Polymer Cross-Linking Information

Technical Information

All plastic materials consist of complex, very large molecules. In the case of those compounds used as insulation and jacketing materials, they are called polymers. A polymer is a large molecule built up by repetition of many, smaller chemical units. Polyethylene consists of a long chain of units, each made of one carbon atom with two associated hydrogen atoms. Figure 1 illustrates a portion of a polyethylene molecule. An actual molecule is approximately 5000 units in length.

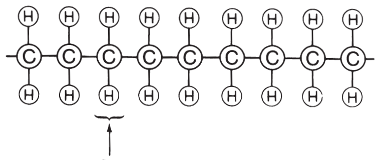

FIGURE 1. Portion of a polyethylene molecule made of repeating units of carbon and hydrogen.

Polyethylene consists of many random molecular chains, with no particular orientation, and no chemical bonds existing between chains. When heat is applied to such a material, the chains are free to slip and flow under relatively small outside force. Such a material is called a thermoplastic. If we are able to introduce cross-linking bonds between adjacent molecular chains, this adds form stability at higher temperatures. There will still be some loss of strength at elevated temperatures, but the crosslinked molecular chains are much more resistant to flow when stress is applied.

Crosslinking can be accomplished chemically or by irradiation. Chemical crosslinking with rubber material is called Vulcanization. It is accomplished by a heat induced reaction between the polymers and a crosslinking agent. For wire and cable insulations, chemical crosslinking is performed by passing the wire through a long pressurized steam tube, called a continuous vulcanizing (C.V.) machine.

Not all materials can be crosslinked, but for those that are able, the results are important. Figure 2 summarizes the effects that polymer crosslinking provides.

In general, mechanical characteristics are improved, especially at higher temperatures. It results in improved resistance to stress cracking and better fluid resistance. There is generally little or no change in flame resistance, electrical characteristics, or thermal stability. One of the most misunderstood results of crosslinking is its effect on long term thermal stability. Uncrosslinked polyethylene is usually rated at 75°C, not due to heat aging, but due to the fact that the material becomes soft and will flow at higher temperatures. Properly compounded and crosslinked polyethylene may have a temperature rating as high as 125°C. The material no longer flows at elevated temperatures and therefore can be effectively used at a higher temperature.

Cross-Linking Provides:

1. Higher tensile strength
2. Improved abrasion/cut through
3. Better crush resistance
4. Solder iron resistance
5. Better over load characteristics
6. Resistance to stress cracking
7. Improved fluid resistance
8. Slightly better flame resistance
9. No change of electricals
10. Negligible change in thermal stability
11. Decrease in flexibility
12. Improved high temperature mechanicals

FIGURE 2.

Polymers may also be crosslinked by means of electron irradiation. During the irradiation process, high energy electrons bombard the insulation system. Figure 3 illustrates two random polyethylene molecules being subject to irradiation. The energy of irradiation ejects a hydrogen atom which then removes a neighboring hydrogen atom, forming molecular hydrogen gas (H_2). The vacant sites on the adjacent polymer chain then combine to create a crosslink bond.

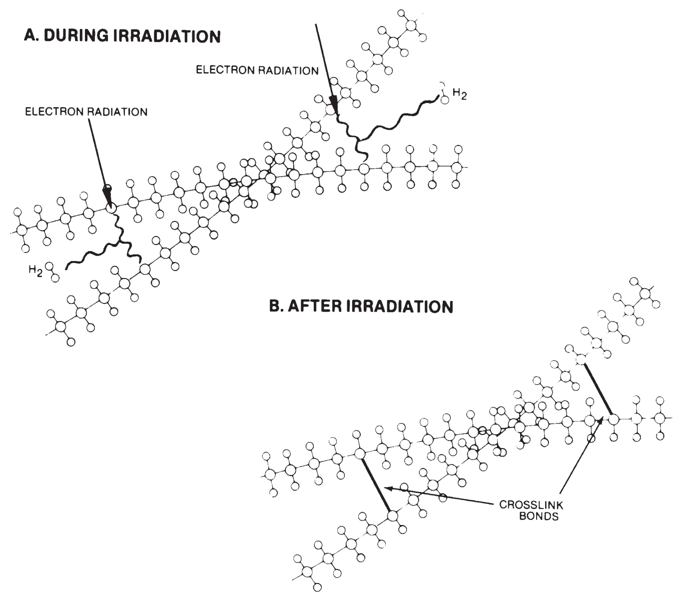

FIGURE 3. Two random polyethylene molecules during and after irradiation crosslinking.

For most plastic materials, equivalent properties may be obtained by the use of either C.V. or irradiation crosslinking, but irradiation may have the following advantages:

1. Irradiation has no lower limit on physical size, smaller conductor sizes, and thin insulation walls may be provided.

2. Irradiation does not use high temperature or pressure. Separator tapes are not required to prevent thin wall insulations from being forced into the conductor strand surface.

3. Irradiation offers the insulation compounder design freedom. Compound additives may be chosen without regard to their reaction to high temperatures and to moisture.

Metric Conversion Data & Temperature Conversion Chart

Technical Information

METRIC CONVERSION FACTORS

TO CHANGE		MULTIPLY BY	TO CHANGE		MULTIPLY BY
			inches	to meters	0.0254
meters	to inches	39.37	feet	to meters	0.3048
meters	to feet	3.28	centimeters	to meters	0.01
meters	to centimeters	100.00	millimeters	to meters	0.001
meters	to millimeters	1000.00	meters	to kilometers	0.001
kilometers	to meters	1000.00	millimeters	to inches	0.03937
inches	to millimeters	25.40	millimeters	to feet	0.00328
feet	to millimeters	304.80	millimeters	to yards	0.00109
yards	to millimeters	914.40	kilometers	to miles	0.6214
miles	to kilometers	1.61	grams	to pounds	2.205×10^3
pounds	to grams	453.6	pounds/kft	to kg/km	1.488
mm^2	CMA	1973.5	pounds force–force	to newtons	4.448
			pounds/in^2	to pascals	6895

TEMPERATURE CONVERSION FACTORS

Degrees Centigrade = 5/9 (° F – 32)　　Degrees Fahrenheit = 9/5 (°C) + 32

°C	°F	°C	°F	°C	°F
– 80	– 112.	26	78.8	81	177.8
– 70	– 94.	27	80.6	82	179.6
– 60	– 76.	28	82.4	83	181.4
– 50	– 58.	29	84.2	84	183.2
– 45	– 49.	30	86.0	85	185.0
– 40	– 40.0	31	87.8	86	186.8
– 35	– 31.0	32	89.6	87	188.6
– 30	– 22.0	33	91.4	88	190.4
– 25	– 13.0	34	93.2	89	192.2
– 20	– 4.0	35	95.0	90	194.0
– 19	– 2.2	36	96.8	91	195.8
– 18	– .4	37	98.6	92	197.6
– 17	1.4	38	100.4	93	199.4
– 16	3.2	39	102.2	94	201.2
– 15	5.0	40	104.0	95	203.0
– 14	6.8	41	105.8	96	204.8
– 13	8.6	42	107.6	97	206.6
– 12	10.4	43	109.4	98	208.4
– 11	12.2	44	111.2	99	210.2
– 10	14.0	45	113.0	100	212.0
– 9	15.8	46	114.8	105	221.
– 8	17.6	47	116.6	110	230.
– 7	19.4	48	118.4	115	239.
– 6	21.2	49	120.2	120	248.
– 5	23.0	50	122.0	130	266.
– 4	24.8	51	123.8	140	284.
– 3	26.6	52	125.6	150	302.
– 2	28.4	53	127.4	160	320.
– 1	30.2	54	129.2	170	338.
0	32.0	55	131.0	180	356.
1	33.8	56	132.8	190	374.
2	35.6	57	134.6	200	392.
3	37.4	58	136.4	250	482.
4	39.2	59	138.2	300	572.
5	41.0	60	140.0	350	662.
6	42.8	61	141.8	400	752.
7	44.6	62	143.6	500	932.
8	46.4	63	145.4	600	1112.
9	48.2	64	147.2	700	1292.
10	50.0	65	149.0	800	1472.
11	51.8	66	150.8	900	1652.
12	53.6	67	152.6	1000	1832.
13	55.4	68	154.4	1100	2012.
14	57.2	69	156.2	1200	2192.
15	59.0	70	158.0	1300	2372.
16	60.8	71	159.8	1400	2552.
17	62.6	72	161.6	1500	2732.
18	64.4	73	163.4	1600	2912.
19	66.2	74	165.2	1700	3092.
20	68.0	75	167.0	1800	3272.
21	69.8	76	168.8	1900	3452.
22	71.6	77	170.6	2000	3632.
23	73.4	78	172.4	2500	4532.
24	75.2	79	174.2	3000	5432.
25	77.0	80	176.0	4000	7232.

Copper Conductor Data

Technical Information

The information listed below is for solid and stranded, annealed copper wire. Conductors which have protective coatings, such as tin, silver, or nickel will have diameters and weight which may vary slightly from this data.

								Single Conductor Max. D.C. Resistance @ 20°C					
Size		Diameter		Area		Weight		Tinned Copper		Silver Coated Copper		2% Nickel Coated Copper	
AWG	Stranding	Inch	mm	Circ. Mils	sq. mm	lbs/kft	kg/km	Ohms/kft	Ohms/km	Ohms/kft	Ohms/km	Ohms/kft	Ohms/km
40	Solid	.0031	.08	10	.005	.03	.04	1240	4068	1150	3773	1320	4331
38	Solid	.004	.10	15.7	.008	.048	.07	735	2411	682	2237	755	2477
36	Solid	.005	.13	25	.01	.076	.11	465	1525	430	1411	470	1542
34	Solid	.0063	.16	40	.02	.12	.18	290	951	271	889	288	945
33	Solid	.0071	.18	50	.03	.15	.22	228	748	212	695	224	735
32	Solid	.008	.20	63	.03	.19	.28	178	584	169	554	175	574
	7/40	.009	.23	70	.04	.21	.31	176	577	164	538	173	567
30	Solid	.010	.25	100	.05	.30	.45	114	374	106	348	110	361
	7/38	.012	.30	110	.06	.34	.50	106	348	98	321	108	354
29	Solid	.0113	.28	127	.06	.38	.56	89	292	82	269	86	282
28	Solid	.0126	.32	160	.08	.48	.71	70	230	63	207	69	226
	7/36	.015	.38	175	.09	.54	.80	68	223	63	207	68	223
	19/40	.015	.38	190	.10	.58	.86	65	213	60	197	66	216
27	Solid	.0142	.36	202	.10	.61	.91	55.5	182	52.5	172	54	177
	7/35	.017	.54	221	.11	.68	1.01	55.8	183	52	171	56	184
26	Solid	.016	.41	254	.13	.77	1.14	44.5	146	41.9	137	43	141
	7/34	.019	.48	278	.14	.86	1.28	42.5	139	39.6	130	42.2	138
	19/38	.020	.51	304	.15	.92	1.37	38.8	127	36.2	119	40.1	131
25	Solid	.018	.46	320	.16	.97	1.44	34.5	113	32.7	107	33.4	109
24	Solid	.020	.51	404	.20	1.22	1.81	27.2	89	26.2	86	26.7	87
	7/32	.024	.61	441	.22	1.37	2.04	26.4	87	24.6	81	25.8	85
	19/36	.025	.63	475	.24	1.47	2.19	24.9	82	23.2	76	25.1	82
23	Solid	.0226	.57	510	.26	1.54	2.29	21.6	71	20.7	68	21.0	69
22	Solid	.025	.63	642	.32	1.95	2.90	17.2	56	16.5	54	16.8	54
	7/30	.030	.76	707	.36	2.18	3.24	16.9	55	15.7	51	16.4	54
	19/34	.032	.81	760	.38	2.33	3.47	15.7	51	14.6	48	15.6	51
21	Solid	.0285	.72	812	.41	2.45	3.64	13.6	45	13.0	43	13.2	43
	19/33	.036	.91	950	.48	2.94	4.37	12.8	42	11.9	39	12.6	41
20	Solid	.032	.81	1022	.52	3.09	4.60	10.7	35	10.3	34	10.5	34
	7/28	.038	.96	1120	.57	3.45	5.13	10.5	34	9.9	32	10.2	33
	10/30	.039	.99	1010	.51	3.10	4.61	11.8	39	11.0	36	11.5	38
	19/32	.040	1.02	1197	.61	3.71	5.52	9.72	32	9.05	30	9.52	31
	26/34	.039	.99	1025	.52	3.19	4.75	11.9	39	11.1	36	11.8	39
19	Solid	.036	.91	1290	.65	3.90	5.80	8.55	28	8.15	27	8.32	27
18	Solid	.040	1.02	1620	.82	4.92	7.32	6.78	22	6.52	21	6.58	21
	7/.0152	.046	1.16	1620	.82	5.02	7.47	7.23	24	6.81	22	7.02	23
	7/26	.048	1.22	1778	.90	5.49	8.17	6.61	22	6.22	20	6.37	21
	16/30	.049	1.24	1616	.82	4.97	7.39	7.55	25	7.02	23	7.32	24
	19/30	.050	1.27	1909	.97	5.90	8.78	6.22	20	5.80	19	6.03	20
	41/34	.049	1.24	1630	.82	5.03	7.48	7.50	25	7.00	23	7.46	24
16	Solid	.051	1.29	2580	1.31	7.82	11.6	4.26	14	4.10	13.4	4.13	13.5
	7/.0192	.058	1.47	2580	1.31	7.97	11.8	4.53	15	4.27	14.0	4.38	14.4
	19/29	.057	1.45	2413	1.22	7.43	11.0	4.82	16	4.54	14.9	4.70	15
	26/30	.060	1.52	2626	1.33	8.07	12.0	4.55	15	4.23	13.9	4.41	14.5
	65/34	.060	1.52	2600	1.32	7.98	11.9	4.74	16	4.43	14.5	4.70	15
15	Solid	.057	1.45	3260	1.65	9.86	14.7	3.38	11.0	3.26	10.7	3.28	10.8
14	7/.0242	.073	1.85	4100	2.08	12.7	19	2.79	9.15	2.69	8.82	—	—
	19/27	.071	1.80	3838	1.94	11.9	18	3.05	10.0	2.87	9.41	2.95	9.68
	19/.0147	.074	1.88	4106	2.08	12.1	18	2.85	9.35	2.68	8.79	—	—
	41/30	.075	1.90	4141	2.10	12.7	19	2.88	9.45	2.69	8.82	2.79	9.15

Copper Conductor Data

(continued)

Technical Information

Size AWG	Stranding	Diameter Inch	Diameter mm	Area Circ. Mils	Area sq. mm	Weight lbs/kft	Weight kg/km	Single Conductor Max. D.C. Resistance @ 20°C: Tinned Copper Ohms/kft	Tinned Copper Ohms/km	Silver Coated Copper Ohms/kft	Silver Coated Copper Ohms/km	2% Nickel Coated Copper Ohms/kft	2% Nickel Coated Copper Ohms/km
12	7/21	.086	2.18	5670	2.87	17.5	26	2.02	6.63	1.94	6.36	2.00	6.56
	7/.0305	.092	2.34	6512	3.30	20.2	30	1.76	5.77	1.69	5.54	1.62	5.31
	19/.0185	.093	2.36	6503	3.29	20.1	30	1.80	5.90	1.69	5.54	—	—
	19/25	.090	2.29	6070	3.07	18.8	28	1.92	3.94	1.81	5.94	1.85	6.07
	37/28	.089	2.26	5900	2.99	18.3	27	2.00	6.56	1.89	6.20	1.97	6.46
	37/27	.099	2.51	7455	3.77	23.0	34	1.58	5.18	1.48	4.85	1.56	5.12
	65/30	.094	2.39	6570	3.33	20.2	30	1.82	5.97	1.69	5.54	1.72	5.64
10	7/.0385	.116	2.95	10376	5.26	32.1	48	1.10	3.61	1.06	3.48	—	—
	37/26	.112	2.84	9410	4.77	29.1	43	1.26	4.13	1.19	3.90	1.24	4.07
	27/24	.123	3.12	10910	5.53	33.7	50	1.05	3.44	—	—	—	—
	105/30	.120	3.05	10553	5.35	33.7	50	1.15	3.77	1.07	3.51	1.13	3.71
8	37/24	.138	3.50	14950	7.57	46.0	68	.77	2.53	—	—	—	—
	133/29	.169	4.29	16851	8.54	53.0	79	.70	2.30	.66	2.16	.69	2.26
	168/30	.172	4.37	16884	8.55	53.2	79	.72	2.36	.67	2.20	.70	2.30
6	61/24	.190	4.83	24640	12.5	77	114	.47	1.54	—	—	—	—
	133/27	.213	5.41	26880	13.6	84	125	.45	1.48	.42	1.38	.44	1.44
5	91/24	.240	6.10	36760	19	113	168	.32	1.05	—	—	—	—
4	105/24	.260	6.60	42420	21	132	196	.28	.92	—	—	—	—
	133/25	.269	6.83	42560	21	134	199	.28	.92	.26	.85	.27	.88
	420/30	.270	6.86	42000	21	130	193	.29	.95	.27	.88	.28	.92
3	125/24	.285	7.24	50500	25	155	231	.24	.79	—	—	—	—
2	150/24	.320	8.13	60600	31	189	281	.19	.62	—	—	—	—
	665/30	.327	8.30	66833	34	214	318	.18	.59	.17	.56	.18	.59
	259/26	.336	8.53	66000	33	203	302	.19	.62	.17	.56	.18	.59
1	225/24	.385	9.78	90900	46	280	417	.13	.43	—	—	—	—
	817/30	.380	9.65	82109	42	266	396	.15	.49	.14	.46	.14	.46
0	259/24	.420	10.7	104636	53	323	481	.12	.39	.11	.36	.11	.36
	275/24	.435	11.0	111100	56	346	515	.11	.36	—	—	—	—
	1045/30	.413	10.5	105023	53	337	501	.12	.39	.11	.36	.11	.36
00	325/24	.470	11.9	131300	66	403	600	.092	.30	—	—	—	—
	375/24	.510	12.9	151500	77	467	695	.079	.26	—	—	—	—
	1330/30	.475	12.0	133665	68	429	638	.092	.30	.086	.28	.089	.28
000	450/24	.545	13.8	181800	92	567	844	.066	.22	—	—	—	—
	1661/30	.535	13.6	166931	84	536	797	.073	.24	.068	.22	.071	.23
0000	550/24	.580	14.7	222200	112	684	1018	.055	.18	—	—	—	—
	2109/30	.590	15	211452	107	683	1016	.058	.19	.054	.18	.056	.18

Coaxial Cable Design Data

Coaxial & Communication Cables

Coaxial Cables

The purpose of a coaxial cable is to transmit radio frequency energy from one point to another with the least possible power loss. To accomplish this purpose Surprenant designs and manufactures coaxial lines with specially alloyed, solid or stranded conductors, and specially compounded dielectric materials possessing low loss factors.

Coaxial design consists of a center of inner conductor, insulated with solid dielectrics of Polyethylene, Irradiated Polyethylene and foamed dielectrics of Polyethylene and Irradiated Polyethylene, Teflon PTFE and Teflon FEP. Over the dielectric core a braided metallic shield or outer conductor is applied. This outer conductor confines the signal within the cable, reduces extraneous interference to tolerable levels, as well as functioning as a return conductor and strength member. The braided metallic shield construction provides the highest degree of RFI shield effectivity and cable flexibility. A jacket is applied over the shield to isolate the shield from adjacent metal surfaces and to repel moisture and other origins of contamination. Typical jacket materials are as follows: Polyvinylchloride, Polyethylene, low smoke/zero halogen and Teflon FEP.

Design Considerations

The four most important considerations in the proper selection of a coaxial cable are: Impedance, Attenuation, Capacitance and Temperature Rating. These characteristics are interrelated and are determined by material selection and the mechanical design of the cable. These characteristics, as well as others, are described in the following paragraphs:

1. Impedance of a coaxial cable is expressed in ohms and is usually determined through known values of capacitance and velocity of propagation. The three common impedance values are 50, 75, and 95 ohm. Impedance matching in electronic systems is of prime importance in order to assure the most efficient operation.

$$Z_8 = \frac{101600}{vc} = \frac{138}{\sqrt{K}} \log_{10} \frac{D}{d}$$

Where: Z_8 = Characteristic Impedance
v = Velocity of Propagation in percent
c = Capacitance in pf/ft
K = Dielectric Constant
D = Dielectric diameter
d = Conductor diameter

2. Attenuation is the power loss in an electrical system. Loss of electrical power in coaxial cables can be attributed to two causes:

a. Conductor resistance that results in power loss due to heating by the R.F. currents passing through the conductor.

b. Dielectric loss caused by poor dielectric materials. It is, therefore, desirable to use dielectric materials having low power factors in order to minimize the latter.

The total loss is expressed in decibels per unit length of cable (db/100ft.). The decibel is a unit used to express the ratio between two amounts of power existing at two points.

By definition:

$$db = 10 \log_{10} \frac{P_1}{P_2}$$ or if expressed as voltage and

current ratios: $$db = 20 \log_{10} \frac{V_1}{V_2} = 20 \log_{10} \frac{I_1}{I_2}.$$

3. Capacitance is the ratio of the electrostatic charge on a conductor to the potential difference between the conductors required to maintain that charge. Capacitance is expressed in micro-microfarads or picofarads per foot.

By definition:

$$c = \frac{7.36k}{\log_{10} \frac{D}{d}}$$

Where: c = Capacitance in pf/ft
K = Dielectric Constant
D = Dielectric diameter
d = Conductor diameter

4. Temperature Rating of a coaxial cable will depend on the dielectric and jacketing material used. A coaxial cable will fall within one of the following four groups.

–55°C to +80°C Polyethylene with PVC jacket.
–55°C to +115°C Irradiated poly with Irradiated PVC jacket.
–65°C to +125°C Irradiated poly dielectric and jacket.
–65°C to +200°C Teflon dielectric and jacket.

5. Velocity of Propagation is the transmission velocity of an electrical signal down a length of cable compared to velocity of light, and is expressed as a percentage of velocity of light.

By definition:

$$v = \frac{1}{\sqrt{K}}$$

Where: v = Velocity of Propagation in percent.
K = Dielectric Constant

6. Dielectric Strength is a term used to describe the limit to which an applied voltage potential may be raised without damage to the insulating material.

7. Corona is a discharge due to the ionization of a gas (usually air) due to a potential gradient exceeding a certain critical value.

8. Corona Initiation Point is the critical value in the application of an electrical potential where corona can first be detected.

9. Voltage Standing Wave Ratio is the ratio of the maximum effective voltage to the minimum effective voltage measured along the length of a mismatched radio frequency transmission line.

Coaxial Conductors

1. CONDUCTORS — (See Table I — Conductor Properties) Surprenant's metallurgical research and processing of copper alloys have advanced several high strength conductor alloys of particular interest to coaxial cable users. It developed Alloy 63 which exhibits many of the advantageous characteristics of the steel alloy conductors while retaining conductivity approaching that of copper. By reference to Table I "Conductor Properties", the design engineer will be able to evaluate the properties of the more commonly used coaxial cable conductor materials to select properties best suited for his end application. By proper selection of the small diameter, high strength materials, greater flexibility is afforded the design engineer to meet his specific impedance and capacitance requirements.

Table I
Conductor Properties

Conductor Materials	Conductivity	Average Tensile	Average Elongation
Annealed Copper	100%	35,000 psi	20%
Surprenant Alloy 63	90%	60,000 psi	12%
Copper Covered Steel			
Hard Drawn	40%	120,000 psi	2%
Soft Drawn	40%	60,000 psi	12%
Hard Drawn	30%	135,000 psi	2%
Soft Drawn	30%	65,000 psi	12%

Dielectric Materials

2. DIELECTRICS (See Table II Dielectric Properties)

a. Extruded Polyethylene is by far the most commonly used material for low temperature coaxial dielectrics. Its low cost, ease of processing, high dielectric strength and low dielectric constant make it an ideal material for coaxial cable design.

b. Irradiated Polyethylene, which exhibits all of the desirable characteristics of polyethylene, also extends the usefulness of this low cost material by improved thermal stability and excellent solder iron resistance.

c. Foamed Dielectrics of irradiated and un-irradiated polyethylene are extruded materials expanded by numerous individual air cells. The incorporation of air reduces the dielectric constant which gives the electrical design engineer greater design flexibility. For example: increased center conductors can be utilized to achieve lower attenuation, and greater mechanical strength while retaining the same size and weight.

d. PTFE Teflon, by virtue of its high temperaure capability, high dielectric strength and low dielectric constant, is the second most popular coaxial cable dielectric. Its ability to withstand cold temperatures and exposure to certain gases and liquids makes it the logical dielectric choice where other materials would be inadequate.

Table II
Dielectric Properties

Material	Dielectric Constant	Specific Gravity	Velocity of Propagation	Temperature Limits
Solid PE	2.26	0.92	66%	–75 to 80°C
Foam PE	1.6	0.59	78%	–75 to 80°C
Irradiated Solid PE	2.26	0.92	66%	–75 to 125°C
Irradiated Foam PE	1.6	0.59	78%	–75 to 125°C
Teflon PTFE*	2.0	2.1	71%	–75 to 200°C

**Limited to +200°C by virtue of silver plated conductors.*

3. SHIELDING

a. Bare copper shields are usually confined to use in the low temperature coaxial cables. Bare Copper will oxidize from exposure to air and this oxidation is accelerated by the presence of moisture.

b. Tin Copper Shields are the least expensive of the protective coated constructions. In addition to providing protection against corrosion, the tin surface serves as an aid to soldering, but is limited in use to temperatures not exceeding 135 to 150°C. Above these temperatures the tin will rapidly oxidize, turn black and corrode.

c. Silver Copper Shields are more commonly used on the high temperature coaxial cables. Silver coatings are useful for temperatures through 200°C for continuous service.

4. JACKETING MATERIALS (Refer to Table III "Jacket Temperature Limits")

a. Polyvinylchloride is the most popular of all jacketing material. Type IIA jackets to MIL-C-17 requires a non-contaminating polyvinylchloride compound.

b. Polyethylene (Type IIIA per MIL-C-17) provides excellent abrasion resistance and weathering properties and is ideally suited for direct burial applications.

c. PTFE Teflon (Type VII per MIL-C-17) — This jacket can be applied by tape wrapping or extrusion techniques. The extruded jacket is of smoother texture, snag free and completely homongeneous. Either type will provide a good high temperature cable jacket which is chemically inert and insoluable in liquids and gases.

d. FEP Teflon (Type IX per MIL-C-17) — This jacket construction has many of the characteristics of PTFE Teflon and the added advantage of being applied by a melt extruding process which is more conducive to longer continuous lengths and lower cost than PTFE Teflon.

e. Cross-linked polyolefin (Type XIV per MIL-C-17) —This jacket is a low smoke, zero halogen jacket which has become the preferred jacket for MIL-C-17 coaxial cable.

f. Cross-Linked Vinyl jackets offer improved thermal stability, solder iron resistance and abrasion resistance while retaining the other good features of polyvinylchloride compounds.

g. Poly/Mylar Tape wrapped jackets provide reduced diameters and lighter weights (.006" wall poly/mylar as compared in a min. of .010" wall on all other jackets shown above) without sacrificing wither cut-through or abrasion. Other jacket types such as extruded nylon, braided nylon, braided fiberglass, irradiated polyethylene and neoprene are available. These types, as well as those shown above are listed in Table III "Jacket Temperature Limits".

Table III
Jacket Temperature Limits

Military Type	Material	Temperature Limits
Type IIA*	Polyvinylchloride	–55°C to +80°C
Type IIIA	Polyethylene	–65°C to +85°C
Type VII*	PTFE Teflon	–65°C to +250°C
Type IX	FEP-Teflon	–65°C to +220°C
—	Cross-Linked Vinyl	–40°C to +115°C
Type XIV	Cross-Linked Polyolefin	–55°C to +115°C
—	Poly/Mylar	–55°C to +115°C
—	Nylon	–55°C to +105°C
—	Neoprene	–55°C to +80°C

**Cables over 1/4 inch –40°C to +90°C.*
***Limited to +200°C by silver plated conductors*

5. SWEEP TESTING — VSWR

Due to system reliability considerations, MIL-C-17 was changed to require certain 50 ohm coaxial cables to conform to difficult Voltage Standing Wave Ratio (VSWR) requirements. This test is also known as the structural return loss requirement, and is one of the most difficult requirements that coaxial cables must pass. Every length of these constructions is tested across a wide frequency range and the losses created by dimensional fluctuations recorded. If the decibel (db) loss is greater than a set maximum at any frequency, the length of cable fails.

Due to high scrap levels and difficulties of manufacture, many of these sweep tested coaxial types are much more expensive. Since some electronic systems may not require this performance and added cost, MIL-C-17 allow certain cables in both swept and unswept versions. Note that many of the constructions shown on Pages 39 and 40 are listed in both versions.

The following abbreviations apply to pages 39 and 40.

BC	Bare Copper
BC/ST-H	Bare Copper Covered Steel (Hard)
FEP	Extruded Fluorinated Ethylene Propylene
FBG	Varnished Fiberglass Braid
NCPVC	Non-Contaminating Polyinylchloride
NPC	Nickel Plated Copper
PE	Extruded Polyethylene
PVC	Extruded Polyvinylchloride
SPC	Silver Plated Copper
SPC/ST-H	Silver Plated Copper Covered (Hard)
SPC/ST-S	Silver Plated Copper Covered Steel (Soft)
TC	Tinned Copper
PTFE	Extruded Polytetrafluoroethylene

Glossary Of Terms

ASTM - American Society for Testing and Materials.

AWG - American Wire Gauge.

AWM - Appliance Wiring Material

Binder Tape - A helically applied tape used for holding assembled cable components in place until additional manufacturing operations are performed.

Braid - A flexible cable covering, armor, core binder or shield of interwoven yarns, fine wires, fibers or flat metal strips.

Cable - A cable is either an insulated conductor (one conductor cable) or a combination of conductors insulated from one another (multiple conductor cable).

Circular Mil (Cmil) - The area of a circle one thousandth of an inch (or one mil) in diameter.

Coating - A material applied to the surface of a conductor to prevent environmental deterioration, facilitate soldering or improve electrical performance.

Color Code - A color system for circuit identification by use of solid colors, tracers, braids, surface printing, etc.

Conductor - A wire or combination of wires not insulated from one another, suitable for carrying an electrical current

Cross Linking - The establishment of chemical bonds between polymer molecule chains. It may be accomplished by heat, vulcanization, irradiation or the addition of a suitable chemical agent.

CSA - Canadian Standards Association.

Drain Wire - An uninsulated conductor utilized in a shielded cable in direct contact with the metallic shield. It provides shield continuity and aids in terminating.

FEP (Fluorinated Ethylene Propylene) A type of high temperature thermoplastic Teflon produced by E.I. Du Pont. It can be utilized for both insulation and jacket applications.

Filler - Any material used in multiconductor cables to occupy the interstices between insulated conductors or to form a core into a desired shape (usually circular).

Flame Retardance - The ability of a burning material to extinguish its own flame once its flame-initiating heat source is removed.

FR - Abbreviation for flame retardant, often used as a prefix to further describe materials (i.e. FR-XLPE).

Halogen - Any of the elements Fluorine, Chlorine, Bromine or Iodine that form group VII A of the periodic table. In cable insulation and jackets, Chlorine, Bromine or Fluorine are typically utilized as flame retardants. They have the undesirable effect of generating corrosive acid gas in the event of fire.

IEEE - Institute of Electrical and Electronics Engineers (Formerly AIEE).

Insulation - Material having a high resistance to the flow of electric current to prevent leakage of current from a conductor.

Irradiation - The exposure of a material to high energy emissions. In insulations and jackets for the purpose of favorably altering the molecular structure (i.e., to crosslink).

Jacket - An extruded plastic or elastomeric material covering applied over an insulation or an assembly of components to provide protection or act as a barrier.

KV (Kilovolt) - A term denoting one thousand volts.

Mica - A transparent to semi-transparent mineral silicate which can be separated into very thin leaves. It is useful as an electrical insulating material and performs at temperatures up to 900°C. When combined with glass or polyester tape it forms the basis for a functional, high temperature cable insulation system.

Mil - The one thousandth part of an inch (.005" = 5 mils).

Multiconductor - More than one insulated conductor within a single cable.

Neoprene (Polychloroprene)
Synthetic rubber compound used for cable jacket when thermoset materials are required.

Nominal - Name or identifying value of a measurable property by which cable components or performance is identified and to which tolerances may be applied.

Pair - A group of two insulated conductors which are twisted together.

PVC (Polyvinyl Chloride) - A thermoplastic or irradiation crosslinked material composed of polymers of vinyl chloride which is used as insulation or jackets.

Shield - Any barrier to the passage of interference causing electrostatic or electromagnetic fields, formed by a conductive layer surrounding a cable core. It is usually fabricated from a metallic tape, braid, foil or wire serve.

Silicone Rubber - Rubber made from silicone polymers and characterized by its retention of flexibility, resilience and tensile strength over a wide temperature range and by the formation of non-conducting ash during combustion.

Solid Wire - A conductor consisting of a single member or strand as distinguished from a stranded conductor.

Stranded Conductor - A conductor composed of a group of wires or combination of groups of wires.

Temperature Rating - The maximum temperature at which a given insulation or jacket may be safely maintained during continuous use without incurring any significant thermally-induced deterioration.

Thermoplastic - A classification of material that can be readily softened and reformed by heating and be rehardened by cooling.

Thermoset - A classification of material which cures (crosslinks) by chemical reaction and then is resistant to the heat related softening effect exhibited by thermoplastic materials.

Triad - A group of three insulated conductors which are twisted together.

UL - Underwriters Laboratories, Inc.

Volt - The practical unit of electromotive force. One volt is required to send one ampere of current through a circuit whose resistance is one ohm.

Voltage Rating - The maximum voltage at which a given cable or insulated conductor may be safely maintained during continuous use in a normal manner.

Vulcanization - An irreversible process during which a rubber or polymeric compound through a change in its chemical structure (i.e. crosslinking), becomes thermoset (usually improving chemical resistance and conferring, improving or extending elastic properties over a greater range of temperature).

XLPE (Crosslinked Polyethylene)
A tough thermoset insulation material made by crosslinking polyethylene polymers by either heat or irradiation processing. (It is classified under the more generic category of crosslinked polyolefins - see below).

XLPO (Crosslinked Polyolefin)
A thermoset material used for insulation or jackets. A polyolefin is a class of hydrocarbon polymers characterized by at least one double bond in the carbon chain. The polyolefins include mainly the polymers and copolymers of ethylene (polyethylene) and propylene (poly propylene). They are made thermosetting (or crosslinked) by chemical means (heating with organic peroxides) or by irradiation (high energy electron beam).