

**ANSI/ICEA S-75-381
NEMA WC 58**

*PORTABLE AND POWER FEEDER CABLES FOR
USE
IN MINES AND SIMILAR APPLICATIONS*

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Portable and Power Feeder Cables for Use in Mines and Similar Applications

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FOREWORD

This Standards Publication for Mining Cable was developed by the Insulated Cable Engineers Association, Incorporated (ICEA) and was approved by the National Electrical Manufacturers Association (NEMA).

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

Requests for interpretation of this Standard must be submitted in writing to:

Insulated Cable Engineers Association, Inc.
P.O. 1568
Carrollton, GA 30112

An official interpretation will be made by the Association.

Suggestions for improvement gained in the use of this publication will be welcomed by the Association.

Working Group Members:

Barry L. Fisher

David L. Fox (deceased)

Mark A. Fuller

L. Drayton Land

Marcel Levitre

Frank LeGase

IN MEMORY

The rewriting of this standard was initiated and diligently pursued by Mr. David Fox of AmerCable Inc. Through his efforts and countless hours invested, publishing of this work was made possible. We would like to both remember David and thank David's family, wife Lis and daughter Stephanie, for the valuable contribution he made to our industry and in the development of this specification.

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ADDITIONAL CONDUCTOR INFORMATION

Section 1 GENERAL

1.1 SCOPE

These standards apply to materials, construction, and testing of insulated cables used for the utilization of electrical energy in surface and underground mines and similar applications. Included are portable cables for use in mining machines, dredges, shovels and similar equipment, and mine power cables for use as connections between units of mine distribution systems. The cables are of the following types:

PORTABLE CABLES 2000 VOLTS OR LESS

Type	W without grounding conductors
Type	G with grounding conductors
Type	G-GC with grounding conductors and one ground-check conductor
Type	G-CGC with grounding conductors and one ground-check conductor in center
Type	PG with single grounding conductor
Type	PCG with single grounding conductor and two control conductors
Type	SHC-GC multiconductor with grounding conductors, one ground check conductor and overall shield
Type	SHD-PCG multiconductor with individually shielded power conductors, center grounding conductor, and one or more control conductors.
Type	SHD Flat multiconductor with individually shielded power conductors, and grounding conductors covered with a conducting extrusion layer.

PORTABLE CABLES 2001–5000 VOLTS (100% INSULATION LEVEL)

Type	G with grounding conductors
Type	SHD-PCG multiconductor with individually shielded power conductors, center grounding conductor, and one or more control conductors.

PORTABLE CABLES 0–25000 VOLTS (100% INSULATION LEVEL)

Type	SH shielded single conductor
Type	SHD with individually shielded power conductors and grounding conductors
Type	SHD-GC with individually shielded power conductors, grounding conductors, and one ground-check conductor
Type	SHD-CGC with individually shielded power conductors, grounding conductors, and one ground-check conductor in center

MINE POWER 2001–25000 VOLTS (100% AND 133% INSULATION LEVEL)

Type	MP with individually shielded power conductors and grounding conductors
Type	MP-GC with individually shielded power conductors, grounding conductor, and one ground-check conductor

1.2 GENERAL INFORMATION

The information in this publication is divided into six sections including two supplements. Sections 3 and 4 cover portable and mine power cables, respectively, with either crosslinked polyethylene or ethylene propylene rubber insulations for phase conductors, plus ground-check conductor insulations. Section 5 covers portable arc welding cables. Section 6 covers test methods.

In this standard, temperatures are expressed in degrees Celsius, masses in grams, liquid volumes in cubic centimeters, and metal resistivities in nanoohm-meter. Other properties are expressed in non-metric units used in the U.S.A.

The Fahrenheit equivalents to degrees Celsius may be calculated by the equation $^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$. The ounce equivalents to grams may be calculated by dividing the number of grams by 28.35. The liquid ounce equivalent to cubic-centimeters may be calculated by dividing cubic centimeters by 29.57. The ohm-circular mil per foot equivalent of nanoohm-meter may be calculated by multiplying nanoohm-meter by 0.602.

Room temperature is defined as $23 \pm 5^{\circ}\text{C}$. Where this temperature cannot be maintained, test measurements may be made at the prevailing ambient room temperature, which shall be recorded.

Conductor size is expressed by cross-sectional area in thousand circular mils (kcmil). For convenience, in the text and several tables, only the equivalent AWG size is used for 211.6 kcmil (4/0 AWG) and smaller conductors. For the kcmil values of AWG sizes, see Section 2.

To convert values in a non-metric unit to the approximate value in an appropriate metric unit, multiply the value in the non-metric unit by the appropriate number from the following as listed below:

From:	To:	Multiplier:
feet (ft)	meters (m)	0.305
inches (in)	millimeters (mm)	25.4
square inches (in ²)	square millimeters (mm ²)	645
thousand circular mils (kcmil)	square millimeters (mm ²)	0.507
ounces avoirdupois (oz av)	grams (gm)	28.4
pounds per 1000 ft (lb/1000 ft)	kilogram per km (kg/km)	1.49
pounds per square inch (psi)	kilopascals (kPa)	6.89
pounds tension or force per inch (lb/in)	newtons per meter (N/m)	175
ohms per 1000 feet (Ω /1000 ft)	milliohms per meter (m Ω /m)	3.28
kilovolts per inch (kV/in) or (volts per mil or V/mil)	megavolts per meter (MV/m) or kilovolts per millimeter (kV/m)	0.0394
megohms - 1000 feet (M Ω -1000 ft)	megohms-meter (M Ω -m)	305
gigaohms - 1000 feet (G Ω -1000 ft)	gigaohms-meter (G Ω -m)	305

1.3 INFORMATION TO BE SUPPLIED BY USER

When requesting proposals from cable manufacturers, the prospective user should describe the cable in reference to pertinent sections of these standards. To help avoid misunderstanding and possible misapplication of cable, he should also provide pertinent information concerning the intended application.

Section 2 CONDUCTORS

Conductors shall meet the requirements of the appropriate ASTM standards referenced in this standard except as noted in 2.1.

2.1 PHYSICAL AND ELECTRICAL PROPERTIES

The conductors used in the cable shall be stranded and shall be copper in accordance with 2.1.1, aluminum in accordance with 2.1.2, or flexible conductors in accordance with 2.1.3, as applicable except cross-sectional area compliance shall be determined by resistance as noted in 2.3. Diameters shall be in accordance with 2.4. The outer layer of an uncoated stranded copper conductor may be tin coated to obtain free stripping of an adjacent polymeric layer.

2.1.1 Copper Conductors

ASTM B 3 for Soft or Annealed Uncoated Copper.
ASTM B 5 for Electrical Grade Copper.
ASTM B 8 for Class B, C, or D Stranded Copper Conductors.
ASTM B 33 for Soft or Annealed Tin-Coated Copper Wire.
ASTM B 193 Test for Resistivity of Electrical Conductor Materials
ASTM B 496 for Compact-Round Stranded Copper Conductors.
ASTM B 784 for Modified Concentric Lay Stranded Copper Conductor.
ASTM B 785 for Compact Round Modified Concentric Lay Stranded Copper Conductor.
ASTM B 787 for 19 Wire Combination Unilay-Stranded Copper Conductors.
ASTM B 835 for Compact Round Stranded Copper Conductors Using Single Input Wire Constructions.

2.1.2 Aluminum Conductors

ASTM B 230 for Electrical Grade Aluminum 1350-H19
ASTM B 231 for Class B, C, or D Stranded Aluminum 1350 Conductors.
ASTM B 233 for Electrical Grade Aluminum 1350 Drawing Stock
ASTM B 400 for Compact-Round Stranded Aluminum 1350 Conductors
ASTM B 609 for Electrical Grade Aluminum 1350 Annealed and Intermediate Tempers
ASTM B 786 for 19 Wire Combination Unilay-Stranded Aluminum 1350 Conductors.
ASTM B 800 for 8000 Series Aluminum Alloy Annealed and Intermediate Tempers.
ASTM B 801 for 8000 Series Aluminum Alloy Wires, Compact-Round, Compressed And Concentric-Lay Class B, C and D Stranded Conductors.
ASTM B 836 for Compact Round Stranded Aluminum Conductors Using Single Input Wire Constructions

2.1.3 Flexible Conductors

ASTM B 172 for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members for Electrical Conductors
ASTM B 173 for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members for Electrical Conductors
ASTM B 174 for Bunch-Stranded Copper Conductors for Electrical Conductors

2.2 CONDUCTOR SIZE UNITS

Conductor size shall be expressed by cross-sectional area in thousand circular mils (kcmil). The AWG equivalents for small sizes shall be found in Table 2-5. The metric equivalents for all sizes are found in Table 2-5 (Metric).

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2.3 CONDUCTOR DC RESISTANCE PER UNIT LENGTH

The DC resistance per unit length of each conductor in a production or shipping length of completed cable shall not exceed the value determined from the schedule of maximum DC resistances specified in Table 2-2 when using the appropriate nominal value specified in Table 2-3 and Table 2-4. The DC resistance shall be determined in accordance with 2.3.1 or 2.3.2.

Where the outer layer of an uncoated stranded copper conductor is tin coated, the direct current resistance of the resulting conductor shall not exceed the value specified for an uncoated conductor of the same size.

When a sample is taken from a multiple conductor cable, the resistance shall comply with the appropriate maximum resistance value specified for a single conductor cable.

2.3.1 Direct Measurement of DC Resistance Per Unit Length

The DC resistance per unit length shall be determined by DC resistance measurements made in accordance with ICEA T-27-581/NEMA WC-53 to an accuracy of plus or minus 0.15% percent. If measurements are made at a temperature other than 25 °C, the measured value shall be converted to resistance at 25 °C by using either; (1) the appropriate multiplying factor obtained from ICEA T-27-581/NEMA WC-53 or (2) a multiplying factor calculated using the applicable formula in ICEA T-27-581/NEMA WC-53.

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 foot (0.305 m) long shall be cut from that reel length, and the direct-current resistance of each conductor shall be measured using a Kelvin-type bridge or a potentiometer.

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

2.3.2 Calculation of DC Resistance Per Unit Length

The DC resistance per unit length at 25 °C shall be calculated using the following formula:

$$R = K \frac{\rho}{A}$$

Where:

R = Conductor resistance in $\Omega/1000$ ft. *

K = Weight increment factor, as given in Table 2-1 or calculated per applicable ASTM standard.

ρ = Volume resistivity in $\Omega\text{-kcmil/ft.}$, determined in accordance with ASTM B 193 using round wires

A = Cross-sectional area of conductor in kcmil, determined in accordance with ICEA T-27-581/NEMA WC-53.

*When the volume resistivity is expressed in nanoohm-meter ($n\Omega\text{-m}$) and area is expressed in square millimeters (mm^2) the resistance is expressed in milliohms per meter ($\text{m}\Omega/\text{m}$).

2.4 CONDUCTOR DIAMETER

The conductor diameter shall be measured in accordance with 6.3.3. The diameters shall not differ from the nominal values shown in Table 2-5 by more than ± 2 percent. See the Appendices for diameter information on flexible conductors.

Table 2-1
Weight Increment Factors, K *

Conductor Type/Size	Weight Factor (K)
Concentric-lay Strand, Class B, C and D	
14 AWG - 1000 kcmil	1.02
Combination Unilay Strand	
All Sizes	1.02
Concentric-lay Strand 8000 Series Aluminum	
All Sizes	1.02
Bunch Strand, Single Bunches	
All Sizes	1.02
Rope-lay Strand Having Concentric Stranded Members	
Classes G and H	
49 wires	1.03
133 wires	1.04
259 wires	1.045
427 wires	1.05
Over 427 wires	1.06
Rope-lay Strand Having Bunch Stranded Members	
Classes I, K and M	
7 Bunch Stranded Members	1.04
19 Bunch Stranded Members	1.05
37 Bunch Stranded Members	1.05
61 Bunch Stranded Members	1.05
7 x 7 Bunch Stranded Members	1.06
19 x 7 Bunch Stranded Members	1.07
37 x 7 Bunch Stranded Members	1.07
61 x 7 Bunch Stranded Members	1.07

*Based on the method specified in either ASTM B 8, ASTM B 172, ASTM B 173, ASTM B 174, ASTM B 231, ASTM B 496, ASTM B 400, ASTM B 786, ASTM B 787, or ASTM B 801 as applicable.

Table 2-2
Schedule for Establishing Maximum Direct Current Resistance
Per Unit Length of Completed Cable Conductors listed in Table 2-3 and 2-4

Cable Type	Maximum DC Resistance
Conductors Listed in Table 2-3	
Single Conductor Cables	Table 2-3 ^a Value Plus 2% (R max = R x 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-3 ^a Value Plus 2% Plus One of the following: 2% - One Layer of Conductors (R max = R x 1.02 x 1.02) 3% - More than One Layer of Conductors (R max = R x 1.02 x 1.03) 4% - Pairs or Other Pre-cable Units (R max = R x 1.02 x 1.04)
Conductors Listed in Table 2-4	
Single Conductor Cables And Flat Parallel Cables	Table 2-4 ^a Value Plus 2% (R max = R x 1.02)
Multiple Conductor Cables and Twisted Assemblies of Single Conductor Cables	Table 2-4 ^a Value Plus 2% Plus 5% (R max = R x 1.02 x 1.05)

^a For conductor stranding or sizes not listed in Tables 2-3 and 2-4, the nominal direct current resistance per unit length of a completed single conductor cable shall be calculated using the following formula:

$$R = \frac{f}{A} \times 10^{-3}$$

Where:

R = Conductor resistance in Ω/1000 ft.

f = Factor from Table 2-6 in Ω-kcmil/1000 ft.

A = Nominal cross-sectional area of conductor in kcmil

Table 2-3
Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25 °C
of Concentric Lay Stranded Conductors

Conductor Size		Concentric Lay Stranded *			
AWG or kcmil	Class B,C,D	Aluminum	Copper		
		Class B,C,D	Uncoated	Coated	
			Class B,C,D	Class B	Class C Class D
10	1.70	1.04	1.08	1.08	1.11
9	1.35	0.825	0.856	0.856	0.874
8	1.07	0.652	0.678	0.678	0.680
7	0.851	0.519	0.538	0.538	0.538
6	0.675	0.411	0.427	0.427	0.427
5	0.534	0.325	0.338	0.338	0.339
4	0.424	0.258	0.269	0.269	0.269
3	0.336	0.205	0.213	0.213	0.213
2	0.266	0.162	0.169	0.169	0.169
1	0.211	0.129	0.134	0.134	0.134
1/0	0.168	0.102	0.106	0.106	0.106
2/0	0.133	0.0810	0.0842	0.0842	0.0842
3/0	0.105	0.0642	0.0667	0.0669	0.0669
4/0	0.0836	0.0510	0.0524	0.0530	0.0530
250	0.0707	0.0431	0.0448	0.0448	0.0448
300	0.0590	0.0360	0.0374	0.0374	0.0374
350	0.0505	0.0308	0.0320	0.0320	0.0320
400	0.0442	0.0269	0.0277	0.0280	0.0280
450	0.0393	0.0240	0.0246	0.0249	0.0249
500	0.0354	0.0216	0.0222	0.0224	0.0224

* Concentric lay stranded includes compressed and compact conductors.

Table 2-3 (Metric)
Nominal Direct Current Resistance in Milliohms Per Meter at 25 °C
of Concentric Lay Stranded Conductors

Conductor Size		Concentric Lay Stranded *			
AWG or kcmil	mm ²	Aluminum	Copper		
		Class A,B,C,D	Uncoated	Coated	
			Class B,C,D	Class B	Class C Class D
10	5.26	5.57	3.41	3.54	3.54 3.64
9	6.63	4.42	2.70	2.80	2.80 2.86
8	8.37	3.51	2.14	2.22	2.22 2.23
7	10.6	2.79	1.70	1.76	1.76 1.76
6	13.3	2.21	1.35	1.40	1.40 1.40
5	16.8	1.75	1.07	1.11	1.11 1.11
4	21.1	1.39	0.846	0.882	0.882 0.882
3	26.7	1.10	0.672	0.699	0.699 0.699
2	33.6	0.872	0.531	0.554	0.554 0.554
1	42.4	0.692	0.423	0.440	0.440 0.440
1/0	53.5	0.551	0.335	0.348	0.348 0.348
2/0	67.4	0.436	0.266	0.276	0.276 0.276
3/0	85.0	0.344	0.211	0.219	0.219 0.219
4/0	107	0.274	0.167	0.172	0.172 0.172
250	127	0.232	0.141	0.147	0.147 0.147
300	152	0.194	0.118	0.123	0.123 0.123
350	177	0.166	0.101	0.105	0.105 0.105
400	203	0.145	0.0882	0.0909	0.0918 0.0918
450	228	0.129	0.0787	0.0807	0.0817 0.0817
500	253	0.116	0.0708	0.0728	0.0735 0.0735

Concentric lay stranded includes compressed and compact conductors.

Table 2-4
Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25 °C
For Flexible Annealed Copper Conductors

Conductor Size AWG or kcmil	Uncoated					Coated				
	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
12	1.67	...	...	1.65	1.68	1.77	...	...	1.77	1.81
10	1.05	...	1.04	1.04	1.06	1.11	...	1.08	1.12	1.14
8	0.660	0.666	0.653	0.666	0.666	0.701	0.708	0.679	0.715	0.715
7	0.523	0.528	0.518	0.528	0.533	0.544	0.561	0.539	0.567	0.573
6	0.415	0.419	0.419	0.419	0.423	0.432	0.445	0.436	0.450	0.454
5	0.329	0.332	0.332	0.332	0.336	0.342	0.353	0.346	0.357	0.360
4	0.261	0.263	0.263	0.263	0.266	0.271	0.280	0.274	0.283	0.286
3	0.207	0.209	0.209	0.211	0.213	0.215	0.222	0.217	0.222	0.227
2	0.164	0.166	0.166	0.167	0.169	0.171	0.172	0.172	0.172	0.181
1	0.131	0.132	0.131	0.133	0.134	0.137	0.140	0.137	0.140	0.144
1/0	0.104	0.105	0.105	0.105	0.106	0.108	0.109	0.109	0.113	0.114
2/0	0.0826	0.0830	0.0834	0.0842	0.0850	0.0859	0.0863	0.0868	0.0904	0.0913
3/0	0.0655	0.0659	0.0662	0.0668	0.0674	0.0682	0.0685	0.0688	0.0717	0.0724
4/0	0.0520	0.0522	0.0525	0.0530	0.0535	0.0541	0.0543	0.0546	0.0569	0.0574
250	0.0442	0.0444	0.0448	0.0448	0.0453	0.0460	0.0462	0.0466	0.0481	0.0486
300	0.0368	0.0370	0.0374	0.0374	0.0377	0.0383	0.0385	0.0389	0.0401	0.0405
350	0.0316	0.0317	0.0320	0.0323	0.0323	0.0328	0.0330	0.0333	0.0347	0.0347
400	0.0276	0.0278	0.0280	0.0283	0.0283	0.0287	0.0289	0.0291	0.0304	0.0304
450	0.0246	0.0247	0.0249	0.0251	0.0251	0.0255	0.0257	0.0259	0.0270	0.0262
500	0.0221	0.0222	0.0224	0.0226	0.0226	0.0230	0.0231	0.0233	0.0243	0.0243
550	0.0202	0.0204	0.0204	0.0206	0.0206	0.0210	0.0212	0.0212	0.0221	0.0221
600	0.0185	0.0187	0.0187	0.0189	0.0189	0.0192	0.0194	0.0194	0.0203	0.0202
650	0.0171	0.0172	0.0174	0.0174	0.0174	0.0178	0.0179	0.0181	0.0187	0.0187
700	0.0159	0.0168	0.0162	0.0162	0.0162	0.0165	0.0167	0.0168	0.0174	0.0174
750	0.0148	0.0149	0.0151	0.0151	0.0151	0.0154	0.0155	0.0157	0.0162	0.0162
800	0.0139	0.0140	0.0141	0.0141	0.0141	0.0144	0.0146	0.0147	0.0152	0.0152
900	0.0123	0.0125	0.0126	0.0126	0.0126	0.0128	0.0130	0.0131	0.0135	0.0135
1000	0.0111	0.0112	0.0113	0.0113	0.0113	0.0115	0.0117	0.0118	0.0122	0.0121

Table 2-4 (Metric)
Nominal Direct Current Resistance in Milliohms Per Meter at 25 °C
for Flexible Annealed Copper Conductors

Conductor Size		Uncoated					Coated				
AWG or kcmil	mm ²	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
12	3.31	5.48	...	...	5.41	5.51	5.81	...	...	5.81	5.94
10	5.26	3.44	...	3.41	3.41	3.48	3.64	...	3.54	3.67	3.74
8	8.37	2.17	2.19	2.14	2.19	2.19	2.30	2.32	2.23	2.35	2.35
7	10.6	1.72	1.73	1.70	1.73	1.75	1.78	1.84	1.77	1.86	1.88
6	13.3	1.36	1.37	1.37	1.37	1.39	1.42	1.46	1.43	1.48	1.49
5	16.8	1.08	1.09	1.09	1.09	1.10	1.12	1.16	1.14	1.17	1.18
4	21.1	0.856	0.863	0.863	0.863	0.873	0.889	0.919	0.899	0.928	0.938
3	26.7	0.679	0.686	0.686	0.692	0.699	0.705	0.728	0.712	0.728	0.745
2	33.6	0.538	0.545	0.545	0.548	0.554	0.561	0.564	0.564	0.564	0.594
1	42.4	0.430	0.433	0.430	0.436	0.440	0.449	0.459	0.449	0.459	0.472
1/0	53.5	0.341	0.344	0.344	0.344	0.348	0.354	0.358	0.358	0.371	0.374
2/0	67.4	0.271	0.272	0.274	0.276	0.279	0.282	0.283	0.285	0.297	0.300
3/0	85.0	0.215	0.216	0.217	0.219	0.221	0.224	0.225	0.226	0.235	0.238
4/0	107	0.171	0.171	0.172	0.174	0.176	0.177	0.178	0.179	0.187	0.188
250	127	0.145	0.146	0.147	0.147	0.149	0.151	0.152	0.153	0.158	0.159
300	152	0.121	0.121	0.123	0.123	0.124	0.126	0.126	0.128	0.132	0.133
350	177	0.104	0.104	0.105	0.106	0.106	0.105	0.108	0.109	0.114	0.114
400	203	0.0906	0.0912	0.0919	0.0928	0.0928	0.0942	0.0948	0.0955	0.0997	0.0997
450	228	0.0807	0.0810	0.0817	0.0823	0.0823	0.0837	0.0843	0.0850	0.0886	0.0860
500	253	0.0725	0.0728	0.0735	0.0741	0.0741	0.0755	0.0758	0.0764	0.0797	0.0797
550	279	0.0663	0.0669	0.0669	0.0676	0.0676	0.0689	0.0696	0.0696	0.0725	0.0725
600	304	0.0607	0.0614	0.0614	0.0620	0.0620	0.0630	0.0636	0.0636	0.0666	0.0663
650	329	0.0561	0.0564	0.0571	0.0571	0.0571	0.0584	0.0587	0.0594	0.0614	0.0614
700	355	0.0522	0.0551	0.0531	0.0531	0.0531	0.0541	0.0548	0.0551	0.0571	0.0571
750	380	0.0486	0.0489	0.0495	0.0495	0.0495	0.0505	0.0509	0.0515	0.0531	0.0531
800	405	0.0456	0.0459	0.0463	0.0463	0.0463	0.0472	0.0479	0.0482	0.0499	0.0499
900	456	0.0404	0.0410	0.0413	0.0413	0.0413	0.0420	0.0427	0.0430	0.0443	0.0443
1000	507	0.0364	0.0367	0.0371	0.0371	0.0371	0.0377	0.0384	0.0387	0.0400	0.0400

Table 2-5
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameter (Inch)						
		Concentric Lay Stranded					Combination	Unilay
AWG	kcmil	Compressed	Compact	Class B*	Class C	Class D	Unilay	Compressed
10	10.38	0.113	...	0.116	0.117	0.117	0.113	...
9	13.09	0.126	...	0.130	0.131	0.132	0.127	...
8	16.51	0.142	0.134	0.146	0.148	0.148	0.143	...
7	20.82	0.159	...	0.164	0.166	0.166	0.160	...
6	26.24	0.178	0.169	0.184	0.186	0.186	0.179	...
5	33.09	0.200	...	0.206	0.208	0.208	0.202	...
4	41.74	0.225	0.213	0.232	0.234	0.235	0.226	...
3	52.62	0.252	0.238	0.260	0.263	0.264	0.254	...
2	66.36	0.283	0.268	0.292	0.296	0.297	0.286	...
1	83.69	0.322	0.299	0.332	0.333	0.333	0.321	0.313
1/0	105.6	0.362	0.336	0.373	0.374	0.374	0.360	0.352
2/0	133.1	0.405	0.376	0.419	0.420	0.420	0.404	0.395
3/0	167.8	0.456	0.423	0.470	0.471	0.472	0.454	0.443
4/0	211.6	0.512	0.475	0.528	0.529	0.530	0.510	0.498
	250	0.558	0.520	0.575	0.576	0.576	0.554	0.542
	300	0.611	0.570	0.630	0.631	0.631	0.607	0.594
	350	0.661	0.616	0.681	0.681	0.682	0.656	0.641
	400	0.706	0.759	0.728	0.729	0.729	0.701	0.685
	450	0.749	0.700	0.772	0.773	0.773	0.744	0.727
	500	0.789	0.736	0.813	0.814	0.815	0.784	0.766

* Diameters shown are for concentric round and modified concentric.

Table 2-5 (Metric)
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameter (mm)						
		Concentric Lay Stranded					Combination	Unilay
AWG	mm ²	Compressed	Compact	Class B*	Class C	Class D	Unilay	Compressed
10	5.26	2.84	...	2.95	2.97	2.97	2.87	...
9	6.63	3.20	...	3.30	3.33	3.35	3.23	...
8	8.37	3.58	3.40	3.71	3.76	3.76	3.63	...
7	10.6	4.01	...	4.17	4.22	4.22	4.06	...
6	13.3	4.52	4.29	4.67	4.72	4.72	4.55	...
5	16.8	5.08	...	5.23	5.28	5.31	5.13	...
4	21.1	5.72	5.41	5.89	5.94	5.97	5.74	...
3	26.7	6.40	6.04	6.60	6.68	6.71	6.45	...
2	33.6	7.19	6.81	7.42	7.52	7.54	7.26	...
1	42.4	8.18	7.59	8.43	8.46	8.46	8.15	7.95
1/0	53.5	9.19	8.53	9.47	9.50	9.50	9.14	8.94
2/0	67.4	10.3	9.55	10.6	10.7	10.7	10.3	10.0
3/0	85.0	11.6	10.74	11.9	12.0	12.0	11.5	11.3
4/0	107	13.0	12.06	13.4	13.4	13.5	13.0	12.6
250	127	14.2	13.21	14.6	14.6	14.6	14.1	13.8
300	152	15.5	14.48	16.0	16.0	16.0	15.4	15.1
350	177	16.8	15.65	17.3	17.3	17.3	16.7	16.3
400	203	17.9	19.28	18.5	18.5	18.5	17.8	17.4
450	228	19.0	17.78	19.6	19.6	19.6	18.9	18.5
500	253	20.0	18.69	20.7	20.7	20.7	19.9	19.5

* Diameters shown are for concentric round and modified concentric.

Table 2-6*
Factors† for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet at 25 °C

Conductor Size	All Sizes		Diameter of Individual Tin Coated Copper Wires in Inches for Stranded Conductors				
	Aluminum	Uncoated copper	0.460 to 0.290, Inclusive	Under 0.290 to 0.103, Inclusive	Under 0.103 to 0.0201, Inclusive	Under 0.0201 to 0.0111, Inclusive	Under 0.0111 to 0.0010, Inclusive
Rope-Stranded							
49 Strands	17865	10892	11153	11210	11327	11568	----
133 Strands	18038	10993	11261	11319	11437	11681	----
259 Strands	18125	11051	11315	11374	11492	11737	----
427 Strands	18212	11104	11370	11428	11547	11793	----
Over 427 Strands	18385	11209	11478	11537	11657	11905	----
Bunch Stranded							
All Sizes	17691	10786	----	----	11217	11456	11579
Rope-Stranded Bunches							
7 Ropes of Bunched Strand	18038	10998	----	----	11437	11681	11806
19, 37, or 61 Ropes of Bunched Strand	18212	11104	----	----	11547	11793	11920
7 x 7 Ropes of Bunched Strand	18385	11209	----	----	11657	11905	12033
19, 37, or 61 x 7 Ropes of Bunched Strand	18559	11315	----	----	11767	12018	12147
Concentric Stranded							
14 AWG - 1000 kcmil	17692	10786	11045	11102	11217	11456	11580

* The factors given in Table 2-6 shall be based on the following:

A. Resistivity

1. A volume resistivity of 10.575 $\Omega \cdot \text{kcmil/ft}$ (100% IACS) at 25°C for uncoated (bare) copper.
2. A 25°C volume resistivity converted from the 20°C values specified in ASTM B 33 for tin coated copper.
3. A volume resistivity of 17.345 $\Omega \cdot \text{kcmil/ft}$ (61% IACS) at 25°C for aluminum.

B. Increase in Resistance Due to Stranding

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

† See Table 2-2 for Use of Factors.

Section 3 PORTABLE SINGLE AND MULTIPLE CONDUCTOR POWER CABLE

3.1 SCOPE

This section covers crosslinked polyethylene and ethylene-propylene-rubber insulated cables with copper conductors for portable use in sizes 8 AWG and larger for use in mining machines, dredges, shovels, and in similar applications. These cables are distinguished by the requirements for the jackets given in 3.21 and Tables 3-3 and 3-4.

Details of construction and dimensions for the voltages at which these cables may be used are given in Table 3-5 through 3-23, 3-25, 3-26. Recommended ampacities and voltage ratings are given in Annex H. Recommended bending radii are given in Annex F and G. Consult the manufacturer for minimum bending radius for re-reeling applications.

The insulations are suitable for conductor temperatures not exceeding 90°C (194°F) for normal operation, 130°C (266°F) for emergency overload conditions and 250°C (482°F) for short-circuit conditions. (See Annex B and C.)

3.2 DC SYSTEMS

DC systems up to and including 2000 volts shall be considered the same as single-phase AC systems. For systems over 2000 volts, consult the manufacturer.

3.3 SINGLE-CONDUCTOR CABLES, NONSHIELDED, 2000 VOLTS OR LESS

These cables shall consist of an insulated conductor with a jacket that meets the requirements for 3.21 and shall be in accordance with Table 3-6. Normal-service cables shall have a heavy-duty jacket and hard-service cables shall have an extra heavy-duty jacket.

3.4 TYPE W AND G TWO-CONDUCTOR CABLES, 2000 VOLTS OR LESS

These cables shall be one of two types: (1) flat twin or (2) two conductor round.

3.4.1 Two-Conductor Flat Twin Cables

3.4.1.1 Type W, without Grounding Conductor

These cables shall consist of two conductors that are separately covered with insulation meeting the requirements of 3.15, and they may have an additional covering (see 3.17). The insulated conductors are then laid parallel under a jacket that meets the requirements of 3.21. A web of the jacket or other material may separate the insulated conductors. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied over the parallel conductors (see 3.21.2). The cables shall be in accordance with Table 3-7.

3.4.1.2 Type G, with Grounding Conductor

These cables shall consist of two power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The two power conductors shall then be laid parallel with a single grounding conductor (see 3.13) between them under a jacket that meets the requirements of 3.21. If the protective covering on the power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductor or within the jacket (see 3.21.2). The cables shall be in accordance with Table 3-7.

3.4.2 Two-Conductor Round Cables

3.4.2.1 Type W, without Grounding Conductor

These cables shall consist of two conductors that are separately covered with insulation meeting the requirements of 3.15 and each conductor may have an additional covering (see 3.17). The power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket which meets the requirements of 3.21. The cables shall be in accordance with Table 3-8.

3.4.2.2 Type G, with Grounding Conductors

These cables shall consist of two power conductors that are separately covered with insulation meeting the requirements of 3.15 and each conductor may have an additional covering (see 3.17). The power conductors, together with two grounding conductors (see 3.13) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The cables shall be in accordance with Table 3-8.

3.5 TYPE W, G, G-GC AND G-CGC. THREE-AND FOUR-CONDUCTOR CABLES, 2000 VOLTS OR LESS

Three-conductor cables shall be one of six types: (1) Type W, round construction, without grounding conductors; (2) Type G, round construction, with grounding conductors; (3) Type G, flat construction, with grounding conductors; (4) Type G-GC, round construction, with grounding conductors and a ground-check conductor; (5) Type G-GC, flat construction, with grounding conductor and a ground-check conductor; and (6) Type G-CGC, round construction, with grounding conductors and a center ground-check conductor. Four-conductor cables shall be one of three types: (1) Type W, round construction, without grounding conductors; (2) Type G, round construction, with grounding conductors; and (3) Type W, flat construction without grounding conductors.

3.5.1 Three- and Four-Conductor, Round Type W Cables without Grounding Conductors

These cables shall consist of three or four power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. Three-conductor cables shall be in accordance with Table 3-9 and four-conductor cables shall be in accordance with Table 3-10.

3.5.2 Three- and Four-Conductor Round Type G Cables with Grounding Conductors

These cables shall consist of three or four power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The power conductors, together with an equal number of grounding conductors (see 3.13) and any necessary fillers, shall be cabled with a left hand lay in accordance with Table 3-5 with one ground wire placed in each interstice. The assembly shall be covered with a jacket that meets the requirements of 3.21. Three-conductor cables shall be in accordance with Table 3-9 and four-conductor cables shall be in accordance with Table 3-10.

3.5.3 Three-Conductor Flat Type G Cable with Grounding Conductors

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The three power conductors shall then be laid parallel with two grounding conductors (see 3.13) in a vertical position between them and under a jacket that meets the requirements of 3.21. If the protective covering on the individual power conductors is omitted, a reinforcement shall be applied over the parallel conductors and grounding conductors. The cables shall be in accordance with Table 3-11.

3.5.4 Three-Conductor Flat G-GC Cable with Grounding Conductor and Ground-Check Conductor

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The three power conductors shall be laid parallel with the insulated ground-check conductor (see 3.12.3) in a vertical position between the black and white power conductors and with the grounding conductor (see 3.13) in a vertical position between the white and red conductors under a jacket that meets the requirements of 3.21. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied over the parallel conductors, grounding conductor and ground-check conductor. The cables shall be in accordance with Table 3-14.

3.5.5 Three-Conductor Round Type G-GC and Type G-CGC Cable

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

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15, two grounding conductors (see 3.13) and one ground-check conductor (see 3.12.2). Each power and ground-check conductor may have an additional covering (see 3.17). All power, grounding and ground-check conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 3-5, and covered with a jacket that meets the requirements of 3.21. The ground-check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 3-12.

3.5.5.2 Type G-CGC, Three-Conductor Round with Grounding Conductors and a Center Ground-Check Conductor

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15, three ground conductors (see 3.13) and one center ground-check conductor (see 3.12.2). Each power and one insulated ground-check conductor may have an additional covering (see 3.17). All power, grounding, and ground-check conductors and any necessary fillers shall be assembled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The ground-check conductor shall be laid in the center of the assembly with one grounding conductor in each of the outer three interstices. These cables shall be in accordance with Table 3-13.

3.5.6 Four-Conductor Flat Type W Cable Without Grounding Conductors

These cables shall consist of four power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The four power conductors shall be laid parallel under a jacket that meets the requirements of 3.21. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied over the parallel conductors. The cables shall be in accordance with Table 3-15. Conductor identification shall be in accordance with and in the sequence of 3.18.

3.6 TYPE W AND G, FIVE- AND SIX-CONDUCTOR, 2000 VOLTS OR LESS

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

3.6.1 Five- And Six-Conductor Round Type W Cables without Grounding Conductor

These cables shall consist of five or six conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The cables shall be in accordance with Table 3-16.

3.6.2 Five-Conductor Round Type G Cables with Grounding Conductor

These cables shall consist of five power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 around a single grounding conductor and covered with a jacket that meets the requirements of 3.21. These cables shall be in accordance with Table 3-16.

3.7 TYPE PG, TWO- AND THREE-CONDUCTORS WITH GROUNDING CONDUCTOR, 2000 VOLTS OR LESS

These cables shall consist of two or three power conductors, which are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The power conductors together with a single grounding conductor (see 3.13.6) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5. The grounding conductor shall be placed between the black and red conductors in the three conductor cable. The assembly shall be covered with a jacket that meets the requirements of 3.21. These cables shall be in accordance with Table 3-17.

3.8 TYPE PCG, TWO- AND THREE-CONDUCTORS WITH GROUNDING CONDUCTOR AND TWO CONTROL CONDUCTORS, 2000 VOLTS OR LESS

These cables shall consist of two or three power conductors, one grounding conductor, and two control conductors (see 3.12.1). The power conductors and control conductors shall be separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The power conductors together with two control conductors and the grounding conductor shall be cabled with a left-hand lay in accordance with Table 3-5. The single grounding conductor in the three-conductor cable shall be placed between the black and red power conductors. Each control conductor shall be in a separate interstice. The black control conductor shall be between the black and white power conductors and the white control conductor shall be adjacent to the white power conductor. These cables shall be in accordance with Table 3-18. The assembly shall be covered with a jacket that meets the requirements of 3.21.

3.9 TYPE G, THREE-CONDUCTOR ROUND WITH GROUNDING CONDUCTORS, 2001-5000 VOLTS

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15. The power conductors, together with an equal number of grounding conductors (see 3.13) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5 with one grounding conductor placed in each interstice and covered with a jacket that meets the requirements of 3.21. The cables shall be in accordance with Table 3-19.

3.10 SHIELDED CABLE 25000 VOLTS OR LESS

3.10.1 Shielded Cables 2000 Volts or Less

3.10.1.1 Type SHD Flat Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors, which are separately covered with insulation in accordance with 3.15, a tape or braid (see 3.17), and a shield, which meets the requirements of 3.19. The three power conductors shall then be laid parallel with one grounding conductor (see 3.13) in a vertical position between the black and white power conductors and one grounding conductor in a vertical position between the white and red power conductors. Reinforcement shall be applied under the jacket. The jacket shall meet the requirements of 3.21.

The resistance of the metal shield over each phase conductor, when measured according to 6.26, shall not exceed 1.28 ohms per 1000 feet at 25 °C.

These cables shall be in accordance with Table 3-27.

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3.10.1.2 Type SHC-GC Round Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation meeting the requirements of 3.15 and may have an additional covering (see 3.17). The power conductors, together with two grounding conductors (see 3.13.1.1), one ground-check conductor (see 3.12.2), and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 3-5. The ground-check conductor shall be laid between the black and white power conductors. The assembly shall be covered with a shield that meets the requirements of 3.19. The overall shield shall maintain contact with the two grounding conductors. (Due to the nature of the design special care must be taken to assure that the grounding conductors are in contact with the shield.) A nonconducting tape may be placed over the shield. A jacket that meets the requirements of 3.21 shall be placed over the completed assembly. These cables shall be in accordance with 3-21.

3.10.1.3 Type SHD Round Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17) and a shield that meets the requirements of 3.19, and three grounding conductors (see Table 3-25), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. These cables shall be in accordance with Table 3-22.

3.10.1.4 Type SHD-GC Round Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17), and a shield that meets the requirements of 3.19, and two grounding conductors (see Table 3-25) and one ground-check conductor (see 3.12.2).

All power conductors, grounding conductors, the ground-check conductor and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The ground-check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 3-22.

3.10.1.5 Type SHD-CGC Round Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17), and metal shield that meets the requirements of 3.19, three grounding conductors (see 3.13.1.2), and one center ground-check conductor (see 3.12.2).

All power and grounding conductors, and any necessary fillers shall be assembled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. A ground-check conductor shall be laid in the center of the assembly with one grounding conductor in each of the outer three interstices. These cables shall be in accordance with Table 3-23.

3.10.1.6 Type SHD-PCG Round Three-Conductor Cables, 2000 Volts or Less

These cables shall consist of three power conductors (see 3.11), which are separately covered with insulation meeting requirements of 3.15, a tape (see 3.17) and a metallic shield which meets the requirements of 3.19, a grounding conductor (see Table 3-26), and one or more control conductors (see 3.12.1) under a unit jacket. The cables shall be in accordance with Table 3-26.

All power conductors, the unit of control conductors and any necessary fillers shall be cabled around the grounding conductor with a left-hand lay, in accordance with the four conductor lay length in Table 3-5.

The jacketed unit of control conductors shall be laid between the black and red power conductors. The cable shall be covered with a jacket that meets the requirements of 3.21. These cables shall comply with the requirements of SHD-GC cables unless otherwise specified in 3.10.1.6 and Table 3-26.

3.10.1.6.1 Control Conductors for Type SHD-PCG Cable

The control conductor shall not be smaller than 10 AWG. A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. If a larger size control conductor is utilized, the number of strands shall not be less than specified for a power conductor of the same size (see Table 3-25). A separator may be used between the conductor and insulation.

3.10.1.6.2 Grounding Conductor for Type SHD-PCG Cable

The grounding conductor for type SHD-PCG shall be coated annealed copper and shall be uncovered. The size and number of strands for the grounding conductor shall be in accordance with Table 3-26.

3.10.1.6.3 Assembly Construction

Control Conductor Insulation, Assembly, and Unit Covering

3.10.1.6.3.1 Insulation For the Control Conductors

The insulation for the control conductors shall be one of the types given in Table 3-2 and shall meet the requirements specified in Table 3-2. The average thickness shall not be less than 0.030 inch for size 10 AWG and shall not be less than 0.045 inch for sizes 8 AWG and larger. The minimum thickness at any point shall not be less than 90 percent of the specified average value. A separator may be used between the conductor and insulation.

3.10.1.6.3.2 Assembly of Control Conductors

The two, three, or four control conductors shall be cabled with a left-hand lay, with any necessary fillers, in accordance with Table 3-5.

The color coding shall be as follows:

No. of Conductors	Colors
1	Yellow
2	Black, White
3	Black, White, Red
4	Black, White, Red, Blue

When only one control conductor is required, the insulation may be applied in two layers.

3.10.1.6.3.3 Unit Covering

The unit jacket for the control conductors shall be one of the types given in Table 3-4. The diameter of the control unit shall be approximately equal to the nominal diameter of an insulated and shielded power conductor.

3.10.2 Shielded Cables 2001 to 5000 Volts

3.10.2.1 Type SH Single Conductor Cables, 2001 to 5000 Volts

These cables shall be covered with an insulation in accordance with 3.15, a tape (see 3.17), a metallic shield that meets the requirements of 3.19, with or without a non-conducting tape over the shield, and a jacket that meets the requirements of 3.21. The cables shall be in accordance with Table 3-20.

3.10.2.2 Type SHD Round Three-Conductor Cables, 2001 to 5000 Volts

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17) and a shield that meets the requirements of 3.19, and three grounding conductors (see Table 3-25), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. These cables shall be in accordance with Table 3-22.

3.10.2.3 Type SHD-GC Round Three-Conductor Cables, 2001 to 5000 Volts

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17), and a shield that meets the requirements of 3.19, and two grounding conductors (see Table 3-25) and one ground-check conductor (see 3.12.2).

All power conductors, grounding conductors, the ground-check conductor and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The ground-check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 3-22.

3.10.2.4 Type SHD-CGC Round Three-Conductor Cables, 2001 to 5000 Volts

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17), and metal shield that meets the requirements of 3.19, three grounding conductors (see 3.13.1.2), and one center ground-check conductor (see 3.12.2).

All power and grounding conductors, and any necessary fillers shall be assembled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. A ground-check conductor shall be laid in the center of the assembly with one grounding conductor in each of the outer three interstices. These cables shall be in accordance with Table 3-23.

3.10.2.5 Type SHD-PCG Round Three-Conductor Cables, 2001 to 5000 Volts

These cables shall consist of three power conductors (see 3.11), which are separately covered with insulation meeting requirements of 3.15, a tape (see 3.17) and a metallic shield which meets the requirements of 3.19, a grounding conductor (see Table 3-26), and one or more control conductors (see 3.12.1) under a unit jacket. The cables shall be in accordance with Table 3-26.

All power conductors, the unit of control conductors and any necessary fillers shall be cabled around the grounding conductor with a left hand lay, in accordance with the four conductor lay length in Table 3-5.

The jacketed unit of control conductors shall be laid between the black and red power conductors. The cable shall be covered with a jacket that meets the requirements of 3.21. These cables shall comply with the requirements specified in 3.10.2.5 and Table 3-26.

3.10.2.5.1 Control Conductors for Type SHD-PCG Cable

The control conductor shall not be smaller than 10 AWG. A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. If a larger size control conductor is utilized, the number of strands shall not be less than specified for a power conductor of the same size (see Table 3-25). A separator may be used between the conductor and insulation.

3.10.2.5.2 Grounding Conductor for Type SHD-PCG Cable

The grounding conductor for type SHD-PCG shall be coated annealed copper and shall be uncovered. The size and number of strands for the grounding conductor shall be in accordance with Table 3-26.

3.10.2.5.3 Assembly Construction

Control conductor insulation, assembly and unit covering

3.10.2.5.3.1 Insulation For the Control Conductors

The insulation for the control conductors shall be one of the types given in Table 3-2 and shall meet the requirements specified in Table 3-2. The average thickness shall not be less than 0.030 inch for size 10 AWG and shall not be less than 0.045 inch for sizes 8 AWG and larger. The minimum thickness at any point shall not be less than 90 percent of the specified average value. A separator may be used between the conductor and insulation.

3.10.2.5.3.2 Assembly of Control Conductors

The two, three, or four control conductors shall be cabled with a left-hand lay, with any necessary fillers, in accordance with Table 3-5.

The color coding shall be as follows:

No. of Conductors	Colors
1	Yellow
2	Black, White
3	Black, White, Red
4	Black, White, Red, Blue

When only one control conductor is required, the insulation may be applied in two layers.

3.10.2.5.3.3 Unit Covering

The unit jacket for the control conductors shall be one of the types given in Table 3-4. The diameter of the control unit shall be approximately equal to the nominal diameter of an insulated and shielded power conductor.

3.10.3 Shielded Cables 5001 to 25000 Volts

3.10.3.1. Type SH Single Conductor Cables, 5001 to 25000 Volts

These cables shall be covered with an insulation in accordance with 3.15, a tape (see 3.17), a metallic shield that meets the requirements of 3.19, with or without a non-conducting tape over the shield, and a jacket that meets the requirements of 3.21. The cables shall be in accordance with Table 3-20.

3.10.3.2 Type SHD Round Three-Conductor Cables, 5001 to 25000 Volts

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17) and a shield that meets the requirements of 3.19, and three grounding conductors (see Table 3-25), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. These cables shall be in accordance with Table 3-22.

3.10.3.3 Type SHD-GC Round Three-Conductor Cables, 5001 to 25000 Volts

These cables shall consist of three power conductors that are separately covered with insulation in accordance with 3.15, a tape (see 3.17), and a shield that meets the requirements of 3.19, and two grounding conductors (see Table 3-25) and one ground-check conductor (see 3.12.2).

All power conductors, grounding conductors, the ground-check conductor and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 3-5 and covered with a jacket that meets the requirements of 3.21. The ground-check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 3-22.

3.11 POWER CONDUCTORS

Power conductors shall be made of annealed coated or uncoated copper wires. The minimum number of wires for each particular size shall comply with Table 3-25. The DC resistance shall comply with Table 2-4.

A separator over the conductor may be used for cables rated 2000 volts or less.

On cables rated above 2000 volts, a stress control layer in accordance with 3.14 shall be applied over the conductor.

3.12 CONTROL AND GROUND-CHECK CONDUCTORS

3.12.1 Control Conductors for Type PCG and SHD-PCG Cables

The control conductor shall not be smaller than 10 AWG. A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. If a larger size control conductor is utilized, the number of strands shall not be less than specified for a power conductor of the same size (see Table 3-25). A separator may be used between the conductor and insulation.

3.12.2 Ground-Check Conductors

The ground-check conductor for Type G-GC, SHC-GC and SHD-GC shall be as given in Tables 3-12, 3-21 and 3-22. A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. If a larger size ground-check conductor is utilized, the minimum number of wires shall not be less than specified for a power conductor of the same size (see Table 3-25). A separator may be used between the conductor and insulation.

The center ground-check conductor for Type G-CGC and SHD-CGC shall contain a minimum of 28 strands of annealed coated or uncoated copper laid around a core of nonmetallic material. The cross-sectional area of the conductor shall not be less than 1800 circular mils. A separator may be used between the conductor and insulation.

3.12.3 Ground-Check Conductor for Flat G-GC

The ground-check conductor for flat G-GC shall be at least an 8 AWG annealed copper conductor and shall be flat, rectangular or oval in shape.

3.13 GROUNDING CONDUCTORS

The grounding conductors shall be annealed copper and shall meet the requirements of Table 2-4

3.13.1 Size and Number

3.13.1.1 Round Type SHC-GC, SHD, SHD-PCG, and SHD-GC

The size and number of wires for grounding conductors in round Type SHC-GC, SHD, and SHD-GC shall be in accordance with Table 3-25.

The grounding conductors for shielded cables shall be uncovered.

3.13.1.2 Type SHD-CGC

The size and number of wires for grounding conductors in Type SHD-CGC shall be in accordance with Table 3-23.

The grounding conductors shall be uncovered.

3.13.1.3 Type SHD FLAT, 2000 Volts or Less

The grounding conductors for Type SHD Flat cables shall be of the size and stranding given in Table 3-27. The grounding conductors shall be separately covered with a conducting extrusion layer. The conducting extruded material shall meet the physical requirements for Insulation Shielding in Section 4.5. The conducting extrusion layer shall be in intimate contact with the shielded conductors.

3.13.2 Flat Twin Type G

The single-grounding conductor for flat twin Type G cables shall be flat, rectangular, or oval in shape, composed of either coated or uncoated copper and shall have a minimum cross-sectional area of 50 percent of the power conductor but not less than the cross-sectional area of an 8 AWG conductor as given in Table 3-7.

The grounding conductor may be covered or uncovered. When used, the outer covering over the grounding conductor shall be green in color and may be in the form of an extruded layer, braid, tape, or other suitable means.

3.13.3 Flat Three-Conductor Type G

The two grounding conductors for flat three-conductor Type G cables shall be flat, rectangular, or oval in shape, composed of either coated or uncoated copper and of the size given in Table 3-11.

The grounding conductors may be covered or uncovered. When used, the outer covering over the grounding conductor shall be green in color and may be in the form of an extruded layer, braid, tape, or other suitable means.

3.13.4 Round Type G, G-GC and G-CGC

The grounding conductors for three-conductor round Type G, G-GC and G-CGC shall be of the size and stranding given in Table 3-25, 3-12 and 3-13, respectively.

The grounding conductors may be covered or uncovered. When used, the outer covering over the grounding conductor shall be green in color and may be in the form of an extruded layer, braid, tape, or other suitable means.

3.13.5 Flat Three-Conductor Type G-GC

The grounding conductors for flat three-conductor Type G-GC cables shall be flat, rectangular, or oval in shape, composed of either coated or uncoated copper and of the size given in Table 3-14.

The grounding conductors may be covered or uncovered. When used, the outer covering over the grounding conductor shall be green in color and may be in the form of an extruded layer, braid, tape, or other suitable means.

3.13.6 Round Five-Conductor Type G, Type PG, and PCG

The single grounding conductor for five-conductor Type G and for Type PG and PCG cables shall be of the size and stranding given in Tables 3-16, 3-17, and 3-18 respectively.

The grounding conductors may be covered or uncovered. When used, the outer covering over the grounding conductor shall be green in color and may be in the form of an extruded layer, braid, tape, or other suitable means.

3.14 STRESS CONTROL LAYER (CONDUCTOR SHIELD)

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

The stress control layer shall be a polymeric covering consisting of a conducting tape, extruded material or extruded material over conducting tape. The layer shall have a minimum thickness of 0.0025 inches.

3.14.1 Extruded Stress Control Layer (Conductor Shield)

3.14.1.1 Physical Properties

Extrudable material, prior to application to the conductor, when tested in accordance with 6.4.15 shall meet the following requirements:

Elongation after air oven test at $121^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for 168 hrs. minimum percent	100
Brittleness temperature not warmer than deg. C	-10

3.14.1.2 Electrical Requirements

3.14.1.2.1 Conducting Stress Control Material

The resistivity of an extruded conducting material when measured according to 6.19 shall not exceed 1000 ohm-meter at room temperature and at the maximum normal operating temperature of the cable.

A conducting non-metallic tape shall have a maximum DC resistance at room temperature of 10,000 ohms per unit square when tested in accordance with ASTM D 4496.

3.14.1.2.2 Nonconducting Stress Control Material

An extruded nonconducting stress controlling material, when measured according to 6.25, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Permittivity (SIC) range	10–1000
60 Hz AC voltage withstand stress, volts per mil, minimum	1500/permittivity

This material is only applicable for conductors having ethylene propylene insulation.

3.15 POWER CONDUCTOR INSULATION

3.15.1 Insulation Physical and Electrical Requirements

The insulation for the power conductor shall meet the requirements given in Table 3-1.

3.15.2 Insulation Thickness

The average thickness shall not be less than specified in Tables 3-6 through 3-23 and Table 3-27. The minimum thickness shall not be less than 90 percent of the specified value. The highest rated circuit

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voltage specified in these tables represents the maximum operating voltage recommended for the given insulation thickness.

3.15.2.1 Optional Extruded Conducting Layer Applied over the Insulation (Insulation Shield)

Type SH, SHD, and SHD-GC cables using EP insulation for cables rated 8–25 kV inclusive, may have an extruded conducting layer applied over the insulation.

When an extruded conducting layer is used, the average insulation thickness and the sum of the average insulation thickness plus the average extruded conducting layer thickness shall be not less than the values given below:

Voltage Rating, kV	Thickness, Inch	
	EP Insulation	EP Insulation plus Extruded Conducting Layer
8	0.115	0.150
15	0.175	0.210
25	0.260	0.295

The minimum insulation thickness shall be not less than 90 percent of the specified values. The minimum thickness of the insulation plus the thickness of the extruded conducting layer at the same point shall be not less than 90 percent of the specified value.

The extruded crosslinked conducting layer shall meet the requirements of 4.5.1. The tension necessary to remove the extruded conducting layer from cable at room temperature shall be not less than 3 lbs. (see 6.20).

A conducting tape shall be applied over the extruded conducting layer. The extruded conducting layer and the conducting tape shall be plainly identified as being conducting (see 3.17). A conducting non-metallic tape shall have a maximum DC resistance at room temperature of 10,000 ohms per unit square when tested in accordance with ASTM D 4496.

3.16 GROUND CHECK AND CONTROL CONDUCTOR INSULATION

The insulation for the ground-check and control conductors shall be one of the types given in Table 3-2 and shall meet the requirements specified in Table 3-2. The average thickness shall not be less than 0.030 inch for sizes 10 AWG and smaller and shall not be less than 0.045 inch for sizes 8 AWG and larger. The minimum thickness at any point shall not be less than 90% of the specified average value.

3.17 TAPES AND BRAIDS

3.17.1 Power Conductors

3.17.1.1 Nonshielded Cables

Colored insulation may be used for circuit identification. If colored insulation is not used, a colored tape or braid or other suitable means of identification shall be used.

3.17.1.2 Shielded Cables

For Types SHC-GC and SHD FLAT (2000 Volts or less), colored insulation may be used for circuit identification. If colored insulation is not used, a colored tape or braid or other suitable means of surface identification shall be used.

For Types SH, SHD, SHD-GC, SHD-PCG, and SHD-CGC Cables (25000 Volts or less), a tape shall be used over the insulation. If a conducting tape is used, it shall be plainly identified as being conducting. For cables rated 5001 volts and higher, the tape shall be conducting.

A conducting non-metallic tape shall have a maximum DC resistance at room temperature of 10,000 ohms per unit square when tested in accordance with ASTM D 4496.

3.17.2 Ground Check and Control Conductors

Colored insulation may be used as identification for ground check and control conductors. If colored insulation is not used, a colored tape or braid or other suitable means of identification shall be used.