Fractions and Their Decimal Equivalents. The decimal equivalents in both inches and millimeters for the more commonly used fractions are given in Table No. 9. One inch equals 25.4 millimeters.

Table No. 9
Decimal Equivalents of Fractions

64ths. (Inches)	Fractions (Inches)	Decimals		64ths. (Inches)	Fractions (Inches)	Decimals	
		(Inches)	(mm.)			(Inches)	(mm.)
1	.....	.0156	0.397	33	.....	.5156	13.097
2	1/32	.0313	0.794	34	17/32	.5313	13.493
3	.....	.0469	1.191	35	.....	.5469	13.890
4	1/16	.0625	1.587	36	9/16	.5625	14.287
5	.....	.0781	1.984	37	.....	.5781	14.684
6	3/32	.0938	2.381	38	19/32	.5938	15.081
7	.....	.1094	2.778	39	.....	.6094	15.478
8	1/8	.1250	3.175	40	5/8	.6250	15.874
9	.....	.1406	3.572	41	.....	.6406	16.272
10	5/32	.1563	3.969	42	21/32	.6563	16.668
11	.....	.1719	4.366	43	.....	.6719	17.065
12	3/16	.1875	4.762	44	11/16	.6875	17.462
13	.....	.2031	5.159	45	.....	.7031	17.859
14	7/32	.2188	5.556	46	23/32	.7188	18.256
15	.....	.2344	5.953	47	.....	.7344	18.653
16	1/4	.2500	6.350	48	3/4	.7500	19.050
17	.....	.2656	6.747	49	.....	.7656	19.447
18	9/32	.2813	7.144	50	25/32	.7813	19.843
19	.....	.2969	7.541	51	.....	.7969	20.240
20	5/16	.3125	7.937	52	13/16	.8125	20.637
21	.....	.3281	8.334	53	.....	.8281	21.034
22	11/32	.3438	8.731	54	27/32	.8438	21.431
23	.....	.3594	9.128	55	.....	.8594	21.828
24	3/8	.3750	9.525	56	7/8	.8750	22.225
25	.....	.3906	9.922	57	.....	.8906	22.621
26	13/32	.4063	10.319	58	29/32	.9063	23.018
27	.....	.4219	10.715	59	.....	.9219	23.415
28	7/16	.4375	11.112	60	15/16	.9375	23.812
29	.....	.4531	11.509	61	.....	.9531	24.209
30	15/32	.4688	11.906	62	31/32	.9688	24.606
31	.....	.4844	12.303	63	.....	.9844	25.003
32	1/2	.5000	12.700	64	1	1.0000	25.400

Handy Equations. The following equations represent the most useful of the mensuration and cost formulae:

Equation 1—To find the *area (A) of a circle*:

$A = \pi r^2$, or $A = 0.7854 d^2$ Where: r = radius
d = diameter
u = 3.1416

Equation 2—To find the *circumference (C) of a circle*:

$C = 2 \pi r$, or $C = \pi d$

Equation 3—To find the *length of an arc* of a circle:

$$\text{length of arc} = \frac{\pi r \varnothing}{180}$$ Where: $\varnothing$ = arc degrees

Equation 4—To find the *area of a triangle* whose angles are designated as A, B and C and the sides opposite as a, b and c:

$$A = \tfrac{1}{2}\, ab \sin C$$

Equation 5—To find the *area of a triangle* whose altitude is h and base is b:

$$A = \frac{hb}{2}$$ Where: A = area of triangle

Equation 6—To find the *hypotenuse* of a right triangle when the two sides are given:

$$H = \sqrt{a^2 + b^2}$$ Where: H = hypotenuse
a = side a
b = side b

Equation 7—To find the *volume of a sphere*:

$$V = (4/3)\, \pi r^3, \text{ or } V = 4.189\, r^3$$

Equation 8—To find the *volume of a cylinder*:

$V = A_b h$ Where: A_b = area of base (πr^2)
h = height of cylinder

Equation 9—To find *compound interest* factor for n years:

$X = (1 + i)^n$ Where: n = number of years
i = interest rate (a fraction)

Equation 10—To find *present worth* of \$1.00 to be spent at the end of any year, n:

$$P\,W = \frac{1}{(1 + i)^n}$$

Equation 11—To find *present worth of an annuity* of \$1.00 for n years:

$$P\,W_a = \frac{1 - (1 + i)^{-n}}{i}$$

Ohms Per Mil-Foot—Temperature Coefficient and Relative Resistance. The **Mil-Foot resistance** of any conductor is the resistance in ohms of one Mil-Foot of the conductor, i. e., a conductor one mil in diameter and one foot long. By knowing the Mil-Foot resistance of a material it is easy to compute the resistance of any size conductor.

The rise or fall in resistance of any material with changes in temperature is expressed by the *temperature coefficient of resistance.* This is a numerical value which gives the decimal change in resistance per degree centigrade which any material undergoes with changes in temperature. Most conductor materials have positive temperature coefficients, i. e., their resistance increases as the temperature is increased. Carbon has a negative temperature coefficient. Some conductor alloys have virtually a *zero temperature coefficient,* i. e., their resistance does not vary with temperature changes. These alloys are used for the coils and resistors in testing instruments. Manganin is an excellent zero temperature coefficient type of wire.

Corrections for resistance changes with temperature are often required in connection with cable fault location work.

Equations which are useful in dealing with the effect of temperature on wire resistance are given on page 22 of Section I.

Table No. 10 gives values of Mil-Foot resistance, temperature coefficient and relative resistance of common conductors and resistance materials.

Table No. 10
Resistance Characteristic of Common Metals

Material	1 Ohms Per Mil-Foot	2 Temperature Coefficient	3 Relative Resistance
Aluminum	16.06	.00446	1.55
Advance	294.00	.00002	28.30
Brass	50.00	.0016	4.82
Copper	10.37	.00393	1.00
Iron	60.14	.0050	5.82
Manganin	290.00	.000015	27.90
Nichrome	675.00	.00017	65.20
Ohmax	1000.00	.000066	96.40
Silver	9.796	.0038	.94
Constantan	294.0	.00001	28.34

Note 1.—Mil-Foot resistance at 20°C.
Note 2.—Temperature Coefficient for an initial temperature of 20°C.
Note 3.—Relative resistance with respect to copper.

Useful Wire Formulas. The resistance of a wire of any size can readily be computed if the *resistivity* of the conductor material is known. The formula is:

$$R = \frac{l}{a} K$$

Where: R = resistance in ohms, l = length in feet, a = area in circular mils and K = mil-foot resistance in ohms. The *mil-foot* resistances of various conductor materials are given in Table No. 10. *Mil-foot resistance* is the resistance of a wire one mil in diameter and one foot long. Other useful copper wire formulas are given in Table No. 11.

Table No. 11
Useful Copper Wire Formulae

(1)—Feet per ohm = Area in cir. mils $\times$ 0.09642

(2)—Ohms per 1000 feet $= \dfrac{10371.176}{\text{Area in cir. mils}}$

(3)—Ohms per pound $= \dfrac{3{,}426{,}279}{(\text{Area in cir. mils})^2}$

(4)—Pounds per ohm $= \dfrac{(\text{Area in cir. mils})^2 \times 0.29186}{1{,}000{,}000}$

(5)—Feet per pound $= \dfrac{330{,}361}{\text{Area in cir. mils}}$

Note: If it is desired to express the above in metric units see Table No. 8 for conversion factors.

Temperature Coefficient Computations. The resistance of most metallic conductors increases as the temperature increases.

The wire tables in this section give the resistance at a temperature of 20° centigrade. If it is desired to find the resistance at some other temperature the following formula may be used:

$$R_t = R_{20}\,[1 + K\,(t - 20)]$$

Where: R_t = resistance at the new temperature
R_{20} = resistance at 20° Centigrade
K = temperature coefficient (see Table No. 10)
t = new temperature

Temperature coefficient of copper is 0.00393 at 20° Cent. It will be noted that temperature coefficients are usually given for an initial temperature of 20° Cent. These coefficients will not be correct for other initial temperatures. The following example illustrates the use of the above formula.

Example: The resistance of 1000 feet of No. 16 gauge copper wire is approximately 4.0 ohms at 20° Cent. What is the resistance at 50° Cent.?

$$R_t = 4.0\ (1 + 0.00393[50\text{-}20]) = 4.47 \text{ ohms}$$

Skin Effect in Conductors. Because of certain self inductance effects alternating current tends to flow in the circumference rather than uniformly throughout a conductor. The magnitude of this effect is proportional to the frequency and the cross section area of the conductor. Its effect is to increase the effective resistance of a conductor. This action is referred to as **skin effect.**

The following table gives the approximate factors by which ohmic resistance of a conductor should be multiplied to determine the effective resistance of a copper conductor so far as skin effect is concerned.

Where Conductor Size in Cir. mils times frequency does not exceed value shown	Multiplying Factor to Get Effective Resistance
10,000,000	1.000
20,000,000	1.008
30,000,000	1.025
40,000,000	1.045
50,000,000	1.070
60,000,000	1.096
70,000,000	1.126
80,000,000	1.158
90,000,000	1.195
100,000,000	1.230
125,000,000	1.332
150,000,000	1.443
175,000,000	1.530
200,000,000	1.622

Example. Determine multiplying factor for a 10,000 circular mil wire at a carrier frequency of 10,000 cycles. $10{,}000 \times 10{,}000 = 100{,}000{,}000$ or a factor of 1.23.

Due to skin effect Copperweld conductors compare favorably, at the higher carrier frequencies with copper. The increase in resistance with frequency of a No. 12—N. B. S. (104 mil) Hard drawn copper wire pair is shown in the following table.

Table No. 12
Effective Resistance of 104 mil Copper Pair for Various Frequencies

Frequency in Cycles	Resistance Per Cct. Mile (in ohms)
D-C	10.30
1000	10.40
5000	11.10
10000	13.00
20000	17.15
30000	20.60
40000	23.30
50000	25.70
75000	30.75
100000	35.10

Wire Gauges. It has been the practice for many years to designate wire sizes by gauge numbers. The present trend is merely to express the size in terms of the diameter in mils (thousandths of an inch). This avoids the confusion inherent to the use of gauge numbers.

There are three gauges used in connection with telephone wires, these are:

(1)—The American Wire Gauge (A. W. G.) (same as Brown and Sharpe Gauge (B & S).

(2)—The Birmingham Wire Gauge (B. W. G.).

(3)—The New British Standard (N. B. S.).

The A. W. G. gauge is extensively used to express the sizes of all types of copper and aluminum wire used in both the telephone and electrical field with the exception of hard drawn copper telephone line wire. It is interesting to note that the mathematical relationship between successive A. W. G. gage numbers is such that a decrease of three gauge numbers results in a wire which is approximately one-half the resistance, double the area and double the weight. This is shown in the following tabular comparison of a No. 1 and a No. 4 copper wire.

No. 1 (AWG) Copper Wire		No. 4 (AWG) Copper Wire
Wt. per mile (lbs.)	1338	667
Area in Cir. Mils.	83690	41740
Ohms per mile	0.6542	1.312

The Birmingham Wire Gauge is used extensively in this country to express the sizes of iron and steel telephone and power line wires. It is arranged in much the same manner as the A. W. G. but the B. W. G. wires for a given gauge number are larger than the A. W. G. gauge.

The New British Standard Gauge is used primarily in this country for hard drawn copper telephone line wires. Its use is giving way, however, to the practice of expressing telephone line wires in terms of decimal equivalents. For example the standard hard drawn line wire sizes are: 0.080 (No. 14 N.B.S.), 0.104 (No. 12 N.B.S.), 0.128 (No. 10 N.B.S.) and 0.165 (no N.B.S. gauge number set up).

A comparison of the respective diameters for the various gauges is given in Table No. 13.

Annealed Copper Wire Table. Copper wire is made by rolling red hot copper billets down to rods about ⅜ inches in size and these are then pulled or drawn through a succession of dies to get the desired size. The drawing process hardens the wire, hence, for all purposes requiring wire that is relatively soft the wire is annealed after it has been drawn. The various characteristics of annealed copper wire in sizes from 4-0 to 40 is given in Table No. 14-A for English units and in Table No. 14-B for metric units. These tables are based on copper wire of 100% conductivity, i. e., 10.371 ohms per mil foot. Commercial copper wire may be expected to depart from those values as much as 1 or 2%.

Table No. 13
Comparison of Wire Gauges—Diameters in Inches

Size	B & S or A. W. G. American Wire Gauge	B. W. G. Birmingham Wire Gauge	N. B. S. New British Standard
4/0	.460	.454	.400
3/0	.410	.425	.372
2/0	.365	.380	.348
1/0	.325	.340	.324
1	.289	.300	.300
2	.258	.284	.276
3	.229	.259	.252
4	.204	.238	.232
5	.182	.220	.212
6	.162	.203	.192
7	.144	.180	.176
8	.128	.165	.160
9	.114	.148	.144
10	.102	.134	.128
11	.091	.120	.116
12	.081	.109	.104
13	.072	.095	.092
14	.064	.083	.080
15	.057	.072	.072
16	.051	.065	.064
17	.045	.058	.056
18	.040	.049	.048
19	.036	.042	.040
20	.032	.035	.036
21	.0285	.032	.032
22	.0253	.028	.028
23	.0226	.025	.024
24	.0201	.022	.022
25	.0179	.020	.020
26	.0159	.018	.018
27	.0142	.016	.0164
28	.0126	.014	.0148
29	.0113	.013	.0136
30	.0100	.012	.0124
31	.0089	.010	.0116
32	.0080	.009	.0108
33	.0071	.008	.0100
34	.0063	.007	.0092
35	.0056	.005	.0084
36	.0050	.004	.0076
37	.0045	....	.0068
38	.0040	....	.0060
39	.0035	....	.0052
40	.0031	...	.0048

Table No. 14-A

Characteristics of Annealed Copper Wire (English Units)

(Courtesy Phillips Electrical Works, Ltd.)

Gauge No. B. & S. or A.W.G.	Diameter in Inches	Cross Sectional Area	Weight		Resistance	
		Circular Mils	Lbs. Per 1000 Ft.	Lbs. Per Mile	Ohms Per 1000 Ft. at 20° C.	Ohms Per Mile at 20° C.
4/0	.4600	211600	640.5	3381.9	.04901	.2587
3/0	.4096	167800	507.9	2681.7	.06180	.3263
2/0	.3648	133100	402.8	2126.7	.07793	.4114
1/0	.3249	105500	319.5	1686.9	.09827	.5188
1	.2893	83690	253.3	1337.4	.1239	.6542
2	.2576	66370	200.9	1060.7	.1563	.8252
3	.2294	52640	159.3	841.10	.1970	1.040
4	.2043	41740	126.4	667.39	.2485	1.312
5	.1819	33100	100.2	529.05	.3133	1.654
6	.1620	26250	79.46	419.54	.3951	2.086
7	.1443	20820	63.02	332.74	.4982	2.630
8	.1285	16510	49.98	263.89	.6282	3.317
9	.1144	13090	39.63	209.24	.7921	4.182
10	.1019	10380	31.43	165.95	.9989	5.274
11	.09074	8234	24.92	131.57	1.260	6.652
12	.08081	6530	19.77	104.38	1.588	8.384
13	.07196	5178	15.68	82.79	2.003	10.57
14	.06408	4107	12.43	65.63	2.525	13.33
15	.05707	3257	9.858	52.04	3.184	16.81
16	.05082	2583	7.818	41.27	4.016	21.20
17	.04526	2048	6.200	32.73	5.064	26.73
18	.04030	1624	4.917	25.96	6.385	33.71
19	.03589	1288	3.899	20.58	8.051	42.51
20	.03196	1022	3.092	16.32	10.15	53.59
21	.02846	810.1	2.452	12.94	12.80	67.58
22	.02535	642.4	1.945	10.27	16.14	85.22
23	.02257	509.5	1.542	8.141	20.36	107.5
24	.02010	404.0	1.223	6.457	25.67	135.5
25	.01790	320.4	.9699	5.121	32.37	170.9
26	.01594	254.1	.7692	4.061	40.81	215.5
27	.01420	201.5	.6100	3.221	51.47	271.7
28	.01264	159.8	.4837	2.553	64.90	342.6
29	.01126	126.7	.3836	2.025	81.83	432.1
30	.01003	100.5	.3042	1.606	103.2	544.9
31	.008928	79.70	.2413	1.254	130.1	686.9
32	.007950	63.21	.1913	1.010	164.1	866.4
33	.007080	50.13	.1517	.8009	206.9	1092.4
34	.006305	39.75	.1203	.6351	260.9	1377.5
35	.005615	31.52	.0954	.5037	329.0	1737.1
36	.005000	25.00	.0756	.3991	414.8	2190.1
37	.004453	19.83	.0600	.3168	523.1	2761.9
38	.003965	15.72	.0476	.2513	659.6	3482.6
39	.003531	12.47	.0377	.1990	831.8	4391.9
40	.003145	9.89	.0299	.1578	1049	5538.7

Table No. 14-B

Characteristics of Annealed Copper Wire (Metric Units)

(Courtesy Phillips Electrical Works, Ltd.)

Gauge No. B. & S. A.W.G.	Diameter m/m	Sectional Area Square m/m	Weight: Kg Per Km	Weight: Pounds Per Km	Resistance Ohms Per Km at 20° C.
4/0	11.68	107.2	953.2	2101.5	.1608
3/0	10.40	85.03	755.9	1666.4	.2028
2/0	9.266	67.43	599.5	1321.5	.2557
1/0	8.252	53.48	475.4	1048.2	.3224
1	7.348	42.41	377.0	831.0	.4066
2	6.544	33.63	299.0	659.1	.5127
3	5.827	26.67	237.1	522.6	.6465
4	5.189	21.15	188.0	414.7	.8152
5	4.621	16.77	149.1	328.7	1.028
6	4.115	13.30	118.2	260.7	1.296
7	3.665	10.55	93.78	206.7	1.634
8	3.264	8.366	74.37	163.9	2.061
9	2.906	6.634	58.98	130.0	2.599
10	2.588	5.261	46.77	103.1	3.277
11	2.305	4.172	37.09	81.75	4.132
12	2.053	3.309	29.42	64.86	5.211
13	1.828	2.624	23.33	51.44	6.571
14	1.628	2.081	18.50	40.78	8.285
15	1.450	1.650	14.67	32.34	10.45
16	1.291	1.309	11.63	25.65	13.17
17	1.150	1.038	9.226	20.34	16.61
18	1.024	.8231	7.317	16.13	20.95
19	.9116	.6527	5.803	12.79	26.42
20	.8118	.5176	4.602	10.14	33.31
21	.7230	.4105	3.649	8.044	42.00
22	.6438	.3255	2.894	6.381	52.96
23	.5733	.2582	2.295	5.059	66.79
24	.5106	.2047	1.820	4.012	84.21
25	.4547	.1624	1.443	3.182	106.2
26	.4049	.1288	1.145	2.523	133.9
27	.3606	.1021	.9078	2.001	168.9
28	.3211	.08098	.7199	1.587	212.9
29	.2859	.06422	.5709	1.258	268.5
30	.2546	.05093	.4527	.9980	338.6
31	.2268	.04039	.3590	.7916	426.9
32	.2019	.03203	.2847	.6276	538.3
33	.1798	.02540	.2258	.4976	678.8
34	.1601	.02014	.1791	.3947	856.0
35	.1426	.01597	.1420	.3130	1079
36	.1270	.01267	.1126	.2480	1361
37	.1131	.01005	.08931	.1968	1716
38	.1007	.007967	.07083	.1561	2164
39	.08969	.006318	.05617	.1236	2729
40	.07987	.005010	.04454	.0981	3441

Breaking Strength of Copper Wire. The process of drawing copper wire through dies increases its tensile strength. Unless it is annealed after drawing it is said to be **hard drawn.** Medium Hard Drawn wire is partially annealed during the drawing process, and soft wire is that which is completely annealed after it is drawn. Hard and medium hard drawn wire is used for line wires, whereas soft wire is used in cables, coils, etc., where it is under little or no tensile strain.

Table No. 15 gives the mechanical and resistance characteristics for hard drawn copper wires for sizes between 4/0 and 18.

Table No. 15
Characteristics of Hard Drawn Copper Wire

Size A.W.G.	Wire Diameter (Inch)	Breaking Load (Pounds)	Tensile Strength Lbs /Sq In	WEIGHT		Maximum Resistance (Ohms Per 1000 Ft. at 68°F.)	CROSS-SECTIONAL AREA	
				Pounds Per 1000 Feet	Pounds Per Mile		Cir Mils	Sq In.
4/0	.4600	8,143	49,000	640.5	3,382	.05045	211,600	.1662
3/0	.4096	6,722	51,000	507.9	2,682	.06361	167,800	.1318
2/0	3648	5,519	52,800	402.8	2,127	.08021	133,100	.1045
1/0	.3249	4,517	54,500	319.5	1,687	.1011	105,500	.08289
1	.2893	3,688	56,100	253.3	1,338	.1287	83,690	.06573
2	.2576	3,003	57,600	200.9	1,061	.1625	66,370	.05213
3	.2294	2,439	59,000	159.3	841 2	.2049	52,630	.04134
4	.2043	1,970	60,100	126.4	667.1	.2584	41,740	.03278
5	1819	1,591	61,200	100.2	529.1	3258	33,100	.02600
..	.1650	1,326	62,000	82.41	435.1	.3961	27,225	.02138
6	.1620	1,280	62,100	79.46	419.6	.4108	26,250	.02062
7	.1443	1,030	63,000	63.02	332.7	.5181	20,820	.01635
..	.1340	894.0	63,400	54.35	287.0	.6006	17,956	.01410
8	.1285	826.0	63,700	49.97	263.9	.6533	16,510	.01297
9	.1144	661.2	64,300	39.63	209.3	.8238	13,090	.01028
..	.1040	550.4	64,800	32.74	172.9	.9971	10,816	.008495
10	.1019	529.2	64,900	31.43	165 9	1.039	10,380	.008155
11	.09074	422.9	65,400	24.92	131.6	1.310	8,234	.006467
12	.08081	337 0	65,700	19.77	104 4	1 652	6,530	.005129
13	.07196	268 0	65,900	15.68	82 77	2 083	5,178	.004067
14	.06408	213.5	66,200	12.43	65 64	2.626	4,107	.003225
15	.05707	169 8	66,400	9.858	52.05	3.312	3,257	.002558
16	05082	135.1	66,600	7.818	41 28	4.176	2,583	.002028
17	.04526	107.5	66,800	6.200	32.74	5.266	2,048	.001609
18	.04030	85.47	67,000	4.917	25.96	6.640	1,624	.001276

Comparative Data for Copper, Copperweld and Iron Telephone Wire. A comparison of the physical properties of copper, Copperweld and galvanized telephone wire can readily be made by reference to Table No. 16. Copperweld is available in both a 30 and 40 per cent conductivity type. The percentage refers to the conductivity of the Copperweld conductor as compared to a copper conductor of the same size.

Table No. 16
Copper, Copperweld and Galvanized Iron Wire Comparisons

Gauge	Diameter (Inch)	Average Weight				Average Breaking Load (Lbs.)		Average Resistance in Ohms at 68 degrees Fahr.			
		Lbs. Per 1000 Feet		Lbs. Per Mile				Per 1000 Feet		Per Mile	
A. W. G.		40% Copperweld	Copper	40% Copperweld	Copper	40% Copperweld	Copper	40% Copperweld	Copper	40% Copperweld	Copper
4	.204	116	126	612	667	3,541	1,970	.6337	.2584	3.35	1.36
5	.182	91.9	100	485	529	2,938	1,591	.7990	.3258	4.22	1.72
6	.162	72.8	79.5	385	420	2,433	1,280	1.008	.4108	5.32	2.17
7	.144	57.8	63.0	305	333	2,011	1,030	1.271	.5181	6.71	2.74
8	.128	45.8	50.0	242	264	1,660	826.0	1.602	.6533	8.46	3.45
9	.114	36.3	39.6	192	209	1,368	661.2	2.020	.8238	10.67	4.35
10	.102	28.8	31.4	152	166	1,130	529.2	2.547	1.039	13.45	5.49
11	.0907	22.8	24.9	121	132	896.3	422.9	3.212	1.310	16.96	6.92
12	.0808	18.1	19.8	95.7	104	785	337.0	4.051	1.652	21.39	8.72
B. W. G.		B.B.	E.B.B.	B.B.	E.B.B.	B.B.	E.B.B.	B.B.	E.B.B.	B.B.	E.B.B.
4	.238	154	154	811	811	2,271	2,028	1.35	1.13	7.15	5.98
6	.203	112	112	590	590	1,652	1,475	1.86	1.56	9.83	8.22
8	.165	74	74	390	390	1,092	975	2.82	2.35	14.87	12.43
9	.148	60	60	314	314	879	785	3.50	2.92	18.47	15.44
10	.134	49	49	258	258	722	645	4.26	3.56	22.48	18.79
12	.109	32	32	170	170	476	425	6.46	5.40	34.12	28.52
14	.083	19	19	99	99	277	247	11.10	9.28	58.59	48.98

Note—E. B. B. is the softest of the galvanized iron telephone wires!

Magnet Wire. Coils, transformer windings, etc., all use what is known as copper magnet wire. This wire is of the soft annealed type and is available in various types of insulation. The most common types with respect to insulation are:

Type	Abbreviation	Type	Abbreviation
Single cotton covered	SCC	Enameled	E
Double cotton covered	DCC	Enamel silk covered	ESC
Single silk covered	SSC	Enamel cotton covered	ECC
Double silk covered	DSC		

Magnet wire is also available in special insulation capable of withstanding high temperatures. For wires larger than No. 12, a double cotton covered wire should be used because of greater ruggedness. Table No. 17 gives the weights and resistances of magnet wires.

Table No. 17 Weights and Resistances of Magnet Wire

(Courtesy Phillips Electrical Works, Ltd.)

B. & S. Gauge	Diameter In Inches	SINGLE COTTON		DOUBLE COTTON		TRIPLE COTTON		SINGLE SILK		DOUBLE SILK	
		Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.
4/0	.4600	1.555	.000076	1.55	.000076	1.54	.000075	...	...	...	...
3/0	.4096	1.960	.00012	1.95	.00012	1.95	.00012	...	...	...	...
2/0	.3648	2.470	.00019	2.46	.00019	2.45	.00019	...	...	...	...
1/0	.3249	3.110	.00030	3.10	.00030	3.08	.00030	...	...	...	...
1	.2893	3.920	.00048	3.90	.00048	3.89	.00048	...	...	...	...
2	.2576	4.940	.00077	4.92	.00077	4.89	.00076	...	...	...	...
3	.2294	6.240	.0012	6.20	.0012	6.15	.0012	...	...	...	...
4	.2043	7.860	.0019	7.80	.0019	7.73	.0019	...	...	...	...
5	.1819	9.900	.0031	9.82	.0031	9.73	.0030	...	...	...	...
6	.1620	12.46	.0049	12.35	.0048	12.23	.0048	...	...	...	...
7	.1443	15.70	.0078	15.55	.0077	15.42	.0077	...	...	...	...
8	.1285	19.78	.0124	19.55	.0123	19.36	.0122	...	...	...	...
9	.1144	24.90	.0197	24.75	.0196	24.40	.0178	...	...	...	...
10	.1019	31.35	.0313	31.14	.0311	30.66	.0306	...	...	...	...
11	.09074	39.62	.0499	39.15	.0493	38.47	.0485	...	...	...	...
12	.08081	49.88	.0792	49.20	.0781	48.46	.0769	...	...	...	...
13	.07196	62.80	.1258	61.80	.1238	60.78	.1217	...	...	...	...
14	.06408	79.00	.1995	77.60	.1959	76.14	.1803	...	...	...	...
15	.05707	99.60	.3171	98.05	.3122	95.30	.3034	...	...	...	...
16	.05082	125.4	.5036	123.2	.4948	119.3	.4792	127	.5100	126	.5060
17	.04526	157.7	.8086	154.5	.7824	148.9	.7540	160	.8102	158	.8001

Table No. 17—Weights and Resistances of Magnet Wire
(Cont. from page 30)

B. & S. Gauge	Diameter In Inches	SINGLE COTTON		DOUBLE COTTON		TRIPLE COTTON		SINGLE SILK		DOUBLE SILK	
		Feet Per Lb	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.	Feet Per Lb.	Ohms Per Lb.
18	.04030	198.0	1.264	193.0	1.232	188.0	1.200	200	1.277	199	1.270
19	.03589	249.0	2.005	243.0	1.956	234.0	1.884	253	2.037	249	2.005
20	.03196	313.0	3.177	304.0	3.086	....	....	318	3.227	313	3.177
21	.02846	393.0	5.030	380.0	4.864	....	....	400	5.120	393	5.030
22	.02535	494.0	7.973	475.0	7.666	....	....	506	8.167	497	8.021
23	.02257	619.0	12.60	582.0	11.85	....	....	633	12.89	620	12.62
24	.02010	776.0	19.92	738.0	18.94	....	....	799	20.51	779	20.00
25	.01790	971.0	31.43	918.0	29.71	....	....	1003	32.47	974	31.53
26	.01594	1215	49.58	1146	46.77	....	....	1270	51.83	1230	50.20
27	.01420	1518	78.13	1410	72.57	....	....	1585	81.58	1525	78.49
28	.01264	1909	123.9	1750	113.57	....	....	2000	129.8	1921	124.7
29	.01126	2347	192.0	2130	174.30	....	....	2478	212.7	2362	193.3
30	.01003	2947	304.1	2640	272.4	....	....	3139	323.9	2987	308.2
31	.008928	3646	474.3	3208	417.4	....	....	3946	513.4	3696	480.8
32	.007950	4519	741.5	3901	640.1	....	....	4900	804.1	4563	748.8
33	.007080	5559	1150	4700	972.4	....	....	6090	1260	5616	1162
34	.006305	6896	1799	5680	1482	....	....	7677	2002	6969	1818
35	.005615	8490	2793	6820	2243	....	....	9610	3161	8661	2849
36	.005000	10342	4290	8050	3339	....	....	11790	4890	10475	4345
37	.004453	12577	6579	9460	4948	....	....	14730	7705	12783	6687
38	.003965	15247	10057	11040	7282	....	....	18350	12103	15500	10224
39	.003531	18433	15322	12830	10672	....	....	22740	18915	18859	15687
40	.003145	22104	23187	14720	15441	....	....	28060	29435	22640	23749

Table No. 18
Characteristics of Galvanized Steel Strand

(Courtesy American Steel and Wire Co.)

Galvanized steel strand is employed in the telephone field primarily for guy wires and as the supporting strand for aerial cable. Strand is commonly stocked in coils of 250, 500 and 1000 feet; also on reels containing 1000, 2500 or 5000 feet.

Number of Wires in Strand	Nominal Diameter of the Strand Inches	Nominal Diameter of Coated Wires in Strand Inches	Approx. Weight of Strand per 1000 Ft. (Lbs.)	MINIMUM BREAKING STRENGTH OF STRAND, LBS.				
				Common Grade	Siemens-Martin Grade	High Strength Grade	Extra High Strength Grade	Utilities Grade *
3	¼	0.120	116.7	1,821	2,979	4,629	6,600	3,150
3	¼	0.120	116.7	....	....	....	....	4,500
3	5/16	0.145	170.6	2,443	4,007	6,214	8,914	6,500
3	⅜	0.165	220.3	3,171	5,186	8,057	11,528	8,500
7	⅛	0.041	31.8	540	910	1,330	1,830	....
7	5/32	0.052	51.3	870	1,470	2,140	2,940	....
7	3/16	0.062	72.9	1,150	1,900	2,850	3,990	....
7	3/16	0.065	80.3	....	....	....	....	2,400**
7	7/32	0.072	98.3	1,540	2,560	3,850	5,400	....
7	¼	0.080	121	1,900	3,150	4,750	6,650	....
7	9/32	0.093	164	2,570	4,250	6,400	8,950	4,600**
7	5/16	0.104	205	3,200	5,350	8,000	11,200	....
7	5/16	0.109	225	....	....	....	....	6,000**
7	⅜	0.120	273	4,250	6,950	10,800	15,400	11,500**
7	7/16	0.145	399	5,700	9,350	14,500	20,800	18,000**
7	½	0.165	517	7,400	12,100	18,800	26,900	25,000**
7	9/16	0.188	671	9,600	15,700	24,500	35,000	....
7	⅝	0.207	813	11,600	19,100	29,600	42,400	....
19	½	0.100	504	7,620	12,700	19,100	26,700	....
19	9/16	0.113	637	9,640	16,100	24,100	33,700	....
19	⅝	0.125	796	11,000	18,100	28,100	40,200	....
19	¾	0.150	1,155	16,000	26,200	40,800	58,300	....
19	⅞	0.177	1,581	21,900	35,900	55,800	79,700	....
19	1	0.200	2,073	28,700	47,000	73,200	104,500	....
37	1	0.143	2,057	28,300	46,200	71,900	102,700	....
37	1⅛	0.161	2,691	36,000	58,900	91,600	130,800	....
37	1¼	0.179	3,248	44,600	73,000	113,600	162,200	....

*The Utilities Grade is used principally by communication and power and light industries.
**Also called Specification Grade. Can be furnished to conform to Western Union and A. T. & T. specifications.

Table No. 19
Resistance of Galvanized Iron Wire

Gauge	Diameter (Inch)	Average Resistance in Ohms at 68 degrees Fahr.			
		Per 1000 Feet		Per Mile	
B.W.G.		B.B.	E.B.B.	B.B.	E.B.B.
4	.238	1.35	1.13	7.15	5.98
6	.203	1.86	1.56	9.83	8.22
8	.165	2.82	2.36	14.87	12.43
9	.148	3.50	2.82	18.47	15.44
10	.134	4.26	3.56	22.48	18.79
12	.109	6.46	5.40	34.12	28.52
14	.083	11.10	9.28	58.59	48.98

Copperweld Strand is used where both high strength and freedom from corrosion characteristics are required. Copperweld strand is generally used in the thirty percent conductivity type. Characteristics are given in the following table.

Table No. 20
Physical Characteristics of Copperweld Guy Strand
(Courtesy Copperweld Steel Company)

Nominal Diameter (Inch) — Size A.W.G.	Actual Diam. (Inch)	BREAKING LOAD Lbs. High Strength 30% Cond.	BREAKING LOAD Lbs. Extra High Strength 30% Cond.	WEIGHT Lbs. Per 1000 Ft.	WEIGHT Lbs. Per Mile	Cross-Section Sq. In.
½ (7 No. 6)	.486	16,890	20,460	515.0	2,719	.1443
7/16 (7 No. 7)	.433	13,910	16,890	408.4	2,157	.1145
⅜ (7 No. 8)	.385	11,440	13,890	323.9	1,710	.09077
11/32 (7 No. 9)	.343	9,393	11,280	256.9	1,356	.07198
5/16 (7 No. 10)	.306	7,758	9,196	203.7	1,076	.05708
3 No. 6	.349	7,639	9,754	220.3	1,163	.06185
3 No. 7	.311	6,291	7,922	174.7	922.4	.04905
3 No. 8	.277	5,174	6,282	138.5	731.5	.03890
3 No. 9	.247	4,250	5,129	109.9	580.1	.03085
3 No. 10	.220	3,509	4,160	87.13	460.0	.02446

Galvanized Iron Telephone Wire. What is known as galvanized iron telephone wire is used both for line wire purposes and in the larger sizes for guy wires. No. 12 (.109) wire is most commonly used for telephone line wire. No. 6 (.203) is often used for guying rural telephone poles where the wire load does not exceed four wires. For long span rural telephone construction the high tensile strength (type 85 or 135) steel wire should be used. Some companies prefer to use the 85 type high strength steel even for short spans because of its greater safety factor.

Table No. 21
Characteristics of Galvanized Iron and Steel Telephone Wire

Gauge B.W.G.	Diameter (Inch)	Average Weight in Lbs. Per 1000 Feet B.B.	Per 1000 Feet E.B.B.	Per Mile B.B.	Per Mile E.B.B.	Average Breaking Loads (Lbs.) B.B.	Average Breaking Loads (Lbs.) E.B.B.
4	.238	154	154	811	811	2271	2028
6	.203	112	112	590	590	1652	1475
8	.165	74	74	390	390	1092	975
9	.148	60	60	314	314	879	785
10	.134	49	49	258	258	722	645
12	.109	32	32	170	170	476	425
14	.083	19	19	99	99	277	247

(See Section IV for data on high tensile strength galvanized steel wire.)

Fusing Currents of Wires. The current at which any wire will fuse and rupture can be determined by the formula:

$$I = A \sqrt{d^3}$$

Where: I—Current in amperes, d—diameter of wire in inches, and A—is a constant whose value for different metals has been established as: Copper = 10,244, Aluminum = 7,585, German Silver = 5,230, Iron = 3,148, Tin = 1,642 and Lead = 1,379.

Telephone fuses are usually made of either lead, lead-tin, bronze or copper wire. The fusing current for several types of metals is given in Tabl No. 22.

Table No. 22
Wire Fusing Currents

Size B.&S. Gauge	Diam. Ins.	Copper A=10244	Aluminum A=7585	German Silver A=5230	Iron A=3148	Tin A=1642
40	.0031	1.77	1.31	.90	.54	.28
38	.0039	2.50	1.85	1.27	.77	.40
36	.0050	3.62	2.68	1.85	1.11	.58
34	.0063	5.12	3.79	2.61	1.57	.82
32	.0079	7.19	5.32	3.67	2.21	1.15
30	.0100	10.2	7.58	5.23	3.15	1.64
28	.0126	14.4	10.7	7.39	4.45	2.32
26	.0159	20.5	15.2	10.5	6.31	3.29
24	.0201	29.2	21.6	14.9	8.97	4.68
22	.0253	41.2	30.5	21.0	12.7	6.61
20	.0319	58.4	43.2	29.8	17.9	9.36
19	.0359	69.7	51.6	35.5	21.4	11.2
18	.0403	82.9	61.4	42.3	25.5	13.3
17	.0452	98.4	72.9	50.2	30.2	15.8
16	.0508	117	86.8	59.9	36.0	18.8
15	.0571	140	103	71.4	43.0	22.4
14	.0641	166	123	84.9	51.1	26.6
13	.0719	197	146	101	60.7	31.7
12	.0808	235	174	120	72.3	37.7
11	.0907	280	207	143	86.0	44.9
10	.1019	333	247	170	102	53.4
9	.1144	396	293	202	122	63.5
8	.1285	472	349	241	145	75.6
7	.1443	561	416	287	173	90.0
6	.1620	668	495	341	205	107

Electrical Insulating Materials. A number of materials are available for use in insulating wires, coils and electrical equipment. The design engineer is concerned with the workability, temperature limitations, and dielectric strength of insulations. The principal properties of the most commonly used insulating materials are given in Table No. 23.

Table No. 23
Characteristics of Common Insulating Materials
(Courtesy Belden Mfg. Co.)

Material	Thickness	Description and Use	Dielectric Strength (Volts Per Mil) Average Values	Approximate Hottest Spot Temperature Limits
Kraft Paper	.003″	A tough brown paper used in construction of tubes, between layers, and as outer covers or wrappers for coils.	60	90°C. (194°F.)
Glassine Paper	.00075″ .0010″ .0015″ .002″	A glossy, hard-finished, translucent paper used between layers of coils.	200	90°C. (194°F.)
Varnished Paper	.002″ .005″	Paper which has been treated with varnish to improve its heat resisting and insulating properties. Used between layers on high voltage windings.	900	105°C. (221°F.)
Varnished Cambric	.007″	Varnish-treated cambric, yellow or black in color and somewhat flexible. Used as core and end insulation for coils.	1100	105°C. (221°F.)
Varnished Silk	.004″	Varnish-treated silk, yellow in color and very flexible. Used where high dielectric strength, minimum weight, or high space factors are required.	1100	105°C. (221°F.)
Asbestos Paper	.025″	Asbestos paper is used principally for core insulation of coils which operate at extremely high temperatures.	20	125°C. (257°F.)
Cotton Tape Fish Paper	.007″ .005″ .010″	Used in finishing form wound coils. A tough, heavy paper, gray in color. Used for insulating washers and coil tubes.	20 200	90°C. (194°F.) 90°C. (194°F.)
Fibre	3/32″ 1/8″ 3/16″	A stiff material insoluble in water or natural oils. Used primarily for bobbin washers.	200	90°C. (194°F.)
Phenol Products	As Required	An exceptionally stable, heat resisting and high dielectric moulded insulation. Used for bobbins and other purposes.	200 to 800	149°C. (300°F.)