MACHINERY'S REFERENCE SERIES

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TABLES AND FORMULAS FOR SHOP AND DRAFTING-ROOM

Compiled by ERIK OBERG

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CONTENTS

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GENERAL TABLES AND FORMULAS.

The Use of Formulas*

Knowledge of algebra is not necessary for the use of formulas in solving simple problems; all the mathematical knowledge necessary is an understanding of the fundamental rules of arithmetic. The letters in formulas simply stand in place of the figures which are applied for specific cases or problems.

We know, for instance, that in spur gearing the pitch diameter times the pitch equals the number of teeth. Then, if D = pitch diameter, P = pitch, and N = number of teeth, the formula expressing this rule is

$$D \times P = N.$$

The rule expressed in this formula says that whatever actual numbers may express the diameter and the pitch, these numbers multiplied will give the number of teeth. Assume that the diameter is 6 inches, and the pitch 4. Then if these numbers are substituted in the formula, we have

$$6 \times 4 = 24.$$

The number of teeth, N, then equals 24. In the same way, if $D = 16$, and $P = 8$, then the number of teeth, N, equals 128. In formulas, each letter stands for a certain dimension or quantity. When solving a problem by the use of a formula, simply replace the letters in the formula by the figures given in a certain problem, and find the result as in a regular arithmetical problem.

In all formulas and other mathematical expressions the various operations should be carried out in the order given, except that all multiplications should be carried out before additions, subtractions, and divisions; and divisions should be carried out before additions and subtractions.

Rules for Mensuration.

Triangle.—Area equals one-half the product of the base and the altitude.

Parallelogram.—Area equals the product of the base and the altitude.

Trapezoid.—Area equals one-half the sum of the parallel sides multiplied by the altitude.

Irregular figure bounded by straight lines.—Divide the figure in triangles, and find the area of each triangle separately. The sum of the areas of all the triangles equals the area of the figure.

Circle.—Circumference equals diameter multiplied by 3.1416.

Circle.—Diameter equals circumference divided by 3.1416.

Circle.—Area equals diameter squared, multiplied by 0.7854.

Circle.—Diameter equals area divided by 0.7854, and the square root extracted of the quotient.

Circular arc.—Length equals the circumference of the circle, multiplied by the number of degrees in the arc, divided by 360.

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* For a more complete explanation of the use of formulas, see MACHINERY'S Jig Sheet No. 16 A, Use of Formulas, or MACHINERY'S Reference Series No. 52, Advanced Shop Arithmetic for the Machinist.

Circular sector.—Area equals the area of the whole circle multiplied by the quotient of the number of degrees in the arc of the sector divided by 360.

Circular segment.—Area equals area of circular sector formed by drawing radii from the center of the circle to the extremities of the arc of the segment, minus area of triangle formed by the radii and the chord of the arc of the segment.

Prism.—Volume equals the area of the base multiplied by the altitude.

Cylinder.—Volume equals the area of the base circle times the altitude.

Pyramid or Cone.—Volume equals the area of the base times one-third the altitude.

Sphere.—Area equals the square of the diameter multiplied by 3.1416.

Sphere.—Volume equals the cube of the diameter times 0.5236.

Spherical sector.—Volume equals two-thirds of the square of the radius of the sphere multiplied by the height of the contained spherical segment multiplied by 3.1416.

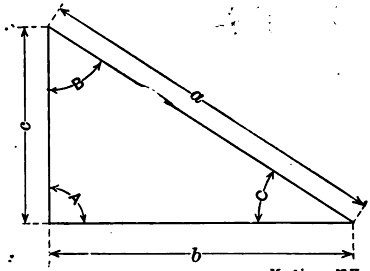
Spherical segment.—Volume equals the radius of the sphere less one-third of the height of the segment, multiplied by the square of the height of the segment, multiplied by 3.1416.

MATHEMATICAL SIGNS

$+$ Plus (sign of addition)	$\sqrt{}$ Square root
$-$ Minus (sign of subtraction)	$\sqrt[3]{}$ Cube root
$\pm$ Plus or Minus	$\sqrt[4]{}$ Fourth root
$\times$ Times (multiplication sign)	$\sqrt[n]{}$ *n*th root
$\div$ Divided by (division sign)	a^2 *a* square (2nd power of *a*)
$:$ Divided by (ratio, proportion)	a^3 *a* cube (3d power of *a*)
$=$ Equals	a^4 fourth power of *a*
$\cong$ Approximately equals	a^n *n*th power of *a*
$>$ Greater than	
$<$ Less than	$\frac{1}{n}$ Reciprocal value of *n*
$\geqq$ Greater than or equal to	
$\leqq$ Less than or equal to	*log* Logarithm
$::$ Equals, (in proportion)	log_e / *hyp log* } Hyperbolic or natural logarithm
$\therefore$ Therefore	
∞ Infinity	$\angle$ Angle
$^\circ$ Degree	*sin* Sine
$'$ Minute	*tan* Tangent
$''$ Second	*cos* Cosine
π (pi) 3.1416	*cot* Cotangent
g Acceleration due to gravity	*sec* Secant
i Imaginary quantity $(\sqrt{-1})$	*cosec* Cosecant
α Alpha (used for angles)	δ Delta (used for angles)
β Beta (used for angles)	ϕ Phi (used for angles)
γ Gamma (used for angles)	ω Omega (used for angles)

Trigonometrical Functions.

$a =$ hypotenuse,
$b =$ opposite side, to angle B,
$c =$ adjacent side, to angle B.



Machinery, N.Y.

Rule.	Formula.
sine of B = opposite side divided by hypotenuse.	$\sin B = \frac{b}{a}$
cosine of B = adjacent side divided by hypotenuse.	$\cos B = \frac{c}{a}$
tangent of B = opposite side divided by adjacent side.	$\tan B = \frac{b}{c}$
cotangent of B = adjacent side divided by opposite side.	$\cot B = \frac{c}{b}$
secant of B = hypotenuse divided by adjacent side.	$\sec B = \frac{a}{c}$
cosecant of B = hypotenuse divided by opposite side.	$\text{cosec}\ B = \frac{a}{b}$

Formulas for Right-Angled Triangles.

Suppose, for instance, that we call the three sides in a right-angled triangle a, b, and c, as shown in the figure above, and the angles opposite those sides A, B, and C. The angle A, of course, is a right or 90-degree angle. Then, for all right-angled triangles these formulas hold true:

$$a = \frac{b}{\cos C}; \qquad a = \frac{b}{\sin B};$$
$$a = \frac{c}{\cos B}; \qquad a = \frac{c}{\sin C};$$
$$c = b \tan C; \qquad b = a \sin B;$$
$$c = a \cos B; \qquad b = c \cot C;$$
$$b = c \tan B; \qquad c = a \sin C;$$
$$b = a \cos C; \qquad c = b \cot B;$$

It will be remembered that expressions such as $c \cot C$ mean simply $c \times \cot C$.

By means of the formulas given above, and a table of sines and tangents, either of the sides in a right-angled triangle may be found when one side and one angle, besides the 90-degree angle, are known. If two sides are known, but no angle outside of the 90-degree angle, the angles are found from the formulas:

$$\sin B = \frac{b}{a}; \qquad \cos B = \frac{c}{a};$$
$$\tan B = \frac{b}{c}; \qquad \cot B = \frac{c}{b};$$
$$\sin C = \frac{c}{a}; \qquad \cos C = \frac{b}{a};$$
$$\tan C = \frac{c}{b}; \qquad \cot C = \frac{b}{c};$$

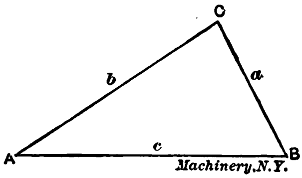
The third side may be found from the formulas

$$a = \sqrt{b^2 + c^2} \qquad b = \sqrt{a^2 - c^2} \qquad c = \sqrt{a^2 - b^2}.$$

The table on page 7 will prove helpful to readers who prefer to use the names for the different sides and angles rather than the letters in the formulas above. This table is arranged so that the required expressions for the parts to be found may be seen at a glance, as soon as the parts given have been located in the column to the left.

Oblique-Angled Triangles.

By means of the tables on pages 8 and 9, any part of an oblique triangle may be found when any three other parts are given. The parts given are found in the left-hand column, where a, b, and c de-



note the sides, and $\angle A$, $\angle B$, and $\angle C$ the angles A, B, and C, respectively, the same as in the triangle in the illustration above. When the line with the parts given has been located in the left-hand column of the table, simply use the formulas in the same line for finding the sides or angles which are not known. In some cases two steps are necessary for the solution; for example, if the sides a and b and the angle A are given, to find the side c; the formula for c is

$$c = \frac{a \sin C}{\sin A},$$

but angle B must first be found from the formula given for the sine for this angle, and then angle C is found from the formula

$$C = 180° - (A + B).$$

First after these operations are completed can the formula for c be applied.

TABLE FOR SOLVING RIGHT-ANGLE TRIANGLES.

Parts Given	Parts to be Found				
	Hypotenuse (Hyp.)	Adjacent Side (Adj.)	Opposite Side (Opp.)	Angle	Opposite Angle
Hyp. and Adj.	——	——	$\sqrt{\text{Hyp.}^2 - \text{Adj.}^2}$	$\text{Cos} = \frac{\text{Adj.}}{\text{Hyp.}}$	$\text{Sin} = \frac{\text{Adj.}}{\text{Hyp.}}$
Hyp. and Opp.	——	$\sqrt{\text{Hyp.}^2 - \text{Opp.}^2}$	——	$\text{Sin} = \frac{\text{Opp.}}{\text{Hyp.}}$	$\text{Cos} = \frac{\text{Opp.}}{\text{Hyp.}}$
Hyp. and Angle	——	Hyp. × Cos	Hyp. × Sin	——	90° − Angle
Adj. and Opp.	$\sqrt{\text{Adj.}^2 + \text{Opp.}^2}$	——	——	$\text{Tan} = \frac{\text{Opp.}}{\text{Adj.}}$	$\text{Cot} = \frac{\text{Opp.}}{\text{Adj.}}$
Adj. and Angle	$\frac{\text{Adj.}}{\text{Cos.}}$	——	Adj. × Tan	——	90° − Angle
Opp. and Angle	$\frac{\text{Opp.}}{\text{Sin.}}$	Opp. × Cot	——	——	90° − Angle

SOLUTION OF OBLIQUE ANGLE TRIANGLES.

Parts Given	Parts to be Found: $a =$	$b =$	$c =$	$\angle A$	$\angle B$	$\angle C$
a–b–c				$\frac{b^2+c^2-a^2}{2bc} = \cos A$	$\frac{a^2+c^2-b^2}{2ac} = \cos B$	$\frac{a^2+b^2-c^2}{2ab} = \cos C$
b–c–$\angle A$	$\sqrt{b^2+c^2-2bc\cos A}$				$\frac{b\sin A}{c-b\cos A} = \tan B$	$\frac{c\sin A}{b-c\cos A} = \tan C$
a–c–$\angle B$		$\sqrt{a^2+c^2-2ac\cos B}$		$\frac{a\sin B}{c-a\cos B} = \tan A$		$\frac{c\sin B}{a-c\cos B} = \tan C$
a–b–$\angle C$			$\sqrt{a^2+b^2-2ab\cos C}$	$\frac{a\sin C}{b-a\cos C} = \tan A$	$\frac{b\sin C}{a-b\cos C} = \tan B$	
a–b–$\angle A$			$\frac{a\sin C}{\sin A}$		$\frac{b\sin A}{a} = \sin B$	$180° - (A+B)$
a–b–$\angle B$			$\frac{b\sin C}{\sin B}$	$\frac{a\sin B}{b} = \sin A$		$180° - (A+B)$
a–c–$\angle A$		$\frac{a\sin B}{\sin A}$			$180° - (A+C)$	$\frac{c\sin A}{a} = \sin C$
a–c–$\angle C$		$\frac{c\sin B}{\sin C}$		$\frac{a\sin C}{c} = \sin A$	$180° - (A+C)$	
b–c–$\angle B$	$\frac{b\sin A}{\sin B}$			$180° - (B+C)$		$\frac{c\sin B}{b} = \sin C$

See page 6 for illustration and explanatory notes.

Parts Given	Parts to be Found					
	$a =$	$b =$	$c =$	$\angle A$	$\angle B$	$\angle C$
b–c–$\angle C$	$\frac{c \sin A}{\sin C}$			$180° - (B + C)$	$\frac{b \sin C}{c} = \sin B$	
a–$\angle A$–$\angle B$		$\frac{a \sin B}{\sin A}$	$\frac{a \sin C}{\sin A}$			$180° - (A + B)$
a–$\angle A$–$\angle C$		$\frac{a \sin B}{\sin A}$	$\frac{a \sin C}{\sin A}$		$180° - (A + C)$	
a–$\angle B$–$\angle C$		$\frac{a \sin B}{\sin A}$	$\frac{a \sin C}{\sin A}$	$180° - (B + C)$		
b–$\angle A$–$\angle B$	$\frac{b \sin A}{\sin B}$		$\frac{b \sin C}{\sin B}$			$180° - (A + B)$
b–$\angle A$–$\angle C$	$\frac{b \sin A}{\sin B}$		$\frac{b \sin C}{\sin B}$		$180° - (A + C)$	
b–$\angle B$–$\angle C$	$\frac{b \sin A}{\sin B}$		$\frac{b \sin C}{\sin B}$	$180° - (B + C)$		
c–$\angle A$–$\angle B$	$\frac{c \sin A}{\sin C}$	$\frac{c \sin B}{\sin C}$				$180° - (A + B)$
c–$\angle A$–$\angle C$	$\frac{c \sin A}{\sin C}$	$\frac{c \sin B}{\sin C}$			$180° - (A + C)$	
c–$\angle B$–$\angle C$	$\frac{c \sin A}{\sin C}$	$\frac{c \sin B}{\sin C}$		$180° - (B + C)$		

See page 6 for illustration and explanatory notes

Formulas for Falling Bodies.

s = space in feet which the body passes through in the time t,
u = space in feet which the body falls in the tth second,
v = velocity in feet per second at the end of the time t.
t = time in seconds the body is falling,
g = acceleration due to gravity = 32.2 feet per second.

$$v = g\,t = \frac{2s}{t} = \sqrt{2\,g\,s} = 8.02\sqrt{s}$$

$$s = g\frac{t^2}{2} = \frac{vt}{2} = \frac{v^2}{2g} = \frac{v^2}{64.4}$$

$$t = \frac{v}{g} = \frac{2s}{v} = \sqrt{\frac{2s}{g}} = \frac{\sqrt{s}}{4.01} = \frac{u}{g} + \frac{1}{2}$$

Horse-Power Formula for Steam Engines.

P = mean effective steam pressure in pounds per square inch,
D = diameter of cylinder piston in inches,
L = length of stroke in feet,
N = number of double strokes per minute,
HP = horse-power of engine,
A = area of piston in square inches,

$$HP = \frac{238\,PLD^2N}{10{,}000{,}000} = \frac{PLAN}{33{,}000}.$$

General Horse-Power Formula.

$HP = \dfrac{P}{550}$, in which P = power in foot-pounds per second.

Relation Between Circumferential Velocity and Revolutions per Minute.

v = circumferential velocity per second,
R = radius of revolving body,
n = number of revolutions per minute,

$$v = \frac{2\pi\,Rn}{60} = 0.1047\;Rn, \qquad n = \frac{9.55\,v}{R}.$$

Formulas for Centrifugal Force.

F = centrifugal force in pounds,
W = weight of revolving body in pounds,
v = velocity of revolving body in feet per second,
R = radius of circle in which body revolves, in feet,
n = number of revolutions per minute.

$$F = \frac{W v^2}{32.2\,R} = \frac{W R n^2}{2933} = 0.000341\;W R n^2;$$

$$W = \frac{2933\,F}{R n^2};\; R = \frac{2933\,F}{W n^2};\; n = \sqrt{\frac{2933\,F}{W R}}$$

ULTIMATE STRENGTH OF COMMON METALS; POUNDS PER SQUARE INCH.

Material	Tension	Compression	Shear	Modulus of Elasticity
Aluminum	15,000	12,000	12,000	11,000,000
Brass, cast	24,000	30,000	36,000	9,000,000
Bronze, gun-metal	32,000	20,000	——	10,000,000
Bronze, manganese	60,000	120,000	——	——
Bronze, phosphor	50,000	——	——	14,000 000
Copper, cast	24,000	40,000	30,000	10,000,000
Copper Wire, annealed	36,000	——	——	15,000,000
Copper Wire, unannealed	60,000	——	——	18,000,000
Iron, cast	15,000	80,000	18,000	12,000,000
Iron Wire, annealed	60,000	——	——	15,000 000
Iron Wire, unannealed	80,000	——	——	25,000,000
Iron, wrought	48,000	46,000	40,000	27,000,000
Lead, cast	2,000	——	——	1,000,000
Steel Castings,	70,000	70,000	60,000	30,000,000
Steel, plow	268,000	——	——	——
Steel, structural	60,000	60,000	50,000	29,000,000
Steel Wire, annealed	80,000	——	——	29,000,000
Steel Wire, unannealed	120,000	——	——	30,000,000
Steel Wire, crucible	180,000	——	——	30,000,000
Steel Wire, susp. bridge	200,000	——	——	30,000,000
Steel Wire, piano	300,000	——	——	——
Tin, cast	3,500	6,000	——	4,000,000
Zinc, cast	5,000	20,000	——	13,000,000

AVERAGE STRENGTH OF COMMON MATERIALS OTHER THAN METALS.

Material	Compression	Tension
Bricks, best hard	12,000	400
Bricks, light red	1,000	40
Brickwork, common	1,000	50
Brickwork, best	2,000	300
Cement, Portland, one month old	2,000	400
Cement, Portland, one year old	3,000	500
Concrete, Portland	1,000	200
Concrete, Portland, one year old	2,000	400
Hemlock	4,000	6,000
Pine, shortleaf yellow	6,000	9,000
Pine, Georgia	8,000	12,000
Pine, White	5,500	7,000
White Oak	7,000	10,000

FACTORS OF SAFETY.

Material	Steady Load	Load Varying from Zero to Maximum in one Direction	Load Varying from Zero to Maximum in both Directions	Suddenly Varying Loads and Shocks
Cast Iron	6	10	15	20
Wrought Iron	4	6	8	12
Steel	5	6	8	12
Wood	8	10	15	20
Brick	15	20	25	30
Stone	15	20	25	30

WORKING STRENGTH OF BOLTS.*

Diameter of Bolt, inches.	Area at Root of Thread, square inches.	Working Section, square inches.	Strength of Bolt, 5,000 pounds Stress.	Strength of Bolt, 6,000 pounds Stress.	Strength of Bolt, 7,000 pounds Stress.	Strength of Bolt, 8,000 pounds Stress.	Strength of Bolt, 10,000 pounds Stress.	Strength of Bolt, 12,000 pounds Stress.
5/8	0.202	0.044	220	264	308	352	440	528
3/4	0.302	0.113	565	678	791	904	1,130	1,356
7/8	0.420	0.200	1,000	1,200	1,400	1,600	2,000	2,400
1	0.550	0.298	1,490	1,788	2,086	2,384	2,980	3,476
1 1/8	0.694	0.411	2,055	2,466	2,877	3,288	4,110	4,932
1 1/4	0.893	0.578	2,890	3,468	4,046	4,624	5,780	6,936
1 3/8	1.057	0.710	3,550	4,260	4,970	5,680	7,100	8,520
1 1/2	1.295	0.917	4,585	5,502	6,419	7,336	9,170	10,504
1 5/8	1.515	1.105	5,525	6,630	7,735	8,840	11,050	13,260
1 3/4	1.746	1.305	6.525	7,830	9,135	10,440	13,050	15,660
1 7/8	2.051	1.578	7,890	9,468	11,046	12,624	15,780	18,936
2	2.302	1.798	8,990	10,788	12,586	14,384	17,980	21,576
2 1/4	3.023	2.456	12,280	14,736	17,192	19,648	24,560	29,472
2 1/2	3.719	3.089	15,445	18,534	21,623	24,712	30,890	37,068
2 3/4	4.620	3.927	19,635	23,562	27,489	31,416	39,270	47,124
3	5.428	4.672	23,360	28,032	32,704	37,376	46,720	56,064
3 1/4	6.510	5.690	28,450	34,140	39,830	45,520	56,900	68,280
3 1/2	7.548	6.666	33,330	39,996	46,664	53,328	66,660	79,992

* The figures for the working strength of bolts as given in the table above show the stress to which it is safe to subject the bolt when due allowance has been made for the stresses in the bolt caused by tightening the nut. The table refers specifically to bolts for cylinder covers, receivers containing fluids under pressure, boilers, etc. In work of this character bolts less than 5/8-inch diameter should not be employed.

Formulas for Strength of Materials.

In the following formulas:

A = area of cross-section of material in square inches,
E = modulus of elasticity,
I = moment of inertia of section about an axis passing through the center of gravity,
J = polar moment of inertia of section,
M_b = maximum bending moment in inch-pounds,
M_t = moment of force tending to twist (torsional moment) in inch-pounds,
P = total stress in pounds,
y = distance from center of gravity to most remote fiber,
S = permissible working stress in pounds per square inch,
Z = section modulus (moment of resistance),
e = elongation or shortening in inches,
l = length in inches,

For tension and compression:

$$P = A \times S; \qquad e = \frac{Pl}{AE}.$$

For shear:

$$P = A \times S.$$

Assume permissible working stress for shear to equal four-fifths the permissible stress in tension.

For bending:

$$M_b = \frac{SI}{y} = SZ$$

For torsion:

$$M_t = \frac{SJ}{y}.$$

The permissible working stress for torsion may be assumed as four-fifths the permissible stress in tension.

Combined bending and torsion:

$$\text{Combined moment} = 0.35\ M_b + 0.65\ \sqrt{M_b^2 + M_t^2}$$

SPECIFIC GRAVITY, FUSING POINT, AND CHARACTERISTICS OF COMMON METALS.

Metal	Melting Point, Degrees F.	Specific Gravity	Color *	Structure **	Electric Conductivity; Silver=100.	Approx. Value per Pound, Dollars	Weight per Cubic Inch, Pounds.
Aluminum	1157	2.56	B-W	M	63.00	0.24	0.0924
Antimony	842	6.71	B-W	B	3.59	0.08	0.2424
Barium	2192	3.75	Y	M	30.61	1025.00	0.1355
Bismuth	485	9.80	G-W	B	1.40	1.60	0.3540
Cadmium	576	8.60	W	M	24.38	1.92	0.3107
Calcium	1472	1.57	Y	M	21.77	2500.00	0.0567
Chromium	4000	6.80	G-W	B	16.00	0.80	0.2457
Cobalt	2932	8.50	P-W	M	16.93	1.60	0.3071
Copper	1929	8.82	P-R	M	97.67	0.14	0.3186
Gold	1913	19.32	Y	M	76.71	288.00	0.6979
Iron, cast	2000	7.20	G-W	B	——	0.01	0.2601
pure	2912	7.80	W	M	14.57	0.01	0.2816
wrought	2800	7.70	G-W	M	——	0.02	0.2780
Lead	618	11.37	B-W	S	8.42	0.04	0.4108
Magnesium	1200	1.74	B-W	M	39.44	4.80	0.0629
Manganese	3452	8.00	G-W	B	15.75	16.00	0.2890
Mercury	—39	13.58	B-W	F	1.75	0.48	0.4909
Nickel	2912	8.80	Y-W	M	12.89	0.45	0.3179
Platinum	3227	21.50	W	M	14.43	324.00	0.7767
Potassium	144	0.87	B-W	S	19.62	3.20	0.0314
Silver	1733	10.53	W	M	100.00	10.40	0.3805
Steel, tool	2532	7.85	W	M	12.00	0.08	0.2837
Tin	446	7.29	W	M	14.39	0.29	0.2634
Tungsten	4000	17.60	W	B	14.00	0.64	0.6353
Vanadium	4278	5.50	W	M	4.95	2500.00	0.1987
Zinc	779	7.15	B-W	M	29.57	0.04	0.2581

* B = blue, G = grey, P = pink, R = red, W = white, Y = yellow.

** B = brittle. F = fluid, M = malleable, S = soft.

DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH.

1/64	0.015 625	11/32	0.343 75	43/64	0.671 875
1/32	0.031 25	23/64	0.359 375	11/16	0.687 5
3/64	0.046 875	3/8	0.375	45/64	0.703 125
1/16	0.062 5	25/64	0.390 625	23/32	0.718 75
5/64	0.078 125	13/32	0.406 25	47/64	0.734 375
3/32	0.093 75	27/64	0.421 875	3/4	0.750
7/64	0.109 375	7/16	0.437 5	49/64	0.765 625
1/8	0.125	29/64	0.453 125	25/32	0.781 25
9/64	0.140 625	15/32	0.468 75	51/64	0.796 875
5/32	0.156 25	31/64	0.484 375	13/16	0.812 5
11/64	0.171 875	1/2	0.500	53/64	0.828 125
3/16	0.187 5	33/64	0.515 625	27/32	0.843 75
13/64	0.203 125	17/32	0.531 25	55/64	0.859 375
7/32	0.218 75	35/64	0.546 875	7/8	0.875
15/64	0.234 375	9/16	0.562 5	57/64	0.890 625
1/4	0.250	37/64	0.578 125	29/32	0.906 25
17/64	0.265 625	19/32	0.593 75	59/64	0.921 875
9/32	0.281 25	39/64	0.609 375	15/16	0.937 5
19/64	0.296 875	5/8	0.625	61/64	0.953 125
5/16	0.312 5	41/64	0.640 625	31/32	0.968 75
21/64	0.328 125	21/32	0.656 25	63/64	0.984 375

Metric Conversion Table.

Linear Measure.

1 kilometer = 0.6214 mile
1 meter = { 39.37 inches / 3.2808 feet }
1 centimeter = 0.3937 inch
1 millimeter = 0.03937 inch

1 mile = 1.609 kilometer
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 inch = 25.4 millimeters

Square Measure.

1 sq. kilometer = 0.386 sq. mile
1 hectare = 2.47 acres
1 are = 1076.4 sq. feet
1 sq. meter = 10.764 sq. feet
1 sq. centimeter = 0.155 sq. inch
1 sq. millimeter = 0.00155 sq. inch

1 sq. mile = 2.589 sq. kilometers
1 acre = 0.405 hectares
1 sq. foot = 0.0929 sq. meter
1 sq. inch = 6.452 sq. centimeters
1 sq. inch = 645.2 sq. millimeters

Cubic Measure.

1 cub. meter = 35.314 cub. feet
1 cub. centimeter = 0.061 cub. inch
1 liter = 0.2642 U. S. gallon
1 liter = 0.0353 cubic foot.

1 cub. foot = 0.02832 cub. meter
1 cub. inch = 16.383 cub. centimeters
1 cub. foot = 28.317 liters
1 U. S. gallon = 3.785 liters

Weight.

1 metric ton = 2,204.6 pounds
1 kilogram = 2.2046 pounds
1 gram = 15.432 grains troy

1 pound = 0.4536 kilogram
1 ounce = 28.35 grams
1 grain troy = 0.0648 grams

MILLIMETERS INTO ENGLISH INCHES.

	0	1	2	3	4	5	6	7	8	9
	0.0000	0.0394	0.0787	0.1181	0.1575	0.1969	0.2362	0.2756	0.3150	0.3543
1	0.3937	0.4331	0.4724	0.5118	0.5512	0.5906	0.6299	0.6693	0.7087	0.7480
2	0.7874	0.8268	0.8661	0.9055	0.9449	0.9843	1.0236	1.0630	1.1024	1.1417
3	1.1811	1.2205	1.2598	1.2992	1.3386	1.3780	1.4173	1.4567	1.4961	1.5354
4	1.5748	1.6142	1.6536	1.6929	1.7323	1.7717	1.8110	1.8504	1.8898	1.9292
5	1.9685	2.0079	2.0472	2.0866	2.1260	2.1653	2.2047	2.2441	2.2834	2.3228
6	2.3622	2.4016	2.4409	2.4803	2.5197	2.5591	2.5984	2.6378	2.6772	2.7165
7	2.7560	2.7953	2.8346	2.8740	2.9134	2.9528	2.9921	3.0315	3.0709	3.1102
8	3.1497	3.1890	3.2284	3.2677	3.3071	3.3465	3.3858	3.4252	3.4646	3.5040
9	3.5434	3.5827	3.6221	3.6614	3.7008	3.7402	3.7795	3.8189	3.8583	3.8977
10	3.9371	3.9764	4.0158	4.0551	4.0945	4.1339	4.1733	4.2126	4.2520	4.2914
11	4.3308	4.3701	4.4095	4.4488	4.4882	4.5276	4.5670	4.6063	4.6457	4.6851
12	4.7245	4.7638	4.8032	4.8426	4.8819	4.9213	4.9607	5.0000	5.0394	5.0788
13	5.1182	5.1575	5.1969	5.2363	5.2756	5.3150	5.3544	5.3937	5.4331	5.4725
14	5.5119	5.5512	5.5906	5.6300	5.6693	5.7087	5.7481	5.7874	5.8268	5.8662
15	5.9056	5.9450	5.9843	6.0237	6.0631	6.1024	6.1418	6.1812	6.2205	6.2599
16	6.2993	6.3386	6.3780	6.4174	6.4568	6.4961	6.5355	6.5749	6.6142	6.6536
17	6.6930	6.7324	6.7717	6.8111	6.8505	6.8898	6.9292	6.9686	7.0079	7.0473
18	7.0867	7.1261	7.1654	7.2048	7.2442	7.2835	7.3229	7.3623	7.4017	7.4410
19	7.4805	7.5198	7.5591	7.5985	7.6379	7.6773	7.7166	7.7560	7.7954	7.8347
20	7.8742	7.9135	7.9528	7.9922	8.0316	8.0710	8.1103	8.1497	8.1891	8.2284
21	8.2677	8.3072	8.3466	8.3859	8.4253	8.4647	8.5040	8.5434	8.5828	8.6221
22	8.6614	8.7009	8.7403	8.7796	8.8190	8.8584	8.8977	8.9371	8.9765	9.0158
23	9.0553	9.0946	9.1340	9.1733	9.2127	9.2521	9.2915	9.3308	9.3702	9.4096
24	9.4490	9.4883	9.5277	9.5670	9.6064	9.6458	9.6852	9.7245	9.7639	9.8033
25	9.8427	9.8820	9.9214	9.9608	10.0000	10.0395	10.0789	10.1182	10.1576	10.1970
26	10.2364	10.2757	10.3151	10.3545	10.3938	10.4332	10.4726	10.5119	10.5513	10.5907
27	10.6301	10.6694	10.7088	10.7482	10.7875	10.8269	10.8663	10.9057	10.9450	10.9844
28	11.0238	11.0631	11.1025	11.1419	11.1813	11.2206	11.2600	11.2994	11.3387	11.3781
29	11.4175	11.4568	11.4962	11.5356	11.5750	11.6143	11.6537	11.6931	11.7324	11.7718
30	11.8112	11.8506	11.8899	11.9293	11.9687	12.0080				

ENGLISH INCHES INTO MILLIMETERS.

Inches	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.7	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.4	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.1	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.8	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.5	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.2	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.7	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.4	300.0	301.6	303.2
12	304.8	306.4	308.0	309.6	311.1	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.8	325.4	327.0	328.6
13	330.2	331.8	333.4	335.0	336.5	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.2	350.8	352.4	354.0
14	355.6	357.2	358.8	360.4	361.9	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.6	376.2	377.8	379.4
15	381.0	382.6	384.2	385.8	387.3	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.0	401.6	403.2	404.8
16	406.4	408.0	409.6	411.2	412.7	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.4	427.0	428.6	430.2
17	431.8	433.4	435.0	436.6	438.1	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.8	452.4	454.0	455.6
18	457.2	458.8	460.4	462.0	463.5	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.2	477.8	479.4	481.0
19	482.6	484.2	485.8	487.4	488.9	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.6	503.2	504.8	506.4
20	508.0	509.6	511.2	512.8	514.3	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.0	528.6	530.2	531.8
21	533.4	535.0	536.6	538.2	539.7	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.4	554.0	555.6	557.2
22	558.8	560.4	562.0	563.6	565.1	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.8	579.4	581.0	582.6
23	584.2	585.8	587.4	589.0	590.5	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.2	604.8	606.4	608.0

For transforming English inches into millimeters, when only a rough estimate is required, it is sufficient to assume one inch = 25 millimeters. As it is very easy to multiply mentally by 25, any number of inches can be transformed approximately without tables or calculations. When transforming millimeters to inches, the number of millimeters is, of course, simply divided by 25 to obtain an approximate result.

GEARING.

Formulas for Spur Gearing.

In the following formulas,

P = diametral pitch,
P_1 = circular pitch,
D = pitch diameter,
D_1 = outside diameter,
N = number of teeth in one gear,
n = number of teeth in mating gear,
A = addendum,
T = thickness of tooth at pitch line,
E = full depth of tooth,
C = distance between centers,
F = clearance.

$$P_1 = \frac{3.1416}{P} \qquad T = \frac{P_1}{2} \qquad P = \frac{N+2}{D_1}$$

$$P = \frac{3.1416}{P_1} \qquad T = \frac{1.5708}{P} \qquad D = D_1 - \frac{2}{P}$$

$$D = \frac{N}{P} \qquad E = \frac{2.157}{P} \qquad D = \frac{D_1 \times N}{N+2}$$

$$A = \frac{1}{P} \qquad E = 0.6866\,P_1 \qquad N = P \times D$$

$$D_1 = \frac{N+2}{P} \qquad C = \frac{N+n}{2\,P} \qquad N = (D_1 \times P) - 2$$

$$F = \frac{0.157}{P} \qquad P = \frac{N}{D}. \qquad D_1 = D + \frac{2}{P}$$

According to the system for cutting gear teeth adopted by the Brown & Sharpe Mfg. Co., any gear of one pitch will mesh into any other gear or into a rack of the same pitch. Eight cutters are required for each pitch. These eight cutters are adapted to cut from a pinion of twelve teeth to a rack, and are numbered respectively, 1, 2, 3, etc. The number of teeth and the pitch for which a cutter is adapted is always marked on each.

No.	1	will cut	wheels from	135	teeth to	a rack.	
"	2	"	"	55	"	134	teeth.
"	3	"	"	35	"	54	"
"	4	"	"	26	"	34	"
"	5	"	"	21	"	25	"
"	6	"	"	17	"	20	"
"	7	"	"	14	"	16	"
"	8	"	"	12	"	13	"

TABLE OF DIAMETRAL AND CIRCULAR PITCH.

Diametral into Circular Pitch.				Circular into Diametral Pitch.			
Diametral Pitch	Circular Pitch	Diametral Pitch	Circular Pitch	Circular Pitch	Diametral Pitch	Circular Pitch	Diametral Pitch
1 1/4	2.513"	11	0.286"	2"	1.571	7/8"	3.590
1 1/2	2.094	12	0.262	1 7/8	1.676	13/16	3.867
1 3/4	1.795	14	0.224	1 3/4	1.795	3/4	4.189
2	1.571	16	0.196	1 5/8	1.933	11/16	4.570
2 1/4	1.396	18	0.175	1 1/2	2.094	5/8	5.027
2 1/2	1.257	20	0.157	1 7/16	2.185	9/16	5.585
2 3/4	1.142	22	0.143	1 3/8	2.285	1/2	6.283
3	1.047	24	0.131	1 5/16	2.394	7/16	7.181
3 1/2	0.898	26	0.121	1 1/4	2.513	3/8	8.378
4	0.785	28	0.112	1 3/16	2.646	5/16	10.053
5	0.628	30	0.105	1 1/8	2.793	1/4	12.566
6	0.524	32	0.098	1 1/16	2.957	3/16	16.755
7	0.449	36	0.087	1	3.142	1/8	25.133
8	0.393	40	0.079	15/16	3.351	1/16	50.266
9	0.349	48	0.065				
10	0.314						

TABLE SHOWING DEPTH OF SPACE AND THICKNESS OF TOOTH IN SPUR GEARS CUT WITH B. & S. MFG. CO.'S CUTTERS.

Pitch of Cutter	Depth to be Cut in Gear	Thickness of Tooth at Pitch Line	Pitch of Cutter	Depth to be Cut in Gear	Thickness of Tooth at Pitch Line
1 1/4	1.726"	1.257"	11	0.196"	0.143"
1 1/2	1.438	1.047	12	0.180	0.131
1 3/4	1.233	0.898	14	0.154	0.112
2	1.078	0.785	16	0.135	0.098
2 1/4	0.958	0.697	18	0.120	0.087
2 1/2	0.863	0.628	20	0.108	0.079
2 3/4	0.784	0.570	22	0.098	0.071
3	0.719	0.523	24	0.090	0.065
3 1/2	0.616	0.448	26	0.083	0.060
4	0.539	0.393	28	0.077	0.056
5	0.431	0.314	30	0.072	0.052
6	0.359	0.262	32	0.067	0.049
7	0.308	0.224	36	0.060	0.044
8	0.270	0.196	40	0.054	0.039
9	0.240	0.175	48	0.045	0.033
10	0.216	0.157			

Formulas for Bevel Gearing.

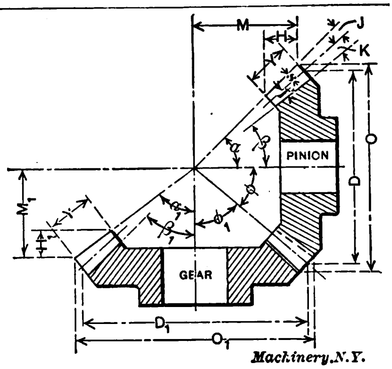
On pages 19, 20, 21, and 22 are given complete sets of bevel gear formulas, covering the cases when the angle between the two shafts to be connected by the gearing equals 90 degrees, more than 90 degrees, and less than 90 degrees; a set of formulas applicable to the solution of miter gears is also given. These formulas are systematically arranged so that the proper formula to use can be very easily found at a glance; and no knowledge of trigonometry is required, except an understanding of the use of tables of sines and tangents. The formulas, in substantially the same form as presented in the accom-

SHAFT ANGLE 90 DEGREES.

$P =$ diametral pitch
$C =$ circular pitch
$N =$ number of teeth in pinion
$N_1 =$ number of teeth in gear
$x =$ shaft angle
$N_2 =$ number of teeth for which to select cutter

$$J = \frac{1}{P} = 0.3183\ C$$

$$K = \frac{1.157}{P} = 0.3683\ C$$



Pinion	Gear
$N = D \times P = \frac{D \times \pi}{C}$	$N_1 = D_1 \times P = \frac{D_1 \times \pi}{C}$
$D = \frac{N}{P} = 0.3183\ C\ N$	$D_1 = \frac{N_1}{P} = 0.3183\ C\ N_1$
$O = D + \frac{2 \cos \phi}{P} = D + 0.6366\ C \times \cos \phi$	$O_1 = D_1 + \frac{2 \sin \phi}{P} = D_1 + 0.6366\ C \times \sin \phi$
$\tan \phi = \frac{N}{N_1}$	$\phi_1 = 90 - \phi$

$$\tan s = \frac{2 \sin \phi}{N}, \qquad \tan f = \frac{2.314 \sin \phi}{N}$$

$\alpha = \phi + s$	$\alpha_1 = \phi_1 + s$
$\beta = \phi - f$	$\beta_1 = \phi_1 - f$
$M = \frac{O_1}{2} - \frac{2 \sin \phi}{P} = \frac{O}{2} \times \cot \alpha = \frac{O_1}{2} - 0.6366\ C \times \sin \phi$	$M_1 = \frac{O}{2} - \frac{2 \cos \phi}{P} = \frac{O_1}{2} \times \cot \alpha_1 = \frac{O}{2} - 0.6366\ C \times \cos \phi$
$H = Y \times \cos \alpha$	$H_1 = Y \times \cos \alpha_1$
$N_2 = \frac{N}{\cos \phi}$	$N_2 = \frac{N_1}{\sin \phi}$

panying tables, were originally contributed to MACHINERY by Herman Isler.

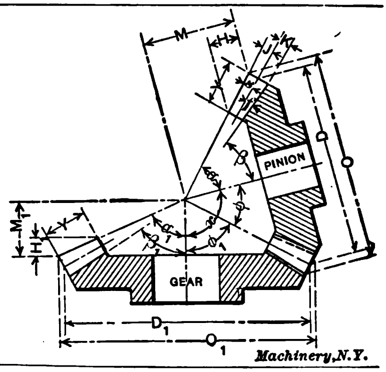
While the tables are self-contained, the following remarks will aid in avoiding misunderstanding of the use of the formulas in the table on page 20, for shaft angles more than 90 degrees. If the formula

SHAFT ANGLE MORE THAN 90 DEGREES.

P = diametral pitch
C = circular pitch
N = number of teeth in pinion
N_1 = number of teeth in gear
x = shaft angle
N_2 = number of teeth for which to select cutter

$$J = \frac{1}{P} = 0.3183\,C$$

$$K = \frac{1.157}{P} = 0.3683\,C$$



Pinion	Gear
$N = D \times P = \frac{D \times \pi}{C}$	$N_1 = D_1 \times P = \frac{D_1 \times \pi}{C}$
$D = \frac{N}{P} = 0.3183\,C\,N$	$D_1 = \frac{N_1}{P} = 0.3183\,C\,N_1$
$O = D + \frac{2\cos\phi}{P} = D + 0.6366\,C \times \cos\phi$	$O_1 = D_1 + \frac{2\cos\phi_1}{P} = D_1 + 0.6366\,C \times \cos\phi_1$
$\tan\phi = \frac{\cos(x - 90°)}{\frac{N_1}{N} - \sin(x - 90°)}$	$\phi_1 = x - \phi$

$$\tan s = \frac{2\sin\phi}{N}, \quad \tan f = \frac{2.314\sin\phi}{N}$$

$a = \phi + s$	$a_1 = \phi_1 + s$
$\beta = \phi - f$	$\beta_1 = \phi_1 - f$
$M = \frac{O}{2} \times \cot a$	$M_1 = \frac{O_1}{2} \times \cot a_1$
$H = Y \times \cos a$	$H_1 = Y \times \cos a_1$
$N_2 = \frac{N}{\cos\phi}$	$N_2 = \frac{N_1}{\cos\phi_1}$

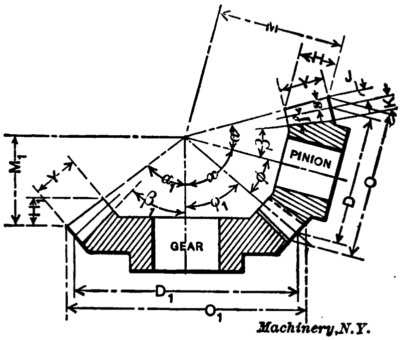
for ϕ_1 in any case gives a value greater than 90 degrees, the gear is an internal gear. This form of gearing can be cast, but cannot ordinarily be cut on any commercial machine. In order to avoid the use of an internal gear, the problem may be solved by using, in place of angle x, an angle equal to 180 degrees $-x$, employing then the formula for $\tan\phi$ given in the table for shaft angles less than 90 degrees, on

SHAFT ANGLE LESS THAN 90 DEGREES.

P = diametral pitch
C = circular pitch
N = number of teeth in pinion
N_1 = number of teeth in gear
x = shaft angle
N_2 = number of teeth for which to select cutter

$$J = \frac{1}{P} = 0.3183\ C$$

$$K = \frac{1.157}{P} = 0.3683\ C$$



Machinery,N.Y.

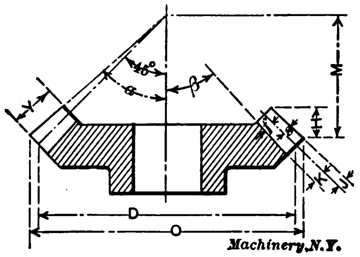
Pinion	Gear
$N = D \times P = \frac{D \times \pi}{C}$	$N_1 = D_1 \times P = \frac{D_1 \times \pi}{C}$
$D = \frac{N}{P} = 0.3183\ C\ N$	$D_1 = \frac{N_1}{P} = 0.3183\ C\ N_1$
$O = D + \frac{2 \cos \phi}{P} = D + 0.6366\ C \times \cos \phi$	$O_1 = D_1 + \frac{2 \cos \phi_1}{P} = D_1 + 0.6366\ C \times \cos \phi_1$
$\tan \phi = \frac{\sin x}{\frac{N_1}{N} + \cos x}$	$\phi_1 = x - \phi$

$$\tan s = \frac{2 \sin \phi}{N}, \quad \tan f = \frac{2.314 \sin \phi}{N}$$

$\alpha = \phi + s$	$\alpha_1 = \phi_1 + s$
$\beta = \phi - f$	$\beta_1 = \phi_1 - f$
$M = \frac{O}{2} \times \cot \alpha$	$M_1 = \frac{O_1}{2} \times \cot \alpha_1$
$H = Y \times \cos \alpha$	$H_1 = Y \times \cos \alpha_1$
$N_2 = \frac{N}{\cos \phi}$	$N_2 = \frac{N_1}{\cos \phi_1}$

page 21. This places the gear on the other side of the apex of the pitch cone, and thus requires the shafts to be extended, but avoids the internal bevel gear. This manner of solving the problem is advisable, as the internal gear would be almost impossible of manufacture.

MITER GEARS.*



$$N = D \times P = \frac{D \times \pi}{C}$$

$$D = \frac{N}{P} = \frac{C \times N}{\pi} = 0.3183\,C\,N$$

$$O = D + \frac{1.4142}{P} = D + 0.45\,C$$

$$\tan s = \frac{1.4142}{N}, \quad \tan f = \frac{1.6362}{N}$$

$$\alpha = 45° + s$$

$$\beta = 45° - f$$

$$M = \frac{O}{2} - \frac{1.4142}{P} = \frac{O}{2} - 0.45\,C$$

$$H = Y \times \cos \alpha$$

$$N_2 = \frac{N}{0.7071} = N \times 1.4142$$

*See table on page 21 for meaning of letters in formulas.

Spiral Gearing.

The tooth angle in spiral gearing is the angle made by the helix or spiral of the teeth with the axis of the gear.

The equivalent diameter of a helical gear is found by dividing the number of teeth in the gear by the diametral pitch of the cutter with it is cut.

N_a = No. of teeth in gear *a*.
N_b = No. of teeth in gear *b*.
R = Velocity ratio = $N_a \div N_b$.
P'' = Normal diametral pitch or pitch of cutter.
E = Equivalent diameter (explained above).
D = Pitch diameter.
C = Center distance.
B = Blank or outside diameter.
T = No. of teeth for which cutter is selected.
L = Lead of spiral.
γ = Angle of axes.
α = Angle of tooth with axis.
t = Thickness of tooth on pitch line.
S = Addendum.
$D'' + f$ = Whole depth of tooth.

$$\gamma = \alpha_a + \alpha_b$$

$$E = \frac{N}{P''}$$

$$E_b + (E_a \times \tan \alpha_a) = 2\,C \times \sin \alpha_a$$

$$D = \frac{E}{\cos \alpha} = E \times \sec \alpha.$$

$$B = D + \frac{2}{P''}$$

$$L = \cot \alpha \times D \times \pi.$$

$$T = \frac{N}{(\cos \alpha)^3}$$

$$t = \frac{1.5708}{P''}.$$

$$S = \frac{1}{P''}.$$

$$D'' + f = \frac{2.1571}{P''}$$

Where subscript letters $_a$ and $_b$ are used, reference is made to two gears *a* and *b*, as for instance, "N_a" and "N_b," where the letter *N* refers to the number of teeth in gears *a* and *b*, respectively, of a pair of gears *a* and *b*.

Cutters for Milling Teeth of Spiral Gears.

The cutters used for milling spiral or helical gears are standard spur gear cutters, the number of a cutter and its pitch for a given case being defined by the angle (with the axis) and the normal pitch. The diagram below gives the numbers of the cutters only, the pitch having been previously determined.

The selection of the cutter is fixed by the formula given in the lower right-hand corner of the diagram. The delimiting curves thereon were plotted by the formula, the area between the curves being the

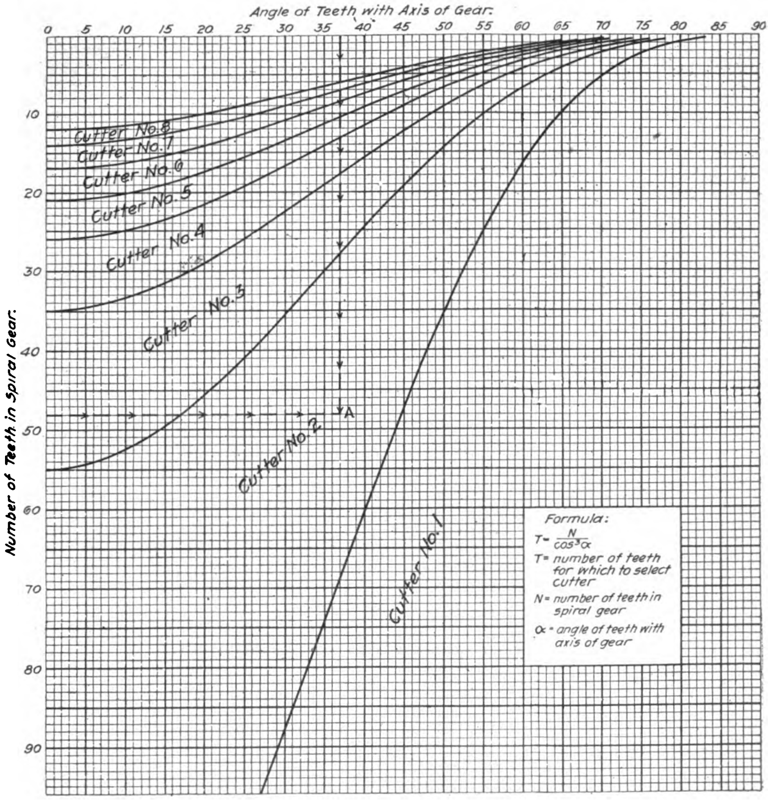


Diagram for Selecting Cutter for Milling Spiral Gear Teeth.

field of intersection of the combinations of angles and numbers of teeth covered by each designated cutter number.

For example, suppose the angle of the teeth of a gear is 37 degrees with its axis, and the number of teeth is 48. The point *A*, at which the horizontal line (representing the tooth number), and the vertical line (representing the angle) intersect, falls within the area marked "Cutter No. 2." Therefore, a No. 2 cutter is required to cut a 48-tooth spiral gear having the teeth at an angle of 37 degrees with its axis.

WORMS AND WORM GEARING.

C.P. Circular Pitch	N Threads per Inch	D. P. Diametral Pitch	H Tooth above Pitch Line	D Working Depth of Tooth	C Clearance	S Depth of Space below Pitch Line	W. D. Whole Depth of Tooth	T Thickness of Tooth on Pitch Line	W Width of Thread Tool at End	B Width of Thread at Top
C. P. Inches	$N = \frac{1}{C.P.}$	$D.P. = \frac{\pi}{C.P.}$	$H = \frac{1}{D.P.}$	$D = 2 \times \frac{1}{D.P.}$	$C = \frac{1}{8} \times \frac{1}{D.P.}$	$S = H + C$	$W.D. = D + C$	$T = \frac{C.P.}{2}$	$W = 0.3148 \times C.P.$	$B = 0.3354 \times C.P.$
2	1/2	1.5708	0.6366	1.2732	0.0795	0.7161	1.8527	1.0000	0.6296	0.6708
1 3/4	4/7	1.7952	0.5570	1.1141	0.0696	0.6266	1.1837	0.8750	0.5509	0.5869
1 1/2	2/3	2.0944	0.4775	0.9549	0.0596	0.5371	1.0145	0.7500	0.4722	0.5031
1 1/4	4/5	2.5133	0.3979	0.7958	0.0497	0.4476	0.8455	0.6250	0.3935	0.4192
1	1	3.1416	0.3183	0.6366	0.0397	0.3580	0.6763	0.5000	0.3148	0.3354
3/4	1 1/3	4.1888	0.2387	0.4775	0.0298	0.2685	0.5073	0.3750	0.2361	0.2515
2/3	1 1/2	4.7124	0.2122	0.4244	0.0265	0.2387	0.4509	0.3333	0.2098	0.2236
1/2	2	6.2832	0.1592	0.3183	0.0199	0.1791	0.3382	0.2500	0.1574	0.1677
2/5	2 1/2	7.8540	0.1273	0.2546	0.0159	0.1432	0.2705	0.2000	0.1259	0.1341
1/3	3	9.4248	0.1061	0.2122	0.0132	0.1193	0.2254	0.1666	0.1049	0.1118
2/7	3 1/2	10.9956	0.0909	0.1819	0.0113	0.1022	0.1932	0.1429	0.0899	0.0958
1/4	4	12.5664	0.0796	0.1591	0.0099	0.0895	0.1690	0.1250	0.0787	0.0838
2/9	4 1/2	14.1372	0.0707	0.1415	0.0088	0.0795	0.1503	0.1111	0.0699	0.0745
1/5	5	15.7080	0.0637	0.1273	0.0079	0.0716	0.1352	0.1000	0.0629	0.0670
1/6	6	18.8496	0.0531	0.1061	0.0066	0.0597	0.1127	0.0833	0.0524	0.0559
1/7	7	21.9911	0.0455	0.0910	0.0056	0.0511	0.0966	0.0714	0.0449	0.0479
1/8	8	25.1327	0.0398	0.0796	0.0049	0.0447	0.0845	0.0625	0.0393	0.0419
1/9	9	28.2743	0.0354	0.0707	0.0044	0.0398	0.0752	0.0555	0.0349	0.0372
1/10	10	31.4159	0.0318	0.0637	0.0039	0.0357	0.0676	0.0500	0.0314	0.0335
1/12	12	37.6992	0.0265	0.0530	0.0033	0.0298	0.0563	0.0416	0.0262	0.0279
1/14	14	43.9824	0.0227	0.0454	0.0028	0.0255	0.0482	0.0357	0.0224	0.0239
1/16	16	50.2655	0.0199	0.0398	0.0524	0.0223	0.0422	0.0312	0.0196	0.0209
1/18	18	56.5488	0.0176	0.0352	0.0022	0.0198	0.0374	0.0277	0.0174	0.0186

Formulas for the Design of Worm Gearing.

N = number of teeth in worm-wheel.
n = number of teeth or threads in worm.
P' = circular pitch of wheel and linear pitch of worm.
l = lead of worm.
g = whole depth of worm tooth.
t' = width of the thread tool at the end.
s = addendum or height of worm tooth above pitch line.
o = outside diameter of the worm.
d = pitch diameter of the worm.
b = bottom or root diameter of the worm.
β = helix angle of worm and gashing angle of wheel.
δ = face-angle of worm-wheel.
D = pitch diameter of the worm-wheel.
O = throat diameter of the worm-wheel.
O' = diameter of the worm-wheel to sharp corners.
U = radius of curvature of the worm-wheel throat.
R = velocity ratio.
C = distance between centers.
x = threaded length of worm.

$l = n \times P'$.
$P' = l \div n$.
$g = 0.6866\,P'$.
$t' = 0.31\,P'$.
$s = 0.3183\,P'$.
$o = d + 2s$.
$d = o - 2s$.
$b = o - 2g$.

Cotangent $\beta = 3.1416\,d \div l$.
$D = N\,P' \div 3.1416$.
$O = D + 2s$.
$U = \frac{1}{2}o - 2s$.
$O' = 2\,(U - U\cos\delta/2) + O$.
$R = N \div n$.
$C = (D + d) \div 2$.
$d = 2C - D$.

Minimum value of $x = \sqrt{O^2 - (O - 4s)^2}$

The outside diameter of the hob is $0.1\,P'$ larger than the outside diameter of the worm. The root diameter of the hob equals the outside diameter of the worm—$1.2732\,P'$.

SCREW THREADS.

Abbreviations Used to Denote Different Screw Thread Standards.

U. S. S. = United States Standard Thread.
U. S. F. = United States Standard Form.
V = V-thread.
B. S. W. = Whitworth Thread (British Standard Whitworth).
B. S. F. = British Standard Fine Screw Thread.
B. A. S. = British Association Standard Thread.
S. F. = French Standard Thread.
S. I. = International Standard Thread.
A. S. M. E. St'd = Standard Machine Screw Thread, adopted by the American Society of Mechanical Engineers.

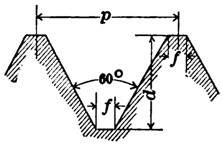


Fig. 1

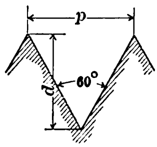


Fig. 2

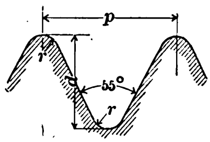


Fig. 3

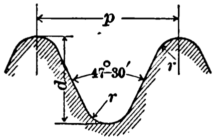


Fig. 4

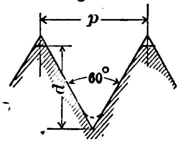


Fig. 5

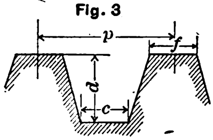


Fig. 6

Standard Screw Threads.

A. L. A. M. St'd = Fine Screw Thread adopted by the Association of Licensed Automobile Manufacturers.

Formulas for Standard Threads.

$$p = \text{pitch} = \frac{1}{\text{Number of threads per inch.}}$$

UNITED STATES STANDARD THREAD (Fig. 1).

$$d = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.64952\,p.$$

$$f = \frac{p}{8}$$

SHARP V-THREAD (Fig. 2.)

$$d = p \times \cos 30 \text{ deg.} = 0.86603\,p$$

WHITWORTH THREAD (Fig. 3.)

$$d = \frac{2}{3} \times \frac{p}{2} \times \cot 27 \text{ deg. } 30 \text{ min.} = 0.64033\,p$$

$$r = 0.1373\,p.$$

BRITISH ASSOCIATION STANDARD THREAD (Fig. 4.)

$$d = 0.6\,p. \qquad r = \frac{2\,p}{11}$$

BRIGGS MODIFIED PIPE THREAD AS MADE IN THE UNITED STATES. (Fig. 5.)

$$d = 0.833\,p.$$

$$\text{flat at top} = \frac{p}{26}$$

At the root of the thread, the groove has no flat, but is sharp, the same as a regular V-thread. (The original Briggs pipe thread, as still made in Great Britain, is slightly rounded off at the top and provided with a fillet at the bottom of the same radius, so that the depth of the thread, instead of being equaal to 0.833 p, as above, is only 0.8 p.)

ACME THREAD. (Fig. 6.)

For Screws.

$$d = \frac{p}{2} + 0.010 \text{ inch},$$

$$f = 0.3707\,p,$$

$$c = 0.3707\,p - 0.0052 \text{ inch}.$$

For Taps.

$$d = \frac{p}{2} + 0.020 \text{ inch},$$

$$f = 0.3707\,p - 0.0052 \text{ inch},$$

$$c = 0.3707\,p - 0.0052 \text{ inch}.$$

The root diameters of screws and taps are the same. The outside diameter of the tap is 0.020 inch greater than the outside diameter of the screw.

The angle between the sides of the Acme thread is 29 degrees.

French and International Standard Threads.

The form of the thread, and the formulas for the thread dimensions are the same as for the United States Standard thread except that the shape of the thread at the bottom may be flat or rounded, as preferred, as long as clearance at this point is provided. The originators of the thread recommended a rounded profile at the root, but in the United States this thread is made exclusively with a flat, the same as the U. S. Standard thread.

UNITED STATES STANDARD THREAD.

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
1/16	64	13/16	10	1 3/4	5	3 3/8	3 1/4
3/32	50	7/8	9	1 13/16	5	3 1/2	3 1/4
1/8	40	15/16	9	1 7/8	5	3 5/8	3 1/4
5/32	36	1	8	1 15/16	5	3 3/4	3
3/16	32	1 1/16	7	2	4 1/2	3 7/8	3
7/32	28	1 1/8	7	2 1/8	4 1/2	4	3
1/4	20	1 3/16	7	2 1/4	4 1/2	4 1/4	2 7/8
5/16	18	1 1/4	7	2 3/8	4	4 1/2	2 3/4
3/8	16	1 5/16	6	2 1/2	4	4 3/4	2 5/8
7/16	14	1 3/8	6	2 5/8	4	5	2 1/2
1/2	13	1 7/16	6	2 3/4	4	5 1/4	2 1/2
9/16	12	1 1/2	6	2 7/8	3 1/2	5 1/2	2 3/8
5/8	11	1 9/16	5 1/2	3	3 1/2	5 3/4	2 3/8
11/16	11	1 5/8	5 1/2	3 1/8	3 1/2	6	2 1/4
3/4	10	1 11/16	5 1/2	3 1/4	3 1/2		

STANDARD SHARP V-THREAD

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
1/16	72	13/16	10	1 3/4	5	3 3/8	3 1/4
3/32	56	7/8	9	1 13/16	5	3 1/2	3 1/4
1/8	40	15/16	9	1 7/8	4 1/2	3 5/8	3 1/4
5/32	32	1	8	1 15/16	4 1/2	3 3/4	3
3/16	24	1 1/16	8	2	4 1/2	3 7/8	3
7/32	24	1 1/8	7	2 1/8	4 1/2	4	3
1/4	20	1 3/16	7	2 1/4	4 1/2	4 1/4	2 7/8
5/16	18	1 1/4	7	2 3/8	4 1/2	4 1/2	2 3/4
3/8	16	1 5/16	7	2 1/2	4	4 3/4	2 5/8
7/16	14	1 3/8	6	2 5/8	4	5	2 1/2
1/2	12	1 7/16	6	2 3/4	4	5 1/4	2 1/2
9/16	12	1 1/2	6	2 7/8	4	5 1/2	2 3/8
5/8	11	1 9/16	6	3	3 1/2	5 3/4	2 3/8
11/16	11	1 5/8	5	3 1/8	3 1/2	6	2 1/4
3/4	10	1 11/16	5	3 1/4	3 1/2		

WHITWORTH STANDARD THREAD.

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
1/16	60	13/16	10	1 3/4	5	3 3/8	3 1/4
3/32	48	7/8	9	1 13/16	5	3 1/2	3 1/4
1/8	40	15/16	9	1 7/8	4 1/2	3 5/8	3 1/4
5/32	32	1	8	1 15/16	4 1/2	3 3/4	3
3/16	24	1 1/16	8	2	4 1/2	3 7/8	3
7/32	24	1 1/8	7	2 1/8	4 1/2	4	3
1/4	20	1 3/16	7	2 1/4	4	4 1/4	2 7/8
5/16	18	1 1/4	7	2 3/8	4	4 1/2	2 7/8
3/8	16	1 5/16	7	2 1/2	4	4 3/4	2 3/4
7/16	14	1 3/8	6	2 5/8	4	5	2 3/4
1/2	12	1 7/16	6	2 3/4	3 1/2	5 1/4	2 5/8
9/16	12	1 1/2	6	2 7/8	3 1/2	5 1/2	2 5/8
5/8	11	1 9/16	6	3	3 1/2	5 3/4	2 1/2
11/16	11	1 5/8	5	3 1/8	3 1/2	6	2 1/2
3/4	10	1 11/16	5	3 1/4	3 1/4		

BRITISH STANDARD FINE SCREW THREAD.

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
1/4	25	1 1/8	9	2	7	3 3/4	4 1/2
5/16	22	1 3/16	9	2 1/8	7	3 7/8	4 1/2
3/8	20	1 1/4	9	2 1/4	6	4	4 1/2
7/16	18	1 5/16	9	2 3/8	6	4 1/4	4
1/2	16	1 3/8	8	2 1/2	6	4 1/2	4
9/16	16	1 7/16	8	2 5/8	6	4 3/4	4
5/8	14	1 1/2	8	2 3/4	6	5	4
11/16	14	1 9/16	8	2 7/8	6	5 1/4	3 1/2
3/4	12	1 5/8	8	3	5	5 1/2	3 1/2
13/16	12	1 11/16	8	3 1/8	5	5 3/4	3 1/2
7/8	11	1 3/4	7	3 1/4	5	6	3 1/2
15/16	11	1 13/16	7	3 3/8	5		
1	10	1 7/8	7	3 1/2	4 1/2		
1 1/16	10	1 15/16	7	3 5/8	4 1/2		

BRITISH ASSOCIATION STANDARD THREAD.

British Association Number	Diameter		Pitch		British Association Number	Diameter		Pitch	
	Millimeters	Inches	Millimeters	Inches		Millimeters	Inches	Millimeters	Inches
0	6.0	0.2362	1.0	0.0394	13	1.2	0.0472	0.25	0.0098
1	5.3	0.2087	0.90	0.0354	14	1.0	0.0394	0.23	0.0091
2	4.7	0.1850	0.81	0.0319	15	0.90	0.0354	0.21	0.0083
3	4.1	0.1614	0.73	0.0287	16	0.79	0.0311	0.19	0.0075
4	3.6	0.1417	0 66	0.0260	17	0.70	0.0276	0.17	0 0067
5	3.2	0.1260	0.59	0.0232	18	0.62	0.0244	0.15	0.0059
6	2.8	0.1102	0.53	0.0209	19	0.54	0.0213	0.14	0.0055
7	2.5	0.0984	0.48	0.0189	20	0.48	0.0189	0.12	0.0047
8	2.2	0.0866	0.43	0.0169	21	0.42	0.0165	0.11	0 0043
9	1.9	0.0748	0.39	0.0154	22	0.37	0.0146	0.098	0.0039
10	1.7	0.0669	0.35	0.0138	23	0.33	0.0130	0.089	0.0035
11	1.5	0.0591	0.31	0.0122	24	0.29	0.0114	0.080	0 0031
12	1.3	0.0511	0.28	0.0110	25	0.25	0.0098	0.072	0.0028

ACME STANDARD THREAD.

Threads per Inch	Depth of Thread	Width of Flat at Top of Screw Thread	Width of Flat at Top of Tap Thread and at Bottom of Screw and Tap Thread	Threads per Inch	Depth of Thread	Width of Flat at Top of Screw Thread	Width of Flat at Top of Tap Thread and at Bottom of Screw and Tap Thread
1	0.5100	0.3707	0.3655	5	0.1100	0.0741	0.0689
1 1/3	0.3850	0.2780	0.2728	5 1/2	0.1009	0.0674	0.0622
1 1/2	0.3433	0.2471	0.2419	6	0.0933	0.0618	0.0566
2	0.2600	0.1853	0.1801	7	0.0814	0.0530	0.0478
2 1/2	0.2100	0.1483	0.1431	8	0.0725	0.0463	0.0411
3	0.1767	0.1286	0.1184	9	0.0656	0.0412	0.0360
3 1/2	0.1529	0.1059	0.1007	10	0.0600	0.0371	0.0319
4	0.1350	0.0927	0.0875	12	0.0517	0.0309	0.0257
4 1/2	0.1211	0.0824	0.0772				

WHITWORTH STANDARD THREAD FOR GAS AND WATER PIPING, COMMONLY KNOWN AS THE STANDARD GAS THREAD.

Nominal Size of Tube	Actual Outside Size of Tube	No. of Threads per Inch	Nominal Size of Tube	Actual Outside Size of Tube	No. of Threads per Inch	Nominal Size of Tube	Actual Outside Size of Tube	No. of Threads per Inch
1/8	0.385	28	1 3/8	1.745	11	2 5/8	3.124	11
1/4	0.520	19	1 1/2	1.882	11	2 3/4	3.247	11
3/8	0.665	19	1 5/8	2.021	11	2 7/8	3.367	11
1/2	0.822	14	1 3/4	2.160	11	3	3.485	11
5/8	0.902	14	1 7/8	2.245	11	3 1/4	3.698	11
3/4	1.034	14	2	2.347	11	3 1/2	3.912	11
7/8	1.189	14	2 1/8	2.467	11	3 3/4	4.125	11
1	1.302	11	2 1/4	2.587	11	4	4.339	11
1 1/8	1.492	11	2 3/8	2.794	11			
1 1/4	1.650	11	2 1/2	3.001	11			

BRIGGS STANDARD PIPE THREAD.

Nominal Size of Tube.	Actual Outside Size of Tube.	No. of Threads per Inch.	Nominal Size of Tube.	Actual Outside Size of Tube.	No. of Threads per Inch.	Nominal Size of Tube.	Actual Outside Size of Tube.	No. of Threads per Inch.
⅛	0.405	27	3	3.500	8	11†	11.750	8
¼	0.540	18	3½	4.000	8	12	12.750	8
⅜	0.675	18	4	4.500	8	13	14.000	8
½	0.840	14	4½	5 000	8	14	15.000	8
¾	1.050	14	5	5.563	8	15	16.000	8
1	1.315	11½	6	6.625	8	16	17.000	8
1¼	1.660	11½	7	7.625	8	17	18.000	8
1½	1.900	11½	8	8.625	8	18	19.000	8
2	2.375	11½	9	9.625*	8	19	20.000	8
2½	2.875	8	10	10.750	8	20	21.000	8

* The original Briggs Standard is 9.688. Present U. S. Standard is 9.625.
† This and larger sizes were not included in Briggs' original standard sizes.

MACHINE SCREW THREADS, AMERICAN SOCIETY OF MECHANICAL ENGINEERS STANDARD.

Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch
0	0.060	80	7	0.151	36	18	0.294	20
1	0.073	72	8	0.164	36	20	0.320	20
2	0.086	64	9	0.177	32	22	0.346	18
3	0.099	56	10	0.190	30	24	0.372	16
4	0.112	48	12	0.216	28	26	0.398	16
5	0.125	44	14	0.242	24	28	0.424	14
6	0.138	40	16	0.268	22	30	0.450	14

SPECIAL MACHINE SCREW THREADS, ADOPTED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch
1	0.073	64	7	0.151	32	14	0.242	20
2	0.086	56	7	0.151	30	16	0.268	20
3	0.099	48	8	0.164	32	18	0.294	18
4	0.112	40	8	0.164	30	20	0.320	18
4	0.112	36	9	0.177	30	22	0.346	16
5	0.125	40	9	0.177	24	24	0.372	18
5	0.125	36	10	0.190	32	26	0.398	14
6	0.138	36	10	0.190	24	28	0.424	16
6	0.138	32	12	0.216	24	30	0.450	16

MACHINE SCREW THREADS, OLD STANDARD.

Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch	Number	Diameter	Threads per Inch
1	0.071	64	8	0.166	32	16	0.272	18
1½	0.081	56	9	0.180	30	18	0.298	18
2	0.089	56	10	0.194	24	20	0.325	16
3	0.101	48	11	0.206	24	22	0.350	16
4	0.113	36	12	0.221	24	24	0.378	16
5	0.125	36	13	0.234	22	26	0.404	16
6	0.141	32	14	0.246	20	28	0.430	14
7	0.154	32	15	0.261	20	30	0.456	14

INTERNATIONAL SYSTEM STANDARD THREAD.

Diameter		Pitch		Diameter		Pitch	
Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
6	0.2362	1.0	0.0394	33	1.2992	3.5	0.1378
7	0.2756	1.0	0.0394	36	1.4173	4.0	0.1575
8	0.3150	1.25	0.0492	39	1.5354	4.0	0.1575
9	0.3543	1.25	0.0492	42	1.6535	4.5	0.1772
10	0.3937	1.5	0.0590	45	1.7716	4.5	0.1772
11	0.4331	1.5	0.0590	48	1.8898	5.0	0.1969
12	0.4724	1.75	0.0689	52	2.0472	5.0	0.1969
14	0.5512	2.0	0.0787	56	2.2047	5.5	0.2165
16	0.6299	2.0	0.0787	60	2.3622	5.5	0.2165
18	0.7087	2.5	0.0984	64	2.5197	6.0	0.2362
20	0.7874	2.5	0.0984	68	2.6772	6.0	0.2362
22	0.8661	2.5	0.0984	72	2.8346	6.5	0.2559
24	0.9449	3.0	0.1181	76	2.9921	6.5	0.2559
27	1.0630	3.0	0.1181	80	3.1497	7.0	0.2756
30	1.1811	3.5	0.1378				

FRENCH SYSTEM STANDARD THREAD.

Diameter		Pitch		Diameter		Pitch	
Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
3	0.1181	0.5	0.0197	24	0.9449	3.0	0.1181
4	0.1575	0.75	0.0295	26	1.0236	3.0	0.1181
5	0.1969	0.75	0.0295	28	1.1024	3.0	0.1181
6	0.2362	1.0	0.0394	30	1.1811	3.5	0.1378
7	0.2756	1.0	0.0394	32	1.2598	3.5	0.1378
8	0.3150	1.0	0.0394	34	1.3386	3.5	0.1378
9	0.3543	1.0	0.0394	36	1.4173	4.0	0.1575
10	0.3937	1.5	0.0590	38	1.4961	4.0	0.1575
12	0.4724	1.5	0.0590	40	1.5748	4.0	0.1575
14	0.5512	2.0	0.0787	42	1.6535	4.5	0.1772
16	0.6299	2.0	0.0787	44	1.7323	4.5	0.1772
18	0.7087	2.5	0.0984	46	1.8110	4.5	0.1772
20	0.7874	2.5	0.0984	48	1.8898	5.0	0.1969
22	0.8661	2.5	0.0984	50	1.9685	5.0	0.1969

WOOD SCREW THREAD.*

No. of Screw	Diameter	Threads per Inch	No. of Screw	Diameter	Threads per Inch	No. of Screw	Diameter	Threads per Inch
0	0.058	32	11	0.203	12	22	0.347	7
1	0.071	28	12	0.216	11	23	0.361	7
2	0.084	26	13	0.229	11	24	0.374	7
3	0.097	24	14	0.242	10	25	0.387	7
4	0.110	22	15	0.255	10	26	0.400	6
5	0.124	20	16	0.268	9	27	0.413	6
6	0.137	18	17	0.282	9	28	0.426	6
7	0.150	16	18	0.295	8	29	0.439	6
8	0.163	15	19	0.308	8	30	0.453	6
9	0.176	14	20	0.321	8			
10	0.189	13	21	0.334	8			

* American Screw Company's Standard.

TOOLS FOR SQUARE THREAD.

No. of Threads per Inch	Width of Point of Tool			No. of Threads per Inch	Width of Point of Tool		
	For Taps	For Screws	For Inside Thread Tools for Nuts		For Taps	For Screws	For Inside Thread Tools for Nuts
1	0.4965	0.5000	0.5035	8	0.0615	0.0625	0.0635
1⅓	0.3715	0.3750	0.3785	9	0.0545	0.0555	0.0565
1½	0.3333	0.3333	0.3363	10	0.0490	0.0500	0.0510
1¾	0.2827	0.2857	0.2887	11	0.0444	0.0454	0.0464
2	0.2475	0.2500	0.2525	12	0.0407	0.0417	0.0427
2½	0.1975	0.2000	0.2025	13	0.0375	0.0385	0.0395
3	0.1641	0.1666	0.1691	14	0.0352	0.0357	0.0362
3½	0.1408	0.1428	0.1448	15	0.0328	0.0333	0.0338
4	0.1235	0.1250	0.1265	16	0.0307	0.0312	0.0317
4½	0.1096	0.1111	0.1126	18	0.0272	0.0277	0.0282
5	0.0985	0.1000	0.1015	20	0.0245	0.0250	0.0255
5½	0.0894	0.0909	0.0924	22	0.0222	0.0227	0.0232
6	0.0818	0.0833	0.0848	24	0.0203	0.0208	0.0213
7	0.0699	0.0714	0.0729				

STANDARD WORM THREAD.

Threads per Inch	Depth of Thread	Width of Flat at Top of Thread	Width of Flat at Bottom of Thread	Width of Thread at Pitch Line	Height of Thread Above Pitch Line
1	0.6866	0.3350	0.3100	0.5000	0.3183
1¼	0.5492	0.2680	0.2480	0.4000	0.2546
1½	0.4577	0.2233	0.2066	0.3333	0.2122
2	0.3433	0.1675	0.1550	0.2500	0.1592
2½	0.2746	0.1340	0.1240	0.2000	0.1273
3	0.2289	0.1117	0.1033	0.1666	0.1061
3½	0.1962	0.0957	0.0886	0.1429	0.0909
4	0.1716	0.0838	0.0775	0.1250	0.0796
4½	0.1526	0.0744	0.0689	0.1111	0.0707
5	0.1373	0.0670	0.0620	0.1000	0.0637
6	0.1144	0.0558	0.0517	0.0833	0.0531
7	0.0981	0.0479	0.0443	0.0714	0.0455
8	0.0858	0.0419	0.0388	0.0625	0.0398
9	0.0763	0.0372	0.0344	0.0555	0.0354
10	0.0687	0.0335	0.0310	0.0500	0.0318
12	0.0572	0.0279	0.0258	0.0416	0.0265
16	0.0429	0.0209	0.0194	0.0312	0.0199
20	0.0343	0.0167	0.0155	0.0250	0.0159

LAG SCREW THREAD SYSTEMS IN COMMON USE.

Diameter	Alternate Systems		Diameter	Alternate Systems		Diameter	Alternate Systems	
	Threads per Inch	Threads per Inch		Threads per Inch	Threads per Inch		Threads per Inch	Threads per Inch
1/4	10	10	1/2	6	6	3/4	4½	5
5/16	9½	9	9/16	5	6	7/8	4½	4
3/8	7	8	5/8	5	5	1	3	4
7/16	7	7	11/16	4½	5			

FINE SCREW THREAD SYSTEM ADOPTED BY THE ASSOCIATION OF LICENSED AUTOMOBILE MANUFACTURERS.

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
$\frac{1}{4}$	28	$\frac{7}{16}$	20	$\frac{5}{8}$	18	$\frac{7}{8}$	14
$\frac{5}{16}$	24	$\frac{1}{2}$	20	$\frac{11}{16}$	16	1	14
$\frac{3}{8}$	24	$\frac{9}{16}$	18	$\frac{3}{4}$	16		

TAP DRILLS FOR A. S. M. E. STANDARD AND SPECIAL MACHINE SCREWS.

Standard Sizes are Marked *

No. of Screw and Threads per Inch	Size of Drill	No. of Screw and Threads per Inch	Size of Drill	No. of Screw and Threads per Inch	Size of Drill	No. of Screw and Threads per Inch	Size of Drill
0–80*	56	5–36	42	9–24	30	20–20*	G
1–72*	53	6–40*	35	10–32	23	20–18	F
1–64	54	6–36	36	10–30*	24	22–18*	K
2–64*	50	6–32	38	10–24	28	22–16	I
2–56	51	7–36*	31	12–28*	17	24–18	$\frac{5}{16}$
3–56*	47	7–32	32	12–24	19	24–16*	N
3–48	48	7–30	33	14–24*	10	26–16*	P
4–48*	43	8–36*	29	14–20	14	26–14	O
4–40	45	8–32	30	16–22*	3	28–16	S
4–36	46	8–30	30	16–20	4	28–14*	R
5–44*	39	9–32*	28	18–20*	A	30–16	V
5–40	40	9–30	28	18–18	1	30–14*	U

TAP DRILLS FOR OLD STANDARD MACHINE SCREWS.

Size of Taps	No. of Threads	Size of Drills	Size of Taps	No. of Threads	Size of Drills	Size of Taps	No. of Threads	Size of Drills
2	48	51	9	28	29	16	24	2
2	56	49	9	30	28	17	16	7
2	64	49	9	32	27	17	18	4
3	40	49	10	24	28	17	20	2
3	48	48	10	28	26	18	16	3
3	56	44	10	30	24	18	18	2
4	32	48	10	32	24	18	20	A
4	36	45	11	24	24	19	16	1
4	40	44	11	28	21	19	18	B
5	30	44	11	30	19	19	20	D
5	32	43	12	20	24	20	16	C
5	36	41	12	22	20	20	18	E
5	40	40	12	24	19	20	20	H
6	30	41	13	20	19	22	16	H
6	32	37	13	24	15	22	18	J
6	36	36	14	20	16	24	14	K
6	40	33	14	22	13	24	16	L
7	28	35	14	24	9	24	18	N
7	30	34	15	18	13	26	14	N
7	32	31	15	20	10	26	16	O
8	24	34	15	24	6	28	14	Q
8	30	30	16	16	13	28	16	S
8	32	30	16	18	10	30	14	T
9	24	30	16	20	6	30	16	V

TAP DRILL TABLE FOR STANDARD AND FINER PITCHES.

	Number of Threads per Inch.																			
	3	3¼	3½	4	4½	5	5½	6	7	8	9	10	11	12	13	14	16	18	20	22	24
1/4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3/16	13/64	13/64
5/16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1/4	1/4	17/64	17/64
3/8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19/64	5/16	5/16	21/64	21/64
7/16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	23/64	23/64	3/8	3/8	25/64	25/64
1/2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13/32	27/64	27/64	7/16	7/16	29/64	29/64
9/16	..	..	..	..	..	..	..	..	..	..	..	..	..	15/32	15/32	31/64	31/64	1/2	1/2	33/64	33/64
5/8	..	..	..	..	..	..	..	..	..	..	..	..	33/64	17/32	17/32	35/64	35/64	9/16	9/16	37/64	37/64
3/4	..	..	..	..	..	..	..	..	..	..	..	5/8	41/64	21/32	21/32	43/64	43/64	11/16	11/16	45/64	45/64
7/8	..	..	..	..	..	..	..	..	..	..	47/64	3/4	49/64	25/32	25/32	51/64	51/64	13/16	13/16	53/64	53/64
1	..	..	..	..	..	..	..	..	..	27/32	55/64	7/8	57/64	29/32	29/32	59/64	59/64	15/16	15/16	61/64	61/64
1 1/8	..	..	..	..	..	..	..	..	61/64	31/32	63/64	1	1 1/64	1 1/32	1 1/32	1 1/32	1 3/64	1 1/16	1 1/16		
1 1/4	..	..	..	..	..	..	..	..	1 5/64	1 3/32	1 7/64	1 1/8	1 9/64	1 5/32	1 5/32	1 11/64	1 11/64	1 3/16	1 3/16		
1 3/8	..	..	..	..	..	..	..	1 11/64	1 13/64	1 7/32	1 15/64	1 1/4	1 17/64	1 9/32	1 9/32	1 9/32	1 19/64	1 5/16	1 5/16		
1 1/2	..	..	..	..	..	..	..	1 19/64	1 21/64	1 11/32	1 23/64	1 3/8	1 25/64	1 13/32	1 13/32	1 27/64	1 27/64	1 7/16	1 7/16		
1 5/8	..	..	..	..	..	..	1 25/64	1 13/32	1 29/64	1 15/32	1 31/64	1 1/2	1 33/64	1 17/32	1 17/32	1 35/64	1 35/64	1 9/16			
1 3/4	..	..	..	..	..	1 1/2	1 33/64	1 35/64	1 37/64	1 19/32	1 39/64	1 5/8	1 41/64	1 21/32	1 21/32	1 43/64	1 43/64	1 11/16			
1 7/8	..	..	..	..	..	1 5/8	1 41/64	1 43/64	1 45/64	1 23/32	1 47/64	1 3/4	1 49/64	1 25/32	1 25/32	1 51/64	1 51/64	1 13/16			
2	..	..	..	..	1 23/32	1 3/4	1 49/64	1 51/64	1 53/64	1 27/32	1 55/64	1 7/8	1 57/64	1 29/32	1 29/32	1 59/64	1 59/64	1 15/16			
2 1/4	..	..	..	..	1 31/32	2	2 1/32	2 1/16	2 3/32	2 3/32	2 1/8	2 1/8	2 9/64	2 5/32	2 5/32	2 11/64	2 11/64				
2 1/2	..	..	..	2 3/16	2 7/32	2 1/4	2 9/32	2 5/16	2 11/32	2 11/32	2 3/8	2 3/8	2 25/64	2 13/32	2 13/32	2 27/64	2 27/64				
2 3/4	..	..	..	2 7/16	2 15/32	2 1/2	2 17/32	2 9/16	2 19/32	2 19/32	2 5/8	2 5/8	2 41/64	2 21/32	2 21/32	2 43/64	2 43/64				
3	..	..	2 41/64	2 11/16	2 23/32	2 3/4	2 25/32	2 13/16	2 27/32	2 27/32	2 7/8	2 7/8	2 57/64	2 29/32	2 29/32	2 59/64	2 59/64				
3 1/4	..	..	2 57/64	2 15/16	2 31/32	3	3 1/32	3 1/16	3 3/32	3 3/32	3 1/8	3 1/8	3 9/64	3 5/32							
3 1/2	..	3 1/8	3 5/32	3 3/16	3 7/32	3 1/4	3 9/32	3 5/16	3 11/32	3 11/32	3 3/8	3 3/8	3 25/64	3 13/32							
3 3/4	3 21/64	3 3/8	3 13/32	3 7/16	3 15/32	3 1/2	3 17/32	3 9/16	3 19/32	3 19/32	3 5/8	3 5/8	3 41/64	3 21/32							
4	3 37/64	3 5/8	3 21/32	3 11/16	3 23/32	3 3/4	3 25/32	3 13/16	3 27/32	3 27/32	3 7/8	3 7/8	3 57/64	3 29/32							

The first Drill Size in each line is for U. S. Standard Tap.

TAP DRILLS FOR PIPE TAPS.

Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps	Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps	Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps
1/8	21/64	5/16	1 1/4	1 15/32	1 15/32	3 1/4	—	3 1/2
1/4	27/64	27/64	1 1/2	1 23/32	1 25/32	3 1/2	3 11/16	3 3/4
3/8	9/16	9/16	1 3/4	—	1 15/16	3 3/4	—	4
1/2	11/16	11/16	2	2 3/16	2 5/32	4	4 3/16	4 1/4
5/8	—	25/32	2 1/4	—	2 13/32	4 1/2	4 11/16	4 3/4
3/4	29/32	29/32	2 1/2	2 9/16	2 25/32	5	5 1/4	5 1/4
7/8	—	1 1/16	2 3/4	—	3 1/32	5 1/2	—	5 3/4
1	1 1/8	1 1/8	3	3 3/16	3 9/32	6	6 5/16	6 1/4

CONSTANTS FOR FINDING DIAMETER AT ROOT OF THREAD.

Threads per Inch	U. S. Standard Thread	Standard V-Thread	Whitworth Standard Thread	Threads per Inch	U. S. Standard Thread	Standard V-Thread	Whitworth Standard Thread
2 1/4	0.5774	0.7698	0.5692	18	0.0722	0.0962	0.0711
2 3/8	0.5470	0.7293	0.5392	20	0.0650	0.0866	0.0640
2 1/2	0.5196	0.6928	0.5123	22	0.0590	0.0787	0.0582
2 5/8	0.4949	0.6598	0.4879	24	0.0541	0.0722	0.0534
2 3/4	0.4724	0.6298	0.4657	26	0.0500	0.0666	0.0493
2 7/8	0.4518	0.6025	0.4454	28	0.0464	0.0619	0.0457
3	0.4330	0.5774	0.4269	30	0.0433	0.0577	0.0427
3 1/4	0.3997	0.5329	0.3940	32	0.0406	0.0541	0.0400
3 1/2	0.3712	0.4949	0.3659	34	0.0382	0.0509	0.0377
4	0.3248	0.4330	0.3202	36	0.0361	0.0481	0.0356
4 1/2	0.2887	0.3849	0.2846	38	0.0342	0.0456	0.0337
5	0.2598	0.3464	0.2561	40	0.0325	0.0433	0.0320
5 1/2	0.2362	0.3149	0.2328	42	0.0309	0.0412	0.0305
6	0.2165	0.2887	0.2134	44	0.0295	0.0394	0.0291
7	0.1856	0.2474	0.1830	46	0.0282	0.0377	0.0278
8	0.1624	0.2165	0.1601	48	0.0271	0.0361	0.0267
9	0.1443	0.1925	0.1423	50	0.0260	0,0346	0.0256
10	0.1299	0.1732	0.1281	52	0.0250	0.0333	0.0246
11	0.1181	0.1575	0.1164	56	0.0232	0.0309	0.0229
12	0.1083	0.1443	0.1067	60	0.0217	0.0289	0.0213
13	0.0999	0.1332	0.0985	64	0.0203	0.0271	0.0200
14	0.0928	0.1237	0.0915	68	0.0191	0.0255	0.0188
15	0.0866	0.1155	0.0854	72	0.0180	0.0241	0.0178
16	0.0812	0.1083	0.0800	80	0.0162	0.0217	0.0160

These constants are subtracted from the outside diameter of the tap or screw; the result is the root diameter of the thread.

TAPPING SPEEDS FOR STANDARD TAPS.

Diameter of Tap	Cast Iron	Wrought Iron	Diameter of Tap	Cast Iron	Wrought Iron	Diameter of Tap	Cast Iron	Wrought Iron
3/16	340	265	5/8	117	91	1 3/8	51	41
1/4	295	230	3/4	96	76	1 1/2	46	38
5/16	240	190	7/8	84	65	1 3/4	40	33
3/8	197	152	1	72	57	2	34	28
7/16	170	122	1 1/8	63	50	2 1/4	30	26
1/2	145	114	1 1/4	57	45	2 1/2	26	23

MISCELLANEOUS TABLES.

TABLE OF DECIMAL EQUIVALENTS OF LETTER SIZE DRILLS.

Letter	Size of Drill in Decimals	Letter	Size of Drill in Decimals	Letter	Size of Drill in Decimals	Letter	Size of Drill in Decimals
Z	0.413	S	0.348	L	0.290	E	0.250
Y	0.404	R	0.339	K	0.281	D	0.246
X	0.397	Q	0.332	J	0.277	C	0.242
W	0.386	P	0.323	I	0.272	B	0.238
V	0.377	O	0.316	H	0.266	A	0.234
U	0.368	N	0.302	G	0.261		
T	0.358	M	0.295	F	0.257		

TWIST DRILL AND STEEL WIRE GAGE.

No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches
1	0.2280	21	0.1590	41	0.0960	61	0.0390
2	0.2210	22	0.1570	42	0.0935	62	0.0380
3	0.2130	23	0.1540	43	0.0890	63	0.0370
4	0.2090	24	0.1520	44	0.0860	64	0.0360
5	0.2055	25	0.1495	45	0.0820	65	0.0350
6	0.2040	26	0.1470	46	0.0810	66	0.0330
7	0.2010	27	0.1440	47	0.0785	67	0.0320
8	0.1990	28	0.1405	48	0.0760	68	0.0310
9	0.1960	29	0.1360	49	0.0730	69	0.0292
10	0.1935	30	0.1285	50	0.0700	70	0.0280
11	0.1910	31	0.1200	51	0.0670	71	0.0260
12	0.1890	32	0.1160	52	0.0635	72	0.0250
13	0.1850	33	0.1130	53	0.0595	73	0.0240
14	0.1820	34	0.1110	54	0.0550	74	0.0225
15	0.1800	35	0.1100	55	0.0520	75	0.0210
16	0.1770	36	0.1065	56	0.0465	76	0.0200
17	0.1730	37	0.1040	57	0.0430	77	0.0180
18	0.1695	38	0.1015	58	0.0420	78	0.0160
19	0.1660	39	0.0995	59	0.0410	79	0.0145
20	0.1610	40	0.0980	60	0.0400	80	0.0135

CUTTING SPEEDS FOR SHAPER, PLANER AND LATHE TOOLS.

	Brass	Cast Iron	Machine Steel	Tool Steel Annealed
Feet Per Minute	75 to 100	25 to 35	18 to 25	15 to 25

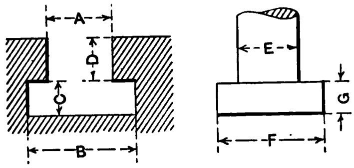
CUTTING SPEEDS FOR MILLING CUTTERS.

	Brass	Cast Iron	Machine Steel	Tool Steel Annealed
Feet per Minute	80 to 120	40 to 60	35 to 45	25 to 35

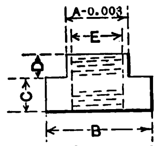
SPEED OF DRILLS

Diameter of Drill Inches	Revolutions per Minute: Wrought Iron and Steel	Revolutions per Minute: Cast Iron	Revolutions per Minute: Brass	Diameter of Drill Inches	Revolutions per Minute: Wrought Iron and Steel	Revolutions per Minute: Cast Iron	Revolutions per Minute: Brass
1/16	1536	1824	3360	1 1/2	64	76	140
1/8	768	912	1680	1 9/16	61	73	134
3/16	512	608	1120	1 5/8	59	70	129
1/4	384	456	840	1 11/16	57	68	125
5/16	307	365	672	1 3/4	55	65	120
3/8	256	304	560	1 13/16	53	63	116
7/16	219	261	480	1 7/8	51	61	112
1/2	192	228	420	1 15/16	49	59	108
9/16	170	203	373	2	48	57	105
5/8	154	182	336	2 1/16	46	55	102
11/16	139	166	305	2 1/8	45	54	100
3/4	128	152	280	2 3/16	43	52	96
13/16	118	140	258	2 1/4	42	51	93
7/8	109	130	239	2 5/16	41	49	91
15/16	102	122	224	2 3/8	40	48	88
1	96	114	210	2 7/16	39	47	86
1 1/16	90	107	197	2 1/2	38	45	84
1 1/8	85	101	186	2 9/16	37	44	82
1 3/16	81	96	177	2 5/8	36	43	80
1 1/4	77	91	168	2 3/4	35	41	76
1 5/16	73	87	160	2 7/8	33	40	73
1 3/8	70	83	153	3	31	38	70
1 7/16	67	79	146				

T-SLOTS AND T-BOLTS.



T-NUTS



Machinery, N.Y.

Slot: A	Slot: B	Slot: C	Slot: D*	Bolt-Head: E	Bolt-Head: F	Bolt-Head: G
1/4	1/2	5/32	3/16	3/16	7/16	1/8
5/16	5/8	5/32	3/16	1/4	9/16	1/8
3/8	11/16	7/32	1/4	5/16	5/8	3/16
7/16	13/16	7/32	9/32	3/8	3/4	3/16
1/2	15/16	9/32	5/16	7/16	7/8	1/4
5/8	1 3/16	13/32	3/8	9/16	1 1/8	11/32
3/4	1 5/16	17/32	1/2	11/16	1 1/4	15/32
7/8	1 5/8	11/16	9/16	3/4	1 1/2	9/16
1	1 7/8	13/16	5/8	7/8	1 3/4	11/16

* Minimum distance possible.
Maximum distance of *D* equals
A + 1/16 for sizes of bolt up to 5/8,
1 for 11/16 size of bolt,
1 1/16 for 3/4 size of bolt,
1 3/16 for 7/8 size of bolt.

A	B	C	D	E
3/16	7/16	1/8	3/32	1/8
1/4	9/16	1/8	1/8	3/16
5/16	5/8	3/16	1/8	1/4
3/8	3/4	3/16	5/32	5/16
7/16	7/8	1/4	3/16	3/8
9/16	1 1/8	11/32	3/16	1/2
11/16	1 1/4	15/32	1/4	5/8
3/4	1 1/2	9/16	5/16	5/8
7/8	1 3/4	11/16	5/16	3/4

Rules for Figuring Tapers.

1. If the taper foot is known, the taper per inch is found by dividing the taper per foot by 12.

2. If the taper per inch is known, the taper per foot is found by multiplying the taper per inch by 12.

3. To find the taper per foot, when the diameters at the large and small ends and the length of the taper are given, subtract the small diameter from the large, divide the remainder by the length of the taper, and multiply the result by 12.

4. To find the diameter at the small end when the diameter at the large end, the length of the taper, and the taper per foot are given, divide the taper per foot by 12, multiply the quotient by the length of the taper, and subtract the resulting dimension from the diameter at the large end.

5. To find the diameter at the large end when the diameter at the small end, the length of the taper, and the taper per foot are given, divide the taper per foot by 12, multiply the quotient by the length of the taper, and add the resulting dimension to the diameter at the small end.

6. To find the dimension between two given diameters of a piece of work, when the taper per foot is given, subtract the diameter at the small end from the diameter at the large end, and divide the remainder by the taper per foot divided by 12.

7. To find how much a piece of work tapers in a certain length, when the taper per foot is given, divide the taper per foot by 12, and multiply the quotient by the dimension of the certain length in which the taper is required.

Rules for Setting over the Lathe Tail-Stock for Taper Turning.

1. To find the amount to set over the tail-stock for work tapering for its full length, when the taper per foot and length of the work are known, divide the taper per foot by 12, multiply the quotient by the length of the work, and divide this result, in turn, by 2.

2. To find the amount to set over the tail-stock for work tapering for its full length, when the diameters at the large and small ends are known, subtract the small diameter from the large, and divide the remainder by 2.

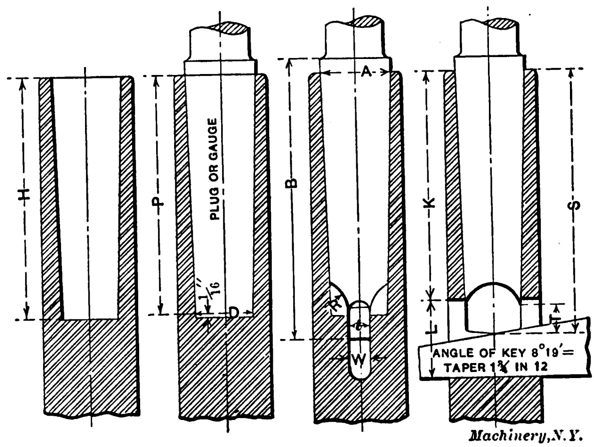
3. To find the amount to set over the tail-stock for work partly tapered and partly straight, when the diameters at the large and small ends of the taper, the length of the taper, and the total length of the work are known, subtract the small diameter from the large, divide the remainder by the length of the taper, multiply the quotient thus obtained by the total length of the work, and finally divide by 2.

4. To find the amount to set over the tail-stock for work partly tapered and partly straight, when the taper per foot and the length of the work are known, divide the taper per foot by 12, multiply the quotient by the length of the work, and divide this result, in turn, by 2.

STANDARD TAPER PINS.

No. of Taper Pin	Diameter at Large End of Pin	Approx. Fractional Size at Large End of Pin	Length of Longest Pin of This Size	No. of Taper Pin	Diameter at Large End of Pin	Approx. Fractional Size at Large End of Pin	Length of Longest Pin of This Size
000000	0.0715	$\frac{5}{64}$	$\frac{5}{8}$	3	0.219	$\frac{7}{32}$	$1\frac{3}{4}$
00000	0.092	$\frac{3}{32}$	$\frac{5}{8}$	4	0.250	$\frac{1}{4}$	2
0000	0.108	$\frac{7}{64}$	$\frac{3}{4}$	5	0.289	$\frac{19}{64}$	$2\frac{1}{4}$
000	0.125	$\frac{1}{8}$	$\frac{3}{4}$	6	0.341	$\frac{11}{32}$	$3\frac{1}{4}$
00	0.147	$\frac{9}{64}$	1	7	0.409	$\frac{13}{32}$	$3\frac{3}{4}$
0	0.156	$\frac{5}{32}$	1	8	0.492	$\frac{1}{2}$	$4\frac{1}{2}$
1	0.172	$\frac{11}{64}$	$1\frac{1}{4}$	9	0.591	$\frac{19}{32}$	$5\frac{1}{4}$
2	0.193	$\frac{3}{16}$	$1\frac{1}{2}$	10	0.706	$\frac{23}{32}$	6

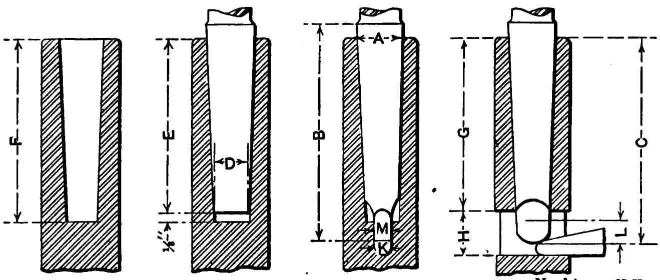
MORSE STANDARD TAPERS.



Machinery,N.Y.

Number of Taper	Diameter of Plug at Small End	Diameter at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Length of Tongue	Thickness of Tongue	Width of Keyway	Shank Depth	Taper per Foot
	D	A	P	B	H	K	L	T	t	W	S	
0	0.252	0.356	2	$2\frac{11}{32}$	$2\frac{1}{32}$	$1\frac{15}{16}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{5}{32}$	0.160	$2\frac{7}{32}$	0.625
1	0.369	0.475	$2\frac{1}{8}$	$2\frac{9}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{13}{64}$	0.213	$2\frac{3}{8}$	0.600
2	0.572	0.700	$2\frac{9}{16}$	$3\frac{1}{16}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	0.260	$2\frac{7}{8}$	0.602
3	0.778	0.938	$3\frac{3}{16}$	$3\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{16}$	$1\frac{1}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	0.322	$3\frac{9}{16}$	0.602
4	1.020	1.231	$4\frac{1}{16}$	$4\frac{3}{4}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{15}{32}$	0.478	$4\frac{1}{2}$	0.623
5	1.475	1.748	$5\frac{3}{16}$	6	$5\frac{1}{4}$	$4\frac{15}{16}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	0.635	$5\frac{3}{4}$	0.630
6	2.116	2.494	$7\frac{1}{4}$	$8\frac{5}{16}$	$7\frac{3}{8}$	7	$1\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	0.760	8	0.626
7	2.750	3.270	10	$11\frac{5}{8}$	$10\frac{1}{8}$	$9\frac{1}{2}$	$2\frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1.135	$11\frac{1}{4}$	0.625

BROWN & SHARPE STANDARD TAPERS.



Machinery, N.Y.

Number of Taper	Diameter at End of Socket	Whole Length of Shank	Shank Depth	Diameter of Plug at Small End	Standard Plug Depth	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Thickness of Tongue
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*	*L*	*M*
1	0.239	1 9/32	1 3/16	0.200	15/16	1 1/16	15/16	3/8	0.135	3/16	1/8
2	0.299	1 19/32	1 1/2	0.250	1 3/16	1 5/16	1 11/64	1/2	0.166	1/4	5/32
3	0.375	1 31/32	1 7/8	0.312	1 1/2	1 5/8	1 15/32	5/8	0.197	5/16	3/16
3	0.385	2 7/32	2 1/8	0.312	1 3/4	1 7/8	1 23/32	5/8	0.197	5/16	3/16
3	0.395	2 15/32	2 3/8	0.312	2	2 1/8	1 31/32	5/8	0.197	5/16	3/16
4	0.402	1 3/4	1 21/32	0.350	1 1/4	1 3/8	1 13/64	11/16	0.228	11/32	7/32
4	0.420	2 3/16	2 3/32	0.350	1 11/16	1 13/16	1 41/64	11/16	0.228	11/32	7/32
5	0.523	2 9/32	2 3/16	0.450	1 3/4	1 7/8	1 11/16	3/4	0.260	3/8	1/4
5	0.533	2 17/32	2 7/16	0.450	2	2 1/8	1 15/16	3/4	0.260	3/8	1/4
5	0.539	2 21/32	2 9/16	0.450	2 1/8	2 1/4	2 1/16	3/4	0.260	3/8	1/4
6	0.599	2 31/32	2 7/8	0.500	2 3/8	2 1/2	2 19/64	7/8	0.291	7/16	9/32
6	0.635	3 27/32	3 3/4	0.500	3 1/4	3 3/8	3 11/64	7/8	0.291	7/16	9/32
7	0.704	3 1/8	3 1/32	0.600	2 1/2	2 5/8	2 13/32	15/16	0.322	15/32	5/16
7	0.720	3 1/2	3 13/32	0.600	2 7/8	3	2 25/32	15/16	0.322	15/32	5/16
7	0.725	3 5/8	3 17/32	0.600	3	3 1/8	2 29/32	15/16	0.322	15/32	5/16
7	0.767	4 5/8	4 17/32	0.600	4	4 1/8	3 29/32	15/16	0.322	15/32	5/16
8	0.898	4 1/4	4 1/8	0.750	3 9/16	3 11/16	3 29/64	1	0.353	1/2	11/32
8	0.917	4 11/16	4 9/16	0.750	4	4 1/8	3 57/64	1	0.353	1/2	11/32
9	1.067	4 3/4	4 5/8	0.900	4	4 1/8	3 7/8	1 1/8	0.385	9/16	3/8
9	1.077	5	4 7/8	0.900	4 1/4	4 3/8	4 1/8	1 1/8	0.385	9/16	3/8
10	1.260	5 27/32	5 23/32	1.0446	5	5 1/8	4 27/32	1 5/16	0.447	21/32	7/16
10	1.289	6 17/32	6 13/32	1.0446	5 11/16	5 13/16	5 17/32	1 5/16	0.447	21/32	7/16
10	1.312	7 1/16	6 15/16	1.0446	6 7/32	6 11/32	6 1/16	1 5/16	0.447	21/32	7/16
11	1.498	6 25/32	6 21/32	1.250	5 15/16	6 1/16	5 25/32	1 5/16	0.447	21/32	7/16
11	1.531	7 19/32	7 15/32	1.250	6 3/4	6 7/8	6 19/32	1 5/16	0.447	21/32	7/16
12	1.797	8 1/16	7 15/16	1.500	7 1/8	7 1/4	6 15/16	1 1/2	0.510	3/4	1/2
13	2.073	8 11/16	8 9/16	1.750	7 3/4	7 7/8	7 9/16	1 1/2	0.510	3/4	1/2
14	2.344	9 9/32	9 5/32	2.000	8 1/4	8 3/8	8 1/32	1 11/16	0.572	27/32	9/16
15	2.615	9 25/32	9 21/32	2.250	8 3/4	8 7/8	8 17/32	1 11/16	0.572	27/32	9/16
16	2.885	10 3/8	10 1/4	2.500	9 1/4	9 3/8	9	1 7/8	0.635	15/16	5/8

The taper per foot is ½ inch, except for No. 10, where the taper is 0.5161 inch per foot.

TABLE GIVING THE AMOUNT OF TAPER IN A CERTAIN LENGTH, WHEN THE TAPER PER FOOT IS GIVEN.

Length of Tapered Portion	Taper per Foot.										
	1/16	3/32	1/8	1/4	3/8	1/2	0.600	5/8	3/4	1	1 1/4
1/32	0.0002	0.0002	0.0003	0.0007	0.0010	0.0013	0.0016	0.0016	0.0020	0.0026	0.0033
1/16	0.0003	0.0005	0.0007	0.0013	0.0020	0.0026	0.0031	0.0033	0.0039	0.0052	0.0065
1/8	0.0007	0.0010	0.0013	0.0026	0.0039	0.0052	0.0062	0.0065	0.0078	0.0104	0.0130
3/16	0.0010	0.0015	0.0020	0.0039	0.0059	0.0078	0.0094	0.0098	0.0117	0.0156	0.0195
1/4	0.0013	0.0020	0.0026	0.0052	0.0078	0.0104	0.0125	0.0130	0.0156	0.0208	0.0260
5/16	0.0016	0.0024	0.0033	0.0065	0.0098	0.0130	0.0156	0.0163	0.0195	0.0260	0.0326
3/8	0.0020	0.0029	0.0039	0.0078	0.0117	0.0156	0.0187	0.0195	0.0234	0.0312	0.0391
7/16	0.0023	0.0034	0.0046	0.0091	0.0137	0.0182	0.0219	0.0228	0.0273	0.0365	0.0456
1/2	0.0026	0.0039	0.0052	0.0104	0.0156	0.0208	0.0250	0.0260	0.0312	0.0417	0.0521
9/16	0.0029	0.0044	0.0059	0.0117	0.0176	0.0234	0.0281	0.0293	0.0352	0.0469	0.0586
5/8	0.0033	0.0049	0.0065	0.0130	0.0195	0.0260	0.0312	0.0326	0.0391	0.0521	0.0651
11/16	0.0036	0.0054	0.0072	0.0143	0.0215	0.0286	0.0344	0.0358	0.0430	0.0573	0.0716
3/4	0.0039	0.0059	0.0078	0.0156	0.0234	0.0312	0.0375	0.0391	0.0469	0.0625	0.0781
13/16	0.0042	0.0063	0.0085	0.0169	0.0254	0.0339	0.0406	0.0423	0.0508	0.0677	0.0846
7/8	0.0046	0.0068	0.0091	0.0182	0.0273	0.0365	0.0437	0.0456	0.0547	0.0729	0.0911
15/16	0.0049	0.0073	0.0098	0.0195	0.0293	0.0391	0.0469	0.0488	0.0586	0.0781	0.0977
1	0.0052	0.0078	0.0104	0.0208	0.0312	0.0417	0.0500	0.0521	0.0625	0.0833	0.1042
2	0.0104	0.0156	0.0208	0.0417	0.0625	0.0833	0.1000	0.1042	0.1250	0.1667	0.2083
3	0.0156	0.0234	0.0312	0.0625	0.0937	0.1250	0.1500	0.1562	0.1875	0.2500	0.3125
4	0.0208	0.0312	0.0417	0.0833	0.1250	0.1667	0.2000	0.2083	0.2500	0.3333	0.4167
5	0.0260	0.0391	0.0521	0.1042	0.1562	0.2083	0.2500	0.2604	0.3125	0.4167	0.5208
6	0.0312	0.0469	0.0625	0.1250	0.1875	0.2500	0.3000	0.3125	0.3750	0.5000	0.6250
7	0.0365	0.0547	0.0729	0.1458	0.2187	0.2917	0.3500	0.3646	0.4375	0.5833	0.7292
8	0.0417	0.0625	0.0833	0.1667	0.2500	0.3333	0.4000	0.4167	0.5000	0.6667	0.8333
9	0.0469	0.0703	0.0937	0.1875	0.2812	0.3750	0.4500	0.4687	0.5625	0.7500	0.9375
10	0.0521	0.0781	0.1042	0.2083	0.3125	0.4167	0.5000	0.5208	0.6250	0.8333	1.0417
11	0.0573	0.0859	0.1146	0.2292	0.3437	0.4583	0.5500	0.5729	0.6875	0.9167	1.1458
12	0.0625	0.0937	0.1250	0.2500	0.3750	0.5000	0.6000	0.6250	0.7500	1.0000	1.2500

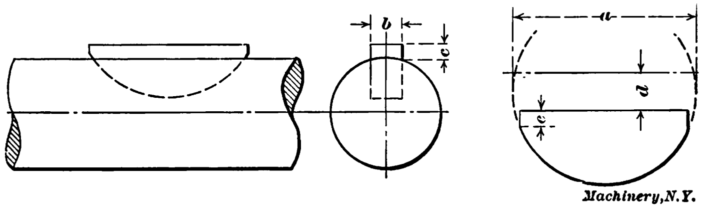
The Jarno Taper.

In the Jarno taper, a definite relation exists between the number of the taper, its length, and the diameters at the large and small ends. Given the number of the taper, the length is as many half inches as expressed by the number, the diameter at the large end as many eighths of an inch, and the diameter as many tenths of an inch as designated by the number of the taper. Thus, a number 7 Jarno taper is seven-halfs or 3½ inches long, ⅞ inch diameter at the large end and 0.7 inch at the small end. The taper per foot of all Jarno tapers is 0.600 inch.

TABLE OF JARNO TAPERS.

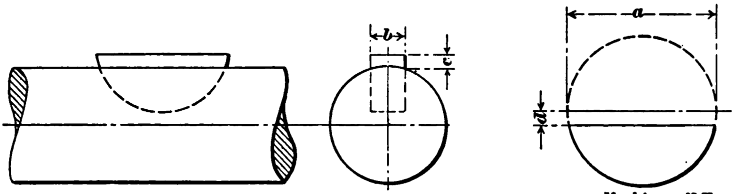
No. of Taper	Diameter at Large End	Diameter at Small End	Length	No. of Taper	Diameter at Large End	Diameter at Small End	Length
2	0.250	0.200	1	12	1.500	1.200	6
3	0.375	0.300	1½	13	1.625	1.300	6½
4	0.500	0.400	2	14	1.750	1.400	7
5	0.625	0.500	2½	15	1.875	1.500	7½
6	0.750	0.600	3	16	2.000	1.600	8
7	0.875	0.700	3½	17	2.125	1.700	8½
8	1.000	0.800	4	18	2.250	1.800	9
9	1.125	0.900	4½	19	2.375	1.900	9½
10	1.250	1.000	5	20	2.500	2.000	10
11	1.375	1.100	5½				

SPECIAL WOODRUFF KEYS.



No. of Key	Diameter of Key	Thickness of Key	Depth of Keyway	Center of Stock from which Key is made to Top of Key	Width of Flat	No. of Key	Diameter of Key	Thickness of Key	Depth of Keyway	Center of Stock from which Key is made to Top of Key	Width of Flat
	a	b	c	d	e		a	b	c	d	e
26	2 1/8	3/16	3/32	17/32	3/32	31	3 1/2	7/16	7/32	13/16	3/16
27	2 1/8	1/4	1/8	17/32	3/32	32	3 1/2	1/2	1/4	13/16	3/16
28	2 1/8	5/16	5/32	17/32	3/32	33	3 1/2	9/16	9/32	13/16	3/16
29	2 1/8	3/8	3/16	17/32	3/32	34	3 1/2	5/8	5/16	13/16	3/16
30	3 1/2	3/8	3/16	13/16	3/16						

STANDARD WOODRUFF KEYS.



Machinery,N.Y.

No. of Key	Diam. of Key	Thickness of Key	Depth of Keyway	Center of Stock from which Key is made to Top of Key	No. of Key	Diam. of Key	Thickness of Key	Depth of Keyway	Center of stock from which key is made to Top of Key
	a	b	c	d		a	b	c	d
1	1/2	1/16	1/32	3/64	B	1	5/16	5/32	1/16
2	1/2	3/32	3/64	3/64	16	1 1/8	3/16	3/32	5/64
3	1/2	1/8	1/16	3/64	17	1 1/8	7/32	7/64	5/64
4	5/8	3/32	3/64	1/16	18	1 1/8	1/4	1/8	5/64
5	5/8	1/8	1/16	1/16	C	1 1/8	5/16	5/32	5/64
6	5/8	5/32	5/64	1/16	19	1 1/4	3/16	3/32	5/64
7	3/4	1/8	1/16	1/16	20	1 1/4	7/32	7/64	5/64
8	3/4	5/32	5/64	1/16	21	1 1/4	1/4	1/8	5/64
9	3/4	3/16	3/32	1/16	D	1 1/4	5/16	5/32	5/64
10	7/8	5/32	5/64	1/16	E	1 1/4	3/8	3/16	5/64
11	7/8	3/16	3/32	1/16	22	1 3/8	1/4	1/8	3/32
12	7/8	7/32	7/64	1/16	23	1 3/8	5/16	5/32	3/32
A	7/8	1/4	1/8	1/16	F	1 3/8	3/8	3/16	3/32
13	1	3/16	3/32	1/16	24	1 1/2	1/4	1/8	7/64
14	1	7/32	7/64	1/16	25	1 1/2	5/16	5/32	7/64
15	1	1/4	1/8	1/16	G	1 1/2	3/8	3/16	7/64

STANDARD WOODRUFF KEYS TO USE WITH VARIOUS DIAMETER SHAFTS.

Diameter of Shaft	Number of Keys	Diameter of Shaft	Number of Keys	Diameter of Shaft	Number of Keys
5/16 — 3/8	1	7/8 — 15/16	6, 8, 10	1 3/8 — 1 7/16	14, 17, 20
7/16 — 1/2	2, 4	1	9, 11, 13	1 1/2 — 1 5/8	15, 18, 21, 24
9/16 — 5/8	3, 5	1 1/16 — 1 1/8	9, 11, 13, 16	1 11/16 — 1 3/4	18, 21, 24
11/16 — 3/4	3, 5, 7	1 3/16	11, 13, 16	1 13/16 — 2	23, 25
13/16	6, 8	1 1/4 — 1 5/16	12, 14, 17, 20	2 1/16 — 2 1/2	25

Rules for Calculating Cutting Speeds and Feeds.

1. To find the number of revolutions per minute, when the diameter of work (or drill) in inches and the cutting speed in feet per minute are known, multiply the diameter by 3.14, and divide the result by 12; then divide the cutting speed by the figure thus obtained.

2. To find the cutting speed in feet per minute, when the diameter of the work (or drill) in inches, and the number of revolutions per

minute are given, multiply the diameter by 3.14 and divide the result by 12; then multiply the quotient thus obtained by the number of revolutions per minute.

3. To find the time required for one complete cut over the work, when the feed per revolution, the total length of the cut, and the number of revolutions per minute are given, divide the total length of the cut by the number of revolutions per minute multiplied by the feed per revolution. If the cutting speed is given, originally, instead of the number of revolutions, find the latter number first from Rule 1.

Rules for Finding Gears for Transmitting Motion between Two Shafts.

1. Place the number cf revolutions of the driven shaft in the numerator, and the corresponding number of revolutions of the driving shaft in the denominator of a fraction (or, in general, write the ratio in the form of a fraction), and multiply the numerator and denominator with the same number, until a new fraction is obtained having numerator and denominator expressing suitable numbers of teeth for the gears. The gear represented by the new numerator is the driving gear, and that represented by the new denominator is the driven gear.

2. If compounding of the gears is necessary or advisable, divide up both numerator and denominator in the fraction, giving the ratio, in two factors, and multiply each pair of factors (one factor in the numerator and one in the denominator making "one pair") by the same numbers, until gears with suitable numbers of teeth are found.

Rules for Finding Change Gears for Screw Cutting in the Lathe.

1. To find the number of threads per inch, if the lead of a thread is given, divide 1 by the lead.

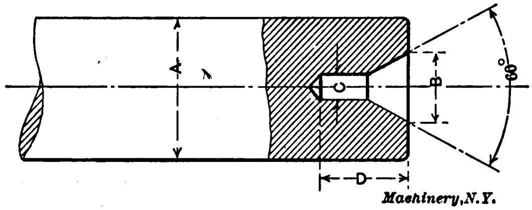
2. To find the "screw-cutting constant" of a lathe, place equal gears on spindle stud and lead-screw; then cut a thread on a piece in the lathe. The number of threads cut with equal gears is called the "screw-cutting constant" of *that particular lathe.*

3. To find the change gears used in simple gearing, when the screw-cutting constant as found from Rule 2, and the number of threads per inch to be cut are given, place the screw-cutting constant of the lathe as numerator and the number of threads to be cut as denominator in a fraction, and multiply numerator and denominator with the same number until a new fraction results representing suitable number of teeth for the change gears. In the new fraction, the numerator represents the number of teeth in the gear on the spindle stud, and the denominator, the number of teeth in the gear on the lead-screw.

4. To find the change gears used in compound gearing, place the screw-cutting constant as found from Rule 2 as numerator, and the number of threads per inch to be cut as denominator in a fraction; divide up both numerator and denominator in two factors each, and multiply each pair of factors (one factor in the numerator and one in the denominator making "a pair") by the same number, until new fractions result representing suitable number of teeth for the change

gears. The gears represented by the numbers in the new numerators are driving gears, and those in the denominators are driven gears.

CENTERS FOR REAMERS AND ARBORS.



Diameter of Arbor A	Largest Diameter of Center B	Drill C	Depth of Hole D	Diameter of Arbor A	Largest Diameter of Center B	Drill C	Depth of Hole D
1/4	1/8	55	5/32	2 3/8	43/64	H	27/32
5/16	5/32	52	3/16	2 1/2	11/16	J	27/32
3/8	3/16	48	7/32	2 5/8	45/64	K	7/8
7/16	7/32	43	1/4	2 3/4	23/32	L	29/32
1/2	1/4	39	5/16	2 7/8	47/64	M	29/32
9/16	9/32	33	11/32	3	3/4	N	15/16
5/8	5/16	30	3/8	3 1/8	49/64	N	31/32
11/16	11/32	29	13/32	3 1/4	25/32	O	31/32
3/4	3/8	25	7/16	3 3/8	51/64	O	1
13/16	13/32	20	1/2	3 1/2	13/16	P	1
7/8	7/16	17	17/32	3 5/8	53/64	Q	1 1/16
15/16	15/32	12	9/16	3 3/4	27/32	R	1 1/16
1	1/2	8	19/32	3 7/8	55/64	R	1 1/16
1 1/8	33/64	5	5/8	4	7/8	S	1 1/8
1 1/4	17/32	3	21/32	4 1/8	57/64	T	1 1/8
1 3/8	35/64	2	21/32	4 1/4	29/32	T	1 1/8
1 1/2	9/16	1	11/16	4 3/8	59/64	U	1 3/16
1 5/8	37/64	A	23/32	4 1/2	15/16	V	1 3/16
1 3/4	19/32	B	23/32	4 5/8	61/64	V	1 3/16
1 7/8	39/64	C	3/4	4 3/4	31/32	W	1 1/4
2	5/8	E	3/4	4 7/8	63/64	X	1 1/4
2 1/8	41/64	F	25/32	5	1	X	1 1/4
2 1/4	21/32	G	13/16				

Rules for Finding Change Gears for Cutting Spirals in the Milling Machine.

First find the "lead" of the milling machine. To find the lead of a milling machine, place equal gears on the worm stud, and on the feed-screw, and multiply the number of revolutions made by the feed-screw in order to produce one revolution of the index head spindle, by the lead of the feed-screw.

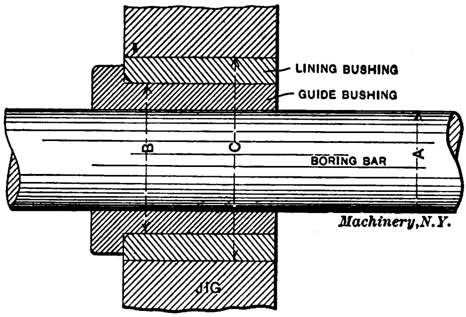
To then find the change gears to be used in a simple train of gearing, when cutting spirals on a milling machine, place the lead of the spiral in the numerator and the lead of the milling machine in the denominator of a fraction, and multiply the numerator and denominator with the same number, until a new fraction is obtained in which the numerator and denominator give suitable numbers of teeth. If

compounding of the gears is necessary, follow the same rule as regards dividing up numerator and denominator in factors, as given on page 44 for compound gearing in the lathe.

Rule for Size of Pulleys and Speed of Shafts.

The number of revolutions of one shaft multiplied with the diameter of the pulley on the same shaft, divided by the number of revolutions of the second shaft, gives the diameter of the pulley of the second shaft.

DIMENSIONS OF BORING BARS AND JIG BUSHINGS.



Diameter of Finished Hole, Reamed	Diameter of Drill	Diameter of Rough Bore	Diameter of Finished Bore	Diameter of Boring Bar A	Diameter of Guide Bushing B	Diameter of Lining Bushing C
0.4375	3/8	0.420	0.430	0.3125	0.5625	0.750
0.500	7/16	0.485	0.495	0.375	0.625	0.875
0.5625	1/2	0.547	0.557	0.4375	0.750	1.000
0.625	9/16	0.610	0.620	0.500	0.875	1.125
0.6875	19/32	0.670	0.682	0.500	0.875	1.125
0.750	5/8	0.730	0.745	0.500	0.875	1.125
0.8125	11/16	0.790	0.807	0.625	1.000	1.250
0.875	3/4	0.855	0.870	0.625	1.000	1.250
0.9375	13/16	0.925	0.940	0.750	1.125	1.4375
1.000	7/8	0.975	0.993	0.750	1.125	1.4375
1.0625	15/16	1.040	1.055	0.8125	1.1875	1.500
1.125	1	1.100	1.118	0.875	1.3125	1.750
1.1875	1 1/16	1.160	1.180	0.9375	1.375	1.750
1.250	1 1/8	1.220	1.243	1.000	1.500	1.875
1.375	1 3/16	1.345	1.368	1.0625	1.500	1.875
1.500	1 5/16	1.470	1.493	1.125	1.625	2.000
1.625	1 7/16	1.595	1.618	1.250	1.8125	2.1875
1.750	1 9/16	1.720	1.743	1.3125	1.9375	2.375
1.875	1 5/8	1.840	1.867	1.375	2.125	2.625
2.000	1 3/4	1.980	1.992	1.500	2.250	2.750
2.250	2	2.210	2.242	1.750	2.500	3.000
2.500	2 3/16	2.460	2.492	2.000	2.750	3.250
2.750	2 3/8	2.710	2.742	2.125	3.000	3.625
3.000	2 5/8	2.960	2.992	2.375	3.375	4.125

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