7.0	21.0
4	60	1.52	7	8	0.75	19.0	1.89	48.0	7.0	21.0
3	60	1.52	6	8	0.77	19.5	2.08*	52.8*	7.0	21.0
2	60	1.52	5	8	0.81	20.5	2.23*	56.6*	7.0	21.0
1	80	2.03	4	8	0.97	24.6	2.48*	62.9*	8.0	24.0
1/0	80	2.03	3	8	1.01	25.6	2.67*	67.8*	8.0	24.0
2/0	80	2.03	2	8	1.10	27.9	2.86*	72.6*	8.0	24.0
3/0	80	2.03	1	8	1.18	29.9	3.12*	79.2*	8.0	24.0
4/0	80	2.03	1/0	8	1.24	31.5	3.30*	83.8*	8.0	24.0

*These cables require extra-heavy-duty jackets (see 7.2.1).

† See Table 7.2-18.

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Table 7.2-10
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-11
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-12
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 7.2.1).

† See Table 7.2-18.

‡ 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 a-c test voltage shall be 3.0 kV for 15 seconds.

Table 7.2-13
2001 to 5000 Volts
Type G Three-conductor Portable Power Cables

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
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-14
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

(Continued)

*These cables require extra-heavy-duty jackets (see 7.2.1).

† See Table 7.2-18.

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Table 7.2-14 (Continued)
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
			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 7.2.1).

† See Table 7.2-18.

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Table 7.2-15
0 to 2000 Volts
Type SHC-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	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 7.2.1).

† See Table 7.2-18.

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Table 7.2-16
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	....

(Continued)

*These cables require extra-heavy-duty jackets (see 7.2.1).

† See Table 7.2-18.

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Table 7.2-16 (Continued)
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
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 7.2.1).

† See Table 7.2-18.

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Table 7.2-17

Jacket Thicknesses For Types And Sizes Of Portable Cables Not Covered By Tables 7.2-2 Through 7.2-16

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 7.2-18 ▲
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	...	...	...	...	...	...	...	...

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Table 7.2-18 (Continued)
Conductors

Power Conductors						Grounding Conductors							
						Two-conductor Cables		Three-conductor Type SHD-GC Cables		All Other Three-conductor Cables		Four-conductor Cables	
Conductor Size, AWG or MCM	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
250	259	31.1	0.790	0.653	16.59	1/0	259	1/0	259	2	259	3	133
250	427	24.2	0.615	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
300	427	26.5	0.673	0.716	18.19	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
350	427	28.6	0.726	0.772	19.61	2/0	259	2/0	259	1	259	2	259
400	259	39.3	0.998	0.825	20.96	3/0	427	3/0	427	1/0	259	1	259
400	427	30.6	0.777	0.826	20.98	3/0	427	3/0	427	1/0	259	1	259
450	259	41.7	1.060	0.876	22.25	3/0	427	3/0	427	1/0	259	1	259
450	427	32.5	0.826	0.878	22.30	3/0	427	3/0	427	1/0	259	1	259
500	259	43.9	1.115	0.922	23.42	4/0	427	4/0	427	2/0	259	1/0	259
500	427	34.2	0.869	0.923	23.44	4/0	427	4/0	427	2/0	259	1/0	259
550	427	35.9	0.912	0.969	24.61	...	...	...	...	...	...	...	...
550	703	28.0	0.711	0.980	24.89	...	...	...	...	...	...	...	...
600	427	37.5	0.952	1.013	25.73	...	...	...	...	...	...	...	...
600	703	29.2	0.742	1.022	25.96	...	...	...	...	...	...	...	...
650	427	39.0	0.991	1.053	26.75	...	...	...	...	...	...	...	...
650	703	30.4	0.772	1.064	27.03	...	...	...	...	...	...	...	...
700	427	40.5	1.029	1.094	27.79	...	...	...	...	...	...	...	...
700	703	31.6	0.803	1.106	28.09	...	...	...	...	...	...	...	...
750	427	41.9	1.064	1.131	28.73	...	...	...	...	...	...	...	...
750	703	32.7	0.831	1.145	29.08	...	...	...	...	...	...	...	...
800	427	43.3	1.100	1.169	29.69	...	...	...	...	...	...	...	...
800	703	33.7	0.856	1.180	29.97	...	...	...	...	...	...	...	...
900	427	45.9	1.166	1.239	31.47	...	...	...	...	...	...	...	...
900	703	35.8	0.909	1.253	31.83	...	...	...	...	...	...	...	...
1000	427	48.4	1.229	1.307	33.20	...	...	...	...	...	...	...	...
1000	703	37.7	0.958	1.320	33.53	...	...	...	...	...	...	...	...

7.3 Preassembled Aerial Cables

7.3.1 Scope. This section covers preassembled aerial cables with one or more individually insulated ethylene-propylene-rubber conductors which are attached to a messenger to form self-supporting aerial cables for use on power transmission and distribution systems operating at 35 kV or less phase to phase.

The characteristics of the completed assembly shall be such that the cable can be installed at a minimum temperature of minus 10°C (14°F).

For ampacities see Appendix E.

7.3.2 Conductors. Conductors shall be either copper or aluminum in accordance with Part 2.

7.3.2.1 Copper. Copper conductors shall be sizes 6 AWG to 750 MCM. The stranding shall be Class B, Class C or compact except that, when required, size 6 AWG may be solid.

7.3.2.2 Aluminum. Aluminum conductors shall be sizes 6 AWG to 750 MCM. The stranding shall be Class B, Class C or compact.

7.3.2.3 Conductor Shielding. Conductor shielding shall be in accordance with 2.4.

7.3.3 Insulation. The insulation shall meet the requirements given in Part 3, except that, for Type I cable, the average insulation thickness shall be not less than that given in Table 7.3-1 and the minimum thickness shall be not less than 90 percent of this value.

7.3.4 Cable Types. The cable shall be one of the types given in Table 7.3-2.

7.3.4.1 Type I Nonshielded, Jacketed or Nonjacketed. Type I cables shall be in accordance with Tables 7.3-1 and 7.3-2, and cables rated 2001-5000 volts shall meet the requirements of 7.9.6.2.

Table 7.3-1
Type I Cables Only

Rated Circuit Voltage, Phase to Phase, Volts	Conductor Size, AWG or MCM	Jacketed Cable: Insulation Thickness at 100 and 133 Percent Insulation Level, mils	mm	Jacket Thickness, mils	mm	Nonjacketed Cable: Insulation Thickness, mils	mm	Test Voltage, kV: a-c	d-c
0-600	6-2	45	1.14	30	0.76	60	1.52	5.5	16.5
	1-4/0	55	1.40	45	1.14	80	2.03	7	21
	225-500	65	1.65	65	1.65	95	2.41	8	24
	525-750	80	2.03	65	1.65	110	2.79	10	30
601-2000	6-2	55	1.40	30	0.76	70	1.78	7	21
	1-4/0	65	1.65	45	1.14	90	2.29	8	24
	225-500	75	1.90	65	1.65	105	2.67	9.5	28.5
	525-750	90	2.29	65	1.65	120	3.05	11.5	34.5
		100 Percent Insulation Level Only							
2001-5000	6	90	2.29	30	0.76	110	2.79	13	35
	4-2/0	90	2.29	45	1.14	110	2.79	13	35
	3/0-4/0	90	2.29	65	1.65	110	2.79	13	35
	225-500	90	2.29	65	1.65	120	3.05	13	35
	525-750	90	2.29	65	1.65	130	3.30	13	35

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7.3.4.2 Type II Shielded, Nonjacketed. Type II cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1 except that the metallic component shall be a helically wrapped nonmagnetic shielding tape having a thickness of at least 4.5 mils (0.114 mm) and shall be applied with a lap of not less than 15 percent of its width.

7.3.4.3 Type III Shielded, Jacketed Type III cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1. A separator tape may be applied over the shielding.

7.3.5 Jacket. Jackets for Type I and III cables shall be one of the following:

	See par.
Neoprene, heavy-duty black.....	4.4.3
Polyvinyl chloride	4.4.5
Polyethylene, black.....	4.4.6
Nitrile-butadiene/polyvinyl-chloride, heavy duty.....	4.4.7
Chlorosulfonated polyethylene, heavy duty.....	4.4.9

The average thickness of the jacket for Type I cables shall be not less than that given in Table 7.3-1 and, for Type III cables, not less than that given in Table 4-3. The minimum thickness shall be not less than 80 percent of these values.

7.3.6 Identification. Each insulated conductor of multiple-conductor cables shall be permanently marked so that circuit identification can be made without exposing the insulation. Single-conductor cables need not have circuit identification. Cables shall be identified to indicate the manufacturer.

7.3.7 Assembly. The insulated conductors shall be cabled together with a suitable lay. The messenger shall be laid parallel to the axis of a single conductor or the cabled conductors. The cabled conductors shall be bound to a copper type messenger by means of a copper binding strap or to an aluminum type messenger by means of an aluminum binding strap. The binding strap shall have a pitch of from 3 to 8 inches (76.2 to 203.2 mm), shall be rectangular with rounded edges, and shall have nominal dimensions not less than those shown in Table 7.3-3.

The messenger shall extend 5 feet (1.52 meters) beyond each end of the conductors for use in installing the cable.

7.3.8 Messenger Sizes. The messenger shall be either composite stranded copper and copper-clad steel in accordance with ASTM B 229, Grade 30 EHS stranded copper-clad steel in accordance with ASTM B 228, stranded aluminum-clad steel in accordance with ASTM B 416, stranded aluminum-alloy conductors (AAAC) in accordance with ASTM B 399, or composite stranded aluminum and aluminum-clad steel (ACSR/AW) in accordance with ASTM B 549. The 9/16-inch copper-clad steel size is based on the use of 19-wire construction rather than the 7-wire for added strength and flexibility.

The messenger sizes for copper-clad steel shall be as given in Table 7.3-4 and for ACSR/AW shall be as given in Table 7.3-5. For other types of messenger, consult the manufacturer.

7.3.9 Design Criteria*. The messenger size should be based on a normal stringing tension of 60°F(15.6°C) not exceeding 30 percent of the ultimate strength and a maximum tension not exceeding 50 percent of the ultimate strength at a heavy loading condition. For further information, see the National Electrical Safety Code, ANSI Standards Publication No. C2.

The messenger sizes given in Tables 7.3-4 and 7.3-5 are of sufficient strength, except for the 750 MCM copper cable, to permit installation of the cables on the basis of a 150-foot (45.7-meter) ruling span with a maximum normal sag of 2.5 feet (0.76 meter) at 60°F (15.6°C) no ice, no wind, and without exceeding the tension limits given in Table 7.3-6.

For the 750-MCM copper cable, the span should be limited to 125 feet (38.1 meters) to satisfy this design criteria.

For single-phase circuits using the messenger as the grounded neutral conductor, the resistance of the messenger should be not greater than that of the conductor. ▲

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

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Table 7.3-2

Type	Description	Type of Insulation, See	Maximum Rated Circuit Voltage, Phase to Phase, kV: 100 Percent Insulation Level	133 Percent Insulation Level
I	Nonshielded			
	Jacketed	3.6 or 3.7	5	2
	Nonjacketed	3.7	5	2
II	Shielded, nonjacketed	3.6 or 3.7	35	25
III	Shielded, jacketed ...	3.6 or 3.7	35	25

Type 7.3-3

Diameter of Cable Assembly Excluding Messenger		Binding Strap: Copper				Aluminum			
		Thickness		Width		Thickness		Width	
inches	mm	mils	mm	mils	mm	mils	mm	mils	mm
0-1.000	0-25.40	25	0.64	250	6.35	30	0.76	250	6.35
1.001 and Over	25.43 and Over	30	0.76	375	9.53	40	1.02	375	9.53

Table 7.3-4
Messenger Size (Copper-clad Steel) (ASTM B 228 or B 229)

Conductor Size, AWG or MCM	Cable Voltage Rating and Power Conductor Material: Up through 5 kV 100 and 133 Percent Insulation Level: Copper	Aluminum	Over 5 through 15 kV 100 and 133 Percent Insulation Level: Copper	Aluminum	Over 15 through 35 kV 100 Percent Insulation Level: Copper	Aluminum
	SINGLE CONDUCTOR					
6*	6D	6D	6D	6D	....	...
4*	4D	6D	4D	6D	....	...
2*	2J	4D	2J	4D	....	...
	TWO AND THREE CONDUCTOR					
6*	5/16	5/16	5/16	5/16	....	...
4*	5/16	5/16	5/16	5/16	....	...
2*	5/16	5/16	5/16	5/16	....	...
1*	5/16	5/16	3/8	5/16	3/8	3/8
1/0	5/16	5/16	3/8	3/8	1/2	3/8
2/0	5/16	5/16	3/8	3/8	1/2	1/2
3/0	3/8	5/16	1/2	3/8	1/2	1/2
4/0	3/8	5/16	1/2	3/8	9/16	1/2
350	3/8	3/8	1/2	1/2	....	...
500	1/2	3/8	9/16	1/2	....	...
750	1/2†	3/8	....	...	....	...

* See limitations on conductor size in Tables 3-1 and 7.3-1.
† See 7.3.9.

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Table 7.3-5
Messenger Size (ACSR/AW) (ASTM B 549)

Conductor Size, AWG or MCM	Cable Voltage Rating and Power Conductor Material					
	Up through 5 kV 100 and 133 Percent Insulation Level		Over 5 through 15 kV 100 and 133 Percent Insulation Level		Over 15 through 35 kV 100 Percent Insulation Level	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
	SINGLE CONDUCTOR					
6*	4-4/3	4-4/3	4-4/3	4-4/3	...	...
4*	2-4/3	4-4/3	2-4/3	4-4/3	...	...
2*	1/0-5/2	2-4/3	1/0-5/2	2-4/3	...	...
	TWO AND THREE CONDUCTOR					
6*	4-2/5	4-2/5	4-2/5	4-2/5	...	...
4*	4-2/5	4-2/5	4-2/5	4-2/5	...	...
2*	4-2/5	4-2/5	4-2/5	4-2/5	...	...
1*	4-2/5	4-2/5	2-2/5	4-2/5	1/0-2/5	2-2/5
1/0	4-2/5	4-2/5	2-2/5	2-2/5	1/0-2/5	2-2/5
2/0	4-2/5	4-2/5	2-2/5	2-2/5	1/0-2/5	1/0-2/5
3/0	2-2/5	4-2/5	1/0-2/5	2-2/5	19 No. 9	1/0-2/5
4/0	2-2/5	4-2/5	1/0-2/5	2-2/5	19 No. 9	1/0-2/5
350	2-2/5	2-2/5	1/0-2/5	1/0-2/5	...	...
500	1/0-2/5	2-2/5	19 No. 9	1/0-2/5	...	...
750	1/0-2/5†	2-2/5	...	...	...	...

* See limitations on conductor size in Tables 3-1 and 7.3-1.

† See 7.3.9.

Table 7.3-6 ▲

Loading Condition	Maximum Tension, Percent of Ultimate Strength
Heavy loading	
1/2 inch(12.7 mm) ice, 4 lb/sq ft(192 Pa) wind force, 0°F(-17.8°C) .	50
Normal loading	
No ice, no wind, 60°F(15.6°C)	30

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7.4 Single- and Multiple-conductor Flexible Cords

7.4.1 Scope. This section covers single, two-, three- and four-conductor flexible cords with conductor sizes 18 to 10 AWG, inclusive, with ethylene-propylene-rubber insulation and with heavy-duty or medium-duty jackets.

Multiple-conductor cords are intended for hard service (300 volts maximum) or extra hard service (600 volts maximum).

Single-conductor cords do not have a service designation. For single-conductor cords, sizes 18 and 16 AWG, the maximum voltage rating is 300 volts. For single-conductor cords, sizes 14, 12 and 10 AWG, the maximum voltage rating is 600 volts.

Ampacities, type designations and voltage ratings are given in Appendix H.

Remote control and drill cords for use in underground coal mines in accordance with U. S. Bureau of Mines requirements for Electric Motor-Driven Mine Equipment and Accessories (Schedule 2G) are covered in Appendix H. ▲

7.4.2 Conductors

7.4.2.1 The conductors shall be annealed uncoated or coated copper wire and shall meet the requirements given in Part 2 except the conductor resistance, as specified in paragraph 2.5, is not required.

The conductor size shall be determined by the method in paragraph 6.3.2.1 which specifies cross-sectional area by diameter measurement, or by paragraph 6.3.2.2 which specifies cross-sectional area by weight.

7.4.2.2 Sizes. The conductors shall be sizes 18 through 10 AWG. The cross-sectional area of the conductors shall be not more than 2.0 percent below the values given in Table 7.4-1, except that if only No. 30 AWG strands are employed on 18 AWG conductors, the cross-sectional area shall be not less than 3 percent below the values given in the table. ▲

7.4.2.3 Stranding. The strands in the conductors shall be no smaller than 36 AWG and no larger than 30 AWG. The individual strands of the conductors shall be bunch stranded (twisted together) or rope stranded. The lay of twist shall not exceed the values given in Table 7.4-1.

7.4.2.4 Separator. A separator, if used, shall consist of a close covering of cotton, paper or other material. Where a separator is not used, the individual strands of the conductor shall be separately coated in accordance with 2.1.1.

Table 7.4-1
Conductor Requirements

Conductor Size, AWG	Cross-sectional Area, CM	Maximum Lay of Twist: Bunch Stranded (Lay of Strands) inches	mm	Rope Stranded (Lay of Ropes) inches	mm
18	1620	1.00	25.4	1.88	47.8
16	2580	1.25	31.8	2.13	54.1
14	4110	1.63	41.4	2.50	63.5
12	6530	2.00	50.8	3.13	79.5
10	10380	2.50	63.5	3.13	79.5

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7.4.3 Insulation. The insulation shall meet the requirements given in Part 3, except that the thickness shall be in accordance with Table 7.4-2 and shall be measured as follows:

7.4.3.1 Average Thickness. The average thickness of the insulation shall be determined in accordance with 6.4.2.1.

7.4.3.2 Minimum Thickness. The minimum thickness of the insulation shall be determined by a pin-gauge dial micrometer which exerts a force of 25 plus or minus 2 grams on the specimen. The pin shall be 0.437 inch (11.1 mm) long and 0.043 inch (1.09 mm) in diameter, and the end of the presser foot which makes contact with the specimen shall be a flat rectangle 0.043 inch (1.09 mm) wide by 0.312 inch (7.92 mm) long.

The conductor and the separator, if any, shall be removed carefully. The specimen of insulation shall be placed carefully on the pin. The specimen shall be so located that the entire length of the presser foot will make contact with it. The presser foot shall be permitted to come to rest gently on the specimen, and the reading shall be taken immediately.

The specimen shall be rotated and several measurements taken in order to determine the actual minimum thickness. The presser foot shall not be in contact with the specimen when the latter is rotated.

7.4.4 Conductor Assembly

7.4.4.1 Circuit Identification. Circuit identification shall be obtained by means of colored insulating compounds, braids or tapes in the following sequence:

Two conductors — black, white
Three conductors — black, white, green, or black, white, red
Four conductors — black, white, red, green

7.4.4.2 Length of Lay. The length of lay of insulated conductors shall not exceed the values given in Table 7.4-3.

7.4.4.3 Fillers. Fillers shall be placed in the interstices of the assembly (see 5.2).

7.4.4.4 Binder. A binder, if used, shall be a tape, braid, wrap of multiple ends of thread, or a combination of these, and shall be applied over the assembled conductors.

Table 7.4-2 ▲
Insulation Thicknesses

Conductor Size, AWG	Hard Service Multiple-conductor Cords				Extra-Hard Service Multiple-conductor Cords and Single-conductor Cords			
	Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm
18-16	30	0.76	27 *	0.69	30	0.76	27 *	0.69
14	30	0.76	27 *	0.69	45	1.14	41 †	1.04
12	30	0.76	27 *	0.69	45	1.14	41 †	1.04
10	45	1.14	41 †	1.04	45	1.14	41 †	1.04

* The minimum thickness at the line of contact between conductors shall be not less than 25 mils (0.64 mm).
† The minimum thickness at the line of contact between conductors shall be not less than 39 mils (0.99 mm).

Table 7.4-3
Maximum Length of Lay

Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
	inches	mm	inches	mm	inches	mm
18	2.00	50.8	2.25	57.2	2.50	63.5
16	2.25	57.2	2.50	63.5	2.75	69.8
14	2.50	63.5	3.25	82.6	3.75	95.2
12	3.00	76.2	3.50	88.9	4.25	108.0
10	3.50	88.9	4.00	101.6	4.75	120.6

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7.4.5 Jackets

7.4.5.1 Heavy-duty Jackets. The jacket shall be a black compound of natural rubber, SBR synthetic rubber, or neoprene or a black or colored compound of nitrile-butadiene/polyvinyl-chloride or chlorosulfonated polyethylene which meets the applicable requirements of Table 7.4-4.

Table 7.4-4▲
Heavy-duty Jackets

	Natural Rubber	SBR	Neoprene	Nitrile butadiene/-polyvinyl-chloride*	Chlorosulfonated Polyethylene
Physical requirements					
Tensile strength, minimum					
psi	3500	1800	1800	1800	1800
MPa	24.1	12.4	12.4	12.4	12.4
Tensile stress at 200 percent elongation, minimum					
psi	500	....	500	500	500
MPa	3.45	....	3.45	3.45	3.45
Elongation at rupture, minimum, percent	500	300	300	300	300
Set, maximum, percent	15	20	20	30	30
Tear resistance, minimum					
pounds per inch	40	....	....	....	....
kN/m	7.0	....	....	....	....
Aging requirements					
After air oven test at 100°C ± 1°C for 168 hours					
Tensile strength, minimum, percentage of unaged value	....	....	50	50	85
Elongation at rupture, minimum percentage of unaged value	....	....	50	50	65
After air oven test at 70°C ± 1°C for 168 hours					
Tensile strength, minimum					
psi	....	1600	....	....	....
MPa	....	11.0	....	....	....
Elongation at rupture, minimum, percent	....	250	....	....	....
After oxygen pressure test at 70°C ± 1°C for 96 hours					
Tensile strength, minimum					
psi	2500	1600	....	....	....
MPa	17.2	11.0	....	....	....
Elongation at rupture, minimum, percent	400	250	....	....	....
After oil immersion test at 121°C ± 1°C for 18 hours--tensile strength and elongation, minimum, percentage of unaged value	....	....	60	60	60

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

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7.4.5.2 Medium-duty Jackets. The jacket shall be a black or colored compound of natural rubber, SBR synthetic rubber, neoprene, nitrile-butadiene/polyvinyl-chloride, chlorosulphonated polyethylene, ethylene propylene rubber or polyvinyl-chloride which meets the applicable requirements of Table 7.4-5.

7.4.5.3 Oil Resistance. The jacket of an oil-resistant cord shall be one of those meeting the requirements of the oil immersion test given in Table 7.4-4 or 7.4-5.

7.4.5.4 Application. The jacket shall be applied over the insulation of a single-conductor cord or over the assembled conductors or binder of multiple-conductor cords.

7.4.5.5 Reinforcement. Reinforcement, if used, shall consist of a braid or a serving of fibrous material under the entire jacket or completely embedded in the jacket.

7.4.5.6 Thickness. The thickness of the jacket shall be in accordance with Table 7.4-6 and shall be determined in accordance with 7.4.3.1 and 7.4.3.2.

7.4.6 Overall Diameters. The minimum average overall diameter of the completed cord shall be in accordance with Table 7.4-7.

Table 7.4-6
Average and Minimum Thicknesses of Jackets

Conductor Size, AWG	Single-conductor Cords				Multiple-conductor Cords ▲							
					Hard Service Two to Four Conductors				Extra Hard Service Two to Four Conductors			
	Average		Minimum		Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
18	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
16	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
14	30	0.76	23	0.58	30	0.76	23	0.58	80	2.04	64	1.63
12	30	0.76	23	0.58	45	1.14	36	0.91	95	2.42	76	1.94
10	30	0.76	23	0.58	60	1.55	48	1.22	95	2.42	76	1.94

Table 7.4-7 ▲
Overall Diameters

Type of Cord	Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
		Minimum inches	Maximum inches	Minimum inches	Maximum inches	Minimum inches	Maximum inches
Hard service	18	0.280	0.315	0.300	0.335	0.325	0.365
	16	0.305	0.340	0.325	0.360	0.350	0.395
	14	0.335	0.375	0.360	0.395	0.390	0.435
	12	0.405	0.455	0.425	0.475	0.465	0.520
	10	0.540	0.606	0.565	0.635	0.625	0.700
Extra hard service	18	0.340	0.385	0.360	0.400	0.385	0.430
	16	0.365	0.410	0.385	0.430	0.410	0.460
	14	0.495	0.550	0.520	0.575	0.560	0.620
	12	0.565	0.625	0.590	0.655	0.640	0.710
	10	0.615	0.685	0.650	0.720	0.700	0.775

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Table 7.4-5
Medium-duty Jackets

	Natural Rubber or SBR	Neoprene	Nitrile-butadiene/-polyvinyl-chloride *	Chloro-sulphonated Polyethylene	Ethylene Propylene Rubber	Polyvinyl Chloride *
Physical requirements						
Tensile strength, minimum						
psi	1500	1500	1500	1500	1500	1600
▲MPa	10.3	10.3	10.3	10.3	10.3	11.0
Elongation at rupture, minimum, percent	300	300	250	300	300	250
Set, maximum, percent	20	20	30	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	50	....	....	50
After oxygen pressure test at 70°C ± 1°C for 96 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value.	70	....	....	70	....	....
After oxygen pressure test at 80°C ± 1°C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value.	....	....	....	....	50	....
After air pressure heat test at 127°C ± 1°C for 20 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	60	....	....	50
After air oven test at 70°C ± 1°C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	....	....	....	70	....	....

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

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7.4.7 Strength of Completed Cord. The mechanical strength of completed two- and three-conductor cord, sizes 16 and 18 AWG, shall be determined by means of a freely hanging weight or a suitable testing machine and shall be such that no conductor will break when the test force given in Table 7.4-8 is applied for 1 minute.

7.4.8 Tests. The cord shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.4 except as otherwise specified in 7.4.8.1.

7.4.8.1 Electrical Tests. Each length of completed single-conductor cord shall withstand either the direct-current or the alternating-current spark test voltage given in Table 7.4-9. Each length of completed multiple-conductor cord shall withstand an alternating-current voltage test unless each individual insulated conductor, prior to assembly, has withstood either an alternating-current spark test or a direct-current spark test. The alternating-current voltage shall be applied for 15 seconds between conductors without immersing the cord in any liquid.

The alternating-current test and the alternating-current spark test shall be in accordance with Underwriters' Laboratories, Inc., "Standards for Flexible Cord and Fixture Wire", UL 62.

The direct-current spark test shall be in accordance with 6.27.4

The test voltages shall be in accordance with Table 7.4-9.

Table 7.4-8
Strength of Completed Cord

Type of Cord ▲	Conductor Size, AWG	Test Force, Two and Three Conductor, Pounds	Test Force, Two and Three Conductor, kg
Hard service	18	175	79.4
	16	200	90.7
Extra hard service	18	200	90.7
	16	225	102

Table 7.4-9
Test Voltages

Conductor Size, AWG	Test Voltages, kV		
	a-c Voltage Test	a-c Spark Test	d-c Spark Test
18	2.0	6.0	....
16	2.0	6.0	....
14	3.0	7.0	16.0
12	3.0	7.0	16.0
10	3.0	7.0	16.0

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7.5 Control Cables

7.5.1 Scope. This section covers multiple conductor ethylene-propylene-rubber-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 coveyance 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 or control 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 over-voltages 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.

7.5.2 Conductors

7.5.2.1 Conductors shall be made of annealed coated or uncoated copper in accordance with Part 2.

7.5.2.2 Sizes 16 AWG and smaller shall be solid or stranded. Sizes larger than 16 AWG shall be stranded. Stranding shall be in accordance with 2.3, Class B or C.

7.5.3 Insulation

7.5.3.1 The insulation shall be of one of the following types:

a. Type I (see 3.6).

b. Type II (see 3.7).

c. A composite insulation consisting of a layer of insulating neoprene or chlorosulfonated polyethylene over a layer of Type I or Type II insulation without any further covering (see 7.5.9.3 and 7.5.9.4).

7.5.3.2 The minimum average thickness of insulation shall be not less than that given in Table 7.5-1. The minimum thickness at any point shall be not less than 90 percent of that given in the table. For composites, the minimum thickness at any point of each layer of material shall not be less than 90 percent of the value specified in Table 7.5-1.

7.5.4 Jacket Over Insulation. Jackets shall not be required over the individual conductors. However, if a jacket is used, it shall be of one of the materials given in 7.5.7 and shall have a minimum average thickness of not less that 15 mils (0.38 mm) and a minimum thickness at any point of not less than 12 mils (0.30 mm).

7.5.5 Circuit Identification. Circuit identification, if used, shall be by any suitable means (see Part 5).

7.5.6 Assembly. The individual conductors or pairs shall be assembled in accordance with Part 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. Use of a separator tape over the assembly shall be permitted.

7.5.7 Overall Jacket

7.5.7.1 Type A, B and C cables shall have an overall jacket in accordance with one of the following:

Thermoplastic

Polyvinyl chloride.....4.4.5
Polyethylene, black 4.4.6

Thermoset

Neoprene, heavy-duty black 4.4.3
Nitrile-butadiene/polyvinyl-chloride heavy-duty.....4.4.7
Chlorosulfonated polyethylene, heavy-duty.....4.4.9

Inner Insulating Layer-Type I

Physical requirements
Tensile strength, minimum
psi 700
MPa.....4.83
Elongation at rupture, minimum, percent 250

Aging Requirements
After air overn test at 121 °C ± 1 °C for 168 hours
Tensile strength, minimum, percentage of unaged value.....75
Elongation, minimum, percentage of unaged value 75

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Table 7.5-1
Conductor Sizes, InsulationThicknesses, and Test Voltages #

Conductor Size	Voltage Rating-300V or 600V						Voltage Rating-1000V					
	Insulation Thickness				Test Voltage kV		Insulation Thickness				Test Voltage kV	
	Single Layer		Composite†				Single Layer		Composite†			
AWG	mils	mm	mils	mm	a-c	d-c	mils	mm	mils	mm	a-c	d-c
20-18	25	0.64	20/10	0.51/0.25	2.5	7.5	...	...	...	...	...	...
16	25	0.64	20/10	0.51/0.25	2.5	7.5	45	1.14	30/15	0.76/0.38	4.5	13.5
14-9	30	0.76	20/10	0.51/0.25	3.0	9.0	45	1.14	30/15	0.76/0.38	4.5	13.5

The voltages shall be determined by the size of the conductor and the rated voltage of the cable and not the apparent thickness of the insulation.

† Composite Thicknesses - Inner Layer/Outer Layer

Inner Insulating Layer-Type II

Physical requirements

Tensile strength, minimum
psi 1200
MPa 8.27

Elongation at rupture, minimum, percent 150

Tensile Strength at 100 percent elongation, minimum
psi 500
MPa 3.45

Aging Requirements

After air oven test at 121 °C ± 1 °C for 168 hours

Tensile strength, minimum, percentage of unaged value 75

Elongation, minimum, percentage of unaged value 75

Outer Insulating Layer

Tensile strength, minimum
psi 1500
MPa 10.34

Elongation at rupture, minimum, percent 300

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 40

7.5.7.2 The minimum average thickness of the jacket shall be not less than that given in Table 7.5-2. The minimum thickness at any point shall be not less than 80 percent of that given in the table.

7.5.8 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.*

7.5.9 Tests

7.5.9.1 The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.5.

7.5.9.2 Electrical tests on completed cable shall be in accordance with 6.27 and 6.28, except that the tests may be made without immersion in water. The dielectric withstand voltage level shall be as specified in Table 7.5-1.

7.5.9.3 Physical and Aging Requirements For Composite Insulations. (See 6.5) Composite insulation shall meet the requirements specified in either 7.5.9.3.1 or 7.5.9.3.2.

* This paragraph has been approved by NEMA as Authorized Engineering Information.

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Table 7.5-2
Overall Jacket Thickness

Calculated Diameter of Cable Under Jacket		Thickness	
inches	mm	mils	mm
0-0.425	0-10.80	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

7.5.9.3.1 If the layers cannot be separated, they shall be tested as a unit construction and shall meet the following requirements:

Physical Requirements
Tensile strength, minimum
psi 1000
MPa 6.90
Elongation at rupture, minimum, percent 250

Aging Requirements
After air oven test at 121 °C ± 1°C for 168 hours
Tensile strength, minimum, percentage of unaged value 75
Elongation, minimum, percentage of unaged value 50

7.5.9.3.2 If the layers can be separated, they shall be tested separately and shall meet the following requirements:

7.5.9.4 Electrical Requirements For Composite Insulations:

Specific surface resistivity, minimum megohms (see 6.23.2) 200,000

Accelerated water absorption (see 6.21*)
Electrical method (EM-60)
Dielectric constant after 24 hours, maximum 4.5
Increase in capacitance, maximum, percent
1 to 14 days 3.5
7 to 14 days 2.0
Stability Factor after 14 days, maximum 1.0

Gravimetric method
Water absorption, maximum, mg/in^2 35

Insulation resistance constant (K) at 15.6 °C (60 °F) (see 7.5.9.2) 12,000

* The test shall be performed on a sample having a 30 or 45 mil total composite wall (inner layer plus outer layer), as applicable and specified in Table 7.5-1.

7.5.10 Optional Flame Test Requirement. This section describes optional flame test requirements for insulated conductors (Tests A and B) and finished cable described within this standard. These tests shall not be applicable unless specifically requested.

7.5.10.1 Flame Resisting Test A - Insulated Conductor

The test apparatus shall consist of the following:

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

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

c. A 4-pound (1.8-kg) weight for 9AWG and smaller conductor sizes to be attached to the lower end of the test specimen to keep it taut.

d. Tirrill burner with an attached pilot light and mounted on a 20-degree angle block. The burner shall have a nominal bore of ⅜ inch (9.5 mm) and a length of approximately 4 inches (102 mm) above the primary air inlets.

e. 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.

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.

2. The specimen continues to burn for more than one minute after the fifth application of flame.

7.5.10.2 Flame Resisting Test B - Insulated Conductor

This test shall be the same as in 7.5.10.1, except for the following:

a. 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 nor more than 9½ inches from the point at which the inner blue cone touches the cable surface.

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b. The valve supplying the gas to the burner proper shall 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.

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

The specimen shall be considered to have failed this test if any of the following occurs:

1. More than 25 percent of the extended portion of the indicator is burned.
2. The specimen continues to burn for more than one minute after any of the flame applications.
3. The surgical cotton is burned.

f. Gas - a supply of ordinary illuminating gas at normal pressure.

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

h. Flame indicators consisting of strips of gummed kraft paper having a nominal thickness of 5 mils (0.127 mm) and a width of ½ inch (12.7 mm)*.

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 9 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 ¼ inch (19.0 mm) from the specimen on the opposite side of the specimen to that to which the flame is to be applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches (127 mm) with an inner blue cone 1 ½ inches (38.1 mm) high. The temperature at the tip of the inner blue cone shall be not less than 836 °C (1500 °F).

The burner, with only the pilot lighted, shall be placed in front of the samples 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 burner stem between the tip of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for 15 seconds. This process shall be repeated four times. During each application of the flame the specimen shall be adjusted, if necessary, so that the top of the inner blue cone touches the surface of the specimen. The duration of burning of this specimen after the fifth application of the flame shall be recorded.

7.5.10.3 Flame Resisting Test - Finished Cable

This test shall be a type test to demonstrate flame resistance of a cable construction. (i.e. insulation and jacket type). The test shall be performed as described in IEEE Standard 383-1974, paragraph 2.5 with the following exceptions:

1. The standards sample to be tested shall be a 7 or 9 conductor, No. 12 AWG rated at 600 volts.
2. Only the ribbon gas burner shall be used as the flame source.
3. Ribbon Gas Burner, American Gas Furnace Company (Cat. No. 10L 11-55 formerly specified as Cat. No. 10X 11-55), or equivalent.

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

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7.6 Concentric-neutral Underground Distribution Cables ▲

7.6.1 Scope. This section covers two-conductor concentric-neutral power cables consisting of one ethylene-propylene-rubber

7.6.1 Scope. This section covers two-conductor concentric-neutral power cables consisting of one ethylene-propylene-rubber-insulated central conductor applied helically overall. These cables are intended for use on single-phase and three phase primary underground distribution systems operating at 2001 to 35 000 volts phase-to-phase at 100 percent insulation level. For ampacities, see Appendix 1.

7.6.2 Central Conductor. Central conductors shall be annealed copper or aluminum. The minimum conductor size shall be in accordance with Table 7.6-1.

7.6.2.1 Copper. Conductors shall be (1) annealed uncoated copper or annealed coated copper either Class B or C stranded or (2) uncoated copper, compact stranded, and shall meet the requirements of Part 2.

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

7.6.2.3 Conductor (Shielding). All conductors shall be covered with a Stress Control Layer in accordance with Part 2.

Table 7.6-1
Minimum Conductor Size

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

7.6.3 Insulation. The shielded central conductor shall be insulated with an ethylene-propylene-rubber compound which meets the requirements given in Part 3. 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 that table.

7.6.4 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 7.6-2, and the minimum thickness at any point shall be not less than 80 percent of the values given in this 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.

Table 7.6-2

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

7.6.5 Concentric Conductor. The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B 5 and the resistivity, tensile, and elongation requirements of ASTM B 3 for uncoated wires, ASTM B 33 for tin coated wires or ASTM B 189 for lead-alloy-coated wires. The number of wires of a specified size shall be not less than that given in Table 7.6-3 for cables used in single phase systems and in either Table 7.6-5 or Table 7.6-6 for three phase system.

The nominal diameters and circular mil areas of the wires in Tables 7.6-3, 7.6-5 and 7.6-6 shall be as follows:

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

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▲ Revised 5-12-1982.

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

1. For single phase systems, at least 98% of the product of the appropriate number of wires given in table 7.6-3 times the appropriate nominal circular mil area tabulated above.

2. For three phase systems at least 98% of the product of the appropriate number of wires given in Tables 7.6-5 or 7.6-6 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 conducting material given in 7.6.4 with a lay not less than six nor more than ten times the diameter over the concentric wires.

7.6.6 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.6. The partial-discharge extinction level shall be in accordance with Table 7.6-4. The electrical requirement tests shall be made without immersion in water.

Table 7.6-3

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 7.6-4

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

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Table 7.6-5
Copper Central Conductor

Copper Insulated Conductor Size, AWG or kcmil	Minimum Number of Concentric 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.

Table 7.6-6
Aluminum Central Conductor

Aluminum Insulated Conductor Size, AWG or kcmil	Minimum Number of Concentric 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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7.7 Concentric-neutral Underground Distribution Cables ▲

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7.8 Metal-clad Cables with Grounding Conductor

7.8.1 Scope. This section covers two-, three- and four-conductor ethylene-propylene-rubber-insulated interlocked armored metal-clad cables with a grounding conductor. Power conductors shall be size 14 AWG through 1000 MCM if of copper, and size 12 AWG through 1000 MCM 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 Part 2. The grounding conductor shall be cabled with the insulated power conductors in one or more sections.

7.8.2.1 Cables Rated 0-2000 Volts. The minimum size of the grounding conductor shall be as given in Table 7.8-1.

▲ 7.8.2.2 Cables Rated 2001 Volts and Above. **The minimum size of the grounding conductor shall be in accordance with Table 7.8-2.**

7.8.3 Conductor Shielding. Conductor shielding shall be used on conductors having rated circuit voltages above 2000 volts.

Table 7.8-1
Grounding Conductor Size for
Cables Rated 0-2000 Volts

Power Conductor Size, AWG or MCM		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

7.8.4 Insulation. The insulation shall meet the requirements given in Part 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 Part 5 and shall be based on the calculated diameter of the individual power conductor. A suitable binder shall be applied over the assembly.

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

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

Table 7.8-2 ●
Grounding Conductor Size for Cables Rated 2001 Volts and Above

Power Conductor Size, AWG or MCM		Minimum Grounding Conductor Size, AWG	
Copper	Aluminum	Copper	Aluminum
8	8	10	8
6	6-4	8	6
4-1	2-2/0	6	4
1/0- 300 MCM	3/0- 400 MCM	3	1
350- 600 MCM	500- 800 MCM	1	2/0
650-1000 MCM	900-1000 MCM	1/0	3/0

▲ Revised 1-17-1980.
● Added 1-17-1980.

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7.9 Nonshielded Single-conductor Power Cable

7.9.1 Scope. This section covers nonshielded single-conductor power cable with ethylene-propylene-rubber 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 K):

(a) Single Conductors

(1) Unspliced cables in random lay in grounded metal conduit indoors above grade in dry locations.

(2) Mounted on insulators in free air.

(b) Triplexed Single Conductors (Factory Assembled)—In conduit or cable trays indoors above grade in dry locations.

(c) 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. *

7.9.2 Conductors. The conductors shall be copper or aluminum in accordance with Part 2. The conductor sizes shall be as given in Table 7.9-1.

7.9.3 Insulation. The insulation shall meet the requirements given in Part 3. The average thickness of the insulation shall be not less than 90 mils (2.29 mm) and the minimum thickness shall be not less than 81 mils (2.06 mm).

7.9.4 Jacket. A jacket which meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyl chloride, 4.4.7 nitrile butadiene/polyvinyl chloride or 4.4.9 chlorosulfonated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.9-1, and the minimum thickness shall be not less than 80 percent of this value.

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

7.9.6 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.9, except as otherwise specified in 7.9.6.1 and 7.9.6.2.

7.9.6.1 Electrical Requirements. Each insulated and jacketed conductor in the completed cable shall be tested in accordance with 6.27 and 6.28 and shall meet the following requirements.

7.9.6.1.1 Alternating-current Voltage Test (See 6.27.2). The conductor shall withstand an alternating-current test voltage of 13 kV, except that the direct-current voltage test may be substituted.

7.9.6.1.2 Insulation Resistance (See 6.28). The conductor shall have an insulation resistance not less than that corresponding to a constant of 12 000 at 15.6°C (60°F).

7.9.6.1.3 Direct-current Voltage Test (See 6.27.3). Upon completion of the insulation resistance test, each conductor shall withstand a direct-current test voltage of 35 kV, unless the alternating-current voltage test is performed.

7.9.6.2 Tests for Discharge Resistance. The samples shall be taken in accordance with 6.23.1.

7.9.6.2.1 Surface Resistivity. The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 200 000 megohms.

7.9.6.2.2 U-bend Discharge. The sample shall be tested in accordance with 6.23.3 with an alternating-current potential of 13 kV. There shall be no voltage breakdown or surface cracking.

Table 7.9-1

Conductor Size, AWG or MCM	Jacket Thickness mils	mm
8-6	30	0.76
4-2/0	45	1.14
3/0-1000	65	1.65

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7.10 Nonshielded Single-conductor Cables for Series-lighting Circuits

7.10.1 Scope. This section covers nonshielded single-conductor cable with ethylene-propylene rubber insulation intended for use in series lighting circuits, as follows:

(a) Nonjacketed—0 to 2000 volts
(b) Jacketed —0 to 5000 volts

7.10.2 Conductors. The conductors shall be copper in accordance with Part 2 and of the sizes given in Table 7.10-1 or 7.10-2.

7.10.3 Insulation

7.10.3.1 Nonjacketed Cable. The insulation for nonjacketed cable shall meet the requirements of 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-1, and the minimum thickness at any point shall be not less than 90 percent of this value.

7.10.3.2 Jacketed Cable. The insulation for jacketed cables shall meet the requirements of 3.6 or 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-2, and the minimum thickness at any point shall be not less than 90 percent of this value.

7.10.4 Jacket. For jacketed cables, a jacket which meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyl chloride, 4.4.7 nitrile butadiene/-polyvinyl chloride or 4.4.9 chlorosulfonated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.10-2, and the minimum thickness shall be not less than 80 percent of this value.

7.10.5 Tests. The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.10, except as otherwise specified in 7.10.5.1 through 7.10.5.3.

7.10.5.1 Voltage Tests (See 6.27). The completed cable shall be tested in accordance with the following paragraphs at the test voltages specified in Table 7.10-1 or 7.10-2:

0 to 2000 volts—6.27.2 or 6.27.3 or 6.27.4
2001 to 5000 volts—6.27.2 or 6.27.3

7.10.5.2 Insulation Resistance (See 6.28). The completed cable shall have an insulation resistance not less than that corresponding to the following at 15.6°C (60°F).

Circuit Voltage, Volts	Insulation Resistance Constant	
	Nonjacketed	Jacketed
0-2000	10 000	6 000
2001-5000	....	12 000

7.10.5.3 Tests for Discharge Resistance. These tests shall be made on cable rated 2001 volts and higher; and the samples shall be taken in accordance with 6.23.1.

7.10.5.3.1 Surface Resistivity. The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 200 000 megohms.

7.10.5.3.2 U-bend Discharge. The sample shall be tested in accordance with 6.23.3 with an alternating-current potential of 13 kV. There shall be no voltage breakdown or surface cracking.

Table 7.10-1
Nonjacketed Cable

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

* 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.

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Table 7.10-2
Jacketed Cable

Circuit Voltage, Volts *	Conductor Size, AWG	Insulation Thickness †		Jacket Thickness		Test Voltage, kV		d-c Spark Test Voltage, kV
		mils	mm	mils	mm	a-c	d-c	
0-1000	12-4	45	1.14	30	0.76	5.0	15.0	16.0
1001-2000	8-4	60	1.52	30	0.76	7.5	22.5	22.5
2001-5000	8-6	90	2.29	30	0.76	13.0	35.0	...
	4	90	2.29	45	1.14	13.0	35.0	...

The following tabulation of series lighting transformer ratings is representative of those in current 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

* 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.

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Part 8 *
APPENDICES

APPENDIX A
ABBREVIATIONS AND SYMBOLS

a-c – alternating-current (adjective)
AWG – American wire gauge
BWG – Birmingham wire gauge
C – Celsius (centigrade)
CM – circular mils
d-c – direct-current (adjective)
F – Fahrenheit
Hz – hertz (electrical frequency in cycles per second)
kg – kilogram(s)
kgf – kilogram force
km – kilometer(s)
kV – kilovolt(s)
MCM – thousands of circular mils
mm – millimeter(s)
psi – pounds per square inch
% – percent
± – plus and minus

APPENDIX B
REPRESENTATIVE TENSILE STRENGTH AND ELONGATION OF NONMAGNETIC METALS

Metal	Tensile Strength		Elongation 2-inch (50.8 mm) Length, Percent
	psi	kgf/mm^2	
Aluminum	13 000 - 45 000	9.14 - 31.6	15 - 45
Ambrac	50 000 - 70 000	35.2 - 49.2	20 - 40
Low Brass	40 000 - 50 000	28.1 - 35.2	40 - 50
Commercial Bronze	35 000 - 42 000	24.6 - 29.5	40
Copper	35 000 - 50 000	24.6 - 35.2	1 - 35
Monel	75 000	52.7	45
Stainless Steel	82 000 - 90 000	57.7 - 63.3	50
Zinc	20 000	14.1	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.

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APPENDIX D
EMERGENCY OVERLOADS

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

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

APPENDIX E
AMPACITIES FOR PREASSEMBLED AERIAL CABLES

For ampacities, see AIEE-IPCEA Power Cable Ampacities, IEEE Publication No. S-135, 1962, Vol. 1 for Copper Conductors or Vol. 2 for Aluminum Conductors, pages 258 through 261.

APPENDIX F ▲

Ampacities for Three-conductor Mine Power Cables
2 001 to 15 000 Volts Copper and Aluminum

Conductor Size, AWG or MCM		Ampacities*			
		2 001 to 8 000 Volts		8 001 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

▲ Revised 9-20-1978.

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APPENDIX G
AMPACITIES AND VOLTAGE RATINGS OF PORTABLE CABLES

G1.1 Ampacities. The recommended ampacities for portable cables are given in Table G-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

G1.2 Voltage Ratings. It is recommended that the various types of portable cables be limited to the following maximum circuit voltages:

2 000 Volts
- Single-conductor nonshielded
- Types W and G, two conductor flat and round
- Type W, three, four, five, and six conductor round
- Type G three conductor flat
- Type G four and five conductor round
- Type G-GC three conductor flat and round
- Type PG two and three conductor
- Type PCG two and three conductor
- Type SHC-GC three conductor

5 000 Volts
- Type G * three conductor round

25 000 Volts
- Type SH single conductor
- Type SHD and SHD-GC

*Shielded cables provide a higher level of safety at ratings over 2 000 volts.

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

Power Conductor Size, AWG or MCM	Single Conductor 0-2 000 Volts Unshielded	Single Conductor 2 001-8 000 Volts* Shielded	Single Conductor 8 001-15 000 Volts* Shielded	Single Conductor 15 001-25 000 Volts* Shielded	Two Conductor Round and Flat 0-2 000 Volts	Three Conductor Round and Flat 0-5 000 Volts Nonshielded	Three Conductor Round 0-8 000 Volts Shielded	Three Conductor Round 8 001-15 000 Volts Shielded	Three Conductor Round 15 001-25 000 Volts Shielded	Four Conductor 0-2 000 Volts	Five Conductor 0-2 000 Volts	Six Conductor 0-2 000 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	1 010	998	...	...	...	...	...	...	...	...	...	...
1 000	1 076	1 061	...	...	...	...	...	...	...	...	...	...

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

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

APPENDIX H
FLEXIBLE CORDS AND REMOTE CONTROL AND DRILL CORDS

H1.1 Ampacities of Flexible Cords. Ampacities of flexible cords are based on the number of current-carrying conductors. The ampacities shown below are based on an ambient temperature of 30°C.

Conductor Size, AWG	Number of Current-carrying Conductors in Cord		
	2	3	4
18	10	7	6
16	13	10	8
14	18	15	12
12	25	20	16
10	30	25	20

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

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

H2.1 National Electrical Code Type Designations and Maximum Voltage Ratings of Multiple-conductor Flexible Cords.

Conductor Size, AWG	Insulation Thickness		Jacket Thickness, 2, 3 and 4 Conductors		NEC Type Designations*		Maximum Voltage Ratings, Volts
	mils	mm	mils	mm			
18	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
18	30	0.76	60	1.53	S, ST	SO, STO	600
16	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
16	30	0.76	60	1.53	S, ST	SO, STO	600
14	45	1.14	80	2.04	S, ST	SO, STO	600
14	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
12	45	1.14	95	2.42	S, ST	SO, STO	600
10	45	1.14	95	2.42	S, ST	SO, STO	600

* S and SO designate extra hard service cords. SJ and SJO designate hard service cords. T designates a thermoplastic (polyvinyl chloride) jacket. O designates an oil-resistant jacket. ▲

▲ Revised 7-12-1978.

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H3.1 Remote Control and Drill Cords. Remote control and drill cords intended for use in underground mines in accordance with Schedule 2G of the U.S. Bureau of Mines comply with the constructions given in 7.4 in sizes 14 to 10 AWG, except for the jackets and number of conductors. The jackets shall be applied in two layers with a reinforcement between them and are approximately 50 mils (1.27 mm) thicker than those shown in Table 7.4-6. The cords shall comply with the flame resistance requirements of Schedule 2G. The outside diameters shall be in accordance with the following table:

Conductor Size, AWG	Number of Conductors	Outside Diameter Nominal inches	Outside Diameter Nominal mm	Outside Diameter Tolerances, Plus and Minus
14	2	0.64	16.3	0.02
	3	0.67	17.0	0.02
	4	0.71	18.0	0.02
	5	0.78	19.8	0.03
	6	0.83	21.1	0.03
	7	0.89	22.6	0.03
12	2	0.68	17.3	0.02
	3	0.72	18.3	0.03
	4	0.76	19.3	0.03
	5	0.83	21.1	0.03
	6	0.89	22.6	0.03
	7	0.98	24.9	0.03
10	2	0.73	18.5	0.03
	3	0.80	20.3	0.03
	4	0.84	21.3	0.03
	5	0.90	22.8	0.03
	6	1.00	25.4	0.03
	7	1.07	27.2	0.03

(Continued)

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APPENDIX I

AMPACITIES FOR TWO-CONDUCTOR CONCENTRIC-NEUTRAL SINGLE-PHASE PRIMARY UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES (SEE 7.6)

Conductor Size, AWG or MCM	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," IPCEA 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 J

AMPACITIES FOR THREE-PHASE UNDERGROUND DISTRIBUTION CABLES (SEE 7.7)

For ampacities see the IPCEA-NEMA Standards Publication Ampacities Including Effect of Shield Losses for Single-conductor Solid-dielectric Power Cable 15 kV through 35 kV, IPCEA P-53-426, NEMA WC 50-1972.

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APPENDIX K
SHIELDING

K1. Definition of Shielding

K1.1 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 conductor and insulation shields.

K2. Functions of Shielding

K2.1 A conductor shield 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.

K2.2 An insulation shield has a number of functions.

(a) To confine the dielectric field within the cable.
(b) 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.
(c) To protect cable connected to overhead lines or otherwise subject to induced potentials.
(d) To limit radio interference.
(e) 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.

K3. Use of Insulation Shielding

K3.1 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.

K3.2 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.

K3.3 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.

K3.4 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.

K4. Grounding of the Insulation Shield

K4.1 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.

K4.2 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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K5. Shield Materials

K5.1 Two distinct types of materials are employed in constructing cable shields.

K5.1.1 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.

K5.1.2 Metallic shields should be nonmagnetic and may consist of tape, braid, concentric serving of wires, or a sheath.

K6. Splices and Terminations

K6.1 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.

K6.2 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 L
MINIMUM BENDING RADIUS FOR CABLES

L1.1 Scope. This appendix contains the minimum values for the radius to which ethylene-propylene-rubber-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 bends are required for such conditions. In all cases the minimum radius specified refers to the inner surface of the cable and not to axis of the cable. For the drum diameter of reels, see Appendix M.

L2.1 Power Cables Without Metallic Shielding or Armor. The minimum bending radius for both single- and multiple-conductor cable with or without lead sheath and without metallic shielding or armor is as shown in Table L-1.

L3.1 Power Cables With Metallic Shielding or Armor

L3.1.1 Interlocked Armored Cables. The minimum bending radius for interlocked armored cables except tape shielded cables is in accordance with Table L-1 but not less than seven times the overall diameter of the cable. For tape shielded cable, see L3.1.3.1.

L3.1.2 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 the cable.

L3.1.3 Shielded Cables

L3.1.3.1 Tape Shielded Cables. The minimum bending radius for all cables with metallic shielding tapes is twelve times the overall diameter of the completed cable.

L3.1.3.2 Wire Shielded Cables. The minimum bending radius for all cables with wire shielding, except portable cables and armored cables, is given in L2.1. For portable cables, see L4.1. For armored cables, see L3.1.1 and L3.1.2.

L4.1 Portable Cables. The minimum bending radius for portable cables during installation and handling in service is six times the cable diameter for cables rated 5 000 volts and less and eight times the cable diameter for cables rated over 5 000 volts. For flat twin cables, the minor diameter is used to determine the bending radius.

Table L-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 Bending 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	

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APPENDIX M
MINIMUM DRUM DIAMETERS OF REELS *

*Excerpted from IPCEA-NEMA Standards Publication for Drum Diameters of Reels for Wires and Cables, IPCEA Pub. No. A-9-428 (Second Edition), NEMA Pub. No. WC 6-1975.

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

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APPENDIX N
ASTM STANDARDS

Throughout this publication, references to ASTM publications refer to the following editions of publications of the American Society for Testing and Materials. Copies of these publications are available directly from the Society at 1916 Race Street, Philadelphia, Pa. 19103.

Publication No. and Year	Title
A 90-69 (1978)	Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, Tests for
B 1-70 (1976)	Hard-Drawn Copper Wire, Specification for
B 2-70 (1976)	Medium-Hard-Drawn Copper Wire, Specification for
B 3-74	Soft or Annealed Copper Wire, Specification for
B 5-78	Tough-Pitch Electrolytic Copper Refinery Shapes, Specification for
B 8-77	Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Specification for
B 29-79	Pig Lead, Specification for
B 33-74	Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for
B 172-71 (1976)	Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, Specification for
B 173-71 (1976)	Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors, Specification for
B 174-71 (1976)	Bunch-Stranded Copper Conductors for Electrical Conductors, Specification for
B 189-74	Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes, Specification for
B 193-78	Resistivity of Electrical Conductors, Test for
B 228-71 (1977)	Concentric-Lay-Stranded Copper-Clad Steel Conductors, Specification for
B 229-71 (1977)	Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors, Specification for
B 230-77	Aluminum-Alloy 1350-H19 Wire, for Electrical Purposes, Specification for
B 231-78	Concentric-Lay-Stranded Aluminum-Alloy 1350 Conductors, Specification for
B 233-78	Aluminum-Alloy 1350 Redraw Rod for Electrical Purposes, Specification for
B 246-64 (1975)	Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes, Specification for
B 263-58 (1976)	Cross-Sectional Area of Stranded Conductors, Determination of
B 399-78	Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors, Specification for
B 400-77	Compact-Round Concentric-Lay-Stranded 1350 Aluminum-Alloy Conductors, Specification for
B 416-69 (1976)	Concentric-Lay-Stranded Aluminum-Clad Steel Conductors, Specification for
B 496-74a (1979)	Compact Round Concentric-Lay-Stranded Copper Conductors, Specification for
B 549-71 (1977)	Concentric-Lay-Stranded Aluminum Conductors, Aluminum-Clad Steel Reinforced (ACSR/AW), Specification for
B 557-79	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
B 609-78	Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes, Specification for
D 257-78	D-C Resistance or Conductance of Insulating Materials, Test for
D 412-75	Rubber Properties in Tension, Test 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 1248-72	Polyethylene Plastics Molding and Extrusion Materials, Specification for
D 1693-70 (1975)	Environmental Stress-Cracking of Ethylene Plastics, Test for
D 3349-74	Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic, Test for
E 8-79	Tension Testing of Metallic Materials, Method of

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APPENDIX O

Additional Conductor Information

Table O-1

Solid Aluminum and Copper Conductors

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

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Table O-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 O-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 O-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 O-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 O-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 O-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 O-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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