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TECHNICAL DRAWING SERIES

MACHINE DRAWING

THE GENERAL PRINCIPLES OF MACHINE DRAWING, SKETCHING, FIGURING, ETC., TOGETHER WITH NUMEROUS PRACTICAL EXAMPLES.

BY

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PREFACE.

THIS treatise is intended to teach the practical application of the principles of projection to the illustration of machinery; to inform the student concerning many of the exceptions to the laws of projection; and finally, to furnish such practical examples as may serve for problems to the student, and suggestions to the draftsman. It aims to encourage a concise graphic expression in the colloquial phrases of modern mechanical drawing, instead of the more classic language which would enforce a rigid adherence to the laws of projection, and the customs of several centuries of architectural draftsmen.

The examples chosen are those which, being faithfully and intelligibly executed, will enable the student to acquire much practical information on the subject by the making of only a few drawings. The number of subjects suitable for these exercises is surprisingly small; for at this period of the student's advancement, it is the art of graphic expression rather than that of drawing which is most required, and this cannot be attained by the making of copies. It is, indeed, almost a waste of time to copy a drawing; since proficiency in penciling may be better acquired by other means, and tracing is much superior as an exercise in inking. The difficulty in obtaining suitable models has, however, necessitated much of this; but it is hoped that the present volume may assist in obviating the trouble by supplying such problems as may lead the student to observe closely, think accurately, and express clearly. The subjects chosen for the exercises are such as have been found suitable for illustrating most of the principles taught, as well as the practical suggestions made in this book.

Much care has been exercised in the making and figuring of these drawings, that they should be complete and correct; but that this should be realized in every detail, is more than the author's experience would lead him to expect. While it is to be desired that the one great lesson of accuracy should be emphasized above all others, it is also to be remembered that draftsmen are not infallible, and it is the minimum, rather than the absence, of mistakes by which we are to judge.

As this book is the advocate of no special systems of lining, figuring, lettering, etc., the plates will be found to represent a variety of types in drawing which may at some time serve the draftsman who is not bound to special methods, but seeks the one and only end to be attained; namely, the art of using all available instrumentalities in securing a terse, accurate, and complete expression of mechanical ideas.

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MACHINE DRAWING.

CHAPTER I.

BOLTS AND SCREWS.

1. **The Representation of Bolts, Nuts, Screws, and Screw-threads,** is of such importance that a thorough knowledge of their proportions, and the conventional method of illustrating them, is of the first consideration to the machine draftsman. Printed tables of the dimensions of bolt-heads, nuts, set-screws, etc., are usually published in connection with treatises on machine design; but it is far better for the student of machine drawing to fix the proportions of the various parts in his mind, and learn to judge for himself of their comparative value. In the present treatise, only the more common types will be illustrated; and it is assumed that the student is already familiar with the theory of the helix and its application to the various forms of screw threads, as well as the drawing of an hexagonal bolt-head and nut.* In the study of the following pages the student is recommended to so master each type that he may rapidly draw or sketch the bolt or screw with its proper proportions, having only the diameter of the thread given.

* For a complete treatise on the helix and its application to the drawing of screw-threads, together with the construction of the hexagonal bolt-head and nut, see Elements of Mechanical Drawing, of this series.

2. **U. S. Standard and V Screw-threads.** — The form of screw-thread commonly used is that of the U. S. Standard, also known as the Franklin Institute Standard, and illustrated by Fig. 1.

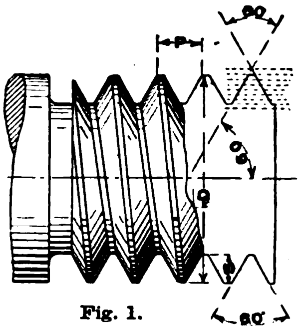


Fig. 1.

The proportion of pitch to diameter is, $P = 0.24\sqrt{D + 0.625} - 0.175$. The depth of the thread S, is 0.65 P, or $\frac{.65}{\text{number of threads per inch}}$. While the pitch in single-threaded screws is, properly speaking, the distance between consecutive threads, the term is often applied to the number of threads per inch. Thus a screw having eight threads to an inch is frequently spoken of as 8 pitch. Although this is obviously wrong, yet it leads to no confusion, since the pitch and the number of threads per inch are reciprocals of each other. The flattening of the thread, as indicated in the figure, is for the purpose of preventing injury to the thread by the bruising of the otherwise sharp V. In the following table, page 5, the proportions are given for the U. S. Standard and V threads from ¼ to 2½ inches diameter, together with the tensile strength of the former when subjected to varying stresses.

Column 1 gives the outside diameter of the thread.

Column 2, the number of threads per inch, the pitch being the reciprocal of this number.

Column 3, the diameter at the root, or bottom of thread.

Column 4, the diameter of drill to be used for any given diameter of thread or tap. It will be noticed that these sizes are a trifle larger than the diameters at root of thread. The increase should be from about four thousandths of an inch for a ¼ inch tap, to ten thousandths for a 2 inch tap.

Columns 5, 6, 7, and 8 are of special value to the machine designer, but are introduced here to enable the student to obtain some appreciation of the strength of the thread. The weakest part being at the root, its strength will be dependent on the diameter of this part, and the tensile strength of the material. In the case of a screw of $1\frac{1}{4}$ inch diameter, the diameter at the root is found in column 3 to be 1.065, the area of which is .78. If it is required that 4000 lbs. be the strain to which every square inch is subjected, then will the thread sustain .78 times 4000 lbs., which is 3120, as given in column 5. In this manner the table is constructed for four, five, six, and seven thousand pounds tensile strength. A valuable application of this table is in determining the size of a screw, having given the total load to be sustained and the permissible strain per square inch. Suppose it is required to obtain the diameter of a bolt sufficient to overcome a resistance of 10000 lbs., and to be strained to only 4000 lbs. per square inch. In column 5 is found the number 9200, which is the nearest to the required amount. Against this number, in column 1, is seen 2, which is the necessary diameter of screw. If, however, the allowable strain per square inch had been 7000 lbs., a screw of $1\frac{5}{8}$ inch diameter could have been used. Columns 9, 10, 11, 12, give the values for V threads for rough iron sizes, corresponding to those for the U. S. standard in columns 1 to 4. It will be observed that the outside diameters in column 9 are from $\frac{1}{64}$ to $\frac{1}{32}$ of an inch larger than those in column 1, this being the amount due to the flattening of the U. S. standard thread.

In connection with this table, one of decimal equivalents is also published. The student should not be dependent on this for the equivalents of eighths and sixteenths of an inch, as they may be so easily memorized and are of such frequent use.

DECIMAL EQUIVALENTS.

Fraction.	Decimal.	Fraction.	Decimal.	Fraction.	Decimal.	Fraction.	Decimal.
$\frac{1}{64}$	.015625	$\frac{17}{64}$	.265625	$\frac{33}{64}$	.515625	$\frac{49}{64}$	.765625
$\frac{1}{32}$	.03125	$\frac{9}{32}$	.28125	$\frac{17}{32}$	.53125	$\frac{25}{32}$	.78125
$\frac{3}{64}$	.046875	$\frac{19}{64}$	.296875	$\frac{35}{64}$	.546875	$\frac{51}{64}$	.796875
$\frac{1}{16}$	.0625	$\frac{5}{16}$	.3125	$\frac{9}{16}$	.5625	$\frac{13}{16}$	.8125
$\frac{5}{64}$	.078125	$\frac{21}{64}$	.328125	$\frac{37}{64}$	.578125	$\frac{53}{64}$	.828125
$\frac{3}{32}$	.09375	$\frac{11}{32}$	.34375	$\frac{19}{32}$	.59375	$\frac{27}{32}$	.84375
$\frac{7}{64}$	.109375	$\frac{23}{64}$	.359375	$\frac{39}{64}$	.609375	$\frac{55}{64}$	.859375
$\frac{1}{8}$	.125	$\frac{3}{8}$	.375	$\frac{5}{8}$	.625	$\frac{7}{8}$	.875
$\frac{9}{64}$	.140625	$\frac{25}{64}$	.390625	$\frac{41}{64}$	.640625	$\frac{57}{64}$	.890625
$\frac{5}{32}$	.15625	$\frac{13}{32}$	.40625	$\frac{21}{32}$	.65625	$\frac{29}{32}$	.90625
$\frac{11}{64}$	.171875	$\frac{27}{64}$	.421875	$\frac{43}{64}$	.671875	$\frac{59}{64}$	.921875
$\frac{3}{16}$	.1875	$\frac{7}{16}$	.4375	$\frac{11}{16}$	.6875	$\frac{15}{16}$	.9375
$\frac{13}{64}$	.203125	$\frac{29}{64}$	.453125	$\frac{45}{64}$	.703125	$\frac{61}{64}$	.953125
$\frac{7}{32}$	.21875	$\frac{15}{32}$	.46875	$\frac{23}{32}$	.71875	$\frac{31}{32}$	.96875
$\frac{15}{64}$	.234375	$\frac{31}{64}$	.484375	$\frac{47}{64}$	.734375	$\frac{63}{64}$	.984375
$\frac{1}{4}$	.25	$\frac{1}{2}$	.5	$\frac{3}{4}$	.75	1	

PROPORTIONS FOR U. S. STANDARD AND V. THREADS.

U. S. STANDARD THREAD.				STRENGTH OF U. S. STAND. THREAD.				THREAD FOR ROUGH IRON SIZES.			
Diameter of Screw.	Threads per Inch.	Diameter at root of Thread.	Diameter of Tap Drill.	Tensile Strength at 4000 lbs. per Sq. Inch.	Tensile Strength at 5000 lbs. per Sq. Inch.	Tensile Strength at 6000 lbs. per Sq. Inch.	Tensile Strength at 7000 lbs. per Sq. Inch.	Diameter of Screw.	Threads per Inch.	Diameter at root of Thread.	Diameter of Tap Drill.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1/4	20	.185	3/16	107	134	161	187	1/4 + 1/64	20	.179	7/32
5/16	18	.240	1/4	181	226	271	316	5/16 + 1/64	18	.232	17/64
3/8	16	.294	5/16	271	339	407	475	3/8 + 1/64	16	.282	5/16
7/16	14	.344	23/64	371	465	558	650	7/16 + 1/64	14	.329	3/8
1/2	13	.400	13/32	500	625	750	875	1/2 + 1/64	13	.382	7/16
9/16	12	.454	15/32	647	809	971	1133	9/16 + 1/64	12	.434	1/2
5/8	11	.507	17/32	807	1009	1211	1413	5/8 + 1/64	11	.483	17/32
11/16	11	.569	37/64	1017	1271	1525	1780	11/16 + 1/32	11	.561	39/64
3/4	10	.620	5/8	1200	1500	1800	2100	3/4 + 1/32	10	.608	21/32
13/16	10	.674	11/16	1430	1780	2140	2500	13/16 + 1/32	10	.671	23/32
7/8	9	.731	3/4	1680	2100	2520	2940	7/8 + 1/32	9	.714	25/32
15/16	9	.793	13/16	1980	2470	2960	3460	15/16 + 1/32	9	.776	27/32
1	8	.837	27/32	2200	2750	3300	3850	1 + 1/32	8	.815	7/8
1 1/8	7	.940	31/32	2770	3460	4160	4850	1 1/8 + 1/32	7	.909	31/32
1 1/4	7	1.065	1 3/32	3120	3900	4680	5460	1 1/4 + 1/32	7	1.034	1 3/32
1 3/8	6	1.160	1 3/16	4240	5300	6360	7420	1 3/8 + 1/32	6	1.117	1 3/16
1 1/2	6	1.284	1 9/32	5120	6400	7680	8960	1 1/2 + 1/32	6	1.243	1 5/16
1 5/8	5 1/2	1.389	1 13/32	6120	7650	9180	10710	1 5/8 + 1/32	5 1/2	1.341	1 13/32
1 3/4	5	1.491	1 1/2	7040	8800	10560	12320	1 3/4 + 1/32	5	1.435	1 1/2
1 7/8	5	1.616	1 5/8	8120	10150	12180	14210	1 7/8 + 1/32	5	1.560	1 5/8
2	4 1/2	1.712	1 3/4	9200	11500	13800	16100	2 + 1/32	4 1/2	1.646	1 23/32
2 1/4	4 1/2	1.962	2	12480	15600	18720	21840	2 1/4 + 1/32	4 1/2	1.896	1 31/32
2 1/2	4	2.176	2 3/16	14800	18500	22200	25900	2 1/2 + 1/32	4	2.098	2 3/16

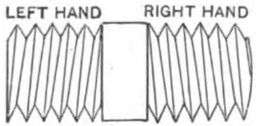


Fig. 2

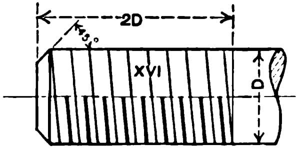


Fig. 3

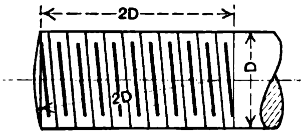


Fig. 4

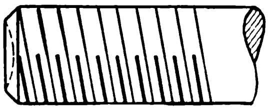


Fig. 5

3. **Representation of V Threads.** It is very rarely that a thread would be shown as in Fig. 2, since the labor of drawing the V is very considerable. The best conventional method of representing the V thread is shown by Fig. 3, although that of Fig. 4 is much used. The objection to the latter form is in the greater length of the heavy lines, which obscures more of the drawing, often making too little space for the figures. It is rarely necessary to draw the exact number of threads per inch required by the table; indeed, the representation is usually clearer when a less number is used, and the drawing of unnecessary lines is also saved. If it is of importance to specify the pitch, it is best done by Roman numerals, indicating the number per inch, as in Fig. 3. A double thread is shown by Fig. 5, for the purpose of calling attention to the difference between it and the single thread. The character of the double thread is better shown by Fig. 6. In the case of a dotted thread, economy in the use of lines is of still greater importance, and the V alone is often shown as illustrated by Fig. 27, page 14.

The end of the screw may be chamfered as in Fig. 3, or rounded as in Fig. 4. When the latter form is used, the length is measured from the intersection of the rounded end and cylinder. Fig. 5 also illustrates a cupped end, used for set-screws requiring to be set into a piece for holding it more securely than by the rounded end of Fig. 18, page 12.

4. Square Threads. In Fig. 7 three forms of the square thread are represented. To the right is the section showing the proportion of pitch to depth of thread. In the middle is drawn the more correct conventional representation, and on the left is the simple form commonly used. In the latter it will be observed that the inner helix is omitted; and in this type of screw it is also better to draw the exact number of threads per inch required, unless the scale be small, or the pitch very fine.

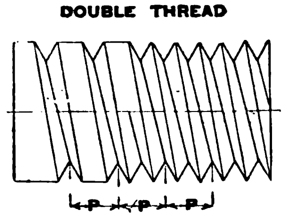


Fig. 6.

5. Buttress Thread. Fig. 8 illustrates a third type, which is sometimes known as a ratchet thread. It is used for imparting motion where the strain is in one direction only, as in a screw-jack. By this means the friction is reduced, while the strength of the V thread is maintained. There is no standard for this thread, but the usual form and proportion are those shown by the figure.

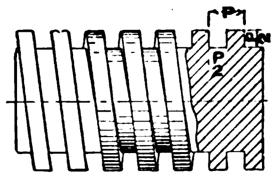


Fig. 7.

6. Bolts and Screws. Save for the hexagonal bolt-head and nut, there is no generally accepted standard for the heads of bolts and screws. It is essential, however, for the draftsman to employ some system in the illustration of forms which occur so frequently as do these. The time required to properly design the head of a bolt, set-screw, or other fastening device, is very considerable, and to have done it once should suffice. When a definite form of head is required, it

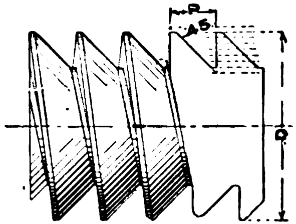


Fig. 8.

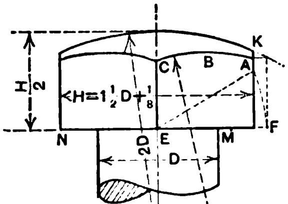


Fig. 9

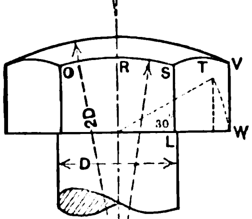


Fig. 10

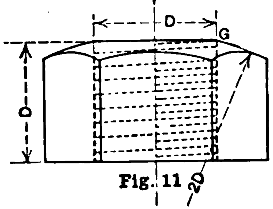


Fig. 11 2D

should only be necessary to produce the same according to certain proportions already fixed, and obtainable either from a ready reference table, or, better still, from memory. As it is generally unnecessary to give all the dimensions of the head or nut on the drawing, it is immaterial whether the representation conforms exactly to the finished size or not. It is therefore a useless delay for the draftsman to spend any more than time enough to produce the desired type of head according to his standard. The following proportions are suggested from standards already in use by many shops.

7. U. S. Standard Hexagonal Head and Nut. Two types of head and nut are illustrated, the rounded or spherical, Figs. 9, 10, 11, and chamfered or conical, Figs. 12, 13, 14. In general the chamfered head is used for sketching, for rough work, and whenever a special finish is not required. The rounded head, which presents a more finished appearance, is used almost exclusively for the heads and nuts of bolts for finished machinery. Three dimensions only are fixed by the Government standard; viz., the distance across flats, or short diameter, commonly marked H, and equal to one and one-half times the diameter of the bolt, plus one-eighth of an inch. Second, the thickness of the head, equal to one-half the short diameter.

Third, the thickness of nut, which is equal to the diameter of the bolt.

In the following suggestions for the drawing of hexagonal heads, it should be remembered that the rounded type is a sphere cut by six planes parallel to the axis, while the chamfered head may be considered as a cone similarly cut.

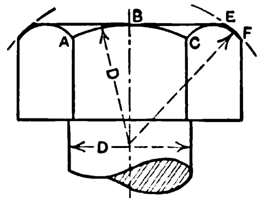


Fig. 12

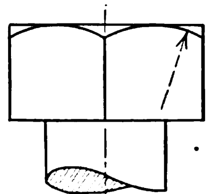


Fig 13

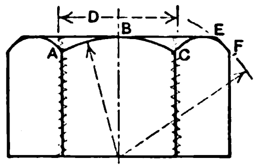


Fig. 14

Fig. 9. Having determined H, or the short diameter, and drawn the edges, lay off the thickness of head, and describe the top with a radius of twice the diameter of bolt. To obtain the arc A B C, determine point B, which is equal in height to K, and through it describe the required arc with radius equal to M N, using care to have C and A of same height. The fine dotted lines show the precise method of finding points A and C by obtaining the long diameter.

Fig. 10. Figure the short diameter, and obtain the long diameter geometrically as shown by the dotted lines. (In small bolts, or drawings to small scale, the long diameter may be made equal to 2 D.) The edge S L is equidistant from V W and the center line, and equal to V W in length. Through S describe arc O R S concentric with curvature of top. Through S and V describe arc S T V with radius equal to L W.

Fig. 11. This differs from the preceding only in that the thickness is equal to the diameter of the bolt. Observe also that the curvature of the top begins at G instead of on the center line.

Figs. 12, 13, and 14. In drawing the chamfered head or nut across

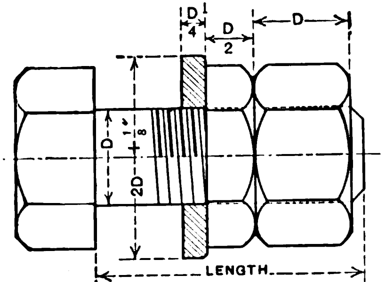


Fig. 15

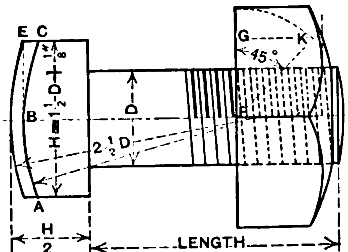


Fig. 16

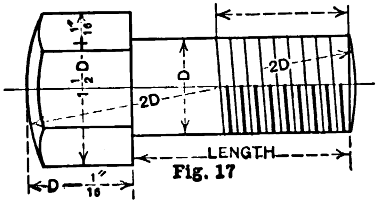


Fig. 17

corners, as in Figs. 12 and 14, describe A B C tangent to top with radius equal to diameter of bolt. From the same center describe arc E F, point F being equal in height to C.

Heads and nuts drawn in connection with the parts which they unite should in general be shown across corners. This will prevent errors in the allowance to be made for hubs, washers, etc., as it gives the maximum space required for the head. The necessity for observing this is at times so great that the bolt is required to be drawn across corners in all views in which it may appear. In sketching bolts, and in the making of bolt lists, it is better to represent them across flats, as they are more easily drawn and figured.

Fig. 15 illustrates a bolt with check-nuts and washers. It is a common practice to make both nuts of the same thickness, and equal to three-quarters of the diameter of the bolt. The more proper form, however, is to make the thickness of the nut sustaining the load equal to the diameter of bolt. Observe also that the outer nut is chamfered on both faces. This might be done in all cases: but polished parts united by bolts having heads and nuts so chamfered, are not so easily wiped, since the oil and dust are likely to lodge under the corners. The necessity for chamfering the outer faces is very great, as otherwise the sharp corners would cause difficulty in handling and soon become marred. The proportions of the head are the same as in Fig. 9.

8. Square-Headed Bolts and Nuts. The proportions for hexagonal heads are usually observed for the square also, save in the radius for the curvature of the top, which is better to be two and one-half diameters.

In Fig. 16, the arc A B C is concentric with the top, and is described through the point B, which is equal in height to E. In drawing the head, or nut, across corners, the geometrical method may be used as shown, remembering that F G is equal to half the short diameter, and F K half the long diameter. Or the long diameter may be made equal to one and one-half the short diameter in small bolts, or where accurate work is not required.

9. Screws. The term screw is usually applied to all classes of bolts without nuts, and the hexagonal and square head types are also called TAP BOLTS. The United States standard proportion for hexagonal heads is frequently adopted for tap bolts, as in Fig. 27, page 14; but in many instances it is desirable to decrease the distance across corners, and increase the thickness, as in the following:

CAP SCREW. Fig. 17. This is an excellent type for many purposes where a small diameter of head is required. The size of the head is made dependent on the distance across corners, instead of across flats. The long diameter may also be made $1\frac{1}{4}$ D + $\frac{1}{16}''$, in which case the thickness of the head should be reduced to D − $\frac{1}{16}''$. The extra thickness of head required for this type makes a good proportioned screw, and is especially suitable for places where frequent adjustment is needed.

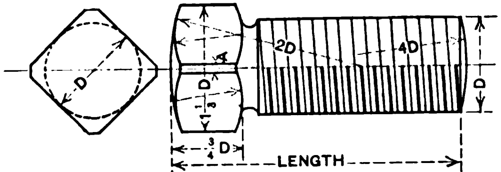


Fig. 18

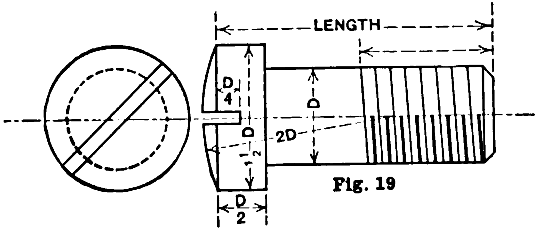


Fig. 19

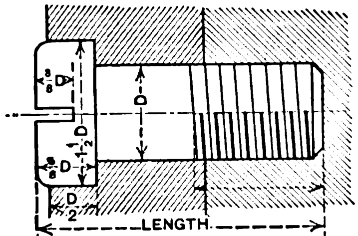


Fig. 20

Set Screw. Fig. 18. This has a square head, having its short diameter equal to the diameter of the screw. The construction will be apparent from the figure, on which the proportions are given. The radius for the point of a set screw should be equal to four diameters of the screw.

Round-Head Screws. Figs. 19 and 20. These differ only in the depth of head and finish of end. The type of Fig. 20 is better adapted for countersunk work, since a variation in the depth of the hole will not affect the appearance of the fit, as would be the case in that of Fig. 19. In representing the end view of a slotted head, always draw the lines of the slot at an angle of 45°, thereby making greater contrast with other lines of the drawing, and thus preventing confusion. The figured length of these screws should always include the head.

Gib Screws, Etc. Figs. 21, 22, and 23 represent three types of square head based on that of Fig. 18. The gib screw head, Fig. 21, is provided with a shoulder to increase the area under the head.

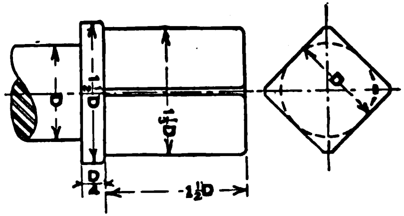


Fig. 21.

The type of Fig. 22 is used when it is desirable to reduce the size of the head to a minimum, or when it is necessary to thread the entire length of the screw, including the head, as is frequently the case with eccentric set-screws. In the latter case the long diameter of the head is usually made equal to the diameter at root of the thread. This proportion of head is also excellent for the squaring of the end of a rod, Fig. 23, as must frequently be done to provide for the use of a box wrench.

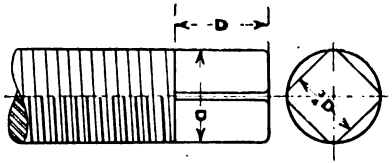


Fig. 22.

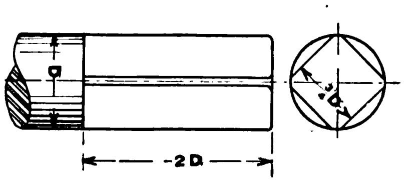


Fig. 23.

10. The Representation of Tapped Holes. When a tapped hole is dotted, it may be shown as in Figs. 24 or 25. If the drawing is already crowded, the conventional representation of Fig. 24 would be objectionable, and the V's only should be shown, as in Fig. 25. These may be drawn free-hand, but care should be used to prevent a ragged appearance.

Fig. 26 illustrates the tapped hole in section; and, as these illustrations are for right-hand threads only,

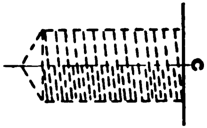


Fig. 24.

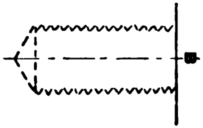


Fig. 25.

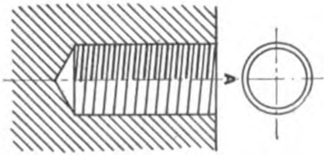


Fig. 26.

the threads will be inclined in the opposite direction to that of Fig. 24.

The end view of a tapped hole is frequently shown by two concentric circles, the outer of which is made equal in diameter to that of the thread.

When a tapped hole is extended beyond the end of the screw, or bolt, as in Fig. 28, it is better to omit the threads in this portion, unless the conventional representation of Fig. 27 be used.

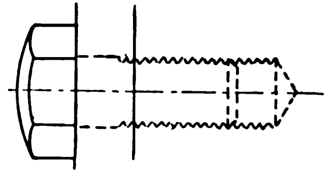


Fig. 27.

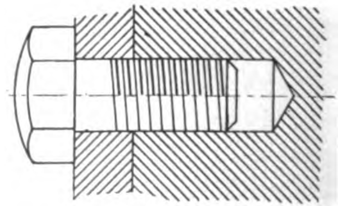


Fig. 28.

CHAPTER II.

GENERAL RULES FOR THE MAKING OF A WORKING DRAWING.

INTRODUCTION.

11. **Technical Drawing** is a graphic language, and may best be studied by subjecting its use to laws similar to those governing other languages. Like others, it has its orthography, grammar, and literature. Its orthography, consisting of the various types of lines; its grammar, being the art of representing objects upon planes, and known as orthographic projection; and finally its literature, consisting of the practical application of these principles to the drawings which we are required to read and write. But in this, as in all languages, we cannot be governed entirely by laws, but must familiarize ourselves with the idioms and conventional methods of the day, remembering always that it is simply a medium for the expression of our thoughts.

A drawing fulfills its object only when it clearly sets forth the ideas to be expressed, and in nowise misleads the reader to whom it is especially addressed. If it fails to do this, it is a poor drawing, regardless of the fact that it may conform to all established laws, and be executed with the greatest precision and elegance. A drawing should be regarded as a business letter to the mechanic, and must first of all be brief, having as few lines and figures as possible. It must completely express the idea, omitting no lines or views necessary to attain this end. It must contain nothing that may mislead, even though it be to violate the laws of projection. The character of the drawing must be determined by the use to which it is put. If a free-hand sketch is sufficiently comprehensive, and will in every way serve the purpose of the finished drawing, it is a waste of labor to make the latter. On the other hand, no pains should be spared in the execution of the drawing if it will better express the designer's conception of the mechanism. No portion of such work should be carelessly done, even in the so-called off-hand sketch, or drawing. A sketch may consist of few lines and be comparatively rude, but it must not be thoughtlessly executed. Again, the draftsman must consider the class of mechanics to whom his drawing is addressed. He should anticipate their wants, and, to a certain extent, guard against mistakes which may arise from their ignorance. Experience alone will make a man proficient in the use of this graphic language, but a knowledge of the laws governing it will greatly facilitate its acquisition.

The development of machine drawing, during the last few years, has resulted in the introduction of many methods and technicalities which were not formerly required. The technical part of architectural drawing has never necessitated such rigid conformity to laws concerning the arrangement of views, methods of sectioning, figuring, and other details; and it is for this reason that many apparent innovations have necessarily been made upon the old established systems of drawing. No one change has caused more discussion than the rigid adherence to the representation of all objects in what is known as the third angle of projection, that is, the placing of the top view on the top of the sheet, the view of the right-hand on the right-hand of the sheet, etc.; in short, placing the view nearest to the face which it represents. But this has now passed the stage when the advantages to be derived by this method may be questioned, and to-day no well conducted drafting room will permit any other system to be used.

This treatise presupposes a knowledge of the use of instruments and the theory of orthographic projection. Its aim is to teach the more concise methods of graphically expressing mechanical ideas.

12. Classes of Drawings. The different types of drawing required for shop uses are as follows:—

THE GENERAL OR ASSEMBLED DRAWING. This consists of a representation of the complete machine, with all of its parts sustaining their proper relations to each other. This drawing may contain information suitable only for assembling the machine, and illustrating the general design; or it may also include some or all of the details of the machine. The drawing of the Tail Stock, PLATE 12, is of this type.

DETAIL DRAWINGS. These illustrate each piece separately, with all of the information necessary for its construction. This type is shown by PLATES 7 and 8. It is customary to devote one or more sheets to forgings, and others to castings, or when the parts are few in number they may be placed on a single sheet.

BOLT DRAWINGS. Where a great variety of bolts is used on a machine, a special drawing of them is required, or a BOLT LIST may be prepared which shall enumerate the sizes, type, and number of each.

MOTION DIAGRAM. This type would be used only in complicated machinery comprising a number of mechanical motions more or less complicated. Such a drawing would instruct concerning the relation of important centers, direction of motion, relative velocity of shaft, etc.

13. The Lay-out of the Drawing. The size of paper used for the drawing is usually determined by certain fixed standards peculiar to each shop and largely dependent on the uses for which the drawings are designed. For the problems of this book, the sizes of 10×14 and 14×20 inches are recommended; but nearly all of the work may be drawn on the smaller size. These dimensions are for the margin line, the size of the paper being as much greater as may seem suitable. From one-half to one inch margin is sufficient. Having put down the paper and ruled the margin, obtain a "lay-out" of the pieces to be represented. This consists in the making of a rude sketch of the various parts and views to be put on the drawing, so that ample room shall be provided for each piece, and the whole be symmetrically arranged. This operation is usually neglected by students, and inevitably leads to trouble, and the loss of much more time than would be required for the preliminary sketch. Where a number of details are to be put on a drawing, as shown on PLATE 8, provision must be made for the proper marking of each piece, as well as the necessary figure lines. If the detail is of a small piece, like some of the screws on this plate, much more space should be allowed than would be sufficient for the piece itself, as the title alone may require more space than the drawing of the piece. If provision for each part, and the necessary views, be not made before the drawing is begun, the draftsman may discover, when it is too late to rectify the mistake, that some piece has been omitted, thus requiring an entire sheet to be devoted to this piece, or the re-drawing of the whole.

14. Number and Arrangement of Views. This discussion of the arrangement of a sheet leads to the consideration of the number and arrangement of views. The only rule for guidance in this matter, is to draw as few views as shall be consistent with the interpretation of the idea, but enough to accomplish this fully. In the valve drawing, PLATE 3, one view would suffice for the complete representation of the object, two being shown here to simplify the problem for the student. In PLATE 9, two views are barely sufficient for the ready reading of the drawing. The character of the view has also much to do with the number of views required; thus, a sectional representation will frequently give more information than two outside, or full, views.

The views should bear such relation to each other as that already prescribed for the orthographic projection of objects in the third angle, the top view on the top of the sheet, the view of the right side of the object to the right of the sheet, etc. A good rule to observe for attaining this end is to place the view nearest the face represented.

In the making of a general drawing which is to be used for assembling only, omit as much detail as possible.

Parts which may be well represented on one view need not necessarily appear on the other views.

Draw nothing that may mislead or that does not assist in conveying the idea to be expressed.

When a written note will serve the making of a second view, do not hesitate to insert it.

In general, show mechanism in its working position, with the parts sustaining their proper relations to each other. Thus, in drawing a valve, let it be either wide open, or closed. In showing a steam cylinder, draw the piston at extreme end of stroke, and the valve in its proper relation to the piston.

15. Scales to be Used. The scale of a drawing is usually dependent on the size of sheet and the number of views. These being determined, use the largest possible scale. Those commonly employed are: Full size, Half size, Quarter size (3 inches = 1 foot), Eighth size ($1\frac{1}{2}$ inches = 1 foot). The scale of 2 inches = 1 foot is much used in locomotive practice, but it is not to be commended for general use, as it requires special division of the scale.

The most convenient form of scale, and indeed the only kind that the author can recommend, is the flat boxwood scale with white edge, graduated alike on both edges. Such a scale, divided into sixteenths for its entire length, and thirty-seconds for the first inch from either end, is suitable for use on the full, half, quarter, and eighth size drawings. In using this form of scale for a half size drawing the reduction is easily made, since all dimensions are halved: but in the quarter size, a difficulty would be experienced if it were necessary to figure the fourth part of all dimensions before laying them off. This, however, may be obviated in the following manner, which is best illustrated by an example. Suppose it is required to lay off $19\frac{7}{8}$ inches. Remembering that one-quarter of an inch of the scale represents one inch, lay off as many quarters as there are inches required, and since one thirty-second of the scale represents one-eighth of an inch, add seven of these divisions to the amount already measured. In short, it is using the scale as though each quarter of an inch was marked as an inch in the same manner as the regular quarter-scale division. The same method may also be applied to the eighth scale. But if the ordinary graduation for a quarter or eighth size be desired, let it be on a scale separated from all other graduations. The ordinary triangular scale, with its numerous graduations and awkward shape, is probably the worst form of scale that was ever devised, especially when made of steel. The draftsman who has any consideration for his eyes will never use a steel scale for general work.

16. Method of Penciling the Drawing. Locate main center lines according to lay-out sketch, and begin to draw the view which best illustrates the object.

Next locate leading lines and surfaces. If the subject be the head-stock of a lathe, draw the spindle, fix the position of bearings and pulleys, and then proceed with the drawing of the casting. If a stub-end drawing is required, as in PLATE 5, lay off the dimensions for the principal lines in much the same order as indicated by the letters alphabetically arranged. First, the diameter and length of the box, A, and B. Then the position of end of rod C, depth of rod G, keys and key ways, intersections, etc.

Omit minor details until all else is finished. If a bolt, key, spring, curve of intersection, or any other such detail occurs, its position may be marked, but the drawing of it should be deferred until all else is proved correct.

Do not complete the views separately, but having one well begun, commence the drawing of others. In this manner errors are more readily detected, the drawing of each view becoming a check to the others.

Ink no part of a drawing until the penciling be complete. In a complicated drawing, students are often tempted to ink a view, or part of a view, which they feel confident to be correct, and before quite finishing the drawing. This should never be done.

17. Method of Inking. The order to be observed in the finishing of a drawing is as follows: Ink all circles and circular arcs, beginning with the smallest. This includes all fillets and rounding of edges. If shade lines are used, shade each arc at the time of inking it. It will be observed then, that the width for both fine and heavy lines is determined by the shading of the first circular arc. Do not use too fine a line, remembering always that the drawing must be distinct even after much use, and possible abuse. Next, ink all other curved lines, such as lines of intersection, etc.

Finally, ink all fine lines, both full and dotted, beginning with the horizontal lines at the top of the drawing, then ink the vertical lines from left to right, after which all inclined lines. Lastly ink the heavy, or shade lines, in the same order.

Section lines should not be drawn until the figuring is completed.

18. **Shade Lines.** By some draftsmen the use of shade lines is condemned, while others consider a drawing as incomplete without them. Both err in adopting either system to the exclusion of the other; for while shade lines may be useless on many drawings, there are others which would be incomplete without them. The draftsman must decide the matter for each drawing which he makes, always using them when they may assist in the reading of the drawing, but otherwise omitting them.

The only practical direction that may be given for the method of using them is to shade the right-hand and lower edges of all surfaces, remembering that in the case of contact between surfaces, the line represents the surface nearest the observer. Where the surfaces are flush, as is the case between the stub-end of the connecting rod and the strap, PLATE 5, the line must be fine. Never shade the intersecting lines between visible surfaces of the same piece, as illustrated by the division line of the faces of a bolt-head. Shade the lower right-hand quadrant of outside circles and the upper left-hand quadrant of inside circles. Do not permit the shade line to encroach on the surface which it bounds.

Cylindrical surfaces are frequently illustrated by fine lines only, when shade lines are used on other surfaces. This method is especially adapted to the illustration of a complex piece having an insufficient number of views or lacking in detail. PLATE 9 will be found to illustrate this method.

19. Line Shading. PLATE 18. It is often necessary to express the character of a surface more clearly than would be done by the simple outline, or by the use of shade lines. This is ordinarily accomplished by the use of line shading. PLATE 18 illustrates the method of shading the more common surfaces. In studying these methods, and in applying them to the practical drawing, it should be observed that the best effects are frequently produced by the fewest lines; and the more we are able to reduce the number of lines of all types, the better the drawing. By the system here shown, much of the cylindrical and conical shading might to advantage be done by a section liner * (Fig. 30), which in the case of large surfaces would insure more regular work. In shading large cylindrical surfaces such as Fig. 1, PLATE 18, use only fine lines for the upper portion. Increase the space between the lines quite rapidly, and stop at about one-half of the radius from the top. The shading of the lower part may be begun at a distance of about one quarter of the radius from the center. These lines may be spaced equally, although the appearance is somewhat improved by increasing the space for the first two or three lines. The cylindrical effect is produced by increasing the width of the lines until near the bottom, when they are slightly decreased in width; but this latter is not necessary save in cylinders of large diameter. Fig. 4 illustrates the section of a cylinder, which being a concave surface, necessitates the drawing of the darker shade lines at the top, but in other respects the method of drawing is the same.

* For a description of this instrument and the method of operating it see page 27.

In the shading of small cylinders the effect is often improved by shading the lower side only. Compare Fig. 3 with the shaft of Fig. 5.

Bell-shaped surfaces are frequently shaded as in Fig. 2; but that of Fig. 3 involves no circular arcs, and for small pieces is equally good. Fig. 8 represents a cone shaded by parallel lines in a manner similar to the cylinder. The usual method of doing this, by drawing all of the shade lines radiating from the vertex, is very difficult, requires more lines, and rarely looks as well.

The pipe shown in Fig. 7 illustrates the method of grading the lines so that the upper and left-hand portion shall represent the illuminated parts. Had the bend been to the right, the shading would have been more simple. The conical portion of the pipe flange shows yet another method that may often be used to advantage. The system used for the shading of the sphere, Fig. 6, will be apparent from the illustration.

It is rarely necessary to shade plane surfaces, and it should be avoided when possible. When necessary to emphasize the fact that a plane is inclined to that of the paper, the method of Fig. 9 may be used.

Fig. 29, page 25, illustrates a method for representing knurled surfaces. The angle of the cross lines must be varied to conform to the ratio of diameter to length of surface, for it will be observed that no change is made in the spacing until a series of lines has been drawn from A to B. The spacing in the cut is slightly exaggerated to better illustrate the method.

20. The Title. The title of a drawing should always be placed in the lower right-hand corner of the sheet, and should designate, first, the name of the mechanism; second, the name of the special detail; third, the scale; fourth, the date, which is always that of the finishing of the drawing. The draftsman's name or initials should be printed in the extreme corner. Besides this, such data as the "time number," the number of drawings belonging to this special machine, and other data may be given; but the information essential to every drawing is that given above.

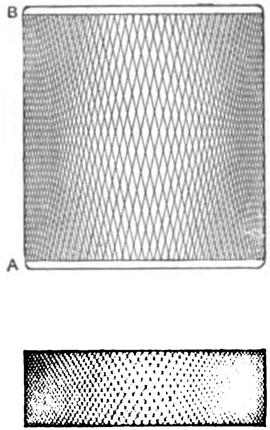


Fig. 29

The student must decide for himself concerning the character of type to be used. Several styles are illustrated in the plates. That most easily acquired is shown in PLATE 9, but it is not so clear as those of PLATES 3 and 7. PLATE 10 illustrates a most excellent style, but rather difficult to execute well. The round writing of PLATE 11 is much used; but it comprises many objectionable forms of letters, and the figures are too indistinct to be used on the dimension lines. Whatever style may be adopted, it should be adhered to until it can be rapidly written, and always without mechanical aid.

In the final cleaning of the sheet, it should be borne in mind that many of the auxiliary lines used as construction lines may be useful to the pattern maker, or possibly to the draftsman, at some later day. Thus it is often well to leave some of these lines on the drawing, even though it may present a less neat appearance.

CHAPTER III.

SECTIONAL VIEWS.

21. **Use of a Section.** For the complete representation of mechanism, it is frequently necessary to make use of a section in order that some details which would otherwise be hidden may be shown in full. The sectional view is a representation of the object after it has been cut by an imaginary plane. When possible, such a view should be used instead of introducing numerous dotted lines, as the latter tend to produce confusion. There are several conventional methods of representing the surface of an object when cut by a plane. That most commonly used, and for most purposes the best, consists of parallel lines, usually drawn at an angle of 45° across the cut surface. By changing the direction of these lines a clear distinction may be produced between the parts of different pieces which may be in contact, and by varying the character of the lines a difference in material may be indicated. PLATE 12 is an excellent example of the use of a section.

22. **Section Liners.** The regulating of the space between the lines of a sectional view is frequently done by the eye, but it may be more easily and rapidly accomplished by the use of a section liner. This is an instrument by means of which the triangle is made to move through equal spaces determined by a gauge, and thus avoiding the care and time usually required for the performing of this operation by the eye. Unfortunately, however, most of the section liners to be found are complicated and unsuitable for the purpose. No more simple or effective tool

has been designed for this use than that shown by Fig. 30, which consists of a strip of wood not over an eighth of an inch thick, having parallel edges, and provided with a stop on either end, one of which is adjustable. The only care necessary to be observed is in keeping the edges of the triangle and slide together; but if the edge of the latter is placed against the blade of a T square, this difficulty is partially overcome. The method of operating, which scarcely requires explanation, is as follows: having drawn a line by the triangle, in the position shown, by means of the second finger push the triangle against stop B while holding the slide firm with the first finger. Next, while holding the triangle fast with the second finger, move the slide until stop A touches the triangle, then draw a second line, and so continue the ruling. Of course practice is required to manipulate the two pieces with ease and rapidity, but the saving of the otherwise necessary strain to the eyes fully compensates for this.

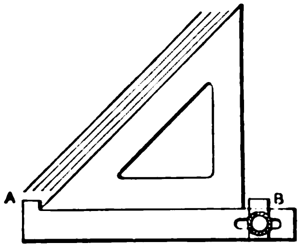


Fig. 30

23. Notation for Section Lining. Plate 17 illustrates the various types of section lines available for the representation of different materials. Save in the case of cast-iron, Fig. 1, there is no general agreement among draftsmen as to the material which each type of lining shall designate. Such a standard was proposed to the American Society of Mechanical Engineers,* but fortunately failed of adoption. It would only have added one more complication to the intricacies of modern machine drawing, and made a misunderstanding possible. If the slightest doubt as to the nature of the material represented is likely to occur, write

* Transactions of the A. S. of M. E., Vol. IX., page 107.

the name of the material on the section. No type of sectioning should be used that involves the making of two widths of lines. Dotted lines should be used sparingly, and types shown by Figs. 4 and 10 are still less desirable.

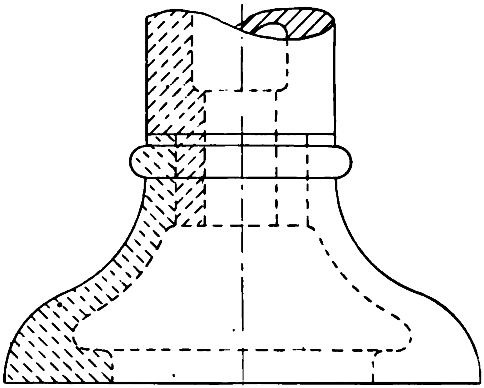


Fig. 31.

In the illustrations of this book the following notation has been used for section lines. Fig. 1 represents cast-iron. Fig. 2, wrought-iron and steel. Fig. 3, brass, bronze, etc. Fig. 4, Babbitt's metal or other lining metals. Fig. 6, brick. Fig. 7, wood, across and with the grain. Fig. 8, stone. Fig. 9 is used to section a surface which is invisible. Fig. 5 is often used to produce a sharp contrast with other sections, and frequently employed on Patent Office work, and for illustrations where figures and figure lines are omitted. It is also used to represent insulating material in connection with electrical apparatus.

Of course many other types may be devised, but it rarely occurs that the variety here represented will not suffice. Care should be exercised in choosing the spacing for section lines that they be not too fine. No rule can be given for the distance, which would be almost entirely dependent on the size of the section represented. It is well to draw a few lines on a waste piece of paper so as to judge of the spacing before ruling the section.

24. Dotted Sections. In some cases it is necessary to represent a piece of mechanism by a full, or external view, when a section is also required to explain some detail of it. Instead of making a separate sectional view, it may often suffice to dot the obscure section, either by the method shown in Fig. 31, one-half of which shows the section by dotted lines, while the other half represents the section by a dotted outline only; or by that of Fig. 32, in which the dotted outline is emphasized by a series of dashes. This second method may be employed to advantage when penciling a somewhat complicated drawing which may, or may not, be shown in section when inked. Thus, in the representation of the Tail Stock of a lathe, PLATE 12, the lines of the penciled drawing would be much confused if the section lines were to be omitted until the inking were done. It is desirable, therefore, that they be indicated in pencil after the manner of Fig. 32, but this should be so carefully and lightly sketched that the erasing of them will be unnecessary. The section lines should *never* be ruled in pencil.

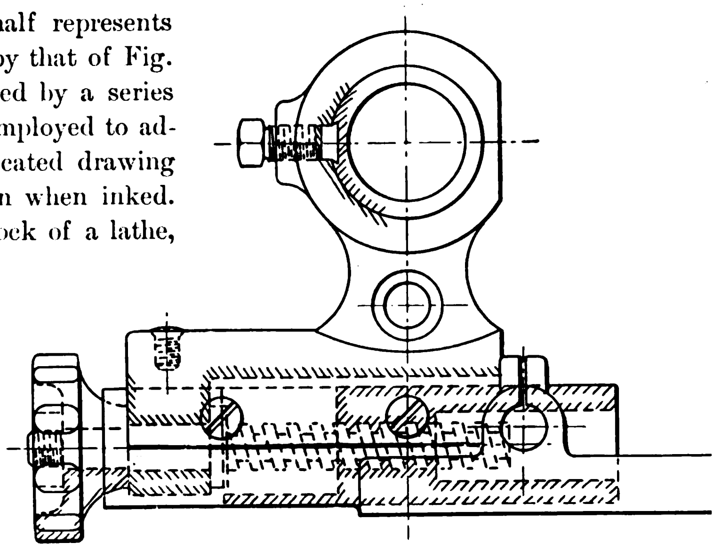


Fig. 32.

25. Colored Sections. It is unfortunate that reproductive processes, such as blue-printing, make the use of color for sectioning impracticable. It is in every respect the best method of representing them; for by varying the shade, adjoining pieces of like material may be

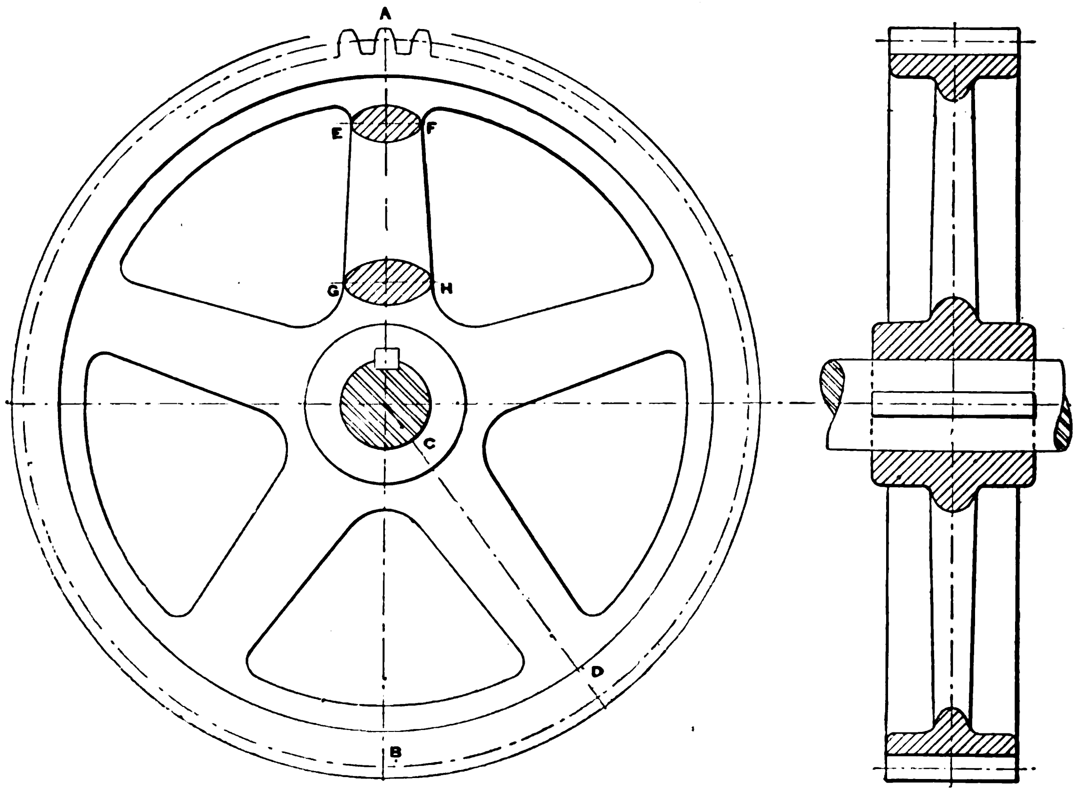


Fig. 33.

clearly shown, and by changing the color the character of the metal may be expressed. The time required to perform the work is also much lessened. Where the system of tracing a drawing is still employed, this method may be used instead of section lining, as is already done in many locomotive works where the tracing, instead of the drawing, is placed on file. The practice of sending to the shop a drawing, instead of a tracing or blue print, is one to be commended, as the best copy is then placed in the hands of the man who finds the most difficulty in reading a drawing.

When colored inks are used for section lining, the metal may be designated by the color of the line instead of by the character of the section line. Black is always used for cast-iron; Prussian blue for wrought-iron and steel; yellow ochre, or Indian yellow, for brass (a very little carmine added to the yellows will give more body to them), burnt sienna and burnt umber for wood, and sometimes for leather.

26. Choice of Cutting Planes. In representing an object in section, great pains should be taken in choosing the position of the cutting plane so as to enable all details requiring explanation to be seen in the clearest manner. As this is one of the most important subjects in connection with the art of technical graphic expression, the student should make a careful study of all the drawings relating thereto, and carefully observe the following general rules:

1. PORTIONS OF THE OBJECT LYING BEYOND THE CUTTING PLANE NEED NOT BE SHOWN ON THE SECTIONAL VIEW unless it may be thought desirable. In Fig. 35, page 33, the flange bolts lying beyond the plane are not shown, since it would only add to the labor of drawing, and produce confusion as well.

In dotted sections this rule is generally observed, while in full sections of a simple char-

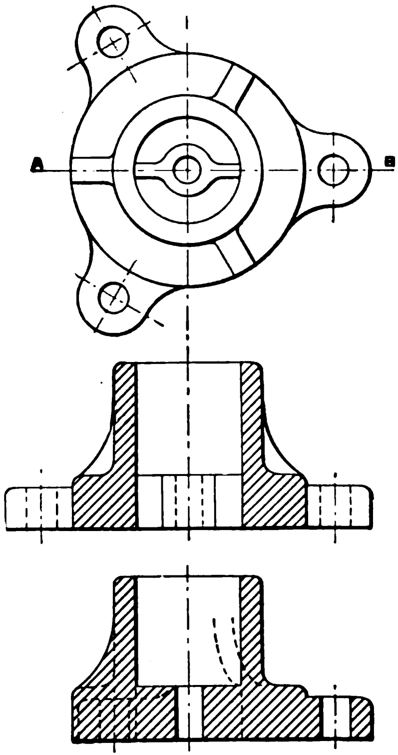


Fig. 34.

acter, like that of the Check Valve, PLATE 2, it is common to draw the lines which are visible beyond the section.

2. IT IS NOT NECESSARY TO SECTION ALL THAT LIES WITHIN THE CUTTING PLANE. In the sectional view of Fig. 33, page 30, the shaft, arm, and tooth are shown in full, although they properly belong in the plane of the section. Again, in the sectional view of the Connecting Rod End, PLATE 5, the top view represents a section on a horizontal plane passing through the center of the rod; but only the boxes and end of the strap are shown in section, because a section of the rod would add nothing to the clearness of the drawing. In general, do not section such details as a shaft, key, bolt, gear tooth, rib, or arm of a wheel. These cases are also illustrated under rule 4.

3. THE PLANE OF THE SECTION NEED NOT BE CONTINUOUS. The sectional view of the Tail Stock, PLATE 12, center view, is a section on planes A B and C D, which are indicated on the right-hand view. This enables one to save the drawing of an extra view, and produces no confusion in the drawing. Indeed, the practice is so common that the note concerning the planes on which the section is made would usually be omitted.

4. A SECTION OF A SYMMETRICAL PIECE SHOULD BE

SUGGESTIVE OF SYMMETRY. Fig. 34 illustrates a cylindrical piece with hub, ears, and ribs. Two sectional views are shown, the upper being the conventional and proper representation, and the lower a strict conformity to the appearance which would be made by a plane, A B, passing directly through the center. By the first section we immediately receive the impression of a cylindrical piece with a flange, having certain hubs and ribs attached thereto. In the second all is confusion, and it conveys no idea of a symmetrical piece. Fig. 33, page 30, is a correct sectional and face view of a gear; but although the section is on A B, only the hub and rim are sectional. The key in the section is shown as though it were on the side, instead of on top of the shaft, so as not to destroy the symmetry of the hub.

Again, in the case of the stuffing-box gland, Fig. 35, the ears are better shown in full, if they are small in comparison with the diameter of the gland. The discretion of the draftsman must be used in showing the flange bolts, since they may be drawn in full, or dotted as in the figure; but in either case their true relation to the cylinder should be shown. To project

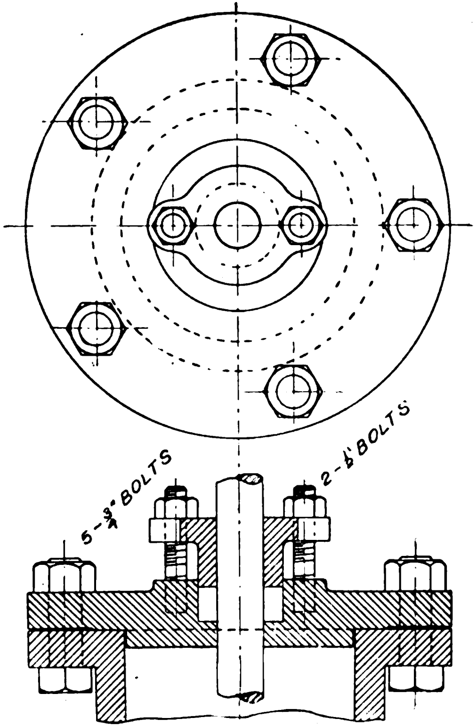


Fig. 35.

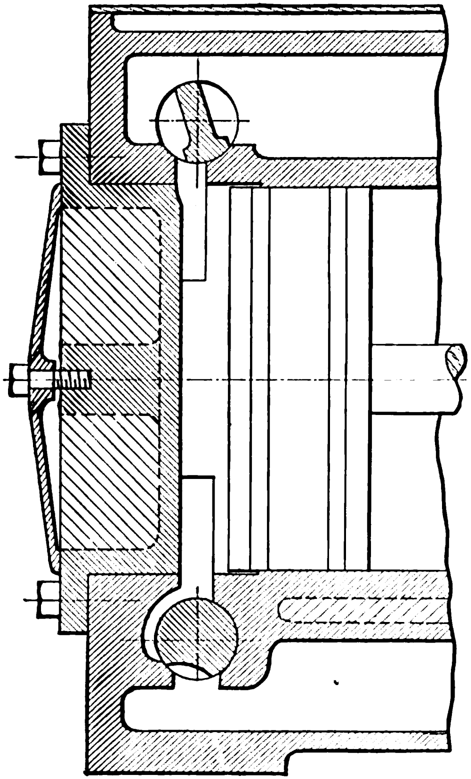


Fig. 36.

the bolt, shown at the left-hand, from its position as drawn in the top view, would add nothing to the information required, but rather tend to mislead.

PLATE 16 is designed to illustrate the foregoing rules and principles concerning sections. Fig. 1 is a free-hand sketch of an Armature Spider. Figs. 3 and 4 are face view and section of the same piece; and Fig. 2 is a section made by a plane similar to that of Fig. 4, but violating the rules for sectioning. The rough sketch is designed to assist the student to a quick comprehension of the several parts, and facilitate the reading of the drawing. The attention is first called to the difference between the sectional views of Figs. 2 and 4. Both are sections on the same plane, A B; but Fig. 2 is a literal interpretation, while Fig. 4 is a conventional one. From Fig. 4 we may see at a glance that there are two turned pieces, the hub C and flange D. These are united by ribs, or arms, E, having upon their end flanges, F, the details of which can only be studied from the front view. The section of Fig. 2 confuses the details by representing all the parts in one section outlined by dotted lines only.

In Fig. 4 it will be observed that the arms are shown on both sides of the center alike, as though there were an even number. The same method was employed in the drawing of a gear, Fig. 33, page 30, and is preferable to the showing of a foreshortened arm, which otherwise would be necessary.

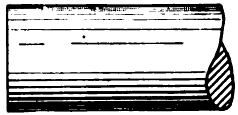


Fig. 37.

Also note that the keyways in hub and arm of Fig. 4 are dotted, while those of Fig. 2, being in full, give a false idea as to the diameters.

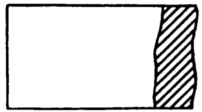


Fig. 38.

An excellent method for distinguishing the section of a rib from the general section is shown by Fig. 36, which is a vertical section through a steam cylinder. The ribs of the cylinder head are easily distinguished from the flanges by using a coarser section line for the former. Similarly the web joining the barrel of the cylinder with the exhaust chest is clearly separated from the general section. In using this type of sectioning, omit the drawing of every other section line on the rib or arm.

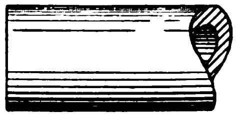


Fig. 39.

27. Broken Sections. When a portion of a rod, bar, pipe, or other symmetrical piece is shown as broken, the section should be suggestive of the shape. Fig. 37 represents a cylindrical rod. Fig. 38, a bar of rectangular section. Fig. 39, a pipe. Fig. 40, a rod of wood. The outlines of these sections may be drawn with an ordinary pen; but the lines should not be jagged save in the representation of wood, as in Fig. 40.

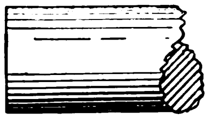


Fig. 40.

It is quite common to show the section made by a plane at right angles to a view upon the view itself. The sections of the gear arm, Fig. 33, page 30, made by the planes E F and G H, illustrate this.

CHAPTER IV.

FIGURING AND SKETCHING.

28. **Figuring.** After the inking of a drawing is completed, and before the section lines are drawn, the figure lines are required to be put on. This is the most important part of the making of a drawing, and requires the greatest care and most experience. Unfortunately, at this stage the student, and not unfrequently the draftsman, becomes wearied with his work, and the subsequent operations are too often hurriedly and carelessly performed. While it may frequently be necessary to make haste in the figuring of a drawing, it must never be hurriedly done; and the most scrupulous care should be exercised in the drawing of every dimension line, and the making and checking of every figure.

As an illustration of the method to be employed in the figuring of a drawing, consider the case of the stub-end, PLATE 5. Suppose the drawing to be in readiness to figure. We have first to consider the class of mechanics for whom this drawing is made. In general, the needs of the pattern-maker are first to be thought of; but inasmuch as a pattern serves for many duplicate pieces, the dimensions of unfinished parts may usually be omitted. In such cases the draftsman will furnish the pattern-maker with a sketch, or tracing, having the necessary figures. This will save the crowding of the drawing with figures which, when once used, are not likely to be required again. If the drawing is to be sent to a distance, where detailed information may not be readily obtained from the draftsman, these figures must not be omitted from the drawing.

The requirements of the forge shop are usually met by sketches specially prepared for that department, but the figures given for the machinist will ordinarily suffice for the smith. In giving dimensions for either pattern-maker or smith, specify finished sizes only, leaving the amount of shrink or finish required to his judgment. In the case cited, figures for the machinist only have been given.

It is customary to draw the figure lines in blue ink and the center lines in carmine; but this order may be reversed, or one color used for both. If colors are used for these lines they are better drawn full: otherwise indicate the center lines by dot and dash, and the dimension lines by dashes. Begin by drawing the dimension lines necessary for locating the center lines and working faces. In the connecting rod the diameter and length of the pin, or box for same, is the first consideration. Next locate end of rod C, after which completely figure that part by dimension lines marked D, E, F, G, H, I, J, K, L. Then consider the gib and key O, P, R, S, etc. Next, the set-screw and strap, and finally, figure the boxes, if figures given for other parts do not already include these.

The dimension lines being completed, the center lines should next be drawn, after which the witness marks (or arrow points) and figures are to be made. The drawing should then be cleaned, and finally section lined.

In figuring detailed drawings like PLATES 7 and 8, great care is necessary to avoid mistakes, and the draftsman will always do well to examine carefully the figures on all parts that fit together. Thus the diameter and length of the bearings must accord with the dimensions for the spindle fitting the same.

The dimensions on a drawing should always indicate the full size, and are independent of the scale to which the drawing may be made. In connection with this it is well to note that the scale dimensions of a drawing should never be spoken of, as great confusion would arise from it. To illustrate: let us suppose a shaft eight inches in diameter to be drawn one-quarter size. It would then measure two inches, but should never be spoken or thought of as other than eight inches, the real diameter; and if the draftsman was asked to add an inch to the diameter, it is his business to see that the proper increase is made according to the scale which he may be using. In this case he would have to add one-quarter of an inch to the diameter as drawn, but it must always be spoken of as one inch.

29. Rules to be observed in figuring Drawings.

1. Dimension and witness lines should be made in blue ink, center lines in carmine, arrow points and figures in black. Or, if black ink only be used, dimension and witness lines may be in dashes, and center lines in dot and dash.

2. Dimension lines may be continuous or broken, as $\longleftrightarrow$ $\longleftarrow 4\frac{1}{4} \longrightarrow$ The latter form is of advantage only in indicating the position to be occupied by the figure.

3. Center lines should never be used as dimension lines.

4. Dimension lines should not be too close to lines of the object.

5. Make arrow point, or witness point, thus $\longleftarrow$, and never thus $\longleftarrow$.

6. Make the arrow points exactly touch the lines to which the dimensions are given.

7. Give dimensions over all, as well as sub-dimensions.

8. Exercise great care in the making of figures, adopting some plain type, and as far as possible, using one size.

9. Separate the numerator and denominator of a fraction by a horizontal line thus, $\frac{5}{8}$, never using an inclined line for this purpose. (The horizontal line may be omitted, by writing the figures above and below the dimension line, as $\xleftrightarrow[4]{3}$.)

10. Write the figures in line with the dimension line, and never inclined or perpendicular to it.

11. Figures should face bottom and right side of drawing.

12. If all dimensions are in inches, the inch mark ″ need not be used; but when feet and inches are to be represented, write as follows, 3 Ft. 6″, or if the foot mark ′ is used the figures should be separated thus, 3′ ⌣ 6″.

13. When using large and small dimensions on the same drawing, it is well to express all dimensions less than three feet in inches, and larger ones in feet and inches, thus 29″, 3′ ∼ 0″, 3 ∼ 5″.

14. First figure that view which illustrates most completely the details of the object.

15. In general, do not repeat figures.

16. Figure to center lines and faced surfaces.

17. Figure diameter of circle, in preference to radius, and draw the line at an angle.

18. If the radius be used instead of diameter, locate clearly, as $\xleftarrow{\text{2″ RAD.}}$, drawing the dimension line toward the center from which the arc was described.

19. Do not draw section lines across the figures.

20. In correcting a figure without altering the drawing, affix the word "make," which indicates a knowledge on the part of the draftsman of the existing discrepancy in the drawing.

30. Finding Dimensions. The figure for a special part may be more readily found by first looking for the arrow point touching one of the lines limiting this part. If the point is not to be found on one view, seek for it on other views, and, failing to find it, the figure may be declared missing. To illustrate, suppose the combined width of gib and key of the connecting rod, PLATE 5, is required. Beginning at the top of the key we find the first arrow point leads to the dimension W, the second to the dimension E, the third to the required dimension O. This method will greatly facilitate the finding of figures on complicated drawings, and enable the workman to determine quickly whether the figure be missing.

31. Method of indicating Surfaces which are to be finished. Although this does not properly come under the head of the subject of figuring, yet it often has to be considered at the same time. On many drawings in all shops it is unnecessary to give this information, and in many shops it is never given. But where drawings are elaborately detailed and the work of construction much subdivided, it is often necessary to indicate this on the drawing. It may be done by writing the word "finish," or simply the letter "f," across the line representing the surface to be finished. Or a colored ink may be used to draw a line parallel with the surface to be finished. This latter method is objectionable from the confusion caused by the increased number of lines, but may be used to advantage on blue prints by using carmine and soda water for the ink. This distinguishes the finish line from all others.

32. Technical Sketching. The ability to make a free-hand technical sketch of a piece of mechanism is of more importance to most mechanics than that of making the ordinary mechanical drawing with instruments. Unfortunately, however, it requires much more skill to do this, not because of the practice required for the clever handling of the pencil, but by reason of the difficulty in executing a drawing without the mechanical checks to errors of judgment in the representation; and also because of the necessity of a more concise expression of the idea than would be given in the drawing. Moreover, a thorough knowledge of projection and the principles of machine drawing are as requisite to technical sketching as to technical drawing. The enumeration of these difficulties is not for the purpose of discouraging the student, but rather to direct his energies toward gaining a mastery of the most efficient method of technical expression.

One of the most important functions of the sketch is in the development of a design. At such a time the engineer cannot resort to the more laborious process of instrumental drawing, but must rapidly express his thoughts by free-hand sketches. Some of these preliminary sketches may be as complete in the important details as the more elaborate drawing which the draftsman must finally make for shop use.

Practice in acquiring this invaluable art of rapidly and clearly expressing one's technical ideas may be acquired in several ways. That most to be commended is the practice of sketching directly from the object according to the method hereinafter explained. A perspective or isometric representation is often useful as a substitute for many views, or to more sharply define certain obscure details; but if the student is unfamiliar with these methods, the orthographic representation will suffice for all cases.

When it is not possible to obtain models from which to work, a good exercise will be found in a free-hand detailing of the parts of a finished drawing, after which the sketch may be tested by making the assembled drawing from it.

A most valuable training, both in sketching and in observation, may also be had from memory sketches. For this purpose choose some simple model or the drawing of a plain object, and, having carefully studied it, set it aside and make a free-hand drawing comprising two or three views.

In the making of all sketches, establish first the center lines and important details as would be done in the making of a drawing, and in general, proceed in a similar manner.

33. **Order to be observed in the Making of a Sketch.** First: Having separated the different parts of the machine, sketch each in detail, omitting nothing necessary to its complete representation. The same care must be used in the choice of views as is necessary in mechanical drawings, and when a portion of a view may be made to substitute the whole it should always be done. See PLATE 11. Use written notes whenever they may save the time of drawing. Complete the sketches of every part before putting on any dimension lines.

Second: Sketch all the necessary dimension lines with the arrow points, but do not figure the sketch. There are reasons for doing this. It insures a more thorough figuring of the drawing, as one is not diverted from the consideration of the dimensions wanted by the measuring of the pieces and writing of the figures; it is productive of neater work, since one is not required to handle the pieces which are likely to be coated with oil or covered by dust; it enables the work to be more rapidly and easily done, since it may be executed at the desk, without reference to the pieces save through the sketch. This will also involve a critical reading of the sketch, and serves as a check to errors of drawing.

Third: Obtain the figures for the dimension lines indicated on the sketch.

34. **Practical Suggestions.** The sketch and its dimensions should accurately represent the object illustrated. It does not follow, however, that the drawing subsequently made from this

sketch shall be a duplicate representation of the pieces sketched. Drawings made from existing mechanisms are intended to reproduce that which the machine was designed to be, rather than to copy the piece already constructed. If an attempt be made to suggest these alterations on the sketch, confusion is very likely to arise. It frequently happens that the dimension of a piece may be found to involve sixteenths or thirty-seconds of an inch when integers or halves or quarters would serve as well: thus, if the diameter of a flange was found to measure $12\frac{1}{16}$ inches, it would ordinarily be inferred that 12 inches was meant, although the former dimension should appear on the sketch.

Use one view if possible, and do not overcrowd the sketch with details.

Exercise such care in the making of the sketch as shall enable it to be readily used by any one familiar with the technique of drawing. The character of a sketch too frequently implies the supposition that it is intended solely for the draftsman who made it, and not unfrequently many details are omitted to be supplied by the memory. For the information which it is intended to convey, the sketch should be as complete as a drawing.

When practicable, it is well to sketch those parts which may be mechanically related, so that reference may be readily made from one to the other.

Sketch objects in their proper position, for it is better thus to suggest the true relation of the lines and surfaces, although the dimensions alone are to be relied on to determine them.

The center lines should always be drawn with care, and the position of dimension lines determined as in the case of a drawing, save that in the latter case more will be required. Figure each piece independent of others. Thus, in the case of a shaft and its bearings, the diameter will appear on each.

PLATES 13, 14, and 15 are good examples of the work required for technical sketching.

35. Sketch Books. Every draftsman should acquire the habit of preserving his sketches, especially those made in connection with the design of a machine, for it not unfrequently happens that an apparently valueless sketch which has been destroyed becomes necessary to the complete development of a detail, or invaluable as a matter of record. Two kinds of sketch books have become a part of the paraphernalia of the modern drafting room; one in which sketches, suggestive of various designs and alterations in machinery, are made, or filed; the other, a copy book in which may be preserved a copy of every sketch sent from the drafting room.

CHAPTER V.

EXAMPLES FOR PRACTICE.

THE plates accompanying these examples are not designed for problems only, but as illustrations to familiarize the student with varied types of drawing, and to enable him to obtain practice in the reading of drawings.

An excellent practice would be the careful study of PLATES 5, 16, and 10, with the end in view of understanding the meaning, and use, of every line and dimension. In this manner one may acquire greater familiarity with the principles already taught, and be better prepared for future work in drawing.

Problem 1, Plate 1. Assembled Drawing of a Locomotive Parallel Rod. The planning of this sheet is so simple as to require no sketch; but since the principles involved do not differ from those of the "lay-out" of the most complicated drawing, it is expedient that the student should perform this work. The size of the sheet within the margin line shall be 10×14 inches. Two views are required, and are best arranged as shown in the "lay-out" sketch. The scale of the drawing will be determined by the dimensions marked D, E, and F, the sum of which when drawn cannot be greater than 10 inches, and should be considerably less to allow for the title, which will require from $1\frac{1}{2}$ to 2 inches. The sum of the dimensions D, E, and F, according to the sketch is 12 inches, which prevents the use of a full-size scale, but makes the half-size possible, as it would require but 6 inches, leaving 4 inches for title, space between the views, and space at top. Having determined H, K, and L, so as to enable the drawing to present the most symmetrical appearance, the center lines may be drawn. It should previously have been observed that the length of the parallel rod is such as to preclude the possibility of drawing it even at half or quarter scale without illustrating the bar as broken, which may of course be done, leaving sufficient space on either end. The only section requiring to be shown is that of the rod, which may be drawn as suggested by the sketch. The practice to be derived from the use of shade lines on this drawing should not be neglected. For the purposes of study, it is well to draw the dimension lines in pencil, so that they may be well considered and changed if necessary, but in practice they should be drawn in ink at first. Figure the drawing so that the dimension of every detail may be obtained.

Problem 2, Plate 2. Assembled Drawing of a Boiler Check Valve. This is to be shown complete with the valve on its seat, the cap screwed down, and the coupling nut partly on. One view is quite sufficient for illustrating every detail, but it is desirable to draw a side view to obtain the practice. The principal view should be sectioned, and the character of the metal designated by the character, or color, of the section line. See that the dimensions are on the drawing before the sectioning be done.

Problem 3, Plate 3. Detailed Drawing for a 2-inch Globe Valve. All of the parts are to be shown separately, in like manner to those of PLATES 7 and 8, but on one sheet. The lay-out of this sheet will require a careful study, involving the consideration of the number and character of the views. Because two views of any of the parts are shown on the plate, it does not follow that the details should be similarly treated. Nuts and washers need not be separated from the bolts, spindles, or shafts to which they belong. See PLATE 15.

A more difficult but most excellent treatment of this problem would be the making of a free-hand detailed sketch of the valve, figuring the same completely. Then, putting aside the plate, make the assembled drawing from these sketches. Either of these methods will require much more time than may at first appear necessary, but to faithfully and accurately produce one such drawing is worth a dozen thoughtlessly executed.

Problem 4, Plates 4, 5, and 6. The Assembled Drawing of a Connecting Rod, the sketches for which are given on PLATE 6. The drawing will be made similar to that of PLATE 5. This is designed to be drawn on a 10×14 inch sheet, and it is evident that a full-sized representation is impossible, but the lay-out sketch will enable the scale to be determined. In obtaining the curve of intersection on the rod, do not draw a special end view, but use the method of Fig. 4, PLATE 4.

As this problem furnishes an excellent example of the intersection of surfaces, the following principles should be thoroughly mastered before attempting the drawing of the rod. The principles involved are applicable to many practical problems, and it is desirable that the student should make a careful study of each of the cases shown.

Fig. 2, PLATE 4, represents a cylinder terminating in a bell-shaped end, and because the surface may be generated by the motion of a line about an axis, it is known as a surface of revolution. The end view of this surface is shown as cut by four planes, A B, C D, A C, B D, parallel to the axis, and the appearance of the object after having been cut is shown by Fig. 1. The problem consists of finding the curve of intersection E F G, together with a similar curve on the upper surface which would be shown on another view.

Fig. 3 illustrates the same case without the line shading. Three views of the cylinder with its bell-shaped end are shown, but they are represented as cut by the planes A^s B^s and B^s D^s, producing the intersecting curves B^F G^F D^F and A^T H^T B^T which it is required to find. Since the points A^s B^s and D^s lie on the surface of the cylinder and at its intersection with the bell-shaped end, their projection on the other views must be at the points marked by the corresponding letters in these views. The limiting points H and G of the curve of intersection are readily determined by extending the lines B^F C^F and B^T C^T until they cut the curve at the points H^F and G^T. The top view of the point H^F must lie between A^T and B^T and directly over H^F. Similarly project G^T on to the front view at G^F. It remains only to determine the intermediate points in the curves. Pass any plane, K L, perpendicular to the axis; this will intersect the curved surface in a circle shown on the side view by O^s P^s M^s N^s; but this circle would be intersected by the plane A^s B^s and B^s D^s at the points O^s P^s M^s and N^s, and hence these points will be points common to the two surfaces, and therefore points of the curve of intersection. Projecting these points on to the front and top views will have determined two points in each curve. In like manner obtain other points.

The following practical application differs from the preceding only in that the curve of the bell-shaped piece is not located. Fig. 4 illustrates this case, and is the same stub-end as that shown in PLATE 5. In the sketch we shall have those dimensions given which are indicated by the figure lines of Fig. 4; but it will be seen that neither of the points H^F or G^T are given, and the position of the center X is unknown. As the curve of the bell-shaped piece is tangent to the neck of the rod, the diameter of which is given, it is only necessary to obtain one point in this curve to fix its position. This is to be determined by revolving the point B^F until it lies in the plane of the paper. To do this an end view will be required; but since economy in the use of lines is advisable, let the line B^F V represent the center line of this end view, and the rectangle B^F W Y V, the half end view of the stub-end. As W is the end view of the point B^F we may obtain its extreme distance from the axis, which may be laid off on the front view at R, thus determining the revolved position of B^F and the required point in the curve. Through this point, and tangent to the neck of the rod, with the given radius, describe the arcs representing the bell-shaped portion, observing that all of the centers must be in the same line X X. These arcs will determine the limiting points of the curves of intersection, and intermediate points may be found as in the preceding problem and as illustrated in this figure.

The method of penciling one view directly over another is commonly used when the view is to serve no other purpose than that of determining lines of intersection.

Fig. 5 illustrates a case in which the cutting plane is tangent to the diameter of the cylinder. Determine the curve from the dimensions given, using the side view only for the purpose of obtaining the curve of intersection, and in the manner illustrated in the preceding problem.

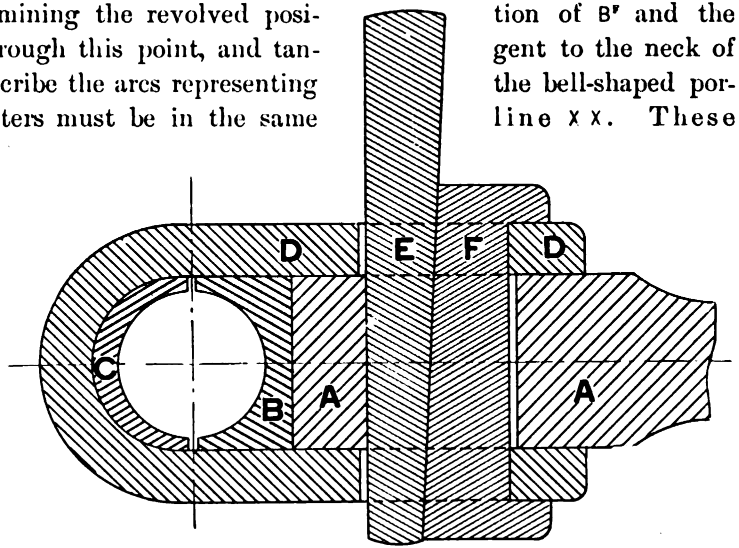


Fig. 41.

THE ACTION OF A GIB AND KEY to produce motion of the strap for taking up the wear in the boxes is illustrated by Fig. 41. A represents the stub-end, B and C the boxes, D the strap, E the key, and F the gib. The parts are shown in such relative position as would exist in a newly fitted connecting rod. The box B bears against the end of the rod, A, and is immovable, all of the motion due to the wear of the boxes being made by C. In order to move the box C toward B, the strap, D, must be made to move to the right. This is accomplished by driving down the taper key, E, so as to increase the distance between the parallel faces of gib and key; and since there can be no motion to the left, the gib is moved to the right, and with it the strap against which it bears.

Problem 5, Plate 9. Details of the Base for a Back Rest. Two views of a back rest for a milling machine are given, to draw the details of the base, illustrating it by three views. The representation given in the plate was chosen to show the use of a dotted section, and the advantages to be derived from the omission of shade lines on cylindrical surfaces. Without the use of these systems it would be very difficult to show all of the details by two views. The only detail omitted is that of the clearance curve cut from the base for the adjusting nut. In the front view this nut is shown in full section, save where it is concealed by the casting. The dotted section of the side view is that made by a plane through the center of the slide.

Of course it would be desirable to detail all of the parts of the back rest as well as the one specified.

Problem 6, Plates 7 and 8, (SEE ALSO FIG. 42). **The Assembled Drawing of a Screw Polishing Machine.** One view only is required for the drawing of this machine, and it may be drawn on a 10x14 inch sheet. Nearly all of the parts will have to be shown in section, and some of the minor details of the parts will have to be explained by notes, such as the slots in the Bearing Nuts, PLATE 7. The details for a leather washer and the oil feeder are shown in Fig. 42. Observe that the spring here shown is that detailed on PLATE 8, but must be shown as compressed when drawn in its proper relation to the other parts. After having determined the lay-out, begin the drawing by locating the center line, and position of bearings with relation to the casting, as given in Fig. 42. Then, without completing any of the details, determine the position of pulleys, collar, tail screw, etc. Be sure that proper provision has been made for taking up the wear of the boxes. In order to avoid confusion it may be found desirable to indicate the different pieces by sectioning them in pencil as directed on page 27.

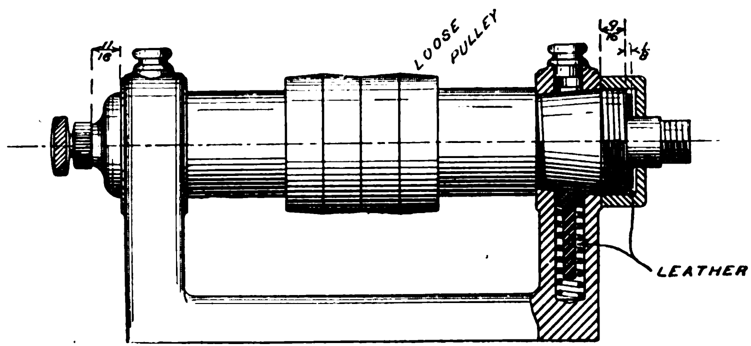


Fig. 42.

A good method of illustrating the degree of a taper is shown on the detail of the bearings, PLATE 8. This signifies an increase in the radius of one-tenth of an inch for every inch of length. If the taper is designated by figures without the lines, it is always questionable whether the increase is in the diameter or the radius. In practice, the taper would usually be designated by a number having reference to some standard used by the shop.

Problem 7, Plate 10. Detail of a Crosshead. The type here shown differs from the ordinary form of crosshead in being made in halves, the parts being united by four bolts which also serve to clamp the piston-rod to the crosshead, and to prevent any movement of the slide-gibs, other than that governed by the gib-screws. Three views of one-half of the crosshead will be required, the only difference between the halves being in the diameter of the hole for the crosshead pin, and the key for the same. A note will suffice to explain this difference; and if thought desirable, one of these holes may be shown in red. Two views of the slide-gib will be sufficient. The pin and screws are also to be detailed. The scale, and the size, number, and arrangement of the sheets, are left to the discretion of the student.

Problem 8, Plate 11. Assembled Drawing of a Crosshead. This is a crosshead designed for a 25 horse-power engine, and is very simple in construction. Two views will suffice for the representation. The end view may be drawn in full; and if not sufficiently clear, one-half of it may be shown in dotted section. It will be observed that the taper for the two ends of the pin is continuous, therefore it was necessary to give only the extreme diameters. The tapped hole in the crosshead pin is for an oiling device, not shown in the sketch.

Problem 9, Plate 12. Details for the Tail Stock of a 17 inch Lathe. Two drawings would be required for these details, one of the upper, and one of the lower casting, which should consist of three views each, and one of the forgings. The latter is the more valuable study, and will necessitate a careful reading of the entire drawing.

The lay-out sheet for the forgings will require much attention, but with proper care it is possible to draw all the parts full size on a 10×14 sheet. The following suggestions will assist the student in making the preliminary lay-out sketch. Arrange the details in five horizontal lines as follows: — First line, the Eccentric Clamp Shaft, shown in the section on A B C D. Draw two views. Second line, the Spindle and the Hand Wheel Handle. The spindle will have to be broken between the taper for the center and the brass nut, which latter need not be drawn. The taper for the spindle should be $\frac{1}{24}''$ in diameter for every inch of length, the outer diameter being $1\frac{5}{16}''$. Third line, the Center and Tail Screw. Make the former to fit the taper in Spindle. The tail screw will have to be broken in the thread, which is left hand, and square. Fourth line, the Side Screw and Spindle Clamp Screw. The former is clearly shown in the section on E F, but the diameters of the collar on the right hand end, and the washer on the left, are not given, it being left for the student to determine. Observe that these parts must clear the lower casting. This piece must be broken in the thread. The spindle clamp screw is well shown in the section on A B C D. Fifth line, the Clamp Screw, Shelf Screws, Spindle Nut Screw, and Spindle Key. Also leave space for title in right-hand lower corner.

See that all parts are completely and correctly represented and figured, that the number of each piece and the character of the metal be specified, and finally, make sure of the accuracy of all by a careful examination of every detail and the checking of the figures.

If the student is not already familiar with a lathe, he should inform himself concerning its construction, design, and management, by such means as he may have at his command. That most to be desired would be the knowledge gained directly from the working machine by that most valuable of all educational methods, observation.

Problem 10, Plates 13, 14, and 15. (ALSO SEE FIG. 43.) **Assembled Drawing of the Head Stock of a 16 Inch Lathe.** The representation required is that shown in Fig. 43, save that it must be more complete, involving the use of much sectioning. It must be figured for machinists only, therefore no figures for finished parts must be omitted. It would be well to draw this full size, although that would necessitate a very large sheet, and the possible

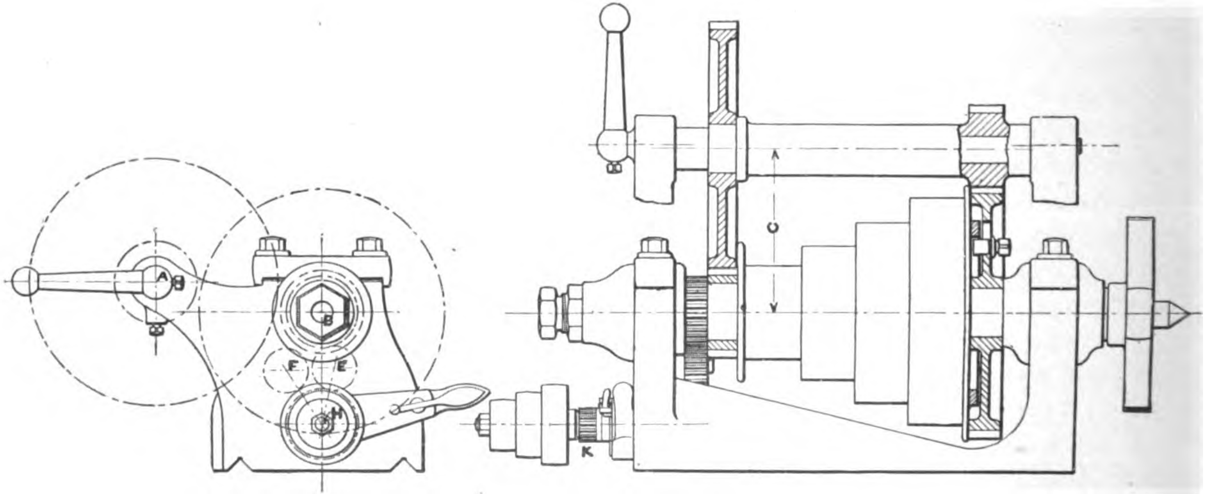


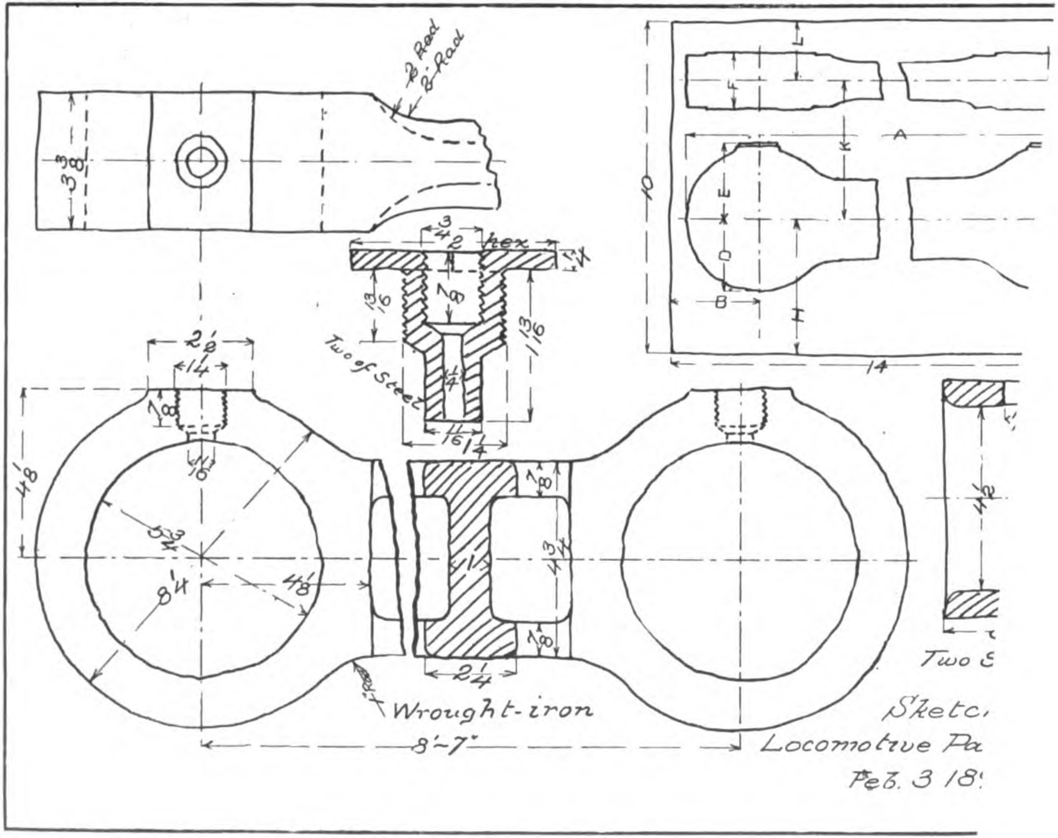
Fig. 43.

separation of the front and side views, each requiring a sheet. The sketches have been drawn to no scale, although the proportion of the various parts have been preserved where practicable. Small parts have necessarily been enlarged in order to make the drawing legible. PLATE 13 includes the main casting, together with the boxes and caps. The cone and coneheads are also here shown. PLATE 14 illustrates small castings and brass details with a few accompanying forgings. PLATE 15 is devoted to forgings and gears. By reference to Fig. 43, it will be observed that in the main view, the upper shaft, called the quill, is a revolved position of that shaft, the center of which is shown on the side view at A. If an attempt had been made to draw this in its proper position behind the main casting, it would have resulted in confusion, and would have required another view to illustrate the simple details shown in the figure. This method of illustrating a train of gears as though their shafts were all in one plane is an excellent device for detailing a system of gearing, showing the gears, shafts, distance between centers, and the actual or relative velocity of the several shafts. In connection with this, an end view should be shown, with the centers of the shafts in their relative positions and the pitch lines of the gears also drawn. When such a representation is made of several trains of mechanism operated by a single driving shaft, but performing different functions, the pitch lines of the different trains may to advantage be represented in different colors. Referring again to Fig. 43, it will be seen that the gears shown in the front view are shown in working contact, the distance between their centers, C, being equal to one-half the sum of their pitch diameters. But in the side view, these same gears are not drawn in contact but in their extreme position to the left. This lateral movement of the back-gear is accomplished by means of an eccentric quill shaft, as may be seen by PLATE 15. The intermediate gears, E F, are for changing the direction of the motion transmitted through the change-gear marked K, to the screw operating the carriage of the lathe, but not shown in the figure. The centers B E and H do not lie in the same plane; and since it would be desirable to represent them in the same sectional plane, when drawing the front view, it will be necessary to draw the shaft having its center at H at a different height in the front view, which would be rather objectionable, or to so change the diameters of gears E and H that the gear E could be shown in the plane of the other two. The error in the drawing made by using this latter method, which is the better of the two, will not be perceptible. The figures for the pitch diameter would of course be figured correctly.

As in the preceding problem, this study should be anticipated by first gaining a thorough knowledge of the lathe and its operation.

PLATE 1.

PLATE 1



Wrought-iron
Two of Steel
hex
8'-7"
Two S
Sketc
Locomotive Pa
Feb. 3 18

PLATE 3.

PLATE 3

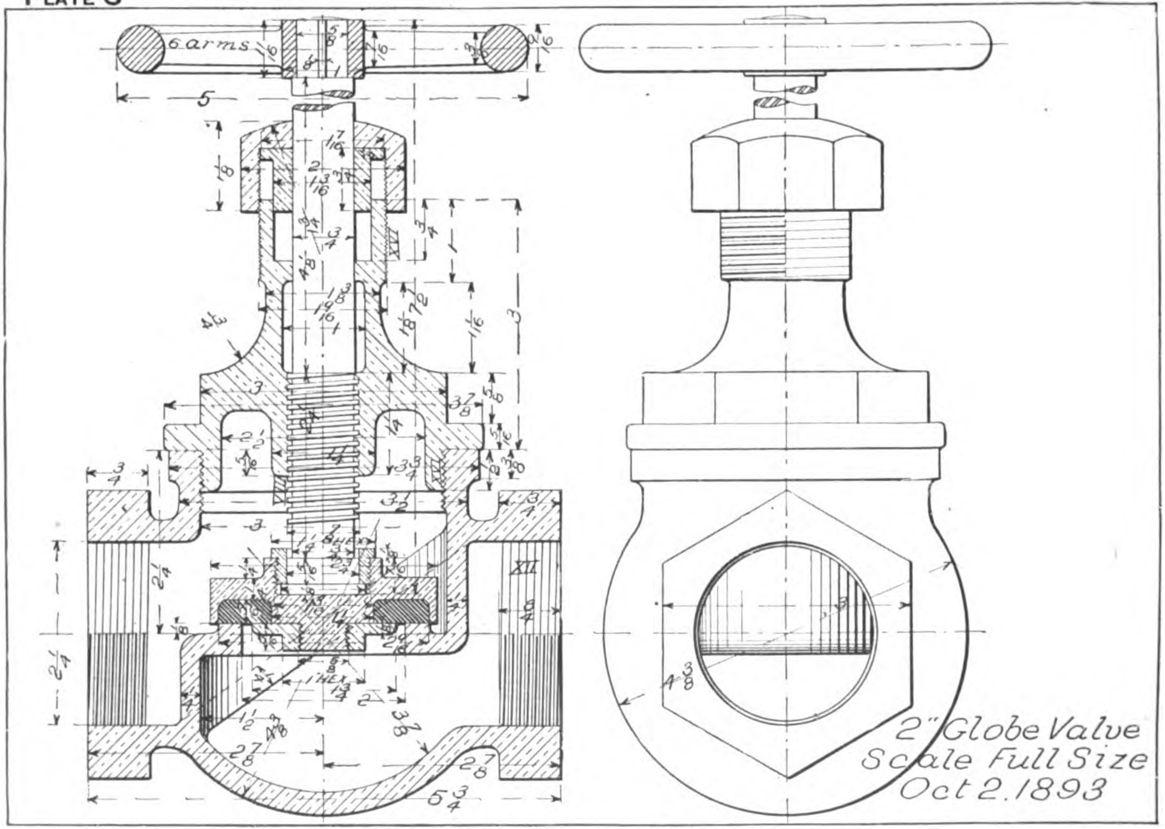


PLATE 5.

PLATE 5

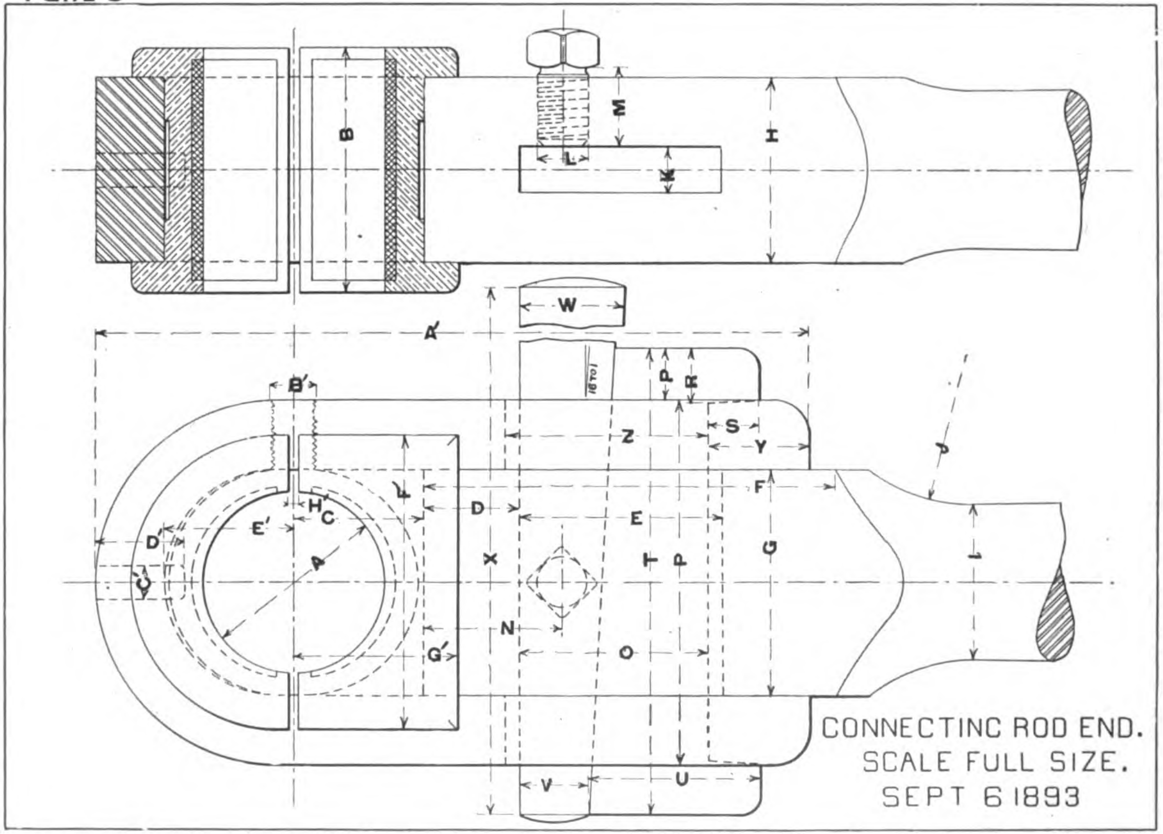


PLATE 7.

PLATE 7

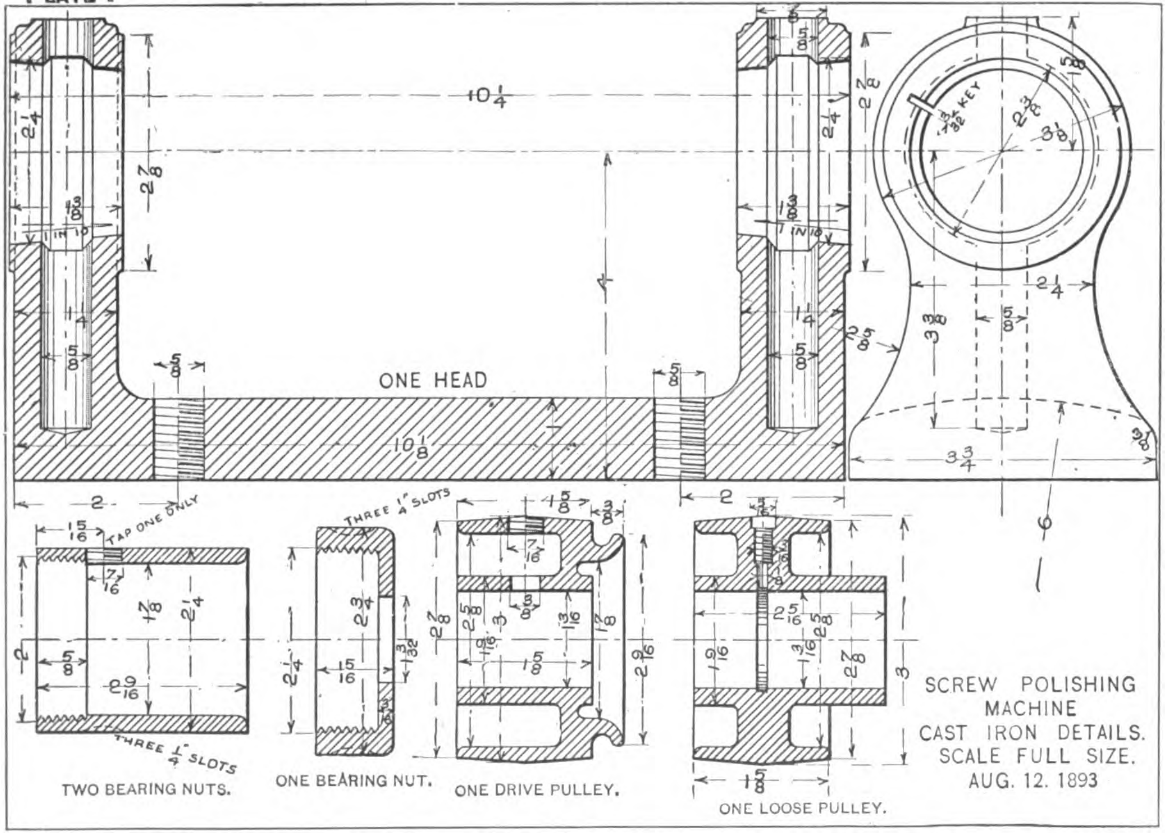

ONE HEAD
TWO BEARING NUTS.
ONE BEARING NUT.
ONE DRIVE PULLEY.
ONE LOOSE PULLEY.
SCREW POLISHING
MACHINE
CAST IRON DETAILS.
SCALE FULL SIZE.
AUG. 12. 1893

PLATE 9.

PLATE 9

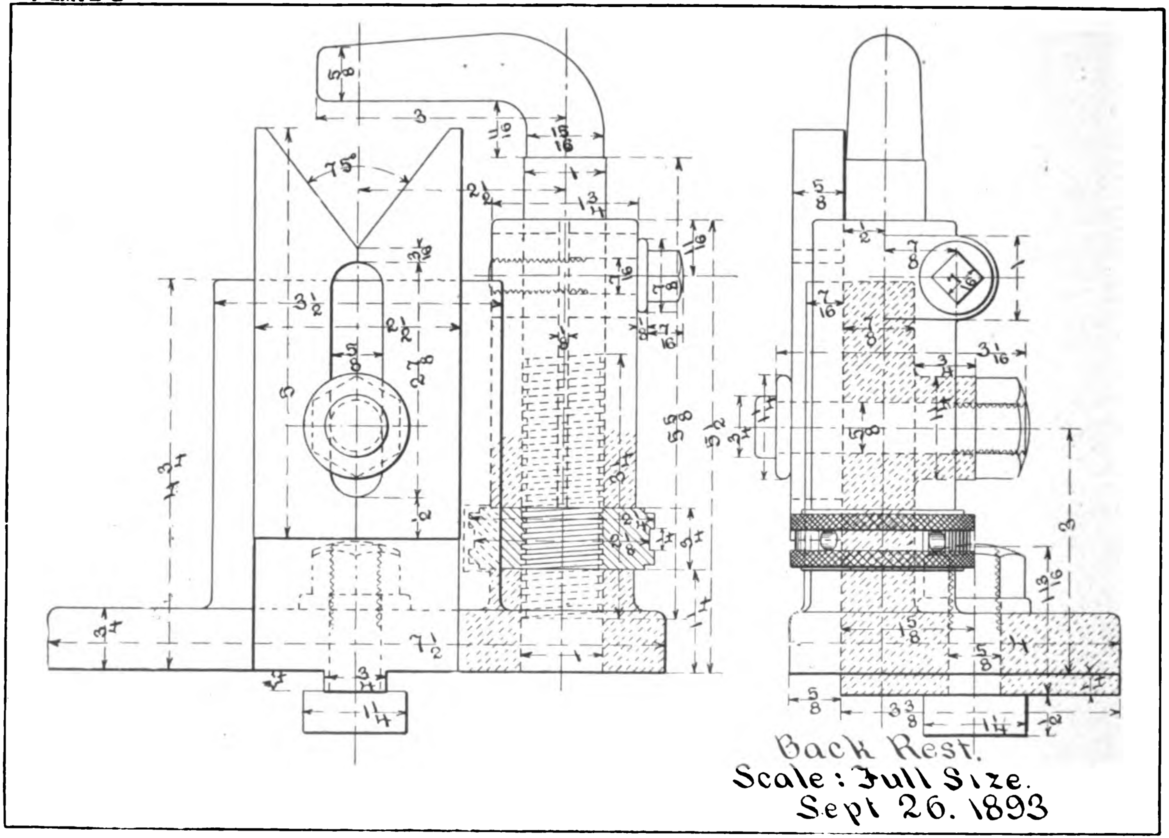


PLATE 11.

PLATE 11

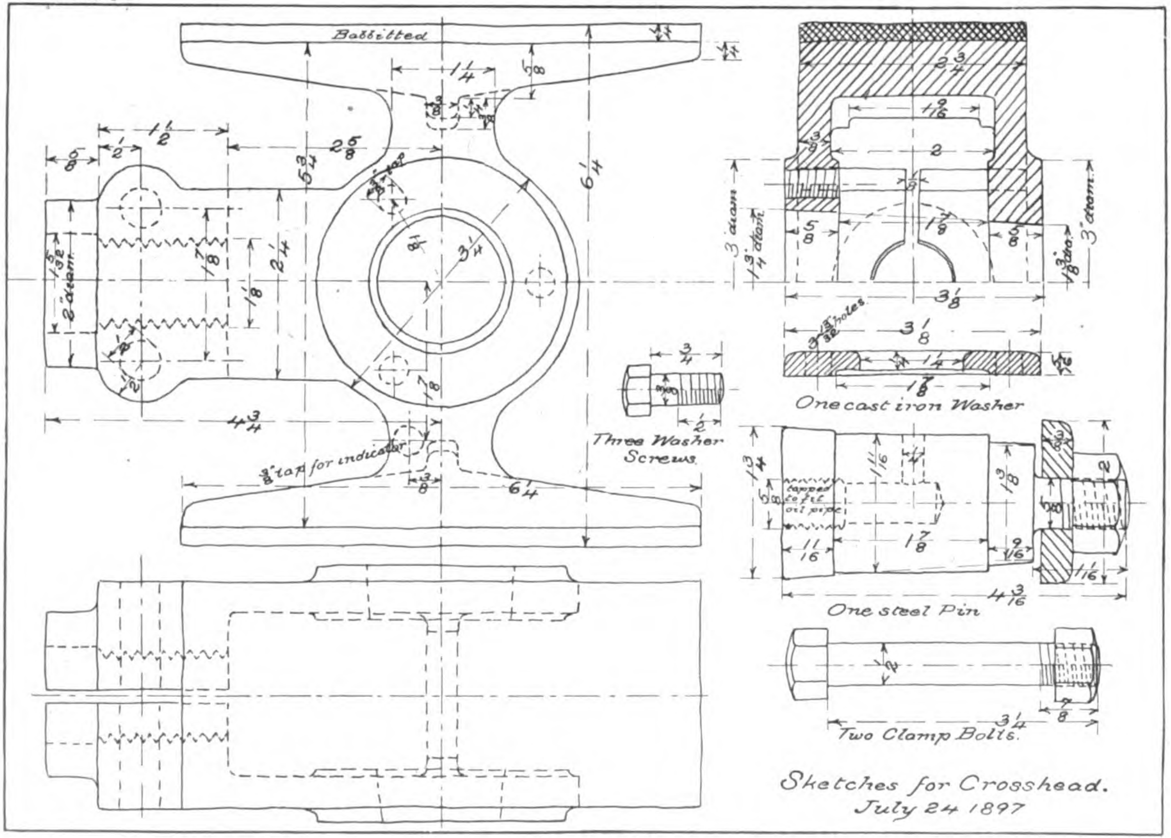
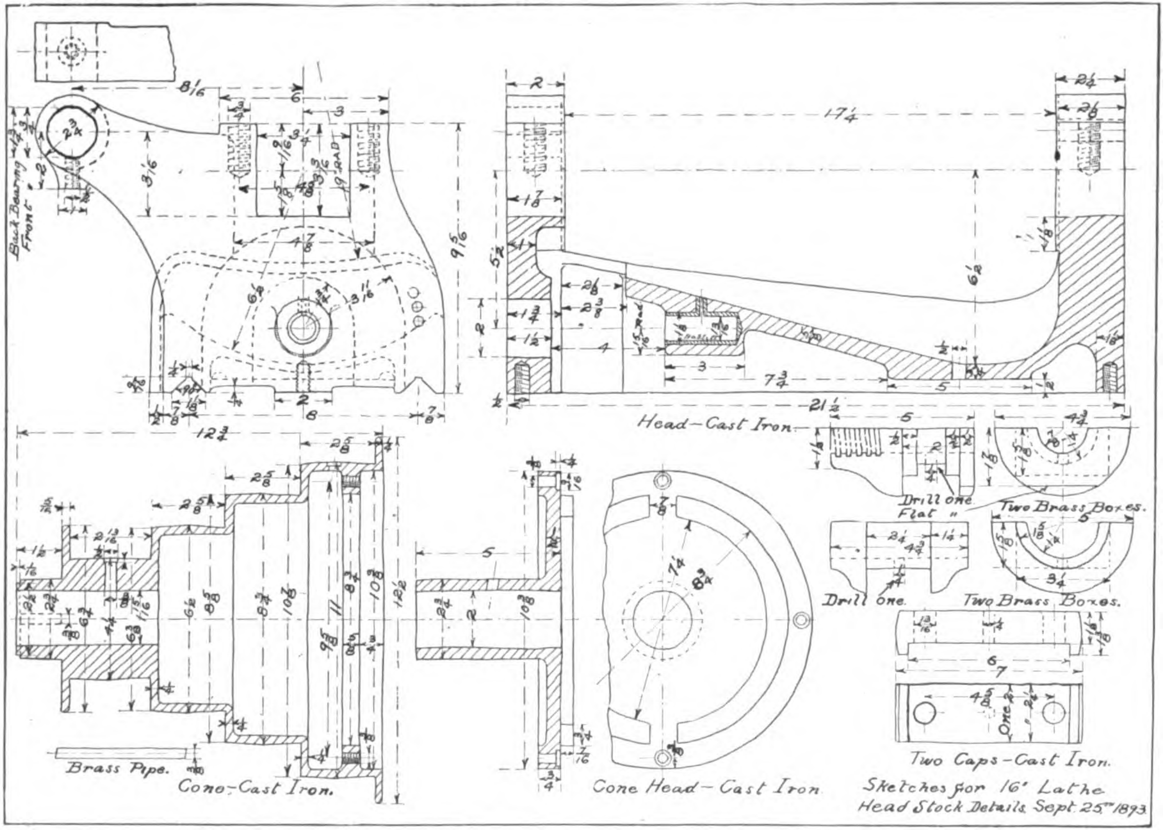

Babbitted
One cast iron Washer
Three Washer Screws
One steel Pin
Two Clamp Bolts.
Sketches for Crosshead.
July 24 1897

PLATE 13.

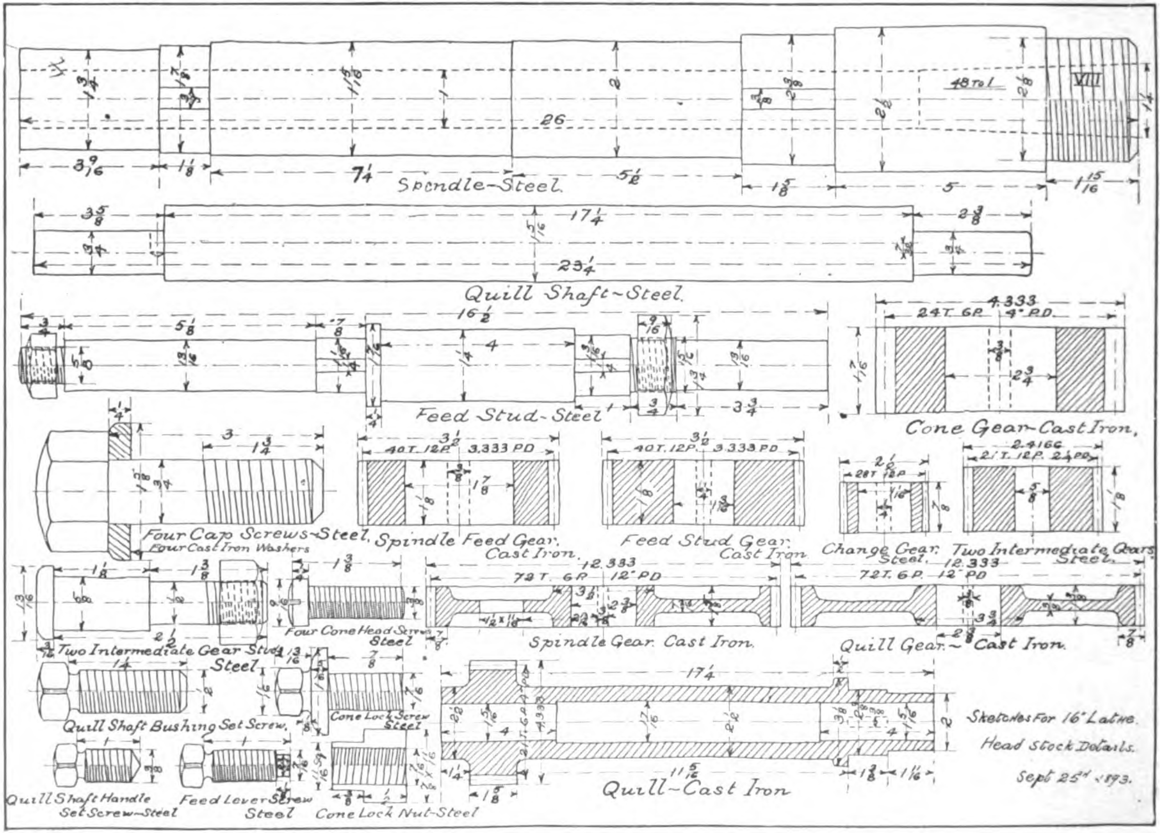
PLATE 13



Head - Cast Iron.
Two Brass Boxes.
Drill one.
Flat "
Drill one.
Two Brass Boxes.
Brass Pipe.
Cone - Cast Iron.
Cone Head - Cast Iron.
Two Caps - Cast Iron.
Sketches for 16' Lathe
Head Stock Details. Sept. 25th 1893.

PLATE 15.

PLATE 15



Spindle-Steel.
Quill Shaft-Steel.
Feed Stud-Steel
Cone Gear-Cast Iron.
Four Cap Screws-Steel.
Four Cast Iron Washers
Spindle Feed Gear. Cast Iron.
Feed Stud Gear. Cast Iron.
Change Gear. Steel.
Two Intermediate Gears Steel.
Two Intermediate Gear Studs Steel.
Four Cone Head Screws Steel
Spindle Gear. Cast Iron.
Quill Gear.~ Cast Iron.
Quill Shaft Bushing Set Screw.
Cone Lock Screw Steel
Quill-Cast Iron
Quill Shaft Handle Set Screw-Steel
Feed Lever Screw Steel
Cone Lock Nut-Steel
Sketches For 16" Lathe.
Head Stock Details.
Sept 25th 1893.

PLATE 17.

PLATE 17

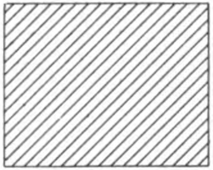


FIG. 1

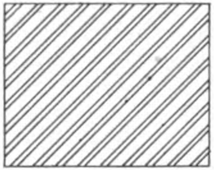


FIG. 2

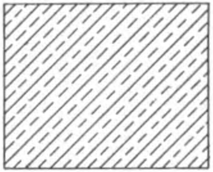


FIG. 3

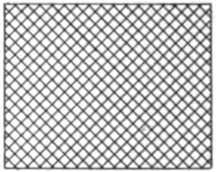


FIG. 4

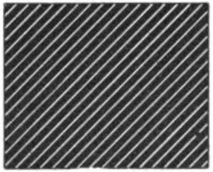


FIG. 5

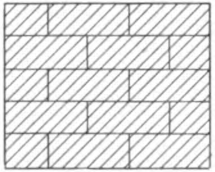


FIG. 6

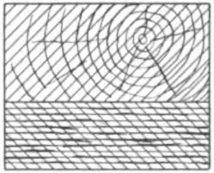


FIG. 7

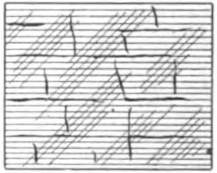


FIG. 8

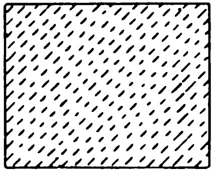


FIG. 9

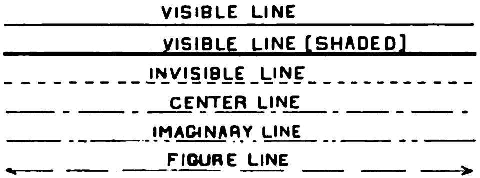


FIG. 11

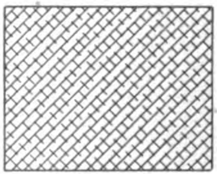


FIG. 10