WATCHMAKERS TABLES.

1914

SUBCRIPTION PREMIUM

THE AMERICAN JEWELER

WATCH MAKERS

TABLES

A collection of useful information concerning the teeth of wheels and pinions; the trains of watches and clocks; lengths of pendulums; quick methods of regulation; methods of finding the number of teeth in missing wheels, etc.

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NOTICE.

So many readers of the American Jeweler have asked at various times for the reprinting of information published in its columns, that we have reprinted the most useful of the tabulated information and present it in a compact and convenient form so that the workman may keep it near him for instant consultation.

The science of gearing for the trains of clocks and watches seems to give the younger members of the trade more trouble than any other one thing and we have therefore given it great prominence by including practically the whole of the volume by F. Shouffelberger on "Wheels and Pinions" which was published originally in French for Swiss workmen and is still regarded as standard.

Many others of the tables have been taken from French sources—principally from the "Almanac de l'Horologerie." Also many English authors' works have been consulted and liberal compilations made.

Several American authorities have also contributed to its columns. It is hoped that this little work shall prove to be of sufficient convenience to our readers to justify its reprinting in new and convenient form.

It will not be sold but may be obtained by sending one dollar for one year's subscription to The American Jeweler and asking for the Watchmakers' Tables as a premium.

THE SIZES OF WHEELS AND PINIONS.

BY F. SHOUFFELBERGER—TRANSLATED BY THEO. GRIBI.

Exact knowledge of the true relative total diameters of wheels and pinions to be established in watches is of comparatively recent date. It is not earlier than 1870 that anything like scientific data touching the solution of this problem was given to the world. The original of the present treatise was published in French, in the Journal Suisse d'horologerie in 1879. Before that, approximations, more or less exact, were all that we possessed. It was, of course, at all times easy to determine the relative diameters of the primitive circles of wheel and pinion gearing into each other, from their center distance, etc., but the quantity to be added to these diameters in order to obtain the best possible transmission of power, even while the correct form of the addenda was known, was a more difficult task, in watches at least, owing to the low numbered pinions that have to be employed in them and the consequent utilization, in many places, of the entire driving capacity of the tooth out to the very apex of its addendum, in order to avoid as much as possible the driving before the lines of centers.

This task is now accomplished, and in the present treatise the watchmaker has a convenient manual, in the form of tables by means of which he can find immediately and without any figuring the exact size of wheel or pinion to be replaced. There is no more "cutting and trying," and no more rounding up necessary after a wheel has been put in.

The workman, having measured the center distance, finds in the tables the correct size of the missing wheel or pinion for that center distance, and either proceeds to cut one just right, or selects one from a stock already cut. It is, however, necessary that the chapter on "observations concerning the use of the tables" be carefully read and understood. To this I would add that in tables III to X the integrals of the quantities between two successive whole numbers have been omitted, the fractions only being given, and the last preceeding integral has to be taken with each fraction as the whole quantity sought.

Although for the every day practical use of the watchmaker the tables are all that is necessary, I have nevertheless thought it well to add the formulae, and their mathematical development, by which the tables are calculated and constructed, in case a wheel or pinion of a combination of numbers other than those found in the tables should have to be replaced. In such a case the workman familiar with trigonometry can readily find the required total diameter by the use of the formulae, or if not conversant with mathematics can request some one who is to solve them for him. But the tables contain all the combinations of numbers usually occurring in watches.

I have taken the liberty to amplify an expression here and there for the sake of greater clearness, as well as to make additions where I thought the needs of the repairer required it.

OBSERVATIONS CONCERNING THE USE OF THE TABLES.

These tables have been calculated for wheels and pinions that are made according to principles generally adopted, viz.:

Pinions of ten leaves and below have a thickness of leaves equal to one-half the space between, i. e., one-third of their pitch. Pinions of 12 and 14 have the thickness of their leaves equal to two-fifths of their pitch. The sides of the leaves are radii and the exedants semi-circles.

The wheels have teeth of a width equal to the space between them. The exedant is epicycloidal, generated by a circle equal to one-half the diameter of the primitive circle of the pinion. The teeth of wheels that have been rounded with the Ingold fraise have a form nearest approaching the epicycloid.

For the dial wheels, whose depth should have very little play, the proportion of the width of the teeth to the spaces between them is given in each table. The teeth of these wheels are as wide as the spaces, and the addenda of the pinions as well as those of the wheels are epicycloidal, generated by a circle whose diameter is equal to half that of the primitive circle of the wheel or pinion into which they gear. The sides of the teeth of wheels and leaves of pinions should be radii.

The more nearly wheels and pinions are made according to the principles here enunciated, the nearer will they approach the sizes given in the tables, and the more perfectly will they transmit the force communicated to them. With a little practice and attention it will be easy to make changes according as the case may require. Thus, a pinion whose leaves are too thick must be taken a trifle larger than the measure indicated, and will require a wheel with the spaces a little wider than the teeth and the addenda a little shorter. The contrary must be followed for a pinion whose spaces are too open, etc.

Some watchmakers, basing their opinion on an observation made by Camus, and reproduced by M. Saunier in his "Treatise on Modern Horology," page 1099, want their pinions a little smaller than the measure indicated. I am of the opinion that it is better to select pinions as near the right size as possible. These pinions will, nevertheless, be generally a little smaller in their primitive diameters than the ideal size would be, and for the following reasons:

First—Pinions, such as we more often find them, are ordinarily too full, i. e., their leaves are thicker than they ought to be, which increases the height of the addenda.

Second—These addenda have generally a form too oval, approaching the form of a semi-ellipse rather than that of a semi-circle.

Third—The teeth of wheels, such as the rounding up cutters leave them, have almost always too short addenda, which relatively to its total diameter, implies a larger primitive circle, corresponding to a pinion smaller in proportion than it ought to be.

Table I, which is the basis of this whole work, has been calculated with the utmost care. Still, having from the start assumed sufficient to calculate the driving angle of the wheel and pinion to one second approximately, more or less, it follows that the fourth figure of the decimals in this table is not always absolutely exact; as, however, the errors arising from this cannot exceed one or two ten thousandths, I found it better to let them stand as they are, rather than drop them and increase the preceding figure by one, which necessarily would have brought in some errors greater than four ten thousandths.

As to the tables II to IX, their utility will be made apparent by the following example:

Suppose that both dial wheels, but not the cannon pinion, are missing in a watch. The cannon pinion has 12 leaves and its diameter is 2.48 millimeters. Looking in table VIII for the column headed Cannon Pinion and the number 2.48, we will find on the same horizontal line the diameters of the three other pieces, hour wheel, intermediate and intermediate pinion, as well as the center distance of the latter, at which the stud should be placed, which is 4 millimeters.

In like manner, having to replace, say an escape wheel pinion of six leaves, gearing into a wheel of sixty teeth and appropriate to a center distance of 8 millimeters, we look in table VII, and in the column of center distances for the latter number and on the same horizontal line of the columns relating to it, we find the diameters of both wheel and pinions necessary, viz: 1.71 for the pinion and 15.22 for the diameter of wheel. In this connection it is important to observe that it is wise never to depend on the size of the remaining wheel or pinion to which the other is to be replaced and matched, but to measure the center distance and go by it, because the depth may originally have been badly pitched, or the wheel may have been of defective proportion from the start. By measuring the center distance and taking it as a guide, it will be shown by the figures in the columns corresponding to it whether such is the case, and if so, and the error is important enough, both wheel and pinion should be changed.

Tables II to IX have been made up by multiplying every center distance by the figures in table 1, columns T and K (see bottom of table). In the same way the diameters of wheel and pinion may be found for any other center distance than those found in the tables.

It will be observed that it is immaterial what system of measurement is employed in the use of the tables, whether that of the English inch or the metric, provided the unit adopted is decimally divided. Nor is the use of the system by douziemes precluded, for, in the example quoted above for the selection of dial wheels, we may take the numbers 2.48 as 24.8 douziemes, or for 248 douziemes, and the center distance will be 40 douziemes in the first and 400 douziemes in the second case. But the use of the tables is certainly more convenient in the employment of a decimal system.

HOW TO DETERMINE THE DIAMETERS OF WHEELS AND PINIONS IN WATCH WORK.

To Mr. Isely, professor of mathematics at Neuchatel (Switzerland) is due the credit of having opened the way to works of the nature of the present one, in publishing[1] the first mathematically calculated tables giving the value of the exedants (addenda) of wheels and their total diameter relative to that of pinions into which they gear. Before him there existed only the tables of Mr. Dauphin[2] and those of Mr. Ch. Ed. Jacot[3] obtained by the graphic method, and insufficiently accurate.

Besides that of Mr. Isely, several methods have been proposed for the calculation of the addenda of wheels; thus, that of Mr. Resal[4] and that of Mr. Saunier[5] which scarcely differs from that taught by Mr. J. Grossman, for some time past, at the Horological School of Locle.

The calculations, according to all these methods, are somewhat laborious, and the work of approximation by the following method is much more rapid. Unfortunately, the latter did not occur to me till too late, when all my calculations were already made by the method practiced in Locle. However, it served me the purpose of verifying and checking them.

(1) Bulletin of the Society of Natural Sciences of Neuchatel, 1873, vol. IX., p. 381.

(2) Revue Chronometrique, July, 1851, vol. III, Suppl't, p. 8. These tables are remarkably exact, and were not sufficiently appreciated at the epoch of their publication.

(3) Practical studies of depthings, Chaux-de-Fonds, 1867.

(4) See Journal Suisse d'horologerie, 1st year, p. 72.

(5) Revue Chronometrique, 1875.

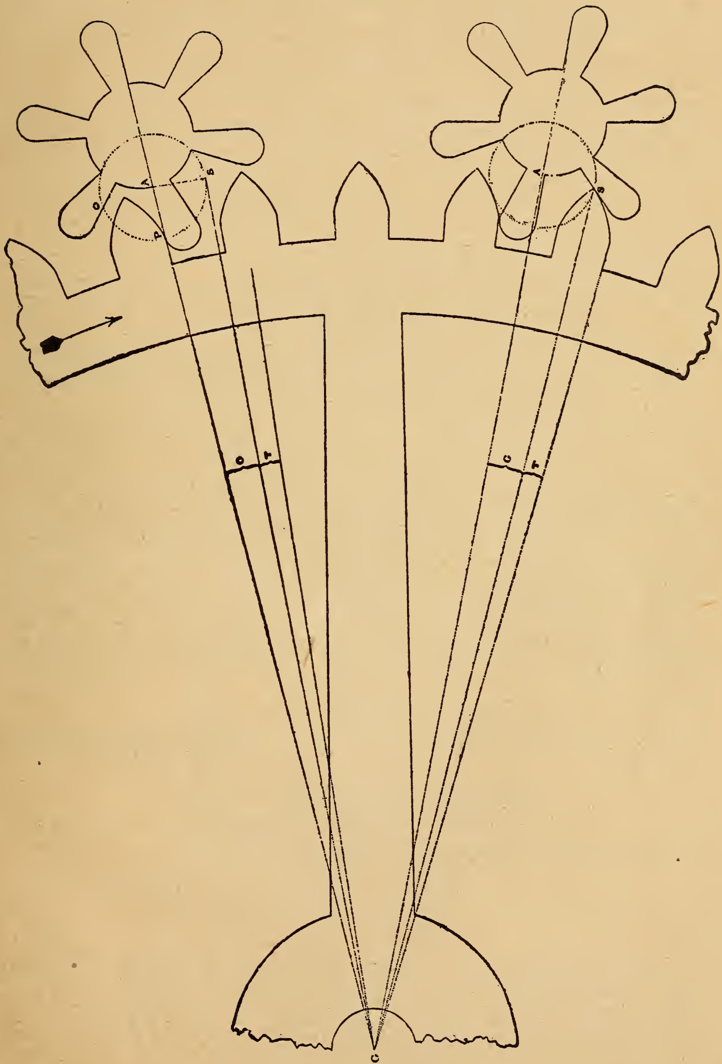


Plate 1.

METHOD PRACTICED AT CHAUX-DE-FONDS FOR DETERMINING THE HEIGHT OF THE EPICYCLOIDAL ADDENDA.

See Plate 1.

Let r = G P = the primitive radius of the wheel.

Let g = A P = A S = the radius of the generating circle.

Let s = G A = r + g = the distance from the center of the generating circle to the center of the wheel.

Let a = G S = the total radius of the wheel.

Let A = the angle which the generating circle has moved over from the moment when the tooth of the wheel and leaf of the pinion were first in contact on the line of centers till the tooth lets go of the pinion leaf.

Let M = G + T = the angle over which the wheel has turned in the same time.

Let T = the angle corresponding to half the width of the wheel tooth and equal to one-fourth of the pitch.

If we assign to g the value of unity, r will express the relative angular velocities of the two, wheel and generating circle, and consequently the relation between the two angles A and M.

Thus, $A = r\ M = r\ G + r\ T$.

Considering the triangle G A S, we find that the value of the angle

$$S = 180° - A - G;$$

$$\text{or } S = 180° - r\ (G + T) - G \qquad \text{(a)}$$

Moreover, trigonometry teaches that

$$\frac{\text{Sin. } G}{g} = \frac{\text{Sin. } S}{s} \qquad \text{(b)}$$

The quantities r, T, g and s figuring in equations (a) and (b) are known. It is therefore only necessary to find, by the method of approximations, a value of G such that when substituted in the two equations the values of S become identical, and we shall possess all the elements for the solution of the problem. It is to be observed that the angle S, being always an obtuse one, it is its supplement and not the angle S itself that we obtain in reducing to figures the equation (b).

For example, let us take a wheel of 48 teeth, driving a pinion of 6, we have:

$$r = 16$$

$$g = 1$$

$$s = 17$$

$$T = \frac{360}{4x48} = 1° \ 52' \ 30''$$

and equation (a) becomes:

$$S = 180° - 16 \ (G + 1°, 52', 30'') - G,$$

and equation (b):

$$\text{Sin. Suppl. } S = 17 \text{ sin. } G.$$

We know in a general way that when a pinion, which is driven, has 12 leaves, the angle M is a little greater than the pitch of the wheel teeth; that it is less when the pinion has 10 leaves and becomes smaller by degrees as the pinion leaves are less in number.

If now we suppose the value of G = 3°, 22′, 20″, equation (a) gives:

$$\text{Suppl. } S = 87°, 19', 40''$$

and equation (b):

$$\text{Suppl. Sin. } S = 89°, 38', 35''.$$

The value given to G is therefore too great.

After a few trials we give to G the value of 3°, 22′, 6.373″ and we obtain:

(a) Suppl. S = 87°, 15′, 48.341″, or, S = 92°, 44′, 11.659″.

(b) Suppl. S = 87°, 15′, 48.3″, or, S = 92°, 44′, 11.7″.

The difference is insignificant and, except in particular cases, it is not necessary to pursue the approximation as closely.

There remains to be determined the angle A, and the sine (a), which latter is the total radius of the wheel. The angle A =r M, as already found by the equation (a), it is in this case: 83°, 53′, 41.968″.

And as

$$\frac{\text{Sin. G.}}{g} = \frac{\text{Sin. A.}}{a}$$

we have

$$\frac{\text{Sin. } 3°, 22', 6.373''}{1} = \frac{\text{Sin. } 83°, 53', 41.968''}{a}$$

whence

$$a = 16.9228,$$

and the height of the addendum

$$= a - r = 0.9228.$$

If we take the primitive radius of the pinion for unity, instead of that of the generating circle, we have for the total radius of the wheel:

$$\frac{a}{2} = 8.4614$$

and for the height of the addendum = 0.4614.

General Table of the Sizes and Relations of Wheels and Pinions Most Used in Watches.—Table I.

Relation of Primitive Circles.	Number of Teeth in the Wheel.	Number of Leaves in the Pinion.	THE PRIMITIVE RADIUS OF PINION=1. Height of Adenda.	THE PRIMITIVE RADIUS OF PINION=1. Total Diameter of Wheel.	THE PRIMITIVE RADIUS OF PINION=1. Total Diameter of Pinion.	PRIMITIVE DIAMETER OF WHEEL=1. Total Diameter of Wheel.	PRIMITIVE DIAMETER OF WHEEL=1. Total Diameter of Pinion.	WHEN CENTER DISTANCE=1. Total Diameter of Wheel.	WHEN CENTER DISTANCE=1. Total Diameter of Pinion.	Relation of Wheel to Pinion.	Driving Angle before the Line of Centers.	Driving Angle after the Line of Centers.	Thickness of Pinion Leaves.	Pitch of the Pinion.
					The Pinions, Etc.							° ′ ″	° ′	° ′
3	42	XIV	0.2583	6.5167	2.1795	1.0861	0.3633	1.6292	0.5449	2.9900		28 43 26	10 17	25 43
10	120	XII	0.3042	20.6085	2.2094	1.0304	0.1105	1.8735	0.2009	9.3276		32 50 43	12	30
9	108	"	0.3032	18.6064	2.2094	1.0337	0.1227	1.8606	0.2209	8.4215		32 42 53	12	30
8	96	"	0.3019	16.6039	2.2094	1.0377	0.1381	1.8449	0.2455	7.5151		32 33 14	12	30
7.50	90	"	0.3012	15.6025	2.2094	1.0402	0.1473	1.8356	0.2599	7.0619		32 27 30	12	30
7	84	"	0.3003	14.6006	2.2094	1.0429	0.1578	1.8251	0.2762	6.6084		32 21 3	12	30
6.66	80	"	0.2997	13.9327	2.2094	1.0450	0.1657	1.8173	0.2882	6.3061		32 16 15	12	30
6	72	"	0.2983	12.5966	2.2094	1.0497	0.1841	1.7795	0.3156	5.7014		32 5 9	12	30
5	60	"	0.2955	10.5909	2.2094	1.0591	0.2209	1.7652	0.3682	4.7936		31 43 35	12	30
4	48	"	0.2915	8.5829	2.2094	1.0729	0.2762	1.7165	0.4419	3.8847		31 12 37	12	30
3	36	"	0.2853	6.5706	2.2094	1.0951	0.3682	1.6426	0.5524	2.9739	° ′ ″	30 24 23	12	30
10	100	X	0.3407	20.6815	2.2094	1.0341	0.1105	1.8801	0.2009	9.3607	0 56 14	35 3 46	12	36
9	90	"	0.3396	18.6792	2.2094	1.0377	0.1227	1.8679	0.2209	8.4545	1 4 17	34 35 43	12	36
8	80	"	0.3383	16.6765	2.2094	1.0423	0.1381	1.8530	0.2455	7.5480	1 14 13	34 45 47	12	36
7.60	76	"	0.3377	15.8754	2.2094	1.0444	0.1454	1.8460	0.2569	7.1854	1 18 53	34 41 7	12	36
7.50	75	"	0.3374	15.6749	2.2094	1.0450	0.1473	1.8441	0.2599	7.0947	1 20 6	34 39 54	12	36
7	70	"	0.3366	14.6731	2.2094	1.0481	0.1578	1.8341	0.2762	6.6412	1 26 46	34 33 14	12	36
6.40	64	"	0.3353	13.4707	2.2094	1.0524	0.1726	1.8204	0.2986	6.0970	1 36 2	34 23 58	12	36
6	60	"	6.3344	12.6689	2.2094	1.0557	0.1841	1.8098	0.3156	5.7341	1 43 9	34 16 51	12	36
5	50	"	9.3314	10.6627	2.2094	1.0663	0.2209	1.7771	0.3682	4.8261	2 5 21	33 54 39	12	36
4	40	"	0.3271	8.6543	2.2094	1.0818	0.2762	1.7309	0.4419	3.9170	2 37 16	33 22 44	12	36
3	30	"	0.3206	6.6412	2.2094	1.1069	0.3682	1.6603	0.5524	3.0059	3 27 2	32 32 58	12	36
10	80	VIII	0.3906	20.7812	2.2618	1.0391	0.1139	1.8892	0.2056	9.1879	6 59 5	38 0 55	15	45
9	72	"	0.3894	18.7789	2.2618	1.0433	0.1257	1.8779	0.2262	8.3027	7 7 23	37 52 37	15	45
8	64	"	0.3880	16.7761	2.2618	1.0485	0.1414	1.8640	0.2513	7.4172	7 17 36	37 42 24	15	45
7.50	60	"	0.3872	15.7744	2.2618	1.0516	0.1508	1.8558	0.2661	6.9743	7 23 40	37 36 20	15	45
7	56	"	0.3864	14.7727	2.2618	1.0552	0.1616	1.8466	0.2827	6.5314	7 30 32	37 29 28	15	45
6	48.	"	0.3839	12.7678	2.2618	1.0640	0.1885	1.8240	0.3231	5.6450	7 47 22	37 12 38	15	45
5	40	"	0.3809	10.7618	2.2618	1.0762	0.2262	1.7936	0.3762	4.7581	8 10 15	36 49 45	15	45
4	32	"	0.3762	8.7525	2.2618	1.0941	0.2827	1.7505	0.4524	3.8697	8 48 7	36 11 53	15	45
10	70	VII	0.4234	20.8468	2.2992	1.0423	0.1150	1.8952	0.2090	9.0670	11 30 29	39 55 14	17 8	51 26
9	63	"	0.4222	18.8445	2.2992	1.0469	0.1277	1.8844	0.2299	8.1961	11 38 53	39 46 50	17 8	51 26
8	56	"	0.4208	16.8416	2.2992	1.0526	0.1437	1.8713	0.2555	7.3250	11 49 14	39 36 29	17 8	51 26
7	49	"	0.4190	14.8379	2.2992	1.0599	0.1642	1.8547	0.2874	6.4535	12 1 19	39 23 24	17 8	51 26
11	66	VI	0.4652	22.9304	2.3491	1.0423	0.1068	1.9109	0.1958	9.7615	17 37 15	42 22 45	20	60
10	60	"	0.4641	20.9283	2.3491	1.0464	0.1175	1.9026	0.2136	8.9092	17 44 15	42 15 45	20	60
9	54	"	0.4629	18.9258	2.3491	1.0514	0.1305	1.8926	0.2349	8.0567	17 52 42	42 7 18	20	60
8	48	"	0.4614	16.9229	2.3491	1.0577	0.1468	1.8803	0.2610	7.2041	18 3 9	41 56 51	20	60
7.50	45	"	0.4605	15.9211	2.3401	1.0614	0.1566	1.8731	0.2764	6.7776	18 9 20	41 50 40	20	60
7	42	"	0.4596	14.9192	2.3491	1.0657	0.1678	1.8649	0.2936	6.3512	18 16 21	41 43 39	20	60
6	36	"	0.4573	12.9145	2.3491	1.0762	0.1958	1.8449	0.3356	5.4977	18 33 34	41 26 26	20	60
5	30	"	0.4538	10.9077	2.3491	1.0908	0.2349	1.8179	0.3915	4.6434	18 56 57	41 3 3	20	60
					FOR DIAL TRAINS. The Pinions Alternately Drive and are being Driven.									WHEEL. Width of the Tooth.
					The Thickness of the Leaves of Pinions are equal to the Spaces.									
4	48	XII	0.2838	8.5829	2.5677	1.0729	0.3210	1.7165	0.5135	3.3437		9 27 33	15	3 45
4	40	X	0.3232	8.6543	2.6465	1.0818	0.3308	1.7309	0.5293	3.2701		10 11 20	18	4 30
4	32	VIII	0.3795	8.7525	2.7589	1.0941	0.3449	1.7505	0.5518	3.1724	0 3 56	11 11 4	22 30	5 38
3	42	XIV	0.2516	6.5167	2.5032	1.0861	0.4172	1.6292	0.6258	2.6033		11 12 21	12 51	4 17
3	36	XII	0.2805	6.5706	2.5610	1.0951	0.4268	1.6426	0.6403	2.5656		11 55 6	15	5
3	30	X	0.3193	6.6412	2.6386	1.1069	0.4398	1.6603	0.6596	2.5170		12 50 15	18	6
					The Thickness of the Leaves of Pinions equal $\frac{2}{5}$ their Pitch.									Pitch.
4	48	XII	0.2424	8.5829	2.4847	1.0729	0.3106	1.7165	0.4969	3.4543		8 39 17	12	7 30
4	40	X	0.2757	8.6543	2.5514	1.0818	0.3189	1.7309	0.5103	3.3919		9 18 19	14 24	9
4	32	VIII	0.3228	8.7525	2.6456	1.0941	0.3307	1.7505	0.5291	3.3083	1 3 40	10 11 20	18	11 15
3	42	XIV	0.2051	6.5167	2.4102	1.0861	0.4017	1.6292	0.6026	2.7038		10 16 1	10 17	8 34
3	36	XII	0.2397	6.5706	2.4794	1.0951	0.4132	1.6426	0.6198	2.6501		10 54 16	12	10
3	30	X	0.2725	6.6412	2.5451	1.0069	0.4242	1.6603	0.6363	2.6094	0 16 33	11 43 27	14 24	12
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P

Table II.

Wheels of 80 Teeth.—Pinions of X Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.			4.	0.98	7.41	8.	1.96	14.82	12.	2.95	22.24
.1	0.02	0.19	.1	1.01	.60	.1	.99	15.01	.1	.97	.42
.2	.05	.37	.2	.03	.78	.2	2.01	.19	.2	3.00	.61
.3	.07	.56	.3	.06	.97	.3	.04	.38	.3	.02	.79
.4	.10	.74	.4	.08	8.15	.4	.06	.56	.4	.04	.98
.5	.12	.93	.5	.10	.34	.5	.09	.75	.5	.07	23.16
.6	.15	1.11	.6	.13	.52	.6	.11	.94	.6	.09	.35
.7	.17	.30	.7	.15	.71	.7	.14	16.12	.7	.12	.53
.8	.20	.48	.8	.18	.89	.8	.16	.31	.8	.14	.72
.9	.22	.67	.9	.20	9.08	.9	.18	.49	.9	.17	.90
1.	0.25	.85	5.	1.23	.26	9.	2.21	.68	13.	3.19	24.09
.1	.27	2.04	.1	.25	.45	.1	.23	.86	.1	.22	.27
.2	.29	.22	.2	.28	.64	.2	.26	17.05	.2	.24	.46
.3	.32	.41	.3	.30	.82	.3	.28	.23	.3	.27	.64
.4	.34	.59	.4	.33	10.01	.4	.31	.42	.4	.29	.83
.5	.37	.78	.5	.35	.19	.5	.33	.60	.5	.31	25.01
.6	.39	.96	.6	.37	.38	.6	.36	.79	.6	.34	.20
.7	.42	3.15	.7	.40	.56	.7	.38	.97	.7	.36	.39
.8	.44	.34	.8	.42	.75	.8	.41	18.16	.8	.39	.57
.9	.47	.52	.9	.45	.93	.9	.43	.34	.9	.41	.76
2.	0.49	.71	6.	1.47	11.12	10.	2.45	.53	14.	3.44	.94
.1	.52	.89	.1	.50	.30	.1	.48	.71	.1	.46	26.13
.2	.54	4.08	.2	.52	.49	.2	.50	.90	.2	.49	.31
.3	.56	.26	.3	.55	.67	.3	.53	19.09	.3	.51	.50
.4	.59	.45	.4	.57	.86	.4	.55	.27	.4	.54	.68
.5	.61	.63	.5	.60	12.04	.5	.58	.46	.5	.56	.87
.6	.64	.82	.6	.62	.23	.6	.60	.64	.6	.58	27.05
.7	.66	5.00	.7	.64	.41	.7	.63	.83	.7	.61	.24
.8	.69	.19	.8	.67	.60	.8	.65	20.01	.8	.63	.42
.9	.71	.37	.9	.69	.79	.9	.68	.20	.9	.66	.61
3.	0.74	.56	7.	1.72	.97	11.	2.70	.38	15.	3.68	.79
.1	.76	.74	.1	.74	13.16	.1	.72	.57	.1	.71	.98
.2	.79	.93	.2	.77	.34	.2	.75	.75	.2	.73	28.16
.3	.81	6.11	.3	.79	.53	.3	.77	.94	.3	.76	.35
.4	.83	.30	.4	.82	.71	.4	.80	21.12	.4	.78	.54
.5	.86	.49	.5	.84	.90	.5	.82	.31	.5	.81	.72
.6	.88	.67	.6	.87	14.08	.6	.85	.49	.6	.83	.91
.7	.91	.86	.7	.89	.27	.7	.87	.68	.7	.85	29.09
.8	.93	7.04	.8	.91	.45	.8	.90	.86	.8	.88	.28
.9	.96	.23	.9	.94	.64	.9	.92	22.05	.9	.90	.46

The Leaves of Pinions take up One-third of the Pitch.

Table III.

Wheels of 75 Teeth.—Pinions of X Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.			4.	1.04	7.38	8.	2.08	14.75	12.	3.12	22.13
.1	0.03	0.18	.1	.07	.56	.1	.11	.94	.1	.15	.31
.2	.05	.37	.2	.09	.75	.2	.13	15.12	.2	.17	.50
.3	.08	.55	.3	.12	.93	.3	.16	.31	.3	.20	.68
.4	.10	.74	.4	.14	8.11	.4	.18	.49	.4	.22	.87
.5	.13	.92	.5	.17	.30	.5	.21	.67	.5	.25	23.05
.6	.16	1.11	.6	.20	.48	.6	.24	.86	.6	.28	.24
.7	.18	.29	.7	.22	.67	.7	.26	16.04	.7	.30	.42
.8	.21	.48	.8	.25	.85	.8	.29	.23	.8	.33	.60
.9	.23	.66	.9	.27	9.04	.9	.31	.41	.9	.35	.79
1.	0.26	.84	5.	1.30	.22	9.	2.34	.60	13.	3.38	.97
.1	.29	2.03	.1	.33	.40	.1	.37	.78	.1	.41	24.16
.2	.31	.21	.2	.35	.59	.2	.39	.97	.2	.43	.34
.3	.34	.40	.3	.38	.77	.3	.42	17.15	.3	.46	.53
.4	.36	.58	.4	.40	.96	.4	.44	.33	.4	.48	.71
.5	.39	.77	.5	.43	10.14	.5	.47	.52	.5	.51	.90
.6	.42	.95	.6	.46	.33	.6	.50	.70	.6	.54	25.08
.7	.44	3.13	.7	.48	.51	.7	.52	.89	.7	.56	.26
.8	.47	.32	.8	.51	.70	.8	.55	18.07	.8	.59	.45
.9	.49	.50	.9	.53	.88	.9	.57	.26	.9	.61	.63
2.	0.52	.69	6.	1.56	11.06	10.	2.60	.44	14.	3.64	.82
.1	.55	.87	.1	.59	.25	.1	.63	.63	.1	.67	26.00
.2	.57	4.06	.2	.61	.43	.2	.65	.81	.2	.69	.19
.3	.60	.24	.3	.64	.62	.3	.68	.99	.3	.72	.37
.4	.62	.43	.4	.66	.80	.4	.70	19.18	.4	.74	.56
.5	.65	.61	.5	.69	.99	.5	.73	.36	.5	.77	.74
.6	.68	.79	.6	.72	12.17	.6	.76	.55	.6	.80	.92
.7	.70	.98	.7	.74	.36	.7	.78	.73	.7	.82	27.11
.8	.73	5.16	.8	.77	.54	.8	.81	.92	.8	.85	.29
.9	.75	.35	.9	.79	.72	.9	.83	20.10	.9	.87	.48
3.	0.78	.53	7.	1.82	.91	11.	2.86	.29	15.	3.90	.66
.1	.81	.72	.1	.85	13.09	.1	.89	.47	.1	.93	.85
.2	.83	.90	.2	.87	.28	.2	.91	.65	.2	.95	28.03
.3	.86	6.09	.3	.90	.46	.3	.94	.84	.3	.98	.21
.4	.88	.27	.4	.92	.65	.4	.96	21.02	.4	4.00	.40
.5	.91	.45	.5	.95	.83	.5	.99	.21	.5	.03	.58
.6	.94	.64	.6	.98	14.02	.6	3.02	.39	.6	.05	.77
.7	.96	.82	.7	2.00	.20	.7	.04	.58	.7	.08	.95
.8	.99	7.01	.8	.03	.38	.8	.07	.76	.8	.11	29.14
.9	1.01	.19	.9	.05	.57	.9	.09	.94	.9	.13	.32

The Leaves of Pinions take up One-third of the Pitch.

Table IV.

Wheels of 70 Teeth.—Pinions of VII Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.			4.	0.84	7.58	8.	1.67	15.16	12.	2.51	22.74
.1	0.02	0.19	.1	.86	.77	.1	.69	.35	.1	.53	.93
.2	.04	.38	.2	.88	.96	.2	.71	.54	.2	.55	23.12
.3	.06	.57	.3	.90	8.15	.3	.73	.73	.3	.57	.31
.4	.08	.76	.4	.92	.34	.4	.76	.92	.4	.59	.50
.5	.10	.95	.5	.94	.53	.5	.78	16.11	.5	.61	.69
.6	.13	1.14	.6	.96	.72	.6	.80	.30	.6	.63	.88
.7	.15	.33	.7	.98	.91	.7	.82	.49	.7	.65	24.07
.8	.17	.52	.8	1.00	9.10	.8	.84	.68	.8	.68	.26
.9	.19	.71	.9	.02	.29	.9	.86	.87	.9	.70	.45
1.	0.21	.90	5.	1.05	.48	9.	1.88	17.06	13.	2.72	.64
.1	.23	2.08	.1	.07	.67	.1	.90	.25	.1	.74	.83
.2	.25	.27	.2	.09	.85	.2	.92	.44	.2	.76	25.02
.3	.27	.46	.3	.11	10.04	.3	.94	.63	.3	.78	.21
.4	.29	.65	.4	.13	.23	.4	.96	.81	.4	.80	.40
.5	.31	.84	.5	.15	.42	.5	.99	18.00	.5	.82	.58
.6	.33	3.03	.6	.17	.61	.6	2.01	.19	.6	.84	.77
.7	.36	.22	.7	.19	.80	.7	.03	.38	.7	.86	.96
.8	.38	.41	.8	.21	.99	.8	.05	.57	.8	.88	26.15
.9	.40	.60	.9	.23	11.18	.9	.07	.76	.9	.91	.34
2.	0.42	.79	6.	1.25	.37	10.	2.09	.95	14.	2.93	.53
.1	.44	.98	.1	.28	.56	.1	.11	19.14	.1	.95	.72
.2	.46	4.17	.2	.30	.75	.2	.13	.33	.2	.97	.91
.3	.48	.36	.3	.32	.94	.3	.15	.52	.3	.99	27.10
.4	.50	.55	.4	.34	12.13	.4	.17	.71	.4	3.01	.29
.5	.52	.74	.5	.36	.32	.5	.19	.90	.5	.03	.48
.6	.54	.93	.6	.38	.51	.6	.22	20.09	.6	.05	.67
.7	.56	5.12	.7	.40	.70	.7	.24	.28	.7	.07	.86
.8	.59	.31	.8	.42	.89	.8	.26	.47	.8	.09	28.05
.9	.61	.50	.9	.44	13.08	.9	.28	.66	.9	.11	.24
3.	0.63	.69	7.	1.46	.27	11.	2.30	.85	15.	3.14	.43
.1	.65	.88	.1	.48	.46	.1	.32	21.04	.1	.16	.62
.2	.67	6.06	.2	.50	.65	.2	.34	.23	.2	.18	.81
.3	.69	.25	.3	.53	.83	.3	.36	.42	.3	.20	29.00
.4	.71	.44	.4	.55	14.02	.4	.38	.60	.4	.22	.19
.5	.73	.63	.5	.57	.21	.5	.40	.79	.5	.24	.38
.6	.75	.82	.6	.59	.40	.6	.42	.98	.6	.26	.56
.7	.77	7.01	.7	.61	.59	.7	.45	22.17	.7	.28	.75
.8	.79	.20	.8	.63	.78	.8	.47	.36	.8	.30	.94
.9	.82	.39	.9	.65	.97	.9	.49	.55	.9	.32	30.13

The Leaves of Pinion take up One-third of the Pitch.

Table V.

Wheels of 64 Teeth.—Pinions of VIII Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.			4.	1.01	7.46	8.	2.01	14.91	12.	3.02	22.37
.1	0.03	0.19	.1	.03	.64	.1	.04	15.10	.1	.04	.55
.2	.05	.37	.2	.06	.83	.2	.06	.28	.2	.07	.74
.3	.08	.56	.3	.08	8.02	.3	.09	.47	.3	.09	.93
.4	.10	.75	.4	.11	.20	.4	.11	.66	.4	.12	23.11
.5	.13	.93	.5	.13	.39	.5	.14	.84	.5	.14	.30
.6	.15	1.12	.6	.16	.57	.6	.16	16.03	.6	.17	.49
.7	.18	.30	.7	.18	.76	.7	.19	.22	.7	.19	.67
.8	.20	.49	.8	.21	.95	.8	.21	.40	.8	.22	.86
.9	.23	.68	.9	.23	9.13	.9	.24	.59	.9	.24	24.05
1.	0.25	.86	5.	1.26	.32	9.	2.26	.78	13.	3.27	.23
.1	.28	2.05	.1	.28	.51	.1	.29	.96	.1	.29	.42
.2	.30	.24	.2	.31	.69	.2	.31	17.15	.2	.32	.60
.3	.33	.42	.3	.33	.88	.3	.34	.34	.3	.34	.79
.4	.35	.61	.4	.36	10.07	.4	.36	.52	.4	.37	.98
.5	.38	.80	.5	.38	.25	.5	.39	.71	.5	.39	25.16
.6	.40	.98	.6	.41	.44	.6	.41	.89	.6	.42	.35
.7	.43	3.17	.7	.43	.62	.7	.44	18.08	.7	.44	.54
.8	.45	.36	.8	.46	.81	.8	.46	.27	.8	.47	.72
.9	.48	.54	.9	.48	11.00	.9	.49	.45	.9	.49	.91
2.	0.50	.73	6.	1.51	.18	10.	2.51	.64	14.	3.52	26.10
.1	.53	.91	.1	.53	.37	.1	.54	.83	.1	.54	.28
.2	.55	4.10	.2	.56	.56	.2	.56	19.01	.2	.57	.47
.3	.58	.29	.3	.58	.74	.3	.59	.20	.3	.59	.66
.4	.60	.47	.4	.61	.93	.4	.61	.39	.4	.62	.84
.5	.63	.66	.5	.63	12.12	.5	.64	.57	.5	.64	27.03
.6	.65	.85	.6	.66	.30	.6	.66	.76	.6	.67	.21
.7	.68	5.03	.7	.68	.49	.7	.69	.94	.7	.69	.40
.8	.70	.22	.8	.71	.68	.8	.71	20.13	.8	.72	.59
.9	.73	.41	.9	.73	.86	.9	.74	.32	.9	.74	.77
3.	0.75	.59	7.	1.76	13.05	11.	2.76	.50	15.	3.77	.96
.1	.78	.78	.1	.78	.23	.1	.79	.69	.1	.79	28.15
.2	.80	.96	.2	.81	.42	.2	.81	.88	.2	.82	.33
.3	.83	6.15	.3	.83	.61	.3	.84	21.06	.3	.85	.52
.4	.85	.34	.4	.86	.79	.4	.86	.25	.4	.87	.71
.5	.88	.52	.5	.88	.98	.5	.89	.44	.5	.90	.89
.6	.90	.71	.6	.91	14.17	.6	.92	.62	.6	.92	29.08
.7	.93	.90	.7	.94	.35	.7	.94	.81	.7	.95	.26
.8	.95	7.08	.8	.96	.54	.8	.97	22.00	.8	.97	.45
.9	.98	.27	.9	.99	.73	.9	.99	.18	.9	4.00	.64

The Leaves of Pinion take up One-third of the Pitch.

Table VI.

Wheels of 60 Teeth.—Pinions of VIII Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.			4.	1.06	7.42	8.	2.13	14.85	12.	3.19	22.27
.1	0.03	0.19	.1	.09	.61	.1	.16	15.03	.1	.22	.46
.2	.05	.37	.2	.12	.79	.2	.18	.22	.2	.25	.64
.3	.08	.56	.3	.14	.98	.3	.21	.40	.3	.27	.83
.4	.11	.74	.4	.17	8.17	.4	.24	.59	.4	.30	23.01
.5	.13	.93	.5	.20	.35	.5	.26	.77	.5	.33	.20
.6	.16	1.11	.6	.22	.54	.6	.29	.96	.6	.35	.38
.7	.19	.30	.7	.25	.72	.7	.32	16.15	.7	.38	.57
.8	.21	.48	.8	.28	.91	.8	.34	.33	.8	.41	.75
.9	.24	.67	.9	.30	9.09	.9	.37	.52	.9	.43	.94
1.	0.27	.86	5.	1.33	.28	9.	2.39	.70	13.	3.46	24.13
.1	.29	2.04	.1	.36	.46	.1	.42	.89	.1	.49	.31
.2	.32	.23	.2	.38	.65	.2	.45	17.07	.2	.51	.50
.3	.35	.41	.3	.41	.84	.3	.47	.26	.3	.54	.68
.4	.37	.60	.4	.44	10.02	.4	.50	.44	.4	.57	.87
.5	.40	.78	.5	.46	.21	.5	.53	.63	.5	.59	25.05
.6	.43	.97	.6	.49	.39	.6	.55	.82	.6	.62	.24
.7	.45	3.15	.7	.52	.58	.7	.58	18.00	.7	.65	.42
.8	.48	.34	.8	.54	.76	.8	.61	.19	.8	.67	.61
.9	.51	.53	.9	.57	.95	.9	.63	.37	.9	.70	.80
2.	0.53	.71	6.	1.60	11.13	10.	2.66	.56	14.	3.73	.98
.1	.56	.90	.1	.62	.32	.1	.69	.74	.1	.75	26.17
.2	.59	4.08	.2	.65	.51	.2	.71	.93	.2	.79	.35
.3	.61	.27	.3	.68	.69	.3	.74	19.11	.3	.81	.54
.4	.64	.45	.4	.70	.88	.4	.77	.30	.4	.83	.72
.5	.67	.64	.5	.73	12.06	.5	.79	.49	.5	.86	.91
.6	.69	.83	.6	.76	.25	.6	.82	.67	.6	.88	27.09
.7	.72	5.01	.7	.78	.43	.7	.85	.86	.7	.91	.28
.8	.75	.20	.8	.81	.62	.8	.87	20.04	.8	.94	.47
.9	.77	.38	.9	.84	.81	.9	.90	.23	.9	.96	.65
3.	0.80	.57	7.	1.86	.99	11.	2.93	.41	15.	3.99	.84
.1	.82	.75	.1	.89	13.18	.1	.95	.60	.1	4.02	28.02
.2	.85	.94	.2	.92	.36	.2	.98	.79	.2	.04	.21
.3	.88	6.12	.3	.94	.55	.3	3.01	.97	.3	.07	.39
.4	.90	.31	.4	.97	.73	.4	.03	21.16	.4	.10	.58
.5	.93	.50	.5	2.00	.92	.5	.06	.34	.5	.12	.77
.6	.96	.68	.6	.02	14.10	.6	.09	.53	.6	.15	.95
.7	.98	.87	.7	.05	.29	.7	.11	.71	.7	.18	29.14
.8	1.01	7.05	.8	.08	.48	.8	.14	.90	.8	.20	.32
.9	.04	.24	.9	.10	66	.9	.17	22.08	.9	.23	.51

The Leaves of Pinions take up One-third of the Pitch.

Table VI

Wheels of 60 Teeth.—Pinions of VI Leaves.

Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.		Center Distance.	TOTAL DIAMETERS.	
	Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.		Pinion.	Wheel.
0.		-	4.	0.85	7.61	8.	1.71	15.22	12.	2.56	22.83
.1	0.02	0.19	.1	.88	.80	.1	.73	.41	.1	.58	23.02
.2	.04	.38	.2	.90	.99	.2	.75	.60	.2	.61	.21
.3	.06	.57	.3	.92	8.18	.3	.77	.79	.3	.63	.40
.4	.09	.76	.4	.94	.37	.4	.79	.98	.4	.65	.59
.5	.11	.95	.5	.96	.56	.5	.82	16.17	.5	.67	.78
.6	.13	1.14	.6	.98	.75	.6	.84	.36	.6	.69	.97
.7	.15	.33	.7	1.00	.94	.7	.86	.55	.7	.71	24.16
.8	.17	.52	.8	.03	9.13	.8	.88	.74	.8	.73	.35
.9	.19	.71	.9	.05	.32	.9	.90	.93	.9	.75	.54
1.	0.21	.90	5.	1.07	.51	9.	1.92	17.12	13.	2.78	.73
.1	.23	2.09	.1	.09	.70	.1	.94	.31	.1	.80	.92
.2	.26	.28	.2	.11	.89	.2	.96	.50	.2	.82	25.11
.3	.28	.47	.3	.13	10.08	.3	.99	.69	.3	.84	.30
.4	.30	.66	.4	.15	.27	.4	2.01	.88	.4	.86	.49
.5	.32	.85	.5	.17	.46	.5	.03	18.07	.5	.88	.68
.6	.34	3.04	.6	.20	.65	.6	.05	.26	.6	.90	.87
.7	.36	.23	.7	.22	.84	.7	.07	.45	.7	.93	26.07
.8	.38	.42	.8	.24	11.03	.8	.09	.65	.8	.95	.26
.9	.41	.61	.9	.26	.23	.9	.11	.84	.9	.97	.45
2.	0.43	.81	6.	1.28	.42	10.	2.14	19.03	14.	2.99	.64
.1	.45	4.00	.1	.30	.61	.1	.16	.22	.1	3.01	.83
.2	.47	.19	.2	.32	.80	.2	.18	.41	.2	.03	27.02
.3	.49	.38	.3	.35	.99	.3	.20	.60	.3	.05	.21
.4	.51	.57	.4	.37	12.18	.4	.22	.79	.4	.08	.40
.5	.53	.76	.5	.39	.37	.5	.24	.98	.5	.10	.59
.6	.56	.95	.6	.41	.56	.6	.26	20.17	.6	.12	.78
.7	.58	5.14	.7	.43	.75	.7	.29	.36	.7	.14	.97
.8	.60	.33	.8	.45	.94	.8	.31	.55	.8	.16	28.16
.9	.62	.52	.9	.47	13.13	.9	.33	.74	.9	.18	.35
3.	0.64	.71	7.	1.49	.32	11.	2.35	.93	15.	3.20	.54
.1	.66	.90	.1	.52	.51	.1	.37	21.12	.1	.22	.73
.2	.68	6.09	.2	.54	.70	.2	.39	.31	.2	.25	.92
.3	.70	.28	.3	.56	.89	.3	.41	.50	.3	.27	29.11
.4	.73	.47	.4	.58	14.08	.4	.43	.69	.4	.29	.30
.5	.75	.66	.5	.60	.27	.5	.46	.88	.5	.31	.49
.6	.77	.85	.6	.62	.46	.6	.48	22.07	.6	.33	.68
.7	.79	7.04	.7	.64	.65	.7	.50	.26	.7	.35	.87
.8	.81	.23	.8	.67	.84	.8	.52	.45	.8	.37	30.06
.9	.83	.42	.9	.69	15.03	.9	.54	.64	.9	.40	.25

The Leaves of Pinions take up One-third of the Pitch.

Table VIII.

Dial Wheels.—Pinions of X and XII Leaves.

WHEELS OF 40 AND 36 TEETH.

Center Distance.	TOTAL DIAMETERS.				Center Distance.	TOTAL DIAMETERS.			
	Intermediate Wheel.	Canon Pinion.	Hour Wheel.	Intermediate Pinion.		Intermediate Wheel.	Canon Pinion.	Hour Wheel.	Intermediate Pinion.
2.	3.29	1.24	3.46	1.02	6.	9.86	3.72	10.39	3.06
.1	.45	.30	.63	.07	.1	10.02	.78	.56	.11
.2	.61	.36	.81	.12	.2	.18	.84	.73	.16
.3	.78	.43	.98	.17	.3	.35	.90	.90	.21
.4	.94	.49	4.15	.22	.4	.51	.97	11.08	.27
.5	4.11	.55	.33	.28	.5	.68	4.03	.25	.32
.6	.27	.61	.50	.33	.6	.84	.09	.42	.37
.7	.44	.67	.67	.38	.7	11.01	.15	.60	.42
.8	.60	.74	.85	.43	.8	.17	.21	.77	.47
.9	.76	.80	5.02	.48	.9	.33	.28	.94	.52
3.	.93	1.86	.19	1.53	7.	.50	4.34	12.12	3.57
.1	5.09	.92	.37	.58	.1	.66	.40	.29	.62
.2	.26	.98	.54	.63	.2	.83	.46	.46	.67
.3	.42	2.05	.71	.68	.3	.99	.52	.64	.73
.4	.58	.11	.88	.73	.4	12.16	.59	.81	.78
.5	.75	.17	6.06	.79	.5	.32	.65	.98	.83
.6	.91	.23	.23	.84	.6	.48	.71	13.15	.88
.7	6.08	.29	.40	.89	.7	.64	.77	.33	.93
.8	.24	.36	.58	.94	.8	.81	.83	.50	.98
.9	.41	.42	.75	.99	.9	.98	.90	.67	4.03
4.	.57	2.48	.92	2.04	8.	13.14	4.96	.85	4.08
.1	.73	.54	7.10	.09	.1	.31	5.02	14.02	.13
.2	.90	.60	.27	.14	.2	.47	.08	.19	.18
.3	7.06	.67	.44	.19	.3	.63	.14	.37	.24
.4	.23	.73	.62	.25	.4	.80	.21	.54	.29
.5	.39	.79	.79	.30	.5	.96	.27	.71	.34
.6	.56	.85	.96	.35	.6	14.13	.33	.89	.39
.7	.72	.91	8.14	.40	.7	.29	.39	15.06	.44
.8	.88	.98	.31	.45	.8	.46	.45	.23	.49
.9	8.05	3.04	.48	.50	.9	.62	.52	.40	.54
5.	.21	3.10	.65	2.55	9.	.78	5.58	.58	4.59
.1	.38	.16	.83	.60	.1	.95	.64	.75	.64
.2	.54	.22	9.00	.65	.2	15.11	.70	.92	.69
.3	.71	.29	.17	.70	.3	.28	.76	16.10	.75
.4	.87	.35	.35	.76	.4	.44	.83	.27	.80
.5	9.03	.41	.52	.81	.5	.61	.89	.44	.85
.6	.20	.47	.69	.86	.6	.77	.95	.62	.90
.7	.36	.53	.87	.91	.7	.93	6.01	.79	.95
.8	.53	.60	10.04	.96	.8	16.10	.07	.96	5.00
.9	.69	.66	.21	3.01	.9	.26	.14	17.14	.05

The Leaves of Pinions take up Two-fifths of the Pitch.

Table IX.

Dial Wheels.—Pinions with VIII and X Leaves.

WHEELS OF 32 AND 30 TEETH.

Center Distance.	TOTAL DIAMETERS.				Center Distance.	TOTAL DIAMETERS.			
	Intermediate Wheel.	Canon Pinion.	Hour Wheel.	Intermediate Pinion.		Intermediate Wheel.	Canon Pinion.	Hour Wheel.	Intermediate Pinion.
2.	3.32	1.27	3.50	1.06	6.	9.96	3.82	10.50	3.17
.1	.49	.34	.68	.11	.1	10.13	.88	.68	.23
.2	.65	.40	.85	.16	.2	.29	.94	.85	.28
.3	.82	.46	4.03	.22	.3	.46	4.01	11.03	.33
.4	.98	.53	.20	.27	.4	.63	.07	.20	.39
.5	4.15	.59	.38	.32	.5	.79	.14	.38	.44
.6	.32	.65	.55	.38	.6	.96	.20	.55	.49
.7	.48	.72	.73	.43	.7	11.12	.26	.73	.55
.8	.65	.78	.90	.48	.8	.29	.33	.90	.60
.9	.81	.85	5.08	.53	.9	.46	.39	12.08	.65
3.	.98	1.91	.25	1.59	7.	.62	4.45	.25	3.70
.1	5.15	.97	.43	.64	.1	.79	.52	.43	.76
.2	.31	2.04	.60	.69	.2	.95	.58	.60	.81
.3	.48	.10	.78	.75	.3	12.12	.64	.78	.86
.4	.65	.16	.95	.80	.4	.29	.71	.95	.92
.5	.81	.23	6.13	.85	.5	.45	.77	13.13	.97
.6	.98	.29	.30	.90	.6	.62	.84	.30	4.02
.7	6.14	.35	.48	.96	.7	.78	.90	.48	.07
.8	.31	.42	.65	2.01	.8	.95	.96	.65	.13
.9	.48	.48	.83	.06	.9	13.12	5.03	.83	.18
4.	.64	2.55	7.00	2.12	8.	.28	5.09	14.00	4.23
.1	.81	.61	.18	.17	.1	.45	.15	.18	.29
.2	.97	.67	.35	.22	.2	.61	.22	.35	.34
.3	7.14	.74	.53	.28	.3	.78	.28	.53	.39
.4	.31	.80	.70	.33	.4	.95	.34	.70	.44
.5	.47	.86	.88	.38	.5	14.11	.41	.88	.50
.6	.64	.93	8.05	.43	.6	.28	.47	15.05	.55
.7	.80	.99	.23	.49	.7	.44	.54	.23	.60
.8	.97	3.05	.40	.54	.8	.61	.60	.40	.66
.9	8.14	.12	.58	.59	.9	.78	.66	.58	.71
5.	.30	3.18	.75	2.65	9.	.94	5.73	.75	4.76
.1	.47	.24	.93	.70	.1	15.11	.79	.93	.82
.2	.63	.31	9.10	.75	.2	.27	.85	16.10	.87
.3	.80	.37	.28	.80	.3	.44	.92	.28	.92
.4	.97	.44	.45	.86	.4	.61	.98	.45	.97
.5	9.13	.50	.63	.91	.5	.77	6.04	.63	5.03
.6	.30	.56	.80	.96	.6	.94	.11	.80	.08
.7	.46	.63	.98	3.02	.7	16.10	.17	.98	.13
.8	.63	.69	10.15	.07	.8	.27	.24	17.15	.19
.9	.80	.75	.33	.12	.9	.44	.30	.33	.24

The Leaves of Pinions take up Two-fifths of the Pitch.

TABLES FOR REGULATING WATCHES.

BY CHARLES T. HIGGINBOTHAM.

When a customer takes a watch into a jewelry store to be set and regulated it is customary for the watchmaker to endeavor to ascertain the length of time since the watch was set, and to divide the amount the watch differs from his regulator by the number of days it has run; then he moves the regulator for the amount of daily error. The necessary calculation is a very simple one when the error is in seconds, but is somewhat more complicated when it runs up into minutes. In this case the minutes must be reduced to seconds, the odd seconds added and the whole divided by the number of days the watch has run since previous setting.

Table 1 is designed to take the place of mental arithmetic in determining the daily rate of a watch. The row of figures, from 1 to 10, across the top, is for the number of minutes of variation. The row of figures, from 1 to 30, running down to the right is for the number of days the watch has run. Running down the column headed with the number of minutes variation and running to the right from the number of days, as indicated by the right hand column, the amount of daily variation will be indicated in the space where these two columns meet. Example: A watch has been running three weeks (21 days), and has varied in that time 7 minutes and 20 seconds. Running down the column headed 7, and to the right from the column marked 21, we find in the space where they meet 20 seconds. This is the daily variation for 7 minutes. Dividing the odd 20 seconds by 21 days we have nearly 1 second, which added to the 20 makes a total variation of 21 seconds. This table will not only prove a convenience for watchmakers, but it will give the customer a clearer idea of how his watch has been running.

The owner of a watch notices that his time piece differs a certain amount from true time, but he rarely realizes—especially if his watch has been running for some time—what a small daily amount it has really varied. Perhaps he says: "My watch is a minute fast." Now, if he has carried it a month the daily variation is only 2 seconds, and when brought to realize that fact he has a better opinion of his watch and of the watchmaker who is caring for it than he might have otherwise formed.

TABLE I

Duration of run, in days.	Figures followed by a dash are minutes; others are seconds. The top line is the variation expressed in minutes.									
1	1-	2-	3-	4-	5-	6-	7-	8-	9-	10-
2	30	1-	1-30	2-	2-30	3-	3-30	4-	4-30	5-
3	20	40	1-	1-20	1-40	2-	2-20	2-40	3-	3-20
4	15	30	45	1-	1-15	1-30	1-45	2-	2-15	2-30
5	12	24	36	48	1-	1-12	1-24	1-36	1-48	2-
6	10	20	30	40	50	1-	1-10	1-20	1-30	1-40
7	9	17	26	34	43	51	1-	1-9	1-17	1-26
8	7	15	22	30	37	45	52	1-	1-7	1-15
9	7	13	20	27	33	40	47	53	1-	1-7
10	6	12	18	24	30	36	42	48	54	1-
11	5	11	16	22	27	33	38	44	49	54
12	5	9	15	20	25	30	35	40	45	50
13	5	9	14	18	23	28	32	37	42	46
14	4	8	13	17	21	26	30	34	39	43
15	4	8	12	16	20	24	28	32	36	40
16	4	7	11	15	19	22	26	30	34	37
17	4	7	11	14	18	21	25	28	32	35
18	3	7	10	13	17	20	23	27	30	33
19	3	6	9	13	16	19	22	25	28	32
20	3	6	9	12	15	18	21	24	27	3
21	3	5	9	11	14	17	20	23	26	28
22	3	5	8	11	14	16	19	22	25	27
23	3	5	8	10	13	16	18	21	23	26
24	2	5	7	10	13	15	17	20	22	25
25	2	5	7	10	12	14	17	19	22	24
26	2	5	7	9	12	14	16	18	21	23
27	2	4	7	9	11	13	16	18	20	22
28	2	4	6	9	11	13	15	17	19	21
29	2	4	6	8	10	12	14	17	19	21
30	2	4	6	8	10	12	14	16	18	20

TO TIME A WATCH IN A FEW MINUTES.

It is sometimes found desirable to regulate a watch approximately in a brief space of time. The watchmaker may have fitted a new hairspring for a customer who must have his watch in—say an hour. The following method will enable a watchmaker to bring it within a minute a day, after which, if he has an hour in which to run it before delivering to his customer he can secure a close approximation.

TABLE II

16000 TRAIN		
Number of minutes counted	Variation in 24 hours	
	Minutes	Seconds
1	10	40
2	5	20
3	3	34
4	2	40
5	2	9
6	1	46
7	1	31
8	1	20
9	1	11
10	1	4

TABLE III

18000 TRAIN		
Number of minutes counted	Variation in 24 hours	
	Minutes	Seconds
1	9	36
2	4	48
3	3	12
4	2	24
5	1	55
6	1	36
7	1	22
8	1	12
9	1	4
10		58

Tables II and III give two sets of tables; one for 16,000 train and one for 18,000 train, which indicate the daily variation a single tick would make in any number of minutes from 1 to 10. The left hand columns designate the number of minutes counted; the columns to the right the amount the variation of one count would amount to in 24 hours.

The balance of an 18,000 train watch gives exactly 18,000 vibrations per hour—300 per minute. The balance of a so-called, 16,000 train watch gives 16,200 vibrations per hour—270 per minute. A little practice will enable a watchmaker to count these vibrations. I do not wish to be understood that a man can count 300 in a minute, but he can soon learn to distinguish between the vibrations and thus count alternate ones. Hold the watch to the ear and count alternate ticks of the escapement. The fingers of one hand provide a ready means of keeping track of the number. Thus: Open one hand. Commencing when the second hand of the clock is at 60; count ticks of the watch to 10; close one finger and without interrupting your count, again count 10; close another finger, and so on until the fingers and thumb have been closed; continue without interruption to open the fingers successively in the same manner, and then close them one by one as before. When all closed the series of 10's that you have counted will amount to 150, and inasmuch as you have counted alternate vibrations the whole amount will be 300, which would be the correct number for an 18,000 train. In case of a 16,000 train, the number of alternate vibrations would be 135.

TABLE OF VARIATIONS FOR 24 HOURS.

For the rapid regulation of watches and clocks, the following table will be found very useful, as it shows immediately the variation in 24 hours, based on a variation stated in seconds, and varying by quarter hours. For instance, if the clock or watch is out seven seconds in three hours, it will be out fifty-six seconds in twenty-four hours; or if it is out three seconds in two hours, it will be out thirty-six seconds in twenty-four. If it has gone out nine seconds in one hour, it will be out 216 seconds in a day. It will thus be seen that by noting the number of seconds as stated in the columns, and making the observations in hours and quarter hours, it is possible to bring the watch closely to time with considerable speed. Simply look in the first column, "Length of Observation," for the time which has elapsed since the watch was last regulated, then note its difference from the standard, one, three, six, eight or nine seconds, and take in the proper column of seconds the number corresponding to the time which has elapsed since the last observation. Thus, if the watch is out nine seconds and it is two hours and fifteen minutes since the last observation was made, it is varying 96 seconds per 24 hours.

Length of Observation.		Variation Stated in Seconds.									
		1	2	3	4	5	6	7	8	9	10
h.	m.										
1		24.0	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0	240.0
1	15	19.2	38.4	57.6	76.8	96.0	115.2	134.4	153.6	172.8	192.0
1	30	16.0	32.0	48.0	64.0	80.0	96.0	112.0	128.0	144.0	160.0
1	45	13.7	27.4	41.1	54.9	68.6	82.3	96.0	109.7	123.4	137.1
2		12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0
2	15	10.7	21.3	32.0	42.7	53.3	64.0	74.7	85.3	96.0	106.7
2	30	9.6	19.2	28.8	38.4	48.0	57.6	67.2	76.8	86.4	96.0
2	45	8.7	17.5	26.2	34.9	43.6	52.4	61.1	69.8	78.5	87.3
3		8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0
3	15	7.4	14.8	22.2	29.5	36.9	44.3	51.7	59.1	66.5	73.8
3	30	6.9	13.7	20.6	27.4	34.3	41.1	48.0	54.9	61.7	68.6
3	45	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6	64.0
4		6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
4	15	5.6	11.3	16.9	22.6	28.2	33.9	39.5	45.2	50.8	56.5
4	30	5.3	10.7	16.0	21.3	26.7	32.0	37.3	42.7	48.0	53.3
4	45	5.1	10.1	15.2	20.2	25.3	30.3	35.4	40.4	45.5	50.5
5		4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2	48.0
5	15	4.6	9.1	13.7	18.3	22.9	27.4	32.0	36.6	41.1	45.7
5	30	4.4	8.7	13.1	17.5	21.8	26.2	30.5	34.9	39.3	43.6
5	45	4.2	8.3	12.5	16.7	20.9	25.0	29.2	33.4	37.6	41.7
6		4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
6	30	3.7	7.4	11.1	14.8	18.5	22.2	25.8	29.5	33.2	36.9
7		3.4	6.9	10.3	13.7	17.1	20.6	24.0	27.4	30.9	34.3
7	30	3.2	6.4	9.6	12.8	16.0	19.2	22.4	23.6	28.8	32.0
8		3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
8	30	2.8	5.6	8.5	11.3	14.1	16.9	19.8	22.6	25.4	28.2
9		2.7	5.3	8.0	10.7	13.3	16.0	18.7	21.3	24.0	26.7
9	30	2.5	5.1	7 6	10.1	12.6	15.2	17.7	20.2	22.7	25.3
10		2.4	4.8	7.2	9.6	12 0	14.4	16.8	19.2	21.6	24.0
10	30	2.3	4.6	6.9	9.1	11.4	13.7	16.0	18.3	20.6	22.9
11		2.2	4.4	6.5	8.7	10.9	13.1	15.3	17.5	19.6	21.8
11	30	2.1	4.2	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.9
12		2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0

Total Diameters of Wheels and Pinions. The Distance Between Centers being Equal to 1.

Number of Teeth in Wheel.	Pinions of 12 leaves.		Pinions of 10 leaves.		Pinions of 8 leaves.		Pinions of 7 leaves.		Pinions of 6 leaves.	
	Diameter		Diameter		Diameter		Diameter		Diameter	
	of the wheel	of the pini'n	of the wheel	of the pini'n	of the wheel	of the pini'n	of the wheel	of the pini'n	of the wheel	of the pini'n
120	1.873	0.201								
116	1.869	0.207								
112	1.865	0.214								
110	1.863	0.217	1.890	0.185						
108	1.860	0.221	1.888	0.188						
106	1.858	0.225	1.886	0.191						
104	1.856	0.228	1.884	0.194						
100	1.850	0.237	1.880	0.201						
96	1.845	0.245	1.875	0.208	1.905	0.171				
92	1.839	0.255	1.870	0.217	1.902	0.179				
90	1.836	0.260	1.868	0.221	1.900	0.183				
88	1.832	0.265	1.865	0.225	1.898	0.188				
86	1.829	0.270	1.862	0.230	1.896	0.192				
84	1.825	0.276	1.859	0.235	1.894	0.196				
80	1.817	0.288	1.853	0.245	1.889	0.206				
78	1.813	0.294	1.849	0.251	1.887	0.210	1.907	0.189		
75	1.806	0.303	1.845	0.260	1.883	0.219	1.904	0.197		
72	1.800	0.316	1.838	0.269	1.878	0.226	1.900	0.204	1.918	0.181
70	1.795	0.323	1.834	0.276	1.875	0.232	1.895	0.209	1.916	0.186
68	1.789	0.331	1.830	0.283	1.871	0.238	1.894	0.215	1.913	0.191
66	1.784	0.340	1.825	0.291	1.868	0.244	1.892	0.220	1.910	0.196
64	1.778	0.349	1.820	0.299	1.864	0.251	1.889	0.227	1.908	0.201
62	1.771	0.358	1.815	0.307	1.860	0.258	1.885	0.233	1.906	0.207
60	1.765	0.368	1.810	0.316	1.856	0.266	1.880	0.240	1.903	0.214
58	1.758	0.379	1.804	0.325	1.851	0.274	1.877	0.248	1.899	0.220
52	1.734	0.414	1.784	0.356	1.836	0.301	1.865	0.272	1.890	0.243
50	1.726	0.428	1.777	0.368	1.830	0.312	1.858	0.281	1.889	0.252
48	1.716	0.442	1.769	0.381	1.824	0.323	1.850	0.292	1.880	0.261
44	1.695	0.473	1.751	0.409	1.810	0.348	1.836	0.315	1.870	0.282
40	1.671	0.510	1.731	0.442	1.797	0.377	1.821	0.340	1.859	0.306
36	1.642	0.552	1.707	0.480	1.774	0.411	1.804	0.372	1.845	0.336
32	1.610	0.603	1.677	0.526	1.750	0.452	1.785	0.409	1.828	0.371
30	1.593	0.632	1.660	0.552	1.737	0.479	1.771	0.431	1.818	0.391
28	1.571	0.660	1.644	0.579	1.722	0.499	1.738	0.453	1.807	0.404
24	1.516	0.729	1.600	0.645	1.683	0 560	1.730	0.512	1.785	0.469

TABLES FOR DIAL WORK.

FOR DIALS OF 12 HOURS.

Cannon pinion.	Minute Wheels.		Hour Wheel.
	Wheel.	Pinion.	
1 turn			$\frac{1}{12}$ turn
8	24	8	32
8	24	7	28
8	20	10	48
8	24	10	40
8	32	10	30
10	24	6	30
10	24	8	40
10	30	8	32
10	30	10	40
10	25	10	48
10	40	10	30
10	40	12	36
10	30	12	48
10	40	14	42
10	40	15	45
12	24	6	36
12	24	7	42
12	36	8	32
12	24	8	48
12	30	10	40
12	24	10	60
12	30	10	48
12	36	12	48
12	48	14	42
12	48	16	48
12	45	15	48
14	32	8	42
14	35	10	48
14	42	12	48
14	42	10	40
16	32	8	48
16	30	10	64
16	48	12	48
18	36	8	48
18	54	10	40
20	40	10	60
20	60	12	48
24	48	10	60

FOR DIALS OF 24 HOURS.

Cannon pinion.	Minute Wheels.		Hour Wheel.
	Wheel.	Pinion.	
1 turn			$\frac{1}{24}$ turn
8	32	7	42
8	32	8	48
10	40	7	42
10	40	8	48
10	40	10	60
10	48	10	50
12	48	10	60
14	56	10	60
14	56	12	72

FOR DIALS OF 10 HOURS.

Cannon pinion.	Wheel.	Pinion.	Hour Wheel.
1 turn			$\frac{1}{10}$ turn
8	20	7	28
8	20	8	32
10	25	8	32
10	20	8	40
10	20	10	50
10	25	10	40
12	24	10	50
12	25	10	48
12	32	12	45
14	40	12	42

FOR DIALS OF 20 HOURS.

Cannon pinion.	Wheel.	Pinion.	Hour Wheel.
1 turn			$\frac{1}{20}$ turn
8	32	7	35
8	32	8	40
10	40	8	40
10	40	10	50
12	48	10	50
12	40	10	60
12	48	12	60
14	56	12	60
14	56	14	70

The following table can be used to determine the total diameter of a pinion when the diameter and the number of teeth of the wheel are known:

Teeth of the Wheel.	Leaves of the Pinion.					
	6	7	8	10	12	14
32	196	225	253	309	364	421
36	177	202	227	278	329	380
40	161	184	207	253	299	345
44	146	167	188	230	272	314
45	144	164	185	226	267	309
48	135	155	174	213	252	291
50	132	150	169	206	243	281
54	121	139	157	192	228	263
55	119	136	153	187	221	256
56	118	135	152	185	219	254
60	111	127	143	174	206	238
64	104	119	134	164	194	225
65	102	116	131	160	189	218
68	96	110	124	152	181	209
70	95	109	123	151	179	206
72	93	106	119	145	172	199
74	91	103	116	142	168	194
75	89	102	115	141	167	192
76	88	101	113	138	163	189
77	87	100	112	137	162	187
78	86	98	111	136	160	184
80	84	96	108	132	156	180
84	80	92	103	126	149	172
88	78	88	99	120	142	164
90	75	86	97	116	138	160
96	71	81	91	111	131	151
100	68	79	87	107	126	145
108	63	72	81	99	117	135
112	60	69	77	95	112	129
120	57	65	73	89	125	122

To use the table, take in the column under the proper number of "leaves of the pinion" that number which corresponds to that in the column of "Teeth of the Wheel." Multiply this number so found by the diameter of the wheel, divide by 1,000 and you will have the total diameter of the pinion in millimeters.

For example, to find the total diameter of a pinion of ten leaves to engage with a wheel of 76 teeth, having 23 mm. diameter. The number corresponding to 76 teeth in the column of pinions of ten leaves is 138. Multiplying 138 by 23 (the diameter of the wheel) and dividing by 1,000, the result is 3.174 mm., which is the total diameter of the pinion.

The following table is a complement of the first, and is used to determine the total diameter of a wheel when the diameter and number of leaves of the pinion are known.

Teeth of the Wheel.	Leaves of the Pinion.					
	6	7	8	10	12	14
32	51	44	39	32	27	24
36	57	49	44	36	30	26
40	62	54	48	39	33	29
44	68	60	53	43	36	32
45	69	61	54	44	37	33
48	74	65	57	46	40	34
50	76	67	59	49	41	36
54	83	72	64	52	44	38
55	84	73	65	53	45	39
56	86	74	66	54	46	40
60	90	79	70	57	49	42
64	96	84	75	61	52	44
65	98	85	76	63	53	46
68	104	91	80	66	54	48
70	105	92	82	67	55	49
72	107	94	84	68	58	50
74	110	97	86	70	59	51
75	112	98	87	71	60	52
76	113	100	88	72	61	53
77	114	101	89	73	62	54
78	116	102	90	74	63	55
80	118	104	93	76	64	56
84	125	108	97	79	67	58
88	128	113	101	83	70	61
90	133	116	103	85	72	63
96	141	123	110	90	76	66
100	152	126	115	93	79	68
108	159	138	123	101	85	74
112	166	145	130	105	89	78
120	175	154	137	112	95	82

Table Showing the Length of a Simple Pendulum

That performs in one hour any given number of oscillations, from 1 to 20,000, and the variation in this length that will occasion a difference of 1 minute in 24 hours.

Calculated by E. Gourdin.

Number of Oscillations per Hour.	Length in Millimeters.	Variation in Length for One Minute in 24 Hours in Millimeters.	Number of Oscillations per Hour.	Length in Millimeters.	Variation in Length for One Minute in 24 Hours in Millimeters.	Number of Oscillations per Hour.	Length in Millimeters.	Variation in Length for One Minute in 24 Hours in Millimeters.
20,000	32.2	0.04	13,200	73.9	0.10	8,200	191.5	0.26
19,000	35.7	0.05	13,100	75.1	0.10	8,100	196.3	0.27
18,000	39.8	0.05	13,000	76.2	0.10	8,000	201.3	0.27
17,900	40.2	0.06	12,900	77.4	0.11	7,900	206.4	0.28
17,800	40.7	0.06	12,800	78.6	0.11	7,800	211.7	0.29
17,700	41.1	0.06	12,700	79.9	0.11	7,700	217.2	0.30
17,600	41.6	0.06	12,600	81.1	0.11	7,600	223.0	0.30
17,500	42.1	0.06	12,500	82.4	0.11	7,500	229.0	0.31
17,400	42.4	0.06	12,400	83.8	0.11	7,400	235.2	0.32
17,300	43.0	0.06	12,300	85.1	0.12	7,300	241.7	0.33
17,200	43.5	0.06	12,200	86.5	0.12	7,200	248.5	0.34
17,100	44.0	0.06	12,100	88.0	0.12	7,100	255.7	0.35
17,000	44.6	0.06	12,000	89.5	0.12	7,000	262.9	0.36
16,900	45.1	0.06	11,900	91.0	0.12	6,900	270.5	0.37
16,800	45.7	0.06	11,800	92.5	0.13	6,800	278.6	0.38
16,700	46.3	0.06	11,700	94.1	0.13	6,700	286.9	0.39
16,600	46.7	0.07	11,600	95.7	0.13	6,600	295.7	0.40
16,500	47.3	0.07	11,500	97.4	0.13	6,500	304.9	0.41
16,400	47.9	0.07	11,400	99.1	0.13	6,400	314.5	0.43
16,300	48.5	0.07	11,300	100.9	0.14	6,300	324.5	0.44
16,200	49.1	0.07	11,200	102.7	0.14	6,200	335.1	0.46
16,100	49.7	0.07	11,100	104.5	0.14	6,100	346.2	0.47
16,000	50.0	0.07	11,000	106.5	0.14	6,000	357.8	0.48
15,900	51.0	0.07	10,900	108.4	0.15	5,900	370.0	0.50
15,800	51.6	0.07	10,800	110.5	0.15	5,800	382.9	0.52
15,700	52.3	0.07	10,700	112.5	0.15	5,700	396.4	0.54
15,600	52.9	0.07	10,600	114.6	0.16	5,600	410.7	0.56
15,500	53.6	0.07	10,500	116.8	0.16	5,500	425.8	0.58
15,400	54.3	0.08	10,400	119.1	0.16	5,400	440.1	0.60
15,300	55.0	0.08	11,300	111.4	0.17	5,300	458.5	0.62
15,200	55.7	0.08	10,200	123.8	0.17	5,200	476.3	0.65
15,100	56.5	0.08	10,100	126.3	0.17	5,100	495.2	0.67
15,000	57.3	0.08	10,000	128.8	0.18	5,000	515.2	0.70
14,900	58.0	0.08	9,900	131.4	0.18	4,900	536.5	0.73
14,800	58.8	0.08	9,800	134.1	0.18	4,800	559.1	0.76
14,700	59.6	0.08	9,700	136.9	0.19	4,700	583.1	0.79
14,600	60.4	0.08	9,600	139.8	0.19	4,600	608.7	0.83
14,500	61.3	0.08	9,500	142.7	0.19	4,500	636.1	0.86
14,400	62.1	0.09	9,400	145.8	0.20	4,400	665.3	0.90
14,300	63.0	0.09	9,300	148.9	0.20	4,300	696.7	0.95
14,200	63.9	0.09	9,200	152.2	0.21	4,200	730.2	0.99
14,100	64.8	0.09	9,100	155.5	0.21	4,100	766.2	1.04
14,000	65.7	0.09	9,000	159.0	0.22	4,000	805.0	1.09
13,900	66.7	0.09	8,900	162.6	0.22	3,950	825.5	1.12
13,800	67.6	0.09	8,800	166.3	0.23	3,900	846.8	1.15
13,700	68.6	0.09	8,700	170.2	0.23	3,850	869.0	1.18
13,600	69.6	0.09	8,600	173.7	0.24	3,800	892.0	1.21
13,500	70.7	0.09	8,500	178.3	0.24	3,750	915.9	1.25
13,400	71.7	0.10	8,400	182.5	0.25	3,700	940.1	1.28
13,300	72.8	0.10	8,300	187.0	0.25	3,650	966.8	1.31

Table of the Length of a Simple Pendulum,

(CONTINUED.)

Number of Oscillations per Hour.	Length in Meters.	To Produce in 24 Hours 1 Minute.		Number of Oscillations per Hour.	Length in Meters.	To Produce in 24 Hours 1 Minute.	
		Loss, Lengthen by Millimeters.	Gain, Shorten by Millimeters.			Loss, Lengthen by Meters.	Gain, Shorten by Meters.
3 600	0.9939	1.38	1.32	1,900	3.568	0.0050	0.0048
3,550	1.0221	1 42	1.36	1,800	3 975	0 0055	0.0053
3,500	1.0515	1.46	1.40	1,700	4.457	0.0062	0.0059
3,450	1.0822	1.50	1 44	1,600	5.031	0.0070	0.0067
3,400	1.1143	1.55	1.48	1,500	5 725	0.0080	0.0076
3,350	1.1477	1.60	1.53	1,400	6.572	0.0091	0.0087
3,300	1.1828	1.64	1.57	1,300	7.622	0.0106	0.0101
3,250	1.2194	1.69	1.62	1,200	8.945	0 0124	0.0119
3,200	1.2578	1 75	1.67	1,100	10 645	0.0148	0.0142
3,150	1.2981	1.80	1.73	1,000	12.880	0.0179	0.0171
3,100	1.3403	1.86	1 78	900	15 902	0.0221	0.0211
3,050	1.3846	1.93	1.84	800	20.126	0 0280	0.0268
3,000	1.4312	1.99	1 90	700	26.287	0 0365	0.0350
2,900	1.5316	2.13	2.04	600	35 779	0.0497	0.0476
2,800	1.6429	2.28	2 18	500	51 521	0.0716	0.0685
2,700	1.7669	2.46	2 35	400	80 502	0.1119	0.1071
2,600	1.9054	2.65	2 53	300	143.115	0.1989	0.1903
2,500	2.0609	2 87	2.74	200	322 008	0.4476	0.4282
2,400	2.2362	3.11	2 97	100	1,288.034	1.7904	1.7131
2,300	2.4349	3.38	3 24	60	3,577.871	4 9732	4.7586
2,200	2 6612	3.70	3.54	50	5,152.135	7.1613	6.8521
2,100	2.9207	4.06	3 88	1	12,880,337.930	17,903.6700	17,130.8500
2,000	3 2201	4.48	4.28				

Dimensions of Chucks for Watchmakers' Lathes.

NAME OF CHUCK	Dia. of Head	Dia. of Body	Dia. of Thread	Pitch of Thread	Angle of Head	Total Length less curve	Largest Hole clear Through	Largest Hole in Front
Dale No. 1	.500	.335	.295	40 Eng.	15°	1.437	m.m. 5.8	m.m. 6.5
Dale A	.500	.335	.325	40 "	15°	1.437	" 6.5	" 6.5
Dale No. 2	.625	.450	.395	30 "	15°	1.812	" 8.	" 10.
Dale B	.625	.450	.435	30 "	15°	1.812	" 10.	" 10.
Dale No. 3	.890	.650	.560	24 "	15°	2.250	" 10.	" 14.
Dale C	.890	.650	.635	24 "	15°	2.250	" 14.	" 14.
Dale No. 4	1.125	.825	.700	20 "	15°	3.125	" 14.	" 18.
Dale D	1.125	.825	.810	20 "	15°	3.125	" 18.	" 18.
Hopkins No. 1	.435	.2285	.187	48 "	25°	1.031	" 2.8	" 4.2
Hopkins No. 2	.530	.325	.250	36 "	25°	1.187	" 4.4	" 6.5
Hopkins No. 3	.460	.260	.220	40 "	25°	1. —	" 3.8	" 5.
Hopkins No. 3 : 4	.530	.3255	.285	40 "	25°	1.360	" 5.2	" 6.5
Hopkins No. 4	.850	.605	.545	24 "	20°	2.437	" 10.	" 13.
Rivett No. 1	.500	.300	.265	40 "	20°	1.250	" 4.8	" 6.
Rivett No. 3	.825	.590	.525	26 Eng.	20°	2.125	m.m. 10.	m.m. 13.
Rivett No. 4	1.025	.750	.665	20 Eng.	20°	2.750	" 13.	" 17.
Stehmens J. & S. No. 1.	.650	.370	.320	34 "	20°	1.812	" 6.5	" 7.
Stehmens J. & S. No. 2.	.650	.380	.325	32 "	20°	1.812	" 6.5	" 7.
Moseley No. 1	.430	.240	.208	48 "	25°	1.250	" 3.8	" 4.7
Moseley No. 1 x 2	.500	.3135	.270	40 "	20°	1.250	" 5.	" 6.5
Moseley No. 2	.500	.314	.270	40 "	Condl	1.562	" 5.	" 6.5
Moseley No. 3 Conoidal.	.600	.400	.350	36 "	Condl	1.750	" 6.5	" 7.
Moseley No. 3, 15 degree	.625	.400	.350	36 "	15°	1.844	" 6.5	" 7.
Moseley " 4, Bench Lathe	.875	.590	.490	25 "	20°	2.312	" 9.5	" 13.
Whitcomb No. 1	.375	.1965	.168	55 Met.	20°	.936	" 2.5	" 3.6
Whitcomb No. 1, Watch Factory	.435	.236	.182	63 "	20°	1.093	" 3.3	" 4.4
Whitcomb No. 1½	.435	.255	.220	63 "	20°	1.140	" 3.8	" 5.
Webster Whitcomb	.500	.3147	.270	63 "	20°	1.312	" 5.	" 6.5
Whitcomb No. 2 Watch Factory	.560	.355	.278	.71 Met.	20°	1.500	m.m. 5.5	m.m. 7.
Whitcomb No. 2½ "	.750	.4725	.370	.85 "	20°	1.531	" 7.	" 9.
Whitcomb No. 3	.865	.590	.508	1. "	20°	2.125	" 10.	" 13.
Whitcomb No. 3 Large Thread	.865	.590	.587	1.25 "	15°	2.187	" 13.	" 13.
Whitcomb No. 4	1.080	.747	.665	1.25 "	15°	2.875	" 13.	" 17.
Whitcomb No. 4 Large Thread	1.080	.747	.745	1.63 "	15°	2.875	" 17.	" 17.
Triumph or Elgin	.500	.275	.250	48 Eng	25°	1.218	" 4.4	" 5.
Mansfield	.500	.300	.270	40 "	20°	1.250	" 4.8	" 6.
Hinkley	.475	.280	.250	40 "	20°	1.312	" 4.2	" 5.5
Stark No. 1	.435	.1875	.165	48 "	22½°	1.108	" 2.3	" 3.5
Stark No. 2	.500	.2205	.185	48 "	22½°	1.250	" 2.8	" 4.2
Stark No. 3 Watchmaker,	.500	.245	.185	48 "	20°	1.218	" 2.8	" 4.5
Stark E	.500	.300	.270	40 "	20°	1.250	" 4.8	" 6.
Stark D	.625	.355	.305	40 "	20°	1.750	" 6.5	" 7.
Stark No. 3 Bench Lathe	.875	.590	.508	26 Eng.	20°	2.125	m.m. 10.	m.m. 13.
Stark No. 4 " "	1.430	.998	.990	20 "	15°	2.312	" 25.	" 25.
Geneva	.425	.235	.200	71 Met.	20°	1.156	" 3.5	" 4.7
Kearney	.500	.300	.265	44 Eng.	25°	1.531	" 4.8	" 6.
Tarrant Bench Lathe	.800	.550	.475	32 "	25°	2.500	" 9.	" 12.
Springfield No. 4	.800	.500	.425	32 "	25°	1.875	" 8.	" 11.
Olin Watchmakers	.500	.311	.270	40 "	20°	1.250	" 5.	" 6.
Pratt & Whitney	.850	.600	.500	24 "	20°	2.063	" 10.	" 13.
Automatic Special	.475	.281	.248	32 "	20°	1.500	" 4.	" 5.5
Ballou & Whitcomb	.475	.3147	.270	63 Met.	15°	1.937	" 5.	" 6.5
Lapper Special	.760	.495	.430	40 Eng.	20°	2.125	" 8.	" 11.
Star Special	.600	.320	.260	40 "	25°	1.563	" 4.8	" 6.5
Ide Bench Lathe	.800	.500	.425	32 "	20°	2.	" 8.	" 11.
Special Tool makers	1.650	1.125	1.125	18 "	12°	7.	" 22.22	" 25.4

Inches expressed in Millimeters and French Lines.			Millimeters expressed in Inches and French Lines.			French Lines expressed in Inches and Millimeters.		
Inches.	Equal to		Millimeters.	Equal to		French Lines.	Equal to	
	Millimeters	French Lines.		Inches.	French Lines.		Inches.	Millimeters
1	25.39954	11.25951	1	0.0393708	0.44329	1	0.088414	2.25583
2	50.79908	22.51903	2	0.0787416	0.88659	2	0.177628	4.51166
3	76.19862	33.77854	3	0.1181124	1.32989	3	0.266441	6.76749
4	101.59816	45.03806	4	0.1574832	1.77318	4	0.355255	9.02332
5	126.99771	56.29757	5	0.1968539	2.21648	5	0.444069	11.27915
6	152.39725	67.55709	6	0.2362247	2.65978	6	0.532883	13.53497
7	177.79679	78 81660	7	0.2755955	3.10307	7	0.621697	15.79080
8	203 19633	90.07612	8	0.3149664	3.54637	8	0.710510	18.04663
9	228.59587	101.33563	9	0.3543371	3 98966	9	0.799324	20.30246
10	253.99541	112.59515	10	0.3937079	4.43296	10	0.888138	22.55829
						11	0.976952	24.81412
						12	1.065766	27.06995

INSTALLING WIRELESS TIME.

The American Jeweler has received so many requests for practical information in regard to putting in wireless time apparatus, that we have had prepared a series of articles on this subject, which will get down to actual facts as plainly as possible, while remaining sufficiently general in their scope to satisfactorily cover the varying conditions to be met with by the numerous retailers who are trying to fit general assertions to their specific conditions before spending any money.

The average retailer knows that time signals are being distributed daily from Washington. He knows that he can buy receiving sets that will operate satisfactorily after he has installed them properly; and he also knows that he must do a large part of the work himself, or have it done for him. Here is where he is at sea.

"Can I buy it, or must I make a part of it? Where do I get it? Just what have I got to buy? What is it called, and how much will it cost? How much do I need, and what shall I order? What shall I do with it after I have bought it?"

These are all questions which the retail jeweler would like to have answered specifically; and that is what we shall try to do, using material which is already in the market, and can be bought and put together with little expense.

No license is required when only a receiving set is used.

The first necessity of a wireless station is the stretch of wires, outside the building, which is called an antenna or aerial. The best results are secured from those antennæ which are highest and have the most wire in them, provided that they are well insulated, but height in such cases counts for more than length of wire. Antennæ vary in length from 50 to 600 feet, and in height from 30 to 650 feet; these extreme lengths and heights are only possible in government installations and by commercial companies on the roofs of big city skyscrapers; therefore it will be seen that there is a wide latitude in which the retailer may accommodate himself to circumstances. Also perfection of electrical joints, insulation and ground count for more than height and length of wire, so that no attempt should be made to economize on solder or insulators.

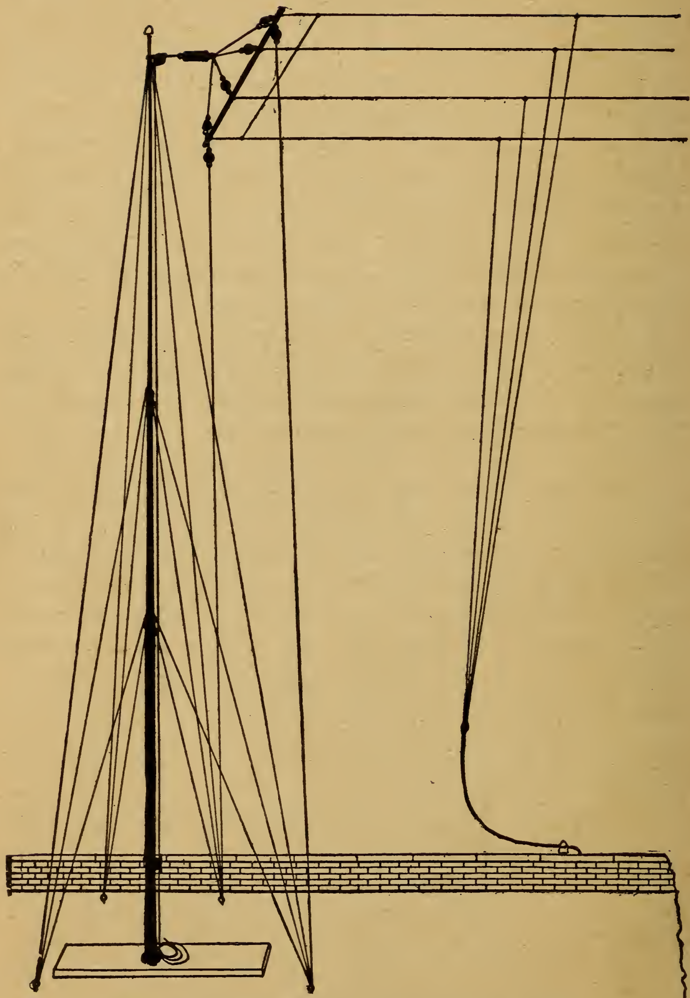
Insurance regulations require that all antennæ should have the lead-in wire conducted down the outside of the building to a 100-ampere switch, with a copper wire not less than No. 4 B. & S. gauge running from this switch to a ground outside of the building. The wires enter the building and lead to the instruments from this switch. This switch is called the lightning switch and must be kept closed to the ground position all the time when the instruments are not in use. Any construction should be submitted to the insurance inspectors and approved by them before work is started as changes are readily made before the goods are ordered, and delay and duplicate freight or express charges avoided, together with much unnecessary correspondence. Besides this there is the certainty that insurance rates will not be increased on the building and its contents, after erection, if plans are approved and the job inspected in accordance with the plans.

This insurance regulation is merely a precaution and should not be taken as an indication of added risk during storms, as a suitably constructed and well grounded antenna is a protection rather than a danger.

Antennae are of two kinds—flat and umbrella. Flat antennæ are arranged in a gridiron of parallel wires. For sending the size, direction and height are all of importance, as they have considerable to do with the natural wave length, as it is difficult to send clearly while using a wave length which is shorter than the natural period of the antenna. The natural wave length is determined from a number of factors, one of which is the length of one of the wires of the antenna plus the length of the vertical wire leading to the instruments.

For receiving, however, the length and direction are not so important, as short waves may be received on any antenna, and if the antenna and tuning coil are too short for a given length of wave, a greater length may be obtained by inserting a coil of wire of suitable length between the antenna and tuning coil. This is called a "loading coil," and may be purchased for a few dollars.

Antennæ need not be of the same height at both ends. Thus advantage may be taken of natural objects to cheaply secure a greater height than would be possible with poles.



Flat top aerial, gas pipe mast and down wires.

For instance, one end of the antenna may be fastened to a cupola, or chimney of a building, eight stories high, and the other to one three stories high, while the jeweler occupies a two-story building between them. In such cases the effective height is that of a point midway on the inclined wire. Thus, if one end is twenty feet high and the other end is 120 feet, then 120—20=100÷2=50 feet, effective height of the aerial; that is, the effect is that of a flat antenna 50 feet high, plus the 20 feet of the down wires, or 70 feet in all. That is, we simply split the irregular figure into a rectangle and a triangle and take half the height of the triangle plus the height of the rectangle.

Low and short antennae (up to 30 feet high) may be supported on wooden poles, as the weight of ice covered wire is not too great in such instances; but for longer wire and greater heights gas pipe is better and cheaper, especially if a permanent installation is being considered.

A Flat Antenna is carried on poles or other supports —either of wood or iron—preferably galvanized gas or steam pipe (which comes in mill lengths of 17 to 21 feet), with the upper length of 1¼ inch, increasing in diameter downward; joints made by screwing on reducing couplings.

Foot.—A floor flange is screwed to the bottom of the pipe and to a 3x8 inch oak plank, long enough to reach across several roof sleepers when spiked to the roof. Both the plank and pipe should be painted with asphaltum and pulley and all guy wires attached before erection. Thread the antenna cable in the pulley and attach both ends to the foot of the pole before erecting. Don't forget this, or you may have to take down the pole again.

Top.—The tube is capped with an ordinary glass telegraph insulator on a wooden peg driven in the top of the upper length of pipe.

Guy Wires.—No. 14 steel, galvanized, with four wires from the top and each joint, running to one-half inch eye bolts or screws in the roof or wall. If the wall is brick or stone, use expansion bolts. Guys to be fastened at their upper ends by twisting around the pipe above a pin through the pole to prevent slipping. Guys to be run at 30 to 45 degrees from the pole, and adjusted by means of a lineman's wire stretcher, or "grip" when fastening to eye bolts. This stretcher can be borrowed, or if not, then perfect adjustment can be secured by using turnbuckles in each guy.

Pulleys.—One Cutter's sleeve pulley, with clamp to fit top of pipe. (One for top of each pole.)

Cable.—Galvanized wire clothesline makes a good cable to raise and hold up the antenna. It must be long enough to run from the foot to the pulley and back to the spreader on the ground or roof.

The above construction, if heavy-weight pipe is used and the work is properly done, is capable of resisting a wind pressure of fifty pounds per foot of surface, while a seventy-five mile wind exerts a pressure of eleven pounds per foot, so that there is an ample margin of safety. To find the length of wire, make a drawing one inch to the foot and measure the lengths of the guys with a foot rule.

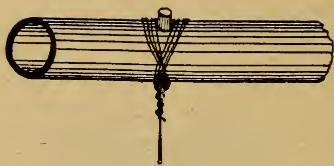
Wire.—A cable composed of seven strands of No. 22 phosphor bronze wire makes the best antenna wire and is generally sold under the name of "bronze antenna wire." It is weather-proof, stronger and more elastic, and consequently more durable than plain wire. Hence it is better for a permanent installation. Seven-strand No. 22 tinned copper cable is good for stretches up to 150 feet and is cheaper than bronze. Hard drawn bare copper telephone wire may be used, but it is weaker than bronze cable and larger sizes should be employed to stand the strain due to sleet storms, ice, etc. No. 12 is a good size, but the gauge will vary according to the length, as longer strands will have a greater strain when covered with sleet, etc., and will need greater strength. Smaller than No. 16, or its equivalent, will break unless used on very short antennæ, and coarser than No. 12 merely adds weight and expense.

To find the quantity, get the distance between the antenna poles, or other supports, and then decide how many strands you will use. This should be an even number, generally four or six, although they vary all the way from one to ten. It is useless to have the strands nearer together than one-fiftieth of their length. It does no harm, but it is a waste of wire. The distance between spreaders, plus 2 feet for sag, plus the length of a down wire, multiplied by the number of strands is the amount needed.

Galvanized steel and plain telegraph wires have also been used, but are not recommended on account of their induction. Do not use aluminum wire, because the joints will corrode in time and introduce resistance, and finally insulation in the electrical circuit, thus compelling you to discard it ultimately.

Spreaders may be of oak, hickory, or other hard wood, as they can be smaller and expose less surface to the wind than would be necessary if softer and weaker wood were used.

Gas or steam pipe makes good spreaders, and if the joints of the wire are soldered to the pipe, the spreaders take the place of the cross wires at each end of the antenna. Pipes should be capped at each end with an eye in the cap to take No. 14 galvanized guy wire. These are run from each end of the pipe to an eye bolt, and are necessary to prevent the antenna from overturning and twisting up in the wind. The caps may be purchased with the pipe, or plain caps may be drilled in the center and heavy screw eyes rivetted in.



The gas pipe should be drilled where the antenna wires will come, and a steel pin put through to prevent the wire from sliding out of position. The wire is then wrapped several times about the pipe so as to include the pin in its turns; the end securely fastened by twisting; the joint soldered to the pipe and taped. This makes a permanent electrical joint. Use solder with a low melting point, and rosin flux so as not to weaken the wire by heating or acid.

A large size wire nail makes a good pin. It should be a trifle larger than the drilled hole and roughly tapered with a file, so that it may be driven in and held in the hole by friction, or a drop of soft solder; then cut off, leaving about a quarter of an inch projecting on each side of the pipe.

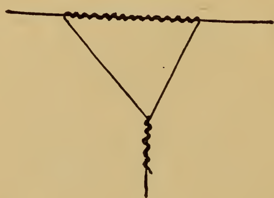
Insulation.—If the antenna is small, so that the stretchers are short, No. 14 galvanized steel bridle wires may be attached to the spreaders, and all run to one eye of an electrose strain insulator—which should be at least 10-inch—with the other eye of the insulator attached to a wire cable running through the pulley at the top of the mast, and down to a cleat or eye bolt. This reduces the number of insulators to one 10-inch at the end of the antenna, and one 2¾-inch ball insulator in the guy wire at each end of the spreader, or six in all.

If the antenna is large, so that the spreaders are longer and the weight is considerable when covered with ice, it is better to use 2¾-inch ball insulators in each bridle wire, so as to distribute the strain, with a 10-inch electrose strain insulator between the bridle and cable.

Natural Supports.—Chimneys on taller adjacent buildings or other supports may be used instead of masts, so long as care is taken to have the wires properly insulated. In such cases greater heights and a larger number of strands in the antenna may be obtained by using longer spreaders, at a much less total cost.

Down Wires.—Wires twisted, soldered and taped to each strand of the antenna, and all running to a common center, are used to conduct the electrical impulses. For receiving, the point at which they join the strands does not make much difference, and they are generally placed where they will be the most convenient to attach to the lead-in wires running down the outside of the building to the instruments. If they are attached midway, it is called a T-shaped antenna; if at one end the antenna is said to be an L-shape. If the height is great, these down wires add something to the effective length of wire in the antenna; otherwise their effect is negligible, except as conductors of the waves gathered by the antenna. They are of the same wire as is used in the antenna. We show herewith the style of joint which is preferred in attaching down wires to the antenna. It will stand twisting and swaying without breaking.

Down wires should be run to a common center, twisted about and soldered to a copper, double covered rubber, or okonite, conductor wire and the joint taped. This wire is then supported on glass telegraph insulators at the bends and run over the roof coping, and down the outside of the building to the lightning switch. The fewer bends in the conductor wire, the better; and they should not be at an acute angle. To get the size of this wire get from a wire table, or an electrician, the number of circular mils in each strand of the antenna wire you have selected; multiply by the number of strands and then get the nearest size of conductor wire which will take that number of mils. This avoids choking of the current.



Say we are using six strands of bronze aerial wire, each strand having seven No. 22 wires.

No. 22 has 642.6 circular mils. Then 642.6x7x6 = 26,989.

No. 6 wire has 26,250 circular mils. Hence we will take No. 6 wire for our down wire in this case. Four strands would call for No. 8 and so on. In measuring for length, leave room for swaying in the wind without breaking or chafing the insulation off the wire.

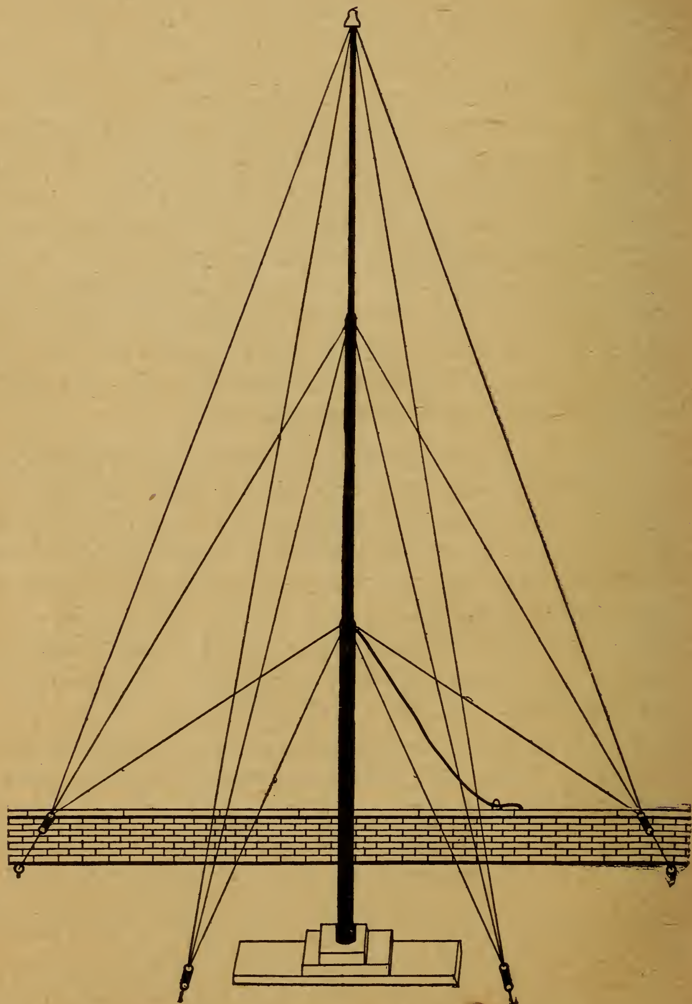
Direction.—For receiving, the direction in which the antenna is run makes little difference. However, care should be taken to avoid exactly paralleling power lines, lighting and street car mains, etc., if they are close enough to cause trouble from induction, as they may cause noises in the telephones which are sometimes difficult to tune out.

Occasionally there may be found jewelers who cannot easily secure two elevated points from which to hang an aerial, and while the umbrella type is not as generally satisfactory as the flat top, still no jeweler need despair on this account. In the beginning, all aerials were of the umbrella type, and the fact that they have gone so largely into disuse is chiefly owing to the circumstance that two points can generally be secured which are already in position, so that practically the whole of the cost is for wire and erection, nothing being paid for masts. Then, too, there is a condenser effect with the flat top aerial which does not exist with the vertical type. The wire in the flat top forms one side of the condenser, and the earth forms the other, so that its electrical capacity is greater than with the same amount of wire used in the umbrella type.

In 2,500 meter wave lengths, such as we are considering, the capacity is important, and in residence districts, or where for other reasons one cannot pass over the property of his neighbor, or attach anything to it, practically all that is left is to go straight up into the air on his own property. When this is done, the umbrella is the cheapest form of aerial which can be erected with one mast, and its lack of capacity or its excess of capacity can be corrected by putting a variable condenser between the aerial and the primary coil, or between the primary and the ground. In the majority of cases it will make no difference which is done.

While no one can tell exactly what he is going to get in an aerial until it is erected and tested, still one feels authorized in going ahead when he knows that he can correct his installation afterwards in such a simple and easy manner as by the manipulation of a variable condenser.

We show a sketch of an aerial of the umbrella type, and would merely add that the umbrella differs from the flat top in that all the braces and mast should be connected together electrically, with the mast insulated in the step at the



Umbrella aerial, gas pipe mast and lead in wire.

bottom, and all braces or guys come together to a common insulator at the outer points, where they are secured to the building.

One of these aerials is giving good results on the roof of a two-story building in the city of Chicago, in a residence district. The top of the mast is eighty-nine feet from the ground. One thousand feet of wire is used for the double purpose of aerial wire and guys for the mast. The foot of the mast is insulated by putting about three inches of cement in the bottom of an ordinary crock, and after it had hardened turning the crock upside down on a pine post, with a wooden cage or step for the foot of the mast to keep it from sliding off the bottom of the crock. It will be seen that this forms a stoneware, petticoated insulator.

Others have been insulated by boiling pine blocks in asphaltum until they were thoroughly impregnated, and using this asphaltum block to step the mast on. Still others have had the mast step on a cement block which had been thoroughly dried out, and the hollow step filled with asphaltum until thoroughly saturated. The important thing is to secure insulation and to avoid a rigid fastening at the foot of the mast, as it must be allowed to sway a little to prevent its working loose or splitting its insulation.

The lead-in wires are taken from the mast and all connections with the mast are preferably soldered. It will be remembered in this connection that height counts for more than length as in the flat top aerials, and that an umbrella has very little of the wire at its greatest height, while the flat top has practically all of the wire at that point; hence the necessity for the condenser spoken of. It is best to run the wires as far into the air as possible, provided safe construction can be assured, as the upper end of the series is the best working end, and an additional ten feet in height has a considerably increased effect on the ease with which the waves are secured.

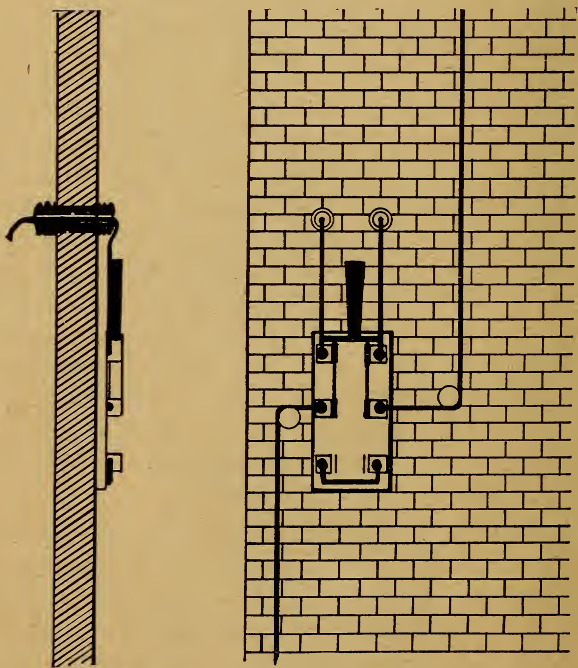
If we contrast the sketch shown on page 48 with the view of the flat top aerial on page 40, we will see that our umbrella practically means confining our aerial to the down wires, which are reversed in position, so that the lower ends are further apart and meet at the top. It will therefore be comprehended that there must be more of them. Still no jeweler need despair of being able to get the time from Washington, because if he cannot put up a good flat top aerial, he can certainly put up one of the umbrella type on his own roof.

The lead-in wire may be attached to the mast at any convenient point, and this is generally done at the lower joint, especially if the aerial wires run in such a position as to furnish support to the lead-in. Care must be taken to see that the lead-in is thoroughly insulated, as well as the aerial. It will not do to rely upon the fact that the lead-in is covered, as in dealing with such voltage one could still get good results if the entire aerial were made of insulated wire. The magnetic waves will permeate anything, and the electric waves at such voltage will penetrate ordinary insulation, as if the wire were bare. It is therefore best to consider the lead-in as if it were made of bare wire, and to keep it thoroughly insulated on glass or other supports. Because of the very high voltage any sharp bend will allow the current to shoot off into the air. This is called a brush discharge, on account of its shape, whenever it is large enough to be visible in the dark. Therefore lead-in wires especially should have no sharp angles in them, as it is sufficiently difficult to lead all of the waves successfully through your instruments without introducing any mechanical difficulties in the path which you are making for them to follow.

We now run our copper lead-in wire down the side of the building, supporting it where necessary on glass or porcelain insulators, which may be the ordinary peg type glass telegraph insulators, fastened by driving the pegs into holes made in the wall by a cold chisel, or gas pipe drill, clamping the wire sufficiently tight so that it cannot sway and chafe the insulation.

Just where the wires shall enter is largely a matter to be decided by the construction of the building and the position of the instruments. It is advisable to have the wire drop vertically to a window or other regular opening, so that the jeweler does not have to leave the room to open and close the lightning switch, which insurance regulations require to be located where the wire enters the building. It should come to a hundred ampere double pole, double throw lightning switch, which is demanded by the underwriters' inspection. The connection of the aerial and ground wires should be made at the middle points of the switch, with a round turn instead of a sharp angle, and it is advisable to have the switch some distance (say a foot) from the vertical drop of the lead-in wire, so that lightning in passing down the wire will not jump from it to the upper jaw of the switch, and thus enter the building and burn out the instruments. The underwriters also require this switch to be connected to the ground with a No. 4 rubber insulated copper wire, which is protected from mechanical injury by enclosing it in molding for at least seven feet from the ground on the exterior of the building.

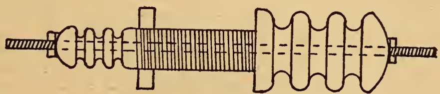
To comply with insurance requirements, the instruments must be completely cut off except when in operation. This is best accomplished by using the double throw, not fused, double pole switch and tying the lower jaws with a loop of ground wire, thus depending entirely on the outside ground. This is much simpler than using a single pole switch and two grounds, one inside for the instruments and one outside for lightning. If you cannot obtain connections with a water pipe, the outer ground may be obtained by digging a hole down to where the earth is damp, and burying in it a metal plate to which the wire from the lightning switch has been riveted or soldered. The surface should be about 2½ feet square. Preferably the hole should be deep enough to reach the ground water level. Where this is not the case, coke, cinders, charcoal or some other material which will hold water and a little salt is placed about the plate, the whole thoroughly wetted and the earth filled in, after inspection and approval by the insurance inspectors.



Double pole, double throw switch, on wall.

Another form of ground is obtained by taking a length of gas pipe, screwing on a pointed end, and then driving the gas pipe down until it has reached the ground water level. A piece of two-inch pipe with a steel point on the lower end, and the ordinary steamfitters' cap on its upper end, may be easily driven in for twenty feet with an ordinary wooden maul, and one or several of these separated a few feet will make excellent grounds where the ground water level is from 10 to 14 feet from the surface, and it is undesirable or too costly to dig a hole of sufficient depth.

Where the building is piped for city water, the best connection from the instruments is made by brightening a section of the water pipe and attaching the ground wire from the instruments to this pipe by means of a ground clamp which can be purchased at a supply store. Where the ground clamp is not used the wire should be stripped of insulation, brightened with sandpaper, wrapped closely several times around the pipe and then soldered to it. This makes a very good connection.



High tension insulator for use in walls.

From the upper jaws of the switch are taken the lead-in wires which run to the instruments, first passing through the lead-in insulators; which are by preference high tension insulators, made of the same material as the strain insulators, and adapted to be placed in position through a hole bored in the window casing or wall. They can be ordered of any dealer in electrical supplies, and should be included with the order for strain insulators for the aerial. They are also called high tension outlet insulators and high tension wall bushings.

Where the insulator can be inserted without interfering with the weights in the window, for instance at the top or at the bottom of the casing, or through a brick wall near the window, it makes a very neat and convenient method of securing a weather-proof joint with little trouble. These high tension insulators have a thread at the center, with a nut fitting on the thread, to clamp them firmly in position. They come both with and without an inserted wire or rod. Where the rod is inserted, it has threads upon each end, with clamping nuts, so that the connection to the lead-in wire outside and the wire running to the instruments is readily made. Where this is not the case, the lead-in wire must be bent and passed through the hole in the insulator, and the outer end puttied, or covered with pitch, tape, or asphaltum, to make a weather-tight joint. This is the arrangement for both receiving and sending.

Where receiving only is done, it is regarded as sufficient to use ordinary porcelain tubes, obtainable at any supply house, for allowing the wire to enter the building, and when this is the case the hole through the building wall should be drilled so that it inclines to the outside and the slant thus obtained is sufficient to deflect the storm water toward the outer end, and prevent its entrance to the interior. In any event all joints should be soldered as the amount of current received is so small that any leakage or resistance is important.

The switch must be placed where it will be convenient of access, and must be kept constantly in the safety position, except when the instruments are in use. The person in charge of the apparatus should make it an invariable rule to throw this switch to the ground position immediately after receiving the time, as otherwise, if an electric storm should come up in the night, lightning may strike the aerial and serious damage might be done to the apparatus and possibly the store. In this lies the essence of the underwriters' requirements.

Now we come to the selection of the instruments, and this involves some considerations of a technical nature, which are difficult to present clearly in a small space, so that conclusions merely will be stated here. Jewelers who desire to read up on the theory of wireless telegraphy cannot do better than to send $1.50 to the United States Naval Institute, Annapolis, Md., for a copy of the "Manual of Wireless Telegraphy for the Use of Naval Electricians," and study carefully the first 100 pages of that work. It excels in clearness and completeness any other work we have found.

All wireless energy moves in the form of waves, and these waves have been taken as the basing unit for the construction of all apparatus. They may be of any length, and in practice it has been found necessary to build the apparatus to handle waves within certain limits. The use of wave lengths has been further limited by international agreement and national laws prescribe that the waves in use for transmission shall be of 200 meters for amateur stations, and experimentation; 300 and 600 meters for commercial telegraphy, and from 600 to 2,500 for naval and other government purposes.

Receiving instruments have a certain adjustability to enable the reception of wave lengths which are intended to be either of the prescribed dimensions, but owing to poor adjustments, or other causes, are not of the length intended. This range of adjustability is called the tuning capacity.

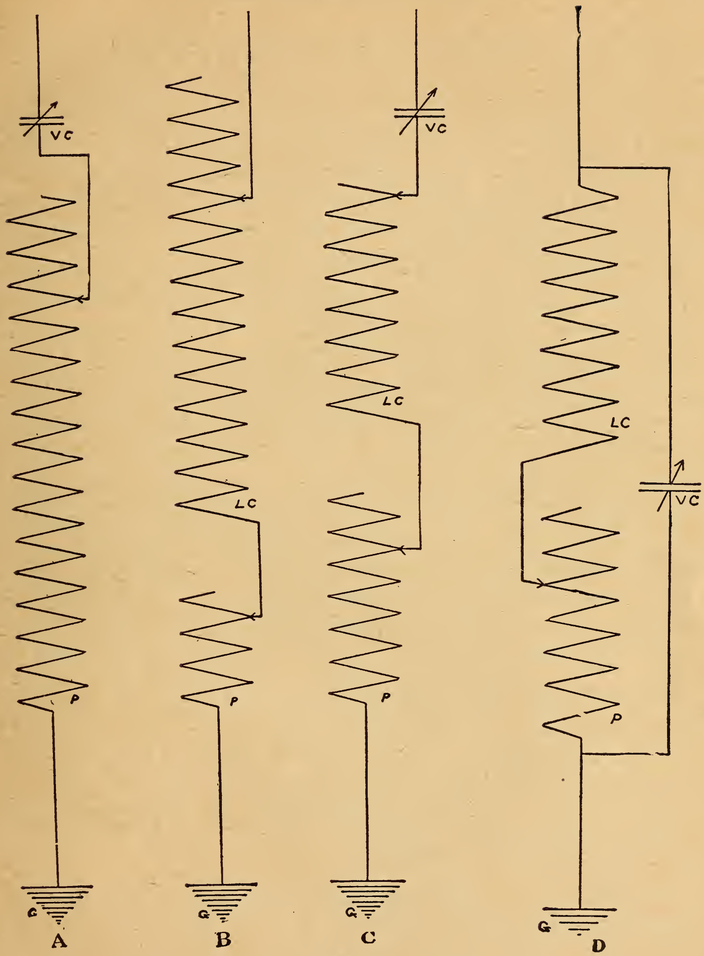
Another thing which must be taken into consideration is that every aerial has what is called its natural wave length, due to its size, and by international agreement the metric system of measurement has been used to define it.

To find the natural period of an aerial in meters, in the case of an L-shaped aerial add the length of one wire of the horizontal part, in meters, to the height of the highest point of the aerial, also in meters, and multiply the sum by 4.2. Where the lead-in wires are taken off from the middle, so that it forms a T-shaped aerial, the height is added to one-half of the length of the aerial; that is, from the point where the lead-in wires join to the highest point of the aerial, plus the height, are the factors in determining the wave length. From this it will be seen that length and height count for more than width in determining the natural wave length of an aerial. To change feet to meters divide the number of feet by 3.281.

The modern and practical receiving system consists of two circuits. One, called the primary or open circuit, consists of the aerial, lead-in wires and a coil of wire called the primary inductance, and the ground wire. It is called open because one end is in the air and the other in the ground, so that the circuit is incomplete. Coupled with it is the second or closed circuit consisting of an adjustable inductive tuner.

In determining the size of the coil to be used in the open circuit tuning coil, and also whether or not other apparatus such as condensers are to be needed, the elements to be considered are (1) the natural period of the aerial which is being used in receiving, and (2) the wave length which is desired to be received. Which of these is the greater, and by how much, determines entirely the apparatus to be used.

Case 1. If the natural period of the aerial used is greater than the wave length to be received (as would be the case for Arlington's time signals if the natural period were 3,000 meters), it is necessary to decrease this natural period by the insertion of a condenser in series. This may be placed between antenna and tuning coil or between tuning coil and ground, there being no choice between the two locations. (See Figure A). However, it is a fact that no jeweler will ever erect an aerial with a natural period anywhere near 2,500 meters, therefore this case does not concern the receiving of time signals from Arlington. The only case where this is of interest to the jeweler is when receiving signals from amateurs, since the wave length, which they must not exceed, i. e., 200 meters, may well be less than the natural period of a medium size aerial.



A. Primary coil of 200 turns, 4½ inches in diameter (232 feet), comprising 40 steps of 5 turns each. G, ground. P, primary. V, C, variable condenser, to adjust primary coil to the aerial. Will take 2,500 meters, but will not receive very short wave lengths.

B. Primary consisting of 50 turns in the primary coil, with 10 steps of 5 turns each. 160 turns in the loading coil, with 8 steps of 20 turns each. Can be used for short wave lengths.

C. Ordinary cheap amateur or experimental set for 300 to 600 meters with loading coil for 2,500 meters, and variable condenser to suit the apparatus to short and umbrella aerials.

D. Primary coil with loading coil and variable condenser in parallel.

Case 2. If the natural period of the aerial is less than the wave length to be received, it is necessary to increase this period by adding inductance in series, this inductance being the tuning coil. This may be done by varying a single large coil by one or more turns at a time, as in the case in figure A (omitting the series condenser, of course), or by varying an exterior coil having large steps and obtaining the finer adjustments by small steps on the tuning coil proper, as shown in figure B. In either case the problem is one of obtaining just the proper number of turns between antenna and ground, and if this be kept in mind, it is just as easy to perform this by the use of the two coils as by a single one. The exterior coil is usually called a "loading coil."

Case 2a. If the natural period of the aerial is very much smaller than the wave length to be received, as when the receiving aerial is very small, it will be found that a very large coil is necessary for resonance. The necessary large number of turns on this coil introduces resistance, and cuts down the intensity of signals. This can be lessened by placing a condenser in parallel with the tuning coil, as shown in Figure C. It is inadvisable for the jeweler to try this form of connection until he is thoroughly familiar with the simpler methods of figures A and B, and after this he may try, if he so desires, what success he may attain with this last form of connection.

If all the inductance is concentrated in a single coil, for receiving 2,500 meters, there will be required at least 150 turns of a coil, 4½ inches in diameter, or about 180 feet, used with a flat top aerial 100 feet long and 60 feet high. Where the aerial is shorter, it is better to also add a variable condenser, and where the aerial is longer and higher, a little less wire will be found necessary in the primary coil. This wire may be placed in the primary circuit in one continuous coil if only 2,500 meter wave lengths are to be received. (See A in illustration). If, however, it is desired to receive other wave lengths as well, then this inductance will be found more readily workable if a portion of it is added as a loading coil in series with the primary, so that the extra wire may be switched in or out as desired. (B).

Even to one totally unacquainted with electricity, or the adjustment of a radio receiver, it would appear that the use of a loading coil should not involve any difficulties, if the elementary fact is kept in mind that what is wanted, roughly speaking, is a suitable number of turns of wire in the primary or open circuit. As a whole it should not be hard to understand the process of adding fifty turns of wire per step by turning the switch in a loading coil, or five turns or so per step in the primary proper. The problem of tuning is really somewhat simpler if a loading coil is used, as instead of forty steps of five turns each in the case of a primary coil containing sufficient inductance in itself, the combined method would require, say, eight steps of twenty turns each, in the loading coil, and ten steps of five turns each in the primary.

For shorter antennae than 100 feet, 200 turns in the primary (232 feet) would be an advantage in that it would take care of almost any small antennae; but there are many other side effects which enter in, the chief one being that if too many turns are left on the coil, as when 120 turns are actually used to receive the signal, leaving 80 turns connected but not actually carrying current, very great losses are often to be found, in some cases amounting to almost total failure to receive signals. For this reason many loading coils are made of several portions entirely separated from each other and adapted to be connected up as needed.

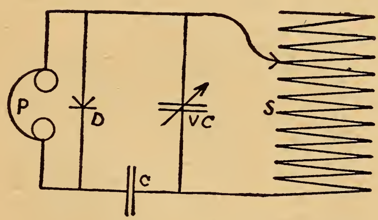
The size of wire in the primary coil is not of absolute importance. Any size between No. 17 B. & S. and No. 22 B. & S. will do. With a still smaller size of wire, less turns will be required. Where they are wound closely together, double silk covered wire (preferably white silk) should be used. It has been found that coloring matter in the insulation of many sorts of wire contains more or less conductive matter, especially among the green grades.

If the primary circuit of your receiver does not allow of the reception of a long enough wave, there are but two alternatives; one is to add inductance in the form of a loading coil; the other is to increase the size of your antennae. The latter is generally erected in the first place at the greatest possible length and height, in order to get the signals as loud as possible, so that practically all that remains is to add more wire in the form of a loading coil, or use a variable condenser to change the wave length.

The jeweler will readily see that if he is purchasing commercial instruments designed to be used at from 300 to 600 meters, with an aerial of 100 feet in length, he will utterly fail to receive 2,500-meter wave lengths with such an apparatus, until he has added extra turns of wire in the shape of a loading coil sufficient in number for him to receive the desired wave length, and if his aerial is very short, as where it has practically height only, in the case of the umbrella type being decided upon through necessity, or where it must be very short owing to his being obliged to confine it to his own property, he will be confronted by the question of capacity. The aerial itself has a certain natural period or wave length by virtue of its own inherent conductive capacity, which in turn is dependent upon the aerial's physical dimensions. This capacity is its "capacity to earth"; that is, it is the capacity of a condenser of which the whole antennae is one plate and the earth is the other. If the natural wave length of the antennae is shorter than the received wave length, we must add inductance in series, as has already been explained, and if its natural wave length is longer, we must add capacity in series.

When we connect up two condensers in series, the resultant capacity of the two is always less than the capacity of the smaller, so if we add a condenser between the aerial and the ground, we are virtually placing two condensers in series, and thus shortening the wave length which is transmitted to the primary coil. As the aerial cannot be increased in most instances without undue expense, we therefore shorten the wave length by the use of condensers. As condensers are very cheap, running in price from $1.50 for the fixed to $5 for the variable, this is generally the better way out of the difficulty, if the jeweler finds after purchase that his instruments are unable to receive the 2500-meter wave length.

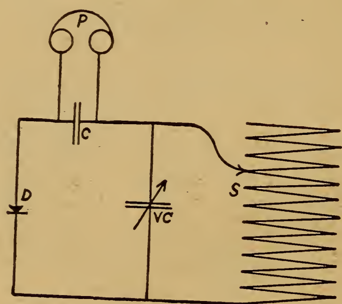
As it is next to impossible for the student to trace out the methods of wiring in commercial sets, we have drawn



Secondary or closed circuit. S, inductance. V. C., variable condenser. C, fixed condenser, D, detector. P, phones.

diagrams of the wiring of three forms of the primary circuit by itself so that they may be contrasted clearly and studied. See A. B. C. The next illustration shows in the same manner the closed, or secondary, circuit. This, like the other, consists of an inductance or coil of wires, and a variable condenser, these two forming a circuit which can be placed in resonance or in tune with the wave length being received by the open circuit. If the variable condenser is of small value, the circuit is adjusted to a short wave length, and as the condenser is increased, the wave length to which the circuit responds is increased. In most sets the inductance is divided into sections, the smallest section being used for the shortest wave lengths, and more and more sections being used as the wave length which one desires to receive is greater and greater.

To detect the energy which is thus set up in the closed circuit, a detector is used. The common form of connection used for this detector circuit is shown in the figure. A fixed condenser and the detector are connected in series across the terminals of the variable condenser, and the telephones are connected across the fixed condenser. In the figure, the telephones are shown shunted across the detector. This is a perfectly workable arrangement, but



Secondary or closed circuit. S, inductance. V. C., variable condenser. C, fixed condenser, D, detector. P, phones.

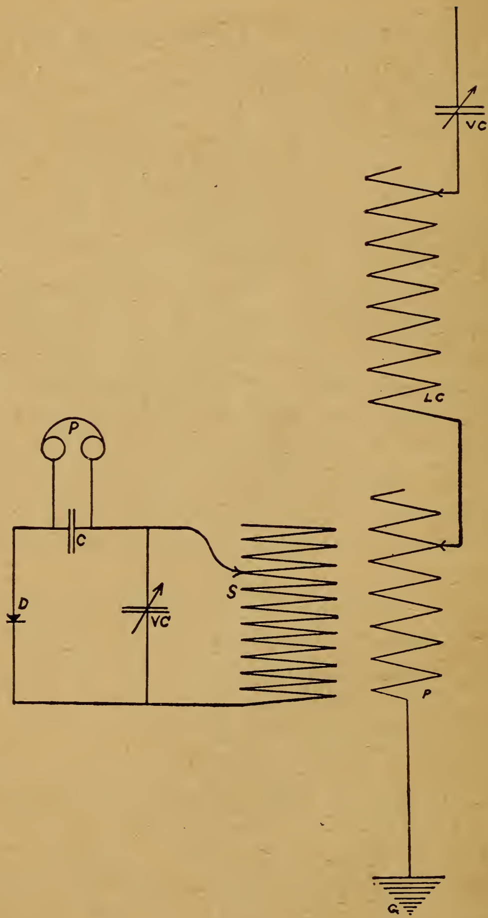
considerably louder signals will be obtained with the telephones across the fixed condenser, as shown in the next illustration.

These 'phones are preferably of at least 1,000 ohms resistance each. Two thousand ohms will give better results as a rule with the average installation, and many are using 2,400 ohms. The probable cause of this variation is that all 'phones are built by hand, and therefore vary, as does all hand work. The result is that if A has a very sensitive pair of 'phones of 1,000 ohms, he will naturally think that the higher resistance is unnecessary. B, on the other hand, may have tried the lower resistance with instruments inferior to A's in sensitiveness, and his personal experience warrants him in using 2,000 ohms. The main thing is to secure an extremely sensitive pair of 'phones. Where this is secured the number of ohms resistance in the 'phones becomes a secondary matter.

Attention is drawn to the fact that even among telephones manufactured for sale to commercial companies the efficiency may be as much as 25 times as great for one make as another, while a comparison of the best makes with those ordinarily sold for amateur use would be greater than this. Too much stress cannot be laid on the necessity for obtaining the best telephone possible. The difference between a good telephone and an inferior make may well be the difference between readable signals and absolute silence.

The jeweler who has any knowledge of electricity will readily recall that when a current passes through a coil of wire, the waves of magnetism are sent out from the wire at right angles to the direction of the current. These waves of magnetism, if brought in contact with another coil of wire, will set up an induced current in the second coil, the strength of this current depending upon the strength of the current in the primary and its nearness to the first coil. This fact is taken advantage of in the closed circuit, the object being to induce in the closed circuit wave lengths of the same dimensions as those in the primary, so that the induced current may operate the telephones, and thus allow us to read the vibrations being received on the aerial. This is accomplished by having a coil of wire, called an inductance, a condenser and pair of 'phones, and a detector in the closed circuit.

The heaviest coupling is reached when the middle of the active primary turns is directly opposite the middle (either



C

Diagram of wiring, showing primary and secondary.

inside or outside) of the active secondary turns. The primary is usually the stationary coil and the secondary moves into or around it, this being optional with the manufacturer. When the sliding secondary is inserted farther in the primary after this middle point has been reached, the coupling again becomes loose.

The process for tuning for a station is as follows: Place the movable coil fairly far away from the fixed coil, and adjust the number of turns in the open circuit coil and at the same time vary the condenser of the closed circuit. In general, it is well to make a fairly small change in the open circuit inductance. Keep this constant for a moment, and vary the closed circuit condenser over its entire range. If no signals are received, change the open circuit again by a small amount, and again vary the condenser. Do this until signals are picked up.

After signals are received, slide the coils still farther apart and adjust each circuit separately until both are exactly in resonance with each other and with the signals; that is, vary the open circuit inductance until the best point is found, and then, leaving it alone, vary the condenser until a still greater maximum is found. In every case, be sure to "go by" the point of maximum signals, that is, be sure that a still further increase of coil, or condenser, as the case may be, will begin to cut down the signals from the maximum loudness or clearness you have obtained.

It is then desirable, if one wishes loud signals, to slide the coils closer together, until again a maximum is obtained. It will be found that after this maximum is obtained, bringing the coils still closer will weaken the signals. This is because the two circuits react on each other if they are too close.

It is advisable, however, to keep the coils as far away as possible, as under these conditions interference from atmospheric electricity and from other stations is lessened.

Too much stress cannot be laid on the necessity for keeping the coils far apart when adjusting for the time signals from Arlington. The signals sent out from that station are what are known technically as "feebly damped," which means that the tuning is very sharp, both at the transmitter at Arlington itself, and also at any receiving station which desires to copy these signals. With such a sharply tuned set it is not possible to receive signals at any distance unless the two coils are kept comparatively far apart. In many cases it has been found that stations reporting inability to receive the Arlington signals could obtain perfectly readable signals as soon as the coils were sufficiently separated and the circuits correctly tuned under these conditions.

If the coils are too close, the tuning adjustments obtained for both open and closed circuits are different from what they would be with the correct "coupling" or separation of coils, and the chances of interference from other sources, as atmospheric electricity or other stations, is vastly greater.

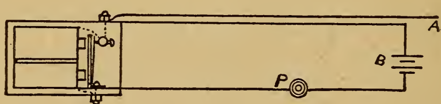
Receivers for wireless purposes are very sensitive. It has been found by experiments that the degree of sensitiveness depends largely on the frequency at which the received signals are sent. Thus messages from a 900-cycle transmitter will produce an audible sound in the receiver when only 0.6 millionths of a volt is used, while impulses from a sixty-cycle set will only produce an audible sound when 620 millionths of a volt are used. It is for this reason that the transmitters operating at 500 to 1,000 cycles are more effective than those operating at lower frequencies.

The sensitiveness of a good telephone receiver depends on the frequency employed to operate it, and also on the natural period of vibration of the diaphragm, so that very thin diaphragms are employed in the most sensitive wireless receivers. The reason the detector is employed is that the oscillations of the current are so rapid that the successive changes neutralize each other and consequently produce no effect on the receiver. The number of oscillations in the Arlington waves is 120,000 per second. These alternations are alternately positive and negative. To operate on these oscillations alone a telephone diaphragm would have to move in one millionth of a second, which, of course, it cannot do. The detector then translates the received oscillations into a current which will operate the receiver.

It has been found that certain substances will pass an alternating current readily in one direction, but will not allow it to proceed in the reverse direction, so that they become a rectifier of the current. There are many of these metallic compounds which conduct the current better in one direction than in another. Those in most common use are silicon, galena (lead ore), iron pyrites, carborundum, etc. The detector consists of one of these substances electrically connected to a binding post, generally by sinking it in fusible metal in a brass cup, with the natural surfaces of the crystals in position to be very lightly touched by a fine metallic point which is connected to the other pole of the detector. By moving this point on the surface of the crystal a number of places will be found which will allow the current to pass and sounds to be heard in the telephone. These places can only be found by trial, moving the point about and using a very light pressure. When the electrical resistance at the point of the detector equals the resistance in the telephones the detector is working at its best, so that it can be readily seen that the amount of pressure is very important, as varying the pressure varies the amount of the resistance in the detector.

The fixed condenser serves to prevent the current, which has been changed by the detector into a form capable of affecting the telephone receiver, from being short circuited by the low resistance path formed by the closed circuit inductance coil. This condenser has nothing whatever to do with the adjustment of the closed circuit to resonance, this being determined, as already pointed out, entirely by the number of turns in the coil, and by the capacity of the variable condenser.

In addition to the advisability of obtaining the most sensitive telephone possible, it is just as important to make use of the most sensitive detector that can be obtained. Assuming that the receiving set is correctly tuned by the user, telephones and detector are even more important than the special make of receiving apparatus used. It will be possible for the jeweler to select his detector from the many advertised in the technical publications. If it is desired to add somewhat to the first cost, and to the complexity of apparatus, the audion or valve detector will give results far superior to any crystal type. On the other hand, the crystal type has the advantage of being cheap, easy to handle, and capable of installation in a very limited space.



Test buzzer. B, battery. P, push button. A, short wire, ending near primary, or attached to the ground of the primary.

The manipulation of the detector, pushing in or drawing out the secondary coil from the primary, turning the knob of the variable condenser and changing the number of turns in the open circuit inductance until the desired sounds are loudest, form the process of tuning.

Where used for receiving time only, this process of tuning need not be gone through with every time it is desired to receive the signals, only slight variation being required with changes of the weather to cut out static and other disturbances.

These crystal detectors are all the subject of patents taken out by Professor Pickard, who has leased them on royalties to various manufacturers. This accounts for the fact that each manufacturer advocates the use of a different substance as a detector. The jeweler may take his choice.

We now come to the final apparatus, which is required for testing out and making sure that no connections are broken anywhere, or that no unusual resistance or short circuits have occurred accidentally since the apparatus was last used. This is called the test buzzer. It consists of an ordinary buzzer, such as can be purchased anywhere, wired up with dry batteries and a push button, and a short wire adapted to carry the magnetic waves to the vicinity of the primary coil. We thus have a simple and cheap apparatus for assuring that we can produce the wireless waves and pass them through the primary at any time. It is of great convenience in adjusting the instruments, particularly in setting the detector. When a very sensitive detector is used, a slight jar may throw it out of adjustment, or the point may be oxidized, or other things may happen which will require its readjustment previous to using.

Many wireless operators dispense with the buzzer, relying upon hearing wireless messages which may be going through the air at the time when they approach the instruments. Where a great deal of amateur work is going on, or in territory which is constantly traversed by the wireless waves of the commercial companies, this may do very well; but the buzzer costs so little that it is worth while to install it, as it then becomes a standard which gives substantially the same wave every time, and thus aids in setting the detector more readily than could be done with waves of varying intensity which may be caught from commercial or amateur sending.

The buzzer should be small and either boxed in or placed at a sufficient distance from the instruments, so that it cannot be heard except through the telephones. These buzzers are made as small as 1x1¼ inches, and are exceedingly cheap.

If the spring is coarse and the armature heavy it will be impossible to set the buzzer to a fine, high note resembling the wireless, and in that case it is advisable to thin the spring a little at the proper point and file down the armature. Otherwise no special instructions are necessary. It is better for the jeweler to simply test his detector with his buzzer to see that the wireless waves will pass through the coils, and then to manipulate his detector until the Arlington waves sound the loudest and clearest. In other words, do not rely too much upon your buzzer. It is simply intended as a test, and you will find that you can set the detector so as to get a loud sound from your buzzer, and then require a different, generally a much lighter adjustment to receive the very faint waves which come in from Washington.

If the jeweler is within five hundred miles of Washington, he will have no difficulty in getting loud sounds with a small aerial, but if he is in North Dakota or Arizona, the adjustment of the detector must be more delicate, and very probably a different position of the switch points in the primary and secondary coils will be necessary. These can only be determined by trial, and knowing that the waves from Washington are sent out twice per day, at 11:55 to 12 m., and 9:55 to 10 p. m., 75th meridian, or Eastern standard time, he should be able to finally adjust his instruments so that they will receive the signals which are known to be coming. After having once accomplished this, its repetition becomes easy.

A similar signal is also sent out from the Navy Yard, Mare Island (San Francisco), at 11:55 a. m., 120th meridian time, for use on the Pacific coast and jewelers in Nebraska have reported that they were able to get both Arlington and Mare Island signals, the latter being three hours later than the other.

The Arlington time signal is the same as that which is sent daily over the Western Union telegraph wires and which any jeweler may hear by going to his railroad telegraph station and listening at 11:55 standard time. The sound in the telephones of the wireless set is rather a high clear note, lasting for .35 of a second for each beat, with the 29th, 56th, 57th, 58th and 59th omitted during each minute, except the last, when there is silence from the 49th to the 59th seconds, followed by a beat of 1.35 seconds, beginning exactly on the hour.

Thus there are ten chances to compare the time; five on the 30th second of each minute (which is plainly marked by the omission of the 29th); and five on the first beat of each minute, which are also preceded by an interval of silence, as explained above.

After a little practice the jeweler will seldom need to listen for the entire five minutes. With a watch in front of him he will catch the time at either the 30th or the first second and note the position of the second hand on the watch.

He can then pass the telephones over to a customer and let him hear the time for himself. This always makes a hit with the customer and is about the best advertising which a retailer can do. Many retailers state that the cost of buying and erecting the apparatus has been many times repaid in advertising thus received, while the value of having an indisputable standard of time is constantly becoming more important. The government makes no charge for the signals, so that there is no further cost after the initial outlay and the instruments will last for years.