magnets in use all the time—that is, in continuous duty—the watts per square inch should not be more than .7.

For magnets in use only a few minutes at a time—that is, intermittent duty—our value can be 2.8 or less.

For magnets for very short time of work—that is, momentary duty—the value can be as high as 11.2.

The rule to find this value is: first find the value AT ÷ winding space and this answer multiplied by itself. Let us call this

$$\left(\frac{AT}{W.S.}\right)^2$$

Then our complete rule is: **Watts per square inch surface =**

$$\frac{\left(\frac{AT}{W.S.}\right)^2 \times .78 \times M.L.T.}{Depth \times Space\ factor} \times M.L.T. + 3.1416 \times depth \times 1{,}000{,}000$$

This means: $\left(\frac{AT}{W.S.}\right)^2$ multiplied by .78, this result by the mean length of turn. This we will call Answer No. 1. Also, multiply the winding depth by the space factor, this result by the sum of the mean length of turn and 3.1416 times the winding depth, and this result by 1,000,000. This we will call Answer No. 2.

Space Factor. In this formula you find the space factor. This is a value which represents the decimal part of the winding space actually occupied by the bare copper. For example, if in Table B, we see that 2630 turns of enamel wire, size No. 25, can be wound in one square inch, but 2630 turns of bare, No. 25, have a cross section of only

```
.000254
   2630
-------
   7620
  1524
   508
-------
.668020
```


Cross section in inches = circular mils × .785 × .000001. A mil = .001 inches and a square mil = .00001 of a square inch, that is, .668 of a square inch, then .668 ÷ 1 = .668 or the ratio of the bare copper in the winding space to the winding space.

Table B values are for coils wound evenly row on row. It is very seldom that coils are wound as carefully as this so it is usual to use a space factor lower than what is shown in the table. A good plan will be to subtract .1 from the value found for all irregular wound coils.

Now we can attempt to work our problem. Let us call our space factor .57.

$$Watts = \frac{\left(\frac{2.94}{1.5}\right)^2 \times .78 \times 3.157}{.375 \times .57 \times 4.345 \times 1{,}000{,}000}$$

```
1.5 ) 294 ( 196          (A)
      15
     ---
     144
     135
     ---
      90
      90
```

```
  196                    (B)
  196
 ----
 1176
1764
 196
 ----
38416
```

```
 38416                   (C)
   .78
 ------
307328
268912
 ------
29964.48
```

```
29964 .48                                   (D)
    3 .157
-----------
 20975136
 14982240
  2996448
  8989344
-----------
94597 .86336      Answer No. 1.

  .375
   .57
-------
  2625
 1875
-------
 .21375                                     (E)
 4 .345
-------
 106875
  85500
  64125
  85500
---------
.92874375                                   (F)
 1000000
---------
928743 .75   call it 930000   Answer No. 2.  (G)
```

Dividing Answer No. 1 by No. 2 we have

```
930000 ) 94597 .86336 ( .1017 +
         930000
         -------
          1597863
           930000
          -------
           6678633
           6510000
          --------
            168633
```

This shows we have a safe beating, and we can now determine the number of turns of wire per coil.

RULES FOR TURNS PER COIL

Multiply width of winding by the depth and the result by the space factor. Divide this answer by the area of the wire cross section in square inches; you will have the turns required.

$$\text{Turns} = \frac{\text{width} \times \text{depth} \times \text{space factor}}{\text{Area of wire section}}$$

Example. Our winding space is 1.5 inches, the depth .375 inches, the activity .57, and the area of our wire = .000254 inches.

$$\text{Turns} = \frac{1.5 \times .375 \times .57}{.000254} =$$

```
  1.5
  .375
 -----
    75
   105
    45
 -------
  .5625
    .57
 -------
  39375
  28125
 -------
 .320625
```

```
.000254 ) .320625 ( 1262 +   call it 1263
          254
          ---
           666
           508
          ----
          1582
          1524
          ----
            585
            508
            ---
             77
```

Then we will wind our coils with 1263 turns of enameled copper wire, size No. 25.

Let us prove our figures to be sure of them. If our M.L.T. is 3.1416 inches, our total number of turns have a length of

1263 turns.
3 .1416

7578
1263
5052
1263
3789

12) 3967 .8408 inches (330 .65 ft. call it 331.
36

36
36

078

The resistance per ft., see Table A = .03231.

331
.03231

331
993
662
993

10 .69461 ohms. call it 10 .7 ohms.

We are to connect two coils together in series so our total resistance = 21.4 ohms. We must multiply this resistance by 1.15 to allow for the fact that after heating a well designed copper coil will increase its resistance at about this value

21 .4
1 .15

1070
214
214

24 .610 ohms hot.

$$\text{Amperes flowing} = \frac{6 \text{ volts}}{24.6} = .244 \text{ amperes}$$

1263 turns
.244 amperes

5052
5052
2526

308 .172 ampere turns

Our required number is 294, so we show a difference in our favor of 14 ampere turns.

Now we can put our coils on the magnet yoke. Fasten them in place by wrapping some sticking-tape around the steel just on each side of the fibre washer. Let the ends of the wire be brought out at least a foot from the coil so you can make the necessary connections.

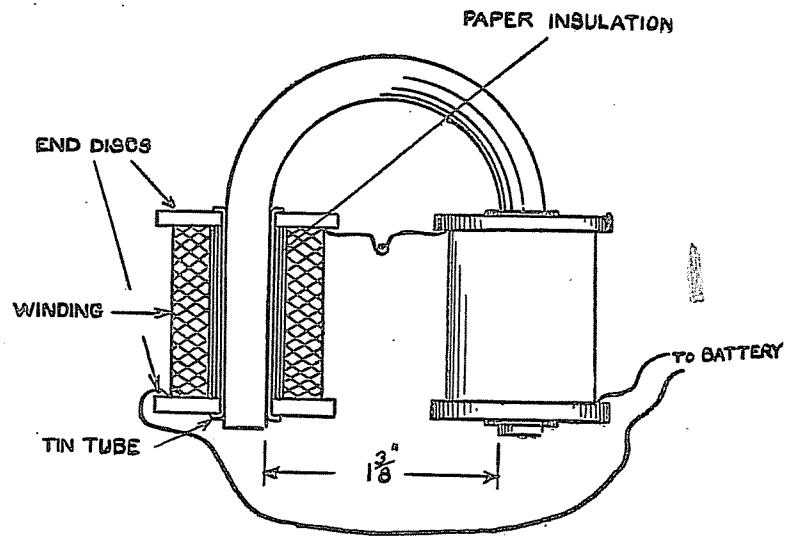


FIG. 88

Figure 88 shows one of these coils split in half to show the paper insulation and the other details of construction. This is close enough for all practical purposes and these rules have been used many times to design magnets.

MOVING CORE MAGNETS

Moving core or plunger magnets are of the type which pull or suck their core up into them. The magnetic guns described in the chapter on magnetic toys and tricks is one of these. In the circuit breaker, also, the pull exerted on the moving core, is quite different from that of a lifting magnet.

The magnetizing force of a solenoid is greatest at its center and only about one-half of the full value at the ends. That fact causes the soft iron core, or plunger as it is often called, to become magnetized and sucked into the hole in the solenoid. As the plunger passes along, it becomes more and more filled with magnetic lines by induction until it becomes saturated. If it is not much longer than the solenoid winding, the pulling effect stops when the magnetic centers of the coil and core are in the same place. From this you will see that the greatest pull comes just after the plunger has passed the middle point of the coil, except for some very long coils and also some very short ones.

The rules for these plunger magnets are somewhat more complicated than are those for the lifting magnet, so we will not give them here, but a few points may be mentioned which will help in planning such a magnet.

Make your coil with a diameter about three times its diameter if possible. The length of the pull is in proportion to the coil length. Make your core at least one and one-half times the length of the coil.

To increase the pull, a short fixed core can be placed in the end opposite to that which the plunger is to enter.

POLARIZED MAGNETS

An electro-magnet pulls its armature one way even though the current in the coil is reversed. But if the armature is made of a permanent magnet in place of the usual soft iron and is placed between the poles of the electro-magnet instead of in front of them, the direction in which it is moved can be changed by changing the direction of current flowing in the coils.

EXPLANATIONS FOR TABLE A

A mil = 1/1000 of an inch.
A circular mil = diameter of the wire in mils × itself.
S.C.C. = Single cotton cover.
D.C.C. = Double cotton cover.
Enam. = Enameled.

Table A

B&S	Copper Wire Outside Diameter						Circular Mils	Foot per lb.	Ohms per ft.
	Bare	Enam.	S.C.C.	D.C.C.	Single Silk	Double Silk			
1	0.2893			0.303			83690	3.947	0.0001237
2	0.2576			0.272			66370	4.977	0.000156
3	0.2294			0.242			52630	6.276	0.0001967
4	0.2043			0.216			41740	7.914	0.000248
5	0.1819		.189	0.194			33100	9.98	0.0003128
6	0.1620		.169	0.174			26250	12.58	0.0003944
7	0.1443		.151	0.156			20820	15.87	0.0004973
8	0.1285	.1306	.1355	0.1416			16510	20.01	0.0006271
9	0.1144	.1165	.1214	0.1274			13090	25.23	0.0007908
10	0.1019	.1040	.1079	0.1129			10380	31.82	0.0009972
11	0.09074	.0927	.0967	.1017			8234	40.12	.001257
12	.08081	.0828	.0868	.0918			6530	50.59	0.0001586
13	.07196	.0704	.078	.083			5178	63.79	.001999
14	.0648	.0661	.0701	.0751			4107	80.44	0.002521
15	.05707	.0591	.0631	.0681			3257	101.4	0.003179
16	.05082	.0528	.0558	.0608	.0528	.0546	2583	127.9	.004009
17	.04526	.0470	.0503	.0553	.0473	.0491	2048	161.3	.005055
18	.0403	.0421	.0453	.0503	.0423	.0441	1624	203.4	.006374
19	.03589	.0377	.0400	.0459	.0379	.0397	1288	256.5	.008038
20	.03196	.0337	.0370	.0420	.0340	.0358	1022	323.4	.01014
21	.02846	.0302	.0335	.0385	.0305	.0323	810.1	407.8	.01278
22	.02535	.0269	.0293	.0333	.0273	.0291	642.4	514.2	.01612
23	.02257	.0241	.0261	.0306	.0246	.0264	509.5	648.4	.02032
24	.02010	.0215	.0241	.0281	.0221	.0239	404.0	817.6	.02563
25	.01790	.0192	.0219	.0259	.0199	.0217	320.4	1031	.03231
26	.01594	.0171	.0199	.0239	.0179	.0197	254.1	1300	.04075
27	.0142	.0153	.0182	.0222	.0162	.0180	201.5	1639	.05138
28	.01264	.0136	.0166	.0206	.0146	.0164	159.8	2067	.06479
29	.01126	.0122	.0153	.0193	.0133	.0151	126.7	2607	.08170
30	.01003	.0109	.0140	.0180	.0120	.0138	100.5	3287	.1030
31	.008928	.0097	.0129	.0169	.0109	.0127	79.70	4145	.1299
32	.007950	.0087	.01195	.01595	.00995	.01175	63.21	5227	.1638
33	.007080	.0077	.01108	.01508	.00908	.01088	50.13	6591	.2066
34	.006305	.0069	.01030	.01430	.00830	.0101	39.75	8311	.2605
35	.005615	.0062	.00961	.01361	.00761	.00941	31.52	10480	.3284
36	.0050	.0055	.00900	.01300	.00700	.00880	25.0	13210	.4142
37	.004453	.0049	.00845	.01245	.00645	.00825	19.83	16660	.5222
38	.003965	.0044	.00796	.01196	.00596	.00776	15.72	21010	.6585
39	.003531	.0039	.00753	.01153	.00553	.00733	12.47	26500	.8304
40	.003145	.0035	.00714	.01114	.00514	.00694	9.888	33410	1.047

Table B

TURNS PER SQUARE INCH

B & S	Beld-Enamel	Single Cotton	Double Cotton	Single Silk	Double Silk
8	57	53	48		
9	72	66	59		
10	90	84	76		
11	113	104	93		
12	141	129	114		
13	177	160	140		
14	221	198	171		
15	277	245	208		
16	348	312	260	351	327
17	437	383	316	437	405
18	548	472	378	548	503
19	681	581	455	682	619
20	852	712	545	848	761
21	1065	868	650	1055	935
22	1340	1128	865	1315	1150
23	1665	1370	1030	1620	1400
24	2100	1665	1215	2010	1705
25	2630	2020	1420	2470	2070
26	3320	2445	1690	3005	2510
27	4145	2925	1945	3680	3010
28	5250	3500	2250	4600	3620
29	6510	4120	2560	5530	4270
30	8175	4900	2930	6810	5100
31	10200	5770	3330	8260	6010
32	12650	6700	3720	9870	6990
33	16200	7780	4140	11850	8160
34	19950	9010	4595	14250	9480
35	25000	10300	5070	16800	10870
36	31700	11750	5550	19850	12430
37	39600	13250	6045	23300	14100
38	49100	14900	6510	27300	15960
39	62600	16600	6935	31700	17850
40	77600	18400	7450	36700	19900

Table C
AMPERE TURNS AND MAGNETIC DENSITY

Cast Iron		Cast Steel		Cold Rolled Steel		Annealed Sht. Iron	
Mag. Density B	Amp. Turns per In.	Mag. Density B	Amp. Turns per In.	Mag. Density B	Amp. Turns per In.	Mag. Density B	Amp. Turns per In.
20000	23	20000	7	20000	6	20000	3
25000	31	25000	7	25000	6	25000	3
30000	44	30000	8	30000	7	30000	3
35000	61	35000	9	35000	8	35000	4
40000	87	40000	9.5	40000	8	40000	4
45000	Cast Iron Highly Satu- rated with Density above 40000	45000	10	45000	8.5	45000	4
50000		50000	11	50000	10	50000	5
55000		55000	13	55000	11	55000	6
60000		60000	15.5	60000	13	60000	8
65000		65000	17.5	65000	15	65000	10
70000		70000	21	70000	17	70000	13
75000		75000	25.5	75000	21	75000	16
80000		80000	31	80000	25	80000	20
85000		85000	38	85000	30	85000	25
90000		90000	50	90000	38	90000	33
95000		95000	70	95000	47	95000	42
100000		100000	110	100000	61	100000	59

Table D
DECIMAL EQUIVALENTS OF ONE INCH

1/64	.015625	17/32	.53125
1/32	.03125	35/64	.546875
3/64	.046875	9/16	.5625
1/16	.0625	37/64	.578125
5/64	.078125	19/32	.5937
3/32	.09375	39/64	.609375
7/64	.109375	5/8	.625
1/8	.125	41/64	.640625
9/64	.140625	21/32	.65625
5/32	.15625	43/64	.671875
11/64	.171875	11/16	.6875
3/16	.1875	45/64	.703125
13/64	.203125	23/32	.71875
7/32	.21875	47/64	.734375
15/64	.234375	3/4	.75
1/4	.25	49/64	.765625
17/64	.265625	25/32	.78125
9/32	.28125	51/64	.796875
19/64	.296875	13/16	.8125
5/16	.3125	53/64	.828125
21/64	.328125	27/32	.84375
11/32	.34375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.
33/64	.515625		

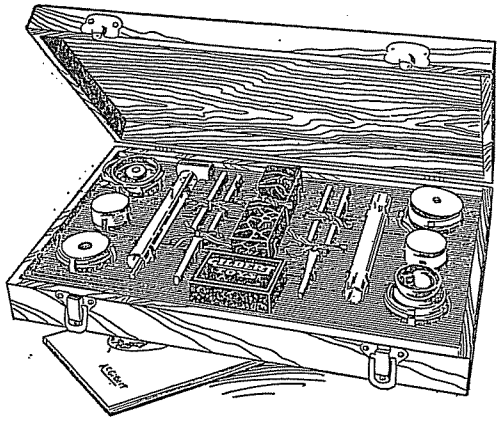
Table E

CIRCUMFERENCES AND AREAS OF CIRCLES

Diam.	Circum.	Area in Sq. Ins.	Diam.	Circum.	Area in Sq. Ins.
1/64	.0491	.0002	4 1/2	14.1372	15.9043
1/32	.0982	.0008	4 5/8	14.5299	16.8002
1/16	.1963	.0031	4 3/4	14.9226	17.7206
1/8	.3927	.0123	4 7/8	15.3153	18.6555
3/16	.5890	.0276	5	15.7080	19.6350
1/4	.7854	.0491	5 1/8	16.1007	20.6290
5/16	.9817	.0767	5 1/4	16.4934	21.6476
3/8	1.1781	.1104	5 3/8	16.8861	22.6907
7/16	1.3744	.1503	5 1/2	17.2788	23.7583
1/2	1.5708	.1963	5 5/8	17.6715	24.8505
9/16	1.7671	.2485	5 3/4	18.0642	25.9673
5/8	1.9635	.3068	5 7/8	18.4569	27.1086
11/16	2.1598	.3712	6	18.8496	28.2744
3/4	2.3562	.4418	6 1/8	19.2423	29.4648
13/16	2.5525	.5185	6 1/4	19.6350	30.6797
7/8	2.7489	.6013	6 3/8	20.0277	31.9191
15/16	2.9452	.6903	6 1/2	20.4204	33.1831
1	3.1416	.7854	6 5/8	20.8131	34.4717
1 1/8	3.5343	.9940	6 3/4	21.2058	35.7848
1 1/4	3.9270	1.2272	6 7/8	21.5985	37.1224
1 3/8	4.3197	1.4849	7	21.9912	38.4846
1 1/2	4.7124	1.7671	7 1/8	22.3839	39.8713
1 5/8	5.1051	2.0739	7 1/4	22.7766	41.2826
1 3/4	5.4978	2.4053	7 3/8	23.1693	42.7184
1 7/8	5.8905	2.7612	7 1/2	23.5620	44.1787
2	6.2832	3.1416	7 5/8	23.9547	45.6636
2 1/8	6.6759	3.5466	7 3/4	24.3474	47.1731
2 1/4	7.0686	3.9761	7 7/8	24.7401	48.7071
2 3/8	7.4613	4.4301	8	25.1328	50.2656
2 1/2	7.8540	4.9087	8 1/8	25.5255	51.8487
2 5/8	8.2467	5.4119	8 1/4	25.9182	53.4563
2 3/4	8.6394	5.9396	8 3/8	26.3109	55.0884
2 7/8	9.0321	6.4918	8 1/2	26.7036	56.7451
3	9.4248	7.0686	8 5/8	27.0963	58.4264
3 1/8	9.8175	7.6699	8 3/4	27.4890	60.1322
3 1/4	10.2102	8.2958	8 7/8	27.8817	61.8625
3 3/8	10.6029	8.9462	9	28.2744	63.6174
3 1/2	10.9956	9.6211	9 1/8	28.6671	65.3968
3 5/8	11.3883	10.3206	9 1/4	29.0598	67.2008
3 3/4	11.7810	11.0447	9 3/8	29.4525	69.0293
3 7/8	12.1737	11.7933	9 1/2	29.8452	70.8823
4	12.5664	12.5664	9 5/8	30.2379	72.7599
4 1/8	12.9591	13.3641	9 3/4	30.6306	74.6621
4 1/4	13.3518	14.1863	9 7/8	31.0233	76.589
4 3/8	13.7445	15.0330	10	31.4160	78.540

MEMORANDUM

MEMORANDUM



WHAT IS SOUND?

Do you know that hearing is just feeling with the ear? That in reality, the thing we call sound, which we think of as a noise or as a musical note, is just an impression on the brain? Very few boys know this, and if you would like to be one of the few that do, you surely want an outfit of

Gilbert Sound Experiments

With one of these outfits you can find out just what sound is—how it is produced—why some pianos sound better than others—why a violin produces a musical tone, and many other things, including a number of startling table rapping tricks with which you can astonish your friends. A big book of instructions tells you how to perform every experiment. Get one of these outfits today. The best toy dealer in your town should have it; if not, write us and we'll tell you where you can get it.

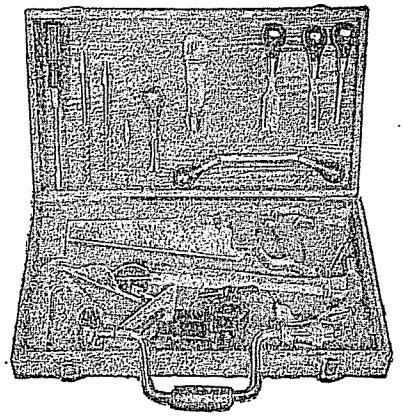
THE A. C. GILBERT COMPANY

509 BLATCHLEY AVE. **NEW HAVEN, CONN.**

In Canada: The A. C. Gilbert-Menzies Co., Limited, Toronto
In England: The A. C. Gilbert Co., 125 High Holborn, London, W. C. 2

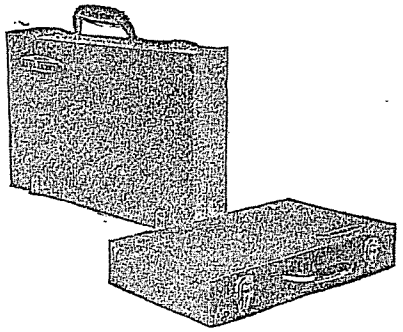
Boy Carpenters

You will find a Gilbert Tool Chest a most valuable home accessory. It will save its cost many times over each year. With it you can do a great many handy things about the house—build yourself useful and attractive pieces of furniture.



Tool Chests with Real Tools

Every tool in a Gilbert Tool Chest is a real tool—the kind a carpenter would buy for his own use. The steel is finely tempered and each tool is perfectly finished. They are the kind real workmen want. In each chest is the book "Gilbert Carpentry," that tells you how to do various kinds of work—how to get the best results.

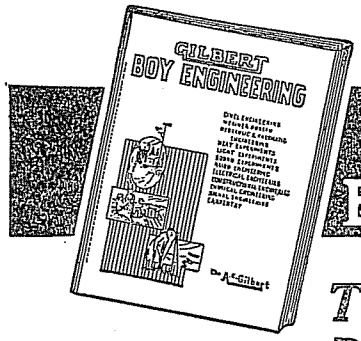


There are Gilbert Tool Chests to fit every need from the smaller chests containing an assortment of small tools to the very complete outfits with the highest grade tools packed in the special Pershing Expeditionary Outfit Chest.

Gilbert Tool Chests are on sale at all good dealers. If unable to find the one you want, write us.

THE A. C. GILBERT COMPANY
New Haven, Conn.

In Canada: The A. C. Gilbert-Menzies Co., Limited, Toronto
In England: The A. C. Gilbert Company, 125 High Holborn, London, W. C. 1

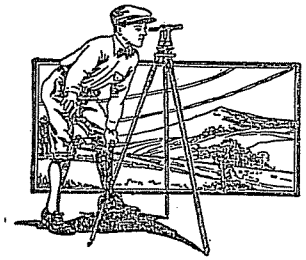


GILBERT BOY ENGINEERING

The Most Helpful Book for Boys Ever Published

Think of it! "Football Strategy," by Walter Camp—"How to Pole Vault," by Former World's Champion, A. C. Gilbert—"Flying," by Eddie Rickenbacker, and "Athletic Training," by the famous Yale trainer, Johnny Mack. Chapters about signalling, wireless, wonderful heat, sound and light experiments, how to build a real weather bureau station of your own, chemistry for boys, electrical, hydraulic and pneumatic engineering and surveying, practical carpentry—all in one finely illustrated book. It's yours for a quarter and worth dollars to you.

The Greatest Book for Boys in Years



Buy it from your dealer, or send us 25c to-day. You'll never be sorry

The A.C. Gilbert Company

509 Blatchley Avenue
New Haven : Conn.