MACHINERY'S REFERENCE SERIES

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NUMBER 31.

SCREW THREAD TOOLS AND GAGES.

CONTENTS

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CHAPTER I.

SCREW THREAD SYSTEMS.

Before entering upon the subject of screw thread tools and gages, we will shortly review the more common screw thread systems, giving the most important information regarding each, and will present such tables and formulas as give the basic information which the ordinary mechanic requires. While a great many more systems than are here reviewed. have been proposed from time to time, only those which have been officially recognized by mechanical men, or which have gained prestige on account of universal use and adoption, here or abroad, will be treated.

The United States Standard Thread.

The United States standard thread, usually denoted U. S. S., has a cross section as shown in Fig. 1. The sides of the thread form an angle of 60 degrees with one another. The top and bottom of the thread

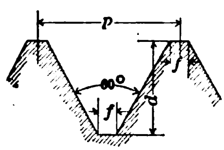


Fig. 1

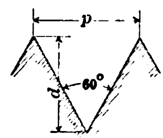


Fig. 2

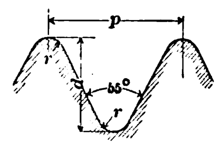


Fig. 3

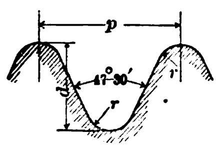


Fig. 4

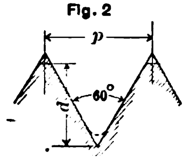


Fig. 5

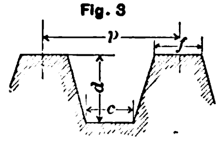


Fig. 6

Figs. 1 to 6. Standard Screw Threads.

are flattened, the width of the flat in both cases being equal to one-eighth of the pitch of the thread. In this connection it may be appropriate to define the expression pitch as well as lead, as these two expressions are very often confused, and the word pitch, in particular, often, though erroneously, used in place of "number of threads per inch." The pitch of a thread is the distance from center to center of two adjacent threads. It is equal to the reciprocal value of the number of threads per inch, or, if expressed in a formula:

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

The lead of a screw thread is the distance the screw will travel forward if turned around one complete revolution. It is evident that for a single threaded screw the pitch and the lead are equal. In a

double threaded screw, the lead equals two times the pitch, in a triple threaded, three times, etc. The definitions given for pitch and lead should be strictly adhered to, as great confusion is often caused by improper interpretation of the meaning of these terms. Confusion is also caused by indefinite designation of multiple thread screws. The most common way to state the lead and the class of thread is perhaps to say *¼ inch lead, double,* which means a screw with a double thread, which, when cut, has the lathe geared for four threads per inch, but each thread is cut only to a depth corresponding to eight threads per inch. The same condition is also expressed by: 4 *threads per inch, double.* These two ways of expressing the number of multiple threads are both correct, but the expression which ought to be used in order to avoid misunderstanding under any circumstances would be: *¼ lead, ⅛ pitch, double thread.*

Returning to the form of the U. S. S. thread, we find that if the thread is flattened one-eighth of the pitch at top and bottom, the depth

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		

of the thread is equal to three-quarters of the depth of a corresponding thread, sharp both at top and bottom. If p equals the pitch of the thread; d, the depth; and f the width of the flat, the following formulas express the relation between these quantities:

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

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

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

Formula for the Number of Threads in the United States Standard Thread System.

In order to fix definitely the number of threads per inch corresponding to any given diameter in the U. S. S. system, Mr. William Sellers, its originator, proposed the following approximate formula:

$$p = 0.24\sqrt{D + 0.625} - 0.175,$$

in which formula p equals the pitch of the thread for any bolt or screw of the diameter D.

This formula is applicable to all screws 1/4 inch and larger in diameter. For diameters below 1/4 inch the formula is modified so as to read:

$$p = 0.23 \sqrt{D + 0.625} - 0.175.$$

This modification, which has met with general acceptance, changing the coefficient 0.24 to 0.23, was proposed by Mr. George M. Bond in 1882. The purpose of the change was to make the formula applicable to screw threads for bolts smaller than one-quarter inch in diameter. Mr. Bond's formula tends to increase the number of threads more rapidly as the diameter decreases, a distinct advantage in the case of small screws.

It will be proper to remark in this connection that screws 11/16, 13/16 and 15/16 inch in diameter, which according to the formula given ought to have 10, 9 and 8 threads per inch, respectively, are in usual manufacturing practice made with 11, 10 and 9 threads per inch.

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		

The Sharp V-Thread.

The sharp V-thread, Fig. 2, is very similar to the U. S. S. thread, except that theoretically it is not provided with any flat, either at the top, nor at the bottom of the thread. In common practice, however, it has proved necessary to provide this thread with a slight flat on top of the thread. There are, unfortunately, some difficulties caused by providing a flat on the top of sharp V-threads, the principal one being that no definite standard for this flat has been settled upon. Some manufacturers have used the same flat as is used for the Briggs standard pipe thread, which, although theoretically rounded at top and bottom, is, in this country at least, made with a small flat on the top of the thread. The width of this flat is selected so as to give exactly the same angle diameter as is obtained when rounding the thread in accordance with Briggs' original proposition. This flat is equal to about one-twenty-fifth of the pitch.

If p equals the pitch of the thread; d, the depth; and f, the width of the flat on the top of the thread, the following formulas express the relation between the various quantities of the sharp V-thread:

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

$$d = p \times \cos 30° = 0.86603\,p.$$

$$f = \frac{p}{25}$$

Attention must be called to the fact that the formula for the width of the flat is selected simply to give an arbitrary value, which is *not* recognized as any *standard element* of the sharp V-thread. In figuring the depth of the thread, this flat is not considered, and the depth is arrived at as if the thread were exactly sharp.

Comparison Between the U. S. S. and the Sharp V-Thread.

The two standards referred to hitherto are the two forms of threads most commonly used in the United States. The objections to the sharp

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		

V-thread, as compared with the U. S. S. thread, are that the comparatively sharp points of the teeth are very frail; that the groove at the bottom of the thread, being sharp, facilitates fracture under strain; that the depth of the thread, being considerably greater than that of the U. S. S. thread, subtracts from the effective area at the root of the thread of the screw, thus impairing the tensile strength of the threaded bolt, and finally, that in case of taps, the sharp V-thread has less endurance and shorter life, and is capable of smaller duty, owing to the frail and easily worn away points of the thread. In spite of all this, however, the sharp V-thread will long continue to be in general use, primarily because it has so thoroughly established itself in the mechanical industries. This form of thread has also another very strong claim, because of being admirably adapted to the making of steam-tight joints. It answers this purpose best of all common forms of thread, and all patch bolt taps, boiler taps and staybolt taps are, as a rule, provided with sharp V-threads.

The Whitworth Standard Thread.

The Whitworth standard thread, Fig. 3, is used chiefly in Great Britain, but to a certain extent also in the United States. Its use here, however, has greatly diminished since the U. S. S. thread commenced to gain general approval. The Whitworth standard is the older one of the two, and was the first recognized screw thread system. In the Whitworth standard thread the sides of the thread form an angle of 55 degrees with one another. The top and the bottom of the thread are rounded to a radius determined by the depth of the thread, which is two-thirds of a thread with the same angle which were sharp at top and bottom. The radius at the top is the same as the radius at

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		

the bottom. If p and d equal the pitch and the depth of the thread, respectively, and r the radius at the top and bottom, then

$$d = \frac{2}{3} \times \frac{p}{2} \times \cot 27^\circ\ 30' = 0.64033\,p.$$

$$r = 0.1373\,p.$$

The advantages of the Whitworth thread are that screws with this form of thread have all the strength possessed by screws with U. S. S. threads, and at the same time have no sharp corners from which fractures may start. Screws and nuts with this form of thread will work well together after continued heavy service when other forms of thread would fail. Whitworth threads are used in the United States chiefly on special screws, such, for instance, as screws for gasoline needle valves, where a liquid-tight and yet working fit is desired. It is also often used for locomotive boiler staybolts. The objections to the Whitworth form of thread are that the angle of 55 degrees cannot be measured or simply laid out with ordinary tools, and that the rounded corners at the top and bottom cannot be produced with any degree of accuracy without great difficulty. The Whitworth standard screw system is denoted B. S. W. (British Standard Whitworth screw thread) in Great Britain.

British Standard Fine Screw Thread.

The British standard fine screw thread is a system of threads recently adopted in Great Britain. The form of the thread is the same as that for the Whitworth standard, but there is a greater number of threads per inch corresponding to a certain diameter than in the Whitworth system. The fine screw thread system is denoted B. S. F., and applies to screws ¼ inch in diameter and larger.

The pitches for the system of fine screw threads are based, approximately, on the formula:

$P = \frac{\sqrt[3]{d^2}}{10}$, for sizes up to and including one inch; and on the formula:

$P = \frac{\sqrt[8]{d^5}}{10}$, for sizes larger than one inch in diameter.

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

In the above formulas

P = pitch, or lead of single-threaded screw, and

d = diameter of screw.

This standard is not intended to make the regular Whitworth standard thread superfluous, but is simply supposed to offer a possibility of a standard fine screw thread for such purposes where the regular Whitworth standard would be too coarse.

British Association Standard Thread.

The British Association standard thread is the standard system for screws of small diameter in Great Britain. It is, however, hardly used at all in the United States, except in the manufacture of tools for the English market. The characteristics of the thread form are similar to those of the Whitworth thread, but the angle between the sides of the thread is only 47 degrees 30 minutes, and the radius at the top and bottom of the thread (see Fig. 4) is proportionally larger, depending upon that the depth of the thread is smaller in relation to the pitch than in the Whitworth standard thread. If p, d and r signify the pitch, the depth, and the radius at the top and bottom of the thread, respectively, then

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

The various sizes of screws in this system are numbered, and a certain number of threads per inch always corresponds to a certain given diameter. The system is founded on metric measurements. It was first originated in Switzerland as a standard for screws used in watch and clock making. This system is therefore also at times referred to as the Swiss small screw thread system.

Briggs Standard Pipe Thread.

The Briggs standard pipe thread is made with an angle of 60 degrees. It is slightly rounded off, both at the top and at the bottom, so that

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
1/8	0.405	27	1 1/2	1.900	11 1/2	5	5.563	8
1/4	0.540	18	2	2.375	11 1/2	6	6.625	8
3/8	0.675	18	2 1/2	2.875	8	7	7.625	8
1/2	0.840	14	3	3.500	8	8	8.625	8
3/4	1.050	14	3 1/2	4.000	8	9	9.688	8
1	1.315	11 1/2	4	4.500	8	10	10.750	8
1 1/4	1.660	11 1/2	4 1/2	5.000	8			

the depth of the thread, instead of being equal to the depth of the sharp V-thread (0.866 × pitch), is only four-fifths of the pitch, or equal to $\frac{0.8}{n}$, if n be the number of threads per inch. The difficulty of producing a thread with rounded top and bottom has, however, caused the manufacturers in this country to modify the original standard. Instead of rounding the bottom of the thread, it is made sharp as shown in Fig. 5. The top is slightly flattened instead of rounded, the flat being carried down just far enough to tangent the top circle of the correct thread form. This thread, as indicated by the name, is used for pipe joints and for many purposes in locomotive boiler work. Taps for producing Briggs standard pipe thread are provided with a taper of 3/4 inch per foot on the diameter.

Whitworth Standard Thread for Gas and Water Piping.

The form of the Whitworth standard thread for gas and water piping is simply the regular Whitworth thread form, and the only difference from the regular Whitworth standard is the number of threads per inch. Most American manufacturers of taps, when making what is called English pipe taps, use the Whitworth form of thread

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			

and the number of threads according to the Whitworth pipe thread system, but make the dimensions for the taps the same as for the Briggs standard in all respects. The taper is also made the same as for the Briggs standard, or ¾ inch per foot.

Square Thread.

The square form of thread is usually made about twice as coarse in pitch as the V or U. S. S. threads, and partly for this reason and partly because of the perpendicular sides of the thread, it is a troublesome thread to cut with taps and dies. There is no standard for the number of threads corresponding to a certain diameter. The depth of the thread is equal to the width of space between the teeth, this space being equal to one-half of the pitch. While theoretically the space between the teeth is equal to the thickness of the tooth, each being one-half of the pitch, it is evident that the thickness of the tooth must be enough smaller than the space to admit at least an easy sliding fit.

The Acme Thread.

The Acme thread, shown in Fig. 6, has of late become widely used, having in most instances taken the place of the square thread on ac-

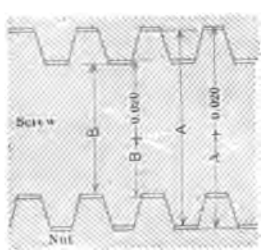


Fig. 7. Acme Standard Screw and Nut.

count of its better wearing qualities, and the comparative ease with which this thread can be produced. Of all standard thread systems the

Acme thread is the only one which has a standard provision for clearance at the top and bottom of the thread. The screw is made of standard diameter, but the nut is made over-size. The relationship between screw and nut is illustrated in Fig. 7. If the diameter of the screw is *A* over the top of the thread, and *B* at the foot of the thread, the corresponding diameters of the nut are $A + 0.020$ and $B + 0.020$ inch. The sides of the thread form an angle of 29 degrees with one another. Considering the screw only, if p is the pitch; d, the depth of the thread; f, the width of the flat at the top of the thread; and c, the width of the flat at the bottom of the thread, then:

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

$$f = 0.3707\,p,$$

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

The Acme thread has many good points, not the least of which is its strength, and the ease with which it may be cut compared with

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

the square thread. This thread is recommended as a substitute for, and to be used in preference to, the square form of thread.

French and International Standard Threads.

The French and international standard threads are of the same form as the U. S. standard, and the formulas given for the latter form of thread apply to the former. The pitches, however, are stated in the metric measure, and are somewhat finer for corresponding diameters than the U. S. S. thread. This is a distinct advantage, especially in the smaller sizes. The standard thread of the international system is denoted S. I. and was adopted by the International Congress for the unifying of screw threads held in Zürich, 1898. This system conforms with slight variations with the system earlier adopted in France, the French standard thread, denoted S. F. In order to provide for clearance at the bottom of the thread in the nut, the congress referred to above specified that the clearance at the bottom of the thread shall not exceed 1/16 of the height of the original triangle. The shape of the bottom of the thread resulting from such clearance is left to the manufacturers. However, the congress recommends rounded profile for said bottom. By this provision choice is given to

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				

the manufacturers to make the bottoms of their threads flat or rounded as desired, and yet have them conform to an interchangeable standard.

Instrument-maker's System.

The standard screw system of The Royal Microscopical Society of London, England, is employed for microscope objectives and the nose pieces of the microscope into which these objectives screw. The form of thread is the Whitworth form, the diameter of the male gage is 0.7626 inch. The number of threads per inch is 36.

Machine Screw Threads.

The American Society of Mechanical Engineers has adopted a standard system of machine screw threads, which undoubtedly will, before long, become the general standard for small diameter screws. Considerable care was taken in determining this standard, in order to settle the questions involved so as to meet the requirements of both the makers of taps and screws, and the users. The basic form of the thread is that of the U. S. standard thread.

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

Lag Screw Threads.

There is no recognized standard for the sizes and corresponding number of threads for lag screws. The following table, however, gives the number of threads according to common practice. While lag screws are largely made according to these systems, there are, however, a number of different systems in use.

LAG SCREW THREAD SYSTEMS IN COMMON USE.

Diameter	Alternate Systems: Threads per Inch	Alternate Systems: Threads per Inch	Diameter	Alternate Systems: Threads per Inch	Alternate Systems: Threads per Inch	Diameter	Alternate Systems: Threads per Inch	Alternate Systems: 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			

Gas Fixture Threads.

Thin brass tubing is threaded with 27 threads per inch, irrespective of diameter. The so-called ornament brass sizes have 32 threads per inch. The standard diameters of the thread are 0.196 inch (large ornament brass size) and 0.148 inch (small ornament brass size).

Fine Screw Thread Systems.

We have previously referred to the British fine screw thread system recently adopted. There is a demand for the adoption in this country of a standard system with a U. S. S. form of thread but with a finer pitch than called for by this standard. The Association of Licensed Automobile Manufacturers has adopted such a standard, but it is, of course, not universally recognized. The objection to the adoption of a standard by a single body of manufacturers is obvious. Even if the standard is one which would recommend itself to general use, it would be better if the opinion and the needs of machine builders in general were considered. On the other hand it may be said in defense of the adopted system that automobile construction is so specialized a manufacture that here doubtless may arise requirements which would not present themselves elsewhere.

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
1/4	28	7/16	20	5/8	18	7/8	14
5/16	24	1/2	20	11/16	16	1	14
3/8	24	9/16	18	3/4	16		

CHAPTER II.

MAKING THREAD TOOLS.

The chief requisites for cutting a correct thread are a correct threading tool, a correct setting of the tool, and a lathe with a reasonably accurate leadscrew. In making a U. S. thread tool a correct 60-degree angle gage is necessary. To produce such a gage, first plane up a piece of steel in the shape of an equilateral triangle as shown at *a* in Fig. 8. After hardening this triangle, grind and lap the edges until the three corner angles prove to be exactly alike when measured with a protractor. This is now the master gage. To produce the female

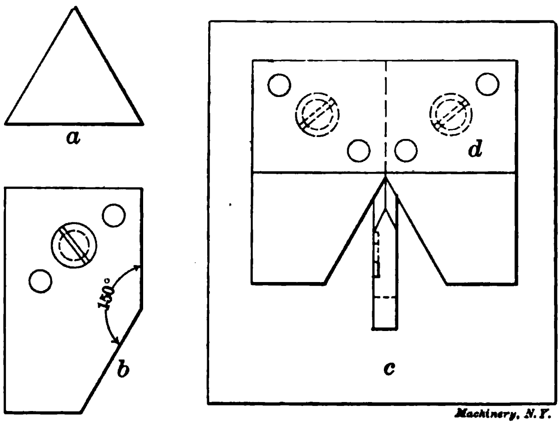


Fig. 8. Gages for Making Threading Tools.

gage, make two pieces, one right- and one left-hand, like that shown at *b* in Fig. 8; harden them and lap the edges that form the 150-degree angle so that they are straight, and square with both sides. When this is done the two pieces should be screwed and doweled to a backing plate *d* as shown, using the master triangle to locate them, thus producing a practically perfect female gage.

In making up the tool, some form of cutter to be used in a holder should be chosen in preference to a forged tool on account of convenience in handling and measuring and the ease with which it may be re-ground without destroying the shape. The tool should be made so that the top will stand level when in the holder, and the clearance should be about 15 degrees, which is ample for a single thread unless the pitch is very coarse. With that amount of clearance the included angle between the sides of the tool in a plane perpendicular to the front edge is approximately 61 degrees 44 minutes. The tool should be planed to that angle as nearly as is possible by measuring with a protractor, then, to test its accuracy, it should be placed top down on a flat piece of glass *c* and tried with the 60-degree gage as shown in Fig. 8. After lapping the tool until it shuts out the light when tried in this manner, the angle may be considered as nearly correct as it is possible to obtain with ordinary means. To adapt the V-thread tool thus made to cut the United States standard form of thread, it is only necessary to grind off the sharp edge an amount equal to one-eighth of the depth of a V-thread of the required pitch, or for 20 threads per inch $\frac{0.866}{20} \times \frac{1}{8} = 0.0054$ inch. To test the accuracy of this grinding, a piece of steel should be turned up to the correct outside diameter and a short shoulder turned down at the end to the correct diameter at the bottom of the thread; then the piece is threaded and the tool fed in until the flat of the tool just tangents the shoulder. Then cut a nick in the edge of a piece of sheet steel with the threading

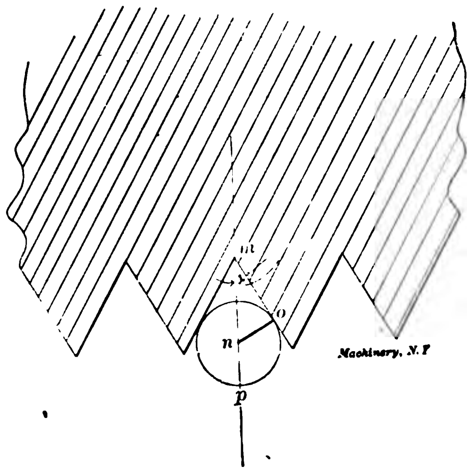


Fig. 9. Measuring the Angle Diameter of a Thread.

tool. This sheet steel piece is now applied like a gage to the threaded cylindrical piece. If the nick in the sheet steel fits the thread so that it shuts out the light the flat of the tool is correct.

In preparing a plug gage for threading it should be made the same as the cylindrical test piece above with a part turned down to the root diameter of the thread except that for V-thread it is customary to leave the shoulder 0.005 inch large on account of the impossibility of producing a perfectly sharp point on the tool. The thread tool should be set level, with the top at the same height as the center line of the spindle of the lathe, otherwise the correct angle will not be reproduced. After a master plug has once been produced, it is not necessary to turn down a portion to the root diameter of the thread, as the work may be compared with the master plug by means of a micrometer fitted with either ball or V points for measuring in the angle of the thread.

It occasionally happens that a tap is to be threaded, or other external threading is to be done, of an odd size or pitch. Where it is desired to originate a master plug in such cases, three wires may be used for measuring the angle of the thread, placing one wire in the angle of the thread on one side of the piece and the other two on the opposite side, one on each side of the corresponding thread, measuring over the whole with a micrometer. The formula for the micrometer reading is obtained as follows: In Fig. 9, assume that *m* is the bottom of a V-thread, the circle showing one wire in place. Then angle $a = 30$ degrees; sin 30 deg. $= 0.5$; $\frac{no}{0.5} = mn$ or $2no = mn$. As *no* and *np* are radii of the same circle, it follows that $mp = 3no = 1\frac{1}{2} \times$ diameter of wire. Multiplying by 2 to add a length *mp* for the opposite side gives $2mp = 3 \times$ diameter of wire. Hence for V-thread,

$$\text{Diameter of screw} - \frac{1.732}{\text{No. thds. per in.}} + (3 \times \text{diameter of wire used})$$

$=$ micrometer reading.

For U. S. form we have to take into account the flat at the bottom of the thread, so instead of using the U. S. constant 1.299 we add to it $\frac{1}{8}$ of 1.732, or 0.2165, giving as a constant 1.5155, making the formula:

$$\text{Diameter of screw} - \frac{1.5155}{\text{No. thds. per in.}} + (3 \times \text{diameter of wire used})$$

$=$ micrometer reading.

The subject of measuring threads with the wire system is more completely treated in Chapter V.

Thread Tools for Threads with Rounded Top and Bottom.

While the development of a correct United States or V-thread tool is a thing requiring a great deal of skill and patience, it is easy compared to the task of producing a tool for the round top and bottom thread, of which the Whitworth and British Association standards are the leading examples. In testing for accuracy, threads of this type are not only measured by gages and micrometers, but the curves must match the angle so evenly that when the male gage is tried in the female from either end, no difference can be detected. The difficulty attending this will be the better appreciated when it is known that some of the leading tap and die manufacturers of this country and Europe have failed in producing threads that would pass the British government's inspection.

It may be laid down as a cardinal principle that the best results are obtained by developing the form first with a flat top and bottom as in the U. S. thread, rounding the corners afterward. The first step of all is to produce a correct angle gage; assuming that we are to work out the Whitworth thread, this would be a gage measuring 55 degrees. Make and harden a steel triangle *A*, Fig. 10, with the angle *x* made as near 55 degrees as is possible by using a bevel protractor; the other two angles are to be equal. Then make an angle iron *B*, making sure that *ab* and *cd* are parallel, and that *be* is square with *ab*. Assuming that *C* and *D* are accurate 2-inch and ½-inch plugs, we put in the pins *EE* in such a position that a line drawn through the centers of *C* and *D*, at right angles to their axes, will make an angle of 27½ degrees with *ab*. This can be done by figuring the distance *fg* as follows: In the triangle *lhk*, $hk = 1 - 0.25 = 0.75$ inch.

$$lk = \frac{0.75}{\tan 27\frac{1}{2}\text{ deg.}} = \frac{0.75}{0.5206} = 1.4406 \text{ inch.}$$

$$1.4406 + \tfrac{1}{2} \text{ diameter of } C - \tfrac{1}{2} \text{ diameter of } D =$$
$$1.4406 + 1 - 0.25 = 2.1906 \text{ inch} = fg.$$

Set the pin *F* near enough to *D* to keep the corner of the triangle from striking the angle iron *B*. Mount the triangle *A* as shown, and set up the fixture on a surface grinder table using a toe strap in the small hole in *A* to hold it in position, and grind first one edge, and then the other. This gives us the male angle gage. A female gage can be made to this by the method described previously for U. S. thread gages.

The tools to be used in making thread tool (see Fig. 11) include:

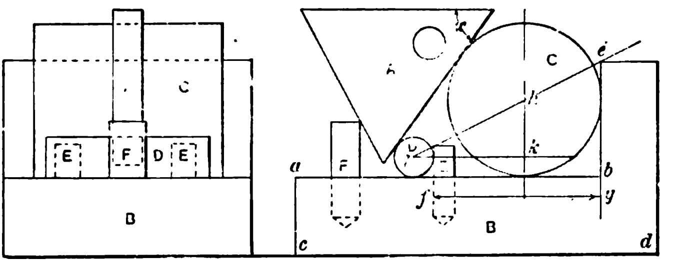


Fig. 10. Method Employed for Obtaining 55 Degree Angular Gage.

an angular tool with a flat point, the width of the point to be such that it reaches to the center of the round in the bottom of the thread, the angle of the tool matching the gage previously made; a female radius tool for forming the point; and a male radius tool for the side radii. For convenience in measuring and getting the exact form required, these tcols should be made with the top square with the face at the cutting edge, *i. e.*, without clearance. The sides and back of all should be ground as well as the top. The tool *a* can be ground by means of an angular block made in the same manner as the male angle gage and should be finished by lapping. The tool *b* can be made in two pieces, one a hardened, ground, and lapped wire, and the other a soft piece made up in such shape that the wire can be soldered or otherwise firmly fastened to it in the correct position. The tool *c* should be made up first as at *c′* and hardened. Then lap the hole carefully to size and grind the outside. After measuring the distance from the hole to the back of the tool, the front can be ground off to *ef* and the bevels ground until the depth of the round part is right.

We now require a shaper with an apron made up to hold the tool-holder at an angle of 15 degrees, as shown in Fig. 12. The apron should fit the clapper-box perfectly. If it does not, it is better to fasten it solid, and let the tools drag back through the cut, sharpening the tools over again before finishing; otherwise, one runs the risk of side shake. With this angular apron we can use the tools made without clearance to produce a tool with correct clearance for the lathe. Two thread tool blanks, one, *a*, of tool steel, and one, *b*, of machine steel, should be set up on the table adapter as shown in the cut with spacing parallels between to avoid interfering with one while planing the other. The blanks should be planed off to exactly the same height, and all measurements for height should be figured from the line *cd*, allowance being made for the difference caused by the 15-degree clearance. Then, after measuring the tools previously made carefully, to determine where the exact center is, we can start forming the blanks, setting the tools sidewise successively by positive measurement from the rib of the adapter. The angular tool comes first and with it we plane down the sides of the tool *a* and the center of *b* so that the point of the tool just reaches the center of the radius. Then using the female radius tool we round the point of *a* and the two points of *b*, coming down until the circle of the tool is just tangent to

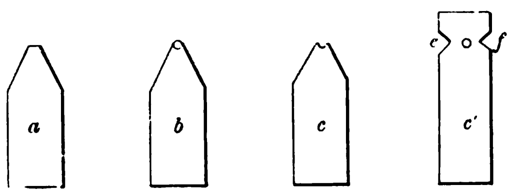


Fig. 11. Tools used for making Whitworth Thread Tools.

the top of the blanks. The male tool will round out the two lower corners of *a* and the center of *b*, being fed down to exact depth.

We now have the thread tool *a*, which can be hardened, and the machine steel blank used as a lap to correct errors in it, reversing the lap occasionally, and using oilstone powder or other fine abrasive as the cutting medium. Great care must be used in putting on the abrasive, as in all lapping operations of this kind points and corners are apt to lap faster than wide surfaces. This operation does not really correct the tool, but equalizes the errors due to imperfect matching of the different cuts, and it can be done so effectively that whatever errors of that kind are left cannot be detected.

To test the tool, turn up a blank plug with a teat equal to the diameter at the bottom of the thread. When this is threaded, the point of the tool should touch the teat just when the outer corners touch the top of the thread. In the angle, the thread should measure by wires, as explained in connection with the U. S. S. thread tool, according to the formula:

$$\text{Diameter of screw} - \frac{1.6008}{\text{No. threads per in.}} + (3.1659 \times \text{diameter of wire used}) = \text{micrometer reading.}$$

For the final test of the fit of the curves with the angle, a tap must be threaded with the tool, and a female gage tapped with the tap. The plug just made must screw into this with an equal amount of friction from either end, and show a full contact on the thread. If this last test is not successful it shows that the lapping is not good enough and must be done over. If the plug does not measure right, it is necessary to go back to the planing and plane up another tool, making such

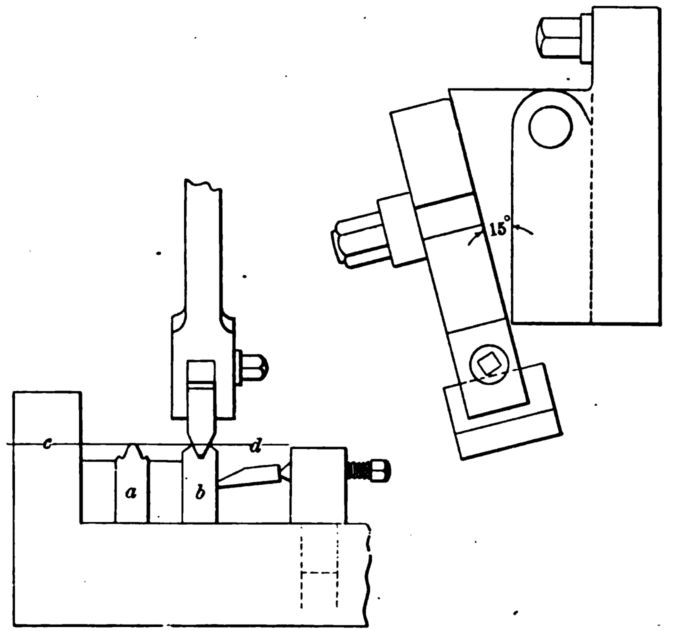


Fig. 12. Method of Planing Whitworth Thread Tools.

allowances as one judges will correct the error. It is sometimes necessary to do this several times before a perfect tool is produced. In the use of the tool in the lathe, great care is necessary to see that it is set at the center of the spindle, and so that the two side curves will scrape the top of the thread at the same time. With the exception of making the angle gage and tool grinding block, this whole procedure has to be carried out for every pitch required.

CHAPTER III.

TOOLS FOR ACCURATE THREAD CUTTING.

Accurate thread cutting seems to be one of the trade secrets which is not easily mastered or often found described in books. The author has seen and done considerable of this work, and although the methods may not be wholly new, they will, no doubt, be of interest to many. The method of making thread chasers, described in the following, was employed by the Pratt & Whitney Co. several years ago, and the table on page 21 and the hob and fixture for grinding the chasers are original with the author. That old saying "Patience is a virtue," is well recognized when doing this class of work. What can be more exasperating than to have a thread tool tear when on the finishing

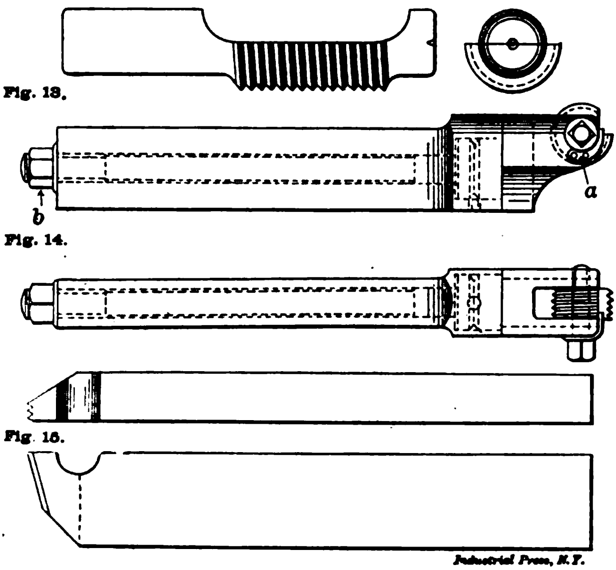


Fig. 13.

Fig. 14.

Fig. 15.

Industrial Press, N.Y.

Figs. 13 to 15. Hobs and Chasers for making Accurate Thread Tools.

cut, or, having made a nice plug and ring gage, to have the ring contract and the plug expand in length when they are hardened? There are a great many such difficulties in the path of the thread gage and tap maker. That one little item, of the thread tool tearing the threads is greatly, if not wholly, overcome by adopting a chaser in place of a single thread tool, as the chaser has three to five threads which tend to keep it from tearing into the work. The chaser is also far superior for cutting U. S. standard threads, as the flat top and bottom are sure to be perfect and can always be held to a standard with the aid of a master hob.

To make a chaser accurately seems at first difficult, but is quite simple when properly understood. The first thing is to make the hob, which is shown in Fig. 13. This requires great care as upon it depend all the tools of that certain pitch. The hobs are all made one-inch

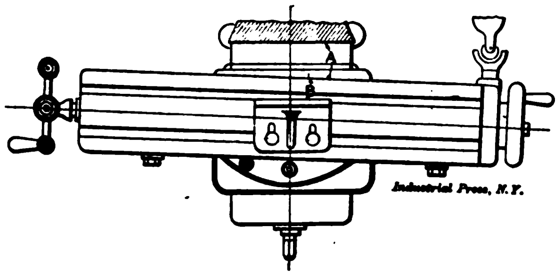


Fig. 16.

Threads per inch	Angle B in Degrees and Minutes.																Angle A	
	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg	Min.	Deg	Min.	Deg.	Min	Deg.	Min.	Deg	Min.
8	..	....	..	....	3	02	2	17	1	49	1	31	1	18	1	08	2	17
10	..	....	3	38	2	26	1	49	1	27	1	13	1	02	..	55	1	49
12	..	....	3	02	2	01	1	31	1	18	1	00	..	52	..	46	1	31
14	..	....	2	36	1	44	1	18	1	01	..	52	..	44	..	39	1	18
16	..	....	2	17	1	31	1	08	..	55	..	46	..	39	..	34	1	08
18	..	....	2	02	1	21	1	00	..	49	..	40	..	35	..	30	1	00
20	3	38	1	49	1	13	..	55	..	44	..	37	..	31	..	27	..	55
22	3	19	1	39	1	06	..	50	..	40	..	33	..	28	..	25	..	50
24	3	02	1	31	1	00	..	46	..	37	..	30	..	26	..	23	..	46
26	2	48	1	24	..	56	..	42	..	34	..	28	..	24	..	21	..	42
28	2	36	1	18	..	52	..	39	..	31	..	26	..	22	..	19	..	39
30	2	27	1	13	..	49	..	37	..	29	..	24	..	21	..	18	..	37
32	2	17	1	08	..	46	..	34	..	27	..	23	..	19	..	17	..	34
36	2	02	1	00	..	40	..	30	..	24	..	20	..	17	..	15	..	30
40	1	49	..	55	..	37	..	27	..	22	..	18	..	16	..	14	..	27
48	1	31	..	46	..	30	..	23	..	18	..	15	..	13	..	12	..	23
56	1	18	..	39	..	26	..	19	..	16	..	13	..	11	..	10	..	19
64	1	08	..	34	..	23	..	17	..	14	..	12	..	10	..	08	..	17
80	..	55	..	27	..	18	..	14	..	11	..	09	..	08	..	07	..	14
100	..	44	..	22	..	15	..	11	..	09	..	07	..	06	..	05	..	11
	¼″		½″		¾″		1″		1¼″		1½″		1¾″		2″			
	Diameter on which chaser is to be used.																	

NOTE.—All hobs to be 1 inch in diameter right-hand thread. Clearance on chasers, 15 degrees.

in diameter, this size having been adopted so that the angles in the table above could be determined and tabulated. To accurately cut the hob, the tool shown in Fig. 14 is utilized. This consists of a small circular thread chaser held in the body of the tool, the forward part of which is made separate from the shank so that it can be swiveled to suit the angle of the thread on the hob. A small piece of steel, *a*, serves as a gage for the cutting face of the circular chaser, so that it can be sharpened and re-set in the holder without disturbing the body of the tool. The nut *b*, on the end of the holder, serves to hold the forward part of the tool securely. After the hob is threaded, it is milled out (as shown in Fig. 13) to its center line and then hardened. The object in milling it in this manner is that it can be easily sharpened by grinding across the face, and this face is also utilized when setting the hob to its proper angle in the milling machine.

The sharpening of the hob is accomplished with the special fixture shown in Fig. 17, which is simple in design, and is made for use on a surface grinder where it is located so that its centers are at right angles with the emery wheel. The most essential point in grinding a hob of this description is to always grind the cutting face radially, in other words, the lower edge of the emery wheel must be in line

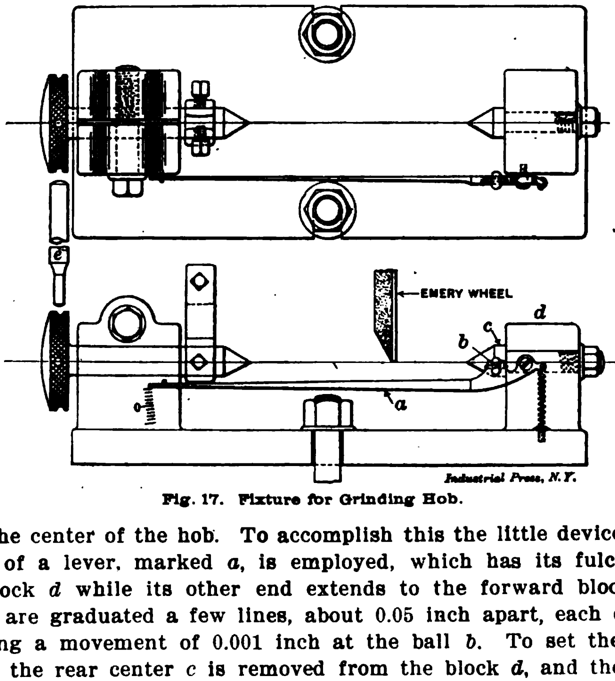


Fig. 17. Fixture for Grinding Hob.

with the center of the hob. To accomplish this the little device in the shape of a lever, marked *a*, is employed, which has its fulcrum on the block *d* while its other end extends to the forward block upon which are graduated a few lines, about 0.05 inch apart, each division equaling a movement of 0.001 inch at the ball *b*. To set the emery wheel, the rear center *c* is removed from the block *d*, and the emery wheel, at rest, is brought down onto the ball *b*. The table of the grinder is run to and fro by hand so that the wheel will pass over the ball; when it forces down the lever so that it registers at zero, this denotes that the lower edge of the wheel is in alignment with the centers of the fixture. The center *c* is then put back in position and the hob, held by a dog, is placed between the centers and sharpened. At no time during grinding is the perpendicular adjustment of the wheel altered.

The hob being completed, the next step is to make, by use of the hob, the chaser shown in Fig. 15. This is made of tool steel, hand forged, and planed on all sides. It has a cutting clearance of 15 degrees and is placed against an angle iron which, in turn, is held on a milling machine table. The hob is held between the centers of the machine spindle and the overhanging arm, as shown in Fig. 18, and when the cutting edge of the hob is accurately located, the spindle is locked in position by means of a wooden wedge which is tapped in between the cone and the frame of the machine. The cutting face of the hob and the body of the chaser stand in a straight line and at an angle of 15 degrees with the table of the machine, as shown in Fig. 19. The most essential point in setting up the machine for this job is to

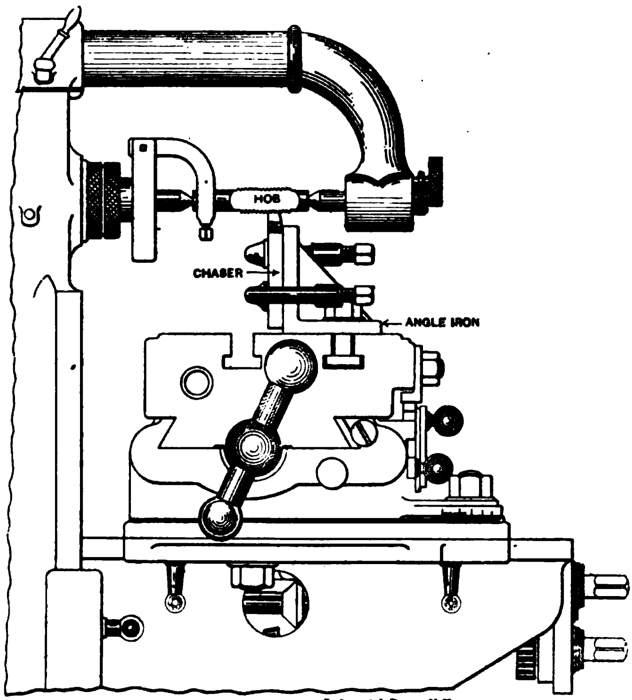


Fig. 18. Milling Machine Arranged for Hobbing Chasers.

get the angle iron located on the table of the machine at the proper angle for the threads to be shaped on the chaser, as a chaser made for use on a ½-inch tap will not work properly on a 2-inch tap of the same pitch, because the angle of the thread is greater on the former than on the latter. The milling machine table must also be swiveled around to the proper angle of the thread on the hob, as the longitudinal movement of the table must correspond to the thread angle. For this purpose we use the table on page 21. The plan view, Fig. 16, shown at the head of this table will serve to illustrate the use of same. This is a plan of the milling machine table, showing it swiveled around, and also the angle iron set in the proper position. As will be seen, the table sets at an angle *A*, which is given in degrees and minutes in the right-hand column of the table, while the angle iron is placed on the table of the machine, making with the edge of the table the angle *B*. This is the proper angle for the threads on the chaser. Should it be desired to make a left-hand thread chaser, the angle iron would be placed at the same angle called for by the table, but in the opposite direction.

As an example, we will suppose that it is desired to make a chaser that is to be used in making taps ½ inch in diameter having 26 threads

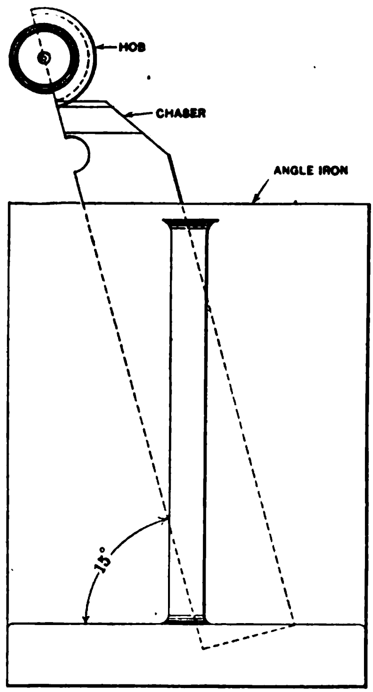


Fig. 19. Hob and Chaser in Position for Hobbing.

per inch. We first look in the "threads per inch" column until we come to 26, then by following along the line we come to the last column, which gives us the angle at which the milling machine table is to be set, or the angle *A*, which equals 0 degree and 42 minutes. On the lower edge of the table are the diameters on which the chasers are to be used, and as in this case this is ½ inch, we follow up that column to the 26 threads per inch line, where we obtain the angle at which the angle iron is to be located on the table of the machine, or angle *B*, which in this case is 1 degree and 24 minutes. The machine being properly set, it is a small matter to shape the thread by moving the table to and fro, gradually feeding it upward until a perfect thread is obtained on the chaser. It is advisable to keep the hob well lubricated when cutting to insure a smooth thread on the chaser. A very good lubricant for this purpose is a mixture of one-half turpentine with one-half good lard oil. This will also be found an excellent lubricant for general thread cutting in the lathe.

Another style of chaser which has proved itself very useful may be

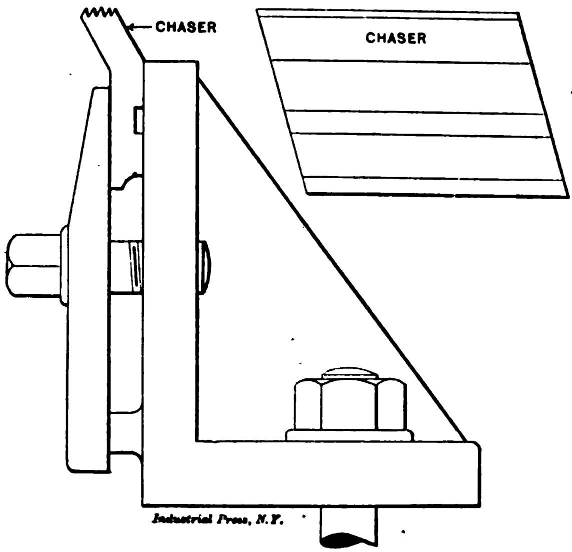


Fig. 20. Fixture for Hobbing Chaser for Pratt & Whitney Thread Tool Holder.

worthy of notice. This is what is known as the Pratt & Whitney chaser, which is shown in Fig. 20. It is made separate from the body of the tool-holder, in the angle iron shown in the same figure. For inside thread cutting, the two tools shown in Fig. 21 can be used very handily. The one marked *a* is for large inside diameters and is composed of a tube through which runs a rod, threaded on each of its ends. Upon the front end is screwed a circular chaser which is held firmly against the tube by a nut on the other end of the rod. This

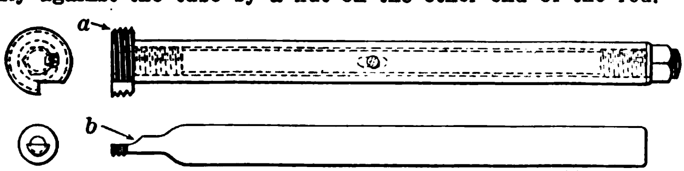


Fig. 21. Chasers for Internal Threads.

makes a very handy device when chasers have to be changed, for by loosening the nut on the end, the chaser can be easily removed with the fingers. The solid chaser, *b*, shown in same figure, is for use in holes of small diameter, one-half of the threaded part being milled off. When sharpening this chaser, care must be taken to always grind the face radially in order to insure accurate results.

CHAPTER IV.

MAKING THREAD GAGES.

It appears to be the general idea that screw plug gages must be made of tool steel, but it has been found very practical to make them of cold rolled stock, which is very soft and easy to cut, but which, when hardened, gives a surface which is fully as hard as tool steel. This hard surface extends deep enough into the thread gage to permit grinding 0.005 inch deep, enough hard surface still remaining to prevent rapid wear when in use. Another reason for using this soft steel is also that it is not likely to change its shape after having been finished, the same as does even the best tool steel, if it has not been properly seasoned after hardening.

For setting a thread tool for cutting a correct thread, a cylindrical thread gage is made, as shown in Fig. 26. This thread gage has the advantage over the ordinary thread gage on the market, that it can be placed between the centers of the lathe, and consequently one does not depend upon any secondary surface against which to set the thread gage. This is the case with the ordinary thread gages, which have to be lined up either against the side of the face-plate of the lathe, or against the side of the work, and in this way small errors are almost always introduced. The thread gage in Fig. 26 is made of machine steel, hardened and ground all over. The main body, *A*, is provided with three grooves, having an inclusive angle of 29, 55, and 60 degrees, respectively, to correspond with the Acme, Whitworth and United States Standard threads, respectively. When the gage is hardened, the two sides of the grooves are ground with the same setting of the slide-rest, the piece *A* being reversed on the lathe centers while grinding. This insures that both sides of the angle in the gage make the same angle with the axis of the gage.

In one end of the body *A* a hole is drilled; this is ground until the bottom of the hole comes exactly in line with the axis or center line of the body *A*. A hardened and lapped plug *B* is inserted into this hole and held with a set-screw, having a brass shoe at the end. The purpose of this plug *B* is to afford a means for setting the thread tool in the lathe at the correct height, or, which is the same, exactly in line with the axis of the spindle. This is done by merely loosening the clamp which holds the thread tool in its holder; then with the thumb of the left hand on the plug *B*, and the forefinger on the thread tool, it is brought instantly in position, so that the upper face of the thread tool touches the lower side of the plug *B*, as shown in the end view of Fig. 26. When in this position, the clamp of the thread tool-holder is again tightened, and the tool is now placed in the correct position

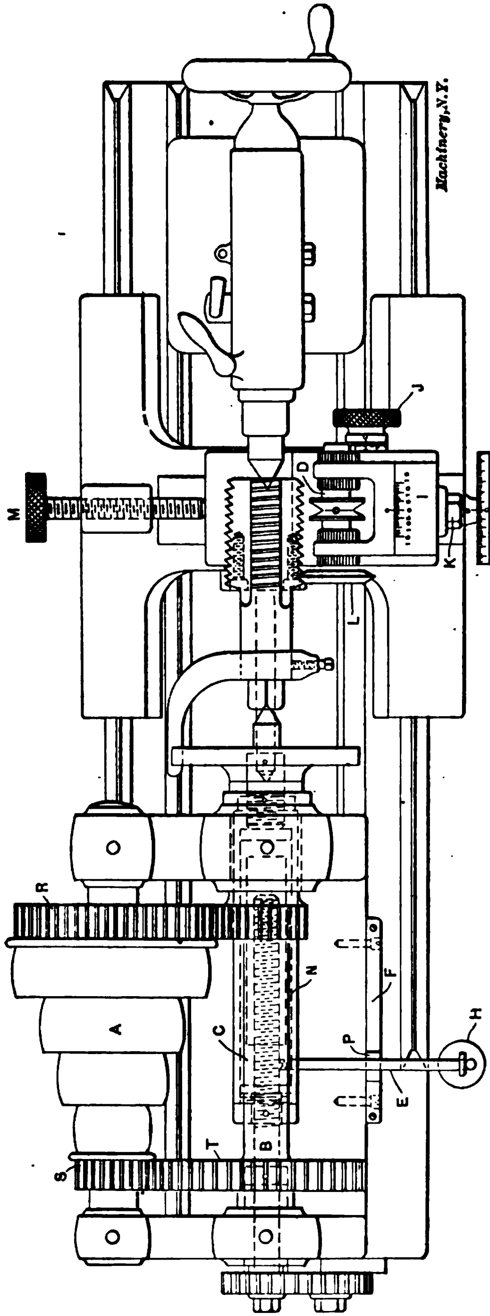


Fig. 22. Lathe for Grinding Taps in the Angle of the Thread.

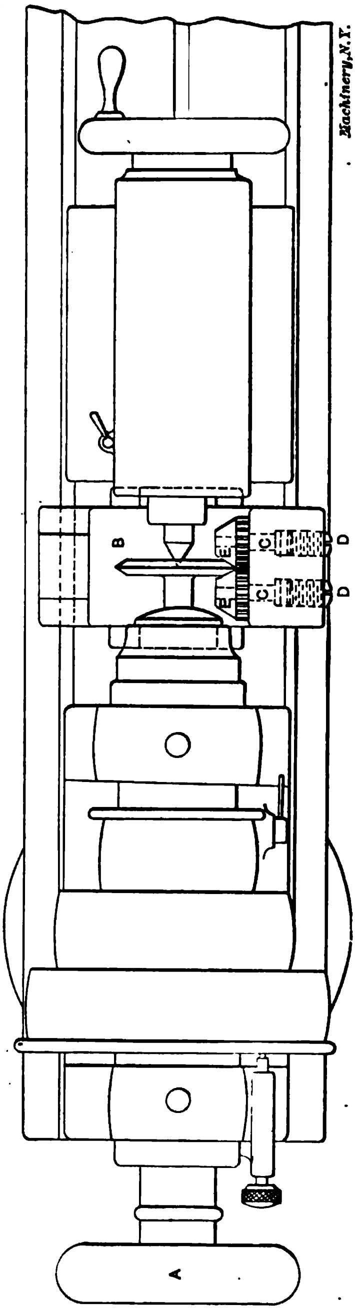


Fig. 23. Bench Lathe with Fixture for Charging Diamond Lap.

as to height. This is a good way of setting the thread tool to the same height as the axis of the lathe centers. This method of setting of the thread tool to height does not necessarily, however, insure that the thread tool in all cases will be set absolutely correct. If the thread tool-holder should be tipped somewhat out of the horizontal position, the top of the thread tool itself would not be horizontal, and consequently, when the gage pin *B* was brought down upon the top of the thread tool, so that the top face would lie perfectly in line with the lower face of gage pin *B*, this pin would not be fully horizontal, and the thread tool would not be set to the exact height of the lathe centers.

With the gage remaining between the lathe centers, the angle of the thread tool is set to a correct central position, sideways. This setting is also a check on the accuracy of the angle of the thread tool. A piece of white paper should be used under the gage and the tool, and a magnifying glass should be employed. First when the tool fits the gage so that all light is shut off, may the setting and the angle be

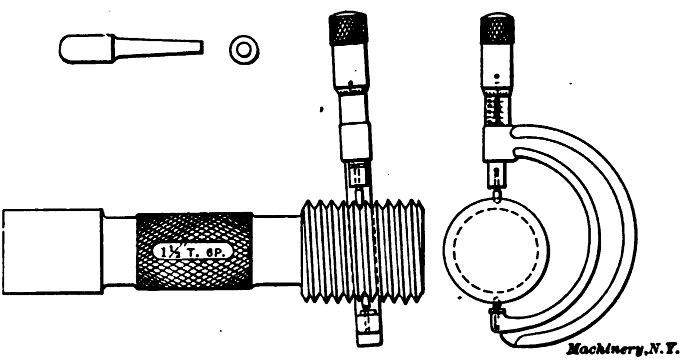


Fig. 24. Comparing Angle Diameters with Ball Point Micrometer.

considered satisfactory. The thread tool being set, we are now ready to proceed to finish thread our screw plug gage, which has previously been roughed out by a chaser having three or four teeth, leaving about 0.005 inch for the finishing single point thread tool. The finishing of the thread is continued until 0.0015 inch is left for lapping. The chaser, as well as the single point tool, should have a clearance of 15 degrees on the front face of the thread tool. This angle has proved to be the most advantageous for all practical purposes.

After having been finish threaded, the screw plug is case-hardened and ready for lapping. A lap made as shown in Fig. 27 is used. It will be seen that this lap is somewhat different from those ordinarily used for this work. The construction shown has been adopted because of the difficulty met with in circular laps which are split on one side for adjustment, but have nothing on the sides to hold the two sections in perfect alignment. Consequently, each of the sides has a tendency to follow the lead of the screw plug when lapping, and difficulty is experienced in getting a thread with perfect lead. The lap here shown, therefore, has a dowel pin *A* on each side for the purpose of holding the two sections in perfect alignment, and the adjusting screws *C* are inserted outside of the dowel pins. The two screws *B*, finally, clamp the two halves together. When the lap is assembled and screwed together, it is roughed out in the lathe with a threading tool, or tapped with three or four different sized taps, following one another in proper rotation. The lap is then taken apart, and planed on the inside to permit of adjustment; three grooves are cut in the thread on each side of the lap, for holding reserves of emery and oil. This will permit constant lubrication of the lap, and constant charging when lapping the screw plug to size. The lap is finished with a master tap, which must be made with extreme accuracy. This tap is ground in the angle of the thread, as shown in Fig. 22, and it is finished to a dimension 0.002 inch below the size diameter of the thread plug to be made, in order to permit the lap to wear down to the size when lapping.

The lathe must be revolved very slowly when grinding the master

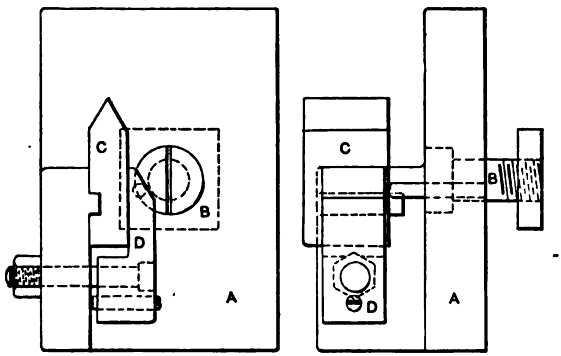


Fig. 25. Gage for Testing the Angle of the Thread.

tap, the revolutions of the spindle being from 20 to 100 per minute, according to the size of the tap. As will be seen in the cut, the cone pulley is placed where the back gears ordinarily are located. Gear *R* is disconnected, and the drive is through gears *S* and *T*. The reason for having the cone pulley in the back, is because it is wanted to use the space directly under the usual location of the cone pulley in the center of the lathe for a mechanism intended to permit a slight adjustment of the lead of the tap when grinding in the angle of the thread.

The feed screw *B* is placed in the center of the lathe bed, directly under the driving spindle, and fits into a solid nut, *C*, from which, through the medium of a casing *N* and a connecting-rod, the carriage is moved. A rod *E* is screwed into the nut *C*, this rod extending over the side of the lathe, and resting upon the edge of plate *F*, which can be so adjusted that it inclines from one end to the other from 0 to 20 degrees. Between this plate and the rod *E*, a shoe *P* is placed. On the extreme end of the rod hangs a weight *H* which holds the rod against the plate *F*. This arrangement serves the purpose of giving a slight change in the lead of the tap being ground, as it is evident

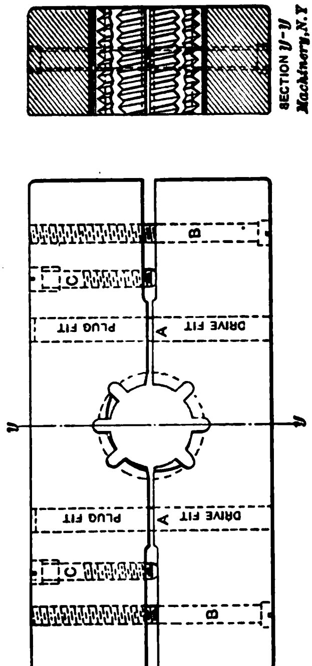


Fig. 27. Lap for Screw Plug Gages.

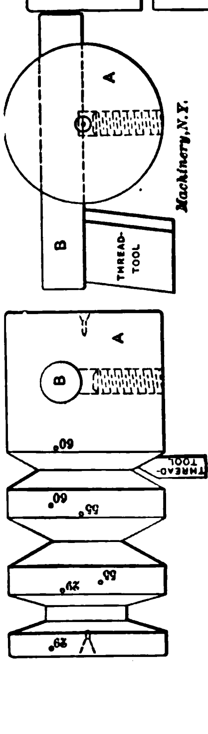


Fig. 26. Gage for Setting Thread Tools.

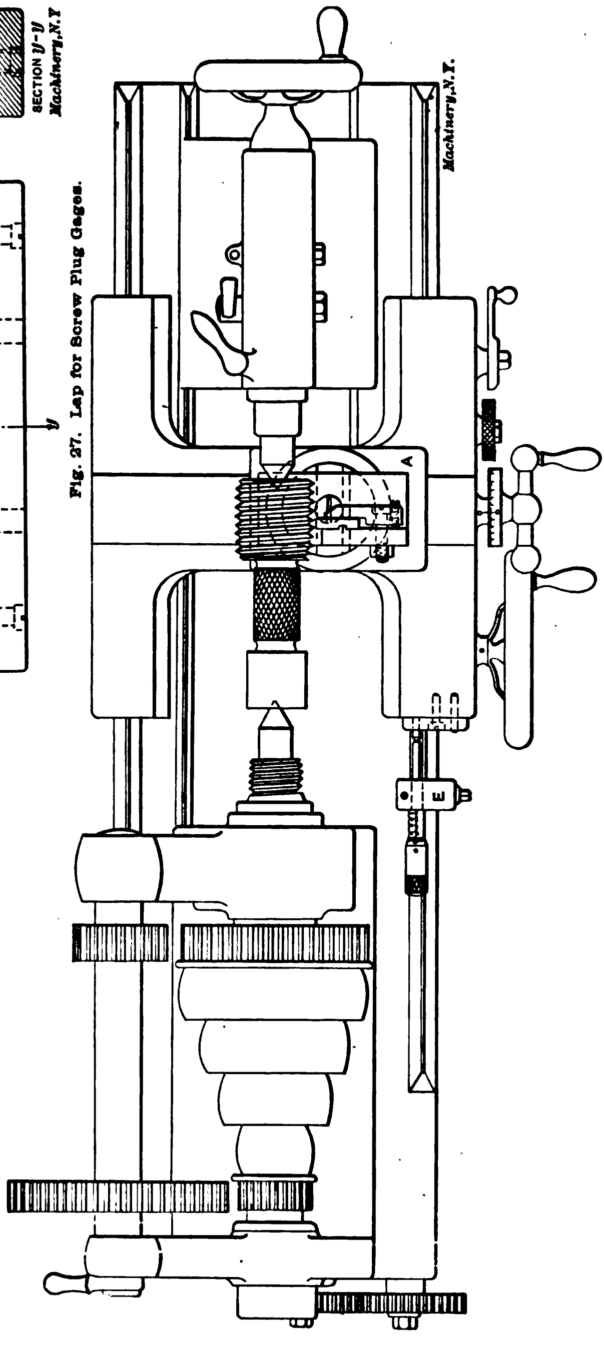


Fig. 28. Final Test of Pitch and Angle of Thread.

that when the rod *E* travels along the plate *F*, on the incline upward, it slightly turns the nut and moves it forward a trifle in excess of the regular forward motion imparted to the nut by the motion of the lead screw. By inclining the plate *F* in the other direction, the motion of the nut may be correspondingly retarded.

A grinding fixture *I* fits the slides on the top of the carriage. On the right-hand side of this fixture is placed a knurled handle *J*, graduated to thousandths of an inch. This handle is for the fine adjustment of the fixture, enabling the grinding wheel to be set correctly to the center of the thread, before starting the grinding operation. The top of the fixture swivels in a vertical plane, so that the wheel *L*, which is made of tool steel and charged with diamond dust, can be set at an angle to the vertical, either to the right or the left, according to the pitch and direction of the thread. This adjustment is made by loosening the nut *K* which binds the head in position when set to the correct angle. The wheel *L* is provided with a shank which fits a tapered hole

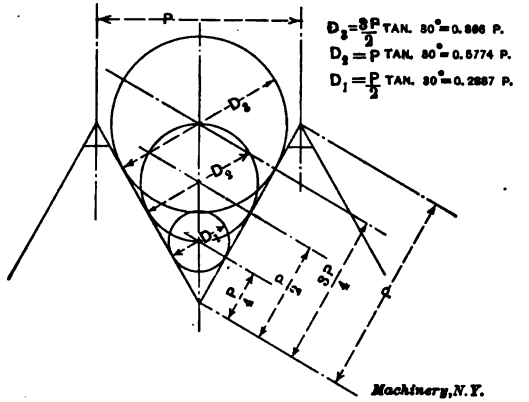


Fig. 29. Formula and Diagram for Determining Ball Points for U. S. Standard and V-Threads.

in the spindle *D*, which latter runs at a speed of 20,000 revolutions per minute. A solid backstop *M* is provided to hold the fixture securely in place while working. The lathe spindle, with the tap, and the grinding spindle run in the same direction, the same as in an ordinary grinder.

A good supply of sperm oil should be used when grinding the tap, and it is necessary to have a cover over the wheel, to prevent the throwing out of oil. This cover, however, is not shown in the cut. Care should be taken not to force the wheel into the work, as if that is done, the shape will soon be destroyed. The wheel should just barely touch the work, and should be fed in a very small amount, say, 0.00025 inch at a time. A sound magnifier or listener should be used, to hear whether the wheel is cutting moderately.

The wheel is charged in the following manner. A chuck, with a tapered hole which fits the shank of the diamond wheel, is placed in the spindle of the bench lathe. as shown in Fig. 23, and the tail-stock center is pushed up at the other end to get a good support when charging. Fixture *B* is placed in the bench lathe, and clamped with a bolt and nut from underneath the lathe, about the same as an ordinary slide-rest. The front end of the fixture extends up vertically above the center of the spindle. In this projecting part, two holes are drilled, reamed, and counterbored, at the same height as the center of the lathe spindle. In these holes are fitted two studs *C C* having a T-head inside the counterbored hole. Between the T-heads of these studs and the screws *D D* lie fiber washers, which act as friction stops. On the other end of plugs *C C* are placed hardened and ground rollers *E E* having one end beveled to a 30-degree angle, while the other end has spur gear teeth milled, which mesh into each other. With the slowest speed of the bench lathe, the fixture is fed in by hand, and having two slides at right angles to each other, the same as an ordinary slide-rest, it can be located to the proper position without much trouble. A piece of soft steel wire should be flattened out to make a spade, with

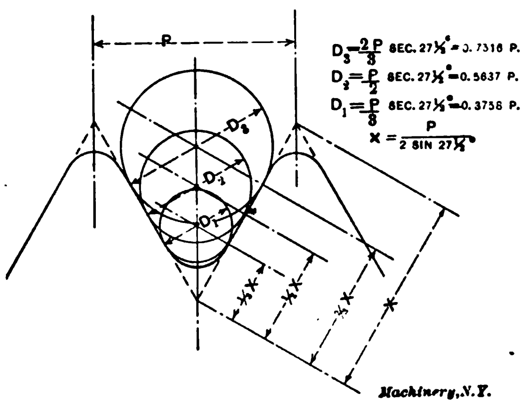


Fig. 30. Formula and Diagram for Determining Ball Points for Whitworth Thread.

which to take up the diamond dust for charging the wheel. One should not try to use a piece of wood, or a brush, as that will only be a waste of diamond. The master tap, which is to be ground, is relieved up to within 1/16 inch from its cutting edge with a file, this being done in order to prevent any more grinding than is absolutely necessary, and to permit the tap to cut freely. The length of the threaded part of the master tap should be about two times its diameter.

The master tap being finished, the lap for the screw plug gages, Fig. 27, is tapped, and ready for use. When charging this thread lap, great care should be taken not to force the lap too much. The spindle of the lathe, where the lapping is done, should be run very slowly, with the back gears in, until the lap is thoroughly charged with emery mixed with sperm oil. Then the lathe may be speeded up to a higher speed, according to the size of the screw plug. It is poor practice to use too much emery on the lap. Reverse the lap often, and use it the same amount on either side. If a large number of screw plugs are to be lapped, all of the same size, lap them all, one at a time, with the lap at the same setting. In this way the lap keeps its shape better, and can be used a long while before being retapped. Do not attempt to tap the lap with the master tap when charged with emery, but use a roughing tap first, and also wash out the lap in benzine before tapping. When the screw plug has been lapped to within 0.0005 inch of its size, it is ground on its outer diameter, if it be a U. S. Standard thread plug, and then finished by lapping after being ground. This will permit the top corners to be kept sharp, and better results will be obtained all around.

BALL DIAMETERS TO BE USED IN DETERMINING CORRECT ANGLE OF THREAD FOR V, U. S., AND BRIGGS STANDARD THREADS.

Threads per inch.	D_3	D_2	D_1
32	0.028	0.018	0.010
28	0.030	0.020	0.010
24	0.035	0.024	0.012
22	0.040	0.026	0.014
20	0.045	0.028	0.014
18	0.050	0.030	0.016
16	0.055	0.035	0.018
14	0.060	0.040	0.020
13	0.065	0.045	0.022
12	0.070	0.050	0.024
11	0.080	0.055	0.026
10	0.085	0.060	0.030
9	0.095	0.065	0.030
8	0.100	0.070	0.035
7	0.120	0.080	0.040
6	0.140	0.095	0.050
5½	0.160	0.110	0.050
5	0.170	0.120	0.060
4½	0.190	0.130	0.065
4	0.220	0.140	0.075
3½	0.240	0.170	0.085
3	0.280	0.190	0.095
2⅞	0.300	0.200	0.100
2¾	0.320	0.220	0.100
2⅝	0.320	0.220	0.110
2½	0.340	0.240	0.110
2⅜	0.360	0.240	0.120
2¼	0.380	0.260	0.130

Great care must be exercised during the lapping operation to see that the angle of the thread is correct. The gaging of the angle of the thread is accomplished in the following manner. Three micrometers are used to measure the correct angle. Two ball points of the same size are placed in tapered holes in each micrometer, as shown in Fig. 24. These ball points are ground all over, and made to a shape as shown in the upper left-hand corner in Fig. 24. The body of these ball points is ground parallel, and then the end is turned and ground to a ball shape as shown. Three sets of ball points are used for each pitch, one to measure the thread near its bottom, one at the center, and one near the top, as indicated in Figs. 29 and 30. The master screw plug is used for comparison; one micrometer is set to the master screw plug at the bottom of the thread, in the manner indicated in Fig. 24, and is then tried on the thread plug being made. The difference in diameter between the measured diameter on the master gage, and that on the plug being made, is noted. Then the two other micrometers, measuring at the center and near the top of the thread, are used, and the difference between the master gage and the screw plug diameters at the places where these micrometers measure, is also noted. If all three micrometers show the same amount of difference

BALL DIAMETERS TO BE USED IN DETERMINING CORRECT ANGLE OF THREAD FOR WHITWORTH STANDARD THREAD.

Threads per inch.	D_3	D_2	D_1
32	0.024	0.018	0.012
28	0.026	0.020	0.014
24	0.030	0.024	0.016
22	0.035	0.026	0.018
20	0.040	0.028	0.018
18	0.040	0.030	0.020
16	0.045	0.035	0.024
14	0.055	0.040	0.026
13	0.060	0.045	0.028
12	0.065	0.045	0.030
11	0.070	0.050	0.035
10	0.075	0.055	0.035
9	0.085	0.060	0.040
8	0.095	0.070	0.045
7	0.110	0.080	0.055
6	0.130	0.095	0.060
5½	0.140	0.100	0.070
5	0.150	0.110	0.075
4½	0.170	0.120	0.085
4	0.190	0.140	0.095
3½	0.220	0.160	0.110
3	0.260	0.190	0.120
2⅞	0.260	0.200	0.130
2¾	0.280	0.200	0.140
2⅝	0.280	0.220	0.140
2½	0.300	0.220	0.150
2⅜	0.320	0.240	0.160
2¼	0.340	0.260	0.170

in relation to the master plug, then the angle of the thread evidently must be correct. After that, the micrometer measuring at the center of the thread is used to measure the size of the screw plug, comparing it with that of the master gage, until the plug is finished to size.

Figs. 29 and 30 show how formulas are derived for the size of the ball points used in measuring. Fig. 29 applies to a 60-degree thread, either sharp V or U. S. Standard, while Fig. 30 gives the formulas for a Whitworth thread. The diameters D_1, D_2, and D_3, respectively, are the diameters of the cylindrical portions of the ball points used, and are, of course, also the diameters of the half-spheres on the end of the ball points. The tables on pages 33 and 34 give these diameters for different pitches, figured approximately from the formulas.

For testing the angle of the screw plug, when finally finished to a limit of 0.0005 inch, it is tried in a testing machine, such as shown in Fig. 28. This machine is simply an ordinary lathe, fitted with a fixture *A*, shown separately in Fig. 25. The tool-post is taken off the lathe, and replaced with this fixture, which is clamped in the T-slot of the tool-post slide, with bolt *B*, Fig. 25. The thread gage *C* is ground all over, and the angle fitted to a master gage. The gage *C* is held by the tongue and groove on the left-hand side of the fixture, and clamped with a strap *D*. To set this gage correctly, in relation to the axis of the spindle of the lathe, as regards height as well as angle, the angle gage, Fig. 26, is used in the same way as has been previously explained in relation to thread cutting. When the fixture has been placed correctly in position, the screw plug is inspected by placing the gage

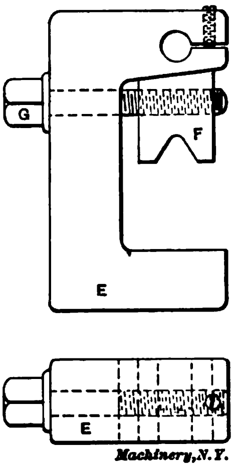


Fig. 31. Holder for Micrometer Stop.

with the hand first to the right and then to the left side of the thread angle. A strong magnifying glass is used with a white paper underneath, and any imperfection of the angle is easily detected, and can be corrected when lapping the last 0.0005 inch to size. If the test gage shows an opening either at the bottom or at the top, the fault is that the lap is worn and must be retapped, or it may be that too much emery has been used. If, for some reason or other, it is impossible to correct the screw plug within 0.0001 inch, when lapping, take a piece of hard wood, or flatten a piece of copper wire, charge it with emery, and hand lap the high points of the angle, while the screw plug is revolving slowly in the lathe. In this way, it is comparatively easy to overcome this trouble, but great care must be taken to follow the thread properly with the hand lap.

To find if a screw thread has a perfect lead, the micrometer stop *E*, Fig. 28, is placed on the left-hand side of the carriage. The holder for this micrometer stop is shown separately in Fig. 31. The construction of this stop is very simple. The micrometer head is an ordinary one, as made for the trade by manufacturers of these instruments. The holder *E* is made similar to a C-clamp, with a hole drilled and reamed to fit the micrometer head. A slot is sawed through the upper jaw, with a stop screw on the top, which prevents the micrometer from being clamped too hard in the holder, in which case the thimble would not revolve freely. Underneath this hole the holder is beveled off, and a V-block *F* is held in position by a screw *G*, entering from the side. The micrometer head is placed in the hole provided for it, with its division reading faced upwards, and the screw *G* clamps the micrometer head and the holder *E* at the same time. When the lead of the screw plug is tested, the carriage is moved one inch along the thread. It is understood that the lead-screw of the lathe is not employed in this case, but one depends upon the micrometer for measuring the correct lead of the screw plug.

The master plug may, of course, also be placed between the centers and comparison be made with the master plug. In this case, the micrometer serves as a comparator. A plate is screwed on the left-hand side of the carriage, provided with a hardened stop against which the end of the micrometer screw bears. It is evident that the carriage must not be moved against the micrometer with too much force, but simply brought up to barely touch against the end of the micrometer screw.

CHAPTER V.

MEASURING SCREW THREAD DIAMETERS.

It is always advisable when measuring screw thread diameters to measure them in the angle, in addition to testing their diameter on the top of the threads and at the bottom of the thread groove, but unless calipers made expressly for the work are at hand, the measurement in the thread angle is apt to be omitted. The tables on pages 38, 39, 40, and 41 were worked out by Mr. Walter Cantelo in 1902 for convenient application in the inspection of screw threads in connection with ordnance inspection for the United States army. The method is known as the three-wire system of screw measurement, because three wires, of the diameter called for in the tables, and applied as shown in the accompanying diagrams, are used in connection with an ordinary flat point micrometer. The dimensions for the standard threads of the systems shown are given in the tables mentioned. For threads of special size or pitch, the values for the various thread parts are easily computed from the formulas given for the kind of thread under consideration. It is especially necessary that the wires used be as nearly round in section as possible, and of uniform diameter.

Two methods of measuring are shown for the 60-degree V, U. S. standard and Whitworth threads, and for each method a formula and table of values are given. The three-wire method is preferred, because the error in the thread groove—if any be present—is taken into consideration twice, while by the single-wire method errors are liable to be introduced by the surface on top of the threads not being exactly concentric with the thread groove. It is evident that for each of the threads the wire to be used in any thread groove is limited in regard to diameters as follows:

The 60-Degree V-Thread.

Maximum diameter of wire $= \frac{p}{0.866} = 1.155\,p$, if p equals the pitch of the thread.

Minimum diameter of wire $= 0.577\,p$.

The U. S. Standard Thread.

Maximum width of thread groove $= \frac{7}{8}\,p$.

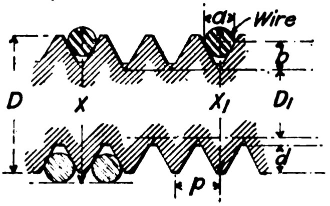
Maximum diameter of wire $= \frac{7}{8} \times \frac{p}{0.866} = 1.010\,p$.

Minimum diameter of wire $= \frac{7}{8} \times 0.577\,p = 0.505\,p$.

The 55-Degree Whitworth Thread.

Let $p_1 =$ distance across thread groove at point where radii are tangent to angle.

U.S STANDARD



n = number of threads per inch

p = pitch = $\frac{1}{\text{no. of threads per inch}}$

d = depth of thread = $0.6495p = \frac{0.6495}{n}$

D = diameter on top of threads

$D_1 = D - \frac{1.5155}{n}$

a = diameter of wire { maximum diam. = $1.010p$; mininum diam. = $0.505p$ }

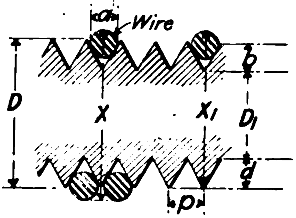
$b = a$

$X = D_1 + 2b + a = D_1 + 3a$

$X_1 = \frac{D}{2} + \frac{D_1}{2} + b + \frac{a}{2} = \frac{D + D_1 + 3a}{2}$

D	n	d	D_1	a and b	X	X_1
1/4"	20"	.0325"	.1742"	0.040"	.2942"	.2721"
5/16	18	.0361	.2283	"	.3483	.3304
3/8	16	.0406	.2803	"	.4003	.3876
7/16	14	.0464	.3292	"	.4492	.4433
1/2	13	.0500	.3834	0.060	.5634	.5317
9/16	12	.0541	.4362	"	.6162	.5893
5/8	11	.0590	.4872	"	.6672	.6460
11/16	11	.0590	.5497	"	.7297	.7086
3/4	10	.0649	.5984	"	.7784	.7643
13/16	10	.0649	.6610	"	.8410	.8267
7/8	9	.0722	.7066	0.100	1.0066	.9408
15/16	9	.0722	.7691	"	1.0690	1.0033
1	8	.0812	.8105	"	1.1105	1.0553
1 1/8	7	.0928	.9085	"	1.2085	1.1667
1 1/4	7	.0928	1.0335	"	1.3335	1.2917
1 3/8	6	.1082	1.1224	"	1.4224	1.3987
1 1/2	6	.1082	1.2474	"	1.5474	1.5237
1 5/8	5 1/2	.1180	1.3494	0.150	1.7994	1.7122
1 3/4	5	.1299	1.4470	"	1.8970	1.8234
1 7/8	5	.1299	1.5720	"	2.0220	1.9484
2	4 1/2	.1443	1.6632	"	2.1132	2.0566
2 1/8	4 1/2	.1443	1.7882	"	2.2382	2.1816
2 1/4	4 1/2	.1443	1.9132	"	2.3632	2.3066
2 3/8	4	.1624	1.9960	"	2.4460	2.4105
2 1/2	4	.1624	2.1210	"	2.5710	2.5355
2 3/4	4	.1624	2.3710	"	2.8210	2.7855
3	3 1/2	.1856	2.5670	0.200	3.1670	3.0835
3 1/4	3 1/2	.1856	2.8170	"	3.4170	3.3335
3 1/2	3 1/4	.2000	3.0337	"	3.6337	3.5668
3 3/4	3	.2165	3.2448	"	3.8448	3.7974
4	3	.2165	3.4948	"	4.0948	4.0474

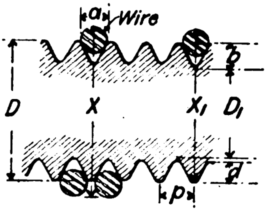
60° V THREAD



n = number of threads per inch
p = pitch = $\frac{1}{\text{no. of threads per inch}}$
d = depth of thread = $0.866p = \frac{0.866}{n}$
D = diameter of top of threads
D_1 = root diameter = $D - 2d$
a = diameter of wire $\begin{cases} \text{maximum diam.} = 1.155p \\ \text{minimum diam.} = 0.577p \end{cases}$
$b = a$
$X = D_1 + 2b + a = D_1 + 3a$
$X_1 = \frac{D}{2} + \frac{D_1}{2} + b + \frac{a}{2} = \frac{D + D_1 + 3a}{2}$

D	n	d	D_1	a and b	X	X_1
1/4"	20"	.0433"	.1634"	0.040"	.2834"	.2667"
5/16	18	.0481	.2163	"	.3363	.3244
3/8	16	.0541	.2667	"	.3867	.3808
7/16	14	.0617	.3138	0.060	.4938	.4656
1/2	12	.0722	.3557	"	.5357	.5178
9/16	12	.0722	.4182	"	.5982	.5803
5/8	11	.0787	.4676	"	.6476	.6363
11/16	11	.0787	.5300	"	.7100	.6987
3/4	10	.0866	.5768	0.100	.8768	.8134
13/16	10	.0866	.6393	"	.9393	.8759
7/8	9	.0962	.6826	"	.9826	.9288
15/16	9	.0962	.7450	"	1.0450	.9912
1	8	.1082	.7835	"	1.0835	1.0417
1 1/8	7	.1237	.8776	"	1.1776	1.1513
1 1/4	7	.1237	1.0026	"	1.3026	1.2763
1 3/8	6	.1443	1.0863	0.150	1.5363	1.4556
1 1/2	6	.1443	1.2113	"	1.6613	1.5806
1 5/8	5	.1732	1.2786	"	1.7286	1.6768
1 3/4	5	.1732	1.4036	"	1.8536	1.8018
1 7/8	4 1/2	.1924	1.4900	"	1.9400	1.9075
2	4 1/2	.1924	1.6150	"	2.0650	2.0325
2 1/8	4 1/2	.1924	1.7400	"	2.1900	2.1575
2 1/4	4 1/2	.1924	1.8650	"	2.3150	2.2825
2 3/8	4 1/2	.1924	1.8900	"	2.4400	2.4075
2 1/2	4	.2165	2.0670	0.200	2.6670	2.5835
2 3/4	4	.2165	2.3170	"	2.9170	2.8335
3	3 1/2	.2474	2.5050	"	3.1050	3.0525
3 1/4	3 1/2	.2474	2.7550	"	3.3550	3.3025
3 1/2	3 1/4	.2664	2.9670	"	3.5670	3.5335
3 3/4	3	.2886	3.1727	"	3.7727	3.7613
4	3	.2886	3.4227	"	4.0227	4.0113

WHITWORTH THREAD



n = number of threads per inch

p = pitch = $\frac{1}{\text{no. of threads per inch}}$

d = depth of thread = $0.6403p = \frac{0.6403}{n}$

D = diameter on top of threads

$D_1 = D - \frac{1.6008}{n}$

a = diameter of wire $\begin{cases} \text{maximum diam.} = 0.840p \\ \text{mininum diam.} = 0.506p \end{cases}$

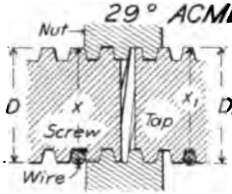
$b = 1.08205a$

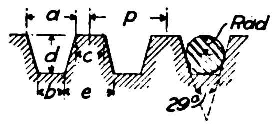
$x = D_1 + 2b + a = D_1 + 3.1657a$

$x_1 = \frac{D}{2} + \frac{D_1}{2} + b + \frac{a}{2} = \frac{D + D_1 + 3.1657a}{2}$

D	n	d	D_1	a	b	x	x_1
1/4	20	.0320	.1699	0.040	.0433	.2965	.2733
5/16	18	.0356	.2235	"	"	.3501	.3313
3/8	16	.0400	.2749	"	"	.4015	.3883
7/16	14	.0457	.3231	"	"	.4497	.4436
1/2	12	.0534	.3666	"	"	.4932	.4966
9/16	12	.0534	.4291	0.060	.0649	.6190	.5907
5/8	11	.0582	.4794	"	"	.6693	.6372
11/16	11	.0582	.5420	"	"	.7319	.7097
3/4	10	.0640	.5899	"	"	.7798	.7649
13/16	10	.0640	.6524	"	"	.8423	.8274
7/8	9	.0711	.6971	"	"	.8870	.8810
15/16	9	.0711	.7596	"	"	.9495	.9435
1	8	.0800	.7999	0.100	.1084	1.1167	1.0583
1 1/8	7	.0915	.8963	"	"	1.2131	1.1690
1 1/4	7	.0915	1.0213	"	"	1.3381	1.2940
1 3/8	6	.1067	1.1082	"	"	1.4250	1.3999
1 1/2	6	.1067	1.2332	"	"	1.5500	1.5250
1 5/8	5	.1281	1.3048	0.150	.1624	1.7796	1.7023
1 3/4	5	.1281	1.4298	"	"	1.9046	1.8273
1 7/8	4 1/2	.1430	1.5193	"	"	1.9941	1.9345
2	4 1/2	.1430	1.6443	"	"	2.1191	2.0595
2 1/8	4 1/2	.1430	1.7693	"	"	2.2441	2.1845
2 1/4	4	.1601	1.8498	"	"	2.3246	2.2873
2 3/8	4	.1601	1.9750	"	"	2.4498	2.4123
2 1/2	4	.1601	2.1000	"	"	2.5748	2.5373
2 3/4	3 1/2	.1830	2.2926	0.200	.2157	2.9240	2.8370
3	3 1/2	.1830	2.5426	"	"	3.1740	3.0870
3 1/4	3 1/4	.1970	2.7574	"	"	3.3887	3.3194
3 1/2	3 1/4	.1970	3.0074	"	"	3.6387	3.5694
3 3/4	3	.2134	3.2164	"	"	3.8477	3.7990
4	3	.2134	3.4664	"	"	4.0977	4.0490

29° ACME SCREW THREAD





SCREW THREAD

p - pitch - $\frac{1}{\text{no. of threads per inch}}$
d - depth of thread - $\frac{p}{2}$ + 0.010"
a - space at top - 0.6293 p
b - space at bottom - 0.3707 p - 0.0052"
c - thickness at top - 0.3707 p
e - thickness at bottom = 0.6293 p + 0.0052"
D - diameter at top of thread
x - D + 0.010"

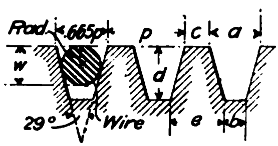
TAP THREAD

p - pitch - $\frac{1}{\text{no. of threads per inch}}$
d - depth of thread = $\frac{p}{2}$ + 0.020"
a - space at top - 0.6293 p + 0.0052"
b - space at bottom - 0.3707 p - 0.0052"
c - thickness at top - 0.3707 p - 0.0052"
e - thickness at bottom - 0.6293 p + 0.0052"
D_1 - diameter at top of thread - D + 0.020"
x_1 - D_1 - D + 0.020"

Threads per inch	p	d	Diameter of wire	Threads per inch	p	d	Diameter of wire
½	2.000"	1.0100"	0.9785"	3	0.3333"	0.1767"	0.1664
¾	1.500	0.7600	0.7349	4	0.2500	0.1350	0.1278
1	1.000	0.5100	0.4913	5	0.2000	0.1100	0.1014
1⅓	0.750	0.3850	0.3694	6	0.1667	0.0933	0.0852
1½	0.667	0.3433	0.3288	7	0.1429	0.0814	0.0736
1¾	0.571	0.2957	0.2824	8	0.1250	0.0725	0.0649
2	0.500	0.2600	0.2476	9	0.1111	0.0655	0.0581
2½	0.400	0.2100	0.1989	10	0.1000	0.0600	0.0527

The wire used is of such diameter, that when laid in the thread groove of the tap, it will be flush with the top of the threads, and when laid in the thread groove of the screw, it will extend beyond the top of the threads 0.010."

THE BROWN AND SHARPE 29° WORM THREAD



p - pitch - $\frac{1}{\text{no. of threads per inch}}$
d - depth of thread - 0.6866 p
a - space at top = 0.665 p
b - space at bottom - 0.310 p
c - thickness at top - 0.335 p
e - thickness at bottom - 0.690 p
w - diam. of wire - 0.5149 p

Pitch	d	Wire Diam.	Pitch	d	Wire Diam.
2.000	1.3732	1.0298	.3333	.2286	.1716"
1.750	1.2015	.9010	.2500	.1716	.1287
1.500	1.0299	.7723	.2000	.1373	.1030
1.250	.8582	.6436	.1667	.1144	.0858
1.000	.6866	.5149	.1250	.0858	.0643
.750	.5150	.3862	.1111	.0763	.0582
.500	.3433	.2574	.1000	.0687	.0515

The wire used is of such diameter that it will be flush with the top of the thread when laid in the thread groove.

Radius on thread = 0.1373 p, and arc forming top of threads contains 125 degrees.

Then $p_1 = p - 2 \sin 62° 30' \times 0.1373\, p = p - 2 \times 0.887 \times 0.1373\, p = p - 0.243\, p = 0.75\, p$, approx.

$$\textbf{Maximum diameter of wire} = 0.75 \times \frac{p}{0.887} = 0.84\, p.$$

$$\textbf{Minimum diameter of wire} = 5/6 \times 0.6068\, p = 0.505\, p.$$

Principle of Method of Measurements.

The dimension D_1 (see tables, pages 38 to 41) must be considered for both the single-wire and three-wire methods and has values as follows:

For the 60-degree thread: The depth equals $0.866\,p$ and as the apex of the thread angle and root of thread groove are at the same point, it follows that $D_1 = D - 0.886\,p \times 2 = D - 1.732\,p$ or $= D - \frac{1.732}{n}$.

For the U. S. Standard thread: The depth equals 6/8 of the 60-degree V thread, being flattened on top and filled in at the root an amount equaling one-eighth of the V thread depth, and the distance from the top of thread to apex of thread angle at root, therefore, equals ⅞ of the V thread depth, or $\frac{7}{8} \times 0.866\,p$ and $D_1 = D - \frac{7}{8} \times 0.866\,p \times 2 = D - 1.5155\,p$ or $= D - \frac{1.5155}{n}$.

For the Whitworth 55-degree thread: The depth equals 4/6 of the 55-degree V thread depth, being filled in at the root and cut away on top an amount equaling 1/6 of the V thread depth. The depth of the 55-degree V thread would be $0.96045\,p$ and the distance from top of Whitworth thread to apex of thread angle at root equals $5/6 \times 0.96045\,p$ or $0.8004\,p$ and $D_1 = D - 2 \times 0.8004\,p = D - 1.6008\,p$, or $= D - \frac{1.6008}{n}$.

From the foregoing it will be seen how the formulas $x = D_2 + 2b + a$ for the three-wire system, and $x_1 = \frac{D}{2} + \frac{D_2}{2} + b + 2a$ for the single-wire system are produced, and also, it will be readily seen how easily the formulas $x = D - \frac{1.732}{n} + 3\,a$ for the 60-degree V thread and $x = D - \frac{1.5155}{n} + 3\,a$ for the U. S. Standard thread, as given in Chapter II, may be arrived at.

The Acme 29-Degree Screw Thread.

For this thread it is best to use a separate wire for each pitch, of such diameter that when laid in the thread groove of the tap or thread plug gage, it will be flush with the tops of the threads when they are of correct dimensions, and when laid in the thread groove of the screw it will extend 0.010 inch beyond the tops of the threads.

The Brown & Sharpe 29-Degree Worm Thread.

For this thread it is best to use a separate wire for each pitch that will be flush with the tops of the threads when laid in the finished thread groove.

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