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Varnished-Cloth-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037
INSULATED CABLE ENGINEERS ASSOCIATION ■ PO BOX P, SOUTH YARMOUTH, MA 02664

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NEMA Standards Publication No. WC 4-1988 (R1993)

VARNISHED-CLOTH-INSULATED WIRE AND CABLE FOR THE TRANSMISSIC AND DISTRIBUTION OF ELECTRICAL ENERGY

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Foreword

This Standards Publication for *Varnished-cloth-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy* [ICEA S-65-375 (Third Edition), NEMA WC 4-1988] 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 users in selecting and obtaining the proper product for their particular needs. 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 sumitted in writing to the Insulated Cable Engineers Association, P.O. Box P, South Yarmouth, MA 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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VARNISHED-CLOTH-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Part 1
GENERAL

1.1 SCOPE

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

Insulation thicknesses, formerly designated in terms of grounded and ungrounded neutral, are now designated in terms of cable insulation levels (see 3.2).

In classifying varnished-tape insulation in these standards, the term "varnished tape" when used alone without further description shall mean either varnished cotton cloth or varnished polyester-glass cloth.

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

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

1.2 GENERAL INFORMATION

These standards cover the requirements for conductors, the various types of insulations and protective coverings and general construction and dimensional details common to most standard types of wires and cables. Where a conflict exists between the requirements of Part 7 and those of Parts 1 to 6, inclusive, the requirements of Part 7 shall apply.

1.3 INFORMATION TO BE SUPPLIED BY PURCHASER

When requesting proposals from cable manufacturers, the prospective purchaser should furnish the following information. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

1.3.1 Characteristics of System on which Cable is to be Used

a. Current—alternating or direct.
b. Frequency—hertz (cycles per second).
c. Normal operating voltage between phases or, if direct current, between conductors.
d. Number of phases and conductors.
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. Description 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.

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 conductors—copper or aluminum.
e. Size of conductors—AWG or circular mils. If other than standard stranding, a complete description should be given.
f. Type of insulation.
g. Thickness of insulation in mils.
   1. On each conductor.
   2. Of belt.
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. Whether or not tests on samples of completed cable are required (see Part 6).

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Part 2
CONDUCTORS

2.1 MATERIAL

Conductors shall be annealed uncoated copper, or annealed coated copper, or aluminum.

2.1.1 Copper Conductors

Uncoated conductors shall be of annealed copper wire in accordance with ASTM B 3.

Coated conductors shall be of annealed copper wire in accordance with ASTM B 33 for tin-coated conductors or ASTM B 189 for lead- or lead-alloy coated conductors.

Compact round stranded conductors shall conform to ASTM B 496.

Annular conductors shall conform to ASTM B 226.

All other concentric stranded conductors shall conform to ASTM B 8.

Compact segmental conductors shall conform to Table 2-5.

2.1.2 Aluminum Conductors

Conductors shall be alloy 1350 aluminum.

The tensile strength of solid conductors shall be 12,000–20,000 psi (8.44–14.06 kgf/mm^2) except that for sizes 1/0 AWG and larger it shall be 9,000–20,000 psi (6.33–14.06 kgf/mm^2).

Stranded conductors shall be either hard-drawn in accordance with ASTM B 230 or three-quarter hard in accordance with ASTM B 609 or half hard in accordance with ASTM B 609. Concentric stranded conductors, except compact round and annular, shall conform to ASTM B 231.

Compact round stranded conductors shall conform to ASTM B 400. Annular conductors shall conform to Table 2-4.

Compact segmental conductors shall conform to Table 2-5.

2.2 SOLID CONDUCTORS

Conductors 8 AWG and smaller shall be solid or, when required for a particular application, stranded. Nominal diameters shall be in accordance with Table 2-1.

2.3 STRANDED CONDUCTORS

2.3.1 Conductors 6 AWG and larger shall be stranded or, when required for a particular application, solid.

Stranded conductors shall be composed of the number of wires given in Tables 2-2 through 2-6. Intermediate sizes take the stranding of the next larger conductor size given in the tables.

2.3.2 Uses of Classes of Stranding

2.3.2.1 CONCENTRIC-LAY CONDUCTORS

Class of Stranding*	Use
B	Power cables
C	Power cables where more flexible stranding than Class B is desired
D	Power cables where extra flexible stranding is desired

* See Tables 2-2 and 2-3.

2.3.2.2 COMPACT ROUND CONDUCTORS

Compact round conductors are intended for use in power cables where a reduced diameter is required.

2.3.2.3 ANNULAR CONDUCTORS

Annular or rope-core conductors are intended for use in power cables where reduced ac losses are required.

2.3.2.4 COMPACT SEGMENTAL CONDUCTORS

Compact segmental conductors are intended for use in power cables where a reduced diameter and reduced ac losses are required and shall consist of three or four compacted segments insulated from each other and assembled with a binder.

2.4 TOLERANCES IN DIAMETER AND CROSS-SECTIONAL AREAS

The following tolerances apply to determinations made on conductors of the completed cable.

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2.4.1 Diameters

Solid Conductors	Diameter		Maximum Variation in Diameter
	mils	mm	
Copper, coated	10 and larger	0.254 and larger	–1%, +3%
	Smaller than 10	Smaller than 0.254	–0.1 mils, +0.3 mil
Copper, uncoated	10 and larger	0.254 and larger	–1%, +1%
	Smaller than 10	Smaller than 0.254	–0.1 mils, +0.1 mil
Aluminum	100 and larger	2.54 and larger	–1%, +1%
	36 up to 100	0.91 up to 2.54	–1 mils, +1 mil
	Smaller than 36	Smaller than 0.91	–0.5 mils, +0.5 mil

2.4.2 Cross-sectional Areas

2.4.2.1 In stranded conductors, the area of cross-section of the completed conductor shall be not less than 98 percent of the area given in Tables 2-2 and 2-3.

2.4.2.2 The cross-sectional area of a stranded conductor shall be the sum of the area of its component wires at any point.

2.5 SEPARATOR

When a separator is applied over the uninsulated conductor or conductors to prevent injury to the varnished tape by contact with the conductor strands, such a separator shall be of a suitable material and shall not be considered part of the insulation wall.

2.6 RESISTANCE OF CONDUCTORS

2.6.1 The dc resistance of Classes C and D stranded coated conductors shall not exceed by more than 2 percent the value calculated from the factors given in Table 2-11.

The dc resistance of all other conductors shall not exceed by more than 2 percent the values given in Tables 2-4, 2-5, and 2-7 through 2-10.

2.6.2 In completed multiple-conductor cables, the increase in resistance due to conductor cabling lay shall not exceed the values given in 2.6.1 by more than the following percentages.

a. One layer of conductors 2
b. More than one layer of conductors 3
c. Pairs or other pre-cabled units 4

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Table 2-1
Solid Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Cross-sectional Area		Nominal Diameter		Approximate Weight*			
					Aluminum		Copper	
	CM	mm^2	mils	mm	Pounds per 1000 feet	kg/km	Pounds per 1000 feet	kg/km
22	640	0.324	25.3	0.643	...	...	1.94	2.88
20	1020	0.519	32.0	0.813	0.942	1.40	3.10	4.61
19	1290	0.653	35.9	0.912	1.19	1.77	3.90	5.81
18	1620	0.823	40.3	1.02	1.49	2.22	4.92	7.32
17	2050	1.04	45.3	1.15	1.89	2.81	6.21	9.24
16	2580	1.31	50.8	1.29	2.38	3.53	7.81	11.6
15	3260	1.65	57.1	1.45	3.00	4.47	9.87	14.7
14	4110	2.08	64.1	1.63	3.78	5.63	12.4	18.5
13	5180	2.63	72.0	1.83	4.77	7.10	15.7	23.4
12	6530	3.31	80.8	2.05	6.01	8.94	19.8	29.4
11	8230	4.17	90.7	2.30	7.57	11.3	24.9	37.1
10	10380	5.261	101.9	2.588	9.56	14.22	31.43	46.77
9	13090	6.631	114.4	2.906	12.04	17.92	39.62	58.95
8	16510	8.367	128.5	3.264	15.20	22.62	49.98	74.38
7	20820	10.55	144.3	3.665	19.16	28.52	63.03	93.80
6	26240	13.30	162.0†	4.115	24.15	35.94	79.44	118.2
5	33090	16.77	181.9†	4.620	30.45	45.32	100.2	149.0
4	41740	21.15	204.3†	5.189	38.41	57.17	126.3	188.0
3	52620	26.67	229.4†	5.827	48.43	72.08	159.3	237.1
2	66360	33.62	257.6†	6.543	61.07	90.89	200.9	298.9
1	83690	42.41	289.3†	7.348	77.03	114.6	253.3	377.0
1/0	105600	53.49	324.9†	8.252	97.15	144.6	319.5	475.5
2/0	133100	67.43	364.8†	9.266	122.5	182.3	402.8	599.5
3/0	167800	85.01	409.6†	10.40	154.4	229.8	507.8	755.8
4/0	211600	107.2	460.0†	11.68	194.7	289.8	640.5	953.2
250	...	127	500.0†	12.70	230.1	342.4	...	...
300	...	152	547.7†	13.91	276.1	410.9	...	...
350	...	177	591.6†	15.03	322.1	479.4	...	...
400	...	203	632.5†	16.07	368.2	547.9	...	...
450	...	228	670.8†	17.04	414.4	616.3	...	...
500	...	253	707.1†	17.96	460.2	684.8	...	...

The data on aluminum conductors smaller than 12 AWG and copper conductors smaller than 14 AWG are given as information only. Such conductors are not considered suitable for use in power and control cables where mechanical stresses govern.

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†See 2.3.

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

Conductor Size, AWG or kcmil	Cross-sectional Area		Class B								
			Number of Wires	Nominal Diameter of Each Wire		Approximate Outside Diameter*		Approximate Weight*			
								Aluminum		Copper	
	CM	mm^2		mils	mm	inches	mm	Lbs. per 1000 ft.	kg/km	Lbs. per 1000 ft.	kg/km
22	640	0.324	7	9.6	0.244	0.029	0.737	...	...	1.975	2.941
20	1020	0.519	7	12.1	0.307	0.036	0.914	...	...	3.154	4.705
19	1290	0.653	7	13.6	0.345	0.041	1.04	...	...	3.974	5.922
18	1620	0.823	7	15.2	0.386	0.046	1.17	...	...	5.015	7.462
17	2050	1.04	7	17.2	0.437	0.052	1.32	...	...	6.324	9.429
16	2580	1.31	7	19.2	0.488	0.058	1.47	...	...	7.974	11.86
15	3260	1.65	7	21.6	0.549	0.065	1.65	...	...	9.959	14.98
14	4110	2.08	7	24.2	0.615	0.073	1.85	...	...	12.68	18.88
13	5180	2.63	7	27.2	0.691	0.082	2.08	...	...	16.01	23.82
12	6530	3.31	7	30.5	0.775	0.092	2.34	6.13	9.12	20.16	30.00
11	8230	4.17	7	34.3	0.871	0.103	2.62	7.72	11.5	25.49	37.80
10	10380	5.261	7	38.5	0.978	0.116	2.95	9.75	14.5	32.06	47.71
9	13090	6.631	7	43.2	1.10	0.130	3.30	12.3	18.3	40.42	60.14
8	16510	8.367	7	48.6	1.23	0.146	3.70	15.5	23.1	51.0	75.9
7	20820	10.55	7	54.5	1.39	0.164	4.16	19.5	29.1	64.2	95.7
6	26240	13.30	7	61.2	1.56	0.184	4.67	24.6	36.7	80.9	121
5	33090	16.77	7	68.8	1.75	0.206	5.24	31.1	46.2	102	152
4	41740	21.15	7	77.2	1.96	0.232	5.88	39.2	58.3	129	192
3	52620	26.67	7	86.7	2.20	0.260	6.61	49.4	73.5	162	242
2	66360	33.62	7	97.4	2.47	0.292	7.42	62.3	92.7	205	305
1	83690	42.41	19	66.4	1.69	0.332	8.43	78.6	117	259	385
1/0	105600	53.49	19	74.5	1.89	0.373	9.46	99.1	147	326	485
2/0	133100	67.43	19	83.7	2.13	0.418	10.6	125	186	411	611
3/0	167800	85.01	19	94.0	2.39	0.470	11.9	157	234	518	771
4/0	211600	107.2	19	105.5	2.68	0.528	13.4	199	296	653	972
250	...	127	37	82.2	2.09	0.575	14.6	235	349	772	1150
300	...	152	37	90.0	2.29	0.630	16.0	282	419	925	1380
350	...	177	37	97.3	2.47	0.681	17.3	329	489	1080	1610
400	...	203	37	104.0	2.64	0.728	18.5	376	559	1236	1840
450	...	228	37	110.3	2.80	0.772	19.6	422	629	1390	2070
500	...	253	37	116.2	2.95	0.813	20.7	469	699	1542	2300
550	...	279	61	95.0	2.41	0.855	21.7	517	768	1700	2530
600	...	304	61	99.2	2.52	0.893	22.7	563	838	1850	2760
650	...	329	61	103.2	2.62	0.929	23.6	610	908	2006	2990
700	...	355	61	107.1	2.72	0.964	24.5	657	978	2160	3220
750	...	380	61	110.9	2.82	0.998	25.3	704	1050	2316	3450
800	...	405	61	114.5	2.91	1.031	26.2	751	1120	2469	3680
900	...	456	61	121.5	3.09	1.094	27.8	845	1260	2780	4140
1000	...	507	61	128.0	3.25	1.152	29.3	939	1400	3086	4590
1100	...	557	91	109.9	2.79	1.209	30.7	1032	1540	3394	5050
1200	...	608	91	114.8	2.92	1.263	32.1	1126	1680	3703	5510
1250	...	633	91	117.2	2.98	1.289	32.7	1173	1750	3859	5740
1300	...	659	91	119.5	3.04	1.315	33.4	1220	1820	4012	5970
1400	...	709	91	124.0	3.15	1.364	34.7	1313	1960	4320	6430
1500	...	760	91	128.4	3.26	1.412	35.9	1408	2100	4632	6890
1600	...	811	127	112.2	2.85	1.459	37.1	1501	2240	4936	7350
1700	...	861	127	115.7	2.94	1.504	38.2	1596	2370	5249	7810
1750	...	887	127	117.4	2.98	1.526	38.8	1643	2440	5403	8040
1800	...	912	127	119.1	3.02	1.548	39.3	1691	2510	5562	8270
1900	...	963	127	122.3	3.11	1.590	40.4	1783	2650	5865	8730
2000	...	1010	127	125.5	3.19	1.632	41.5	1877	2790	6176	9190

The data on aluminum conductors smaller than 12 AWG and copper conductors smaller than 14 AWG are given as information only. Such conductors are not considered suitable for use in power and control cables where mechanical stresses govern.

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Table 2-3
Concentric Stranded Class C and D Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Cross-sectional Areas		Class C			Class D		
			Number of Wires	Nominal Diameter of Each Wire		Number of Wires	Nominal Diameter of Each Wire	
	CM	mm^2		mils	mm		mils	mm
22	640	0.324	...	...	...	...	...	...
20	1020	0.519	...	...	...	...	...	...
19	1290	0.653	...	...	...	...	...	...
18	1620	0.823	...	...	...	...	...	...
17	2050	1.04	...	...	...	...	...	...
16	2580	1.31	...	...	...	...	...	...
15	3260	1.65	...	...	...	...	...	...
14	4110	2.08	19	14.7	0.373	37	10.5	0.267
13	5180	2.63	19	16.5	0.419	37	11.8	0.300
12	6530	3.31	19	18.5	0.470	37	13.3	0.338
11	8230	4.17	19	20.8	0.528	37	14.9	0.378
10	10380	5.261	19	23.4	0.594	37	16.7	0.424
9	13090	6.631	19	26.2	0.665	37	18.8	0.478
8	16510	8.367	19	29.5	0.749	37	21.1	0.536
7	20820	10.55	19	33.1	0.841	37	23.7	0.602
6	26240	13.30	19	37.2	0.945	37	26.6	0.676
5	33090	16.77	19	41.7	1.06	37	29.9	0.759
4	41740	21.15	19	46.9	1.19	37	33.6	0.853
3	52620	26.67	19	52.6	1.34	37	37.7	0.958
2	66360	33.62	19	59.1	1.50	37	42.4	1.08
1	83690	42.41	37	47.6	1.21	61	37.0	0.940
1/0	105600	53.49	37	53.4	1.36	61	41.6	1.06
2/0	133100	67.43	37	60.0	1.52	61	46.7	1.19
3/0	167800	85.01	37	67.3	1.71	61	52.4	1.33
4/0	211600	107.2	37	75.6	1.92	61	58.9	1.50
250	...	127	61	64.0	1.63	91	52.4	1.33
300	...	152	61	70.1	1.78	91	57.4	1.46
350	...	177	61	75.7	1.92	91	62.0	1.57
400	...	203	61	81.0	2.06	91	66.3	1.68
450	...	228	61	85.9	2.18	91	70.3	1.79
500	...	253	61	90.5	2.30	91	74.1	1.88
550	...	279	91	77.7	1.97	127	65.8	1.67
600	...	304	91	81.2	2.06	127	68.7	1.74
650	...	329	91	84.5	2.15	127	71.5	1.82
700	...	355	91	87.7	2.23	127	74.2	1.88
750	...	380	91	90.8	2.31	127	76.8	1.95
800	...	405	91	93.8	2.38	127	79.4	2.02
900	...	456	91	99.4	2.53	127	84.2	2.14
1000	...	507	91	104.8	2.66	127	88.7	2.25
1100	...	557	127	93.1	2.36	169	80.7	2.05
1200	...	608	127	97.2	2.47	169	84.3	2.14
1250	...	633	127	99.2	2.52	169	86.0	2.18
1300	...	659	127	101.2	2.57	169	87.7	2.23
1400	...	709	127	105.0	2.67	169	91.0	2.31
1500	...	760	127	108.7	2.76	169	94.2	2.39
1600	...	811	169	97.3	2.47	217	85.9	2.18
1700	...	861	169	100.3	2.55	217	88.5	2.25
1750	...	887	169	101.8	2.59	217	89.8	2.28
1800	...	912	169	103.2	2.62	217	91.1	2.31
1900	...	963	169	106.0	2.69	217	93.6	2.38
2000	...	1010	169	108.8	2.76	217	96.0	2.44

The data on aluminum conductors smaller than 12 AWG and copper conductors smaller than 14 AWG are given as information only. Such conductors are not considered suitable for use in power and control cables where mechanical stresses govern.

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Table 2-4
Annular Conductors

Nominal Conductor Size, kcmil	Cross-Sectional Area, mm^2	Nominal Rope Size		Nominal Diameter of Each Wire		Number of Strands in Each Layer				Actual Area, Circular mils	Maximum Outside Diameter*		DC Resistance ohms/1000 Ft. at 25°C	
		inches	mm	inches	mm	First	Second	Third	Total		inches	mm	Copper	Aluminum
750	380	0.375	9.525	0.1172	2.977	12	18	24	54	741,735	1.108	28.14	0.0147	0.0241
800	405	0.468	11.89	0.1110	2.819	16	21	28	65	800,865	1.164	29.57	0.0136	0.0223
900	456	0.500	12.70	0.1172	2.977	16	22	28	66	906,565	1.234	31.34	0.0120	0.0197
1000	507	0.563	14.30	0.1255	3.188	16	21	28	65	1,023,766	1.346	34.19	0.0106	0.0174
1250	633	0.750	19.05	0.1255	3.188	21	26	33	80	1,260,020	1.533	38.94	0.00864	0.0142
1500	760	1.000	25.40	0.1255	3.188	26	32	38	96	1,512,024	1.783	45.29	0.00720	0.0118
1750	887	1.125	28.58	0.1280	3.251	30	35	42	107	1,753,088	1.923	48.84	0.00621	0.0102
2000	1010	1.312	33.32	0.1284	3.261	34	40	46	120	1,978,387	2.114	53.70	0.00550	0.00902
2500	1267	1.500	38.10	0.1440	3.658	34	40	46	120	2,488,320	2.394	60.81	0.00438	0.00718
3000	1520	1.625	41.28	0.1620	4.115	33	38	45	116	3,044,304	2.627	66.73	0.00358	0.00587
3500	1774	2.000	50.80	0.1620	4.115	40	45	52	137	3,595,428	3.007	76.38	0.00306	0.00502
4000	2027	2.250	57.15	0.1620	4.115	45	51	57	153	4,015,332	3.262	82.85	0.00274	0.00449

*The following plus tolerances are included in the maximum outside diameters:

Nominal Conductor Size, kcmil	Plus Tolerance	
	inches	mm
750 to 3000, inclusive	0.030	0.762
3001 to 3500, inclusive	0.035	0.889
3501 to 4000, inclusive	0.040	1.016

Table 2-5
Segmental Conductors

Conductor Size, kcmil	Cross-sectional Area, mm^2	Number of Segments*						DC Resistance, ohms per 1000 Feet at 25°C	
		Four Segments			Three Segments				
		Number of Wires	Nominal Diameter over Binder Tape		Number of Wires	Nominal Diameter over Binder Tape			
			inches	mm		inches	mm	Copper	Aluminum
1000	507	148	1.152	29.26	111	1.170	29.72	0.0108	0.0177
1250	633	148	1.289	32.74	183	1.320	33.53	0.00867	0.0142
1500	760	148	1.412	35.87	183	1.430	36.32	0.00723	0.0119
1750	887	244	1.526	38.76	183	1.530	38.86	0.00619	0.0101
2000	1010	244	1.632	41.45	273	1.630	41.40	0.00542	0.00889
2250	1140	244	1.730	43.94	...	...	...	0.00482	0.00790
2500	1267	244	1.824	46.33	...	...	...	0.00434	0.00711
3000	1520	364	1.998	50.75	...	...	...	0.00361	0.00592
3500	1774	364	2.159	54.84	...	...	...	0.00310	0.00508
4000	2027	364	2.309	58.65	...	...	...	0.00271	0.00444

*The diameters of segmental conductors shall be measured over the binder tape.

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Table 2-6
Dimensions of Compact Round Stranded Conductors, Copper or Aluminum

Conductor Size, AWG or kcmil	Cross-sectional Area		Number of Wires	Overall Diameter	
	CM	mm^2		inches	mm
8	16510	8.367	7	0.134	3.40
6	26240	13.30	7	0.169	4.29
4	41740	21.15	7	0.213	5.41
2	66360	33.62	7	0.268	6.81
1	83690	42.41	19	0.299	7.59
1/0	105600	53.49	19	0.336	8.53
2/0	133100	67.43	19	0.376	9.55
3/0	167800	85.01	19	0.423	10.74
4/0	211600	107.2	19	0.475	12.07
250	...	127	37	0.520	13.21
300	...	152	37	0.570	14.48
350	...	177	37	0.616	15.65
400	...	203	37	0.659	16.74
450	...	228	37	0.700	17.78
500	...	253	37	0.736	18.69
550	...	279	61	0.775	19.69
600	...	304	61	0.813	20.65
650	...	329	61	0.845	21.46
700	...	355	61	0.877	22.28
750	...	380	61	0.908	23.06
800	...	405	61	0.938	23.83
900	...	456	61	0.999	25.37
1000	...	507	61	1.060	26.92

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Table 2-7
Nominal DC Resistance of Annealed Coated Copper Conductors (Solid)

Conductor Size, AWG	20°C		25°C	
	Copper		Copper	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
22	16.9	55.3	17.2	56.4
20	10.5	34.6	10.7	35.2
19	8.37	27.5	8.53	28.0
18	6.64	21.8	6.77	22.2
17	5.26	17.2	5.36	17.6
16	4.18	13.7	4.26	14.0
15	3.31	10.9	3.37	11.1
14	2.63	8.61	2.67	8.78
13	2.08	6.83	2.12	6.96
12	1.65	5.42	1.68	5.53
11	1.31	4.30	1.34	4.39
10	1.039	3.408	1.059	3.475
9	0.8156	2.676	0.8317	2.729
8	0.6465	2.121	0.6592	2.163
7	0.5126	1.682	0.5227	1.715
6	0.4067	1.334	0.4147	1.361
5	0.3226	1.058	0.3290	1.079
4	0.2557	0.8391	0.2608	0.8556
3	0.2028	0.6655	0.2068	0.6786
2	0.1609	0.5278	0.1640	0.5381
1	0.1275	0.4184	0.1300	0.4267
1/0	0.1006	0.3301	0.1026	0.3366
2/0	0.07980	0.2618	0.08137	0.2670
3/0	0.06330	0.2077	0.06454	0.2118
4/0	0.05019	0.1647	0.05117	0.1679

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Table 2-8
Nominal DC Resistance of Annealed Coated Copper Conductors, Class B and Compact Stranded

Conductor Size, AWG or kcmil	20°C		25°C	
	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
22	...	...	...	...
20	11.0	36.0	11.2	36.7
19	...	...	...	...
18	6.92	22.7	7.05	23.1
17	...	...	...	...
16	4.35	14.3	4.44	14.6
15	...	...	...	...
14	2.68	8.78	2.73	8.96
13	2.12	6.96	2.16	7.10
12	1.69	5.53	1.72	5.64
11	1.34	4.39	1.36	4.47
10	1.059	3.476	1.080	3.544
9	0.8406	2.758	0.8571	2.812
8	0.6662	2.186	0.6793	2.229
7	0.5283	1.733	0.5387	1.767
6	0.4192	1.375	0.4274	1.402
5	0.3325	1.091	0.3390	1.112
4	0.2636	0.8647	0.2688	0.8817
3	0.2090	0.6859	0.2132	0.6993
2	0.1658	0.5439	0.1690	0.5546
1	0.1314	0.4312	0.1340	0.4397
1/0	0.1042	0.3419	0.1063	0.3486
2/0	0.08267	0.2712	0.08429	0.2765
3/0	0.06557	0.2151	0.06686	0.2194
4/0	0.05145	0.1688	0.05247	0.1721
250	0.04400	0.1444	0.04487	0.1472
300	0.03667	0.1203	0.03739	0.1227
350	0.03143	0.1031	0.03205	0.1051
400	0.02722	0.08930	0.02775	0.09106
450	0.02419	0.07938	0.02467	0.08094
500	0.02178	0.07144	0.02220	0.07285
550	0.02000	0.06562	0.02039	0.06691
600	0.01834	0.06015	0.01870	0.06134
650	0.01675	0.05496	0.01708	0.05603
700	0.01555	0.05103	0.01586	0.05203
750	0.01452	0.04763	0.01480	0.04856
800	0.01361	0.04465	0.01388	0.04553
900	0.01210	0.03969	0.01234	0.04047
1000	0.01089	0.03572	0.01110	0.03642
1100	0.009898	0.03247	0.01009	0.03311
1200	0.009073	0.02977	0.009251	0.03035
1250	0.008710	0.02858	0.008881	0.02914
1300	0.008375	0.02748	0.008540	0.02802
1400	0.007777	0.02551	0.007930	0.02602
1500	0.007258	0.02381	0.007401	0.02428
1600	0.006805	0.02233	0.006939	0.02276
1700	0.006405	0.02101	0.006530	0.02143
1750	0.006222	0.02041	0.006344	0.02081
1800	0.006049	0.01984	0.006168	0.02023
1900	0.005730	0.01880	0.005843	0.01917
2000	0.005444	0.01786	0.005551	0.01821
2500	0.004398	0.01443	0.004484	0.01471
3000	0.003665	0.01202	0.003737	0.01226
3500	0.003172	0.01041	0.003234	0.01061
4000	0.002775	0.009105	0.002830	0.009284
4500	0.002491	0.008171	0.002540	0.008332
5000	0.002242	0.007354	0.002286	0.007499

NOTE—For resistance of conductors of multiple-conductor cables, see 2.6.2.

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Table 2-9
Nominal DC Resistance of Aluminum and Annealed Uncoated Copper Conductors (Solid)

Conductor Size, AWG or kcmil	20°C				25°C			
	Aluminum		Copper		Aluminum		Copper	
	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km
22	...	...	16.2	53.2	...	...	16.5	54.2
20	16.6	54.5	10.1	33.2	16.9	55.6	10.3	33.9
19	13.2	43.3	8.05	26.4	13.5	44.2	8.21	26.9
18	10.5	34.3	6.39	21.0	10.7	35.0	6.51	21.4
17	8.29	27.2	5.05	16.6	8.45	27.7	5.15	16.9
16	6.59	21.6	4.02	13.2	6.72	22.1	4.10	13.4
15	5.21	17.1	3.18	10.4	5.32	17.5	3.24	10.6
14	4.14	13.6	2.52	8.28	4.22	13.8	2.57	8.44
13	3.28	10.8	2.00	6.56	3.35	11.0	2.04	6.69
12	2.60	8.54	1.59	5.21	2.66	8.72	1.62	5.31
11	2.07	6.78	1.26	4.14	2.11	6.92	1.29	4.22
10	1.637	5.372	0.9988	3.277	1.670	5.480	1.018	3.341
9	1.299	4.262	0.7925	2.600	1.325	4.348	0.8080	2.651
8	1.030	3.378	0.6281	2.061	1.050	3.446	0.6404	2.101
7	0.8165	2.679	0.4981	1.634	0.8330	2.733	0.5079	1.666
6	0.6479	2.125	0.3952	1.297	0.6609	2.168	0.4029	1.322
5	0.5139	1.686	0.3134	1.028	0.5242	1.720	0.3196	1.049
4	0.4074	1.336	0.2485	0.8152	0.4156	1.363	0.2534	0.8312
3	0.3231	1.060	0.1971	0.6466	0.3296	1.081	0.2010	0.6593
2	0.2562	0.8406	0.1563	0.5128	0.2614	0.8575	0.1594	0.5228
1	0.2032	0.6665	0.1239	0.4065	0.2072	0.6799	0.1264	0.4145
1/0	0.1611	0.5284	0.09825	0.3223	0.1643	0.5391	0.1002	0.3287
2/0	0.1278	0.4191	0.07793	0.2557	0.1303	0.4276	0.07946	0.2607
3/0	0.1013	0.3325	0.06182	0.2028	0.1034	0.3392	0.06303	0.2068
4/0	0.08035	0.2636	0.04901	0.1608	0.08197	0.2689	0.04998	0.1640
250	0.06801	0.2231	...	...	0.06938	0.2276	...	...
300	0.05668	0.1859	...	...	0.05782	0.1897	...	...
350	0.04858	0.1594	...	...	0.04956	0.1626	...	...
400	0.04250	0.1394	...	...	0.04336	0.1422	...	...
450	0.03779	0.1240	...	...	0.03855	0.1265	...	...
500	0.03401	0.1116	...	...	0.03469	0.1138	...	...

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Table 2-10
Nominal DC Resistance of Aluminum and Annealed Uncoated Copper, Concentric and Compact Stranded Conductors

Conductor Size, AWG or kcmil	20°C				25°C			
	Aluminum		Copper		Aluminum		Copper	
	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km	ohms per 1000 ft.	ohms per km
22	...	...	...	...	...	...	...	...
20	...	...	10.3	33.9	...	...	10.5	34.6
19	...	...	...	...	...	...	...	...
18	...	...	6.51	21.4	...	...	6.64	21.8
17	...	...	...	...	...	...	...	...
16	...	...	4.10	13.4	...	...	4.18	13.7
15	...	...	...	...	...	...	...	...
14	...	...	2.57	8.45	...	...	2.63	8.61
13	...	...	2.04	6.69	...	...	2.08	6.83
12	2.66	8.71	1.62	5.32	2.71	8.89	1.65	5.42
11	2.11	6.92	1.29	4.22	2.15	7.06	1.31	4.30
10	1.670	5.479	1.019	3.342	1.704	5.590	1.039	3.408
9	1.325	4.347	0.8083	2.652	1.352	4.435	0.8242	2.704
8	1.050	3.446	0.6407	2.102	1.071	3.515	0.6532	2.143
7	0.8328	2.732	0.5080	1.667	0.8496	2.788	0.5180	1.700
6	0.6608	2.168	0.4031	1.322	0.6741	2.212	0.4110	1.348
5	0.5241	1.720	0.3197	1.049	0.5347	1.754	0.3260	1.070
4	0.4155	1.363	0.2534	0.8315	0.4239	1.391	0.2584	0.8479
3	0.3295	1.081	0.2010	0.6595	0.3362	1.103	0.2050	0.6725
2	0.2613	0.8574	0.1594	0.5230	0.2666	0.8747	0.1626	0.5333
1	0.2072	0.6798	0.1264	0.4147	0.2114	0.6935	0.1289	0.4228
1/0	0.1643	0.5390	0.1002	0.3288	0.1676	0.5499	0.1022	0.3352
2/0	0.1303	0.4275	0.07949	0.2608	0.1329	0.4362	0.08105	0.2659
3/0	0.1034	0.3391	0.06305	0.2069	0.1054	0.3460	0.06429	0.2109
4/0	0.08196	0.2689	0.04999	0.1640	0.08361	0.2743	0.05098	0.1672
250	0.06937	0.2276	0.04231	0.1388	0.07077	0.2322	0.04315	0.1416
300	0.05781	0.1897	0.03526	0.1157	0.05897	0.1935	0.03595	0.1180
350	0.04955	0.1626	0.03022	0.09916	0.05055	0.1658	0.03082	0.1011
400	0.04336	0.1422	0.02645	0.08677	0.04423	0.1451	0.02697	0.08847
450	0.03854	0.1264	0.02351	0.07713	0.03931	0.1290	0.02397	0.07864
500	0.03468	0.1138	0.02116	0.06941	0.03538	0.1161	0.02157	0.07078
550	0.03153	0.1034	0.01962	0.06310	0.03217	0.1055	0.01961	0.06434
600	0.02890	0.09483	0.01763	0.05784	0.02949	0.09674	0.01798	0.05898
650	0.02668	0.08753	0.01627	0.05340	0.02722	0.08930	0.01659	0.05444
700	0.02477	0.08128	0.01511	0.04958	0.02527	0.08292	0.01541	0.05056
750	0.02312	0.07586	0.01410	0.04628	0.02359	0.07739	0.01438	0.04718
800	0.02168	0.07112	0.01322	0.04338	0.02211	0.07255	0.01348	0.04424
900	0.01927	0.06322	0.01175	0.03856	0.01966	0.06449	0.01198	0.03932
1000	0.01734	0.05690	0.01058	0.03471	0.01769	0.05804	0.01079	0.03539
1100	0.01577	0.05172	0.009617	0.03155	0.01608	0.05277	0.009806	0.03217
1200	0.01445	0.04741	0.008816	0.02892	0.01474	0.04837	0.008989	0.02949
1250	0.01387	0.04552	0.008463	0.02777	0.01415	0.04643	0.008629	0.02831
1300	0.01334	0.04377	0.008137	0.02670	0.01361	0.04465	0.008297	0.02722
1400	0.01239	0.04064	0.007556	0.02479	0.01264	0.04146	0.007705	0.02528
1500	0.01156	0.03793	0.007052	0.02314	0.01179	0.03870	0.007191	0.02359
1600	0.01084	0.03556	0.006612	0.02169	0.01106	0.03628	0.006742	0.02212
1700	0.01020	0.03347	0.006223	0.02042	0.01041	0.03414	0.006345	0.02082
1750	0.009910	0.03251	0.006045	0.01983	0.01011	0.03317	0.006164	0.02022
1800	0.009634	0.03161	0.005877	0.01928	0.009829	0.03225	0.005992	0.01966
1900	0.009127	0.02995	0.005568	0.01827	0.009311	0.03055	0.005677	0.01863
2000	0.008671	0.02845	0.005289	0.01735	0.008846	0.02902	0.005393	0.01769
2500	0.007005	0.02298	0.004273	0.01402	0.007146	0.02344	0.004357	0.01429
3000	0.005837	0.01915	0.003561	0.01168	0.005955	0.01954	0.003631	0.01191
3500	0.005052	0.01657	0.003082	0.01011	0.005154	0.01691	0.003142	0.01031
4000	0.004421	0.01450	0.002697	0.008847	0.004510	0.01480	0.002749	0.009021
4500	0.003967	0.01302	0.002420	0.007939	0.004047	0.01328	0.002467	0.008095
5000	0.003570	0.01171	0.002178	0.007146	0.003642	0.01195	0.002221	0.007286

NOTE—For the resistance of conductors of multiple-conductor cables, see 2.6.2.

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Table 2-11
Factors for Determining Nominal Resistance of Stranded Conductors per 1000 Feet

Minimum Conductivity,	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 0.201 to 0.0111, Inclusive		Under 0.0111 to 0.0030, Inclusive	
Percent	61		100		97.66		97.16		96.16		94.16		93.15	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
Concentric Strand Up to 2000 kcmil	17342	17691	10579	10786	10832	11045	10888	11102	11001	11217	11235	11456	11356	11579

The dc resistance of the conductor per 1000 feet at 20°C or 25°C shall not exceed by more than 2 percent the value calculated by dividing the appropriate factor from the above table by the nominal circular mil area of the conductor as given in Tables 2-2, 2-3, and 2-6. For resistance of conductors of multiple-conductor cables, see 2.6.2.

The factors in Table 2-11 are based on the following:

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

B. Aluminum – A resistance of 17.002 ohms – circular mil/foot at 20°C and 17.345 ohms – circular mil/foot at 25°C for 61 percent conductivity.

C. Weight and resistance allowance for stranding for concentric strands, Classes B, C, and D up to 2,000 kcmil – 2 percent.

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Part 3
INSULATION

3.1 MATERIAL

The insulation shall consist of varnished cloth tapes meeting the dimensional, electrical, and physical requirements specified in Part 3.

3.2 INSULATION THICKNESSES

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

Thicknesses of insulation given in Table 3-1 shall apply to nonshielded and shielded single-conductor cables and to multiple-conductor cables with individually shielded conductors. The thicknesses of insulation given in Table 3-2 shall apply to multiple-conductor cables without individually shielded conductors. For multiple-conductor nonbelted cables, the thickness of insulation on each conductor shall be equal to the thickness of the conductor insulation plus the thickness of the belt insulation given in Table 3-2.

The average thickness of the insulation shall be not less than that given in Table 3-1 or 3-2.

The minimum thickness shall be not less than 90 percent of the values given in Table 3-1 or 3-2 (see 6.6).

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

3.2.1.1 For Three-phase Systems with 100 or 133 Percent Insulation Level (Grounded or Ungrounded Neutral)

Select the thickness value from the applicable column of Table 3-1 or 3-2.

3.2.1.2 For Delta Systems Where One Leg May Be Grounded for Periods over 1 Hour

Multiply the circuit voltage (phase-to-phase) by 1.73 and use the resulting voltage to select the corresponding insulation thickness from the 100 percent insulation level column of Table 3-1 or 3-2.

3.2.1.3 For Single- and Two-phase Systems with 100 Percent Insulation Level (Grounded)

Multiply the voltage to ground by 1.73 and use the resulting voltage value to select the corresponding insulation thickness from the 100 percent insulation level column of Table 3-1 or 3-2.

3.2.1.4 For Single- and Two-phase Systems with 133 Percent Insulation Level (Ungrounded)

Select the thickness for the circuit voltage (phase to phase) from the 133 percent insulation level column of Table 3-1 or 3-2.

3.2.1.5 For DC Systems Up To and Including 2000 Volts

Select the thickness from the column for the 100 percent insulation level in Table 3-1 or 3-2. For dc systems over 2000 volts, consult the manufacturer.

3.2 APPLICATION OF TAPES

Varnished tapes shall be wrapped helically over the conductor or over the assembled conductors, as required, and shall be of such widths that they will lie smoothly and be as free from wrinkles as practical.

3.4 SLIPPER COMPOUND

A slipper compound, where used, shall be nonhardening and shall have no deleterious effect on the varnished tapes, the conductor or other components of the cable assembly. The slipper compound shall be applied so as to exclude air and moisture as far as possible and to form with the varnished tape a firm semiflexible wall of insulation. Where the cable is intended for use in a vertical position, a minimum amount of slipper compound shall be used.

3.5 INSULATION TYPES AND REQUIREMENTS

The type of insulation shall be (1) varnished cotton tape or (2) varnished polyester-glass tape. Varnished tapes shall be substantially free from blisters and other imperfections and shall have the characteristics given in this standard.

The insulation materials shall be suitable for use (1) in nonshielded and shielded single-conductor cables, (2) in multiple-conductor cables with individually shielded conductors at not more than 21,000 volts between phases at a 133 percent Insulation level (ungrounded) or 28,000 volts between phases at a 100 percent insulation level (grounded) and (3) in multiple-conductor cables without individually shielded conductors at not more than 10,000 volts between phases.

The conductor temperature shall not exceed that given in Table 3-3.

3.5.1 Cloth and Varnished Coating

The cloth of varnished cotton tape shall consist of uniformly woven cotton and the number of threads per inch shall be not less than 60×55. Methods of sampling

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and testing, except as specifically covered in these standards, shall be in accordance with ASTM D 295.

The cloth of varnished polyester tape shall consist of uniformly woven polyester and glass fiber. The polyester fiber shall be in the wrap direction with not less than 30 ends per inch and the glass fiber shall be in the fill direction with not less than 26 ends per inch. Methods of sampling and testing, except as specifically covered in these standards, shall be in accordance with ASTM D 2400.

The varnished coating shall be pliable and shall not show cracks readily visible to the unaided eye when the varnished tape is doubled upon itself.

3.5.2 Thickness

The average thickness of the varnished tapes shall be not less than 0.006 inch (0.15 mm) and not more than 0.013 inch (0.33 mm).

The thickness of an individual tape shall not vary from the average by more than ±20 percent but in no case shall the tolerance exceed ±0.0015 inch (0.038 mm).

3.5.3 Tensile Strength

The tensile strength (measured lengthwise) of varnished tapes removed from the completed cable shall be not less than 2400 psi (1.69 kgf/mm^2).

3.5.4 Dielectric Strength of Individual Tapes

The average dielectric strength of varnished tapes removed from the completed cable shall be not less than the following (see 6.18):

Temperature	Average Breakdown Voltage Stress, Volts Per Mil
Room	800
85°C	625

These tests apply only to tapes having a width of ¾ inch (19.05 mm) or more.

3.5.5 Effect of Heat

(See 6.19.) The varnish coating of the varnished tapes shall not be materially softer nor more tacky after heating than before the test.

3.6 ELECTRICAL REQUIREMENTS

3.6.1 Test Voltages

The cable shall withstand the test voltage given in Table 3-4 for 5 consecutive minutes, except that braid-covered cables shall withstand the ac spark test voltage given in Table 3-7 (see 6.2).

3.6.2 Insulation Resistance

(See 6.3.) The insulation resistance of any conductor shall be not less than the values given in Table 3-5 or 3-6, except that for armored cables and cables with protective nonmetallic jackets over metallic sheaths, it shall be not less than 80 percent of these values.

For multiple-conductor belted cables, the value corresponding to the total thickness of the conductor and belt insulation shall be used. For multiple-conductor non-belted nonshielded cables, the value corresponding to the thickness of the insulation on each conductor shall be used.

3.7 ADDITIONAL REQUIREMENTS

3.7.1 Ionization Factor

(See 6.4.) For single-conductor metallic-sheathed or shielded cable rated above 8000 volts and for each conductor of multiple-conductor cable rated above 8000 volts with individually shielded conductors, the difference between the power factors shall not exceed 3.5 percent.

3.7.2 Long-time High-voltage Test

(See 6.15.) Shielded or metallic-sheathed cables rated above 8000 volts shall withstand 80 percent of the test voltage given in Table 3-4 for 6 hours.

3.7.3 Bend Test for Metallic-sheathed Cables

(See 6.16.) The measured thickness after bending of insulation and metallic sheath shall be not less than 80 percent of the measured average thickness of an unbent portion of the cable adjacent to the bent specimen. There shall be no more than two adjacent insulating tapes torn at the same spot. The total number of insulating tapes torn in any one foot of conductor or belt insulation, if any, shall not exceed two in any ten consecutive tapes.

A tear is defined as any separation in a single tape exceeding the lap of the insulating tape or ¼ inch if the tapes are not lapped.

3.7.4 Power Factor

(See 6.17.) The power factor for shielded or metallic-sheathed cables rated above 8000 volts shall not exceed the values given in Table 3-8. If the insulation thickness but not the rated voltage is known, the voltage rating shall be that corresponding to the thickness given for the 100 percent insulation level in Tables 3-1 and 3-2.

3.7.5 Flame Test

(See 6.20.) Fibrous-covered cables shall meet the following requirements:

a. The specimen shall not continue to burn longer than 1 minute after removal of the gas flame.
b. The flame shall not progress beyond either of the 2-inch (50.8-mm) indicators.
c. The cotton shall not be ignited by falling particles or drops. Flameless charring of the cotton is to be ignored.

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Table 3-1
Insulation Thicknesses for Nonshielded and Shielded Single-conductor Cables and Multiple-conductor Cables with Individually Shielded Conductors

Voltage, Phase-to-Phase, Volts*	Conductor Size, AWG or kcmil	Insulation Thickness			
		100 Percent Insulation Level†		133 Percent Insulation Level†	
		mils	mm	mils	mm
0–600	14–8	45	1.14	45	1.14
	7–2	60	1.52	60	1.52
	1–4/0	80	2.03	80	2.03
	213–500	95	2.41	95	2.41
	501–1000	110	2.79	110	2.79
	over 1000	125	3.18	125	3.18
601–1000	14–2	60	1.52	60	1.52
	1–4/0	80	2.03	80	2.03
	213–500	95	2.41	95	2.41
	501–1000	110	2.79	110	2.79
	over 1000	125	3.18	125	3.18
1001–3000	10–4/0	95	2.41	95	2.41
	213–1000	110	2.79	110	2.79
	over 1000	125	3.18	125	3.18
3001–5000	8–4/0	140	3.56	140	3.56
	213 and larger	155	3.94	155	3.94
5001–8000	6 and larger	170	4.32	190	4.83
8001–10000	6 and larger	190	4.83	235	5.97
10001–12000	6 and larger	220	5.59	250	6.35
12001–15000	6 and larger	250	6.35	330	8.38
15001–21000	2 and larger	345	8.76	455	11.56
21001–23000	2 and larger	375	9.53	...	...
23001–28000	1 and larger	455	11.56	...	...

*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.

†See notes following Table 3-2.

NOTE—Refer to Part 4 for shielding requirements.

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Table 3-2
Insulation Thicknesses for Multiple-conductor Cables without Individually Shielded Conductors

Voltage, Phase-to-Phase, Volts*	Conductor Size, AWG or kcmil	Insulation Thickness							
		100 Percent Insulation Level†				133 Percent Insulation Level†			
		Conductor		Belt		Conductor		Belt	
		mils	mm	mils	mm	mils	mm	mils	mm
0–600	14–8	45	1.14	0	0	45	1.14	0	0
	7–2	60	1.52	0	0	60	1.52	0	0
	1–4/0	80	2.03	0	0	80	2.03	0	0
	213–500	95	2.41	0	0	95	2.41	0	0
	501–1000	95	2.41	30	0.76	95	2.41	30	0.76
	over 1000	110	2.79	30	0.76	110	2.79	30	0.76
601–1000	14–2	60	1.52	0	0	60	1.52	0	0
	1–4/0	80	2.03	0	0	80	2.03	0	0
	213–500	95	2.41	0	0	95	2.41	0	0
	501–1000	95	2.41	30	0.76	95	2.41	30	0.76
	over 1000	110	2.79	30	0.76	110	2.79	30	0.76
1001–3000	10–2	80	2.03	30	0.76	80	2.03	30	0.76
	1–500	95	2.41	30	0.76	95	2.41	30	0.76
	501–1000	95	2.41	45	1.14	95	2.41	45	1.14
	over 1000	110	2.79	45	1.14	110	2.79	45	1.14
3001–5000	8–4/0	95	2.41	60	1.52	95	2.41	60	1.52
	213–1000	110	2.79	60	1.52	110	2.79	60	1.52
	over 1000	110	2.79	80	2.03	110	2.79	80	2.03
5001–8000	6 and larger	110	2.79	95	2.41	110	2.79	110	2.79

*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.

Notes apply to both Table 3-1 and 3-2.

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

100 Percent Level—Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within 1 minute. While these cables are applicable to the great majority of cable installations that 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 fault section.

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

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

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

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Table 3-3
Maximum Conductor Temperature

Rated Circuit Voltage Phase-to-Phase, Volts	Maximum Conductor Temperature, Degrees C	
	Single-conductor Cables, and Multiple-conductor Cables with Individually Shielded Conductors	Multiple-conductor Cables without Individually Shielded Conductors
0–5000	85	85
5001–8000	83	80
8001–15000	77	...
15001–21000	72	...
21001–28000	70	...

Table 3-4
AC Test Voltage, kV

Conductor Size, AWG or kcmil	Thickness of Insulation on Individual Conductors					
	45 mils (1.14 mm)	60 mils (1.52 mm)	80 mils (2.03 mm)	95 mils (2.41 mm)	110 mils (2.79 mm)	125 mils (3.18 mm)
14–11	2.5	3.5	...	...	...	...
10–9	2.5	3.5	4.5	6.5	...	...
8	2.5	3.5	4.5	6.5	9.0	11.0
7	...	3.5	4.5	7.0	9.5	11.5
6–5	...	4.0	5.0	7.5	10.0	12.0
4–2	...	5.0	5.5	8.0	10.5	12.5
1–4/0	...	...	6.0	8.5	11.0	13.5
213–1000	...	...	...	9.0	11.5	14.0
1001 and larger	...	...	...	...	11.5	14.0

Conductor Size, AWG or kcmil	Thickness of Insulation on Individual Conductors					
	140 mils (3.56 mm)	155 mils (3.94 mm)	170 mils (4.323 mm)	190 mils (4.83 mm)	205 mils (5.21 mm)	220 mils (5.59 mm)
8	13.5	15.5	...	...	...	...
7	14.0	16.0	...	...	...	...
6–5	14.5	16.5	18.5	20.0	22.0	23.5
4–2	15.0	17.0	19.0	20.5	22.5	24.0
1–4/0	15.5	18.0	19.5	21.0	23.0	24.5
213–500	16.0	18.5	20.0	22.0	23.5	25.5
501 and larger	16.0	18.5	20.0	22.0	24.0	26.0

Conductor Size, AWG or kcmil	Thickness of Insulation on Individual Conductors					
	235 mils (5.97 mm)	250 mils (6.35 mm)	330 mils (8.38 mm)	345 mils (8.76 mm)	375 mils (9.53 mm)	455 mils (11.56 mm)
6–5	25.0	27.0	37.5	...	...	...
4–3	26.0	27.5	38.0	40.5	...	...
2	26.0	27.5	38.0	40.5	45.0	53.5
1–4/0	26.5	28.0	38.5	41.0	45.5	54.0
213–500	27.0	29.0	39.0	41.5	46.0	55.0
501 and larger	27.5	29.5	39.5	42.0	46.5	55.5

NOTE—See 6.2.1 and 6.2.2.

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Table 3-5
Minimum Insulation Resistance of Solid, Concentric and Compact Stranded, and Segmental Cables, Megohms – 1000 Feet (304.8 meters) at 15.6°C (60°F)

Conductor Size, AWG or kcmil		Thickness of Insulation on Individual Conductors																	
	mils	45	60	80	95	110	125	140	155	170	190	205	220	235	250	330	345	375	455
	mm	1.14	1.52	2.03	2.41	2.79	3.18	3.56	3.94	4.32	4.83	5.21	5.59	5.97	6.35	8.38	8.76	9.53	11.56
14		945	1145	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13		880	1060	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12		805	985	1140	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11		745	885	1060	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10		680	835	980	1105	1215	...	...	...	...	...	...	...	...	...	...	...	...	...
9		625	775	905	1025	1130	...	...	...	...	...	...	...	...	...	...	...	...	...
8		575	710	830	950	1050	1145	1230	1310	...	...	...	...	...	...	...	...	...	...
7		...	655	765	875	970	1060	1145	1220	...	...	...	...	...	...	...	...	...	...
6		...	595	705	805	900	985	1065	1135	1190	1275	1340	1395	1460	1510	1740	1785	1865	...
5		...	550	645	745	830	910	990	1055	1125	1190	1250	1305	1360	1410	1640	1680	1760	...
4		...	495	590	680	765	840	910	980	1065	1105	1165	1215	1270	1320	1535	1575	1650	...
3		...	450	540	625	700	775	840	905	960	1024	1080	1130	1180	1230	1445	1485	1550	...
2		...	405	490	570	640	710	775	825	895	945	1000	1050	1100	1145	1340	1395	1465	1615
1		...	...	445	520	590	655	710	770	820	875	920	970	1015	1065	1250	1295	1370	1510
1/0		...	...	400	470	530	585	645	700	745	800	845	890	935	1000	1165	1200	1270	1410
2/0		...	...	360	425	485	535	590	640	690	735	780	830	860	900	1085	115	1180	1320
3/0		...	...	330	385	440	490	535	585	630	670	715	755	795	835	1000	1035	1090	1230
4/0		...	...	295	350	395	445	490	535	575	615	655	695	725	765	925	955	1015	1145
250		...	...	...	320	365	415	455	495	535	575	610	650	705	720	875	905	960	1085
300		...	...	...	300	340	380	420	460	500	535	570	605	650	670	820	850	900	1040
350		...	...	...	280	320	355	395	435	470	505	535	570	605	635	775	800	855	975
400		...	...	...	265	310	340	375	420	445	475	505	540	570	600	735	760	810	925
450		...	...	...	250	285	320	365	390	420	455	485	515	545	570	705	735	785	890
500		...	...	...	240	270	305	340	360	405	435	460	495	520	545	675	700	750	860
600		...	...	...	...	250	280	315	345	375	405	435	470	485	510	635	655	700	805
700		...	...	...	...	230	265	295	325	350	380	405	430	455	480	595	615	660	760
750		...	...	...	...	225	255	285	315	340	365	395	420	445	470	580	595	645	740
800		...	...	...	...	220	245	275	305	330	355	380	405	430	455	560	585	615	720
900		...	...	...	...	210	235	265	290	315	340	365	385	410	430	540	560	595	695
1000		...	...	...	...	200	225	250	275	300	325	345	370	390	415	515	535	575	665
1250		...	...	...	...	...	205	230	250	270	295	315	335	350	370	470	485	520	610
1500		...	...	...	...	...	190	210	230	250	270	295	310	325	350	435	450	485	565
1750		...	...	...	...	...	185	200	215	230	250	280	300	310	325	410	425	460	535
2000		...	...	...	...	...	165	190	200	220	235	255	280	300	310	385	395	430	505
2250		...	...	...	...	...	145	170	175	190	205	220	240	255	270	340	355	380	445
2500		...	...	...	...	...	135	150	165	175	195	210	225	240	255	315	340	365	425
3000		...	...	...	...	...	125	140	155	165	180	195	210	220	235	300	310	335	395
3500		...	...	...	...	...	115	130	145	150	170	180	195	205	220	280	290	315	370
4000		...	...	...	...	...	110	120	135	145	160	170	185	195	205	265	275	295	350

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Table 3-6
Minimum Insulation Resistance of Annular Conductor Cable, Megohms – 1000 Feet (304.8 meters) at 15.6°C (60°F)

Conductor Size,	mils	110	125	140	155	170	190	220	235	250	330	345	375	455
kcmil	mm	2.79	3.18	3.56	3.94	4.32	4.83	5.59	5.97	6.35	8.38	8.76	9.53	11.56
750		190	215	235	265	285	305	350	375	395	495	510	545	630
800		180	205	230	255	275	295	335	360	380	475	490	525	610
900		170	195	220	240	260	280	320	340	360	450	470	500	580
1000		160	180	200	220	240	260	295	315	335	420	435	470	545
1250		...	160	175	195	215	230	265	280	300	375	390	420	490
1500		...	140	155	170	185	200	230	245	260	330	345	370	435
1750		...	130	145	160	170	185	215	230	245	310	320	350	410
2000		...	120	130	145	160	170	200	210	225	285	295	320	375
2500		...	105	115	130	140	155	175	185	200	255	285	290	340
3000		...	95	110	120	130	145	165	170	190	240	250	270	320
3500		...	85	95	105	115	125	145	155	165	210	220	235	285
4000		...	80	85	95	105	115	130	145	150	190	205	215	260

Table 3-7
AC Spark-test Voltage for Braid-covered Cables

Insulation Thickness		AC Spark-test Voltage, kV
mils	mm	
45	1.14	5.0
60	1.52	7.0
80	2.03	9.0
95	2.41	11.0
110	2.79	13.0
125	3.18	15.0
140	3.56	17.0
155	3.94	19.0
Over 155	Over 3.94	20.0

Table 3-8
Maximum Power Factor

Temperature		Maximum Power Factor, Percent	
°F	°C	Single-conductor and Shielded Cable	Multiple-conductor Belted Cable
Room to 122	50	6.0	8.0
131	55	6.4	8.9
140	60	7.0	10.0
149	65	7.4	11.1
158	70	8.0	12.5
167	75	8.7	14.0
176	80	9.6	16.0
185	85	11.0	18.0

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Part 4
SHIELDING AND COVERINGS

SHIELDING

4.1 SHIELDING OF VARNISHED-CLOTH-INSULATED CABLES

When required, insulation shielding shall consist of metallic nonmagnetic tape except that, where the shielding is in substantially continuous contact with a grounding conductor or metallic sheath capable of carrying fault currents, nonmetallic conducting tape may be used in lieu of metallic tape. Nonmetallic tape shall have a sufficiently low resistance to maintain the surface of the insulation at substantially ground potential under normal operating conditions. Metallic shielding shall be protected against chemical action from any cable compound, such as rubber-compound-filled tape, in contact with it.

4.1.1 Metallic Tape Shields

Metallic tape shall be at least 2.5 mils (0.0635 mm) thick. The tape shall be substantially free from burns, and joints shall be made electrically continuous by welding, soldering, or brazing.

When applied so as to completely cover the insulation, the minimum lap shall be 10 percent.

When one tape is applied with a gap, the maximum space between successive turns shall be 15 percent of the tape width, and the metallic tape shall be in intimate contact with the insulation.

4.2 SHIELDING PRACTICE

4.2.1 Voltage Limits

Shielding is required for cables rated above the three-phase line voltages give in 4.2.2, 4.2.3, and 4.2.4 except that, if the cable is to be operated at a voltage below the shielding limits shown in these paragraphs, shielding is not required.

To obtain the equivalent three-phase voltage for single-phase or two-phase ac systems or for dc systems, multiply the line-to-line voltage by the factors shown in the table below.

4.2.2 Single-conductor Nonsheathed Cables

4.2.2.1 INSTALLED ON INDIVIDUAL FULL-VOLTAGE INSULATORS

Shielding shall not be used.

4.2.2.2 IN CONTACT WITH CONDUCTING OR SEMI-CONDUCTING SURFACES

Shielding is required for voltages above 8000 volts.

4.2.3 Single-conductor Metallic-sheathed Cables

Shielding is not required.

4.2.4 Multiple-conductor Nonsheathed and Unarmored Cables

Shielding is required for voltages above 8000 volts. If all of the insulation is on the conductors, each conductor shall be shielded. If part of the insulation is in the belt, the shielding shall be applied over the belt.

NOTE—Under unusual safety or operating conditions, nonsheathed cables rated below 8000 volts may require shielding. (This note has been approved by NEMA as Authorized Engineering Information.)

4.2.5 Multiple-conductor Metallic-sheathed Cables and/or Metallic Armored Cables

Shielding is required for the individual conductors of nonbelted cables rated above 10000 volts. Shielding is not required for belted cables.

Multiplying Factors for Equivalent Three-phase Voltages for Single- or Two-phase AC Systems or for DC Systems

Single- and Two-phase AC Systems*, 5000 Volts or Less	Single- and Two-phase AC Systems*, Over 5000 Volts			DC Systems, 5000 Volts or Less
	One Side Grounded	Mid-point Grounded	Ungrounded	
1	1.73	0.866	0.866	1

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

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Table 4-1
Angle of Cotton and Spun Rayon Braids

Calculated Diameter Under Braid		Value of Tangent	Corresponding Braid Angle, Degrees
inches	mm		
0–1.000	0–25.40	0.700	35
1.001–1.500	25.43–38.10	0.839	40
1.501 and over	38.13 and over	1.000	45

Table 4-2
Thickness of Cotton and Spun Rayon Braids

Calculated Diameter Under Braid		Minimum Thickness of Braid		Corresponding Minimum Size and Ply
inches	mm	inches	mm	
Class B				
0–0.200	0–5.08	0.016	0.41	30/2
0.201–0.350	5.11–8.89	0.017	0.43	26/2
0.351–0.800	8.92–20.32	0.020	0.51	20/2
0.801–1.500	20.35–38.10	0.026	0.66	12/2
1.501–3.000	38.13–76.20	0.032	0.81	8/2
Class C				
0–0.200	0–5.08	0.020	0.51	20/2
0.201–0.300	5.11–7.62	0.022	0.56	16/2
0.301–0.600	7.65–15.24	0.026	0.66	12/2
0.601–1.000	15.27–25.40	0.032	0.81	8/2
1.001–1.500	25.43–38.10	0.037	0.94	6/2
1.501–2.000	38.13–50.80	0.045	1.14	4/2
2.001–3.000	50.83–76.20	0.056	1.42	4/3

OUTER COVERINGS

4.3 GENERAL

A protective outer covering shall be applied over the insulation of single-conductor cables and over the core assembly of multiple-conductor cables. Coverings shall be of one of the following types:

a. Fibrous covering—See 4.4.
b. Thermoplastic jacket—See 4.5.
c. Reinforced neoprene jacket—See 4.6.
d. Metallic covering and/or associated coverings—See 4.7.

4.4 FIBROUS COVERINGS

4.4.1 General

The outer covering shall consist of a single braid when the diameter of the following is 1 inch (25.4 mm) or less and shall consist of two braids or of a tape and braid (a tape and braid is the equivalent of two braids) when the diameter of the following exceeds 1 inch (25.4 mm):

a. Over the insulation of a single-conductor cable.
b. Over the assembled core of a multiple-conductor nonbelted cable. On nonbelted cables requiring a binder (see 5.5) the tape may be considered as the binder.
c. Over the belt of a multiple-conductor belted cable.

4.4.2 Compound-filled Tapes

Tapes used as protection over the insulation of single-conductor cables or over the core of multiple-conductor cables shall be in accordance with 4.4.2.1 and 4.4.2.2. Tapes may be used in place of cotton braids, except that they shall not be used as the final covering of either a single- or multiple-conductor cable.

4.4.2.1 MATERIAL

Compound-filled tape shall be made from cloth treated on one or both sides with an insulating com-

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pound. The thickness shall be not less than 10 mils (0.254 mm) when measured in accordance with 6.8.

4.4.2.2 APPLICATION

Tape shall be applied helically and overlapped and a minimum of 10 percent of its width.

4.4.3 Cotton, Rayon, and Suitable Synthetic Yarn Braids

4.4.3.1 MATERIALS

Braids shall consist of cotton, spun rayon, or synthetic yarn. Cotton or spun rayon of at least two piles shall be used in Class B and C braids.

4.4.3.2 CLASSES OF BRAIDS

4.4.3.2.1 COTTON AND SPUN RAYON BRAIDS

Cotton and spun rayon braids shall be of one of the following two classes:

a. Class B braids shall be suitable for use in normal indoor installation.
b. Class C braids shall be suitable for outdoor use and rough service.

4.4.3.2.2 SYNTHETIC BRAIDS

Synthetic braids shall be closely woven and capable of complying with 4.4.4.

4.4.3.3 ANGLE OF COTTON AND SPUN RAYON BRAIDS

The braid shall be so constructed that the tangent of the angle between the cotton or spun rayon thread and a line in the braid surface parallel to the axis of the core shall be not less than that specified in Table 4-1.

4.4.3.4 THICKNESS OF BRAIDS

The minimum thickness of cotton and spun rayon braids shall be as given in Table 4-2.

The average thickness of each synthetic braid shall be not less than 45 mils (1.14 mm). The minimum thickness shall be not less than 90 percent of the average thickness.

For braids over flat twin conductor cables, the equivalent diameter under the braid shall be determined by multiplying the nominal diameter of the individual insulated conductor by 1.64.

4.4.3.5 CARRIERS, ENDS, AND PICKS FOR COTTON AND SPUN RAYON BRAIDS

4.4.3.5.1 CARRIERS AND ENDS

The number of carriers and the number of ends per carrier used in applying the braid shall be so selected that all requirements of 4.4.3 will be met.

4.4.3.5.2 PICKS PER INCH

The number of picks per inch shall be not less than the value determined from the following formula:

$$P = \sqrt{\left[\frac{1}{tE+M}\right]^2 - \left[\frac{C}{2\pi(D+T)}\right]^2}$$

Where—

P = Picks per inch.
T = Thickness of Braid, in inches = 2t
t = Diameter of one end of cotton, in inches $= \frac{0.0279\ K}{\sqrt{S}}$
S = Cotton size.
E = Number of ends per carrier.
C = Number of carriers.
D = Diameter under braids, in inches. To determine D for braids over twin wires, use 1.64 times the diameter of the individual conductor before twinning.
M = Space between each set of carrier threads, in inches = $X(0.011+7.0t^2E^2)$
K = Cabling factor for plied yarn, Table 4-3.
X = Closeness constant, Table 4-4.

For convenience in computing the more usual braid construction, the formula for picks may be reduced to:

$$P = \sqrt{Y - \frac{Z}{(D+T)^2}}$$

Where—

$Y = \frac{1}{(tE+M)^2}$
$Z = 0.0253C^2$

See Table 4-5 for values of Z and Table 4-6 for values of Y.

See the following for picks per inch for typical braids—

Class B braids—Table 4-7.
Class C braids—Table 4-8.

Table 4-3
Values of K

	K
2 ply	1.60
3 ply	2.00
4 ply	2.36

Table 4-4
Values of X

Calculated Diameter Under Braid		Class B and C Braids
inches	mm	
0–0.500	0–12.70	1.1
0.501 and over	12.73 and over	1.0

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Table 4-6
Values for Y for Some of the Most Commonly Used Constructions of Class B and C Braids

Size of Yarn	Thickness of Braid (T)	For Diameters 0.500 Inch (12.70 mm) and Under				For Diameters over 0.500 Inch (12.70 mm)						
		2 End	3 End	4 End	5 End	2 End	3 End	4 End	5 End	6 End	7 End	8 End
30/2	0.0163	1081	592	358	233	...	...	...	...	...	...	...
26/2	0.0175	982	526	312	220	...	...	...	...	...	...	...
24/2	0.0182	930	492	290	185	...	...	...	...	...	...	...
20/2	0.0200	807	416	241	151	878	446	259	163	...	...	...
16/2	0.0223	683	339	193	118	738	365	207	127	...	...	...
14/2	0.0238	616	302	168	103	664	324	180	111	...	...	...
12/2	0.0258	538	257	142	85	582	276	152	92	59	40	28
10/2	0.0282	462	214	115	68	497	231	125	74	48	32	22
8/2	0.0316	379	170	89	52	407	183	96	56	35	23	16

4.4.3.5.3 Double Cotton and Spun Rayon Braids

Where two braids are specified, the outer braid shall be determined by the diameter over the inner braid. Where two braids are applied in one operation this standard shall apply to both braids except that the picks per inch and angle of braid for inner braids shall be governed by the construction of the machine. The size and ply of the inner braid shall conform to this standard and the number of ends shall be not less than that used in the outer braid.

4.4.3.6 Measurements of Braids

Methods for determining the number of carriers and ends, picks per inch, braid angle, and braid thickness are given in 6.9.

Table 4-5
Values of Z

Number of Carriers	Z
12	3.65
16	6.49
20	10.13
24	14.59
36	32.80
48	58.40

4.4.4 Saturants and Finishes

4.4.4.1 Moisture- and Flame-Retarding Finish

Fibrous braids shall be thoroughly saturated with a high-melting-point asphalt and coated with a dark-colored flexible coating material such as stearine pitch or high-softening-point asphalt. The finished wire shall meet the flame test described in 6.20 and the melt test described in 6.21.

4.4.4.2 Surface Protection

Smooth black-finished braid shall be coated with a flexible paint lacquer and/or wax to prevent adhesion between turns and to serve as a lubricant.

Braids for outdoor service shall be coated with mica flake or some other suitable material.

4.4.4.3 Paint-Filled and Finished Braid

The cable shall be run through a suitable slow-burning gray or drab-colored paint, and each braid shall be filled with the paint. The braid covering shall be coated with a finished compound similar to the paint used.

The finished cable shall meet the flame test described in 6.20.

4.5 THERMOPLASTIC JACKETS

4.5.1 General

These jackets consist of a thermoplastic compound and shall meet the requirements of 4.5.3 or 4.5.4.

Thermoplastic jackets are suitable as coverings for outdoor aerial installation, in conduit above ground where precautions are taken to avoid condensate, and for damp locations and corrosive atmospheres but are not suitable for direct burial or other installations considered as wet locations (see 4.5.2). (This paragraph has been approved by NEMA as Authorized Engineering Information.)

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4.5.2 Definition of Locations

4.5.2.1 Dry Location

A dry location is one that is not normally subject to dampness or wetness. Such a location may be temporarily subjected to dampness or wetness such as is found in buildings under construction.

4.5.2.2 Damp Location

A damp location is one that may be subject to a moderate degree of moisture (e.g., some basements, some barns, some cold-storage warehouses, outdoor aerial installations, etc.).

4.5.2.3 Wet Location

A wet location is one that is subject to saturation with water or other liquids (e.g., washrooms in garages, installations underground or in concrete slabs, or masonry in direct contact with the earth, etc.).

4.5.3 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 (see 6.12):

Physical Requirements	
Tensile strength, minimum	
psi	1500
kgf/mm^2	1.05
Elongation at rupture, minimum, percent	100
Aging Requirements	
After air oven test at 100°C±1°C for 5 days	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	60
After oil immersion test at 70°C±1°C for 4 hours	
Tensile strength, minimum, percentage of unaged value	80
Elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121°C±1°C, maximum, percent	50
Heat shock, 121°C±1°C,	No Cracks
Cold bend, –10°C±1°C	No Cracks*

* The cold bend test shall be made on the completed cable except that, in the case of interlocked armored cable, it shall be made before armoring.

4.5.4 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 for a minimum installing temperature of –10°C (14°F) and shall meet the following requirements (see 6.12):

Physical Requirements	
Tensile strength, minimum	
psi	1400
kgf/mm^2	0.98
Elongation at rupture, minimum, percent	350
Aging Requirements	
After air oven test at 100°C±1°C for 48 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	75
Heat distortion, 90°C±1°C, maximum, percent	25
Absorption coefficient, minimum	3200†
Environmental cracking	No Cracks

†A certification by the manufacturer of the polyethylene compound that this requirement has been complied with shall suffice.

4.5.5 Jacket Thickness

The average thickness of thermoplastic jackets shall be not less than those given in Table 4-9 (see 6.7). The minimum thickness shall be not less than 70 percent of the values given the table.

Table 4-9
Thickness of Thermoplastic Jackets

Calculated Diameter of Cable Under Jacket‡		Jacket 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

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

4.6 REINFORCED NEOPRENE JACKET

This jacket shall be applied directly over the insulation or core assembly and shall consist of a sandwich of

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Table 4-7*
Picks Per Inch – Typical Class B Braids

Calculated Diameter Under Braid (D)		Number of Carriers	Size Ply Ends	30 2 2	30 2 3	26 2 2	26 2 3	24 2 2	24 2 3	20 2 2	20 2 3	20 2 4	20 2 5	16 2 2	16 2 3	16 2 4	16 2 5	12 2 2	12 2 3	12 2 4	12 2 5	8 2 3	8 2 4	8 2 5
Inches	mm																							
0–0.090	0–2.29	12		27.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		22.6	...	20.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.091–0.110	2.31–2.79	12		28.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		24.7	...	22.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.111–0.125	2.82–3.18	12		29.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		27.0	...	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.126–0.150	3.20–3.81	12		30.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		28.6	17.8	26.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.151–0.175	3.84–4.44	16		29.8	19.7	28.0	18.1	27.1	17.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		24		25.3	12.3	23.1	...	22.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.176–0.200	4.47–5.08	16		30.6	20.9	28.7	19.3	27.8	18.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		24		27.0	15.5	25.2	13.4	24.2	12.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.201–0.225	5.11–5.72	16		...	...	29.3	20.1	28.5	19.3	26.2	17.3	11.0	...	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	26.6	15.8	25.6	14.8	23.2	12.2	...	...	...	...	...	...	...	...	...	...	...	...	...
0.226–0.250	5.74–6.35	16		...	...	29.7	20.6	28.9	19.8	26.6	17.9	12.0	...	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	27.6	17.4	26.6	16.4	24.2	14.0	...	...	...	...	...	...	...	...	...	...	...	...	...
0.251–0.300	6.38–7.62	16		...	...	30.2	21.2	29.3	20.2	26.9	18.2	12.9	8.7	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	28.6	18.9	27.6	18.0	25.3	15.8	...	...	...	...	...	...	...	...	...	...	...	...	...
0.301–0.350	7.65–8.89	16		...	...	30.4	21.7	29.6	20.9	27.2	19.0	13.7	9.8	25.1	16.9	11.8	...	...	...	...	...	...	...	...
		24		...	...	29.4	20.1	28.4	19.2	26.0	17.1	10.9	...	23.7	14.8	8.5	...	...	...	...	...	...	...	...
0.351–0.400	8.92–10.16	16		...	...	...	...	...	...	27.6	19.4	14.1	...	25.4	17.2	12.3	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	...	26.5	18.0	12.2	...	24.3	15.7	10.0	...	...	...	...	...	...	...	...
0.401–0.450	10.19–11.43	16		...	...	...	...	...	...	27.9	19.6	14.4	10.9	25.6	17.5	12.7	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	...	26.9	18.5	12.9	8.8	24.6	16.3	11.0	...	...	...	...	...	...	...	...
0.451–0.500	11.46–12.70	16		...	...	...	...	...	...	28.1	19.8	14.6	...	25.7	17.7	12.9	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	...	27.2	18.9	13.5	9.5	25.0	16.8	11.6	...	...	...	...	...	...	...	...
0.501–0.600	12.73–15.24	24		...	...	...	...	...	...	28.8	20.1	14.6	10.9	26.3	17.9	12.7	9.1	...	...	...	...	...	...	...
0.601–0.800	15.27–20.32	24		...	...	...	...	...	...	29.1	20.5	15.2	11.6	26.6	18.4	13.4	10.0	23.6	15.7	11.2	8.0	...	...	...
		36		...	...	...	...	...	...	28.6	19.6	14.0	10.0	26.0	17.4	12.0	8.0	22.8	14.6	9.5	...	...	...	...
0.801–1.000	20.35–25.40	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.8	16.2	11.6	8.7	...	...	...
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.3	15.4	10.7	...	...	...	...
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	22.7	14.5	9.2	...	...	...	...

Calculated Diameter Under Braid (D)		Number of Carriers	Size	30	30	26	26	24	24	20	20	20	20	16	16	16	16	12	12	12	12	8	8	8
			Ply	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
inches	mm		Ends	2	3	2	3	2	3	2	3	4	5	2	3	4	5	2	3	4	5	3	4	5
1.001–1.200	25.43–30.48	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.9	16.3	11.9	9.0	13.1	9.2	6.7
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.6	15.8	11.2	8.1	12.5	8.4	5.5
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.1	15.2	10.3	...	12.1	7.1	...
1.201–1.500	30.51–38.10	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	24.0	16.4	12.0	9.2	13.2	9.4	6.9
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.8	16.1	11.6	8.6	12.8	8.9	6.2
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	23.5	15.7	11.0	7.8	12.3	8.1	5.0
1.501–2.000	38.13–50.80	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.3	9.5	7.2
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.1	9.2	6.8
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12.8	8.8	6.1
2.001–3.000	50.83–76.2	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.4	9.6	7.2
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.3	9.5	7.1
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13.2	9.3	6.9

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Table 4-8*
Picks per Inch – Typical Class C Braids

Calculated Diameter Under Braid (D)		Number of Carriers	Size	20	20	16	16	16	12	12	8	8	8	6	6	6	4	4	4	4	4
			Ply	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
Inches	mm		Ends	2	3	2	3	4	2	3	3	4	5	2	3	4	3	4	5	3	4
0–0.090	0–2.29	12		22.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		16.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.091–0.110	2.31–2.79	12		23.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		18.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.111–0.125	2.82–3.18	12		24.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		21.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.126–0.150	3.20–3.81	12		25.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		16		23.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.151–0.175	3.84–4.44	16		24.8	14.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		24		19.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.176–0.200	4.47–5.08	16		25.5	16.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		24		21.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0.201–0.225	5.11–5.72	16		...	...	23.8	14.9	...	20.6	12.0	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	20.4	...	...	16.7	...	...	...	...	...	...	...	...	...	...	...	...
0.226–0.250	5.74–6.35	16		...	...	25.8	15.6	9.8	21.0	12.8	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	21.6	11.1	...	18.1	...	...	...	...	...	...	...	...	...	...	...	...
0.251–0.300	6.38–7.62	16		...	...	...	16.3	10.9	21.6	13.6	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	...	13.2	...	19.4	...	...	...	...	...	...	...	...	...	...	...	...
0.301–0.350	7.65–8.89	16		...	...	...	...	...	22.0	14.3	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	20.5	11.8	...	...	...	...	...	...	...	...	...	...	...
0.351–0.400	8.92–10.16	16		...	...	...	...	...	22.3	14.7	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	21.1	12.9	...	...	...	...	...	...	...	...	...	...	...
0.401–0.450	10.19–11.43	16		...	...	...	...	...	22.5	15.0	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	21.6	13.6	...	...	...	...	...	...	...	...	...	...	...
0.451–0.500	11.46–12.70	16		...	...	...	...	...	22.7	15.2	...	...	...	...	...	...	...	...	...	...	...
		24		...	...	...	...	...	21.9	14.1	...	...	...	...	...	...	...	...	...	...	...
0.501–0.600	12.73–15.24	24		...	...	...	...	...	23.2	15.2	11.8	7.3	...	16.4	9.5	5.0	6.6	...	...	...	...
0.601–0.800	15.27–20.32	24		...	...	...	...	...	...	...	12.5	8.3	5.3	16.8	10.3	6.4	7.6	3.9	...	...	...
		36		...	...	...	...	...	...	...	11.1	5.9	...	15.8	8.5	...	5.0	...	...	...	...
0.801–1.000	20.35–25.40	24		...	...	...	...	...	...	...	12.9	8.9	6.3	17.2	10.8	7.2	8.3	5.0	...	...	...
		36		...	...	...	...	...	...	...	12.0	7.6	4.3	16.5	9.7	5.5	6.9	...	...	...	...
		48		...	...	...	...	...	...	...	10.8	...	...	15.6	8.1	...	4.4	...	...	...	...

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Calculated Diameter Under Braid (D)		Num-	Size	20	20	16	16	16	12	12	8	8	8	6	6	6	4	4	4	4	4
		ber of	Ply	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
inches	mm	Carriers	Ends	2	3	2	3	4	2	3	3	4	5	2	3	4	3	4	5	3	4
1.001–1.200	25.43–30.48	24		...	...	...	...	...	...	...	...	...	...	17.3	11.0	7.5	8.7	5.7	...	...	...
		36		...	...	...	...	...	...	...	...	...	...	17.0	10.3	6.5	8.0	4.6	...	...	...
		48		...	...	...	...	...	...	...	...	...	...	16.4	9.3	...	7.0	...	...	...	...
1.201–1.500	30.51–38.10	24		...	...	...	...	...	...	...	...	...	...	17.4	11.2	7.8	8.8	5.8	...	...	...
		36		...	...	...	...	...	...	...	...	...	...	17.2	10.8	7.1	8.2	5.0	...	...	...
		48		...	...	...	...	...	...	...	...	...	...	16.8	10.2	6.1	7.4	...	...	...	...
1.501–2.000	38.13–50.80	24		...	...	...	...	...	...	...	...	...	...	...	...	...	9.0	6.1	4.3	6.6	4.3
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	8.6	5.6	3.6	6.3	3.6
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	8.1	4.8	...	5.5	...
2.001–3.000	50.83–76.2	24		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.8	4.5
		36		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.6	4.2
		48		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.3	3.7

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neoprene-compound tapes or reinforced-neoprene-compound tapes. After vulcanization of the jacket, a finishing compound shall be applied over the cable.

This jacket is suitable as covering for cables used in outdoor aerial installations, in conduit above ground where precautions are taken to avoid condensate, and in damp locations and corrosive atmospheres, but are not suitable for direct burial or in wet locations (see 4.5.2).

4.6.1 Physical Requirements

The neoprene compound used in the all-neoprene-compound tapes and in reinforced-neoprene-compound tapes shall meet the following requirements (see 6.12):

Physical Requirements	
Tensile strength, minimum	
psi	1200
kgf/mm^2	0.84
Elongation at rupture, minimum, percent	250
Set maximum, percent	20
Aging Requirements	
After air oven test at 70°C±1°C for 168 hours	
Tensile, strength minimum	
psi	75
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 at rupture, minimum, percentage of unaged value	60

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

4.6.2 Jacket Thickness

The average thickness of the reinforced neoprene jacket shall be not less than the values given in Table 4-10. The minimum thickness shall be not less than 75 percent of the thickness given in the table.

4.7 METALLIC AND ASSOCIATED COVERINGS

4.7.1 Scope

This section covers the following:

Division I—(See 4.7.3 through 4.7.16.) Materials, constructions, and requirements for metallic and associated coverings recommended for use under normal conditions of installation, operation, and maintenance of power and lightning circuit wires and cables that are insulated with varnished cloth. It also covers submarine cables.

Division II—(See 4.7.17 through 4.7.22.) Round wire armor for borehole, shaft, and vertical riser cable.

Division III—(See 4.7.23 through 4.7.25.) Round wire armor for buried cable.

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

Table 4-10
Thickness of Reinforced Neoprene Jacket

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
0–0.500	0–12.70	70	1.78
0.501–1.000	12.73–25.40	110	2.79
1.001 and larger	25.43 and larger	150	3.81

4.7.2 General

4.7.2.1 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.

4.7.2.2 Types of Metallic Coverings

The types and conditions of installation are as follows:

a. Metallic sheath— lead or aluminum
   1. Conduit, ducts, troughs, or raceways;
   2. Suspended from aerial messenger; or
   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; or
   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 metallic sheathed 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 metallic sheathed cables to be suspended from an aerial messenger strand.

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

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

   Interlocked-metal tape armor when applied to a metallic sheathed cable 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. Vertical riser, borehole, and shaft cable for end suspension; or
   3. Direct burial in trenches and subjected to unusual longitudal stress.

Jute covering is not required on 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 has been approved by NEMA as Authorized Engineering Information.)

Division I
METALLIC AND ASSOCIATED COVERINGS FOR INSULATED CABLES

4.7.3 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 non-metallic coverings; to non-application over insulated electric cable for use on power and lighting circuits.

4.7.4 Metallic Sheath

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

4.7.4.1 Lead Sheath

4.7.4.1.1 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.

4.7.4.1.2 Thickness of Lead

The average thickness of the lead sheath shall be not less than the values given in Table 4-11. The minimum thickness shall be not less than 90 percent of the values over the lead sheath, see 4.7.14.3 and 4.7.15.5 for the thickness of the lead sheath.

Table 4-11
Thickness of Lead Sheath

Calculated Diameter of Cable Under Jacket†		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 cables, if several cables are to be pulled in together in one duct; if the sections are extra long, or if the handling is severe or awkward during installation as in some transformer vaults. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

4.7.4.1.3 Measurement of Thickness of Lead

The thickness shall be measured in accordance with 6.10.

4.7.4.1.4 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.

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4.7.4.2 Aluminum Sheath

4.7.4.2.1 Type of Aluminum

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

4.7.4.2.2 Thickness of Aluminum

The average thickness of the aluminum sheath shall be in accordance with Table 4-12. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

Table 4-12
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	2.14
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.

4.7.4.2.3 Measurement of Thickness of Aluminum

The thickness shall be measured in accordance with 6.10.

4.7.4.2.4 Reapplication of Aluminum Sheaths

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

4.7.4 Jute Serving over Metallic Sheath Without Metallic Armor

4.7.5.1 Jute Servings

The average thickness of one serving (or two servings) of the jute applied over metallic sheathed cable for mechanical protection shall be not less than that given in Table 4-13.

4.7.5.2 Application

When jute servings are required, the metallic sheathed cable shall be run through hot asphalt or tar compound, and then served with a closely woven layer of No. 16/3 impregnated jute yarn or plied jute of equivalent thickness. If two servings are required, they shall be closely wound and applied with opposite directions of lay. The inner serving shall be an impregnated jute yarn that shall be run through hot asphalt or tar compound before the application of the outer serving that 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 materials that will prevent sticking of adjacent turns of the cable when wound on a reel.

4.7.6 Flat Metal Tape Armor

4.7.6.1 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.

4.7.6.2 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) not 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.

4.7.6.3 Galvanizing Test

4.7.6.3.1 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.

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Table 4-13
Thickness of Jute Servings over Metallic Sheath (Without Metallic Armor)

Calculated Diameter of Cable Under Jute Serving*		Thickness of Jute Servings			
		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.

4.7.6.3.2 ADHERENCE OF COATING

The zinc coating shall remain adherent without flaking or spalling when the strip is subjected to a 180-degree bend over a mandrel ⅛ inch (3.18 mm) in diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake and none of it can be removed from the strip by rubbing with the fingers.

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

4.7.6.4 WIDTH

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

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

Table 4-14
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
0–0.0450	0–11.43	0.750	19.0
0.451–1.000	11.46–25.40	1.000	25.4
1.001–1.400	25.43–35.56	1.250	31.8
1.401–2.000	35.59–50.80	1.500	38.1
2.001–3.500	50.83–88.90	2.000	50.8
3.501 and larger	88.93 and larger	3.000	76.2

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

4.7.6.5 THICKNESS

(See 6.8.2.) The average thickness of metal tape shall be not less than that given in Table 4-15.

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 for bare metal.

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

Table 4-15
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.

4.7.6.6 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.

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4.7.7 Interlocked Metal Tape Armor

4.7.7.1 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.

4.7.7.2 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 electrogalvanizing 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 4.7.6.2 and 4.7.6.3 for flat steel tape.

4.7.7.3 Width

The nominal width of metal tape may be less than but shall be not greater than that given in Table 4-16.

Table 4-16
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.

4.7.7.4 Thickness

(See 6.8.2.) The average thickness of metal tape shall be not less than that given in Table 4-17.

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 for bare metal.

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

4.7.7.5 Nonmagnetic Tape

When nonmagnetic tapes, such as aluminum, brass, bronze, zinc, stainless steel tapes are used, the widths shall be in accordance with 4.7.7.3 and the thickness in accordance with 4.7.7.4.

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

4.7.8 Galvanized Steel Wire Armor

4.7.8.1 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 4.7.17 through 4.7.25. All tests shall be made prior to application of the wire to the cable.

4.7.8.2 Tensile Strength, Elongation, and Torsion

4.7.8.2.1 Tensile Strength

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 E8.

4.7.8.2.2 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.

4.7.8.2.3 Torsion Test

The zinc-coated wire shall withstand, without fracture, the minimum number of twists specified in Table 4-18. 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 the equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 4-17
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	38.14 and larger	25	0.64	30	0.76

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Table 4-18
Number of Twists (Torsion Test)

Diameter of Coated Wire		Minimum Number of Twists
mils	mm	
238–166	6.05–4.22	7
165–110	4.19–2.79	10
109–65	2.77–1.65	14

4.7.8.3 GALVANIZING TESTS

4.7.8.3.1 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 4-19. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90.

4.7.8.3.2 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 4-20. 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.

4.7.8.4 SIZE OF ARMOR

The sizes of armor wire for Division I applications, including submarine cables, shall be as given in Table 4-21. If the service requirements are exceptionally severe, larger sizes of armor wire may be required. (This sentence has been approved by NEMA as Authorized Engineering Information.)

The tolerance in diameter for galvanized steel wire shall be as given in Table 4-22.

4.7.8.5 LAY

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter.

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

4.7.8.6 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.

4.7.9 Jute Bedding for Armored Cable

See 4.7.11 for interlocked armored cable.

4.7.9.1 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 4.7.12.1 before it is run through the first application of compound.

4.7.9.2 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 4.7.8.6. Adjacent layers of jute shall be applied with opposite directions of lay.

4.7.9.3 THICKNESS

The average thickness of jute bedding under the armor in the finished cable shall be not less than that given in Table 4-23. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the bedding.

4.7.10 Jute Serving Overall for Armored Cable

See 4.7.11 for interlocked armored cable.

4.7.10.1 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 that will prevent sticking of adjacent turns of the cable when wound on a reel.

4.7.10.2 DIRECTION OF LAY

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

4.7.11 Jute for Interlocked Armored Cable

4.7.11.1 JUTE BEDDING

If jute bedding is required, the application and direction of lay shall be in accordance with 4.7.9.1 and 4.7.9.2 The thickness shall be as specified for metal taped cable in Table 4-23.

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Table 4-19
Minimum Weights of Zinc Coating

Nominal Diameter of Coated Wire		Size, BWG	Minimum Weight of Zinc Coating	
mils	mm		Ounces per Square Foot of Exposed Wire Surface	Grams per 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 4-20
Mandrel Diameter for Adherence of Coating Tests

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

Table 4-21
Size of Galvanized Steel Armor Wire for Cables for Division I Applications, Including Submarine Cables

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0–0.750	0–19.05	12	109	2.77
0.751–1.000	19.08–25.40	10	134	3.40
1.001–1.700	25.43–43.18	8	165	4.19
1.701–2.500	43.21–63.50	6	203	5.16
2.501 and larger	63.53 and larger	4	238	6.05

Table 4-22
Tolerances in Diameter

Nominal Diameter of Coated Wire		Tolerances, mils
mm	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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4.7.11.2 JUTE SERVING OVERALL

If jute serving overall is required, it shall be in accordance with 4.7.10.

4.7.12 Core Covering for Nonsheathed and Nonjacketed Cable With Metallic Armor

4.7.12.1 CORE COVERING FOR NONSHEATHED AND NONJACKETED CABLE

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.

4.7.12.2 COMPOUND-FILLED TAPE

The tape shall meet the requirements of 4.4.2.1 and 4.4.2.2.

4.7.13 Core Covering for Thermosetting and Thermoplastic Jacketed Cable Under Armor

4.7.13.1 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 4-23.

4.7.13.2 INTERLOCKED ARMOR

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

4.7.13.3 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 4-23.

4.7.14 Thermosetting Coverings over Metallic Sheath

4.7.14.1 THERMOSETTING COVERING

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

The neoprene compound shall meet the following requirements (see 6.12):

Physical Requirements	
Tensile strength, minimum	
psi	1200
kgf/mm^2	0.84
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements	
After air over 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 at rupture, minimum percentage of unaged value	60

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

4.7.14.2 THICKNESS

The average thickness of the thermosetting covering shall be not less than that given in Table 4-24. The

Table 4-23
Thickness of Jute Bedding for Armored Cable

Calculated Diameter of Cable Under Jute Bedding*		Thickness of Jute Bedding					
		Metal Taped Cable		Round Wire Armored Cable			
				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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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 4-24.

Table 4-24
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

4.7.14.3 Thickness of Lead Sheath

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 4-25. The minimum thickness shall be not less than 90 percent of the values given in the table.

Table 4-25
Thickness of Lead Sheath for Cables Having Thermosetting or Thermoplastic Covering 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.

4.7.14.4 Thickness of Aluminum Sheath

If a thermosetting covering is applied over an aluminum sheath, the average thickness of the aluminum sheath shall be as given in Table 4-12.

4.7.15 Thermoplastic Jacket over Metallic Sheath

4.7.15.1 Thermoplastic Jackets

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 4.5.3, or
b. Black polyethylene meeting the requirements given 4.5.4.

4.7.15.2 Thickness

The average thickness of the thermoplastic jacket shall be not less than that given in Table 4-26. The minimum thickness shall be not less than 70 percent of the values given in the table.

4.7.15.3 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 that is at least 10 mils (0.254 mm) larger than the diameter over the sheath but not over 40 mils (1.02 mm) larger. No movement of the 2 inch (50.8 mm) ring shall take place within a period of 1 minute when weight is applied to the upper end of the sample. The weight to be applied shall be equal to 10 pounds per inch (0.18 kgf/mm) of outside diameter of the metallic sheath minus the weight of the prepared sample, rounded off to the nearer half pound.

Table 4-26
Thickness of Thermoplastic Jacket over Metallic Sheath

Calculated Diameter over Sheath		Thickness of Covering	
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

4.7.15.4 Spark Test on Each Length of Cable

The jacket shall withstand the ac spark test voltage given in Table 4-27. 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.

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Table 4-27
Spark-test Voltage for Thermoplastic Jacket

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

4.7.15.5 THICKNESS OF LEAD SHEATH

If a thermoplastic jacket is applied over a lead sheath, the thickness of the lead sheath shall be in accordance with 4.7.14.3.

4.7.15.6 THICKNESS OF ALUMINUM SHEATH

If a thermoplastic jacket is applied over an aluminum sheath, the average thickness of the aluminum sheath shall be the same as that given in Table 4-12.

4.7.16 Thermoplastic Jacket over Metallic Armor

4.7.16.1 THERMOPLASTIC JACKETS

If used, a thermoplastic jacket shall be extruded over the metallic armor and shall fit tightly thereto. It shall be either black or colored polyvinyl chloride meeting the requirements of 4.5.3 or black polyethylene meeting the requirements of 4.5.4.

4.7.16.2 THICKNESS

The average thickness of the thermoplastic jacket shall be not less than that specified in Table 4-28. The minimum thickness shall be not less than 70 percent of the values 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 covering.

4.7.16.3 SPARK TEST ON EACH LENGTH OF CABLE

The jacket shall withstand the ac spark-test voltage given in Table 4-27. The voltage shall be applied between an electrode at the outside surface of the jacket and the metallic armor for not less than 0.15 second.

Division II
ROUND WIRE ARMOR FOR BOREHOLE, SHAFT, AND VERTICAL RISER CABLE

4.7.17 Scope

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

4.7.18 General

The requirements of Division I (4.7.3 through 4.7.16) pertaining to quality of materials, design, and construction, apply also to borehole, 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.

4.7.19 Borehole Cable (Suspended at One End Only)

4.7.19.1 ARMOR

Galvanized round steel wire shall be used for borehole cable.

4.7.19.2 SIZE OF ARMOR WIRE

The size of armor wire shall be as given in Table 4-29.

Table 4-28
Thickness of Thermoplastic Jacket over Metallic Armor

Calculated Diameter of Cable under Thermoplastic 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

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4.7.19.3 Spark Test on Each Length of Cable

The jacket shall withstand the ac spark-test voltage given in Table 4-27. 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.

Table 4-29
Size of Galvanized Steel Armor Wire for Borehole Cable

Calculated Diameter of Cable under Jute Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0–0.750	0–19.05	12	109	2.77
0.751–1.000	19.08–25.40	10	134	3.40
1.001–1.700	25.43–43.18	8	165	4.19
1.701–2.500	43.21–63.50	6	203	5.16
2.501 and larger	63.53 and larger	4	238	6.05

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

4.7.19.3 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."

4.7.20 Shaft Cable

If shaft cable is to be clamped to the shaft structure or wall, the metallic covering used (either tape or wire) shall comply with the requirements of 4.7.3 through 4.7.16. If, during installation, the shaft cable is suspended from one end, galvanized round steel wire armor shall be used.

The size of the armor wires shall be as given in Table 4-30, but the tensile safety factor shall be not less than five.

Table 4-30
Size of Galvanized Steel Armor Wire for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable under Jute Bedding		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0–1.000	0–25.40	12	109	2.77
1.001–1.700	25.43–43.18	10	134	3.40
1.701–2.500	43.21–63.50	8	165	4.19
2.501 and larger	63.53 and larger	6	203	5.16

4.7.21 Vertical Riser Cable (Suspended at One End Only)

4.7.21.1 Nonsheathed Cable for Installation within Buildings

4.7.21.1.1 Size of Armor Wire

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

The tensile safety factor [based on 50,000 psi (35.2 kgf/mm^2)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table should be used.

4.7.21.2 Size of Armor Wire for Sheathed Vertical Riser Cable

The size of armor wire for sheathed vertical riser cable for indoor installation shall be in accordance with 4.7.19.2 for borehole cable, but with a tensile safety factor of not less than four.

4.7.22 Wire-band Serving

If wire-band servings are used 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 4-31.

The wire bands shall be applied sufficiently tightly to prevent their movement along the cable during installation.

Table 4-31
Spacing and Length of Band Servings

Calculated Diameter over the Armor Wire		Maximum Band Spacing		Length of Band	
inches	mm	feet	meters	inches	mm
0–1.500	0–38.10	50	15.2	3	76.2
1.501–2.500	38.13–63.50	35	10.7	4	102.0
2.501 and larger	63.53 and larger	25	7.6	4	102.0

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Division III
ROUND WIRE ARMOR FOR BURIED CABLE

4.7.23 Scope

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

4.7.24 General

The requirements of Division I (4.7.3 through 4.7.16) pertaining to quality of materials, design, and construction apply also to buried round wire armored cables, except as to particular details expressly set forth in the following sections or as otherwise modified.

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

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

The lengths of lay of the armor wires shall be not less than three nor more than twelve times their pitch diameter. This lay shall be used such that the armor will be applied closely without appreciable space between wires.

A jute serving as specified in 4.7.10 shall be applied over the armor.

Table 4-32
Thickness of Jute Bedding and Size of Armor Wire

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

*For cable diameters over 2.500 inches (63.50 mm) where greater strength is desired than is obtainable with No. 6 BWG (203 mils) (5.16 mm) or where the required number of wires exceeds the capacity of the armoring machines, a No. 4 BWG (238 mils) (6.05 mm) wire may be used.

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Part 5
CABLING, FILLERS, AND BINDERS

5.1 ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES

Multiple-conductor cables shall be assembled in accordance with Part 5. Two-conductor shielded cables shall be round.

5.2 MULTIPLE-CONDUCTOR ROUND CABLES

The individual conductors shall be cabled together with 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 of any cable shall not exceed the value calculated from the factor given in the following table. The individual conductor diameter is the calculated overall diameter of that conductor.

Number of Conductors in Cable	Multiplying Factors Based on Calculated Diameter
2	30 times individual conductor diameter
3	35 times individual conductor diameter*
4	40 times individual conductor diameter

*This value also applies to the completed conductor diameter in a triplexed cable.

5.3 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).

For two-conductor shielded cable, see 5.1 and 5.2.

5.4 FILLERS

Fillers shall be used in the interstices of multiple-conductor round cables 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.

If used in cables having moisture-resistant fibrous coverings, fillers shall be moisture resistant.

If used in cables having a sheath or jacket, fillers need not be moisture-resistant.

Fillers shall have no deterious effect on other components in the completed cable.

5.5 BINDER TAPES OR TWINE

A suitable binder shall be applied over the assembled conductors of non-belted cables, except flat twin cables.

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Part 6
TESTING AND TEST METHODS

6.1 SUMMARY OF TESTS REQUIRED

Type of Test	Size and Voltage Rating	Frequency	See Paragraph
A. Routine Tests on Completed Cables			
1. AC voltage	Each size and voltage	Each length	6.2
2. Insulation resistance	Each size and voltage	Each length	6.3
3. Ionization factor	Each size rated over 8000 volts	Each length	6.4
4. DC conductor resistance	Each size and voltage	Each length	6.5
B. Routine Tests on Short Samples of Completed Cable			
1. Dimensional measurements	Each size and voltage	*	6.6–6.11
2. Jackets	...	...	6.12
C. Additional Tests on Samples of Completed Cable, When Required			
1. High-voltage long-time	Each size rated over 8000 volts	*	6.15
2. Bending	Each size and voltage	*	6.16
3. Power factor	Each size rated over 8000 volts	*	6.17
4. Dielectric strength on individual tapes	Each size and voltage	*	6.18
5. Effect of heat	Each size and voltage	*	6.19
6. Horizontal flame	Each size rated 5000 volts and less	*	6.20
7. Melt	Each size rated 5000 volts and less	*	6.21

* Test samples shall be taken in accordance with the following:

Quantity of Completed Cable Ordered		Number of Samples
feet	meters	
Less than 10,000	Less than 3048	0
10,000 or major fraction†	3048 or major fraction	1

†A major fraction is considered to be 5,000 feet (1524 meters), or more.

ROUTINE TESTS ON COMPLETED CABLES

6.2 VOLTAGE TEST

Each length of completed cable shall be subjected to a voltage test. Cables with a shield, sheath, and/or armor shall be tested with these components grounded and without immersion in water.

The test shall be made with an alternating potential from a transformer and generator of ample capacity. The frequency of the test voltage shall be nominally between 25 and 60 Hz and shall have a wave shape approximating a sine wave as closely as possible.

The initially applied ac test voltage shall be not greater than the rated ac voltage of the cable under test 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 20 seconds and not less than 100 percent in 60 seconds.

The length of the electrode for the ac spark test and the speed of the cable through the electrode shall be such that any point of the cable will be in contact with the electrode for at least 1 second.

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6.2.1 Single-conductor Cables

6.2.1.1 Single-conductor cables with a shield and/or sheath shall be tested between the conductor and shield and/or sheath at the specified voltage (see Table 3-4).

6.2.1.2 Single-conductor cables with a jacket (see 4.5) but without a shield or sheath shall be tested at the specified voltage (see Table 3-4) between conductor and ground. The ground shall be provided by immersing the cable in water no longer than necessary to make the test.

6.2.1.3 Single-conductor cables with a braid covering but without a shield or sheath shall be tested at the specified spark-test voltage (see Table 3-7). If a conducting braid is used, the test shall be made prior to the application of the braid.

6.2.2 Multiple-conductor Cables

6.2.2.1 Multiple-conductor cables with a belt shall be tested between conductors at twice the voltage given in Table 3-4 for the thickness of insulation on the individual conductors.

6.2.2.2 Multiple-conductor belted cables with a shield or sheath shall be tested in accordance with 6.2.2.1 and, in addition, shall be tested between conductor and shield or sheath. The test voltage for the latter test shall be 58 percent of the voltage specified in 6.2.2.1, except that for cables rated 5001 volts and higher 133 percent insulation level the test voltage shall be 80 percent of the voltage specified in 6.2.2.1.

6.2.2.3 Multiple-conductor belted cables with a jacket but without a shield or sheath shall be tested in accordance with 6.2.2.1 and, in addition, shall be tested between conductor and ground. The ground shall be provided by immersing the cable in water no longer than necessary to make the test. The test voltage between conductor and ground shall be 58 percent of the voltage specified in 6.2.2.1, except that for cables rated 5001 volts and higher 133 percent insulation level the test voltage shall be 80 percent of the voltage specified in 6.2.2.1.

6.2.2.4 Multiple-conductor belted cables with a braid covering but without a shield or sheath shall be tested at the specified spark test voltage (see Table 3-7) based on the total thickness of the conductor insulation and the belt insulation. If a conducting braid is used, the test shall be made prior to the application of the braid.

6.2.2.5 Multiple-conductor nonbelted cables without a shield shall be tested between conductors and between the conductors and sheath or ground at the specified test voltage (see Table 3-4). The ground for cables with a jacket but without sheath shall be provided by immersing the cable in water no longer than necessary to make the test.

6.2.2.6 Multiple-conductor nonbelted cables with a braid covering but without a shield or sheath shall be tested at the specified spark test voltage (see Table 3-7). If a conducting braid is used, the test shall be made prior to the application of the braid.

6.2.2.7 Multiple-conductor nonbelted cables with individually shielded conductors shall be tested between conductor and shield and/or sheath at the specified test voltage (see Table 3-4). If the cable has a sheath, the sheath shall be electrically connected to the shield.

6.2.3 Cables with Metallic Armor

Single- and multiple-conductor cables shall be tested at 80 percent of the voltage specified in 6.2.1 or 6.2.2.

6.2.4 Sheathed Cables with a Thermosetting or Thermoplastic Covering

Single- and multiple-conductor cables shall be tested at 90 percent of the voltage specified in 6.2.1 or 6.2.2.

6.3 INSULATION RESISTANCE

6.3.1 Test Apparatus

The test apparatus shall consist of a source of constant potential from 100 to 500 volts and such other apparatus as is listed in ASTM D 257.

6.3.2 Test Procedure

The insulation resistance of each conductor in each length of cable shall be measured after the voltage test given in 6.2. Connections shall be made in accordance with Table 6-1. The current shall be measured after a 1-minute electrification with a continuous dc potential of not less than 100 volts nor more than 500 volts, the conductor being negative with respect to the sheath or ground.

6.3.3 Correction Factors

If the temperature at which the test is made differs from 15.6°C (60°F), the measured resistance shall be corrected to the resistance at 15.6°C (60°F) by means of the multiplying factors given in Table 6-2.

For cables tested on reels and not immersed in water, the temperature shall be the mean of the readings of two thermometers, one in the reel cable hole and one in the outer layer of cable, with the thermometer bulbs in contact with the cable.

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6.4 IONIZATION FACTOR

The power factor shall be measured at room temperature at voltages corresponding to 80 and 20 volts per mil of the insulation thickness. This test shall be made with single-phase voltage.

If the test is made at any temperature between 10°C (50°F) and 24°C (75°F), inclusive, each power factor value shall be corrected to the corresponding value at 25°C (77°F) by deducting 4 percent of that value per degree C difference between the actual temperature and 25°C (77°F). If the test is made at a temperature of 25°C (77°F) or above, no correction shall be made.

6.5 DC CONDUCTOR RESISTANCE

The resistance of each conductor in each length of cable shall be measured. When the dc resistance is measured at other than 20°C (68°F) or 25°C (77°F), it shall be corrected by using the multiplying factors given in Tables 6-3 and 6-4.

Factors for temperatures other than those given in the tables shall be obtained by interpolation or shall be calculated from the formula given in the footnotes to Tables 6-3 and 6-4.

The temperature shall be the mean of the readings of two thermometers, one in the cable hole in the reel and one in the outer layer of cable, with the thermometer bulbs in contact with the cable.

If the corrected resistance of any conductor exceeds the value given in 2.6, the test on that length of cable shall be repeated not less than 16 hours later.

Table 6-1
Connections for Insulation Resistance Tests

Types of Cables	Immersed or Dry	Single-Conductor Cable	Multiple-conductor Cable	
			Belted	Nonbelted
Shielded* and sheathed	D	A	...	A
Shielded* and nonsheathed	D	A	...	A
Nonshielded and sheathed	D	A	C	C
Nonshielded and nonsheathed				
Single-conductor jacketed	I	A	...	...
Single-conductor braided	No test	...	...	...
Multiple-conductor jacketed	I	...	C	C
Multiple-conductor braided	D	...	B	B
Shielded over assembly only	D	...	C	C

C—Conductor to ground.

B—Each conductor to all other conductors.

C—Each conductor to all other conductors and to shield, sheath, or ground.

D—Tested dry.

I—Tested while immersed in water.

*Shielded on individual conductors.

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Table 6-2
Temperature Correction Factors for Insulation Resistance

Temperature		Multiplying Factor	Temperature		Multiplying Factor	Temperature		Multiplying Factor
°C	°F		°C	°F		°C	°F	
0	32	0.56	12	...	0.76	...	75	3.5
...	33	0.56	...	54	0.77	24	...	3.6
1	...	0.56	...	55	0.80	...	76	3.8
...	34	0.56	13	...	0.81	25	77	4.3
...	35	0.56	...	56	0.83	...	78	4.6
2	...	0.56	...	57	0.86	26	...	4.9
...	36	0.57	14	...	0.87	...	79	5.0
...	37	0.57	...	58	0.90	...	80	5.4
3	...	0.57	15	59	0.95	27	...	5.7
...	38	0.58	15.6	60	1.0	...	81	5.9
...	39	0.58	16	...	1.1	...	82	6.4
4	...	0.58	...	61	1.1	28	...	6.6
...	40	0.59	...	62	1.2	...	83	6.9
5	41	0.59	17	...	1.3	...	84	7.5
...	42	0.60	...	63	1.3	29	...	7.7
6	...	0.60	...	64	1.4	...	85	8.2
...	43	0.60	18	...	1.5	30	86	9.0
...	44	0.61	...	65	1.5	...	87	9.7
7	...	0.62	...	66	1.7	31	...	10.0
...	45	0.62	19	...	1.7	...	88	11.0
...	46	0.63	...	67	1.8	...	89	12.0
8	...	0.64	20	68	2.0	32	...	12.0
...	47	0.64	...	69	2.1	...	90	13.0
...	48	0.65	21	...	2.3	...	91	14.0
9	...	0.66	...	70	2.3	33	...	14.0
...	49	0.67	...	71	2.5	...	92	15.0
10	50	0.69	22	...	2.7	...	93	16.0
...	51	0.70	...	72	2.7	34	...	16.0
11	...	0.72	...	73	3.0	...	94	18.0
...	52	0.72	23	...	3.1	35	...	19.0
...	53	0.74	...	74	3.3	...	95	19.0

NOTE—Multiplying factors for fractional temperatures shall be interpolated linearly.

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Table 6-3
Temperature Correction Factors for Resistance of Copper Conductors

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

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

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

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

Where—
R_1 = Resistance at 20°C.
R_2 = Measured resistance at test temperature, T_2.
R_3 = Resistance at 25°C.

For more accurate determination of resistance, allowing for different conductivities, see "Copper Wire Tables," NBS HB 100, which is available from the National Technical Information Service, (703) 487-4650 or 5285 Port Royal Rd., Springfield, VA 22161.

Table 6-4
Temperature Correction Factors for Resistance of Aluminum Conductors

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

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

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

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

Where—
R_1 = Resistance at 20°C.
R_2 = Measured resistance at test temperature, T_2.
R_3 = Resistance at 25°C.

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ROUTINE TESTS ON SHORT SAMPLES OF COMPLETED CABLE

6.6 MEASUREMENT OF INSULATION THICKNESS

6.6.1 Single-conductor Cables and Multiple-conductor Nonbelted Cables with Individually Shielded Conductors

6.6.1.1 Cables Having a Diameter over the Insulation of Less Than 0.250 Inch (6.35 mm)

The diameter over the insulation and the diameter of the conductor shall be measured at three places at each end of the cable, and the six measurements shall be averaged. The average thickness of insulation shall be determined in accordance with the following formula:

$$\frac{\text{Average diameter over the insulation} - \text{Average diameter of the conductor*}}{2}$$

*Diameter over the separator if a separator is used over the conductor.

The measurements shall be made with a micrometer caliper having flat sides on both the anvil and the end of the spindle.

6.6.1.2 Cables Having a Diameter over the Insulation of 0.250 Inch (6.35 mm) or Greater

The diameter over the insulation and the diameter of the conductor shall be measured by means of a circumference tape once at each end of the cable in a plane perpendicular to the axis of the cable, and the two measurements shall be averaged. The average thickness of insulation shall be determined in accordance with the following formula:

$$\frac{\text{Average diameter over the insulation} - \text{Average diameter of the conductor*}}{2}$$

*Diameter over the separator if a separator is used over the conductor.

6.6.1.3 Minimum Thickness

The minimum thickness of insulation shall be determined by direct measurement at both ends of the cable.

6.6.2 *Multiple-conductor Nonshielded Cables*

6.6.2.1 Belt Insulation

The diameter over the belt insulation and the corresponding diameter under the belt insulation (i.e., over the core of the insulated conductor assembly) shall be measured by means of a circumference tape once at each end of the cable in a plane perpendicular to the axis of the cable, and the two measurements shall be averaged. The average thickness of the belt insulation shall be determined in accordance with the following formula:

$$\frac{\text{Average diameter over the belt insulation} - \text{Average diameter under the belt insulation}}{2}$$

The minimum thickness of the belt insulation shall be determined by direct measurement at both ends of the cable.

6.6.2.2 Conductor Insulation

The diameter over the conductor insulation and the corresponding diameter of the conductor itself shall be measured by means of a circumference tape once for each conductor at each end of the cable in a plane perpendicular to the axis of the cable (e.g., a 3-conductor cable will require six sets of measurements on each conductor that shall be averaged, and the average thickness of insulation for each conductor shall be determined in accordance with the following formula:

$$\frac{\text{Average diameter over conductor insulation} - \text{Average diameter of the conductor*}}{2}$$

*Diameter over the separator if a separator is used over the conductor.

The minimum thickness of the conductor insulation shall be determined by direct measurement at both ends of the cable.

6.7 THICKNESS OF JACKETS

6.7.1 Thermoplastic Jacket

The thickness shall be measured with any type of micrometer reading to 0.001 inch and suitable for measurements of this character or by means of an optical micrometer.

The thermoplastic 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.

6.7.2 Reinforced Neoprene Jacket

The average thickness shall be determined by the use of a diameter tape and shall be considered as one-half

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of the difference in measurement under and over the jacket.

The minimum thickness shall be measured directly with a micrometer.

6.8 THICKNESS OF TAPES

6.8.1 Compound-filled Tape

Compound-filled tape, when not bonded to the underlying material, shall be removed from no less than 6 inches (152 mm) of the insulated conductor or assembled core. The thickness of the tape shall be determined by means of a dial micrometer having a presser foot 0.25 inch (6.35 mm)±0.01 inch in diameter and exerting a total force of 85 grams, the load being applied by means of a weight. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

6.8.2 Metallic Shielding Tape or Steel Tape

Metallic shielding tape or steel tape shall be removed from 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 surface 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.

6.9 MEASUREMENTS OF BRAIDS

The average diameter under the braid shall be measured with a suitable micrometer or diameter tape.

The number of carriers and the number of ends per carrier shall be determined by examination of the braid.

The number of picks per inch shall be determined on a 4 inch (102 mm) specimen, after wiping the outside of the braid with chloroform.

The angle of the braid shall be determined by the formula:

$$\text{Tangent of the angle} = \frac{2\pi P(D+T)}{C}$$

Where –

P = Picks per inch

D = Diameter under braid in inches.

T = Thickness of braid in inches = 2t.

t = Diameter of one end of cotton,

$$\text{inches} = \frac{0.0279K}{\sqrt{S}}$$

S = Cotton size.

C = Number of carriers.

K = Cabling factor for plied yarns as follows:

2 ply—1.60

3 ply—2.00

4 ply—2.36

A specimen of braid approximately 2 inches (50.8 mm) long shall be carefully slit and removed from the completed cable and immersed in chloroform or some other suitable solvent for 5 minutes. The solvent shall be decanted and the operation repeated until the cotton is substantially free of saturating and finishing material. This specimen shall then be dried by pressing it between blotting papers. The specimen shall be measured by means of a dial micrometer having a presser foot 0.4 inch (10.2 mm) in diameter and exerting a weight on the sample of 50 grams. Five readings shall be taken at different points on a specimen, and the average of these readings shall be taken as the thickness of the braid. In the case of a double braid, each braid shall be removed and measured separately.

6.10 THICKNESS OF METALLIC SHEATHS

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

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

6.11 THICKNESS OF JUTE BEDDINGS AND SERVINGS

The thickness of jute bedding under the armor shall be determined by the use of a diameter tape and shall be considered as ½ of the difference in the measurements under and over the serving. The measurement in each case shall be the average of five readings taken at different points along the serving.

6.12 TESTS FOR JACKETS

Jackets shall be tested in accordance with the following paragraphs in the ICEA S-19-81/NEMA Standards Publication WC 3 for *Rubber-insulated Wire and Cable*:

a. Thermoplastic Jackets . . . . . 6.4.15 and 6.19

b. Thermosetting Jackets 6.4

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ADDITIONAL TESTS ON SAMPLES OF COMPLETED CABLE, WHEN REQUIRED (SEE 6.1)

6.13 ARMORED CABLES

In the case of armored cables, these tests shall be made before armoring.

6.14 LENGTH OF SAMPLES

The effective length of the samples under test (exclusive of the ends) shall be as follows:

a. High-voltage long-time test – not less than 30 feet (9.14 meters).
b. Bend test and power factor test – not less than 10 feet (3.05 meters) not more than 20 feet (6.10 meters) for each test.

See Table 6-5 for a sample calculation of the total length of the various samples.

6.15 HIGH-VOLTAGE LONG-TIME TEST

This test shall be made on samples at room temperature in accordance with the procedure given in 6.2.

6.16 BEND TEST FOR METALLIC-SHEATHED CABLES

6.16.1 Lead-sheathed Cables

A sample of lead-sheathed cable shall be selected for this test. If the cable has a supplementary covering over the lead sheath, the sample may be selected either before or after the application of the covering. If selected after application of the covering, the covering shall be removed before making the test. The test shall be made at room temperature.

6.16.1.1 METHOD OF BENDING SAMPLES

The samples shall be bent 180 degrees around a cylindrical form having a diameter in accordance with Table 6-6. The sample shall then be straightened and bent 180 degrees in the opposite direction around the same or a similar form and again straightened. This cycle of operation shall be performed twice, making a total of four bending operations. The cable shall be held during the bending operations so that it cannot revolve around its own axis. The ends of the sample shall not be sealed.

6.16.1.2 METHOD OF MEASURING DEFORMATION

While the cable is straightened out prior to the last bending operation, it shall be possible to slip over the cable without damaging it, a rigid caliper having an 18 inch (0.457 meter) face and an internal dimension that is 20 percent larger than the normal diameter of the cable; however, in no case shall the internal dimension of the caliper be less than ¼ inch (6.35 mm) larger than the normal diameter of the cable.

6.16.1.3 RESULTS OF BENDING TEST

6.16.1.3.1 METHOD OF PHYSICAL EXAMINATION

After the last bending operation and while the cable is still bent, three adjacent pieces, each approximately 1 foot (0.3048 meter) long, shall be cut from the center of that portion of the sample that has been subjected to the most bending. The deformation shall be measured on the center 1 foot (0.3048 meter) piece (see 6.16.1.3.2). The insulation and lead sheath thicknesses shall be measured.

The outer covering shall then be stripped from all three pieces. The insulation shall be removed, one tape at a time, and carefully examined for damage, particularly for torn tapes.

6.16.1.3.2 DEFORMATION MEASUREMENT

The deformation shall be measured on the center 1 foot (0.3048 meter) specimen selected in accordance with 6.16.1.3.1 before it is dissected. This specimen is presumed to have been subjected to the most bending and, therefore, to show the greatest distortion. This specimen shall be cut carefully so that the ends are smooth and perpendicular to the axis of the cable.

6.16.1.3.3 MEASUREMENT OF INSULATION THICKNESS

The maximum and minimum thickness of the insulation shall be determined at each end of the bent center specimen by scale measurement.

6.16.1.3.4 MEASUREMENT OF LEAD SHEATH THICKNESS

A ring of sheath shall be carefully removed from the bent center specimen after the thickness of the insulation has been measured. The thickness of the sheath shall be measured with a suitable micrometer caliper at not less than ten points spaced approximately equally around the circumference. Care shall be taken to select the thickest and thinnest parts as nearly as can be determined by visual inspection.

6.16.2 Aluminum-sheathed Cables

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Table 6-5
Length of Test Samples

Rated Voltage of Cable, kV	Length of Test Sample							
	Bending Test		Power Factor Test		High-Voltage Long-time Test		Total	
	feet	meters	feet	meters	feet	meters	feet	meters
8.0 and less	13	3.96	...	...	...	...	13	3.96
Over 8.0	17	5.18	13	3.96	35	10.67	65	19.81

Table 6-6
Diameter of Cylindrical Form for Bending Tests

Single-conductor Cables and Nonbelted Multiple-conductor Cables, Shielded or Nonshielded

Thickness of Conductor Insulation		Diameter of Cylindrical Form as a Multiple of the Cable Diameter *					
		inches	mm	inches	mm	inches	mm
mils	mm	0–0.750	0–19.05	0.751–1.500	19.08–38.10	Over 1.500	Over 38.10
155 and less	3.94 and less	8	8	10	10	12	12
170 to 310	4.32 to 7.87	10	10	11	11	12	12
Over 310	Over 7.87	11	11	12	12	12	12

Multiple-conductor Belted Cables

Outside Diameter		
inches	mm	Diameter of Cylindrical Form as a Multiple of the Cable Diameter*
1.000 and less	25.4 and less	8
1.001–1.500	25.43–38.10	10
Over 1.500	Over 38.10	12

*Flat twin cables shall be bent on the minor axis only, and the minor diameter shall be used in computing the bending diameter.

6.17 POWER FACTOR TESTS

6.17.1 Voltage and Temperature

The power factor of the insulation shall be measured at the rated phase-to-phase voltage at the following three temperatures in the order given:

a. Room Temperature.
b. Temperature approximately midway between room temperature and the maximum conductor temperature.
c. Maximum conductor temperature (see Table 3-3).

6.17.2 Frequency and Wave Form

The frequency of the test voltage shall be between 25 and 60 Hz, inclusive, and shall have a wave shape approximating a sine wave as closely as possible. The source of power and the testing equipment shall have ample capacity.

6.18 DIELECTRIC STRENGTH OF INDIVIDUAL TAPES

Tests shall be made on tapes removed from the completed cable.

Not less than five tapes (unless the cable has fewer than five tapes, in which case all tapes shall be taken) nor more than ten tapes shall be taken from any one sample of cable. The tapes shall be selected so that they are as representative as possible of all of the tapes used.

Five tests at room temperature and five tests at 85°C shall be made on each tape so selected. The dielectric strength shall be tested in accordance with the step-by-step method described in ASTM D 295, except as specifically covered in this standard. The starting voltage shall be as given in Table 6-7. Test results at each temperature shall be averaged separately.

6.19 EFFECT OF HEAT

The varnished cloth tape shall be placed in petrolatum heated to 150°C±1°C and maintained at that temperature for 15 minutes. The tape shall be removed, allowed to cool to room temperature, and examined.

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Table 6-7

Temperature	Starting Voltage Stress, Volts Per Mil
Room	650
85°C	475

6.20 HORIZONTAL FLAME TEST

See Underwriters Laboratories, Inc. *Standard for Varnished-cloth Wire and Cable,* UL 133.

6.21 MELT TEST

A 6 inch (15.2 mm) sample of the finished cable shall be wrapped with a piece of clean white glazed paper, except for 1 inch (25.4 mm) at each end of the cable. The cable shall be suspended horizontally by its ends in an electrically heated oven that is equipped with a suitable automatic temperature control and that has been heated to between 148°F and 152°F (64.2°C and 66.7°C). The cable shall be allowed to remain in the oven for ½ hour and shall then be allowed to cool.

The paper shall not adhere to the cable nor shall the compound have become sufficiently fluid to be transferred to the paper. A slight discoloration of the paper shall not be regarded as a transfer of the compound provided that there is no perceptible ridge of compound on the paper.

6.22 RETESTS FOR TESTS ON SAMPLE

(See exception in 6.12.)

6.22.1 If all of the samples pass the tests described in Part 6, the lot of cable that they represent shall be considered as meeting the requirements of this standard.

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

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

6.23 VOLTAGE TESTS AFTER INSTALLATION

If metallic-armored (except submarine cable), metallic-sheathed or shielded cables, or cables installed entirely on insulators are tested after installation, they shall be tested immediately with an ac or dc test voltage.

The ac test voltage shall not exceed 80 percent of the test voltage given in Table 3-4 applied for the specified time. For cables rated 600 volts or less, this test voltage shall not exceed 2000 volts.

The dc test voltage shall be 2.0 times the applicable ac test voltage provided the temperature of the cable does not exceed 25°C (77°F). If the temperature exceeds 25°C (77°F), the multiplying factor of 2 shall be reduced by 0.013 for each degree in excess of 25°C (77°F).

6.23.1 AC Voltage Test

This test shall be made with 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 Hz and shall have a wave shape approximating a sine wave as closely as possible.

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

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

6.23.2 DC Voltage Test

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

The initially applied dc voltage shall be not greater than 2.0 times the rated ac voltage of the cable.

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

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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 METAL-CLAD CABLES WITH GROUNDING CONDUCTOR

7.1.1 Scope

This section covers two-, three-, and four-conductor varnished-cloth-insulated interlocked armored metal-clad cables with an uninsulated grounding conductor. Circuit conductors shall be size 4 AWG through 1000 kcmil if of copper, and size 2 AWG through 1000 kcmil if of aluminum. The cable constructions shall be:

Type A – Varnished-cloth-insulated circuit conductors, interlocked armored, rated not more than 28,000 volts at the 100 percent insulation level and 21,000 volts at the 133 percent insulation level, for use in dry locations.

Type B – Varnished-cloth-insulated and jacketed circuit conductors, interlocked armored, rated not more than 28,000 volts at the 100 percent insulation level and 21,000 volts at the 133 percent insulation level, for use outdoors or in damp locations above ground.

Type C – Varnished-polyester-glass-cloth insulated and jacketed circuit conductors, interlocked armored, rated not more than 5000 volts, for use outdoors or in damp locations above ground.

7.1.2 Conductors

Insulated circuit conductors and the grounding conductor shall be made of copper or aluminum and shall meet the requirements given in Part 2. The grounding conductor shall consist of one or more sections. The minimum size of the grounding conductors shall be as given in Table 7-1.

7.1.3 Insulation

The varnished-cloth insulation shall meet the requirements given in Part 3. For Type A and B cables, the thickness shall be in accordance with Table 3-1. For Type C cables, the thickness shall be in accordance with Table 7-2. The minimum thickness shall be not less than 90 percent of the thickness given in the tables.

7.1.4 Shielding

Shielding in the form of metallic tapes shall be used over the insulation of cables having a three-phase line voltage above 5000 volts. In the case of systems other than three phase, the voltage to ground shall be multiplied by 1.73 and the resulting voltage used to determine if shielding is required. Shielding tape and its application shall be in accordance with Part 4.

7.1.5 Covering for Unshielded Type A Cables

A tape or braid shall be applied over the insulation of unshielded Type A cables. Braids and tapes shall be in accordance with Part 4.

Table 7-1
Minimum Grounding Conductor Size

Power Conductor Size AWG or kcmil		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
3/0–250	250–400	4	2
300–400	500–600	3	1
500–700	700–1000	2	1/0
750–1000		1	

Table 7-2
Insulation Thicknesses for Type C Metal-clad Cables

Rated Circuit Voltage, Phase-to-Phase, Volts	Conductor Size, AWG or kcmil	Insulation Thickness	
		mils	mm
0–600	4–4/0	45	1.14
0–600	213–750	60	1.52
601–1000	4–750	60	1.52
1001–3000	4–750	80	2.03
3001–5000	4–750	110	2.79

7.1.6 Jacket for Type B and C Cables

A polyvinyl chloride jacket shall be applied over the insulation of nonshielded Type B and C cables and over the shielding of shielded Type B cables. The jacket shall be in accordance with 4.5.3. The average thickness shall be not less than that given in Table 7-3. The minimum thickness on Type B cables shall be not less than 70 percent of the average thickness and, on Type C cables, shall be not less than 90 percent of the average thickness.

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7.1.7 Assembly

The insulated circuit conductors and the uninsulated grounding conductor shall be cabled together with or without fillers. The lay shall be in accordance with Part 5. A suitable binder shall be applied over the assembly.

7.1.8 Armor

An interlocked metal armor meeting the requirements of 4.7.7 shall be applied over the assembly.

7.1.9 Electrical Tests on Completed Cable

The cable shall be tested in accordance with 6.2 through 6.5.

The ac test voltage for Types A and B cables shall be 80 percent of the voltage given in Table 3-4, and for Type C cables shall be the voltage given in Table 7-4.

The insulation resistance for Types A and B cables shall be not less than 80 percent of the value given in Table 3-6 and for Type C cable shall be not less than the value given in Table 7-5.

The ionization test voltages for Types A and B cables rated over 8000 volts shall be based on the thickness of the insulation. (This test does not apply to Type C cables.)

Table 7-3
Thickness of Jacket for Type B and C Metal-clad Cables

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
0–0.425	0–10.79	45	1.14
0.426–0.700	10.82–17.78	60	1.52
0.701–1.050	17.81–26.67	80	2.03
1.051–2.400	26.70–60.96	95	2.41

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Table 7-4
AC Test Voltage, kV, for Type C Metal-clad Cables

Conductor Size, AWG or kcmil	Thickness of Insulation on Individual Conductors			
	45 mils (1.14 mm)	60 mils (1.52 mm)	80 mils (2.03 mm)	110 mils (2.79 mm)
4	4.0	5.0	6.4	13.0
3	4.0	5.0	6.4	13.0
2	4.0	5.0	6.4	13.0
1	4.8	6.0	6.8	13.0
1/0	4.8	6.0	6.8	13.0
2/0	4.8	6.0	6.8	13.0
3/0	4.8	6.0	6.8	13.0
4/0	4.8	6.0	6.8	13.0
250	...	7.2	9.2	13.0
300	...	7.2	9.2	13.0
350	...	7.2	9.2	13.0
400	...	7.2	9.2	13.0
450	...	7.2	9.2	13.0
500	...	7.2	9.2	13.0
600	...	9.2	9.2	13.0
700	...	9.2	9.2	13.0
750	...	9.2	9.2	13.0

Table 7-5
Minimum Insulation Resistance for Type C Metal-clad Cables, Megohms – 1000 Feet at 15.6°C (60°F)

Conductor Size, AWG or kcmil	Thickness of Insulation on Individual Conductors			
	45 mils (1.14 mm)	60 mils (1.52 mm)	80 mils (2.03 mm)	110 mils (2.79 mm)
4	355	455	570	725
3	325	415	520	655
2	290	375	475	610
1	260	335	425	555
1/0	235	305	390	505
2/0	210	275	350	460
3/0	190	245	320	420
4/0	170	220	285	380
250	...	205	270	355
300	...	190	245	325
350	...	175	230	305
400	...	165	215	285
450	...	160	205	270
500	...	150	195	260
600	...	140	180	240
700	...	130	170	225
750	...	125	160	220

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Part 8*
APPENDICES

Appendix A
ABBREVIATIONS AND SYMBOLS

ac – alternating current (adjective)
kg – kilogram(s)
AWG – American Wire gauge
kgf – kilogram force
BWG – Birmingham wire gauge
km – kilometer(s)
C – Celsius (centigrade)
kV – kilovolt(s)
CM – circular mils
kcmil – thousands of circular mils
dc – direct-current (adjective)
mm – millimeter(s)
F – Fahrenheit
psi – pounds per square inch
Hz – hertz (electrical frequency in cycles per second)
% – percent
± – plus or minus

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Appendix B
REPRESENTATIVE TENSILE STRENGTH AND ELONGATION OF NONMAGNETIC METALS

Metal	Tensile Strength		Elongation 2-inch (50.8 mm) Length, Percent
	psi	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	82,000–9,0000	57.7–63.3	50
Zinc	20,000	14.1	60

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

C1.1 MAXIMUM CONDUCTOR TEMPERATURE – OPERATING

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

C1.2 MAXIMUM CONDUCTOR TEMPERATURE – EMERGENCY OVERLOAD

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

C1.3 MAXIMUM CONDUCTOR TEMPERATURE – SHORT CIRCUIT

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

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Appendix D
SHIELDING

D1.1 DEFINITION OF SHIELDING

Shielding of an electric power cable is the practice of confirming the dielectric field of the cable to the insulation of the conductor or conductors.

D2.1 FUNCTIONS OF SHIELDING

D2.1.1 To be effective, shielding must adhere to or remain in intimate contact with the insulation under all conditions.

D2.1.2 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.

D3.1 USE OF INSULATION SHIELDING

D3.1.1 The use of shielding involves consideration of installation and operating conditions. Definite rules cannot be established on a practical basis for all cases, but the following features should be considered as a working basis for the use of shielding.

D3.1.2 Where there is no metallic covering or shield over the installation, the electric field will be 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 that may be destructive to insulations and to protective jackets. If the surface of the cable is separated from ground by a thin layer of air and the air gap is subjected to a voltage stress that exceeds the dielectric strength of air, a discharge will occur, causing ozone formation.

D3.1.3 The ground may be either a metallic conduit, a damp nonmetallic conduit or a metallic binding tape or rings on an aerial cable, a loose metallic sheath, etc. Likewise, damage to nonshielded cable may result when the surface of the cable is moist or covered with soot, soapy grease, or other conducting film and the external field is partly confined by such conducting film so that the charging current is carried by the film to some spot where it can discharge to ground. The resultant intensity of discharge may be sufficient to cause burning of the insulation or jacket.

D3.1.4 Where nonshielded jacketed cables are used in underground ducts containing several circuits that must be worked on independently, the external field if sufficiently intense can cause shocks to those who handle or contact energized cable. In cases of this kind, it may be advisable to use shielded cable. Shielding used to reduce hazards of shock should have a resistance low enough to operate protective equipment in case of fault. In some cases, the efficiency of protective equipment may require proper size ground wires as a supplement to shielding. The same considerations apply to exposed installations where cables may be handled by personnel who may not be acquainted with the hazards involved.

D4.1 GROUNDING OF THE INSULATION SHIELD

D4.1.1 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.

D4.1.2 The shield should operate at or near ground potential at all times. Frequent grounding of shields reduces the possibility of open sections on nonmetallic covered cable. Multiple grounding of shields is desirable in order to improve the reliability and safety of the circuit. All grounding connections should be made to the shield in such a way as to provide a permanent low resistance bond. Shielding that does not have adequate ground connections due to discontinuity of the shield or to improper termination may be more dangerous than nonshielded nonmetallic cable and hazardous to life.

D5.1 SHIELD MATERIALS

Two distinct types of materials are employed in constructing cable shields:

D5.1.1 Nonmetallic shields consist of a conducting tape. The tape may be conducting compound, fibrous tape faced or filled with conducting compound, or conducting fibrous tape.

D5.1.2 Metallic shields should be nonmagnetic and may consist of tape, braid, or a sheath.

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D6.1 SPLICES AND TERMINATIONS

The insulation shields must be removed completely at splices and terminations, otherwise excessive current and flashover will result.

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Appendix E
MINIMUM BENDING RADIUS FOR CABLES

E1.1 SCOPE

This appendix contains the minimum values for the radius to which varnished-cloth-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 the axis of the cable. For the drum diameter of reels, see Appendix G.

E2.1 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 given in Tables E-1 and E-2.

E3.1 POWER CABLES WITH METALLIC SHIELDING OR ARMOR

E3.1.1 Interlocked Armored Cables

The minimum bending radius for all interlocked armored cables except shielded is seven times the overall diameter of the cable.

E3.1.2 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.

E3.1.3 Tape Shielded Cables

The minimum bending radius for all cables with metallic shielding is twelve times the overall diameter of the completed cable.

Table E-1
Single-conductor and Multiple-conductor Nonbelted Cables*

		Overall Diameter of Cable					
		inches	mm	inches	mm	inches	mm
Thickness of Conductor Insulation		0.750 and less	19.05 and less	0.751 to 1.500	19.08 to 38.10	Over 1.500	Over 38.10
mils	mm	Minimum Bending Radius as a Multiple of Cable Diameter					
155 and less	3.94 and less	5		6		7	
170–315	4.32–7.99	6		6½		7	
Over 315	Over 7.99	6½		7		7	

*Flat twin cable shall be bend on the minor axis only, and the minor diameter shall be used in computing the bending radius.

Table E-2
Multiple-conductor Belted Cables

Outside Diameter		Minimum Bending Radius as a Multiple of Cable Diameter
inches	mm	
Under 1.000	Under 25.40	5
1.001–1.500	25.43–38.10	6
Over 1.500	Over 38.10	7

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Appendix F
MINIMUM INSTALLATION TEMPERATURE

The minimum temperature at which the cable should be installed is –10°C (14°F).

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Appendix G
MINIMUM DRUM DIAMETERS OF REELS*

*Excerpted from *Wire and Cable Packaging*, NEMA Standards Publication No. WC 26.

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	14
b. Over 2000 volts	
1. Nonjacketed with concentric wires	...
2. All others	14
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 0.85	
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	...
0.51–1.00	...
1.01–1.25	...
1.26–1.50	...
Over 1.50	...

†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 H
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 USA.

Publication No. and Year	Title
A90-81 (R 1987)	*Tests for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles*
B 3-74 (R 1985)	*Specification for Soft or Annealed Copper Wire*
B 8-86	*Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard or Soft*
B 29-79 (R 1984)	*Specification for Pig Lead*
B 33-81 (R 1985)	*Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes*
B 189-81 (R 1985)	*Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes*
B 226-71 (R 1985)	*Specification for Cored, Annular, Concentric-Lay-Stranded Copper Conductors*
B 230-85	*Specification for Aluminum 1350-H19 Wire for Electrical Purposes*
B 323-61(1969)	*Specification for Aluminum Wire, EC-H14 or -H24, for Electrical Purposes*
B 400-86	*Specification for Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductors*
B 496-81 (R 1985)	*Specification for Compact Round Concentric-Lay-Stranded Copper Conductors*
B 609 (R 1985)	*Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes*
D 257-78 (R 1983)	*Tests for D-C Resistance or Conductance of Insulating Materials*
D 295-84 (R 1984)	*Testing Varnished Cotton Fabrics and Varnished Cotton Fabric Tapes Used for Electrical Insulation*
D 2400-84	*Specification for Varnished Glass-Polyester Cloth Used for Electrical Insulation*
E 8-88	*Tension Testing of Metallic Materials*

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist purchasers in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

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

(Standardization Policies and Procedures, p. 2)

Dimensions

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

(Standardization Policies and Procedures, p.8)

Categories of Standards

National Electrical Manufacturers Association Standards are of two classes:

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

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

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

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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