

Insulation



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Section 3-19: Wire, Cable and Assemblies (Except Magnet Wire)

New Developments

◀ Large-size solid aluminum conductor cable for primary and secondary electric power distribution lines is said to be less expensive, lighter, and more resistant to corrosion than comparable stranded copper or aluminum cables.

◀ Polyurethane rubber is beginning to find more general use in cable jackets.

◀ The "A" revision of MIL-W-22759 has been published with revised wording of the "stranding" paragraphs which opens the specification to the use of unilay stranding methods.

◀ A method of completely shielding PTFE wires and/or providing an outer conductor for coaxial applications involves the use of thin wall tubing which can be "swaged" or sunk down against an insulated wire inserted loosely into a length of the plated copper tubing. There are length limitations.

◀ A colloiddally dispersed blend of butadiene-acrylonitrile synthetic rubber and polyvinyl chloride for cable coverings is said to offer toughness, smoothness, flexibility, and resistance to abrasion and heat deformation, and to give outstanding service when ex-

posed to weather, light, fuel, oil, or ozone.

◀ A class 130 flexible apparatus lead wire has been developed based on ethylene propylene rubber. Until now, only silicone rubber was recognized for this service.

◀ Cross-linked polyethylene is being used in aluminum cable rated at 38,000 volts. A PVC jacket is used.

◀ A new family of adhesive thermoplastic copolymers for the wire and cable industry has been developed. The copolymers are essentially polyethylene with attached carboxyl groups.

Author Credit

This entire section was staff prepared.

INTRODUCTION

Wires and cables are an extremely complex subject. Thousands of pages could be written (and have been written). There is no simple and easy way to classify wires and cables—some are described by form (such as flat), some by general application (such as power) or by specific application (such as switchboard), some by type of conductor (such as copper), some by type of insulation (such as varnished cambric), some by property (such as high temperature), some by outer covering (such as steel armored), and some by voltage rating. Understandably, all this makes it very difficult to know where to begin and where to end in any fundamental discussion of wires and cables.

In order to simplify this situation, this section has been prepared with the intention of giving readers basic knowledge on wires and cables—ter-

minology, selection considerations, common calculations and size data, construction materials (both metals and insulations), etc. This type of information is designed to permit readers to determine where their interests lie so that they may consult manufacturers for specific recommendations.

TERMINOLOGY AND DEFINITIONS

The following definitions are a portion of those approved by the American Standards Association (ASA C42.35 1957):

Armored Cable—a cable provided with a wrapping of metal, usually steel wires or tapes, primarily for the purpose of mechanical protection.

Bare Conductor—a conductor not covered with insulating material.

Bunched Stranding—a term applied to a group of strands twisted together in a random manner in the same direction in one operation without regard to geometric arrangement of specific strands.

Cable—either a stranded conductor with or without insulation and other coverings (single-conductor cable), or a combination of conductors insulated from one another (multiple-conductor cable).

Cable Core—the portion of an insulated cable lying under the protective covering or coverings.

Cable Core Binder—a wrapping of tapes or cords around the several conductors of a multiple-conductor cable used to hold them together. (NOTE: Cable core binder is usually supplemented by an outer covering of braid, jacket, or sheath.)

Cable Filler—the material used in multiple-conductor cables to occupy the interstices formed by the assembly of the insulated conductors, thus forming a cable core of the desired shape (usually circular).

Cable Sheath—the protective covering applied to cables. (NOTE: For power cables the sheath is usually lead.)

Composite Conductor—two or more strands of different metals, such as aluminum and steel or copper and steel, assembled and operated in parallel.

Compression Cable—a pipe type cable in which the pressure medium (oil or gas) is separated from the insulation by an impervious membrane or sheath.

Concentric-Lay Cable—either: (a) A concentric-lay conductor as defined

dizing conditions. Tin, which can be applied by a "hot dip" process, is used to protect the base metal from corrosion and to enhance solderability—tin-lead alloys are also used. Silver provides moderate temperature protection, corrosion protection, excellent solderability, and high conductivity. Gold offers excellent resistance to chemical attack and enhances solderability.

A great many alloys are available with a large number of them designed for high temperature resistance wire. Several alloys are currently of interest for high temperature applications requiring good conductivity and high strength and flex life. These include a chromium-cadmium-copper alloy which provides high strength with a slight sacrifice in conductivity. Another, which is in common use, is cadmium copper—it is easy to work with and relatively inexpensive—its major drawback is a softening temperature of 175 to 200°C. Chromium copper, although it has desirable properties similar to the other alloys mentioned here, reportedly is rather erratic. Zirconium copper is said to

be much easier to handle and very consistent.

Metals for shielding may serve a number of purposes. In coaxial cables, the shielding in combination with the conductor and insulation determines the electrical characteristics with the goal of matching of impedance to reduce power loss of signals or rf energy. In power cables shielding prevents surface discharges by providing even stress distribution. Shielding also restricts the electrical field of the conductor to the insulation and prevents external interference.

Conductive polyethylenes are available for use as inner layers and/or outer jacketing on communications and power cables. Various degrees of conductivity can be supplied for such purposes as voltage stress relief shielding in high-voltage cables, as an electrical interference barrier, and as lightning protection.

An electrically conductive treatment applied to fiber glass roving is designed for automotive ignition systems and other electrostatic shielding applications.

Metals which are used for armor

provide many different types of physical protection. Properties of typical metals are shown in the tables on other pages.

Insulation and Jacketing Materials

Quite naturally, the primary insulation on a wire or cable is used for insulation purposes. In those cases where the primary insulation is the only covering, it may also be considered to be fulfilling jacketing functions. Jacketing provides protection against moisture, solvents, acids, alkalis, fungus, chemicals, heat, radiation, and physical abuse such as abrasion and cutting. Jacketing also holds cable elements together and prevents contact between shielding and ground.

The method of applying the insulation or jacketing material will influence end properties. Application methods include braiding, extruding, taping, and dip coating. Different forms of the same material may be applied by different methods with different properties resulting.

Nearly all of the materials used for primary insulation and jacketing have been described in other sections and

Properties of Metals at 20°C									
Metal	Specific Gravity	Specific Heat, Cal./Gram-°C	Melting Point °C	Resistivity, Microhm-Cm	Resistivity, Ohms (mil. foot)	Temperature Coef. of Resistivity, per °C	Thermal Cond., Cal-Cm/Sec-°C Cm ²	Thermal Coef. of Linear Expansion /°C	Tensile Strength, Lbs./Sq. In.
ALUMINUM.....	2.71	0.214	660	2.828	17.00	.00446	0.52	23 x 10 ⁻⁶	24,000
BRASS									
Commercial Bronze									
(90% Cu—10% Zn).....	8.80	0.092	1045	4.66	28.03	.00145	0.45	18 x 10 ⁻⁶	95,000
Low Brass									
(80% Cu—20% Zn).....	8.67	0.092	995	5.95	35.78	.00114	0.34	19 x 10 ⁻⁶	105,000
High Brass									
(70% Cu—30% Zn).....	8.53	0.092	930	6.90	41.50	.00098	0.26	20 x 10 ⁻⁶	120,000
COPPER									
Annealed Wire									
(100% Cond).....	8.89	0.0921	1083	1.7241	10.37	.00393	0.92	17 x 10 ⁻⁶	36,000-40,000
Hard Drawn Wire									
(97.5% Cond).....	8.89			1.7683	10.63	.00383			50,000-70,000
GOLD.....	19.30	0.031	1063	2.42	14.55	.0034	0.71	14.2 x 10 ⁻⁶	
IRON.....	7.86	0.107	1535	10	60.14	.0050	0.16	11.7 x 10 ⁻⁶	50,000
LEAD.....	11.3	0.031	327	22	132.31	.0039	0.083	28 x 10 ⁻⁶	1,800-4,000
MOLYBDENUM.....	10.2	0.061	2625	5.7	34.28	.0033	0.35	5 x 10 ⁻⁶	100,000
NICKEL.....	8.9	0.105	1452	7.8	46.91	.006	0.14	14 x 10 ⁻⁶	155,000
PLATINUM.....	21.45	0.032	1773	10.60	63.75	.00300	0.17	3.9 x 10 ⁻⁶	
SILVER.....	10.5	0.056	960	1.63	9.80	.0038	1.01	18 x 10 ⁻⁶	42,000
STEEL (Mild).....	7.8	0.107	1300-1475	12	72.17	.005	0.11	9 x 10 ⁻⁶	50,000-70,000
TIN.....	7.3	0.054	232	11.5	69.16	.0042	0.15	21 x 10 ⁻⁶	4,000-5,000
TUNGSTEN.....	19.3	0.032	3410	5.52	33.20	.0045	0.18	4 x 10 ⁻⁶	490,000
ZINC.....	7.14	0.092	419	6	36.08	.00347	0.27	28 x 10 ⁻⁶	7,000-30,000

readers should refer to sections 3-1, 3-2, 3-3, 3-4, 3-7, 3-10, 3-11, 3-12, 3-13, 3-15, and 3-16 for additional details. In some cases, information on magnet wires in section 3-18 would also apply. It also should be remembered that fibrous materials are often coated or impregnated. Highlights of important insulating and jacketing materials will be briefly mentioned in the discussion that follows with references to the sections in which additional general data may be found—since many of these materials are specially compounded for wires and cables, readers should consult the manufacturers for specific data.

Acrylic—available in fibrous form for yarn servings and braids. Acrylic

coating and impregnant also available (mostly for other uses). Other synthetic fibers find greater use for wire and cable insulation than the acrylics. In general, acrylics offer desirable physical and electrical properties and good resistance to most chemicals and weathering. For special purpose insulation, acrylic elastomers can be used—they provide excellent ozone resistance and good aging properties but chemical resistance is spotty—see section 3-11.

Anodic Films—most of the publicity and possible potential for anodic film insulation (aluminum oxide coating on aluminum conductor) is concentrated in the magnet wire application area but some other wire appli-

cations have been suggested. The coating is thin, space-saving, inorganic, and resistant to extreme temperatures (3600°F melting point). Although anodic film insulated conductors can be bent and processed without rupturing the film, flexibility is limited relative to other insulations.

Asbestos—fibrous asbestos wire and cable insulation is used in the form of yarn servings, felts, lap, roving, and braid. Asbestos reinforced or combined with other materials also is used. Where space is important, asbestos papers and purified asbestos papers may be used. Commonly, felted asbestos insulated wires and cables are available with all-asbestos insulation, in combination with varnished

BARE SOLID COPPER WIRE

Size*, Diameter*, Area*, Weight*, Breaking Strength and Resistance**

Size AWG	NOMINAL DIAMETER Inches	CROSS SECTIONAL AREA		NOMINAL WEIGHT Lbs./M ft.	HARD DRAWN		MEDIUM HARD DRAWN			ANNEALED	
		Circular Mils	Square Inches		Minimum Breaking Strength Lbs.	Max. d-c Resistance (@ 20 C Ohms M Ft.)	Minimum Breaking Strength Lbs.	Maximum Breaking Strength Lbs.	Max. d-c Resistance (@ 20 C Ohms M Ft.)	Maximum Breaking Strength Lbs.	Max. d-c Resistance (@ 20 C Ohms M Ft.)
50	0.0010	1.00	.785X10 ⁻⁴	0.00303	.....	.....	.....	.....	.....	.....	.....
49	0.0011	1.21	.950X10 ⁻⁴	0.00366	.....	.....	.....	.....	.....	.....	.....
48	0.0012	1.44	1.13X10 ⁻⁴	0.00436	.....	.....	.....	.....	.....	.....	.....
47	0.0014	1.96	1.54X10 ⁻⁴	0.00593	.....	.....	.....	.....	.....	.....	.....
46	0.0016	2.56	2.01X10 ⁻⁴	0.00775	.....	.....	.....	.....	.....	.....	.....
45	0.0018	3.24	2.54X10 ⁻⁴	0.00981	.....	.....	.....	.....	.....	.....	.....
44	0.0020	4.00	3.14X10 ⁻⁴	0.0121	.....	27.0X10 ³	.....	.....	26.8X10 ³	.....	25.9X10 ³
43	0.0022	4.84	3.80X10 ⁻⁴	0.0147	.....	22.3X10 ³	.....	.....	22.2X10 ³	.....	21.4X10 ³
42	0.0025	6.25	4.91X10 ⁻⁴	0.0189	.....	17.2X10 ³	.....	.....	17.2X10 ³	.....	16.6X10 ³
41	0.0028	7.84	6.16X10 ⁻⁴	0.0237	.....	13.8X10 ³	.....	.....	13.7X10 ³	.....	13.2X10 ³
40	0.0031	9.61	7.55X10 ⁻⁴	0.0291	.....	11.2X10 ³	.....	.....	11.2X10 ³	.....	10.8X10 ³
39	0.0035	12.2	9.62X10 ⁻⁴	0.0371	.....	880	.....	.....	876	.....	847
38	0.0040	16.0	12.6X10 ⁻⁴	0.0484	.....	674	.....	.....	671	.....	648
37	0.0045	20.2	15.9X10 ⁻⁴	0.0613	.....	533	.....	.....	530	.....	512
36	0.0050	25.0	19.6X10 ⁻⁴	0.0757	.....	431	.....	.....	429	.....	415
35	0.0056	31.4	24.6X10 ⁻⁴	0.0949	.....	344	.....	.....	342	.....	331
34	0.0063	39.7	31.2X10 ⁻⁴	0.120	.....	272	.....	.....	270	.....	261
33	0.0071	50.4	39.6X10 ⁻⁴	0.153	.....	214	.....	.....	213	.....	206
32	0.0080	64.0	50.3X10 ⁻⁴	0.194	.....	168	.....	.....	166	.....	162
31	0.0089	79.2	62.2X10 ⁻⁴	0.240	.....	136	.....	.....	135	.....	131
30	0.0100	100	78.5X10 ⁻⁴	0.303	.....	108	.....	.....	107	.....	104
29	0.0113	128	100X10 ⁻⁴	0.387	.....	84.5	.....	.....	84.0	.....	81.2
28	0.0126	159	125X10 ⁻⁴	0.481	.....	67.9	.....	.....	67.6	.....	65.3
27	0.0142	202	158X10 ⁻⁴	0.610	.....	53.5	.....	.....	53.2	.....	51.4
26	0.0159	253	199X10 ⁻⁴	0.765	.....	42.7	.....	.....	42.4	.....	41.0
25	0.0179	370	252X10 ⁻⁴	0.970	.....	33.7	.....	.....	33.5	.....	32.4
24	0.0201	404	317X10 ⁻⁴	1.22	.....	26.7	.....	.....	26.6	.....	25.7
23	0.0226	511	401X10 ⁻⁴	1.55	.....	21.1	.....	.....	21.0	.....	20.3
22	0.0253	640	503X10 ⁻⁴	1.94	.....	16.9	.....	.....	16.8	.....	16.2
21	0.0285	812	638X10 ⁻⁴	2.46	.....	13.3	.....	.....	13.2	.....	12.8
20	0.0320	1,020	804X10 ⁻⁴	3.10	.....	10.5	.....	.....	10.5	.....	10.1
19	0.0359	1,290	1,01X10 ⁻³	3.90	.....	8.37	.....	.....	8.32	.....	8.05
18	0.0403	1,620	1,28X10 ⁻³	4.92	85.5	6.64	67.6	.....	6.61	49.1	6.39
17	0.0453	2,050	1,61X10 ⁻³	6.21	108	5.26	84.9	96.2	5.23	62.0	5.05
16	0.0508	2,580	2,03X10 ⁻³	7.81	135	4.18	106	120	4.16	73.0	4.02
15	0.0571	3,260	2,56X10 ⁻³	9.87	170	3.31	133	151	3.29	98.6	3.18
14	0.0641	4,110	3,23X10 ⁻³	12.4	214	2.63	167	189	2.61	124	2.52
13	0.0720	5,180	4,07X10 ⁻³	15.7	268	2.09	209	237	2.07	157	2.00
12	0.0806	6,530	5,13X10 ⁻³	19.8	337	1.65	262	297	1.64	197	1.59
11	0.0907	8,230	6,46X10 ⁻³	24.9	423	1.31	327	372	1.30	249	1.26
10	0.1019	10,380	8,15X10 ⁻³	31.43	529.3	1.039	410.4	467.5	1.033	314.0	.9988
9	0.1144	13,090	0.01028	39.62	660.9	.8241	513.9	585.9	.8199	380.3	.7925
8	0.1285	16,510	0.01297	49.98	826.1	.6532	644.0	734.8	.6498	479.8	.6281
7	0.1443	20,820	0.01635	63.03	1030	.5180	806.7	921.2	.5153	605.1	.4981
6	0.1620	26,240	0.02061	79.44	1280	.4110	1010	1154	.4088	762.6	.3952
5	0.1819	33,090	0.02599	100.2	1590	.3260	1265	1446	.3243	961.5	.3134
4	0.2043	41,740	0.03278	126.3	1970	.2584	1584	1814	.2571	1213	.2485
3	0.2294	52,620	0.04133	159.3	2439	.2050	1984	2273	.2039	1529	.1971
2	0.2576	66,360	0.05212	200.9	3002	.1625	2450	2814	.1617	1928	.1563
1	0.2893	83,690	0.06573	253.3	3688	.1289	3074	3484	.1282	2432	.1239
1/0	0.3249	105,600	0.08291	319.5	4518	.1022	3731	4311	.1016	2985	.09825
2/0	0.3648	133,100	0.1045	402.8	5519	.08021	4599	5330	.07980	3763	.07793
3/0	0.4096	167,800	0.1318	507.8	6720	.06362	5665	6588	.06330	4744	.06182
4/0	0.4600	211,600	0.1662	640.5	8143	.05045	6980	8143	.05019	5983	.04901

*From NBS Circular 31, 4th Ed.

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cambric (where moisture is a factor), or in combination with a thermoplastic (for switchboard work). The asbestos felt is impregnated with either a flame and heat resisting compound or a flame, heat, and moisture resisting compound. Suitable for lower voltage work, asbestos provides excellent heat and radiation resistance, non-flammability, flexibility, and resistance to most chemical conditions. It is used for power cable, rheostat wire, apparatus cable, lead wire, range wire, appliance wires and cords, mining cable, and other applications where heat is a problem. See section 3-3.

Buna N is also known as nitrile rubber. Specific properties depend on the actual composition but generally, Buna N rubber offers excellent resistance to oils and solvents. Ozone resistance is good and is determined somewhat by the blend used. Buna N rubbers are the result of the copolymerization of acrylonitrile and butadiene. See section 3-11.

Butyl Rubber—a polymer of isobutylene with small amounts of isoprene. This is an increasingly popular insulation and jacketing material. When properly compounded, butyl rubber is characterized by excellent resistance to oxidation and aging, exceptional ozone resistance, and very good electrical properties. Resistance to moisture, physical abuse, and chemicals is also good. Applications include low and high voltage power cables, apparatus and equipment leads, control cables, and various other cables. See section 3-11.

Cellulose Acetate—available in yarn form for wire servings and braids as well as in film form for taped insulation. These materials are characterized by very good electrical properties per unit thickness. They are non-corrosive with moderate to good resistance to chemicals. The film has been used for lead wire insulation. Moisture resistance is good. See sections 3-3 and 3-13.

Ceramic—ceramic insulations are available in the form of fibrous alumina-silica yarns for servings and braids and also in the form of coatings. Heat and radiation resistances are excellent. Manufacturers should be consulted in regard to film flexi-

bility and uses. Ceramic beads are another form used to provide physical separation. See sections 3-3 and 3-16. Also see *mineral insulation* below.

Chlorosulfonated Polyethylene—this vulcanizable material has good electrical properties and exceptional resistance to ozone. It has very good resistance to oxidation by sunlight, weather, chemicals, and relatively high temperatures. Although resilience is generally lower than that of natural and synthetic rubbers at room temperature, it is equal or better at 212°F. It is relatively resistant to oils.

Cotton—cotton is used for servings and braids. Flexibility and strength are good. Treatments are required to provide chemical and fungus resistance. Heat resistance is limited. See section 3-3.

Ethylene-propylene rubber—these materials are reported to offer excellent resistance to ozone and weathering, good low temperature properties, good to excellent heat resistance and high temperature properties (250-300°F), excellent electrical properties, good stress-strain properties, fair to good tear strength, poor to fair oil resistance, and excellent corona resistance. Applications include flexible cord jackets, flexible leads for class B apparatus, and possible use in the high voltage field. Two types of the polymer are available—the copolymer based on ethylene and propylene only, and the terpolymer in which a small amount of unsaturation pendant to the chain is added. The rubber reportedly can be flame-proofed. See section 3-11.

Fluoroelastomers—a number of these materials are available and some are suggested for use as wire insulations in critical applications where high costs are justified. Properties of the different types vary but generally, they all are characterized by excellent heat and chemical resistance. Five types are described in section 3-11.

Fluorinated ethylene propylene—FEP is similar to polytetrafluoroethylene (described later) but has a melting point about 50°C lower and slightly different physical properties. It is more easily processed than PTFE. Heat resistance and chemical inertness are outstanding. This material

will likely be used in increasing amounts where requirements are severe. Foamed FEP with a dielectric constant of about 1.6 is also used—it permits reductions in cable weight and diameter. See section 3-10.

Gases—because of the complex construction and handling problems involved, gas filled cables are used only where necessary. See section 3-1.

Glass—glass fibers are used in yarn servings and braids. High tensile strength, non-flammability, flexibility, and resistance to moisture and high temperatures are characteristics of glass fibers. Dielectric properties and protection against abrasion depend on other materials or treatments. See section 3-3.

Mica—mica is used as an insulation wrap in wires and cables to a very limited degree. See section 3-15.

Mineral Insulation—mineral insulated (MI) cable and thermocouple wire consists of one or more conductors surrounded by magnesium oxide insulation and enclosed in a liquid- and gas-tight metallic sheathing. Because the construction is completely inorganic, the cable is very heat resistant and inert to most conditions. See section 3-16.

Natural Rubber—rubber by itself is lacking in many properties required of wire and cable insulating and jacketing materials. However, by proper compounding and mixing with other products, it can be converted to a material with excellent physical properties, good electrical properties, and fair to moderate ozone resistance and chemical resistance. See section 3-11.

Neoprene—chemically, this synthetic rubber is known as polychloroprene. Its first use as a cable jacketing material was reported in 1933. Its application over lead sheathed and rubber insulated cables has grown rapidly since that time. Although the electrical properties of neoprene are inferior to many other insulations, they are adequate for low voltage work. The physical properties of neoprene are similar in some respects to natural rubber but it is considerably better from the standpoint of resistance to oil, ozone, heat, weather, sunlight, and aging. It does not support combustion and resists abrasion and cutting. It is used for a wide

work, a specially purified grade is required. The material is used in solid extruded forms and there is also some work being done with foams. In addition, polypropylene film is being used, either alone or in combination with such films as polyethylene or polytetrafluoroethylene, as a cable or core wrap to act as a thermal (during extrusion) or moisture barrier in cable constructions—and, providing additional electrical and mechanical side benefits. See section 3-10.

Polytetrafluoroethylene—this is the most thermally stable and chemically resistant of all carbonaceous insulating compounds. It is unaffected by sunlight, moisture, and practically all chemicals. Temperature range is -90 to $+250^{\circ}\text{C}$ and electrical properties are very constant over the temperature range and a wide range of frequencies. Insulation may be applied by extrusion, taping, dip-coating, and in cases where another material is used, by dispersion coating. Both conventional and ribbon type wires and cables are made. Corona resistant modified PTFE compositions are available. See section 3-10.

Polytrifluorochloroethylene — this material approaches PTFE in many properties but is characterized by somewhat lower heat resistance. See section 3-10.

Polyvinyl chloride—PVC is widely used for primary wire insulation or jacketing on communication wires, control cables, bell wire, building wire, hook-up wire, fixture wire, appliance cords, power cables, lighting cables, motor leads, etc. Many different formulations are available including grades for high temperatures, low temperatures, flame resistance, deformation resistance, etc. Dielectric strength is excellent and flexibility is very good. Some formulations may have limitations when considering toughness, moisture resistance, and resistance to chemicals. However, by proper compounding, these properties can generally be tailored to meet the requirements of the application. PVC is probably the most versatile of the lower cost, conventional temperature wire insulations in round and ribbon forms. See section 3-10.

Rayon—this is a synthetic used for

yarn serving and braid applications generally in the same applications where cotton can be used. See section 3-3.

SBR is a styrene-butadiene copolymer synthetic rubber characterized by good electrical properties and moisture resistance. Ozone resistance, physical properties, and chemical resistance are generally improved by blending with other materials. In this respect, it should be mentioned that both the synthetic and natural rubbers are not used "straight" but are blended with each other and other products in order to improve properties. Thus, this discussion runs the risk of over-generalization—wire and cable producers should be consulted for specific information. See section 3-11.

Silica—silica fibers produced from melted quartz offer properties similar to fiber glass but even higher heat resistance (above 2000°F). They offer possibilities as yarn servings. See section 3-3.

Silicone rubber—silicone rubber extrusions offer retention of good electrical properties, resilience, and flexibility after long-time heat aging at class 180 temperatures and higher. Excellent ozone resistance, low temperature flexibility, long life, low moisture absorption, weather resistance, radiation resistance, and corona resistance are other characteristics. Resistance to some oils, solvents, and strong acids is relatively poor. Aircraft wires, nuclear cable, lighting wire, power cable, control cable, shipboard cable, heat and cold appliance wires, lead wires, etc., are uses. See section 3-11.

Silk—used very little today as yarn serving and braid. See section 3-3.

Varnished Cambric—tape wraps of varnished cambric for insulation of wires and cable offer properties that lie between those of rubber and impregnated paper. This applies to dielectric strength, flexibility, resistance to moisture and heat, and handling cable connections and terminations. It provides greater moisture resistance than paper and higher voltage ratings than rubber. In dry locations, it may be used without a lead sheath. It can be used for low and moderate voltage cables. See section 3-7.

Vinylidene fluoride—this thermoplastic resin, a fluorocarbon which is characterized by very good mechanical, electrical, and chemical properties, is currently undergoing long term field tests in a variety of applications. In primary insulation and in jackets for multi-conductor cables, it has performed successfully at temperatures from -80° to 300°F . The material can be easily extruded, or applied as a solution or dispersion coating. See section 3-10.

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SUPPLIER DIRECTORY LISTING

NOTE: Numbers in parentheses following each product covered in this section correspond with the numbers shown in front of each supplier of products listed here (thus indicating which firms supply the product concerned). Only company names are listed here — see Part 4, section 4-1, for addresses of suppliers. Bold face type indicates advertisers — see advertisers' listing at back of book for page numbers of advertisements.

Products Covered in this Section

Listed According to Insulation and Jacketing Materials Used

Acrylic (8, 34, 36)
Anodic films (64)
Asbestos (8, 13, 19, 24, 27, 34, 36, 37, 40, 52, 71, 74, 81, 85, 90, 95)
Buna N (nitrile) (8, 16, 26, 31, 34, 48, 61, 78)
Butyl rubber (3, 8, 12, 13, 16, 17, 26, 34, 36, 37, 48, 58, 61, 78, 95)
Cellular or foamed dielectric (3, 5, 6, 10, 13, 14, 16, 17, 21, 24, 27, 28, 36, 37, 44, 48, 52, 55, 69, 72, 73, 76, 78, 81, 83, 85, 93)
Cellulose acetate (8, 13, 14, 27, 34, 36, 52, 95)
Ceramic (4, 7, 23, 35, 45, 52, 56, 57, 71)
Chlorosulfonated polyethylene (3, 13, 16, 26, 34, 36, 37, 52, 61, 78, 95)
Cotton (5, 8, 12, 13, 17, 27, 28, 34, 36, 47, 48, 57, 71, 74, 90, 95)
Fluoroelastomers (13, 16, 34)
Fluorinated ethylene propylene (6, 8, 9, 13, 16, 17, 19, 26, 38, 44, 54, 55, 69, 74, 79, 85, 89, 94)
Gas filled (12, 36, 44)
Glass fiber (2, 8, 10, 13, 16, 17, 19, 21, 27, 28, 34, 36, 37, 40, 43, 44, 47, 59, 67, 69, 74, 82, 85, 90, 98)
Mica (8, 16, 19, 27, 43, 52, 74)
Mineral (magnesium oxide) insulated (25, 36, 40, 52, 71, 85, 90)
Natural rubber (3, 6, 13, 16, 26, 31, 34, 36, 48, 58, 79, 81)
Neoprene (3, 5, 6, 8, 13, 16, 17, 26, 31, 34, 36, 37, 48, 58, 61, 73, 74, 78, 79, 81, 95)
Nylon (3, 5, 6, 8, 12, 13, 14, 15, 17, 19, 21, 24, 26, 27, 28, 31, 34, 36, 37, 40, 44, 47, 48, 52, 53, 54, 55, 57, 62, 65, 69, 71, 73, 74, 78, 79, 81, 83, 85)

90, 95, 98;
C-fiber (12, 30, 40, 70)
Fiber (12, 2, 24, 30, 30, 40, 70, 95)
Polyamide fiber (8, 13, 14, 21, 24, 27, 52, 57, 74, 85)
Polyester fiber (8, 9, 13, 19, 24, 34, 36, 52, 57, 74)
Polyester film (8, 13, 19, 24, 34, 36, 38, 52, 57, 74, 83, 95)
Polyethylene (3, 5, 6, 8, 10, 12, 13, 14, 15, 16, 17, 19, 21, 24, 26, 27, 29, 31, 34, 36, 37, 42, 44, 46, 48, 52, 55, 57, 58, 61, 65, 69, 71, 72, 73, 74, 76, 78, 81, 83, 85, 93, 95)
Polyethylene, chemically cross-linked (2, 12, 13, 16, 19, 26, 28, 31, 34, 36, 37, 42, 46, 61, 69, 73, 78, 83, 85, 93)
Polyethylene irradiated (8, 16, 21, 24, 34, 42, 55, 69, 72, 73, 76, 78, 81)
Polyimide film (85)
Polypropylene (3, 6, 8, 13, 14, 15, 16, 21, 24, 27, 28, 34, 36, 39, 44, 52, 65, 78, 81, 83, 85, 98)
Polytetrafluoroethylene (5, 8, 9, 10, 13, 14, 16, 17, 19, 20, 21, 27, 28, 31, 34, 36, 37, 38, 42, 43, 44, 52, 54, 69, 73, 74, 79, 80, 81, 83, 85, 88, 89, 90, 94, 97)
Polytrifluoroethylene (8, 10, 12, 14, 15, 16, 27, 28, 31, 34, 36, 42, 52, 57)
Polyurethane rubber (61)
Polyvinyl chloride (3, 5, 6, 8, 10, 13, 14, 16, 17, 19, 21, 24, 26, 27, 28, 29, 31, 34, 36, 37, 40, 42, 44, 48, 52, 53, 55, 58, 61, 65, 69, 71, 72, 73, 74, 76, 78, 80, 81, 82, 83, 85, 88, 90, 93, 95, 98)
Kevlar (5, 6, 8, 13, 17, 21, 24, 27, 34, 36, 48, 52, 65, 76, 95)
Silica fibers (27, 34, 52, 74, 91)
Silicone rubber (8, 9, 10, 12, 13, 16, 19, 22, 24, 26, 27, 28, 31, 34, 36, 37, 42, 46, 52, 54, 65, 78, 81, 83, 95, 98)
Slit (8, 13, 34, 47, 57, 69)
SBR (Styrene-butadiene) (3, 5, 6, 8, 13, 16, 26, 31, 36, 37, 48, 58, 61, 76, 81, 95)
Varnished cambric (8, 12, 19, 24, 27, 34, 36, 37, 56, 78, 81, 95)
Vinylidene fluoride (6, 9, 13, 34, 74, 79, 80, 85)

Listed According to Application, Function, Type, or Form

Aerial (2, 3, 5, 8, 12, 14, 17, 19, 21, 26, 27, 34, 36, 37, 42, 46, 58, 72, 76, 83, 85, 95)
Aircraft and missile (3, 5, 6, 8, 9, 13, 14, 16, 17, 19, 20, 21, 26, 27, 31, 34, 35, 36, 37, 39, 41, 43, 44, 47, 48, 52, 55, 63, 65, 66, 72, 73, 74, 75, 76, 79, 81, 83, 85, 88, 89, 90, 91, 95, 98)
Alloy (not insulated) (8, 11, 41, 47, 48, 57, 66, 84, 86, 98)
Apparatus (3, 5, 6, 8, 9, 14, 16, 17, 19, 21, 26, 27, 36, 37, 52, 63, 66, 72, 73, 74, 76, 81, 83, 85, 93, 96)
Appliance (3, 5, 8, 9, 12, 13, 14, 17, 19, 21, 26, 27, 31, 34, 36, 37, 42, 45, 52, 57, 58, 63, 66, 76, 81, 83, 84, 85, 89, 92, 95, 98)
Armored (8, 12, 19, 21, 26, 34, 36, 37, 42, 44, 46, 52, 61, 73, 76, 81, 82, 90)
Automotive (5, 8, 12, 13, 14, 17, 19, 21, 26, 27, 31, 34, 42, 57, 65, 66, 81, 83, 93, 98)
Balloon insulated (8, 26, 83)
Bare (not insulated) (3, 5, 8, 12, 13, 14, 21, 26, 31, 32, 34, 36, 41, 48, 51, 57, 71, 76, 84, 86, 90, 98)
Building (3, 8, 12, 21, 26, 34, 36, 46, 58, 65, 81, 98)
Cable terminations (1, 8, 10, 13, 16, 26, 33, 34, 46, 52, 61, 74, 83, 87, 90)
Cable (not insulated) (8, 12, 27, 32, 36, 41, 76, 84, 86)
Coaxial (1, 2, 5, 8, 9, 10, 12, 13, 14, 16, 17, 19, 21, 22, 26, 27, 36, 37, 38, 42, 43, 44, 46, 52, 55, 61, 63, 65, 66, 67, 72, 73, 76, 79, 81, 83, 85, 88, 89, 90, 93, 98)
Coiled (5, 6, 8, 13, 17, 26, 34, 64, 76, 80, 84, 93)
Communication (3, 5, 6, 8, 9, 12, 13, 14, 16, 17, 19, 21, 26, 27, 34, 36, 37, 44, 46, 52, 55, 61, 63, 65, 66, 72, 73, 74, 76, 79, 81, 83, 85, 89, 92, 95, 98)
Control (3, 5, 6, 8, 9, 12, 13, 14, 16, 17, 21, 26, 27, 34, 36, 37, 44, 48, 52, 57, 58, 61, 63, 65, 66, 72, 73, 74, 79, 81, 83, 89, 95, 98)
Cord sets (5, 13, 26, 34, 36, 63, 65, 76, 87, 93, 95, 98)
Delay (8, 21, 32, 44, 72, 73)
Direct burial (3, 5, 8, 12, 14, 16, 17, 19, 21, 26, 27, 34, 36, 37, 38, 44, 48, 58, 61, 65, 74, 76, 81, 83, 95, 98)
Electronic (1, 2, 5, 6, 8, 9, 13, 14, 16, 17, 18, 19, 21, 26, 27, 31, 34, 35, 36, 37, 38, 44, 47, 48, 52, 55, 57, 61, 63, 65, 66, 68, 72, 73, 74, 76, 79, 80, 81, 83, 84, 85, 88, 89, 91, 93, 97, 98)
Fixture (3, 6, 8, 9, 12, 17, 19, 21, 26, 27, 31, 34, 36, 37, 48, 58, 65, 66, 81, 83, 93, 95, 98)
Harnesses and assemblies (3, 6, 8, 10, 13, 19, 22, 26, 27, 29, 30, 34, 38, 40, 42, 43, 44, 52, 55, 60, 63, 65, 70, 71, 74, 75, 79, 80, 83, 88, 96, 98)

Heating (8, 11, 19, 21, 26, 27, 34, 36, 37, 52, 57, 66, 79, 88, 95, 98)
High temperature (1, 5, 6, 8, 9, 10, 12, 13, 14, 16, 17, 19, 20, 21, 22, 26, 27, 31, 34, 35, 36, 37, 38, 42, 43, 44, 46, 52, 55, 57, 61, 64, 66, 67, 72, 73, 74, 79, 80, 81, 83, 85, 88, 89, 90, 91, 95, 97, 98)
High voltage (1, 3, 5, 8, 9, 10, 12, 13, 14, 16, 17, 19, 20, 21, 26, 27, 31, 34, 36, 37, 38, 42, 46, 48, 65, 66, 72, 73, 76, 80, 81, 83, 85, 89, 91, 93, 95, 98)
Hoar-up (3, 5, 6, 8, 9, 10, 12, 13, 14, 17, 19, 20, 21, 26, 27, 31, 34, 36, 37, 38, 42, 43, 44, 52, 65, 66, 72, 73, 74, 76, 79, 80, 81, 82, 83, 85, 88, 89, 93, 95, 97, 98)
Ignition (5, 8, 9, 12, 13, 14, 16, 17, 19, 21, 26, 31, 34, 38, 52, 65, 66, 76, 81, 83, 85, 98)
Lead covered (3, 8, 12, 19, 26, 27, 34, 36, 37, 40, 52, 56, 71, 79)
Lighting (3, 8, 12, 14, 16, 19, 21, 26, 27, 31, 34, 36, 37, 48, 58, 65, 83, 95, 98)
Line (3, 5, 8, 12, 21, 26, 34, 36, 48, 58, 65, 83, 98)
Machine tool (3, 6, 8, 12, 14, 17, 21, 26, 27, 31, 34, 36, 37, 48, 58, 65, 66, 74, 89, 98)
Mining (3, 8, 12, 14, 16, 17, 19, 21, 26, 27, 34, 36, 37, 42, 48, 58, 65, 95)
Motor lead (3, 5, 8, 9, 12, 13, 14, 16, 17, 19, 21, 26, 27, 31, 34, 36, 37, 38, 42, 43, 48, 52, 65, 66, 72, 73, 79, 81, 82, 83, 89, 93, 95, 98)
Multi-conductor (1, 3, 5, 6, 8, 9, 10, 12, 13, 14, 16, 17, 19, 20, 21, 22, 26, 27, 31, 34, 36, 37, 39, 42, 44, 48, 52, 55, 58, 61, 65, 66, 72, 73, 74, 76, 79, 80, 81, 83, 88, 89, 90, 93, 95, 97, 98)
Plated or coated (not insulated) (3, 5, 8, 21, 26, 27, 31, 34, 36, 41, 44, 81, 84, 86)
Power (3, 5, 8, 9, 12, 13, 19, 21, 22, 26, 27, 34, 36, 37, 38, 48, 52, 57, 58, 65, 66, 72, 73, 81, 95, 96, 98)
Radio and television (3, 5, 6, 8, 9, 12, 13, 14, 16, 17, 19, 21, 26, 27, 31, 34, 36, 37, 38, 42, 44, 48, 65, 73, 81, 83, 84, 93, 98)
Resistance (8, 11, 12, 19, 31, 32, 34, 37, 47, 49, 52, 57, 73, 79, 83, 90, 98)
Ribbed (flat) (5, 6, 8, 9, 10, 11, 14, 17, 22, 26, 31, 32, 38, 41, 42, 48, 50, 52, 64, 65, 73, 79, 80, 81, 83, 84, 88, 96)
Service entrance (3, 8, 12, 26, 34, 36, 37, 48, 58, 83)
Shielded (3, 5, 6, 8, 9, 12, 13, 14, 16, 17, 19, 21, 22, 26, 27, 31, 34, 36, 37, 38, 42, 43, 44, 48, 52, 55, 58, 65, 66, 67, 72, 73, 74, 76, 79, 80, 81, 83, 88, 89, 90, 93, 95, 97, 98)
Shipboard (3, 8, 9, 12, 16, 17, 19, 26, 27, 34, 36, 37, 42, 43, 44, 46, 52, 55, 61, 66, 73, 74, 76, 81, 83, 95, 98)
Signal (3, 5, 8, 12, 17, 21, 26, 27, 34, 36, 37, 38, 44, 48, 52, 55, 58, 65, 66, 72, 73, 74, 76, 81, 83, 95, 98)
Submarine (6, 9, 12, 17, 26, 27, 36, 37, 42, 44, 46, 61, 66, 73, 74, 83, 88, 95, 98)
Switchboard (3, 6, 8, 12, 14, 17, 19, 21, 26, 27, 34, 36, 37, 42, 48, 63, 65, 66, 73, 81, 83, 89, 95, 96, 98)
Telephone (8, 12, 13, 14, 17, 21, 26, 27, 29, 34, 36, 42, 48, 65, 66, 76, 81, 83, 89, 93, 96, 98)
Thermocouple (6, 8, 9, 19, 21, 25, 26, 27, 32, 40, 42, 43, 52, 57, 66, 67, 71, 72, 73, 74, 76, 79, 81, 83, 88, 90, 91, 92)
Tinsel (not insulated) (8, 36, 41, 76, 98)
Underground (3, 8, 12, 16, 17, 19, 21, 26, 34, 36, 37, 48, 58, 65, 76, 81, 83, 95, 98)

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