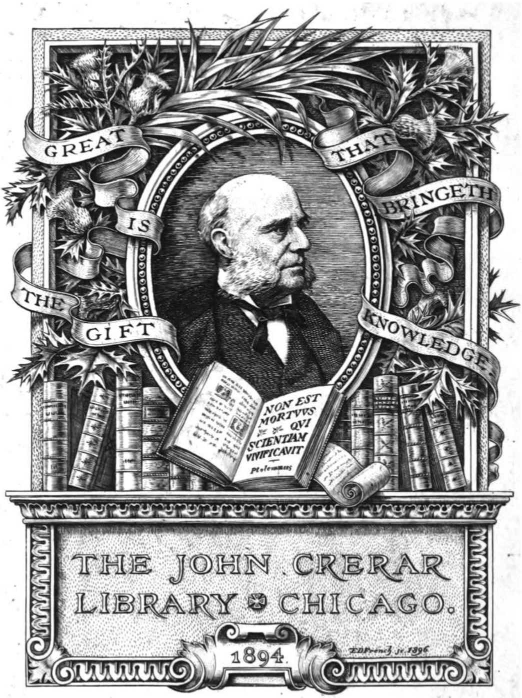

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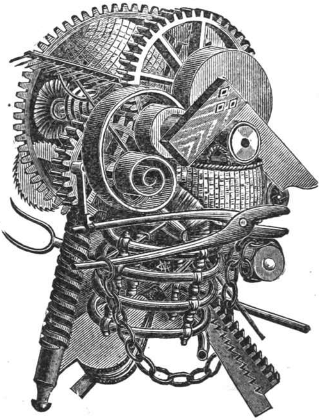
LOETZER'S HAND-BOOK

OF

Practical Rules and Tables

FOR MACHINISTS AND ENGINEERS.



Revised and Enlarged.

Especially written and prepared for
Mechanics not technically educated.

C. E. LOETZER.

FIFTH EDITION.

1900.

PREFACE.

The author of this work, a practical Mechanic of many years of experience, has time and again realized the necessity of placing in the hands of Machinists and Mechanics of similar pursuits a practical book of reference, written in plain and comprehensible language, containing such valuable rules and information as are usually only in possession of, and obtained by Mechanics of many years of application and experience. This information is found only in elaborately written scientific and expensive works, requiring a technical education to be understood, which the larger portion of our Mechanics have not had the privilege and pleasure of obtaining.

The object of this hand-book is, to place in the hands of all, especially the younger, such desirable rules and information, written in such a manner, and at so low a price as to be within easy reach and understanding of all.

I trust it will find a welcome place in the pocket or tool-chest of every fellow workman; well knowing that once there it will be of valuable service to him and help him over many a difficult job.

THE AUTHOR.

Preface to Fourth and Fifth Edition.

The rapid sale of many thousand copies of each of the preceding four editions of this little book, in every State and Territory, Canada, Mexico and other Foreign Countries since its first issue, but a few years ago, and the hundreds of unsolicited flattering testimonials received from all classess of mechanics and engineers in all positions, are the most gratifying indications that this work is appreciated and meets the requirements of my fellow workman. I am thus spurred to renewed and greater efforts to please the knowledge-seeking contingent of craftsmen and have revised and enlarged this volume to thrice its orginal size, containing much new matter and many additional illustrations, which I trust may prove as useful and be as favorably received as former editions.

THE AUTHOR.

THE SCREW.

The usefulness and importance of the screw in applied mechanics is incalculable. It occupies a prominent position in every construction of whatever name or nature. Machinery, buildings and constructions of all kins; instruments commodities, household articles, everywhere and in everything we find it filling the same important place. It is also a means of power unequaled by any other in simplicity and usefulness.

It will, therefore, without further effort, occur to the mind of every mechanic how important it is that he should be thoroughly familiar with the same and its construction in all its details.

The screw in itself is a wedge or inclined plane wound around a parallel spindle in the form of a spiral, which is called the thread.

The "pitch" of the screw is the distance it will pass through an object parallel to the axis of its spindle by one revolution, or the distance between the centres of two threads.

Threads "per pitch" signifies the number of threads contained in one inch, measuring at the root if V thread, and at the right edge if square thread.

The "diameter of the screw" is the outside diameter of the thread.

The value or the amount of power of a screw depends entirely upon the proportion between its pitch and its diameter. A screw with a coarse pitch is less powerful than a screw with a finer pitch; in other words, as the pitch increases, the power decreases; and as the pitch decreases, the power increases. When it gains speed it loses power, and when it loses speed it gains power, all other circumstances being equal.

For Example: A screw 2 inches in diameter and 2 threads per inch, with a 2-foot lever will raise a given weight four times quicker by one revolution, than a 2-inch screw with 8 threads would, using the same lever. The screw with 2 threads per inch, however, would require nearly four times as much power to raise the weight, than the one with 8 threads per inch would require.

ABBREVIATIONS.

For the sake of convenience the following abbreviations will be used:

C. N.	for	Common or Convenient Number.
D. S.	"	Driving Screw.
Ths.	"	Threads per inch.
×	"	Multiply, example, 3×6=18.
÷	"	Divide, " 20÷10=2.
+	"	Plus or Add, " 4+2=6.
—	"	Minus or Sub., example, 10—5=5.
=	"	Equal, example, 2=2.
∴	"	Therefore.
″	"	Inch or Inches.
′	"	Foot or Feet.

LATHE SCREW-CUTTING.

COMMON NUMBER.

Most all of the modern build lathes are indexed, which index is figured or found from one Common Number, by which the teeth in each of the gears may be divided exactly, and the additional number of teeth in every next larger gear will be the same as the C. N. For example: If the smallest gear of a lathe is of 24 teeth, the next 28 teeth, the next 32 and so on, then the C. N. is 4. If the teeth increase by 5, then the C. N. is 5. If by 6, then 6, etc.

Lathes that have no C. N. and whose gears are irregular, any number may be used to multiply by, which will then be the C. N. This rule also holds good for lathes that have a C. N. in case a thread is desired to be cut that the index does not show.

DRIVING SCREW.

The D. S. of a lathe is the next thing of importance that the operator must thoroughly acquaint himself with to be able to correctly figure threads and gearing for that particular lathe.

In most lathes the true relation of the D. S. to the lathe spindle is maintained. In all such cases the D. S. is correctly represented and figured by the number of its threads per inch.

On a lathe where the true relation of the D. S. is changed by reason of a different sized gear on the feed spindle to that on the lathe spindle, the number of threads per inch on the D. S. does not correctly represent the same. and the correct D. S must be found, which is done as follows:

RULE—Take two gears of equal size, use one as driver, the other as driven, with any convenient size intermediate gear. Cut a thread, and the number per inch thus found will be the D. S.

This rule is the best test to determine the D. S. of any lathe.

RULE 1.

HOW TO FIND TWO GEARS.

RULE—Take the D. S. as a numerator, and the required threads per inch as denominator; multiply each by the C. N. The new numerator thus found will be the driver, and the new denominator will be the driven. In other words, the result of the multiplying of the D. S. (new numerator) must be placed on the lathe spindle and is the driver.

And the result of the multiplying of the required threads per inch (the new denominator) must be placed on the D. S. and is the driven.

EXAMPLE.

D. S. 4, Ths. 8, C. N. 10.

$$\therefore \frac{4}{8} \times 10 = \frac{40,}{80,} \quad \begin{matrix}\text{Driver.}\\ \text{Driven.}\end{matrix}$$

NOTE—This rule is the fundamental principle of all rules for thread cutting, If a right-hand thread is to be cut, use one intermediate gear. It a left-hand thread, use two intermediate gears.

NOTE 2—When the driver or spindle gear is nonchangeable or assumed, use this rule to find the driven:

RULE—Multiply the number of teeth of the spindle gear or driver by the desired number of threads then divide that product by the number of threads per inch on the D. S. The result will be the gear to put on the D. S. or the driven.

EXAMPLE.

		Spindle gear or driver.
D. S. 4.	Ths. 8.	32.

$\therefore$ 8 × 32 = 256, then 256 ÷ 4 = 64, the driven.

RULE 2.

HOW TO FIND FOUR OR COMPOUND GEARS.

Two gears will cut many plain and many fractional threads, except when very fine or very coarse. To cut very fine thread with two gears, that required on the lathe or feed spindle would be inconveniently small, and that required on the D. S. would be inconveniently large. It would be difficult, if not impossible, to find such small or large gears in the shop.

In all such cases it will be more convenient to use four gears, which will be found as follows:

RULE—First find two gears as shown in Rule 1; then find two numbers to multiply together into the driver without a remainder, and two numbers to multiply together in the driven without a remainder; then multiply each of the two numbers so found by any C. N. The result will be the two drivers and the two driven to use.

EXAMPLE.

D. S. 4, Ths. 20, C. N. 6.

$$\frac{4}{20} \times 6 = \frac{24}{120}$$

You now have 24 as the driver and 120 as the driven. Take 24 and find two numbers that will multiply together and make the same, as: $4 \times 6 = 24$; then take 120 and do likewise, as: $10 \times 12 = 120$. Then multiply 4 and 6, and 10 and 12 by the C. N. The result will be the two drivers and the two driven to use, and the full example will read as follows:

D. S. 4, Ths. 20, C. N. 6.

$$\frac{4}{20} \times 6 = \frac{24 \,.\, 4 \,.\, 6}{120 \,.\, 10 \,.\, 12} \times 6 = \frac{24 \,.\, 36 \text{ drivers.}}{60 \,.\, 72 \text{ driven.}}$$

To prove the gears so found use this rule:

RULE—Multiply the first driver 24 by the desired number of threads 20, divide that product by the first driven 60, then multiply that quotient 8 by the second driver 36, and divide that product by the number of threads per inch on the D. S. 4. The result will be the second driven 72.

EXAMPLE.

```
                 24 first driver.
                 20 desired threads.
                ----
First driven  60)480(8 quotient.
              36 second driver.
               8 quotient.
             ----
D. S. 4)288(72 second driven.
        28
        ---
         8
         8
        ---
```

RULE 3.

HOW TO CUT FRACTIONAL THREADS PER INCH.

Fractional threads per inch means: A certain number of whole threads and a fraction of another contained in one inch.

The easiest way to measure fractional threads is as follows: Take any number of threads until they measure even inches, then count the number of threads in that number of inches.

When the pitch of the screw is given in the form of a fraction, as $\frac{3}{8}$ pitch, then the bottom figure indicates the number of threads, and the top figure the number of inches. $\frac{3}{8}$ pitch would be, one thread in $\frac{3}{8}$ of an inch, or 8 threads in 3 inches, or $2\frac{2}{3}$ threads per inch.

RULE—Find the number of whole threads in even inches, then find the number of threads on the D. S. in the same number of inches, and multiply by any C. N., same as Rule 1.

For instance, the desired thread is $4\frac{1}{2}$ per inch, and the D. S. is 6 threads per inch. It will in that case be seen that 9 whole threads are found in two inches, and 12 threads in two inches of the D. S.

The example will therefore read as follows:

D. S. 6, Ths. $4\frac{1}{2}$, C. N. 4.
D. S. instead of 6 use 12. 48 driver.
× 4 = —
Ths. " " $4\frac{1}{2}$ " 9. 36 driven.

D. S. 4, Ths. $3\frac{1}{4}$ C. N. 6.
D. S. instead of 4 use 16. 96 driver.
× 6 = —
Ths. " " $3\frac{1}{4}$ " 13. 78 driven.

D. S. 4, Ths. $11\frac{1}{2}$. C. N. 3.
D. S. instead of 4 use 8. 24 driver.
× 3 = —
Ths. " "$11\frac{1}{2}$" 23. 69 driven.

D. S. 4, Ths. $2\frac{1}{3}$, C. N. 5.
D. S. instead of 4 use 12. 60 driver.
× 5 = —
Ths. " " $2\frac{1}{3}$ " 7. 35 dirven.

RULE 4.

HOW TO CUT THREADS PER PITCH.

RULE—Multiply the top figure by the number of threads per inch on the driving screw, use that product as the numerator and the bottom figure as the denominator, then multiply each by the C. N.

EXAMPLE.

D. S. 4, Pitch $\frac{3}{8}$ of an inch, C. N. 6.

$$\frac{4 \times 3 = 12}{8 = 8} \times 6 = \frac{72 \text{ driver.}}{48 \text{ driven.}}$$

When the pitch is measured by whole inches, use this rule:

RULE—Multiply the number of whole inches by the number of threads per inch of the driving screw, and use that product for the numerator, and for the denominator use 1, and proceed as per Rule 1.

EXAMPLE.

D. S. 2, Pitch 3 inches, C. N. 16.

$$\frac{3 \times 2 = 6.}{1} \times 16 = \frac{96 \text{ driver.}}{16 \text{ driven.}}$$

When the pitch of a thread is given in one or several whole and part of another inch, as: 1 thread in $2\frac{3}{4}$ inches, proceed as follows:

RULE—Find the number of even threads in even inches, which will be 4 even threads in 11 inches. then multiply the number of inches (11) containing the even threads by the number of threads in one inch of the driving screw. Use that product as the numerator and the even threads, which are 4, as the denominator.

A $2\frac{3}{4}$ pitch we find contains 4 even threads in 11 inches. We find driving screw at 2 threads per inch contains 22 threads in 11 inches, hence the example will read as follows:

EXAMPLE.

D. S. 2, Pitch $2\frac{3}{4}$ inches, C. N. 5.

$$\text{Numerator, D. S. use } \frac{22}{4} \times 5 = \frac{110 \text{ driver.}}{20 \text{ driven.}}$$

Denominator, Pitch $2\frac{3}{4}$" 4

RULE 5.

PITCH OF DRIVING SCREW—HOW TO FIND GEARS FOR SAME.

When the driving screw of a lathe is measured and designated by its pitch, as for instance $\frac{3}{8}$ pitch, use the following rule to find the gearing for any desired thread:

As shown above the top figure of the fraction always designates the inch or inches, and the bottom figure always designates the number of whole threads contained in the same; consequently a $\frac{3}{8}$ pitch driving screw would have 8 threads in 3 inches.

RULE—To find the driver, simply take the bottom figure of the fraction and multiply the same by the C. N. as Rule 1. To find the driven take the top figure of the fraction and multiply the same first by the desired number of threads to be cut, then multiply that product by the C. N.

EXAMPLE.

D. S. $\frac{3}{8}$ pitch, Ths. 6, C. N. 4.

$$\frac{3 \times 6 = 18.}{8 \quad = 8,} \quad \text{Reverse } \frac{8,}{18,} \times 4 = \frac{32 \text{ driver.}}{72 \text{ driven.}}$$

In order to avoid becoming confused in the use of this rule, another way to use the same is as follows: Place the figures of the pitch ahead of the example, following that reverse the same and proceed to figure as per rule. Your example would read like this:

D. S. $\frac{3}{8}$ pitch, Ths. 6, C. N. 4.

$$\frac{3}{8} \quad \frac{8}{3 \times 6} = \frac{8}{18} \times 4 = \frac{32 \text{ driver.}}{72 \text{ driven.}}$$

DOUBLE AND TREBLE THREADS.

THE USE OF, AND HOW TO CUT THE SAME.

Very coarse pitched screws are used for the purpose of raising some piece of work or machinery very quickly where but little power is required. In all such cases the diameter of the screw is not sufficient to have one full standard thread cut on same. The groove would be too deep and wide for the diameter; therefore double and treble threads are cut, dividing the coarse groove and the coarse space into smaller grooves and smaller spaces, maintaining a better proportion and better strength of the spindle on which such threads are cut.

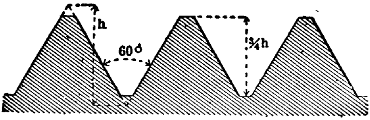
When cutting double or treble threads, let the lathe spindle gear be such as will divide evenly into as many parts as threads required, namely: If cutting a double thread, the teeth on the spindle gear must divide evenly in two parts; if treble threads, in three parts, etc.

When the first thread is cut, draw a line across the top of an intermediate gear tooth, mark it No. 1 and divide the spindle gear into as many parts as threads required, then take the spindle gear off sufficient to clear the intermediate gear, pull the belt around so that No. 2 will gear into the same place, go ahead and cut the second thread.

When the lathe has a feed spindle gear twice the size of the lath spindle gear, divide one-half of the gear instead of the whole.

UNITED STATES STANDARD SCREW THREADS.

The United States Standard for screws and threads is the standard recommended by Franklin Institute, December 15, 1864, and subsequently adopted by the Navy Department of the U. S., by the R. R. Master Mechanics and Master Car Builders' Associations, by all leading tool builders, manufacturers, engineering and mechanical establishments, and is now in general use throughout the entire country. Angle between threads, 60 degrees. Flat at top and bottom ⅛ of pitch. Number of square threads per inch equals half the number of angular threads.



Diam. of Screw.	Thr'ds per Inch.	Diam. at Root in Decms.	Diam. at Root in Fracts.	Diam. of Screw.	Ther'ds per Inch.	Diam. at Root in Decms.	Diam. at Root in Fracts.
¼	20	.185	3/16	2	4½	1.712	1 46/64
5/16	18	.240	15/64	2¼	4½	1.962	1 31/32
⅜	16	.294	19/64	2½	4	2.176	2 11/64
7/16	14	.344	11/32	2¾	4	2.426	2 27/64
½	13	.400	13/32				
9/16	12	.454	29/64	3	3½	2.629	2⅝
⅝	11	.507	33/64	3¼	3½	2.878	2⅞
¾	10	.602	⅝	3½	3¼	3.100	3 7/64
⅞	9	.731	47/64	3¾	3	3.317	3 5/16
1	8	.838	27/32	4	3	3.567	3 9/16
1⅛	7	.940	15/16	4¼	2⅞	3.798	3 51/64
1¼	7	1.065	1 1/16	4½	2¾	4.028	4 1/32
1⅜	6	1.160	1 5/32	4¾	2⅝	4.256	4 17/64
1½	6	1.285	1 19/64				
1⅝	5½	1.389	1 25/64	5	2½	4.480	4 31/64
1¾	5	1.491	1 31/64	5¼	2½	4.730	4 47/64
1⅞	5	1.616	1 39/64	5½	2⅜	4.953	4 61/64
				5¾	2⅜	5.203	5 13/64
				6	2¼	5.423	5 27/64

HOW TO FIND ROOT DIAMETER OF U. S. STANDARD THREADS.

To find the difference in diameter between the bottom and top of thread, divide the constant 1.298 by the number of threads used, the quotient is the amount the screw is smaller in diameter at root.

If, for example, a screw 1½" diameter has 6 threads per inch cut on same, then the constant 1.298 divided by 6, will give the quotient .215 or 13-64", which is the amount the screw is smaller at root; thus .215 deducted from 1½", gives its root diameter as 1.285, or 1 19-64, which is the size the blank nut must be bored out to.

To find the diameter at root of thread for sizes other than standard, deduct the amount, as given in following table opposite the thread used:

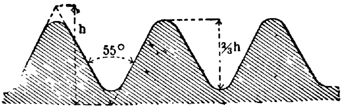
Threads per Inch.	Amount to Deduct In Decms.	Amount to Deduct In Fracts.	Threads per Inch.	Amount to Deduct In Decms.	Amount to Deduct In Fracts.
20	.065	1-16	4 1-2	.288	9-32
18	.072	5-64	4	.326	21-64
16	.081	5-64	3 1-2	.371	23 64
14	.093	3 32	3 1-4	.400	25 64
13	.10	3-32	3	.433	27-64
12	.108	7-64	2 7-8	.452	7-16
10	.130	1-8	2 3-4	.472	15-32
9	.144	9 64	2 5-8	.494	31-64
8	.163	5-32	2 1-2	.520	33-64
7	.185	3-16	2 3-8	.547	35-64
6	.215	13-64	2 1-4	.577	9-16
5 1-2	.236	15-64	2	.649	41-64
5	.259	1-4	1	.1298	1 19-64

Wrought Iron Pipe Threads and Dimensions.

Inside Diam'ter Nominal	Threads per Inch	Weight per Foot of length	Thickn's of Metal	Actual Outside Diam'ter	Actual Inside Diam'ter	Internal Area
1/8	27	.24	.068	.405	.27	.057
1/4	18	.42	.088	.54	.364	.104
3/8	18	.56	.091	.675	.494	.191
1/2	14	.84	.109	.84	.623	.304
3/4	14	1.12	.113	1.05	.824	.533
1	11½	1.68	.134	1.315	1.048	.862
1¼	11½	2.24	.140	1.66	1.38	1.496
1½	11½	2.68	.145	1.9	1.611	2.038
2	11½	3.61	.154	2.375	2.067	3.355
2½	8	5.74	.204	2.876	2.468	4.783
3	8	7.54	.217	3.5	3.067	7.388
3½	8	9	.226	4.	3.548	9.887
4	8	10.66	.237	4.5	4.026	12.730
4½	8	12.49	.246	5.	4.508	15.939
5	8	14.50	.259	5.563	5.045	19.990
6	8	18.76	.280	6.625	6.065	28.889
7	8	23.27	.301	7.625	7.023	38.737
8	8	28.18	.322	8.625	7.982	50.039
9	8	33.70	.344	9.625	8.937	63.633
10	8	40.	.366	10.75	10.019	78.838

Whitworth's English Gas Pipe Threads.

Inside Diameter in Inches.	1/8	1/4	3/8	1/2	3/4	1 to 2	2¼ to 2½
No. of Threads per Inch.	28	19		14		11	7.2



Whitworth's English Standard Screw Threads.

Diameter of Screw.	No. of V Thds. per In.	Diameter of Screw.	No. of V Thds. per In.	Diameter of Screw.	No. of V Thds. per In.
1-4	20	1 3/8	6	3 1/2	3 1/4
5-16	18	1 1/2	6	3 3/4	3
3-8	16	1 5/8	5	4	3
7-16	14	1 3/4	5	4 1/4	2 7/8
1-2	12	1 7/8	4 1/2	4 1/2	2 7/8
5-8	11	2	4 1/2	4 3/4	2 3/4
3-4	10	2 1/4	4	5	2 3/4
7-8	9	2 1/2	4	5 1/4	2 5/8
1	8	2 3/4	3 1/2	5 1/2	2 5/8
1 1/8	7	3	3 1/2	5 3/4	2 1/2
1 1/4	7	3 1/4	3 1/4	6	2 1/2

Angle between threads, 55 degrees. Rounded top and bottom 1-6 of pitch. Number of square threads per inch equals half number of V threads in both standards.

TAPERS.

HOW TO TURN TAPERS.

When a piece of work is to be turned taper its full length, and the required amount of taper is given, all that is necessary in that case is, to set the tail-stock over to half of the required taper.

But when part of a piece of work only is to be tapered, the job is more difficult, and the following rule should be used:

RULE—First reduce the entire length of the job to inches, divide that by the number of inches to be tapered, then multiply that quotient by the amount of taper required and set the tail-stock over to one-half of that.

For instance, we have a piece 4 feet long, desiring 6 inches of same to be turned $\frac{1}{8}$ of an inch taper, proceed as follows:

4′ × 12″ = 48 inches, 48″ divided by 6 goes 8 times; then multiply 8 by $\frac{1}{8}$, 8 × $\frac{1}{8}$ = 1 whole, or 1 inch. Then set tail-stock over to $\frac{1}{2}$ inch.

FULL EXAMPLE.

12″ × 4′ = 48″.   6)48(8 × $\frac{1}{8}$ = 1′.
48
—

HOW TO BORE TAPERS.

To accurately bore any desired taper requires a compound head, the usefulness of which all modern tool builders have long since realized; and a modern lathe without such compound head is rather the exception.

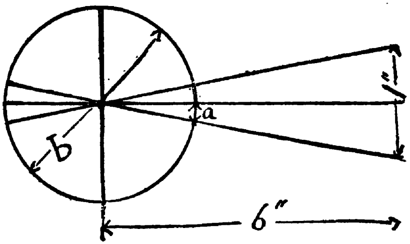
When the desired taper and length of the hole is known, proceed as follows:

RULE—Set the head over to as near the required amount as you can, then scribe a mark on the smooth part of the side of the head showing the exact length of the hole from that mark to the end of the head towards the face-plate. Next place a square against the face-plate, bring up your carriage until the mark on the head touches the edge of the blade of the square, allowing the same to rest against the head at the mark; then adjust your compound head until the hollow or distance between the end of the head and the blade of the square, measures just half of the desired taper.

When the base of the compound head is round use this rule:

RULE—Take a pair of dividers and scribe a circle with a diameter equal to the diameter of the base of the compound head, and with this centre for the apex of the angle, scribe two straight lines at the desired angle, as shown in the illustration, where the angle is 1 inch to 6 inches, and *b* is the diameter of the base of compound head. The base shou'd have two reference marks on it; one showing when the head is standing at exactly a right angle to the centre line of lathe, and another showing when it is parallel with the centre line. When setting to bore a taper hole the head should be swung around until it is parallel with the lathe centre-line, then set the dividers to the distance *a*, and place one point in the reference mark on the stationery part of the head and swing the movable part around until the reference mark on it is even with the other point of the dividers and the rest will be at the desired angle.

ILLUSTRATION.



SHRINK-FITS.

The following table of allowances for Shrink-Fits will be found an excellent guide to bore or turn to, and in all ordinary cases will be found sufficiently correct to give entire satisfaction. In all cases, however, the best judgment must be employed; and the kind of metal used, its outside diameter or size, its degree of fineness, etc., as well as the facilities for heating and expanding and the labor to be performed by the work when finished must all be taken into consideration and the fit made accordingly.

If a good quality of wrought iron or steel is used a trifle more may sometimes be allowed, whereas if cast iron is used it would not be safe to go beyond these sizes and it may sometimes be necessary to go a trifle less.

Size in Inches.	Amount to Allow.
2″ and under	1-1000 or less
2″-4″	1-100″
4″-6″	1-64″
6″-9″	3-128″
9″-12″	1-32″
12″-18″	3 64″
18″-24″	1-20″
24″-35″	1-18″
35″-45″	1-16″
45″-55″	1-14″
55″-65″	1-12″

Amount of shrinkage allowed for locomotive wheel centres and tires, as adopted by the American Railway Master Mechanics' Association, June, 1886:

Size.	Amount of Allowance.
48″ or less	.040
34″ " "	.047
50″ " "	.053
56″ " "	.060
62″ " "	.066
66″ " "	.070

SLIDING FITS, AMOUNT OF SWING TO ALLOW WHEN CALIPERING.

It is not only difficult, but entirely impossible to establish definite rules and figures that can be adopted by all mechanics as a guide to govern themselves by when making a fit with adjustable calipers.

To be able to turn or bore a fit with the aid of such calipers is so wholly a matter of good judgment and delicacy of touch that it denotes a high degree of skill and proficiency on the part of the workman who can do so and know that he is doing so without resorting to the "cutting and trying" method.

The following table, while by no means a positive guide for all, will, however, prove of value to many and tend to develop good judgment and proficiency on this point.

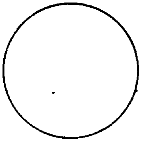
The table shows the distance the calipers should swing in a hole to have it fit a shaft the size of which was transferred onto the calipers. Thus if a hole is to be bored to have it slide onto a 3″ shaft, one point of the calipers would require to swing ½″ in the hole with the other resting against one side.

TABLE.

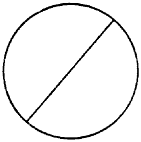
Diam. of Hole in Inch.	Swing of Calipers.	Diam. of Hole in Inch.	Swing of Calipers.	Diam. of Hole in Inch.	Swing of Calipers.
1 to 2	¼	22 to 26	1½	62 to 66	4
2 " 3	⅜	26 " 30	1¾	66 " 70	4¼
3 " 4	½	30 " 34	2	70 " 74	4½
4 " 6	⅝	34 " 38	2¼	74 " 78	4¾
6 " 8	11/16	38 " 42	2½	78 " 82	5
8 " 10	¾	42 " 46	2¾	82 " 86	5¼
10 " 12	⅞	46 " 50	3	86 " 90	5½
12 " 15	1	50 " 54	3¼	90 " 95	5¾
15 " 18	1⅛	54 " 58	3½	95 " 100	6
18 " 22	1¼	58 " 62	3¾		

CIRCLES.

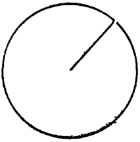
A circle is a plain figure, bounded by a curved line, all points of which are equally distant from a point within, called the centre, thus:



The diameter of a circle is a straight line drawn through its centre, touching both sides, thus:



The radius of a circle is half the diameter, thus:



An arc is any part of the circumference of a circle, thus:

The area of a circle is the number of square inches it contains. Used in connection with the steam engine, it means the number of square inches in the piston, or valve, against which steam acts.

RULES.

1. To find the *circumference* of a circle, *multiply the diameter* by 3.1416; the product will be the circumference.

Or, multiply the diameter by 22 and divide that product by 7.

EXAMPLE, DIAMETER OF CIRCLE 30″.

Hence, 22 × 30 = 660, then 660 ÷ 7 = 94 2-7″ circumference.

Or, multiply the diameter by 355 and divide that product by 113. This rule is more nearly correct.

EXAMPLE, DIAMETER OF CIRCLE 30″.

Hence, 355 × 30 = 10650, *then* 10650 ÷ 113 = 94¼″ circumference.

2. To find the *diameter* of a circle, *divide the circumference* by 3.1416 the quotient is the diameter.

Or, multiply the circumference by 7 and divide by 22.

EXAMPLE, CIRCUMFERENCE OF CIRCLE 56 4-7″.

Hence, 7 × 56 4-7 = 396, then 396 ÷ 22 = 18″ diameter.

Or, multiply the circumference by 113 and divide by 355.

EXAMPLE, CIRCUMFERENCE OF CIRCLE.

56 62-113″.

Hence, 113 × 56 62-113 = 6390, then 6390 ÷ 355 = 18″ diameter.

3. To find the area of a circle, multiply the diameter by the circumference, and divide by 4,

the quotient is the area. Or multiply half the circumference by half the diameter, the product is the area. Or multiply the square of the diameter by .7854.

EXAMPLE.

Diameter of circle, 12″; square of same, 144″; thus .7854 × 144 = 113.09, area.

HOW TO FIND THE SQUARE AND CUBE OF A CIRCLE.

When a number is multiplied by itself once, the product is known as the square of that number; when multiplied by itself twice it is known as the cube of that number. If the number designates the size of a circle then the product becomes respectively the square or cube of that circle as the case may be.

EXAMPLE.

Circle 6″ diameter, then multiplied once as 6 × 6 = 36, the square, and multiplied twice by itself as 6 × 6 = 36 and 6 × 36 = 216 the cube of a 6″ circle.

How to find the diameter of an arc, or the complete circle from a part of the same only:

Suppose you are given a broken piece of a pulley, or cylinder, or a piece from any other part of a machine of which the diameter became lost, and you are required to find the same, use the following rule:

RULE—Lay the broken piece on a clean smooth board or piece of new tin, scribe an arc as large as the piece will permit, then draw three circles with the centre of each on the arc, these circles intersecting each other about $\frac{1}{4}$; then draw two lines across the points where the circles intersect, and the point where the two lines cross each other will be the centre of your circle or half of its diameter.

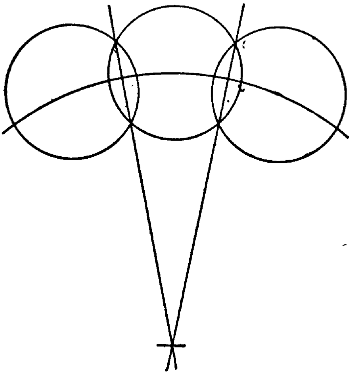


ILLUSTRATION.

To find the length of side for an inscribed square of a given circle, *multiply* the diameter by .7071.

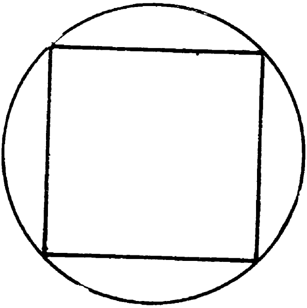
EXAMPLE, DIAMETER OF CIRCLE 6″.

Thus, .7071 × 6 = 4.4226 or $4\frac{1}{2}$″ nearly.

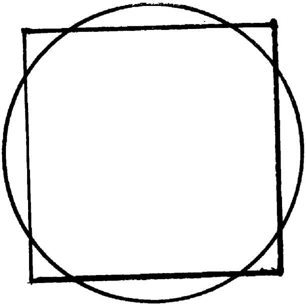
To find the diameter of a circle for a given inscribed square, *divide* the length of side by .7071.

EXAMPLE.

Length of side of given square 4.2426 or 4½″; thus, 4.2426 ÷ 7071 = 6″.



To find the length of side for a square whose area is equal to that of a given circle, *multiply* the diameter by .8862.



EXAMPLE, DIAMETER OF CIRCLE 6″.

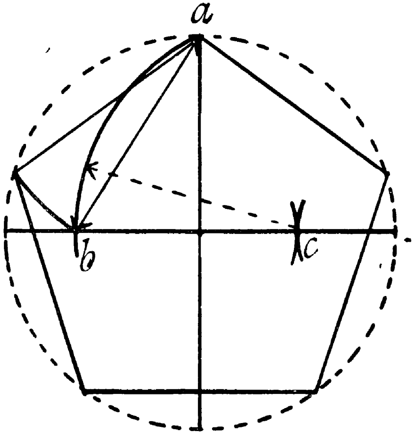
Thus, .8862 × 6 = 5.3172, or 5 5-16″ square. Area of same is 28.27, same as 6″ circle.

☞ To find the diameter of a circle whose area is equal to that of a given square, *divide* the length of side by .8862.

EXAMPLE—Length of side of square 5.3172 or 5 5-16″; thus 5.3172 ÷ .8862 = 6″ diameter.

TO LAY OUT A PENTAGON.

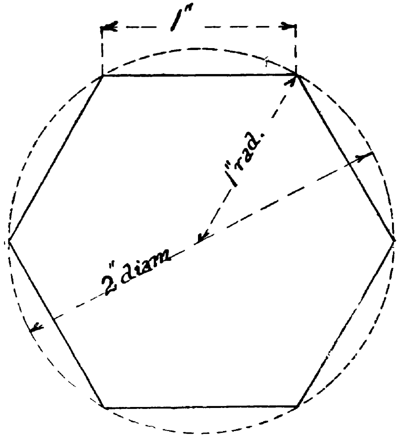
To lay out a circle or round piece of work five-sided, bisect the horizontal line and find the point



c, then set a pair of dividers on the point *c* to the point *a*, and scribe an arc, thus finding the point *b*, then set a pair of dividers to the distance *a* and *b*, which will step of the circle into five equal spaces.

HOW TO LAY OUT A HEXAGON.

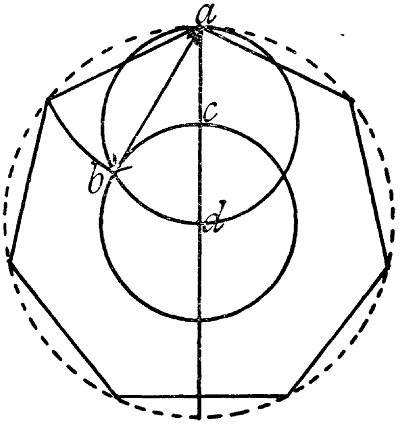
To lay out a round piece of work six-sided (hexagon) as for a nut, set a pair of dividers to



one half of the diameter which distance will step off the circumference into six equal spaces.

TO LAY OUT A HEPTAGON.

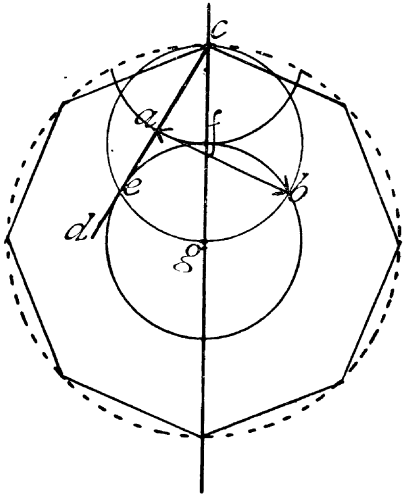
To lay out a circle or round piece of work seven-sided, draw two smaller circles within the large one from centers *c* and *d*, whose diameters are equal to the radius of the large one, thus finding



the point *b* where both circles intersect, then set a pair of dividers to the distance *a* and *b*, which will step off the circle into seven equal spaces.

TO LAY OUT AN OCTAGON.

To lay out a circle eight-sided, draw two smaller circles within the large one, from centres *f* and *g*, equal to the radius of the large circle, and an arc from the centre *c*, then draw the line from *c* to *d*,



just touching the inner circle at *e*, thus finding the distance from *a* to *b*, and a pair of dividers set to that distance will step off the circle into eight equal spaces.

Circumference of Circles.

ADVANCING BY EIGHTHS.

Diam.	CIRCUMFERENCES.							
	0	⅛	¼	⅜	½	⅝	¾	⅞
0	.0	.3927	.7854	1.178	1.570	1.963	2.356	2.748
1	3.141	3.534	3.927	4.319	4.712	5.105	5.497	5.890
2	6.283	6.675	7.068	7.461	7.854	8.246	8.639	9.032
3	9.424	9.817	10.21	10.60	10.99	11.38	11.78	12.17
4	12.56	12.95	13.35	13.74	14.13	14.52	14.92	15.31
5	15.70	16.10	16.49	16.88	17.27	17.67	18.06	18.45
6	18.84	19.24	19.63	20.02	20.42	20.81	21.20	21.59
7	21.99	22.38	22.77	23.16	23.56	23.95	24.34	24.74
8	25.13	25.52	25.91	26.31	26.70	27.09	27.48	27.88
9	28.27	28.66	29.05	29.45	29.84	30.23	30.63	31.02
10	31.41	31.80	32.20	32.59	32.98	33.37	33.77	34.16
11	34.55	34.95	35.34	35.73	36.12	36.52	36.91	37.30
12	37.69	38.09	38.48	38.87	39.27	39.66	40.05	40.44
13	40.84	41.23	41.62	42.01	42.41	42.80	43.19	43.58
14	43.98	44 37	44.76	45.16	45.55	45.94	46.33	46 73
15	47.12	47.51	47.90	48.30	48.69	49.08	49.48	49.87
16	50.26	50.65	51.05	51 44	51.83	52.22	52.62	53.01
17	53.40	53.79	54.19	54 58	54.97	55.37	55.76	56.15
18	56.54	56.94	57.33	57.72	58.11	58.51	58.90	59.29
19	59.69	60.08	60.47	60.86	61.26	61 65	62.04	62.43
20	62.83	63.22	63.61	64.01	64.40	64.79	65.18	65.58
21	65.97	66.36	66.75	67.15	67.54	67.93	68.32	68.72
22	69.11	69.50	69.90	70.29	70.68	71.07	71.47	71.86
23	72.25	72.64	73.04	73 43	73.82	74.22	74.61	75 00
24	75.39	75.79	76.18	76.57	76.96	77.36	77.75	78.14
25	78.54	78.93	79.32	79.71	80.10	80.50	80.89	81 28
26	81 68	82.07	82.46	82.85	83.25	83.64	84 03	84.43
27	84.82	85.21	85.60	86.00	86.39	86.78	87.17	87.57
28	87.96	88.35	88.75	89.14	89.53	89.92	90.32	90.71
29	91.10	91.49	91.89	92.28	92.67	93.06	93.46	93 85
30	94.24	94.64	95.03	95.42	95.81	96.21	96.60	96.99
31	97.39	97.78	98.17	98.57	98.96	99.35	99.75	100.14
32	100.53	100.92	101.32	101.71	102.10	102.49	102.89	103 29
33	103.67	104.07	104.46	104.85	105.24	105.64	106.03	106.42
34	106.81	107.21	107.60	107.99	108.39	108.78	109.17	109.56
35	109 96	110.35	110.74	111.13	111.53	111.92	112.31	112.71
36	113.10	113.49	113.88	114.28	114.67	115.06	115.45	115.85
37	116.24	116.63	117.02	117.42	117.81	118.20	118.61	118.99
38	119.38	119.77	120.17	120.56	120.95	121.34	121.74	122.13
39	122.52	122.92	123.31	123.70	124.09	124.49	124.88	125.27
40	125.66	126.06	126.45	126.84	127.24	127.63	128.02	128.41
41	128.81	129.20	127.59	129.98	130.38	130.77	131.16	131.55
42	131.95	132.34	132.73	133.13	133.52	133.91	134.30	134.70
43	135.09	135.48	135.87	136.27	136 66	137.05	137.45	137.84
44	138.23	138.62	139.02	139.41	139.80	140.19	140.59	140.98
45	141.37	141.76	142.16	142.55	142.94	143.34	143.73	144.12

Areas of Circles.

ADVANCING BY EIGHTHS.

Diam.	AREAS.							
	0	⅛	¼	⅜	½	⅝	¾	⅞
0	.0	.0122	.0490	.1104	19.63	.3068	.4417	.6013
1	.7854	.9940	1.227	1.484	1.767	2.073	2.405	2.761
2	3.1416	3.546	3.976	4.430	4.908	5.411	5.939	64.91
3	7.068	7.669	8.295	8.946	9.621	10.32	11.04	11.79
4	12.56	13.36	14.18	15.03	15.90	16.80	17.72	18.66
5	19.63	20.62	21.64	22.69	23.75	24.85	25.96	27.10
6	28.27	29.46	30.67	31.91	33.18	34.47	35.78	37.12
7	38.48	39.87	41.28	42.71	44 17	45.66	47.17	48.70
8	50.26	51.84	53.45	55.08	56.74	58.42	60.13	61.86
9	63 61	65.39	67.20	69.02	70.88	72.75	74.69	76.58
10	78.54	80.51	82.51	84.54	86.59	88.66	90.76	92.88
11	95.03	97.20	99.40	101.6	103.8	106.1	108.4	110.7
12	113.0	115.4	117.8	120.2	122.7	125.1	127.6	130.1
13	132.7	135.2	137.8	140.5	143.1	145.8	148.4	151.2
14	153 9	156.6	159.4	162.2	165.1	167.9	170.8	173.7
15	176.7	179.6	182.6	185.6	188.6	191.7	194.8	197.9
16	201.0	204.2	207.3	210.5	213.8	217.0	220.3	223.6
17	226.9	230.3	233.7	237.1	240.5	243.9	247.4	250.9
18	254.4	258.0	261.5	265.1	268.8	272.4	276.1	279.8
19	283.5	287.2	291.0	294.8	298.8	302.4	306.3	310.2
20	314.1	318.1	322.0	326.0	330.0	334.1	338.1	342.2
21	346.3	350.4	354.6	358.8	363.0	367.2	371.5	375.8
22	380.1	384 4	388.8	393.2	397.6	402.0	406.4	410.9
23	415.4	420.0	424.5	429.1	433.7	438.3	443.0	447.6
24	452 3	457.1	461.8	466.6	471.4	476.2	481.1	485.9
25	490.8	495 7	500.7	505.7	510.7	515.7	520.7	525.8
26	530 9	536.0	541.1	546.3	551.5	556 7	562.0	567.2
27	572.5	577.8	583.2	588.5	593.9	599.3	604.8	610.2
28	615 7	621.2	626.7	632.3	637.9	643.5	649.1	654.8
29	660.5	666.2	671.9	677.7	683.4	689.2	695.1	700.9
30	706.8	712.7	718.6	724.6	730.6	736.6	742.6	748.6
31	754 8	760.9	767.0	773.1	779.3	785.5	791.7	798.0
32	804.3	810.6	816.9	823.2	829.6	836.0	842.4	848.8
33	855.3	861.8	868.3	874.9	881.4	888.0	894.6	901.3
34	907.9	914.7	921.3	928.1	934.8	941.6	948.4	955.3
35	962.1	969.0	975.9	982.8	989.8	996.8	1003.8	1010.8
36	1017 9	1025.0	1032.1	1039.2	1046.3	1053.5	1060.7	1068.0
37	1075.2	1082.5	1089.8	1097.1	1104.5	1111.8	1119.2	1126.7
38	1134.1	1141.6	1149.1	1156.6	1164.2	1171.7	1179.3	1186.9
39	1194.6	1202.3	1210.0	1217.7	1225.4	1233.2	1241.0	1248.8
40	1256.6	1264.5	1272.4	1280.3	1288.2	1296.2	1304.2	1312.2
41	1320.3	1328.3	1336.4	1344.5	1352.7	1360.8	1369.0	1377.2
42	1385.4	1393.7	1402.0	1410.3	1418.6	1427.0	1435.4	1443.8
43	1452.2	1460.7	1469.1	1477.6	1486.2	1494.7	1503.3	1511.9
44	1520.5	1529.2	1537.9	1546.6	1555.3	1564.0	1572.8	1581.6
45	1590.4	1599.3	1608.2	1617.0	1626.0	1634.9	1643.9	1652.9

HOW TO FIGURE SPEED.

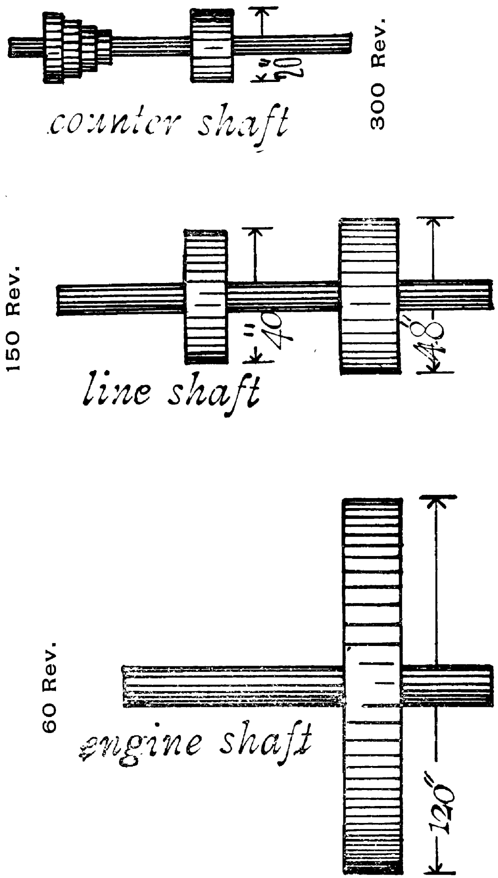
The ability to accurately and without difficulty find the speed of any shaft or machine, or to find the correct size of a pulley in order to make a shaft or machine run the desired speed, is an enviable accomplishment for any mechanic to possess.

To attain this accomplishment is, however, not very difficult. A moderate amount of study and application will help anyone to become proficient.

1—HOW TO FIND SPEED.

The first to do is to find the number of revolutions per minute of the main or line shaft, and to always reduce the diameter of all pulleys to inches and to figure the same as such. Then find the speed of the line shaft as follows:

RULE—Multiply the number of inches of the driving pulley on the engine shaft by the number of revolutions per minute of the engine; divide that product by the diameter of the driven pulley on the line shaft; the result will be the speed of the line shaft per minute.


20"
counter shaft
300 Rev.
150 Rev.
40"
48"
line shaft
60 Rev.
engine shaft
120"

EXAMPLE.

Speed of engine per minute, 60 revolutions.
Driving pulley on engine, 10 ft. = 120 in.
Driven pulley on line shaft, 4 ft. = 48 in. .

```
      120
       60
    ------
48)7200(150 revolutions of line shaft
   48            per minute.
   ---
   240
   240
   ---
```

You now have the speed of the line shaft, simply continue the same process of figuring until you reach the shaft, pulley or machine you desire to known the speed of.

Always multiply the driver in inches by its own number of revolutions per minute, and divide that product by the driven in inches; the result is always the number of revolutious per minute of the driven.

2—HOW TO FIND THE SIZE OF A PULLEY FOR ANY REQUIRED SPEED.

Suppose you have a counter-shaft with a pulley on, which is to run 300 revolutions per minute, and you wish to find the size of the pulley to put on the line shaft to drive it, reverse the order of things and proceed in this manner:

RULE—Multiply the counter-shaft pulley by the number of revolutions per minute the countershaft is to run; then divide that product by the number of revolutions of your line shaft; the result will be the size of the pulley to use.

EXAMPLE.

Counter-shaft, 300 revolutions per minute.
Pulley on counter shaft, 20 inches.
Line shaft, 150 revolutions per minute.

```
        300
         20
      ------
  150)6000(40 inches, size of pulley for
      600           line shaft.
      ---
```

THE STEAM ENGINE.

There is no end of literature written on the subject of the steam engine. The manner, however, in which a great portion of it is written rather has a tendency to bewilder the average reader, than to assist him, and the tendency is to invest the subject with additional difficulties rather than to simplify it.

It shall be our aim to treat the subject in as plain and simple terms as possible, to make it comprehensible to all.

All steam engines, of whatever design or for whatever purpose employed, are embraced in two classes:

1. High pressure or non-condensing engines.
2. Low pressure or condensing engines.

1. A high-pressure or non-condensing engine is an engine that exhausts the used steam direct from its cylinder to the open air. Therefore the pressure of the outgoing steam must exceed the atmospheric pressure or 15 pounds to the square inch. Thus it will be seen that 15 pounds of the average steam pressure against the piston of a high pressure engine will not be converted into work, as it is lost in overcoming the pressure of the atmosphere.

2. A low pressure or condensing engine is an engine that exhausts its steam from the cylinder into a condenser, where it is quickly condensed or reduced to water, thereby creating a vacuum in that end of the cylinder and making a considerable portion of the 15 pounds of atmospheric pressure available as effective force against the opposite side of the piston.

SIMPLE AND COMPOUND ENGINES.

All engines, whether high or low pressure, are also divided into:

1. Simple engines.
2. Compound engines.

1. Simple engines are all engines, whether they are double (as the locomotive) or single, which use steam only once.

2. Compound engines are such as use the steam twice or three times, by passing the same from one cylinder into another before finally exhausting to the air or condenser.

CUT-OFFS.

All engines, whether high or low pressure, simple or compound, are also divided as to their particular style of cut-off into three principal classes, viz:

1. Positive cut-off.
2. Adjustable cut-off.
3. Automatic cut-off.

1. In the positive cut-off the steam is cut off at the same point in each stroke of the piston, and the governor governs the admission of steam from the steam-pipe to the *steam chest* of the cylinder.

2. In the adjustable cut-off the point of cut-off can be adjusted and is governed at will by the engineer, by means of a screw, hand wheel, or as in the locomotive, by the reverse lever, to suit the variations of grade, load or travel.

3. In the automatic cut-off the governor governs the valve gear, thereby governing the admission of steam direct to the cylinder, instead of the steam chest, as in the positive cut-off.

The governor therefore entirely and automatically governs the admission of steam for a longer or shorter period of each stroke direct to the cylinder, according to the variation of load; hence the term "automatic."

HORSE POWER OF STEAM ENGINES.

The power which a steam engine can furnish is generally expressed in "horse power;" the "nominal horse power" is admitted to be a force capable of raising a weight of 33,000 pounds one foot high in one minute. In other words the standard horse power is 33,000 foot pounds. A foot-pound is one pound lifted one foot per minute, or an equivalent amount of force, such as half a pound lifted two feet per minute, or twelve pounds lifted one inch per minute.

The force of gravity is so widespread and so thoroughly understood that power is always compared with the process of lifting. Watt, an inventor of note, found 33,000 foot-pounds to be the average force exerted by the common English draught-horse of his time, which comparison was also applied to the steam engine, hence the term "horse power."

If an engine is rated at 25 horse power, it is therefore recognized as being capable of raising 33,000 pounds one foot high twenty-five times in each minute.

HOW TO FIND THE HORSE POWER OF AN ENGINE.

RULE—Multiply the area of the piston in inches by the average steam pressure in pounds per square inch; multiply this product by the travel of the piston in feet per minute, and divide that product by 33,000; the quotient is the horse power.

EXAMPLE.

Diam. of piston, 16″; area of same, 201″.

Steam pressure, 50 lbs.

Engine 18″ stroke at 80 revolutions per minute makes number of feet of travel of piston 240.

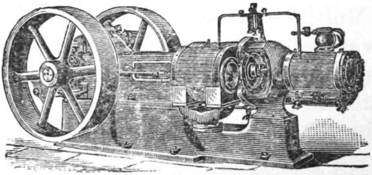
```
         201 area of piston.
          50 steam pressure.
        -----
       10050
         240 piston travel.
      -------
      402000
     20100
    --------
33000)2412000(73 1-11 nominal horse.
     231000
    -------
      102000
       99000
      ------
        3000
```

To find the travel of the piston in feet per minute, use this rule:

RULE—Multiply the travel of the piston in inches by twice the number of revolutions of the engine and divide by 12.

EXAMPLE.

18″ stroke 80 revolutions, hence $160 \times 18 = 2880 \div 12 \doteq 240$ feet of piston travel per minute.



HOW TO FIND THE HORSE POWER OF A COMPOUND ENGINE.

It is customary in designing compound engines to make the diameter of the large cylinder of such size that its area shall be about three times as great as that of the small one. If, for example, the small cylinder is 15″ diameter, its area is 176″; then the area of the large one is about three times 176″ or 528″, or about 26″ diameter. This arrangement becomes necessary for the purpose of gaining a margin in favor of the larger cylinder over that of the smaller one; as the area of the small one is balanced by an equal amount of area in the large one for which there is no gain in power. This amount of area must be deducted from the area of the large cylinder and the margin thus remaining in favor of same is the amount of area to be multiplied by its average steam pressure, and not the total area.

The small cylinder is termed the high pressure cylinder, and the large one the low pressure cylinder, which in this case is done to express the difference only, and does not imply that it is a condensing engine; meaning that the pressure per square inch is less or lower in the larger cylinder than that of the smaller one. If the steam exhausts out of the last cylinder into a condenser then it is known as a compound low pressure or condensing engine; if not, it is known simply as a compound engine.

The average or mean pressure in a low pressure cylinder is found to be about one-third that of the high pressure cylinder. Sixty pounds pressure in the small cylinder will furnish about 20 lbs. pressure in the large one. Thus, to find the horse power of a compound engine, figure the high pressure cylinder first, same as if it were a simple engine and note the result; then deduct the area of the high pressure cylinder from that of the low pressure cylinder, and multiply the remaining area by its average steam pressure, which is about one-third of that in first cylinder; multiply that product by the number of feet of piston travel per minute, which is the same as for first cylinder, and divide by 33,000; the result will be the horse power furnished by the low pressure cylinder, which amount added to that of the high pressure cylinder is the combined horse power of the compound engine.

EXAMPLE.

Diameter of small cylinder 16″, area 201″; diameter of large cylinder 27¾″, area 604″, less 201″ = 403″, margin of area. Average steam pressure in small cylinder 60 lbs.; average steam pressure in large cylinder 20 lbs. Stroke 18″, at 150 revolutions make 450 feet of piston travel per minute.

Thus 201 × 60 = 12,060, and 12,060 × 450 = 5,427,000 ÷ 33,000 = 164 horse power of small cylinder.

And 403 × 20 = 8,060, and 8,060 × 450 = 3,627,000 ÷ 33,000 = 109, horse power of large cylinder; then 164 + 109 = 273, combined horse power of both cylinders.

NOTE.—The only accurate method of finding the horse power of an engine is, of course, by the use of the steam engine indicator; but as such an instrument is not always at hand nor its use convenient, the above rules will be found excellent substitutes, and will give results so nearly correct as to answer all practical purposes.

AVERAGE STEAM PRESSURE.

The mean or average steam pressure as computed in connection with the horse power of the steam engine is less than the boiler pressure, according to the point of cut-off, and is found by multiplying the boiler pressure by the decimals in the following table opposite to the given point of cut-off. If, for example, the boiler pressure is 90 lbs. and the valve cuts off at ¼ stroke, then 90 × .597 = 53.73, average steam pressure. If 110 lbs. is the boiler pressure and cut-off occurs at ½ stroke, then 110 × .847 = 93.17, average steam pressure, etc.

¼	stroke	multiply	boiler	pressure	by	.597
⅓	"	"	"	"	"	.670
⅜	"	"	"	"	"	.743
½	"	"	"	"	"	.847
⅝	"	"	"	"	"	.919
⅔	"	"	"	"	"	.937
¾	"	"	"	"	"	.966
⅞	"	"	"	"	"	.992

HOW TO SET A SLIDE VALVE.

First satisfy yourself that the valve rod connections are properly adjusted as to length, then proceed as follows:

RULE—Place the crank pin on the dead centre, then move the eccentric round in the direction the engine is intended to run, until the valve begins to open the steam port and shows the required amount of lead, usually about 1-32, then fasten your eccentric. Next turn the engine over (always in the direction it is intended to run) on the opposite centre and if the lead is the same (as it will be if your connections are of correct length) the valve is correctly set.

NOTE 1—To determine if your connections are adjusted to the proper length, before setting valve, proceed as follows:

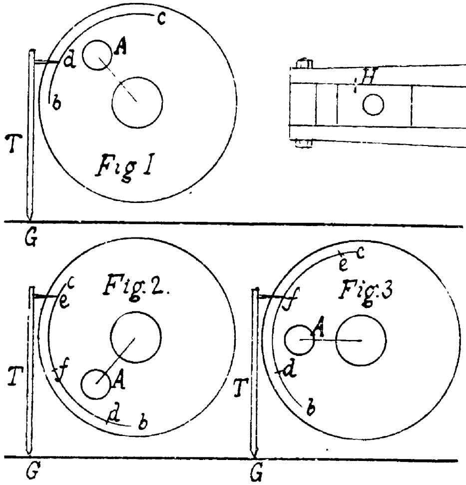
Turn the engine round by hand and scribe a mark on the valve seat each side of the valve where it stops and commences to travel the other way. If the distance from the marks to the steam ports on both sides is equal, your length is correct; if not, lengthen or shorten the same until it is so.

For the sake of convenience, the eccentric may be loosened and it can be pulled around instead of the entire engine, to determine the same thing.

NOTE 2—To find the dead centre of the crank pin, use a surface gauge. Set it on the bed-plate opposite to the crank-shaft and adjust the needle to the centre of the shaft. Then place the surface gauge opposite to the crank pin and pull the engine around until the centre of the crank-pin comes to the height of the needle.

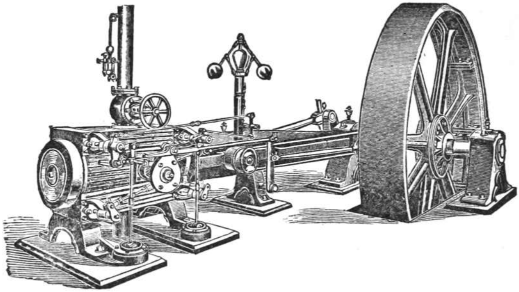
If a surface gauge is not at hand, a thin piece of board with one end pointed to the height of the centre of the shaft may be used. This method may be employed in all ordinary cases. However, where a surface gauge cannot be used or when a more accura e method is desired, the following method should be employed:

Scribe an arc *b c*, as shown in Fig. 1, upon the side or surface of the crank disc or fly wheel, all points of same equally distant from centre of shaft. Place the crank at any convenient distance *A* above the centre, and from any convenient fixed point *G* on the floor, or frame of engine, and with a tram *T* mark off a point *d* on the arc *b c*; also, while in this position, scribe a line *H* on the cro shead and guides. Turn the crank below the centre; this will cause the line *H* on the crosshead to move away from its mate on the guide, and finally return to it; when both are again in line. stop turning the crank; it will then have the position as shown at *A* in Fig. 2. From the fixed point *G*, and with the tram *T*, mark off a point *e* on the arc *b c*. With the dividers find the point *f* midway between *e* and *d*; and turn the crank so that the point of the tram will be on the point *f*, as shown in Fig. 3; the crank will then be on one of its dead centres. In a similar way the other dead centre is found. One precaution is necessary in turning the crank to its dead centre—move the crank a little above its centre, and then back until the point *f* coincides with the end of the tram. The reason for this is to make the crank pin press against the same brass for all positions of the crank, so as to obviate any error that might arise from looseness in the crank-pin and crosshead pin bearings.



An engine with a rock-arm is of *indirect* connection, in which case the crank-pin always leads the eccentric.

An engine without a rock-arm is of direct connection and in that case the eccentric always leads the crank-pin.



HOW TO SET THE VALVES OF A CORLISS ENGINE.

To set the valves of a Corliss engine is really no more difficult than it is to set a common slide valve, when it is borne in mind that the four edges of the slide valve are each represented in the Corliss by a separate valve. The upper or steam valves represent the outer edges, and the lower or exhaust valves represent the inner edges of the slide valve, and each of these separate valves performs the functions of one of the edges only.

The upper or steam valves admit and cut off the steam, and the lower or exhaust valves open and close the exhaust. Both the end of each valve and its seat on the cylinder bear marks to set by, which become exposed to view by remov- the back bonnets or valve covers from the cylinder. So also is the hub of the wrist-plate, and its corresponding hub of the stand which supports the same marked for its central and its extreme travel positions.

To set the valves proceed as follows: Remove the back bonnets or valve covers thus exposing the valve and seat marks, then connect the eccentric hook or rod to its pin on the wrist-plate, and turn the eccentric around loose on the shaft, and notice that the centre mark on wrist-plate just lines with the two marks on wrist-plate stand hub at both extremes of its travel; if it does not do so, lengthen or shorten the rod as the case may require until it does exactly line on both sides. Then place the wrist-plate in a vertical position, bringing the two centre marks exactly in line and adjust the valve rods until the steam valves show by the closing edge marks upon their ends that they overlap or cover the ports from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch, according to the size of engine, and the exhaust valves just open, say from 1-64 to 1-16 of an inch. Then place the crank on either dead centre and move the eccentric around loose on the shaft in the direction the engine is to run, a trifle more than at right angles, ahead of the crank until the steam valve on the same end as the piston just begins to show lead, or opens from 1-32 to 1-8 according to size and make of engine; then fasten the eccentric in that position and move the engine around on the other dead centre (always in the direction the engine is to run) and see that the steam valve on that end shows the same lead or opening; if it does, the adjustment is correct, if not, lengthen or shorten the wrist plate rod attached to that valve, as the case may require.

Then adjust and equalize the cut-off by blocking up the governor to about its average position when running; move the engine around by hand and measure the distance traveled by the crosshead when valve unhooks, and adjust until the desired distance, equal on each end, is obtained.

HOW TO LINE UP AN ENGINE.

Draw a line through the cylinder, attaching one end of it to a stick fastened to the cylinder by one of the stud nuts, and the other end to a stake driven to the floor at the back end of the bed-plate or fastened to same by a screw clamp. Then with a piece of hard wood or stiff wire pointed at each end and equal in length to half the diameter of the cylinder, set the line so that when one point of the wood or wire is placed against the cylinder, the other end will feel the line; if it will do this from four opposite points of the cylinder at each end, the line is exactly central to the cylinder. Next see if this line passes through the centre of the shaft; if so, the shaft is in line with the cylinder, if not it must be raised or lowered as the case may be. Now turn the engine-shaft around until the crank-pin almost touches the line; then ascertain by measurement whether the line is central to the collars on the crank-pin. Then turn the shaft on the other centre until the crank-pin again feels the line, and if the measurements correspond, the shaft is in line, or rather at right angle to the cylinder; if not it must be adjusted.

HOW TO SPEED AN ENGINE.

1. To find the diameter of engine-shaft pulley for governor belt.

The number of revolutions the governer is intended to run is always given by the builder. Hence to find the size of pulley to put on the engine shaft for any desired speed of the engine use the following rule:

RULE—Multiply the diameter of the governor pulley in inches by the number of revolutions of the governor, and divide that product by the desired number of revolutions of the engine. The result will be the diameter of the pulley to put on the engine shaft.

EXAMPLE.

Speed of governor 100 revolutions per minute.
Size of governor-pulley, 8 inches.
Desired speed of engine, 80 rev. per minute.

```
      100
        8
     ----
   80)800(10 inches, size of pulley for
      800           engine shatt.
     ----
```

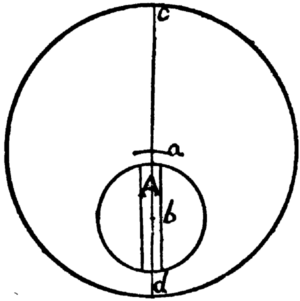
2. To find the diameter of the governor-shaft pulley. .

RULE—Multiply the number of revolutions of the engine by the diameter of the pulley on the engine shaft, then divide that product by the number of revolutions of the governor.

EXAMPLE.

Number of rev. of engine, 80 per minute.
Diameter of pulley on engine shaft. 10 inches.
Speed of governor, 100 rev. per minute.

```
       80
       10
     ----
  100)800(8 inches. size of pulley for
      800          governor.
     ----
```



HOW TO FIND THE THROW OF AN ECCENTRIC.

RULE--Measure the eccentric on the heaviest side, then measure the same on the opposite or light side. The difference between the two measurments will be the throw.

HOW TO LAY OUT AN ECCENTRIC.

RULE--Put a centre *A* across the hole parallel to centre *a* of the eccentric and mark the exact centre of the hole by a light centre-punch mark *b*. Then scribe a line *c d* from the heaviest point of the throw across the centre-punch mark *b* of the hole. Next set a pair of dividers to exactly half of the desired throw; set one point of the dividers into the centre-punch mark *b* of the hole and with the other point scribe a mark *a* across the line *c d*. The point *a* where the mark crosses the line *c d* will be the centre of the eccentric, from which point lay out the outside diameter.

HORSE POWER OF STEAM BOILERS.

As each department of practice in which steam boilers are used has its own measure of horse power, it becomes self evident that the horse power of a boiler cannot be given with exactness independent of the special service to which it is put and without considering all the attendant conditions.

A boiler may be capable of supplying an automatic cut-off engine, having all the refinements of economic workings with sufficient steam to develop 100 horse power; whereas, the same boiler supplying an ordinray side-valve engine may be able to develop only 75 or 80 horse power, etc. In short, many conditions must be considered to calculate the horse power of a boiler with any degree of accuracy, such as the style and make of boiler, design, quality of material used in its con-truction, amount of heating surface, grate surface, amount of pressure carried, conditions of cleanliness, degree of purity of water used, draft, quality and kind of fuel used, attendance, the special use to which it is put, etc., etc.

In general practice, however, it is customary to consider a certain number of feet of heating surface equivalent to one horse power, and to allow a certain number of feet of grate surface for each horse power; these, when the other conditions are not known or given, and the approximate horse power of a boiler is to be determined, are taken as a basis for the calculation; that is, its heating surface is found and the grate surface determined; from this data then, the approximate amount of fuel that may be consumed per hour on that amount of grate surface, and the amount of water that would be evaporated per hour by that amount of heating and grate surface, and the volume of steam that may thus be produced can all be approximately determined.

In tublar boilers 15 square feet of heating surface is considered equivalent to one horse power.

In flue and locomotive boilers 12 to 14 feet of heating surface is considered equivalent to one horse power.

In cylinder boiler 10 square feet of heating surface is considered equivalent to one horse power.

One square foot of grate surface is allowed to each 40 to 60 square feet of heating surface, the average being 50 square feet, or about 1 square foot of grate surface to each 3 horse power. Thus a boiler having a heating surface of 1500 square feet would require about 30 to 35 square feet of grate surface; and the 1500 square feet of heating surface divided by 14, the number of square feet of heating surface required for one horse power, will give the approximate horse power of the boiler; thus, 1500 ÷ 14 — 107 horse power.

The heating surface of a boiler comprises all the surfaces exposed to the action of the fire and which have water on the other side. If a boiler is externally fired it will include from ½ to ⅔ of the circumference of the shell its entire length and the total internal circumference of the flues their entire length; all these surfaces in inches added together and divided by 144 will give the number of square feet of heating surface, and that quotient divided by 15 will give the approximate horse power of the boiler.

If the boiler has a fire box and is internally fired, then all sides of the fire box above the grates, the crown sheet, and the internal circumferences of all the flues their entire length comprise the heating surface, which found in inches and divided by 144, will give the numb r of square feet of same, and that quotient divided by 12, 13 or 14, as the case may require, will give the horse power.

From 2 to 4 lbs. of coal are required per hour for each horse power. Wasteful and badly managed engines and boilers will show a consumption of 5, 6 and some as high as 7 lbs. of coal, while the best practice is not satisfied with anything larger than $1\frac{3}{4}$ lbs of coal per hour for each horse power. A 100 horse power boiler, therefore, to be working economically, ought not to consume over 200 to 400 lbs. of coal per hour, or an average of 300 lbs., which would be a total of 3000 lbs. of coal for a working day of 10 hours.

A pound of coal under ordinary favorable conditions will evaporate about 10 lbs. of water in the boiler. The 300 or 400 lbs. of coal necessary for a 100 horse power boiler per hour, will therefore evaporate from 3000 to 4000 lbs. of water per hour, which amount divided by $8\frac{1}{3}$, the weight of 1 gallon of water, will show the number of gallons evaporated in a 100 horse power boiler per hour; thus, $3000 \div 8\frac{1}{3} = 360$ gallons, and $10 \times 360 = 3600$ per day of 10 hours.

SAFETY-VALVES.

A safety-valve is, as its name implies, a device attached to the boiler for the purpose of assuring its safety against explosion from excessive pressure. It is designed to prevent the pressure from exceeding a certain limit by automatically opening when that limit is reached and allowing the surplus steam to escape, until the pressure has fallen a little below that limit, when it again automatically closes.

In construction the safety-valve is an extremely simple device, but in point of service extremely important. It must under no circumstances be neglected and allowed to become inoperative.

When determinating the area of a safety-valve for a certain boiler, it is of the utmost importance that the pressure to be carried be definitely known, as pressure and velocity are two constant factors that must enter into the calculation. Steam under high pressure decreases in volume but increases in velocity, and the area of a safety-valve for a boiler intended to carry 100 lbs. pressure per square inch would require to be less than if the same boiler was intended to carry only 50 lbs. pressure. So, also, does the lift of the valve decrease with the increase of pressure; that is it does not lift as high under a high pressure as it does under a lower pressure, because under a high pressure the volume of steam decreases and the velocity increases, thus permitting a greater number of pounds pressure to escape through a smaller opening at a faster rate. These seeming irregularities are nevertheless facts abundantly substantiated from actual tests by competent engineers.

While there does not seem to be any definite rule recognized among boilermakers for proportionating safety-valves, the following proportions are nevertheless closely adhered to in general practice, to allow 1″ of area of safety-valve for each 66 square feet of heating surface; or about 1″ of area of safety-valve for each $1\frac{3}{4}$ square feet of grate surface.

To find the pressure per square inch that safety valve will blow off at, multiply the weight of the ball in pounds by the length of the lever in inches; then multiply the weight of the lever by one half of its length in inches; next multiply the weight of the valve and stem by their distance from the fulcrum in inches and add these products together; then divide this sum by the length of the fulcrum in inches and again divide that quotient by the area of the valve, the last quotient will be the pressure in pounds the valve will blow off at.

EXAMPLE.

Weight of ball	48 lbs.
Length of lever......................	24 inches.
Weight of lever......................	3 lbs.
One-half length of lever	12 inches.
Weight of valve and stem...........	3 lbs.
Diam. of valve $2\frac{1}{2}$ inches, area of same	4.9 inches.

Then, 48 × 24 = 1152
and 3 × 12 = 36
and 3 × 3 = 9

Total, 1197

Then 1197 ÷ 3 = $397\frac{1}{3}$ ÷ 4.9 = 81 lbs. pressure safety valve will blow off at.

A shorter and easier method of obtaining the same result is as follows: Remove the ball from the lever, then with spring scales attached directly over the centre of the stem, lift the lever, stem and valve from its seat and note the number of pounds of weight shown on the scales. Then multiply the weight of the ball by the length of the lever, and divide that product by the distance of the valve from the fulcrum, to which quotient add the number of pounds as shown by the scales, and then divide that sum by the area of the valve, the quotient will be the pressure in pounds the valve will blow off at.

EXAMPLE.

Weight of ball......................	48 lbs.
Length of lever......................	24 inches.
Distance of valve from fulcrum......	3 inches.
Weight shown by scales..............	6 lbs.
Diam. of valve $2\frac{1}{2}''$, area of same .. .	4.9 inches.

Then, 48 x 24 = 1152 ÷ 3 = 384 + 6 = 390 ÷ 4.9 = 80 lbs pressure per inch valve will blow off at.

To find the weight of ball necessary to place on a safety-valve to blow off at a given pressure, multiply the area of the valve by the pressure in pounds, multiply that product by the distance of the valve from the fulcrum; then multiply the weight of the lever by one-half its length in inches, next multiply the weight of the valve and stem by their distance from the fulcrum, then add these last two products together and subtract their sum from the first product, and divide the remainder by the length of the lever; the quotient will be the required weight of the ball.

EXAMPLE.

Diam. of valve 2½″, area of same......	4.9 inches.
Pressure............................	81 lbs.
Distance of valve from fulcrum.....	3 inches.
Weight of lever....................	3 lbs.
One-half length of lever	12 inches.
Weight of valve and stem...........	3 lbs.
Length of lever.....................	24 inches.

Then, 4.9 × 81 = 397⅓ × 3 = 1197. And 3 × 12 = 36, and 3 × 3 = 9 36 + 9 = 45. Then, 1197 − 45 = 1152 ÷ 24 = 48 lbs. weight of ball.

The shorter method is to multiply the area of the valve by the pressure in pounds, from that product deduct the weight of the valve, stem and lever shown by the scales as above described; then multiply the remainder by the distance of the valve from the fulcrum, and divide that product by the length of the lever, the quotient will be the weight of the ball.

EXAMPLE.

Diam. of valve 2½″, area of same.....	4.9 inches.
Pressure............................	80 lbs.
Weight of valve, stem and lever as shown by scales...................	6 lbs.
Distance of valve from fulcrum......	3 inches.
Length of lever.....................	24 inches.

Thus, 4.9 × 80 = 392 − 6 = 386 × 3 = 1158 ÷ 24 = 48 lbs. weight of ball.

HYDRAULIC INFORMATION, AND CAPACITY AND POWER OF PUMPS.

A gallon of water (U. S. standard) weighs $8\frac{1}{3}$ lbs. and contains 231 cubic inches.

A cubic foot of water weighs 1000 ounces, or $62\frac{1}{2}$ lbs. and contains 1,728 cubic inches, or $7\frac{1}{2}$ gallons.

A column of water 1 foot high exerts a pressure of .434 lbs. per square inch at base. Hence to find the pressure for a given height or feet head, multiply the height by .434, the product will be the pressure per square inch.

A column of water 2.31 feet high exerts a pressure of 1 lb. per square inch at the base. Hence to find the height or feet head, the pressure being known, multiply the pressure by 2.31, the product is the height in feet.

To find the capacity or number of gallons a vessel, tank, barrel or cylinder will hold, multiply the mean area in inches by the depth in inches and divide by 231, the quotient will be the quantity in gallons or fractions thereof. For a pump cylinder multiply the area by the length of stroke and divide as above.

EXAMPLE.

Tank or cylinder 30″ diameter, area 706.8; depth or length of stroke 24″; hence, $706.8 \times 24 = 16{,}963.2 \div 231 = 73.6$ gallons.

PUMPS.

The ordinary speed for pumps is 100 feet of piston travel per minute. If a pump is of 12″ stroke it will make 100 strokes per minute, or 50 strokes each way; if it is of 6″ stroke it will make 200 strokes, or 100 each way; if of 24″ stroke it will make 50 strokes, or 25 each way, etc.

A large pump must be worked slowly, whereas a small one can be run much faster. According to theory it requires a given quantity of power to raise a given quantity of water a given height in a given length of time, and it is immaterial whether it is raised with a large or a small pump. The power required to work a small pump fast is the same as to work a large pump slow for the same given height and quantity of water, which it is estimated requires approximately one horse power to raise 60 gallons of water per minute 33 feet high.

Each nominal horse power of a boiler requires approximately one cubic foot of water per hour.

CAPACITY OF PUMPS.

To find the capacity of a double acting pump in U. S. gallons per minute, multiply the area of the water cylinder in inches by the length of stroke in inches, and that product by the number of strokes per minute, and divide the last product by 231, the quotient will be the number of gallons per minute.

EXAMPLE.

Water cylinder 6″ diameter, area of same 28.27; length of stroke 8″; number of single strokes per minute, 150. Then, $28.27 \times 8 = 226.16$ and $226.16 \times 150 = 33{,}924 \div 231 = 146$ gallons per minute.

NOTE.—For a single acting pump multiply by half the number of strokes.

Another rule is, the piston travel being 100 feet per minute, to square the diameter of the water cylinder and multiply by 4, the product is the number of gallons per minute.

EXAMPLE.

Water cylinder 6″ diameter, square of same is 36″; then $6 \times 6 = 36$ and $36 \times 4 = 144$ gallons, approximately.

To find the required diameter for a water cylinder to move a given quantity of water per minute at 100 feet of piston travel, divide the given number of gallons by 4 and extract root, which will be the required diameter in inches.

EXAMPLE.

144 gallons desired to be moved; then, 144 ÷ 4 = 36, root of which is 6″, which is the diameter for water cylinder.

The area of the steam piston multiplied by the steam pressure gives the total pressure that can be exerted. The area of the water piston multiplied by the water pressure gives the total resistance. A margin of from 20 to 40 per cent. in favor of the steam piston must be made between the power and the resistance to move the pistons at the required speed.

To find the horse power necessary to elevate a given quantity of water per minute to a given height, multiply the total weight of the given number of gallons to be elevated per minute by the height in feet, and divide by 33,000, to which an allowance of 25 per cent. should be added for water friction, and a further allowance of 25 per cent. for loss in steam cylinder.

CAPACITY OF PUMP CYLINDERS.

The following table shows the amount of water in gallons the different size cylinders will move for each stroke. Then to find the total number of gallons moved per minute, multiply the amount given in table by the number of strokes per minute.

Length of Stroke in Inches and Capacity per Stroke in Gallons.

Diameter Cylinder In Inches.	1	2	3	4	5	6	7	8	10	12
1	.0038	.0067	.0102	.0136	.0170	.0204	.0238	.0272	.0340	.0408
1¼	.0053	.0106	.0159	.0212	.0266	.0319	.0372	.0425	.0531	.0637
1½	.0076	.0153	.0229	.0306	.0382	.0459	.0535	.0612	.0765	.0918
1¾	.0104	.0208	.0312	.0416	.0521	.0625	.0729	.0833	.1041	.1249
2	.0136	.0272	.0408	.0544	.0680	.0816	.0952	.1088	.1360	.1632
2¼	.0172	.0344	.0516	.0688	.0860	.1033	.1205	.1377	.1721	.2071
2½	.0212	.0425	.0637	.0850	.1062	.1275	.1487	.1700	.2125	.2550
2¾	.0257	.0514	.0771	.1028	.1285	.1543	.1800	.2057	.2571	3085
3	.0306	.0612	.0918	.1224	.1530	.1836	.2142	.2448	.3060	.3672
3¼	.0359	.0719	.1078	.1438	.1795	.2156	.2515	.2875	.3594	.4313
3½	.0416	.0833	.1249	.1666	.2082	.2499	.2915	.3332	.4165	.4998
3¾	.0479	.0957	.1435	.1914	.2393	.2871	.3350	.3828	.4785	.5743
4	.0544	.1088	.1632	.2176	.2720	.3264	.3808	.4352	.5440	.6528
4½	.0688	.1377	.2065	.2754	.3442	.4131	.4819	.5508	.6885	.8262
5	.0850	.1700	.2550	.3400	.4250	.5100	.5950	.6800	.8500	1.0200
5½	.1028	.2057	.3085	.4114	.5142	.6171	.7199	.8228	1.0285	1.2342
6	.1224	.2448	.3672	.4896	.6120	.7344	8568	.9792	1.2240	1.4688
7	.1666	.3332	.4998	.6664	.8330	.9996	1.1662	1.3328	1.6660	1.9992
8	.2176	.4352	.6528	.8704	1.0880	1.3056	1.5232	1.7408	2.1760	2.6112
9	.2754	.5508	.8262	1.1016	1.3770	1.6524	1.9278	2.2032	2.7540	3.3048
10	.3400	.6800	1.0200	1.3600	1.7000	2.0400	2.3800	2.7200	3.4000	4.0800
12	.4896	.9792	1.4688	1.9584	3.4480	2.9376	3.4272	3.9168	4.8960	5.8752
15	.7650	1.5300	2.2950	3.0600	3.8250	4.5960	5.3550	6.1200	7.6500	9.1800
18	1.1016	2.2032	3.3048	4.4064	5.5080	6.6096	7.7112	8.8128	11.0160	13.2192
20	1.3600	2 7200	4.0800	5.4400	6.8000	8.1600	9.5200	10.8800	13.6000	16.3200
24	1.9584	3.9168	5.8752	7.8336	9.7920	11.7504	13.7088	15.6672	19.5840	23.5008

PRESSURE OF WATER.

The following table shows the pressure in pounds per square inch for the various heights up to 1000 feet head. By this table, from the pounds pressure per square inch, the feet head is readily obtained, and vice versa:

Feet Head..	Pressure per square inch.	Feet Head..	Pressure per square inch.	Feet Head..	Pressure per square inch.	Feet Head..	Pressure per square inch.	Feet Head..	Pressure per square inch.
5	2.16	80	34.65	155	67.14	230	99.63	310	134.28
10	4.33	85	36.82	160	69.31	235	101.79	320	138.62
15	6.49	90	38.98	165	71.47	240	103.96	330	142.95
20	8.66	95	41.15	170	73.64	245	106.13	340	147.28
25	10.82	100	43.31	175	75.80	250	108.29	350	151.61
30	12.99	105	45.48	180	77.97	255	110.46	360	155.94
35	15.16	110	47.64	185	80.14	260	112.62	370	160.27
40	17.32	115	49.81	190	82.30	265	114.79	380	164.61
45	19.49	120	51.98	195	84.47	270	116.96	390	168.94
50	21.65	125	54.15	200	86.63	275	119.12	400	173.27
55	23.82	130	56.31	205	88.80	280	121.29	500	216.58
60	25.99	135	58.48	210	90.96	285	123.45	600	259.90
65	28.15	140	60.64	215	93.13	290	125.62	700	303.22
70	30.32	145	62.81	220	95.30	295	127.78	800	346.54
75	32.48	150	64.97	225	97.46	300	129.95	900	389.86
								1000	433.18

GLOBE AND GATE VALVES.

All valves used for the flow of liquids and gases may be comprised principally into two classes—*globe and gate valves.*

The globe valve is so well known among mechanics that it scarcely needs an explanation, and for small sizes, ranging up to 1½″ or 2″, are for general purposes most used; but for sizes above 2″ running all the way up to 60″ of opening the gate valve is the most serviceable and practical. In fact, for large sizes and some purposes gate valves only are used, the better type of which are the double gate compound wedge straight way valve, such as made by the Cayuta Wheel and Foundry Co., Sayre, Pa., which is so constructed that it will open and close under any pressure without friction or strain. When closing the last half turn of stem seats the gates, and when opening the first half turn of the stem releases the gates, thus raising or lowering the gates for the remainder of the distance in a perfectly free and released condition.

The loss of pressure through a globe valve is nearly 90 per cent. greater than through a gate valve. Tests have shown that a 3″ globe valve full open on a 3″ water main, having a pressure of 80 lbs. per square inch, caused a loss of 39 lbs. pressure per square inch, while a 3″ gate valve placed in the same position and full open caused a loss of only 4 lbs. pressure per square inch. In other words, the 3″ globe valve caused a decrease in pressure of from 80 lbs. to 41 lbs. per square inch, while the 3″ gate valve, in the same place, only caused a fall of from 80 lbs. to 76 lbs. per square inch, both valves being full open and the pipe discharging free into the air.

SPECIFIC GRAVITY.

The weight of a cubic foot of water is designated as being 1000 ounces. (The exact figures are 997.68 ounces.) This weight has become accepted the world over as the basis for comparing the weights of the different substances, and the relative weight of a substance in ounces to that of water is known as its specific gravity.

Water as the basis and its weight being 1000 ounces per cubic foot, its specific gravity is therefore expressed as 1, while the weight of cast iron compared therewith is found to be nearly 7¼ times greater, or weighing 7200 ounces per cubic foot, its specific gravity therefore becomes known as 7.21, and by the same comparison cork is found to weigh ony 250 ounces per cubic foot, or ¼ that of water, and its specific gravity thus becomes known as .25, etc.

Names of Substances. Metals.	Specific Gravity.	Weight per cubic foot.	Weight per cubic inch.
Aluminum	2.6	162.	.096
Antimony, cast	6.7	418.	.241
Brass, cast	8.1	504.	.291
Brass, rolled	8.4	524.	.302
Bronze and Gun Metal	8.5	529.	.303
Copper, cast	8.7	542.	.305
Copper, rolled	8.8	5 49.	.317
Gold, cast, pure	19 25	1204.	.696
Gold, pure, hammered	19.5	1217.	.700
Iron, cast	7.21	450.	.260
Iron, wrought	7.77	480.	.277
Lead	11.4	712.	.410
Mercury at 32° F	13.62	849.	.491
Platinum	21.5	1342.	.771
Silver	10.5	655.	.380
Steel	7.85	490.	.283
Speltre or Zinc	7.	437.	.255
Tin, cast	7.35	459.	.264
Type Metal	10.45	653.	.380

Names of Substances. Woods.	Specific Gravity.	Weight per cubic foot.	Weight per cubic inch.
Boxwood, dry	1.04	64.8	.037
Cherry	.67	42.	.024
Lignum Vitæ	1.33	83.	.048
Maple, dry	.79	49.	.028
Oak, live, dry	.95	59.	.034
Oak, white, dry	.70	44.	.026
Pine, white, perfectly dry	.40	25.	.015
Pine, yellow, Southern	.72	45.	.026
Sycamore, perfectly dry	.59	37.	.019
Spruce	.40	25.	.015
Walnut, black	.61	38.	.022
Miscellaneous.			
Diamond	3.44 to 3.55		.200
Mica	2.93	183.	.111
Cork	.25	15.6	.009
Glass	2.98	186.	.112
Gutta Percha	.98	61.1	.022
Ivory	1.82	114.	.067
Ice at 32° F	.92	57.5	.033
India Rubber	.93	58.	.034
Rosin	1.1	68.6	.040
Sulphur	2.	125.	.072
Tallow	.94	58.6	.034
Tar	1.	62.4	.036
Water, pure	1.	62.4	.036
Water, sea	1.02	64.3	.037

BELTING, NOTES AND RULES.

NOTES.

Hot boxes, breaking of pulleys, slipping and breaking of belts, unequal motion of shafting and machinery, and unsatisfactory results generally are so often directly traceable to illy designed and improper belting that the importance of a little practical information leading to well directed application in this line must of necessity at once become apparent to every intelligent reader.

The two sides of a belt are known respectively: one as the flesh side and the other as the grain or hair side. The grain (hair) side is usually the smoothest, while the flesh side, though rougher is the strongest. The question at once arises as to which of the two is the proper side to run on the pulley. The grain (hair) side should be run on the pulley for the following reasons: The constant strain upon a belt doing duty has a tendency to crack the grain (hair) side, which tendency increases with age, it is therefore better to crimp the same than to stretch it as the case would be if run out, while the flesh side being the strongest would be subjected to the least friction and wear by running same out, thus preserving the strength of the belt for a much longer period. Again, the belt as well as the pulley adhere best when smooth; the grain (hair) side being the smoothest will, of course, adhere better and pull 30 per cent. more against pulley than the flesh side will pull.

Belts must be kept soft and pliable, but well protected against water and moisture, and should be kept clean and free from accumulations of dust and grease, especially lubricating oil.

A belt of insufficient width for its load must of necessity be kept very tight to do its work, thus subjecting it to a strain beyond its capacity, thereby reducing its period of life to a minimum, at the same time producing some of the unsatisfactory conditions mentioned above. Whereas, a belt of sufficient width may be run loose, will do its work satisfactory and last much longer.

In locating shafting and machinery it is desirable to so locate the same (counter-shafts especially) that the belts will run in opposite directions from the line shaft, thus relieving the bearings from a good percentage of the friction otherwise existing if the belts all pulled one way from the line shaft. It is also important that proper distances are maintained, experience having amply proven that short belts though of proper width, are provokingly given to slipping. If possible, belts running up and down should be run at a slight angle, better results being obtained therefrom.

A speed of 3750 feet of belt motion per minute according to some authorities should be the limit for quick motion belts, while others maintain that a speed of 3000 feet per minute should not be exceeded. The last figure is calculated to be doubly safe, and may be considered a good standard.

RULES.

TRANSMITTING POWER OF BELTS.

To find the *transmitting power* of a belt, single thickness, the width being given: multiply the diameter of the driving pully in inches by its number of revolutions per minute, and that product by the width of the belt in inches, and divide by 3300, the quotient will be the horse power transmitted. For double thickness belt divide by 2100.

EXAMPLE.

Driving pulley, 26 inches diameter.
Number of revolutions, 255 per minute.
Width of belt, 3 inches.
Thus 26 × 255 = 6630 × 3 = 19,890 ÷ 3300 = 6 horse power transmitted by single belt. For double belt 19,890 ÷ 2100 = 9½ horse power nearly.

REQUIRED WIDTH TO TRANSMIT A GIVEN HORSE POWER.

To find the *required width* of a belt to transmit a given horse power, multiply for single belt 33000 by the horse power; next multiply the diameter of the driving pulley in inches by the number of revolutions per minute, then divide the former product by the latter, the quotient will be the required width of belt in inches. For double belt multiply 2100 by the horse power instead of 3300 as for a single belt.

EXAMPLE.

Driving pulley, 24 inches diameter.
Number of revolutions, 250 per minute.
Horse power to be transmitted, 10.
Thus for single belt 3300 × 10 = 33,000, and 24 × 250 = 6000, then 33,000 ÷ 6000 = 5½ inches, required width of belt. For double belt, 2100 × 10 = 21,000 ÷ 6000 = 3½ inches, required width of belt.

EXAMPLE NO. 2.

Driving pulley, 48 inches diameter.
Number of revolutions, 200 per minute.
Horse power to be transmitted, 64.
Thus for double belt, 2100 × 64 = 134,400, and 48 × 200 = 9,600, then 134,400 ÷ 9600 = 14 inches, width of belt. For single belt, 3300 × 64 = 211,200 ÷ 9,600 = 22 inches, required width of belt.

TO FIND THE REQUIRED LENGTH.

To find the required *length* of a belt, add the circumferences of the two pulleys and divide by 2; then add that quotient to double the distance between the centres of the two shafts, the result will be the desired length of belt.

EXAMPLE.

One pulley 36 inches diameter, circumference of same, 113 inches.
Other pulley 22 inches diameter, circumference of same 69 inches.
Distance between centres of shafts, 15 feet.
Thus 113 + 69 = 182 ÷ 2 = 91, then 91 inches ÷ 12 = 7 feet and 7 inches, to which add 30 feet, and the desired length of belt will therefore be 37 feet and 7 inches.

TO FIND THE NUMBER OF FEET CONTAINED IN A ROLL.

To find the *number of feet* of belt contained *in a roll*, add to the diameter of the roll in inches, the diameter of the hole in centre of roll, multiply this sum by the number of coils in roll, then multiply this product by 131. The three figures on the left represent the number of feet in roll.

EXAMPLE.

Roll $37\frac{5}{8}$ inches diameter. Hole $4\frac{5}{8}$ inches diameter. Number of ·oils, 84. Thus, $37\frac{5}{8} + 4\frac{5}{8} = 42\frac{1}{4} \times 84 = 3549 \times 131 = 464{,}919$ or 464 feet of belt in roll.

TO FIND APPROXIMATE WEIGHT OF BELT.

To find the approximate *weight of a belt*, multiply the length in feet by the width in inches and divide for single belt by 13, for double belt by 8, the quotient will be the weight in pounds, nearly.

EXAMPLE.

Length of belt, 44 feet. Width of same, 3 inches. Thus $44 \times 3 = 132 \div 13 = 10$ pounds, single belt. For double belt, $132 \div 8 = 16\frac{1}{2}$ pounds.

SHAFTING.

NOTES.

An illy proportioned shaft is as much and more of an annoyance and source of expense than an illy proportioned belt.

A shaft should not only be large enough to transmit a given horse power, but should in addition thereto have a margin of strength allowed in its favor to successfully withstand the unexpected that is liable to occur at any time.

A shaft may be of sufficient diameter to transmit a given horse power under ordinary favorable circumstances, but may not be of sufficient strength to successfully withstand any sudden jerk, motion or accident, and the result is a kinked or broken shaft with attending annoyance and expense.

The strains upon a shaft are known respectively as the transverse and tortional strains.

The transverse strain tends to pull against the shaft at right angles to its axis and produces kinks.

The tortional strain is in line with its axis and tends to twist the shaft.

To counteract the tortional strain, the diameter of shaft must principally be considered.

To counteract the transverse strain the distance between bearings must be taken into consideration.

A shaft may be of sufficient diameter to withstand the tortional strain, and may at the same time be deficient in strength against the transverse strain; or the bearings may not be as near to each other as they ought to be; in either event the result will be a kinked shaft, as observation will abundantly substantiate.

For a line shaft a distance of 8 feet between bearing or hangers is considered, for general business, a good standard and will give satisfactory results.

Shafting generally is divided into three classes:

1. Head shafts and prime movers.
2. Line shaft or second movers.
3. Countershafts.

A head shaft is used when it is inconvenient to belt direct to line shaft, or when it becomes necessary to decrease or increase the speed between engine and line shaft. It must of necessity be heavier and stronger than line shaft, and should be as short as possible and well supported.

A line shaft is, as its name indicates, a line of shafting from which power is taken at intervals to countershafts. The same should be so placed, when possible to do so, that belts will run from it in opposite directions, thus counteracting, in a large measure, the transverse strain upon it.

A countershaft simply transmits power to a machine and need not be so large, as the tortional strain upon same is but a trifle; the transverse strain being most in evidence, and the shorter the shaft is the better it will withstand the strain.

RULES.

TRANSMITTING POWER OF COUNTERSHAFTS.

To find the horse power a countershaft is capable of transmitting, multiply the cube of the diameter of shaft by its number of revolution per minute and divide by the constant 30 if cold rolled iron is used, or by 50 if turned iron is used; the quotient will be the horse power that it can transmit.

EXAMPLE.

Shaft 2″ diameter, cube of same is 8″. Speed 200 revolutions per minute. Then, $8 \times 200 = 1600 \div 30 = 53$ horse power for cold rolled iron; and for turned iron $1600 \div 50 = 32$ horse power.

TO FIND THE DIAMETER OF COUNTERSHAFT TO TRANSMIT A GIVEN HORSE POWER.

To find the diameter to transmit a given horse power at a given speed, multiply the constant 30, if cold rolled iron is to be used, or 50 if turned iron is to be used, by the given horse power, and divide by the given number of revolutions, the quotient will be the cube of the shaft, which referred to the table on page 74 will give its corresponding diameter.

EXAMPLE.

Horse power to be transmitted, 32. Given number of revolutions, 200. Turned iron to be used. Then $50 \times 32 = 1600 \div 200 = 8''$, the cube diameter of which is $2''$, see table.

TRANSMITTING POWER OF LINE SHAFTING, BEARINGS 8′ APART.

To find the horse power a line shaft is capable of transmitting, multiply the cube of the diameter of the shaft by its number of revolutions per minute, and divide by the constant 50 if cold rolled iron is used, or by 90 if turned iron is used.

EXAMPLE.

Shaft $3''$ diameter, cube of same is $27''$. Speed 150 revolutions per minute. Then, $27 \times 150 = 4050 \div 50 = 81$ horse power for cold rolled iron: and for turned iron, $4050 \div 90 = 45$ horse power;

TO FIND DIAMETER FOR A LINE SHAFT TO TRANSMIT A GIVEN HORSE POWER, BEARINGS 8′ APART.

To find the diameter for a line shaft to transmit a given horse power at a given speed, multiply the constant 50 if cold rolled iron is used, or by 90 if turned iron is used, by the given horse power, and divide by the given number of revolutions, the quotient will be the cube, then from following table find its corresponding diameter.

EXAMPLE.

Horse power to be transmitted, 81. Given number of revolutions, 150. Cold rolled iron to be used. Then, $50 \times 81 = 4050 \div 150 = 27''$ the cube, diameter of which is $3''$ size of shaft.

For head shafts use the constant 75, if cold rolled iron is used, or 125 if turned iron is used, and proceed as per above rules.

TABLE OF DIAMETERS AND CUBES OF SAME.

This table will be found convenient for the use of above rules, as the respective cube or diameter the example may require will readily be found by comparing.

DIAM.	CUBE.	DIAM.	CUBE.	DIAM.	CUBE
1	1.	2 3/8	13.40	5	125.
1 1/16	1.19	2 7/16	14.48	5 1/4	144.70
1 1/8	1.42	2 1/2	15.63	5 1/2	166.37
1 3/16	1.67	2 9/16	16.83	5 3/4	190.11
1 1/4	1.97	2 5/8	18.08	6	216.
1 5/16	2.26	2 11/16	19.41	6 1/4	244.14
1 3/8	2.60	2 3/4	20.79	6 1/2	274.63
1 7/16	2.97	2 13/16	22.25	6 3/4	307.55
1 1/2	3.38	2 7/8	23.76	7	343.
1 9/16	3.82	2 15/16	25.34	7 1/4	381.08
1 5/8	4.29	3	27.	7 1/2	421.88
1 11/16	4.80	3 1/8	30.52	7 3/4	465.48
1 3/4	5.36	3 1/4	34.32	8	512.
1 13/16	5.95	3 3/8	38.44	8 1/4	561.52
1 7/8	6.59	3 1/2	42.88	8 1/2	614.12
1 15/16	7.27	3 5/8	47.63	8 3/4	669.92
2	8.	3 3/4	52.73	9	729.
2 1/16	8.77	3 7/8	58.17	9 1/4	791.45
2 1/8	9.59	4	64.	9 1/2	857.37
2 3/16	10.47	4 1/4	76.78	9 3/4	926.86
2 1/4	11.39	4 1/2	91.13	10	1000.
2 5/16	12.36	4 3/4	107.16		

TRANSMITTING POWER OF IRON AND STEEL WIRE ROPE.

In order to accurately compute the transmitting power of iron and steel wire rope, all the eperating conditions should be known and taken into consideration; but as these are so extremely variable in practice it is impossible to lay down rules that will answer in all cases.

The following rules, however, cover all ordinary cases, and for general practical business give very satisfactory results.

The pulley for wire rope should be not less than 100 times the diameter of the rope, and is more often of even greater diameter, as the larger it is, the better the results will be. A $\frac{1}{2}''$ rope should run over a pulley not less than 4′ 2″ in diameter, etc.

TRANSMITTING POWER.

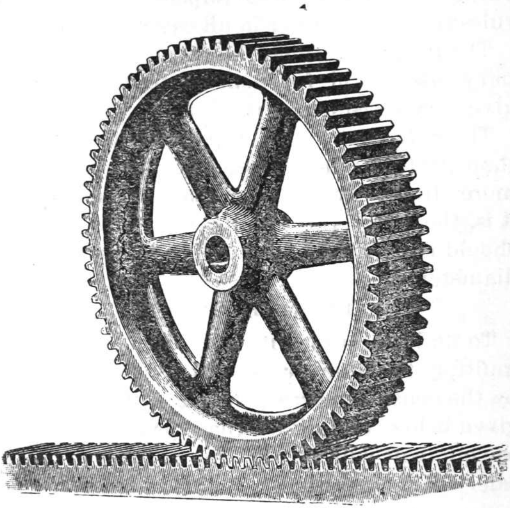
To find the transmitting power of wire rope, multiply the number of feet traveled per minute by the constant corresponding to its diameter as given below, and divide that product by 33,000, the quotient will be the horse power that can safely be transmitted.

IRON WIRE ROPE.

Diameter	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Constant	140	187	250	375	562	750	1500

EXAMPLE.

Diameter of rope, $\frac{1}{2}''$. Speed per minute, 1600 feet. Constant to multiply by, 250. Then, 250 × 1600 = 400,000 ÷ 33,000 = 12 horse power.



GEARS AND GEAR-TEETH.

(INVOLUTE SYSTEM.)

Of all mechanical subjects, that of Gear-wheels and Gear-teeth is the least understood by many otherwise good, practical mechanics. While the subject is by no means one of the simplest in mechanics, it is nevertheless one of the most interesting and instructive, and well worthy the studious attention of every machinist.

The amount of literature written on the subject is almost limitless. The most of which, however, is written in such a manner that it can be understood only by those already well advanced on the subject, and the average workman who attempts to master the same from those works will soon become confused and mystified and drop the subject as hopeless. Such matter, instead of being a help to the uneducated practical mechanic, in most cases proves only a stumbling block to him and discourages him from further effort. We thus find the proper explanation as to the scarcity of knowledge on the subject among the average workmen.

While it is by no means the writer's intention to herein present an elaborate scientific treatise, it is the intention to so simplify the subject that the thoughtful reader shall be able to readily grasp the fundamental principles, thus furnishing him a key to intelligently read such information as may hereafter fall into his hands.

The following terms and explanations designate the principal points in gears, and in order to be able to draw a gear and to lay out the teeth on same, it is necessary that they be fully understood. Reference being had to the accompanying cut on page 82.

The *pitch diameter* and *pitch line B*.

The *diametrical pitch*, or the number of teeth per inch of the pitch diameter.

The *circular pitch*, or the distancs between the centres of two teeth on the pitch-line.

The outside diameter, or *addendum line E*.

The inside diameter, or *dedendum or root line F*.

The *clearance line G*, showing full depth of tooth.

The *base line D*, or line for centres from which the faces and flanks of the teeth are scribed with dividers.

The *pitch diameters* of a pair of wheels are the diameters they would be if they were blank discs rolling against each other. Thus if a distance of 9″ between two centres is to be supplied with a pair of wheels at a ratio of two to one, the distances to the point of contact, known as the *pitch point* would be respectively 3″ and 6″, and the diameters of a pair of blank discs would therefore be 6″ and 12″. If gears are to be used these diameters would then be the *pitch diameters* of same, and circles drawn to these diameters would be known as the *pitch lines.* It is thus plain to be seen that the *outside diameter* for gear wheels must of necessity be enough larger to supply the teeth.

The *diametrical pitch* is the number of teeth a wheel has per inch of its pitch diameter. Thus if a wheel has a pitch diameter of 5″ and has four teeth per inch of its pitch diameter it will have 5 × 4 = 20 teeth and its *diametrical pitch* would therefore be known as 4 pitch. (See cut.)

The *circular pitch* is the distance on the pitch line from the centre of one tooth to the centre of the next. In 4 pitch the distance from centre to centre of the teeth on pitch line will be found to be .785 or a trifle over 25-32″; in 5 pitch it is .628 or a trifle over ⅝″, etc. (See table of tooth dimensions.)

The *outside diameter* is larger than the pitch diameter in proportion to the diametrical pitch of its teeth, and is found by adding two "pitch parts" to the pitch diameter. Thus, if a gear has a pitch diameter of 5″ and is of 4 pitch its outside diameter will be found by adding 2 one-fourths of an inch, or ½″ to the pitch diameter, giving the outside diameter as 5½″; if 8 pitch is used 2 one-eights of an inch or ¼″ is added, making wheel 5¼″ outside diameter; if 14 pitch is used 2 one fourteenths of an inch would be added, etc.

A circle drawn to the outside diameter is known as the *addendum line E.* A circle drawn inside of the pitch line by the same distance or two "pitch parts" less in diameter is known as the *dedendum or root line F.* Thus finding the theoretical depth of the tooth to which a certain amount of clearance about one-eighth of a "pitch part" or 1-16 of the depth of tooth must be added and a circle drawn to that distance inside of the dedendum or root line is known as the *clearance line G.*

The *base line D* is a circle inside of the pitch line by one-sixtieth of the pitch diameter and is used as a line for centres from which the faces and flanks of the teeth are scribed with dividers. Thus a wheel having a pitch line 5″ diameter will have a base line inside of same at a distance of 1 12″ or 4 10 12″ diameter.

Theoretically there is no limit as to the sizes or pitches of gear teeth; that is, they can be made of any size or pitch desired. In practical machine construction, however, and as a matter of economy they are confined to certain definite sizes known as "standard" pitches. The following table gives 23 standard pitches as most commonly used by some of the leading manufacturers of gears in America. It also gives the amount of addendum or distance from pitch line to outside diameter; the theoretical depth of tooth in decimals and fractions nearly, and the circular pitch in decimals and fractions nearly:

TOOTH DIMENSIONS FOR 23 STANDARD PITCHES.

Diametrical Pitch.	Addendum or distance from Pitch Line to outside Diam.	Addendum and Dedendum or depth of Tooth to Root Line.		Circular Pitch or Distance from Centre to Centre of Tooth.		Clearanc.
		In Deci	In Fract.	In Deci.	In Fract.	
2	.500	1.	1″	1.571	1 9-16″	.079
2½	.400	.800	8 10″	1.257	1 1-4″	.063
3	.333	.666	8-12″	1.04	1 3-64″	.052
4	.250	.500	1-2″	.785	25-32″	.039
5	.200	.400	4-10″	.628	5-8″	.031
6	.166	.332	4-12″	.524	17 32″	.026
7	.143	.286	9 32″	.449	29-64″	.022
8	.125	.250	1-4″	.393	25 64″	.020
9	.111	.222	7-32″	.349	11 32″	017
10	.100	.200	2-10″	.314	5 16″	.016
11	.091	.182	3 16″	.2[illegible]6	9 32″	.014
12	.083	.166	——	.262	17-64″	.013
14	.072	.144	9-64″	.224	7-32″	.011
16	.067	.134	——	.196	——	.010
18	.056	.112	——	.175	——	.009
20	.050	.100	1-10″	.157	5-32″	.008
22	.045	.090	3-32″	.143	9-64″	.007
24	.042	.084	——	.131	——	.006
28	.036	.074	——	.128	1-8″	.006
32	.033	.066	1-16″	.098	3-32″	.005
36	.028	.056	——	.087	——	.004
40	.025	.050	——	.079	5-64″	.004
48	.021	.042	——	.065	1-16″	.003

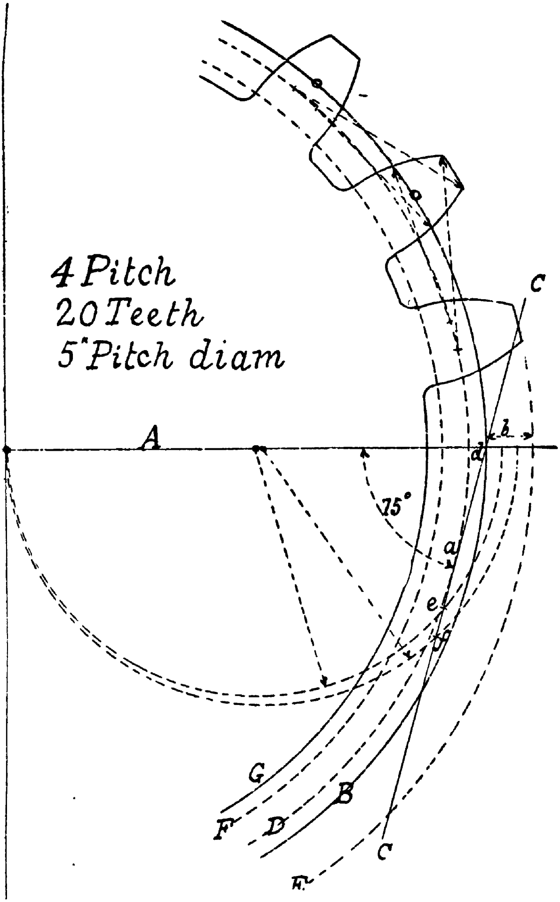
NOTE.—The decimals of this table are the correct sizes, the fractions in most cases are also correct, while in some they are only approximately so, always within less than $\frac{1}{64}$ inch and are added to assist in more readily reading the decimals. In some cases the fractions could not be given.

HOW TO DRAW THE SPUR GEAR AND TO LAY OUT THE TEETH ON SAME.

To draw the spur gear and its teeth proceed as shown in cut, page 82, where, for want of space, a portion only of the full circles are shown. The dimensions, however, are full size thus illustrating the method as clearly as though the complete wheel were shown.

Draw a straight line *A* somewhat longer than the diameter of the wheel to be drawn, then from a centre on same draw the pitch line *B* to the given pitch diameter, which in this case is 5″, then draw the line *CC* through the pitch point *d* and across the line *A* at an angle of 75 degress to same; then draw the addendum line *E* two "pitch parts" larger in diameter than the pitch line, which in this case is two ¼″, or one-half inch, draw the dedendum or root line *F* by the same distance smaller in diameter than the pitch line, draw the clearance line *G* inside of dedendum or root line by 1-16 of depth of tooth, or more nearly correct .039 as per table; then draw the base line *D* inside of pitch line just touching the line *CC* at *a*, which will always be found to be the required distance of 1-60″ of the pitch diameter.

Space the pitch line to the circular pitch, in this case .785, or a trifle over 25-32″, thus dividing the same into 20 equal spaces, divide these spaces by stepping off the pitch line a second time and the pitch line will then be divided into 40 spaces, 20 of same for teeth and 20 of same for spaces between the teeth. Then divide the space *b* be-


4 Pitch
20 Teeth
5" Pitch diam
A
C
b
d
75°
a
e
G
F
D
B
C
E

tween the pitch line and addendum line of the line *A* into 3 equal parts, scribe two circles from the divisions of the space *b* from centres on the line *A* across the line *CC* thus finding the distance from the pitch point *d* to *e* and *d* to *f* on the line *CC* which use for the face and flank radii. Then set the dividers to the distance *d f*, place one point of same on the base line *D* and with the other draw the face of the tooth from the pitch line *B* to the addendum line *E*: again set the dividers to the distance *d e* and draw the flank of the tooth from the pitch line to the base line. From the base line to the dedendum or root line draw straight radical lines and from the root line to the clearance line round the corners thus completing the tooth.

NOTE—In the cut the flank radius is continued below the base line to the root line instead of the straight radial lines, which method in this case forms a wider tooth at the root line, thus increasing its strength and is for that purpose often em ployed.

This method is employed by prominent European manufacturers and wheels so constructed run smooth and give entire satisfaction.

NOTE 2—If the number of teeth is greater than 36, or if the pitch is small, the face radius is then drawn from the base line *D* to the addendum line *E* instead of from the pitch line *B*.

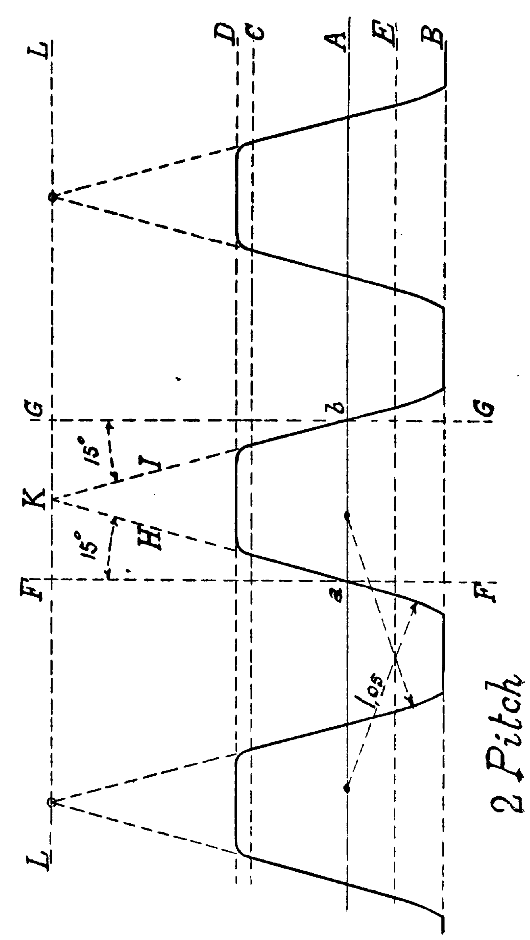
HOW TO DRAW THE RACK.

For the rack, the pitch and the tooth dimensions are the same as for the spur wheel, so, also, are the same lines drawn excepting, of course, that they are drawn straight instead of circles as for the wheel. See cut. page 85.

Draw the pitch line *A*, the addendum line *B*, the dedendum or root line *C*, the clearance line *D* and a line *E* midway between the pitch line and addendum line. Step off the pitch line to the circular pitch same as for a wheel; draw two lines *FF* and *GG* at right angles to the pitch line through the pitch points *a* and *b*, then draw two lines *H* and *I* at an angle of 15 degrees to the lines *FF* and *GG*, also through the pitch points *a* and *b* down to the line *E*, thus forming that part of the tooth from the root line *C* to the line *E*.

Then divide 2.10 by the diametrical pitch used, set the dividers to that quotient, place one point of same on the pitch line and with the other scribe the curve from *E* to *B*, thus completing the tooth.

NOTE—As a matter of convenience when a portion only, say 3 or 4 teeth, of the rack is drawn to serve as a templet for the purpose of constructing a cutter or tool by the apex *K* of the lines *H* and *I* may be found and a line *LL* drawn through the apex parallel to the pitch line. This line *LL* may then be stepped off to the circular pitch, and degree lines *H* and *I* can then be drawn from the points of that line, thus simplifying the drawing somewhat.



L
D
C
A
E
B
G
K
F
J
H
15°
15°
a
b
1,05
2 Pitch

BEVEL GEARS.

In spur gears the axis of a pair of wheels are parallel and the teeth are at the right angles to the faces of the wheels. In bevel gears the axis meet at an angle and the teeth therefore are on a bevel, hence the term.

When the axis of a pair of bevel gears are at right angles and the gears are equal, the centre line *C* from the pitch point *B* to the apex *H* will be at an angle of 45 degrees to both axis and they are then called mitre gears.

The pitch diameter *BB* is known as the *working* pitch diameter. The outside diameter or addendum line is the line *EE*, and the clearance line is *GG*.

The distance *E I* is known as the back radius, according to which the back templet is drawn.

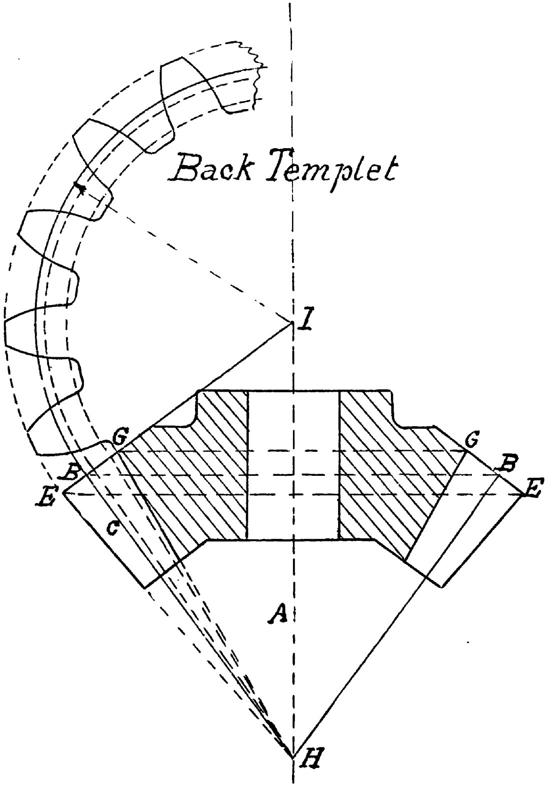
The number of teeth in the bevel gear is based upon the working pitch diameter; but the outline of same is not drawn to a circle of that diameter, but to a circle drawn to the diameter of the back radius *E I*, which will, of course, have a greater number of teeth than are necessary for the wheel. Thus the cut shows a gear of 2 1-6″ pitch diameter, using 6 pitch it will therefore have 13 teeth, whereas the back templet for same will be 2 4-6 pitch diameter and will have 16 teeth. It is as if the teeth were first drawn upon a flat sheet, which is then wrapped about the conical back rim of gear and the outline of the teeth transferred from same onto the run of the wheel.

All the lines of the teeth, tops, sides and bottoms must meet at apex *H*.

HOW TO DRAW THE BEVEL GEAR AND THE TEETH FOR SAME.

Draw the axis *A*, draw the given pitch diameter *BB* at right angles to same, draw the line *C* from *B* to *H* to the given centre angle, draw the back rim line *E I* at right angles to the centre line *C*, thus finding the back centre *I*. Lay off the addendum from *B* to *E*, and the dedendum and clearance from *B* to *G*.

Draw the addendum line or outside diameter *EE*, the dedendum or root line and the clearance line *GG*. Draw the lines *E H* and *G H*. Then from the back centre *I* draw the back templet same as a spur gear of that diameter, thus finding the correct outline of teeth.



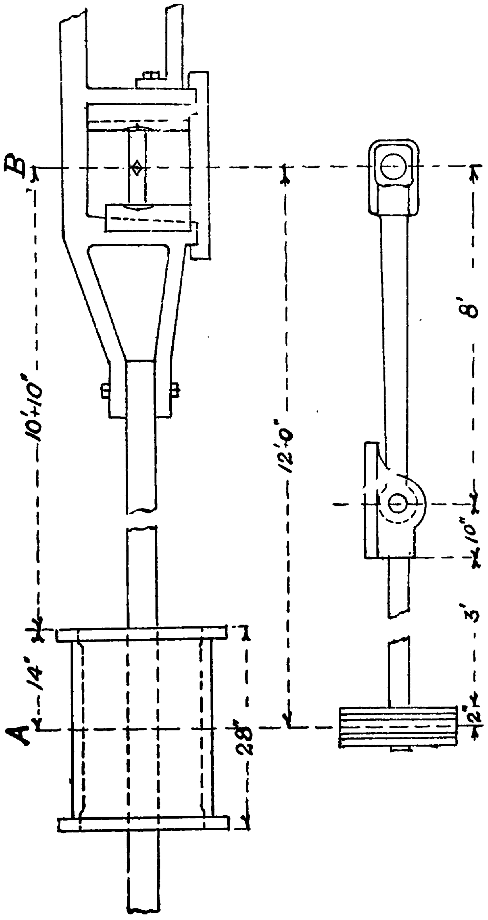
6 Pitch
13 Teeth
$2\frac{1}{6}''$ Pitch diam.

HOW TO LAY OUT SHOES AND WEDGES.

(LOCOMOTIVE.)

To lay out shoes and wedges the starting point is taken from the lengthwise centre *A* of the cylinder, from which point, when properly located, the centre *B* for the main pedestal jaw is found as follows: Add one half of the piston head, all that part of the piston-rod between the piston-head and cross head, the distance of the cross-head from its face to the centre of the pin, and all of the main rod from centre to centre of brasses together as shown in cut. Then from the centre *A* measure off the total distance so found to a point *B* on the frame above the jaw, thus locating that centre. Carry that poin down to temporary centres placed between the shoe and wedge and with a pair of dividers set to one-half of the width of the box, scribe the shoe and the wedge, thus showing the amount to plane off. Then with the trams, set to the length of the side rod from centre to centre of brasses, find the centre of the back jaw and lay out that shoe and wedge in like manner.

NOTE—In most cases it is more convenient to work from the face of the cylinder. In all such cases simply deduct the distance from *A* to the face, or one-half of length of cylinder from the total length. (See cut, page 90.)


B
A
10'+10"
14"
28"
12'0"
8'
10"
3'
2"

STANDARD DIMENSIONS OF KEYS AND KEY-WAYS.

The following rules and table for keys and key-ways are adhered to and recommended by leading manufacturers, and give good satisfaction.

GENERAL RULE.

The width of the key should equal one-fourth diameter of shaft.

The thickness of the key should equal one-sixth diameter of shaft.

The depth in hub for a straight key-way should be one half thickness of key.

The depth in hub at large end, for a taper key-way, should be three fifths thickness of key.

Standard taper for all key-ways should be 3 16 inches in 1 foot of length.

The depth to be cut in hub for taper key-ways, at large end, is greater than those cut straight, for the reason that unless this was done the depth in hub at small end would not be sufficient, especially in long key-ways.

For extra long key-ways the depth cut in hub might be slightly increased, but for the average run of work the table will be found correct.

Manufacturers who adopt this rule will always find their key-ways of correct proportion, and will have no difficulty in duplicating their work, thus saving themselves much care and annoyance.

TABLE OF DIMENSIONS OF KEYS AND KEY-WAYS.

Size of Hole.	Preferred Width of Key Way.	Nearest Fractional Width.	Preferred Thickness of Key.	Nearest Fractional Thickness.	Depth to be Cut in Hub for straight Key.	Depth at Large End for Taper Key.
1 in.	.25	$\frac{1}{4}$	.166	3 16	.093	.112
$1\frac{1}{16}$	.265	$\frac{1}{4}$	.177	3 16	.093	.112
$1\frac{1}{8}$	.281	$\frac{1}{4}$	.187	3-16	.093	.112
$1\frac{3}{16}$	.296	$\frac{5}{16}$	.198	7-32	.109	.131
$1\frac{1}{4}$	.312	$\frac{5}{16}$	.208	7 32	.109	.131
$1\frac{5}{16}$	.328	$\frac{5}{16}$	.219	7-32	.109	.131
$1\frac{3}{8}$	.343	$\frac{3}{8}$	.229	1-4	.125	.15
$1\frac{7}{16}$	.359	$\frac{3}{8}$	.239	1 4	.125	.15
$1\frac{1}{2}$	.375	$\frac{3}{8}$	.25	1 4	.125	.15
$1\frac{9}{16}$	.39	$\frac{3}{8}$	.26	1-4	.125	.15
$1\frac{5}{8}$	.406	$\frac{7}{16}$	.271	9 32	.141	.168
$1\frac{11}{16}$	.421	$\frac{7}{16}$	.281	9 32	.141	.168
$1\frac{3}{4}$	.437	$\frac{7}{16}$	.292	9-32	.141	.168
$1\frac{13}{16}$	.453	$\frac{7}{16}$	.302	9-32	.141	.168
$1\frac{7}{8}$	.468	$\frac{1}{2}$	.312	11 32	.171	.206
$1\frac{15}{16}$	.484	$\frac{1}{2}$	.323	11-32	.171	.206
2	.5	$\frac{1}{2}$	.333	11-32	.171	.206
$2\frac{1}{16}$	.515	$\frac{1}{2}$	.344	11-32	.171	.206
$2\frac{1}{8}$	.531	$\frac{1}{2}$	.354	11-32	.171	.206
$2\frac{3}{16}$	.547	$\frac{1}{2}$	.364	11-32	.171	.206
$2\frac{1}{4}$	.563	$\frac{1}{2}$	.375	11-32	.171	.206
$2\frac{5}{16}$	.578	$\frac{1}{2}$	.385	11-32	.171	.206
$2\frac{3}{8}$	.593	$\frac{5}{8}$	.396	7-16	.218	.262
$2\frac{7}{16}$	.609	$\frac{5}{8}$	.406	7-16	.218	.262
$2\frac{1}{2}$	.625	$\frac{5}{8}$	.416	7-16	.218	.262
$2\frac{9}{16}$	.641	$\frac{5}{8}$	.427	7 16	.218	.262
$2\frac{5}{8}$	.656	$\frac{5}{8}$	.437	7-16	.218	.262
$2\frac{11}{16}$	.672	$\frac{5}{8}$	.448	7 16	.218	.262
$2\frac{3}{4}$	.687	$\frac{5}{8}$	.458	7-16	.218	.262
$2\frac{13}{16}$	.703	$\frac{5}{8}$	.469	7-16	.218	.262
$2\frac{7}{8}$	.719	$\frac{3}{4}$	.479	1-2	.25	.3
$2\frac{15}{16}$	.734	$\frac{3}{4}$	.49	1-2	.25	.3
3	.75	$\frac{3}{4}$	.5	1-2	.25	.3

TABLE OF DIMENSIONS OF KEYS AND KEY-WAYS.—(CONTINUED.)

Size of Hole.	Preferred Width of Key-Way.	Nearest Fractional Width.	Preferred Thickness of Key.	Nearest Fractional Thickness.	Depth to be Cut in Hub for straight Key.	Depth at Large End for Taper Key.
3 1/8	.781	3/4	.521	1-2	.25	.3
3 3/16	.797	3/4	.531	1-2	.25	.3
3 1/4	.812	3/4	.542	1-2	.25	.3
3 3/8	.844	7/8	.562	5-8	.312	.375
3 7/16	.859	7/8	.573	5 8	.312	.375
3 1/2	.875	7/8	.583	5-8	.312	.375
3 5/8	.906	7/8	.604	5 8	.312	.375
3 11/16	.923	7/8	.614	5 8	.312	.375
3 3/4	.937	7/8	.625	5-8	.312	.375
3 7/8	.969	1	.646	11-16	.343	.412
3 15/16	.984	1	.656	11-16	.343	.412
4	1.	1	.666	11-16	.343	.412

WEIGHT OF IRON AND STEEL PER CUBIC AND SQUARE FOOT.

CAST IRON.

One cubic foot weighs	450	lbs.
One square foot 1 inch thick weighs....	$37\frac{1}{2}$	"
A bar 1 in. square and 1 ft. long weighs	$3\frac{1}{8}$	"

WROUGHT IRON.

One cubic foot weighs	480	lbs.
One square foot 1 inch thick weighs....	40	"
A bar 1 in. square and 1 ft long weighs	$3\frac{1}{3}$	"

STEEL.

One cubic foot weighs	490	lbs.
One square foot 1 inch thick weighs....	$40\frac{4}{5}$	"
A bar 1 in. square and 1 ft. long weighs	$3\frac{2}{5}$	"

HOW TO FIND THE WEIGHT OF SQUARE AND FLAT IRON AND STEEL BARS.

As shown above, a bar of cast iron 1 inch square and 1 foot long or its equivalent weighs.. $3\frac{1}{8}$ lbs.
Wrought iron......................... $3\frac{1}{3}$ "
Steel .... $3\frac{2}{5}$ "

Hence to find the weight of a bar the number of feet of square inches it contains must first be found, then multiply that number of feet by $3\frac{1}{3}$ if wrought iron; $3\frac{1}{8}$ if cast iron ; $3\frac{2}{5}$ if steel, the result will be the total weight of the bar.

To find the number of feet of square inches contained in a bar proceed as follows :

1. If the bar measures even whole inches thick by even whole inches wide, as 3″ by 3″, or 2″ by 3″, or 1″ by 4″, then multiply the width by the

thickness and that product by the length in feet. The result will be the total number of feet of square inches. Then mutiply that poduct, if wrought iron, by $3\frac{1}{3}$, the result will be the total weight of the bar.

EXAMPLE.

Bar 2″ by 3″ by 10 feet long.

$\therefore$ 2″ × 3″ = 6, then 6 × 10 = 60, then $3\frac{1}{3}$ × 60 = 200 lbs.

2. If the bar measures even $\frac{1}{2}$ inches thick and even $\frac{1}{2}$ inches wide, as $\frac{1}{2}$″ by 1″, $1\frac{1}{2}$″ by $1\frac{1}{2}$″, or 2″ by $2\frac{1}{2}$″, then multiply the total number of sectional square $\frac{1}{2}$ inches by the length of bar in feet, and divide that product by 4, the quotient will be the number of feet of square inches in the bar.

EXAMPLE.

$1\frac{1}{2}$″ by $1\frac{1}{2}$″ by 12 feet long.

$1\frac{1}{2}$″ by $1\frac{1}{2}$″ contains nine square half inches, hence 9 × 12 = 108, then 108 ÷ 4 = 27 feet of square inches. Then $3\frac{1}{3}$ × 27 = 90 lbs.

3. If the bar measures even $\frac{1}{4}$ inches thick and even $\frac{1}{4}$ inches wide, as 1″ by $1\frac{1}{4}$″, or $\frac{3}{4}$″ by $\frac{3}{4}$″, or 1″ by $\frac{3}{4}$″, then multiply the total number of sectional square $\frac{1}{4}$ inches by the length of the bar in feet and divide that product by 16, the quotient will be the number of feet of square inches in the bar.

EXAMPLE.

1″ by $\frac{3}{4}$″ by 10 feet long.

1″ by $\frac{3}{4}$″ contains 12 square $\frac{1}{4}$ inches, hence 12 × 10 = 120, then 120 ÷ 16 = $7\frac{1}{2}$ feet of square inches. Then $3\frac{1}{3}$ × $7\frac{1}{2}$ = 25 lbs.

4. If the bar measures even $\frac{1}{8}$ inches wide and even $\frac{1}{8}$ inches thick, as 1″ by $1\frac{1}{8}$″, or $\frac{1}{2}$″ by $\frac{7}{8}$″, or 1″ by $1\frac{3}{8}$, then multiply the total number of sectional square $\frac{1}{8}$ inches by the length of the bar in feet, and divide that product by 64, the quotient will be the number of feet of square inches in the bar.

EXAMPLE.

1″ by $\frac{3}{8}$″ by 8 feet long.
1″ by $\frac{3}{8}$″ contains 24 square $\frac{1}{8}$ inches, hence 24 × 8 = 192, then 192 ÷ 64 = 3 feet of square inches. Then $3\frac{1}{3}$ × 3 = 10 lbs.

HOW TO FIND THE WEIGHT OF ROUND STEEL AND IRON PER FOOT.

To find the weight per foot of round steel and wrought iron, reduce the diameter to $\frac{1}{4}$ inches; square the same then divide that product by 6. The result will be the number of lbs. contained in one foot.

EXAMPLE.

2″ round contains (8) eight $\frac{1}{4}$ inches in diameter; hence 8 × 8 = 64, then 64 ÷ 6 = $10\frac{2}{3}$ lbs., the weight of one foot of 2″ round steel. Or, $2\frac{1}{4}$″ contains (9) nine $\frac{1}{4}$ inches in diameter, hence 9 × 9 = 81, then 81 ÷ 6 = $13\frac{1}{2}$ lbs. per foot.

Or, $1\frac{3}{4}$ round = (7) seven $\frac{1}{4}$ inches, hence 7 × 7 = 49, then 49 ÷ 6 = $8\frac{1}{6}$ lbs. per foot.

NOTE.—If the diameter is reduced to $\frac{1}{8}$ inches and squared, then divide by 24, the result will be the weight per foot.

EXAMPLE.

$2\frac{1}{8}$″ round contains (17) seventeen $\frac{1}{8}$ inches in diameter, hence 17 × 17 = 289, then 289 ÷ 24 = 12 lbs.

If the diameter is reduced to $\frac{1}{16}$ inches and squared, then divide by 96. The result will be the weight per foot.

EXAMPLE.

$2\frac{3}{16}$ round contains (35) thirty-five $\frac{1}{16}$ inches in diameter, hence 35 × 35 = 1225, then 1225 ÷ 96 = $12\frac{3}{4}$ lbs.

Weight of Round and Square Iron per Foot.

Size Inches.	Round.	Square.	Size Inches.	Round.	Square.
¼	.165	.211	4½	53.760	68.448
⅜	.373	.47[illegible]	4¾	59.900	76.264
½	.663	.845	5	66.350	84.480
⅝	1.043	1.320	5¼	73.172	93.168
¾	1.493	1.901	5½	80.304	102.24
⅞	2.032	2.588	5¾	87.776	111.75
1	2.654	3.380	6	95.552	121.66
1⅛	3.359	4.278	6¼	103.70	132.04
1¼	4.147	5.280	6½	112.16	142.81
1⅜	5.019	6.390	6¾	120.96	154.01
1½	5.972	7.604	7	130.04	165.63
1⅝	7.010	8.926	7¼	139.54	177.67
1¾	8.128	10.352	7½	149.32	190.13
1⅞	9.333	11.883	7¾	159.45	203.02
2	10.616	13.520	8	169.85	216.33
2⅛	11.988	15.263	8¼	180.69	230.06
2¼	13.440	17.112	8½	191.80	244.22
2⅜	14.975	19.066	8¾	203.26	258.8
2½	16.588	21.120	9	215.04	273.79
2⅝	18.293	23.292	9¼	227.15	289.22
2¾	20.076	25.56	9½	239.60	305.056
2⅞	21.944	27.939	9¾	252.37	321.33
3	23.888	30.416	10	265.40	337.92
3¼	28.040	35.704	10¼	278.92	355.30
3½	32.512	41.408	10½	292.68	372.70
3¾	37.332	47.534	10¾	306.80	390.80
4	42.464	54.084	11	321.21	409.00
4¼	47.952	61.055	12	382.20	486.70

Weight of Flat Iron per Foot.

SIZES.	1/8	3-16	1/4	3/8	1/2	5/8	3/4	7/8	1
1/2	21	31	.42	.63					
3/4	.32	48	.63	.95	1.27	1.58			
1	42	.63	.84	1.26	1.69	2.11	2.53	2.96	
1 1/4	52	.79	1.05	1.58	2.11	2.64	3.16	3.70	4.22
1 3/8	.58	.87	1.16	1.74	2.32	2.90	3.48	4.06	4.64
1 1/2	.63	.95	1.27	1.90	2.53	3.17	3.80	4.44	5.07
1 3/4	.74	1.11	1.48	2.21	2.95	3.70	4.43	5.43	5.91
2	.84	1.27	1.69	2.53	3.38	4.22	5.07	5.92	6.76
2 1/4	.95	1.42	1.90	2.85	3.80	4.75	5.70	6.65	7.60
2 1/2	1.06	1.58	2.11	3.17	4.22	5.28	6.33	7.40	8.45
2 3/4	1.16	1.74	2.32	3.49	4.64	5.81	6.97	8.13	9.29
3	1.27	1.90	2.53	3.80	5.07	6.34	7.60	8.87	10.14
3 1/4	1.37	2.06	2.74	4.12	5.49	6.86	8.24	10.09	10.98
3 1/2	1.48	2.22	2.95	4.43	5.91	7.39	8.87	10.87	11.83
3 3/4	1.58	2.38	3.17	4.75	6.34	7.92	9.51	11.65	12.68
4	1.69	2.53	3.38	5.07	6.76	8.45	10.14	11.83	13.52
4 1/4	1.80	2.69	3.69	5.39	7.18	8.98	10.78	12.57	14.37
4 1/2	1.90	2.85	3.80	5.70	7.60	9.50	11.41	13.31	15.21
4 3/4	2.01	3.01	4.01	6.02	8.03	10.03	12.05	14.05	16.06
5	2.11	3.17	4.22	6.34	8.45	10.56	12.67	14.79	16.90
5 1/4	2.22	3.33	4.44	6.66	8.87	11.08	13.20	15.53	17.75
5 1/2	2.32	3.48	4.65	6.98	9.29	11.61	13.93	16.29	18.59
5 3/4	2.43	3.65	4.87	7.29	9.72	12.14	14.56	17.01	19.43
6	2.53	3.80	5.07	7.60	10.14	12.67	15.20	17.75	20.28

Weight of Octagon Steel Bars per Foot.

Size.	Lbs.	Size.	Lbs.	Size.	Lbs.	Size.	Lbs.
1-8	.04	1	2.82	2 5/8	19.45	4 3/4	62.52
3-16	.10	1 1/8	3.56	2 3/4	21.28	5	70.60
1-4	.18	1 1/4	4.40	2 7/8	23 28	5 1/4	77.80
5-16	.28	1 3/8	5.32	3	25 36	5 1/2	85.15
3 8	.40	1 1/2	6.34	3 1/8	27.50	5 3/4	93.12
7-16	.54	1 5/8	7.32	3 1/4	29.28	6	101.45
1-2	.70	1 3/4	8.64	3 3/8	32 10	6 1/2	117.12
9-16	.89	1 7/8	9.92	3 1/2	34.56	7	138.24
5-8	1.10	2	11.28	3 5/8	37.05	8	180.48
11-16	1.33	2 1/8	12.71	3 3/4	39.68	9	227.84
3-4	1.58	2 1/4	14.24	4	45.12	10	282.40
13 16	1.83	2 3/8	15.88	4 1/4	50.84	11	340.60
7 8	2.16	2 1/2	17.65	4 1/2	56.96	12	405.80
15 16	2.48						

Weight of Plate Iron per Square Foot.

Thickness	Pounds	Thickness	Pounds	Thickness	Pounds
1-32	1.259	17-32	21.400	1 1-16	42.799
1-16	2.517	9-16	22.659	1 1-8	45.317
3-32	3.777	19-32	23.917	1 3-16	47.834
1-8	5.035	5-8	25.176	1 1-4	50.352
5-32	6.293	21-32	26.435	1 5 16	52.869
3-16	7.552	11-16	27.694	1 3-8	55.387
7-32	8.811	23 32	28.952	1 7-16	57.904
1-4	10.070	3 4	30.211	1 1-2	60.422
9-32	11.329	25-32	31.470	1 9-16	62.94
5-16	12.588	13-16	32.729	1 5-8	65.458
11-32	13.847	27-32	33.988	1 11-16	67.975
3-8	15.106	7-8	35.247	1 3-4	70.493
13-32	16 364	29-32	36.505	1 13-16	73.010
7-16	17.623	15-16	37.764	1 7-8	75.528
15-32	18.882	31-32	39.023	1 15-16	78.046
1-2	20.141	1	40.282	2	80.564

Weight per Square Foot of Sheet Wrought Iron, Steel, Copper and Brass.

FOR THICKNESS BY AMERICAN (BROWN & SHARP'S) GAUGE

No. of Gauge.	Thickness in Inches.	Iron.	Steel.	Copper	Brass.
0000	.46	18.46	18.70	20.84	19.69
000	.4096	16.44	16.66	18.56	17.53
00	.3648	14.64	14.83	16.53	15.61
0	.3249	13.04	13.21	14.72	13.90
1	.2893	11.61	11.76	13.11	12.38
2	.2576	10.34	10.48	11.67	11.03
3	.2294	9.21	9.33	10.39	9.82
4	.2043	8.20	8.31	9.26	8.74
5	.1819	7.30	7.40	8.24	7.79

WEIGHT PER SQUARE FT. OF SHEET WROUGHT IRON, STEEL, COPPER AND BRASS.—(CONTINUED.)

No. of Gauge.	Thickness in inches.	Iron.	Steel.	Copper.	Brass.
6	.1620	6.50	6.59	7.34	6.93
7	.1443	5.79	5.87	6.54	6.18
8	.1285	5.16	5.22	5.82	5.50
9	.1144	4.59	4.65	5.18	4.90
10	.1019	4.09	4.14	4.62	4.36
11	.0907	3.64	3.69	4.11	3.88
12	.0808	3.24	3.29	3.66	3.46
13	.0720	2.89	2.93	3.26	3.08
14	.0641	2.57	2.61	2.90	2.74
15	.0571	2.29	2.32	2.59	2.44
16	.0508	2.04	2.07	2.30	2.18
17	.0453	1.82	1.84	2.05	1.94
18	.0403	1.62	1.64	1.83	1.73
19	.0359	1.44	1.46	1.63	1.54
20	.0320	1.28	1.30	1.45	1.37
21	.0285	1.14	1.16	1.29	1.22
22	.0253	1.02	1.03	1.15	1.08
23	.0226	.906	.918	1.02	.966
24	.0201	.807	.817	.911	.860
25	.0179	.718	.728	.811	.766
26	.0159	.640	.648	.722	.682
27	.0142	.570	.577	.643	.608
28	.0126	.507	.514	.573	.541
29	.0113	.452	.458	.510	.482
30	.0100	.402	.408	.454	.429
31	.0089	.358	.363	.404	.382
32	.0080	.319	.323	.360	.340
33	.0071	.284	.288	.321	.303
34	.0063	.253	.256	.286	.270
35	.0056	.225	.228	.254	.240

Weight of Sheets of Wrought Iron, Steel, Copper and Brass.

Weights per Square Foot. Thickness by Birmingham Gauge.

No. of Guage.	Thickness In Inches	Iron.	Steel.	Copper.	Brass.
0000	.454	18.22	18.46	20.57	19.43
000	.425	17.95	17.28	19.25	18.19
00	.38	15.25	15.45	17.21	16.26
0	.34	13.64	13.82	15.40	14.55
1	.3	12.04	12.20	13.59	12.84
2	.284	11.40	11.55	12.87	12.16
3	.259	10.39	10.53	11.73	11.09
4	.238	9.55	9.68	10.78	10.19
5	.22	8.83	8.95	9.97	9.42
6	.203	8.15	8.25	9.20	8.69
7	.18	7.22	7.32	8.15	7.70
8	.165	6.62	6.71	7.47	7.06
9	.148	5.94	6.02	6.70	6.33
10	.134	5.38	5.45	6.07	5.74
11	.12	4.82	4.88	5.44	5.14
12	.109	4.37	4.43	4.94	4.67
13	.095	3.81	3.86	4.30	4.07
14	.083	3.33	3.37	3.76	3.55
15	.072	2.89	2.93	3.26	3.08
16	.065	2.61	2.64	2.94	2.78
17	.058	2.33	2.36	2.63	2.48
18	.049	1.97	1.99	2.22	2.10
19	.042	1.69	1.71	1.90	1.80
20	.035	1.40	1.42	1.59	1.50
21	.032	1.28	1.30	1.45	1.37
22	.028	1.12	1.14	1.27	1.20
23	.025	1.00	1.02	1.13	1.07
24	.022	.883	.895	1.00	.942
25	.02	.803	.813	.906	.856
26	.018	.722	.732	.815	.770
27	.016	.642	.651	.725	.685
28	.014	.562	.569	.634	.599
29	.013	.522	.529	.589	.556
30	.012	.482	.488	.544	.514
31	.01	.401	.407	.453	.428
32	.009	.361	.366	.408	.385
33	.008	.321	3.25	.362	.342
34	.007	.281	2.85	.317	.300
35	.005	.201	2.02	.227	.214

HOW TO FIND THE WEIGHT OF CAST IRON BALLS.

To find the weight of Cast Iron Balls, multiply the cube of the diameter by .1377. Or multiply the cube of the diameter in inches by 3 and divide that product by 22, the quotient will be the weight nearly.

EXAMPLE.

Diam. 5″, cube of same 125″; hence, 3 × 125″ = 375, then 375 ÷ 22 = 17 $\frac{1}{22}$ lbs.

NOTE.—To find the cube of a ball, square the diameter, then multiply that product by the diameter, the result will be the cube.

EXAMPLE 5″ BALL.

∴ 5 × 5 = 25 the square, then 5 × 25 = 125 the cube. Or 6 × 6 = 36 the square, then 6 × 36 = 216 the cube.

WEIGHT OF BALLS.

Diam. in Inches.	Cast Lead	Cast Copper	Cast Brass	Cast Iron	Diam. in Inches.	Cast Lead	Cast Copper	Cast Brass	Cast Iron
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
½	.026	.021	.019	.017	5	26.0	20.8	18.6	17.0
¾	.088	.070	.063	.058	¼	30.1	24.1	21.5	19.8
1	.209	.167	.148	.136	½	34.7	27.7	24.7	22.7
¼	.408	.325	.290	.266	¾	39.6	31.7	28.3	25.9
½	.705	.562	.501	.460	6	45.0	36 0	32 0	29.4
¾	1.12	.893	.795	.731	½	57.2	45.8	40.8	37.4
2	1.67	1.33	1.19	1.07	7	71.5	57.2	50.9	46.8
¼	2.38	1.90	1.69	1.55	½	88.0	70.3	62.6	57.5
½	3.25	2.60	2.32	2.13	8	106.	85.3	76.0	69.8
¾	4.34	3.47	3.09	2.83	½	127.	102.	91.2	83.7
3	5.63	4.50	4.01	3.68	9	151.	121.	108.	99.4
¼	7.15	5.72	5.10	4.68	½	178.	143.	127.	117.
½	8.94	7.14	6.36	5.85	10	208.	167.	148.	136.
¾	11.0	8.79	7.83	7.19	½	241.	193.	172.	158.
4	13.4	10.7	9.50	8.73	11	277.	222.	198.	182.
¼	16.0	12.8	11.4	10.5	½	317.	253.	226.	207.
½	18.9	15.2	13.5	12.4	12	360.	288.	257.	236.
¾	22.7	17.9	15.9	14.6					

WEIGHT OF CAST IRON PIPE PER LINEAL FOOT.

Bore in Inches	THICKNESS OF METAL IN INCHES.									Bore in Inches
	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
2	5.5	8.7	12.3	16.1	20.3	24.7	29.5	34.5	39.9	2
2 1/2	6.8	10.6	14.7	19.2	24.0	29.0	34.4	40.0	46.0	2 1/2
3	7.9	12.4	17.2	22.2	27.6	23.3	39.3	45.6	52.2	3
3 1/2	9.2	14.3	19.6	25.3	31.4	37.6	44.2	51.0	58.3	3 1/2
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4	4
4 1/2	11.7	18.0	24.5	31.5	38.7	46.2	54.0	62.1	70.6	4 1/2
5	12.9	19.8	27.0	34.5	42.3	50.5	59.9	67.7	76.7	5
5 1/2	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.9	5 1/2
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	89.0	6
7	17.8	27.2	36.9	46.8	57.1	67.7	78.5	89.8	101.	7
8	20.3	30.8	41.7	52.9	64.4	76.2	88.4	101.	114.	8
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	112.	126.	9
10	25.2	38.2	51.5	65.2	79.2	93.4	108.	123.	138.	10

WEIGHT OF CAST IRON PIPE PER LENIAL FOOT.—(Continued.)

THICKNESS OF METAL IN INCHES.

Bore in Inches	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	Bore in Inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
11	27.6	41.9	56.5	71.3	86.5	102.	118.	134.	150.	11
12	30.1	45.6	61.4	77.5	93.9	111.	128.	145.	163.	12
13	32.5	49.2	66.3	83.6	101.	119.	138.	156.	175.	13
14	35.0	52.9	71.2	89.7	109.	128.	147.	167.	187.	14
15	37.4	56.6	76.1	95.9	116.	136.	157.	178.	199.	15
16	39.1	60.3	81.0	102.	123.	145.	167.	189.	212.	16
18	44.8	67.7	90.9	114.	138.	162.	187.	211.	236.	18
20	49.7	75.2	101.	127.	153.	179.	206.	233.	261.	20
22	54.6	82.6	111.	139.	168.	197.	226.	‘55	285.	22
24	59.6	89.9	120.	151.	182.	214.	245.	278.	310.	24
26	64.5	97.3	131.	164.	198.	231.	266.	300.	335.	26
28	69.4	105.	140.	176.	212.	249.	286.	323.	360.	28
30	74.2	112.	150.	188.	227.	266.	305.	345.	384.	30

NOTE.—For each joint, add a foot to length of pipe.

BELL AND SPIGOT PIPE FOR WATER OR GAS.

Diameter.	Head 100 ft. Pressure, 43 lbs.		Head 200 ft. Pressure, 86 lbs.		Head 300 ft. Pressure 130 lbs.		Lead per Joint.	Hemp per Joint.	Diameter.
	Thickness.	Weight per Length	Thickness.	Weight per Lenght	Thickness.	Weight per Length	Pounds	Ounces	
1	.26	16	.26	16	.26	16	2.0	1.8	1
1¼	.26	20	.26	20	.26	20	2.25	1.5	1¼
1½	.26	36	.26	36	.26	36	2.75	1.75	1½
2	.36	63	.41	72	.45	81	3.25	2.25	2
2½	.36	81	.41	90	.45	99	3.90	2.5	2½
3	.38	167	.41	177	.45	200	4.40	2.8	3
4	.40	230	.42	243	.45	260	5.50	3.5	4
5	.42	295	.45	315	.48	338	6.80	4.4	5
6	.43	364	.47	393	.51	426	8.00	5.0	6
8	.46	513	.51	567	.56	624	11.50	7.0	8
10	.50	685	.56	765	.62	852	14.50	8.5	10
12	.53	870	.60	985	.68	1110	18.00	11.0	12
14	.56	1074	.65	1229	.73	1399	21.50	13.0	14
16	.60	1293	.69	1496	.79	1723	24.00	15.0	16
18	.63	1532	.74	1788	.85	2065	27.00	16.0	18
20	.66	1788	.78	2104	.91	2444	31.50	20.0	20
24	.75	2407	.87	2803	1.02	3290	37.00	24.0	24
30	.87	3482	1.01	4027	1.19	4783	51.00	33.0	30
36	.98	4699	1.14	5460	1.36	6543	75.00	48.0	36
40	1.09	5807	1.23	6525	1.48	7858	85.00	54.0	40
42	1.10	6147	1.28	7100	1.54	8568	90.00	58.0	42
48	1.25	7982	1.41	8946	1.71	10857	110.00	70.0	48
60	1.40	11000	1.62	13000	1.83	15000	150.00	100.0	60

1″ and 1¼″ in 6′ lengths; 1½″ and 2″ in 9′ lengths; 3″ and upwards in 12′ lengths. Weights for lead and hemp are approximate only.

STANDARD FLANGE PIPE DIMENSIONS.

At a joint meeting of committees of the American Society of Mechanical Engineers and the Master Steam Fitters' Association together with a number of representative manufacturers, held in the rooms of the American Society of Mechanical Engineers in New York City. Wednesday, July 18, 1894, the following standard of dimensions for Flanged Steam Pipe and Fittings, for a working pressure of 200 pounds was recommended for adoption.

Pipe Size, inches.	Pipe Thickness $P \cdot\cdot 100 \frac{d}{4s} .333\left(1-\frac{d}{100}\right)$	Thickness, nearest fraction, inches.	Stress on pipe per square inch at 200 lbs.	Flange Diameters, inches.	Flange Thickness, inches.
2	.409	7/16	460	6	5-8
2 1/2	.429	7/16	550	7	11-16
3	.448	7/16	690	7 1/2	3-4
3 1/2	.466	1/2	700	8 1/2	13-16
4	.486	1/2	800	9	15-16
4 1/2	.498	1/2	900	9 1/4	15-16
5	.525	1/2	1000	10	15-16
6	.563	9/16	1060	11	1
7	.60	5/8	1120	12 1/2	1 1-16
8	.639	5/8	1280	13 1/2	1 1/8
9	.678	11/16	1310	15	1 1/8
10	.713	3/4	1330	16	1 3-16
12	.79	13/16	1470	19	1 1/4
14	.864	7/8	1600	21	1 3/8
15	.904	15/16	1600	22 1/4	1 3/8
16	.946	1	1600	23 1/2	1 7-16
18	1.02	1 1/16	1690	25	1 9-16
20	1.09	1 1/8	1780	27 1/2	1 11-16
22	1.18	1 3/16	1850	29 1/2	1 13-16
24	1.25	1 1/4	1920	31 1/2 32	1 1/4 1 7/8
26	1.30	1 5/16	1980	33 3/4 34 1/4	1 7/8 2
28	1.38	1 3/8	2040	35 36 1/2	1 15/16 2 1/16
30	1.48	1 1/2	2000	38 38 3/4	1 1/2 2 1/8
36	1.71	1 3/4	1920	44 1/2 45 3/4	1 3/4 2 3/8
42	1.87	2	2100	51 52 3/4	1 7/8 2 5/8
48	2.17	2 1/4	2130	57 1/2 59 1/2	2 2 3/4

NOTE.—Sizes up to 24 inches are designed for 200 lbs. or less. Sizes from 24 to 48 inches are divided into two scales; one for 200 lbs., the other for less. Two sizes of bolts given are for medium and high pressures.

Bolt Circle Diameter, inches.		Number of Bolts.	Bolt Size Diameters, inches.		Bolt Length, inches.	Stress on each bolt per square inch, at bottom of thread at 200 lbs.	Pipe Size, Inches.
	4¾	4	½	⅝	2	825	2
	5¼	4	½	⅝	2¼	1050	2½
	6	4	½	⅝	2½	1330	3
	6½	4	½	⅝	2½	2530	3½
	7¼	4	⅝	¾	2¾	2100	4
	7¾	8	⅝	¾	3	1430	4½
	8½	8	⅝	¾	3	1630	5
	9⅝	8	⅝	¾	3	2360	6
	10¾	8	⅝	¾	3¼	3200	7
	11¾	8	⅝	¾	3½	4190	8
	13	12	⅝	¾	3½	3610	9
	14¼	12	¾	⅞	3½	2970	10
	16½	12	¾	⅞	3¾	4280	12
	18¾	12	⅞	1	4¼	4280	14
	20	16	⅞	1	4¼	3660	15
	21¼	16	⅞	1	4¼	4210	16
	22¾	16	1	1⅛	4¾	4540	18
	25	20	1	1⅛	5	4490	20
	27¼	20	1	1¼	5½	4320	22
29¼	29½	20	1	1¼	5½	5130	24
31¼	31¾	24	1	1¼	5¾	5030	26
33½	34	28	1	1¼	6	5000	28
35½	36	28	1⅛	1⅜	6¼	4590	30
42	42¾	32	1⅛	1⅜	6½	5790	36
48½	49½	36	1¼	1½	7¼	5700	42
54¾	56	44	1⅜	1½	7¾	6090	48

Weight and Strength of Iron Chains.

Diam. of rod of which links are made.	weight of chain per ft. run.	Breaking strain of the chain.		Diam. of rod of which links are made.	Weight of chain per ft. run.	Breaking strain of the chain.	
Ins.	Lbs.	Lbs.	Tons.	Ins.	Lbs.	Lbs.	Tons.
3/16	.325	1731	.773	1	9.26	49280	22.00
1/4	.579	3069	1.37	1 1/8	11.7	59226	26.44
5/16	.904	4794	2.14	1 1/4	14.5	73114	32.64
3/8	1.30	6922	3.09	1 3/8	17.5	88301	39.42
7/16	1.78	9408	4.20	1 1/2	20.8	105280	47.00
1/2	2.31	12320	5.50	1 5/8	24.4	123514	55.14
9/16	2.93	15590	6.96	1 3/4	28.4	143293	63.97
5/8	3.62	19219	8.58	1 7/8	32.6	164505	73.44
11/16	4.38	23274	10.39	2	37.0	187152	83.55
3/4	5.21	27687	12.36	2 1/4	46.9	224448	100.2
13/16	6.11	32301	14.42	2 1/2	57.9	277088	123.7
7/8	7.10	37632	16.80	2 3/4	70.0	335328	149.7
15/16	8.14	43277	19.32	3	83.3	398944	178.1

Table of Decimal Equivalents of One Inch.

1-64	.015625	17-64	.265624	33-64	.515625	49-64	.765625
1-32	.03125	9-32	.28125	17-32	.53125	25-32	.78125
3-64	.046875	19-64	.296875	35-64	.546875	51-64	.796875
1-16	.0625	5-16	.3125	9-16	.5625	13-16	.8125
5-64	.078125	21-64	.328125	37-64	.578125	53-64	.828125
3-32	.09375	11-32	.34375	19-32	.59375	27-32	.84375
7-64	.109375	23-64	.359375	39-64	.609375	55-64	.859375
1-8	.125	3-8	.375	5-8	.625	7-8	.875
9-64	.140625	25-64	.390625	41-64	.640625	57-64	.890625
5-32	.15625	13-32	.40625	21-32	.65625	29-32	.90625
11-64	.171875	27-64	.421875	43-64	.671875	59-64	.921875
3-16	.1875	7-16	.4375	11-16	.6875	15-16	.9375
13-64	.203125	29-64	.453125	45-64	.703125	61-64	.953125
7-32	.21875	15-32	.46875	23-32	.71875	31-32	.96875
15-64	.234375	31-64	.484375	47-64	.734375	63-64	.984375
1-4	.25	1-2	.50	3-4	.75	1	

STANDARD UNITED STATES GAUGE.

No. of Gauge.	Approximate thickness in fractions of an inch.	Approximate thickness in decimal parts of an inch.	Weight per square foot in pounds avoirdupois.
0000000	1-2	.5	20.00
000000	15 32	.46875	18.75
00000	7 16	.4575	17.50
0000	13 32	.40625	16.25
000	3 8	.375	15.
00	11-32	.34375	13.75
0	5 16	.3125	12.50
1	9 32	28125	11.25
2	17-64	.265625	10.625
3	1-4	.25	10.
4	15 64	.234375	9.375
5	7-32	.21875	8.75
6	13 64	.203125	8.125
7	3-16	.1875	7.5
8	11-64	.171875	6.875
9	5 32	.15625	6.25
10	9 64	.140625	5.625
11	1-8	.125	5.
12	7-64	.109375	4.375
13	3-32	.09375	3.75
14	5 64	.078125	3.125
15	9 128	.0703125	2.8125
16	1 16	.0625	2.5
17	9 160	.05625	2.25
18	1 20	.05	2.
19	7 160	.04375	1.75
20	3-80	.0375	1.50
21	11 320	.034375	1.375
22	1-32	.03125	1.25

STANDARD UNITED STATES GAUGE.—(Continued.)

No. of Gauge.	Approximate thickness in fractions of an inch.	Approximate thickness in decimal parts of an inch.	Weight per square foot in pounds Avoirdupois.
23	9-320	.028125	1.125
24	1-40	.025	1.
25	7-320	.021875	.875
26	3-160	.01875	.75
27	11-640	.0171875	.6875
28	1-64	.015625	.625
29	9-640	.0140625	.5625
30	1-80	.0125	.5
31	7-640	.0109375	.4375
32	13-1280	.01015625	.40625
33	3-320	.009375	.375
34	11-1280	.00859375	.34375
35	5 640	.0078125	.3125
36	9-1280	.00703125	.28125
37	17-2560	.006640625	.265625
38	1-160	.00625	.25

For the purpose of securing uniformity of gauge throughout the United States, Congress, under date March 3d, 1893, adopted the above as the legal standard for determinating the thickness of uncoated iron and steel sheets, allowing a variation of 2½ per cent either above or below for practical use and application.

DIFFERENT STANDARDS FOR WIRE GAUGE IN USE IN THE UNITED STATES.

Number of Wire Guage.	American or Brown & Sharpe.	Birmingham or Stubbs'.	Washburn & Moen Mfg. Co. Worcester, Ms.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke, Mass.	Old English from Brass Mfgrs.' List
000000	....	.....	.46	....	....	....
00000	....	.....	.43	.45	....	....
0000	.46	.454	.393	.4	....	....
000	.40964	.425	.362	.36	.3586	....
00	.3648	.38	.331	.33	.3282	....
0	.32486	34	.307	.305	.2944	....
1	.2893	.3	.283	.285	.2777	....
2	.25763	.284	.263	.265	.2591	....
3	.22942	.259	.244	.245	2401	....
4	.20431	.238	.225	.225	.223	....
5	.18194	.22	.207	.205	2047	....
6	.16202	.203	.192	.19	.1885	....
7	14428	.18	177	.175	.1758	....
8	.12849	165	.162	.16	.1605	....
9	.11443	.148	.148	.145	.1471	...
10	.10189	.134	.135	.13	.1351	....
11	.090742	.12	.12	.1175	.1205	....
12	.080808	.109	.105	.105	.1055	....
13	.071961	.095	.092	.0925	.0928	....
14	.064084	.083	.08	.08	.0816	.083
15	.057068	.072	.072	.07	.0726	.072
16	.05082	.065	.063	.061	.0627	.065
17	045257	.058	.054	.0525	.0546.	.058
18	.040303	.049	.047	.045	.0478	.049
19	03589	.042	.041	.04	.0411	.04
20	.31961	.035	.035	.035	.0351	.035
21	.028462	.032	.032	.031	.0321	.0315
22	.025347	.028	.028	.028	.029	.0295
23	.022571	.025	.025	.025	.0261	.027

DIFFERENT STANDARDS OF WIRE GAUGES USED IN THE UNITED STATES.—(Continued.)

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs'.	Washburn & Woen Mfg. Co. Worcester, Ms.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke Mass.	Old English from Brass Mfgrs'. List.
24	.0201	.022	.023	.0225	.0231	.025
25	.0179	.02	.02	.02	.0212	.023
26	.01594	.018	.018	.018	.0194	.0205
27	.014195	.016	.017	.017	.0182	.01875
28	.012641	.014	.016	.016	.017	.0165
29	.011257	.013	.015	.015	.0163	.0155
30	.010025	.012	.014	.014	.0156	.01375
31	.008928	.01	.0135	.013	.0146	.01225
32	.00795	.009	.013	.012	.0136	.01125
33	.00708	.008	.011	.011	.013	.01025
34	.006304	.007	.01	.01	.0118	.0095
35	.005614	.005	.0095	.0095	.0109	.009
36	.005	.004	.009	.009	.01	.0075
37	.004453	....	.0085	.0085	.0095	.0065
38	.003965	....	.008	.008	.009	.00575
39	.003531	....	.0075	.0075	.0083	.005
40	.003144	....	.007	.007	.0078	.0045

WEIGHTS AND MEASURES.

TROY WEIGHT.

24 grains....................1 pennyweight (dwt.)
20 pennyweights..........1 ounce (oz.) 480 grains
12 ounces................1 pound (lb.) 5760 grains
20 grains..............................1 scruple
3 scruples...................1 dram 60 grains
8 drams.......................1 ounce 480 grains
12 ounces...............1 pound 5760 grains (gr.)

AVOIRDUPOIS WEIGHT.

27.34375 grains.......................... 1 dram
16 drams.....................1 ounce 437½ grains
16 ounces.....................1 pound 7000 grains
28 pounds........................1 quarter (qr.)
4 quarters....1 hundredweight (cwt.) 112 pounds
20 hundredweight..........1 ton (T) 2240 pounds

U. S. LIQUID MEASURE.

4 gills.............1 pint (pt.) 28.875 cubic inches
2 pints...........1 quart (qt.) 57.750 cubic inches
4 quarts.......... 1 gallon (gal.) 231 cubic inches
63 gallons.......................1 hogshead (hhd)
2 hogsheads..... ....1 pipe (p)
2 pipes................................. 1 ton

U. S. DRY MEASURE.

2 pints..........1 quart (qt.) 67.2006 cubic inches
4 quarts.1 gallon (gal.) 8 pts. 268.8025 cubic inches
2 gallons..1 peck (pk.) 16 pts. 8 qts. 537.605 cubic inches.
4 peck......1 bushel (bush.) 64 pts. 32 qts. 8 gals. 2150.42 cubic inches.

LONG MEASURE.

12 inches...........................1 foot (ft.)
3 feet.....................1 yard (yd.) 36 inches
5½ yards......................1 rod (rd.) 16½ feet
40 rods.........1 furlong (fur.) 220 yards 660 feet
8 furlongs 1 mile (m.) 320 rods 1760 yards 5280 feet
3 miles 1 league (l.) 960 rods 5280 yards 15840 feet

SQUARE MEASURE.

144	square	inches..................	1	square	foot
9	"	feet..........	1	"	yard
30¼	"	yards..................	1	"	rod
40	"	rods	1	"	rood
4	"	roods	1	"	acre
640	"	acres	1	"	mile

CIRCULAR MEASURE.

60 seconds (″)	1 minute
60 minutes	1 degree
30 degrees	1 sign
12 signs or 360°	1 circle

HOW TO FIND THE REQUIRED SPEED FOR EMERY WHEELS.

To find the proper number of revolutions an emery wheel must run per minute, divide 14,400 by the diameter in inches of the wheel, the quotient will be the correct number of revolutions.

EXAMPLE.

14,400 ÷ 12″ = 1200, which is the number of revolutions per minute a wheel 12″ must make.

Or 14,400 ÷ 8 = 1800; or 14,400 ÷ 6 = 2400, etc.

HOW TO FIND THE REQUIRED SPEED FOR CIRCULAR SAWS.

To find the proper number of revolutions a circular saw must run per minute, divide 36,000 by the diameter in inches of the saw, the quotient will be the correct number of revolutions.

EXAMPLE.

36,000 ÷ 60″ = 600, which is the number of revolutions per minute a 60″ saw must make. Or 36,000 ÷ 24 = 1500; or 36,000 ÷ 30 = 1200, etc.

WEIGHT OF RAILS PER MILE.

To find the number or tons of rails for one mile of single track, divide the weight per yard by 7, then multiply that quotient by 11.

EXAMPLE.

Weight of rail 56 lbs. per yard; hence, 56 ÷ 7 = 8, then 8 × 11 = 88 tons per mile.

TO PREVENT BABBITT METAL OR LEAD FROM EXPLODING.

Before pouring the metal or lead throw a piece of rosin about the size of a large hickory nut or walnut into the ladle and allow it to melt This method, though simple, is effectual and has proven highly satisfactory.

SPEED AND WEIGHT OF GRINDSTONES.

A speed of from 500 to 600 circumferential feet per minute for grindstones is a good standard and gives satisfactory results; hence, to find the number of revolutions the stone should run, divide the number of circumferential feet per minute by the circumference of the stone in feet, the quotient will be the number of revolutions.

EXAMPLE.

Stone 42″ diameter; circumference of same 11 feet nearly. Circumferential speed per minute 600 feet; then 600 ÷ 11 = 54 revolutions per minute.

WEIGHT OF GRINDSTONES.

To find the weight of a grindstone, multiply the area in inches by the thickness in inches, and divide by 12.25, the quotient will be the weight in pounds.

EXAMPLE.

Stone 30″ diameter; area of same is 706″; thickness of stone is 6″. Then, 706 × 6 = 4236 ÷ 12.25 = 345 lbs., weight of stone.

HOW TO DRILL AND SAW GLASS.

To drill glass, use a hard-tempered drill and a solution of camphor dissolved in turpentine, which apply the same as oil is applied when drilling iron or steel.

To saw glass, use a fine tooth, hard tempered saw and apply the same solution.

It must, of course, not be expected that glass can be drilled or sawed as rapidly as metal, as it requires more skill and care to operate on same; it can, however, be done very satisfactorily with the aid of this solution, combined with skill and judgment.

HOW TO ETCH OR ENGRAVE ON STEEL AND IRON.

To etch on steel, prepare a solution of muriatic acid 1 ounce, and nitric acid ½ ounce. Coat the piece of metal you wish to etch or write on with melted beeswax and allow it to cool. Then write the inscription plainly with any sharp pointed instrument through the beeswax to the metal, making sure that the metal is exposed where the inscription is to show. Then apply the acid with a feather or a stick, or even a rag, carefully filling each letter or character, and let it remain from two to thirty minutes, according to the depth desired for the lettering, after which immerse in water and remove the beeswax and acid, and rub over with oil to prevent further rust or tarnish.

HOW TO FIND THE DIAMETER A BICYCLE IS GEARED TO.

When it is said that a 28″ wheel is geared to say 63″, it means that the combination of the sprockets are such that one revolution of the pedals will advance the 28″ wheel a distance equal to that which a wheel 63″ in diameter would advance in one revolution.

To find the diameter a wheel is geared to, multiply the diameter of the wheel carrying the small sprocket by the number of teeth in large sprocket, and divide by the number of teeth in small sprocket, the quotient is the diameter the wheel is geared to.

EXAMPLE.

Diameter of wheel, 28″.
Large sprocket, 18 teeth.
Small sprocket, 8 teeth.
Then $28 \times 18 = 504 \div 8 = 63''$.

As the circumference of 63″ is found to be 198″ nearly, or $16\frac{1}{2}$ feet, it will thus be seen that one revolution of the pedals will advance the rider that distance. Then if 5280, which is the number of feet in a mile, is divided by $16\frac{1}{2}$, it is found that it requires 320 revolutions of the pedals to travel one mile.

INDEX.

TESTIMONIALS.

The following are only a few of the many unsolicited testimonials constantly received by the Author, which shows how very favorable this little work has been received and how popular it has become with all classes of mechanics and engineers.

SAYRE, PA.

I have found your Hand-Book of Practical Rules and Tables a very valuable and convenient work, and take pleasure in saying that for general every day shop practice, its worth and usefulness to all grades of practical workmen, in whatever capacity employed, cannot be overestimated.

Yours Respectfully,

C. H. WELCH,

Gen. Foreman L. V. R. R. Shops.

PITTSBURG, PA.

Your Hand Books were duly received. We are much pleased with its contents and regret that it is not two thousand pages instead of its present size, and containing as good and useful matter for practical mechanics.

Yours Respectfully, M. J. GARNIER.

BARNESVILLE, MINN.

I find your book to be of very much value. Please send me 16 copies cloth, and 2 copies leather bindings. AARON ELG.

WINNEPEG, MANITOBA.

Your Hand-Book having met with much favor here, I therefore have much pleasure in ordering 12 more leather copies. GEO. ROMETHWAITE.

CHICOPEE FALLS, MASS.

We received the Hand-Book and examined it. It is a useful book for all machinists.

J. STEVENS ARMS & TOOL CO.

RICHMOND, IND.

Please send me 4 more leather bound books. Everyone is well pleased with their book.

C. C. WORRALL.

WAUKESHA, WIS.

I am very much pleased with your book, and so are all of the boys that have seen it. Please send me at once, 11 leather, and 20 cloth bindings.

A. BLAIR.

AUBURN, N. Y.

I have examined your Hand-Book and find it a very commendable work, exactly filling the place you have intended for it, giving to machinists, even those with the smallest knowledge of figures, a ready and comprehensible means of solving a great many difficult problems.

W. H. CRANE.

CHATTANOOGA, TENN.

I like your book; it sells well. Everybody I have shown it to has ordered a copy.

D. T. JONES.

CLIFTON FORGE, VA.

Please send me two of your Hand-Books. Its just the thing I want, as most mechanical books are written in such a style, that unless one has an extra good education and is well up in algebra cal and geometrical problems they are of little or no use to him.

E. M. MILLER.

HAGERSTOWN, MD.

I have been looking over your book on mechanics. I am very much pleased and taken with its contents, and would like our men to get copies of it. Will you please advise me what rates we can get. An early reply will oblige.

H. E. PASSMORE,
Asst. M. of M., Wn. Md. R. R.

PHILADELPHIA, PA.

I am just in receipt of your valuable little book. I have just had my father's opinion of it (he being an engineer of international repute;) he says it is *all right*. WM. C. HENDERSON.

BRIDGETON, N. J.

We have a large number of machinists in this locality, and every man should have one of your "Practical Rules and Tables for Machinists." I keep one within reach and have always found it easy to understand and helpful in my work.
A. S. LAMBERT.

PARIS, TEXAS.

Please send me one of your Machinists' Hand-Books. Send it as soon as you can get it here. I have had one for the last five years and I have lost or mislaid it in traveling around. I would not be without one for a five dollar bill.
THOS. DALEY.

SAN FRANCISCO, CAL.

Your Hand-Book arrived safely, and am very much pleased with it. Enclosed find money for 27 copies of cloth and 3 of leather binding. Mr. M. J. Haley, foreman machinist of the Union Iron Works highly recommends your valuable book. Also James Smith, foreman tool maker, says that every machinist should own one. For my part, will state that I consider a machinist's kit incomplete without one.
FERNANDO A. SMITH.

I. A. OF M. "JOURNAL."

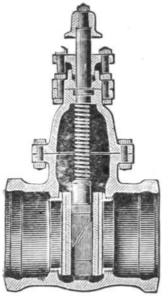
We wish to call special attention to an advertisement on third page cover of this issue, of the book advertised by C. E. Loetzer. This is a handy book for shop use and one every machinist should have. EDITOR.

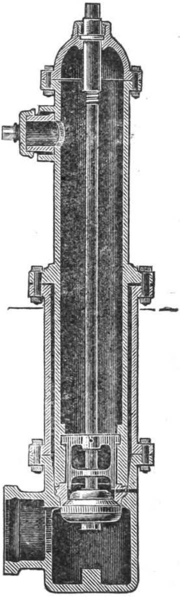
K-U-TA Fire Hydrants

All working parts removable without digging, are satisfactory and save expense.

K-U-TA Valves

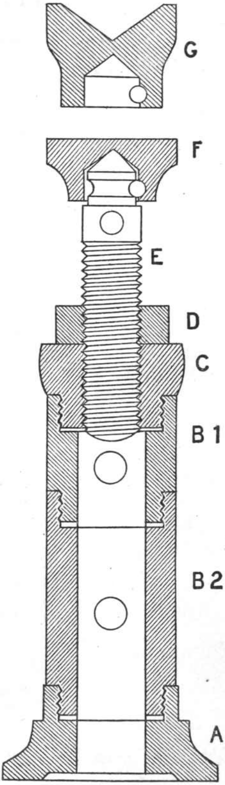
Are strong, simple, reliable, furnish the best service under all conditions, and do not get out of order.





Loetzer's Multiple Extension Screw Jack

(Patent applied for.)



This screw jack, see cut, is made up of threaded interchangeable sections, which, when screwed together, form a jack or blocking for variable heights. If a short jack is desired screw section C into the base A; if a higher one is wanted one or more of the section pieces B2 and B1 are used between C and A. When so built up the sections can not fall apart and scatter.

SIZES AND USE.

These jacks are made in three sizes—No. 1, 2 and 3—and are principally used for blocking up and supporting work on planers, milling machines, drill presses, boring mills, etc.

For putting springs under locomotives, fitting rod straps or other like work they have no equal; in fact, their uses and advantages are so numerous and unlimited that when once used they become indispensable and save their cost many times. Wooden blocks, chunks of iron, wedges, pieces of sheet iron and tin, and other relics from the scrap heap heretofore used for these purposes are done away with and displaced by a common sense practical device, which not only avoids annoyance, but saves a lot of valuable time, and makes the operation of adjusting work to a nicety a pleasure.

When adjustment is made the jamb-nut D will hold it rigid.

The head F is loosely swiveled on top of set screw to accommodate any uneven surface.

When it is desired to use the jack on a lathe, the base is furnished threaded in bottom to receive a bolt, which secures it to the face plate.

The set screws are U. S. Standard, and any standard screw can be used if a longer or shorter one than that furnished is desired, or to replace a broken one.

Extra sectional pieces B three or four inches long or longer, and extra head G, or base, will be furnished at moderate prices.

A regular Jack comprises the following pieces, viz. : A base A, either plain hole or threaded for bolt, two sectional pieces B, one and two inches long respectively, top piece C, jamb-nut D, long set screw E, and the head F, with flat top.

DIMENSIONS AND PRICES.

No. 1—1″ diam. body, ½″ set screw, adjustment 2″ to 7″, $1.50.

No. 2—1¼″ diam. body, ⅝″ set screw, adjustment 2″ to 7½″, $1.75.

No. 3—1½″ diam. body, ⅞″ set screw, adjustment 2½″ to 8″, $2.25.

CAYUTA WHEEL & FOUNDRY CO.,
Sayre, Pa.

ADDITIONAL TESTIMONIALS.

BALTIMORE, MD.

Kindly send me a copy of your book, fourth edition. I expect to follow shortly with a large order. I will say it is the best book published for machinists. I know machinists, who have told me that they would not part with it for twenty-five dollars. ROBT. J. VOLLMER.

PHILADELPHIA, PA.

Your favor of the 27th ult., with your very interesting Hand Book was duly received. I beg to thank you for the same. I am greatly pleased with the plain and simple way you treat interesting mechanical problems. This book should be in the hands of every mechanical engineer, foreman and workman in the different mechanical industries in the country. You have accomplished what other writers have failed to do. You have made your book interesting and easily understood by anyone who has a common school education, and who has never had the time and opportunity to perfect themselves in the higher branches of mathematics. H. L. MOULTON
Mechanical and Mill Engineer.

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