AN INTRODUCTION TO MACHINE DRAWING AND DESIGN

D. A. LOW

Longmans' Elementary Science Manuals.

AN INTRODUCTION
TO
MACHINE DRAWING
AND
DESIGN

BY

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PREFACE.

It is now generally recognised that the old-fashioned method of teaching machine drawing is very unsatisfactory. In teaching by this method an undimensioned scale drawing, often of a very elaborate description, is placed before the student, who is required to *copy* it. Very often the student succeeds in making a good copy of the drawing placed before him without learning very much about the object represented by it, and this state of matters is sometimes not much improved by the presence of the teacher, who is often simply an art master, knowing nothing about machine design. It is related of one school that a pupil, after making a copy of a particular drawing, had a discussion with his teacher as to whether the object represented was a sewing machine or an electrical machine. Evidently the publisher of the drawing example in this case did not adopt the precaution which a backward student used at an examination in machine design: he put on a full title above his drawing, for the information of his examiner.

Now, if machine drawing is to be of practical use to any one, he must be able to understand the form and arrangement of the parts of a machine from an inspection of suitable drawings of them without seeing the parts themselves. Also he ought to be able to make suitable drawings of a machine or parts of a machine from the machine or the parts themselves.

In producing this work the author has aimed at placing before young engineers and others, who wish to acquire the skill and knowledge necessary for making the simpler *working drawings* such as are produced in engineers' drawing offices, a number of good exercises in drawing, sufficient for one session's work, and at the same time a corresponding amount of information on the design of machine details generally.

The exercises set are of various kinds. In the first and simplest certain views of some machine detail are given, generally drawn to a small scale, which the student is asked to reproduce *to dimensions marked on these views*, and he is expected to keep to these dimensions, and not to measure anything from the given illustrations. In the second kind of exercise the student is asked to reproduce certain views shown *to dimensions given in words or in tabular form.* In the third kind of exercise the student is required to make, in addition to certain views shown to given dimensions, others which he can only draw correctly if he thoroughly understands the design before him. In the fourth kind of exercise the student is asked to make the necessary working drawings for some part of a machine which has been previously described and illustrated, *the dimensions to be calculated by rules given in the text.*

The illustrations for this work are all new, and have been specially prepared by the author from *working drawings*, and he believes that they will be found to represent the best modern practice.

As exercises in drawing, those given in this book are not numbered exactly in their order of difficulty, but, unless on the recommendation of a teacher, the student should take them up in the order given, omitting the following:—28, 29, 30, 39, 46, 51, 53, 54, 60, 61, 62, 66, 72, and 73, as he comes to them, until he has been through Chaps. I.–XVI.; he may then work out the above before going on to the miscellaneous exercises.

In addition to the exercises given in this work the student should practise making freehand sketches of machine details from actual machines or good models of them. Upon these sketches he should put the proper dimensions, got by direct measurement from the machine or model by himself. These sketches should be made in a note-book kept for the purpose, and no opportunity should be lost of inserting a sketch of any design which may be new to the student, always putting on the dimensions if possible. These sketches form excellent examples from which to make working drawings. The student should also note any rules which he may meet with for proportioning machines, taking care, however, in each case to state the source of such information for his future guidance and reference.

As machine drawing is simply the application of the principles of descriptive geometry to the representation of machines, the student of the former subject, if he is not already acquainted with the latter, should commence to study it at once.

D. A. L.

GLASGOW: *March*, 1887.

PREFACE TO THE EIGHTH EDITION.

To this edition many new illustrations and exercises have been added, and the whole work has been thoroughly revised and improved, in order that it may more fully deserve the popularity which it has already gained.

D. A. L.

LONDON: *July*, 1898.

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AN INTRODUCTION

TO

MACHINE DRAWING AND DESIGN.

I. INTRODUCTION.

Drawing Instruments.—For working the exercises in this book the student should be provided with the following:—A well-seasoned yellow pine *drawing-board*, 24 inches long, 17 inches wide, and ⅝ inch or ½ inch thick, provided with cross-bars on the back to give it strength and to prevent warping. A T *square*, with a blade 24 inches long attached permanently to the stock, *but not sunk into it.* One 45° and one 60° *set square.* The short edges of the former may be about 6 inches and the short edge of the latter about 5 inches long. A *pair of compasses* with pen and pencil attachments, and having legs from 5 inches to 6 inches long. A *pair of dividers*, with screw adjustment if possible. A *pair of small steel spring pencil bows* for drawing small circles, and a *pair of small steel spring pen bows* for inking in the same. A *drawing pen* for inking in straight lines. All compasses should have *round points*, and if possible *needle* points. A piece of india-rubber will also be required, besides two pencils, one marked H or HH and one marked HB or F; the latter to be used for lining in a drawing which is not to be inked in, or for freehand work.

Pencils for mechanical drawing should be sharpened with a *chisel point*, and those for freehand work with a *round point*

Do not wet the pencil, as the lines afterwards made with it are very difficult to rub out.

Drawing-paper for working drawings may be secured to the board by *drawing-pins*, but the paper for finished drawings or drawings upon which there is to be a large amount of colouring should be *stretched* upon the board.

The student should get the best instruments he can afford to buy, and he should rather have a few good instruments than a large box of inferior ones.

Drawing-paper.—The names and sizes of the sheets of drawing paper are given in the following table :—

	Inches
Demy	20 × 15
Medium	22 × 17
Royal	24 × 19
Imperial	30 × 22
Atlas	34 × 26
Double Elephant	40 × 27
Antiquarian	52 × 31

The above sizes must not be taken as exact. In practice they will be found to vary in some cases as much as an inch.

Cartridge-paper is made in sheets of various sizes, and also in rolls.

Hand-made paper is the best, but it is expensive. Good cartridge-paper is quite suitable for ordinary drawings.

Centre Lines.—Drawings of most parts of machines will be found to be symmetrical about certain lines called *centre lines.* These lines should be drawn first with great care. On a pencil drawing centre lines should be thin continuous lines ; in this book they are shown thus —-—-—.

After drawing the centre line of any part the dimensions of that part must be marked off from the centre line, so as to insure that it really is the centre line of that part : thus in making a drawing of a rivet, such as is shown at (*a*) fig. 1, after drawing the centre line, half the diameter of the rivet would be marked off on each side of that line, in order to determine the lines for the sides of the rivet.

Inking.—For inking in drawings the best Indian ink should be used, and not common writing ink. Common ink does not dry quick enough, and rapidly corrodes the drawing pens. The pen should be filled by means of a brush or a narrow strip of paper, and not by dipping the pen into the ink.

In cases where there are straight lines and arcs of circles touching one another *ink in the arcs first*, then the straight lines; in this way it is easier to hide the joints.

Colouring.—Camel's-hair or sable brushes should be used; the latter are the best, but are much more expensive than the former. The colour should be rubbed down in a dish, and the tint should be light. The mistake which a beginner invariably makes is in having the colour of too dark a tint.

First go over the part to be coloured with the brush and *clean* water for the purpose of damping it. Next dry with clean blotting-paper to take off any superfluous water. Then take another brush with the colour, and beginning at the top, work from left to right and downwards. If it is necessary to recolour any part let the first coating dry before beginning.

Engineers have adopted certain colours to represent particular materials; these are given in the following table:—

Table showing Colours used to represent Different Materials.

MATERIAL	COLOUR
Cast iron	Payne's grey or neutral tint.
Wrought iron	Prussian blue.
Steel	Purple (mixture of Prussian blue and crimson lake).
Brass	Gamboge with a little sienna or a very little red added.
Copper	A mixture of crimson lake and gamboge, the former colour predominating.
Lead	Light Indian ink with a very little indigo added.
Brickwork	Crimson lake and burnt sienna.
Firebrick	Yellow and Vandyke brown.
Greystones	Light sepia or pale Indian ink, with a little Prussian blue added.
Brown freestone	Mixture of pale Indian ink, burnt sienna, and carmine.
Soft woods	For ground work, pale tint of sienna.
Hard woods	For ground work, pale tint of sienna with a little red added.
	For graining woods use darker tint with a greater proportion of red.

Printing.—A good drawing should have its title 'printed,' a plain style of letter being used for this purpose, such as the following :—

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0

The following letters look well *if they are well made*, but they are much more difficult to draw.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0

For remarks on a drawing the following style is most suitable :—

abcdefghijklmnopqrstuvwxyz

All printing should be done by freehand.

Border lines are seldom put on engineering drawings.

Working Drawings.—A good working drawing should be prepared in the following manner. It must first be carefully outlined in pencil and then inked in. After this all parts cut by planes of section should be coloured, the colours used indicating the materials of which the parts are made. Parts which are round may also be lightly shaded with the brush and colours to suit the materials. The centre lines are now inked in with *red* or *blue ink*. The red ink may be prepared by rubbing down the cake of crimson lake, and the blue ink in like manner from the cake of Prussian blue. Next come the *distance* or *dimension* lines, which should be put in with *blue* or *red ink*, depending on which colour was used for the centre lines. Dimension lines and centre lines are best put in of different colour. The arrow-heads at the ends of the dimension lines are now put in with *black ink*, and so are the figures for the dimensions. The arrow-heads and the figures should be made with a common writing pen. The dimensions should be put on neatly. Many a good drawing has its appearance spoiled through being slovenly dimensioned.

We may here point out the importance of putting the dimensions on a working drawing. If the drawing is not dimensioned, the workman must get his sizes from the drawing by applying his rule or a suitable scale. Now this operation takes time, and is very liable to result in error. Time is therefore saved, and the chance of error reduced, by marking the sizes in figures.

In practice it is not usual to send original drawings from the drawing office to the workshop, but copies only. The copies may be produced by various 'processes,' or they may be tracings drawn by hand. Many engineers do not ink in their original drawings, but leave them in pencil ; especially is this the case if the drawings are not likely to be much used.

Scales.—The best scales are made of ivory, and are twelve inches long. Boxwood scales are much cheaper, although not so durable as those made of ivory. If the student does not care to go to the expense of ivory or boxwood scales, he can get paper ones very cheap, which will be quite sufficient for his purpose. The divisions of the scale should be marked down to its edge, so that measurements may be made by applying the scale directly to the drawing. For working such exercises as are in this book the student should be provided with the following scales :—

A scale of 1, or 12 inches to a foot.
" $\frac{1}{2}$ " 6 "
" $\frac{1}{3}$ " 4 "
" $\frac{1}{4}$ " 3 "
" $\frac{1}{6}$ " 2 "

A scale of 1 is spoken of as 'full size,' and a scale of $\frac{1}{2}$ as 'half size.'

Engineers in this country state dimensions of machines in feet, inches, and fractions of an inch, the latter being the $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, &c. In making calculations it is generally more convenient to use decimal fractions, and then substitute for the results the equivalent fractions in eighths, sixteenths, &c. The following table will be found useful for this purpose :—

Decimal Equivalents of Fractions of an Inch.

Fraction	Decimal Equivalent	Fraction	Decimal Equivalent
$\frac{1}{32}$	·03125	$\frac{17}{32}$	·53125
$\frac{1}{16}$	·0625	$\frac{9}{16}$	·5625
$\frac{3}{32}$	·09375	$\frac{19}{32}$	·59375
$\frac{1}{8}$	·125	$\frac{5}{8}$	·625
$\frac{5}{32}$	·15625	$\frac{21}{32}$	·65625
$\frac{3}{16}$	·1875	$\frac{11}{16}$	·6875
$\frac{7}{32}$	·21875	$\frac{23}{32}$	·71875
$\frac{1}{4}$	·25	$\frac{3}{4}$	·75
$\frac{9}{32}$	·28125	$\frac{25}{32}$	·78125
$\frac{5}{16}$	·3125	$\frac{13}{16}$	·8125
$\frac{11}{32}$	·34375	$\frac{27}{32}$	·84375
$\frac{3}{8}$	·375	$\frac{7}{8}$	·875
$\frac{13}{32}$	·40625	$\frac{29}{32}$	·90625
$\frac{7}{16}$	·4375	$\frac{15}{16}$	·9375
$\frac{15}{32}$	·46875	$\frac{31}{32}$	·96875
$\frac{1}{2}$	·5	1	1·0

Engineers use a single accent (′) to denote *feet*, and a double accent (″) to denote *inches*. Thus 2′ 9″ reads two feet nine inches.

II. RIVETED JOINTS.

Two plates or pieces to be riveted together have holes punched or drilled in them in such a manner that one may be made to overlap the other so that the holes in the one may be opposite the holes in the other. The rivets, which are round bars of iron, or steel, or other metal, are heated to redness and inserted in the holes; the head already formed on the rivet, and called the tail, is then held up, and the point is hammered or pressed so as to form another head. This process of forming the second head on the rivet is known as riveting, and may be done by hand-hammering or by a machine.

Forms of Rivet Heads.—In fig. 1 are shown four different forms of rivet heads: (*a*) is a *snap head*, (*b*) a *conical head* (*c*) a *pan head*, and (*d*) a *countersunk head*.

Proportions of Rivet Heads.—The diameter of the snap head is about 1·7 times the diameter of the rivet, and its height about ·6 of the diameter of the rivet. The conical head has a diameter twice and a height three quarters of the rivet diameter. The greatest diameter of the pan head is about 1·6, and its height ·7 of the rivet diameter. The greatest diameter of the countersunk head may be one and a half, and its depth a half of the diameter of the rivet.

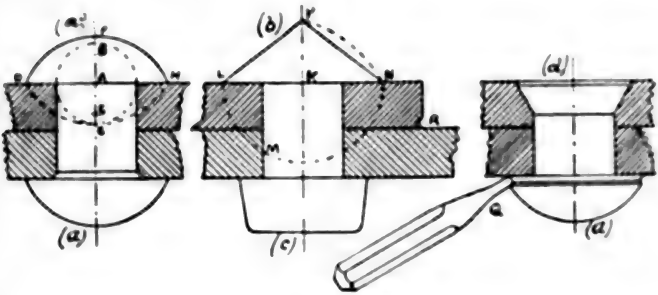


FIG. 1.

In fig. 1 at (*a*) and (*b*) are shown geometrical constructions devised by the author for drawing the snap and conical head for any size of rivet, the proportions being nearly the same as those given above.

Geometrical Construction for Proportioning Snap Heads.—With centre A, and radius equal to half diameter of rivet, describe a circle cutting the centre line of the rivet at B and C. With centre B and radius BC describe the arc CD. Make BE equal to AD. With centre E and radius ED describe the arc DFH.

Construction for Conical Head.—With centre K, and radius equal to diameter of rivet, describe the semicircle LMN, cutting the side of the rivet at M. With centre M and radius MN describe the arc NP to cut the centre line of rivet at P. Join PL and PN.

When a number of rivets of the same diameter have to be shown on the same drawing the above constructions need only be performed on one rivet. After the point E has been discovered the distance AE may be measured off on all the other rivets, and the arcs corresponding to DFH drawn with radii equal to ED. In like manner the height KP of the conical head may be marked off on all rivets of the same diameter with conical heads.

Caulking.—In order to make riveted joints steam- or water-tight the edges of the plates and the edges of the heads of the rivets are burred down by a blunt chisel or caulking tool as shown at Q and R.

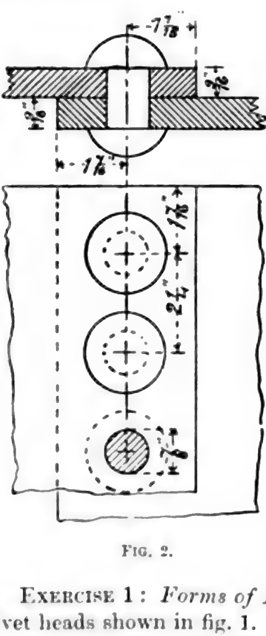


FIG. 2.

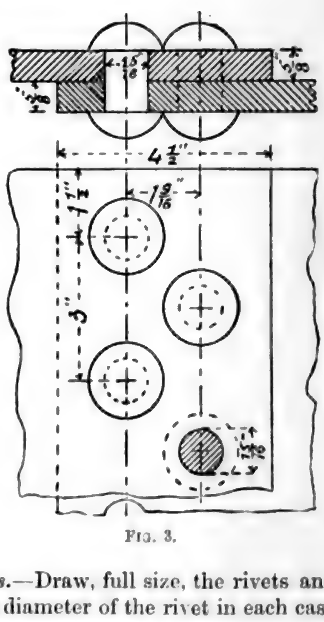


FIG. 3.

EXERCISE 1 : *Forms of Rivets.*—Draw, full size, the rivets and rivet heads shown in fig. 1. The diameter of the rivet in each case to be 1⅛ inches, and the thickness of the plates ⅞ inch.

EXERCISE 2 : *Single Riveted Lap Joint.*—Draw, full size, the plan and sectional elevation of the *single riveted lap joint* shown in fig. 2.

Table showing the Proportions of Single Riveted Lap Joints for various Thicknesses of Plates. (Plates and Rivets Steel.)

Thickness of plates	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$
Diameter of rivets	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$
Pitch of rivets .	$1\frac{7}{16}$	$1\frac{11}{16}$	2	$2\frac{1}{16}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{3}{8}$

Distance from centre of rivets to edge of plate = $1\frac{1}{2}$ times diameter of rivets.

All the dimensions are in inches.

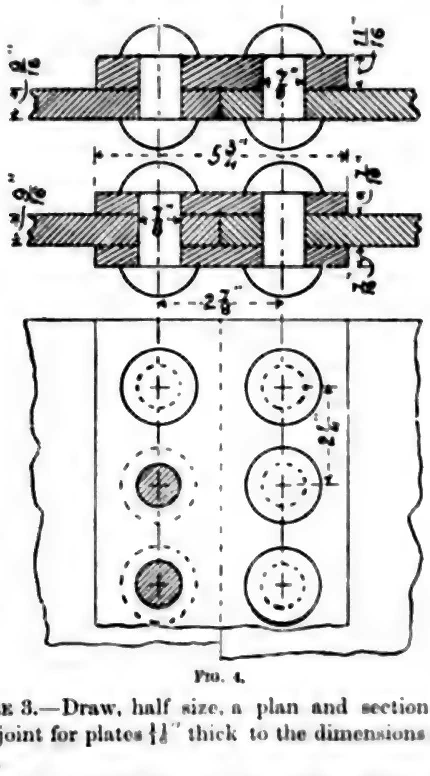


FIG. 4.

EXERCISE 3.—Draw, half size, a plan and section of a single riveted lap joint for plates $\frac{11}{16}$" thick to the dimensions given in the above table.

EXERCISE 4: *Double Riveted Lap Joint.*—Draw, full size, the two views of the *double riveted lap joint* shown in fig. 3.

Table showing the Proportions of Double Riveted Lap Joints for various Thicknesses of Plates. (Plates and Rivets Steel.)

Thickness of plates	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
Diameter of rivets	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$
Pitch of rivets	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{13}{16}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$
Distance between rows of rivets	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{11}{16}$	$1\frac{3}{4}$	$1\frac{13}{16}$	$1\frac{15}{16}$	2	$2\frac{1}{8}$

Distance from edge of plate to centre line of nearest row of rivets $= 1\frac{1}{2}$ times the diameter of the rivets. The rivets are placed zigzag, as in fig. 3.

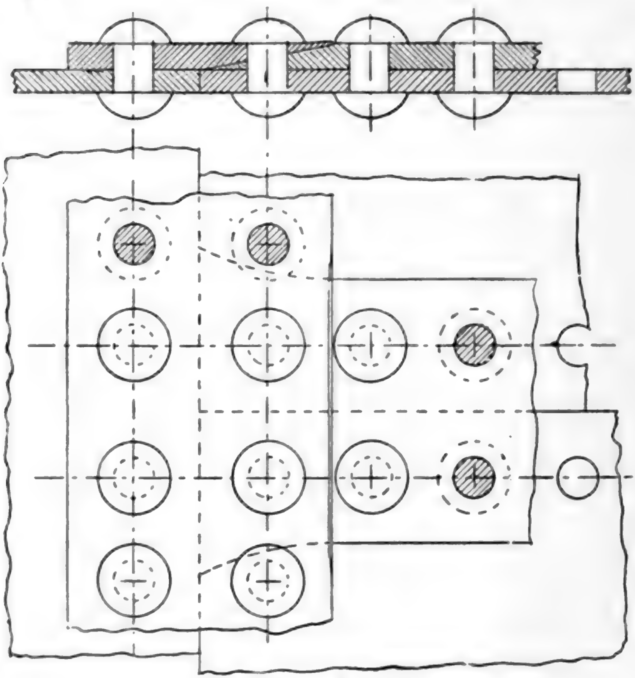


Fig. 5.

Exercise 5.—Draw, half size, a plan and section of a double riveted lap joint for plates $\frac{7}{8}$ inch thick to the dimensions given in the above table.

EXERCISE 6: *Single Riveted Butt Joints.*—In fig. 4 are shown *single riveted butt joints.* One of the sectional views shows a butt joint with one *cover plate* or *butt strap*; the other sectional view shows the same joint with two cover plates; the third view is a plan of both arrangements. Draw all these views full size.

EXERCISE 7.—Fig. 5 shows a plan and sectional elevation of the connection of three plates together, which are in the same plane, by means of single riveted butt joints and single cover plates. The

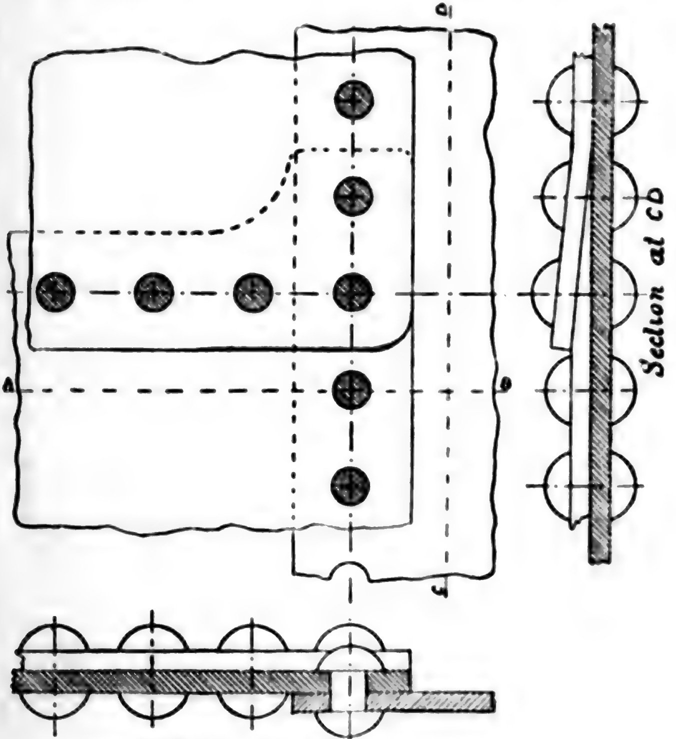


FIG. 5.

butt straps where they overlap are forged so as to fit one another as shown, and thus form a close joint. Draw these views to the scale of 6 inches to a foot.

The plates are $\frac{1}{2}$ inch thick and the butt straps $\frac{9}{16}$ inch thick. All other dimensions must be deduced from the table for single riveted lap joints.

EXERCISE 8.—The connection of three plates by single riveted lap joints is shown in fig. 6. To make the joint close one plate has a portion of its edge thinned out, and the plate above it is set up at this part so as to lie close to the former.

Draw the three views shown in fig. 6 to the same scale as the last exercise.

The plates are $\frac{7}{16}$ inch thick. All other dimensions to be obtained from table for single riveted lap joints.

EXERCISE 9: *Corner of Wrought-iron Tank.*—This exercise is to illustrate the connection of plates which are at right angles to one another by means of *angle irons*. Fig. 7 is a plan and elevation of the corner of a wrought-iron tank. The sides of the tank are riveted to a vertical angle iron, the cross section of which is clearly shown in the plan. Another angle iron of the same dimensions is used in the same way to connect the sides with the bottom. The sides do not come quite up to the corner of the vertical angle iron, excepting at the bottom where the horizontal angle iron comes in. At this point the vertical plates meet one another, and the edge formed is rounded over to fit the interior of the bend of the horizontal angle iron so as to make the joint tight. Draw half size.

The dimensions are as follows: angle irons $2\frac{1}{2}$ inches × $2\frac{1}{2}$ inches × $\frac{3}{8}$ inch; plates $\frac{3}{8}$ inch thick; rivets $\frac{11}{16}$ inch diameter and 2 inches pitch.

EXERCISE 10: *Gusset Stay.*—In order that the flat ends of a steam boiler may not be bulged out by the pressure of the steam they are strengthened by means of stays. One form of boiler stay, called a 'gusset stay,' is shown in fig. 8. This stay consists of a strip of wrought-iron plate which passes in a diagonal direction from the flat end of the boiler to the cylindrical shell. One end of this plate is placed between and riveted to two angle irons which are riveted to the shell of the boiler. A similar arrangement connects the other end of the stay plate to the flat end of the boiler. In this example the stay or gusset plate is $\frac{3}{4}$ of an inch thick; the angle irons are 4 inches broad and $\frac{1}{2}$ inch thick. The rivets are 1 inch in diameter. The same figure also illustrates the most common method of connecting the ends of a boiler to the shell. The end plates are *flanged* or bent over at right angles and riveted to the shell as shown. The radius of the inside curve at the angle of the flange is $1\frac{1}{4}$ inches. Draw this example to a scale of 3 inches to 1 foot.

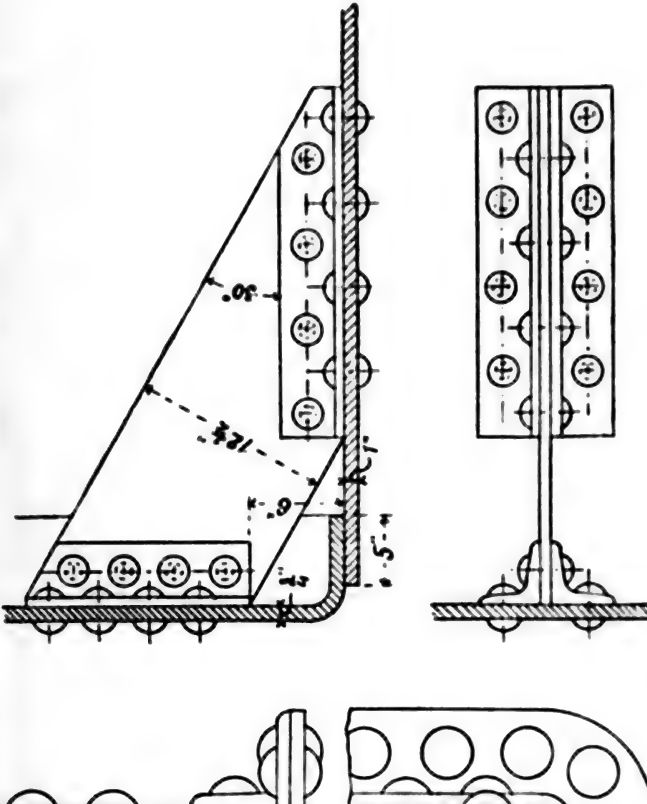


FIG. 6.

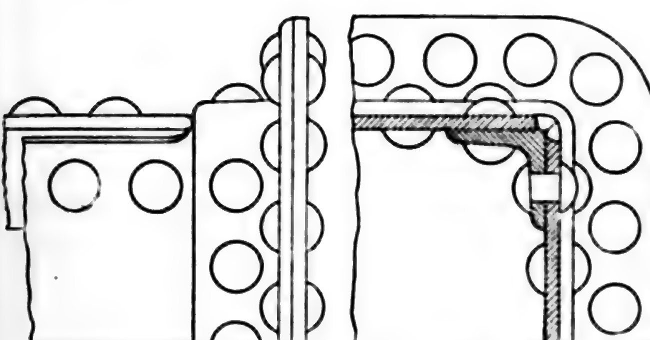


FIG. 7.

III. SCREWS, BOLTS, AND NUTS.

Screw Threads.—The various forms of screw threads used in machine construction are shown in fig. 9. The *Whitworth* V thread is shown at (*a*). This is the standard form of triangular thread used in this country. The angle between the sides of the V is 55°, and one-sixth of the total depth is rounded off both at the top and bottom. At (*b*) is shown the *Sellers* V thread, which is the standard triangular thread used by engineers in America. In this form of thread the angle between the sides of the V is 60°, and one-eighth of the total depth is cut square off at the top and bottom. The *Square* thread is shown at (*c*). This form is principally used for transmitting motion.

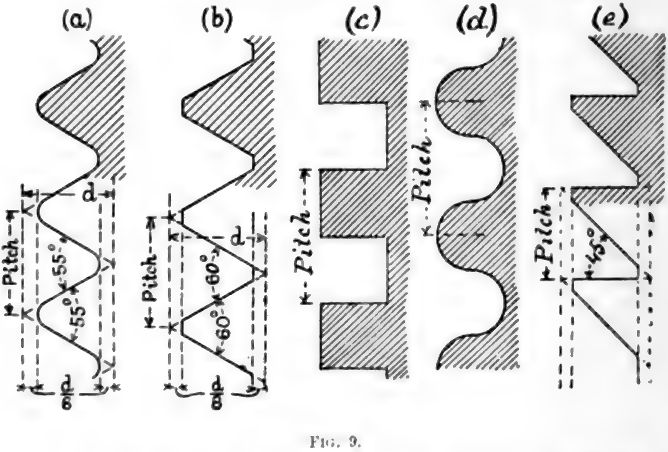


FIG. 9.

Comparing the triangular and square threads, the former is the stronger of the two ; but owing to the normal pressure on the V thread being inclined to the axis of the screw, that pressure must be greater than the pressure which is being transmitted by the screw ; and therefore, seeing that the normal pressure on the square thread is parallel, and therefore equal to the pressure transmitted in the direction of the axis of the screw, the friction of the V thread must be greater than the friction of the square thread. In the case of the triangular thread there is also a tendency of the pressure to burst the nut. The *Buttress* thread shown at (*c*) is designed to combine the advantages of the V and square threads, but it only has these advantages when the pressure is transmitted in one direction ; if the direction of the pressure be reversed, the friction and bursting action on the nut are even greater than with the V thread, because of the greater inclination of the slant side of the buttress thread. The angles of the square thread are frequently rounded to a greater or less extent to render them less easily damaged. If this rounding is carried to excess we get the *Knuckle* thread shown at (*d*). The rounding of the angles increases both the strength and the friction.

EXERCISE 11 : *Forms of Screw Threads.*—Draw to a scale of three times full size the sections of screw threads as shown in fig. 9. The pitch for the Whitworth, Sellers, and buttress threads to be ⅜ inch, and the pitch of the square and knuckle threads to be ½ inch.

Dimensions of Whitworth Screws.

Diameter of screw	Number of threads per inch	Diameter at bottom of thread	Diameter of screw	Number of threads per inch	Diameter at bottom of thread	Diameter of screw	Number of threads per inch	Diameter at bottom of thread
⅛	40	·093	1¼	7	1·067	3½	3¼	3·106
3/16	24	·134	1⅜	6	1·162	3¾	3	3·323
¼	20	·186	1½	6	1·286	4	3	3·573
5/16	18	·241	1⅝	5	1·369	4¼	2⅞	3·805
⅜	16	·295	1¾	5	1·494	4½	2⅞	4·055
7/16	14	·346	1⅞	4½	1·590	4¾	2¾	4·284
½	12	·393	2	4½	1·715	5	2¾	4·534
⅝	11	·508	2¼	4	1·930	5¼	2⅝	4·762
¾	10	·622	2½	4	2·180	5½	2⅝	5·012
⅞	9	·733	2¾	3½	2·384	5¾	2½	5·238
1	8	·840	3	3½	2·634	6	2½	5·488
1⅛	7	·942	3¼	3¼	2·856			

Gas Threads[1] (*Whitworth Standard*).

Diameter of screw	⅛	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2
Number of threads per inch . .	28	19	19	14	14	14	11	11	11	11	11

[1] Used for wrought-iron and brass tubes.

Representation of Screws.—The correct method of representing screw threads involves considerable trouble, and is seldom adopted by engineers for working drawings. For an explanation of the method see the author's Text-book on Practical Solid Geometry, Part II., problem 134. A method very often adopted on working drawings is shown in fig. 15; here the thin lines represent the points, and the thick lines the roots of the threads. In fig. 16 is shown a more complete method. The simplest method is illustrated by figs. 10, 11, 13, and 14.

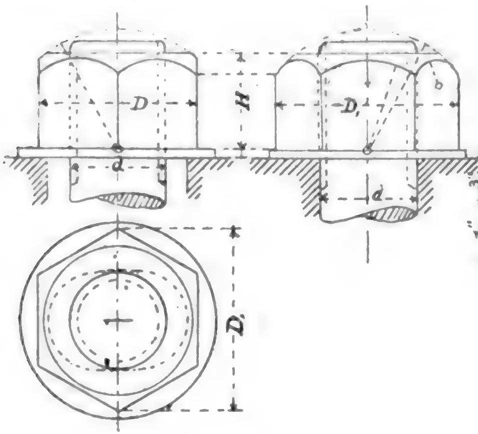


FIG. 10.

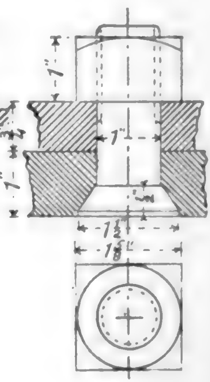


FIG. 11.

Here dotted lines are drawn parallel to the axis of the screw as far as it extends, and at a distance from one another equal to the diameter of the screw at the bottom of the thread.

Forms of Nuts.—The most common form of nut is the hexagonal shown in figs. 10, 13, 14, 15, and 16; next to this comes the square nut shown in fig. 11. The method of drawing these nuts will be understood by reference to the figures; the small circles indicate the centres, and the inclined lines passing through them the radii of the curves which represent the chamfered or bevelled edge of the nut. In all the figures but the first the chamfer is just sufficient to touch the middle points of the sides, and in these cases the drawing of the nut is simpler.

Forms of Bolts.—At (*a*), fig. 12, is shown a bolt with a

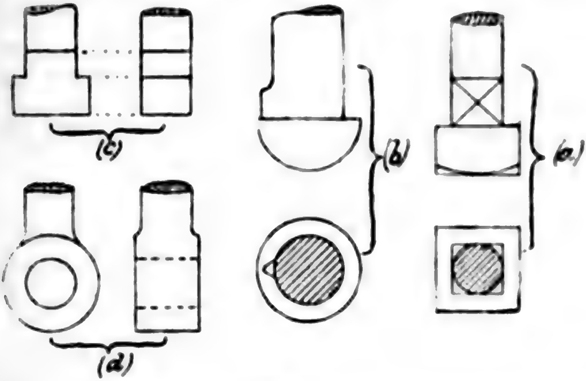


FIG. 12.

square head and a square neck. If this form of bolt is passed through a square hole the square neck prevents the bolt from turning when the nut is being screwed up. Instead of a

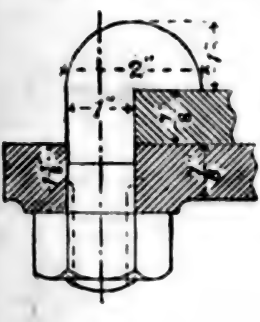


FIG. 13.

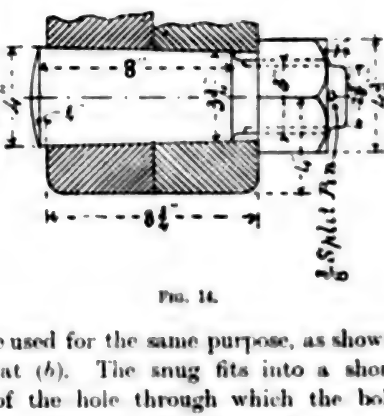


FIG. 14.

square neck a snug may be used for the same purpose, as shown on the cup-headed bolt at (*b*). The snug fits into a short groove cut in the side of the hole through which the bolt passes. At (*a*) the diagonal lines are used to distinguish the flat side of the neck from the round part of the bolt above it. At (*c*) is shown a tee-headed bolt, and at (*d*) an eye-bolt. Fig. 13 represents a hook bolt. A bolt with a countersunk head is shown in fig 11. If the countersunk head be lengthened so as to take up the whole of the unscrewed part of the bolt, we get the taper bolt shown in fig. 14, which is often used in the couplings of the screw shafts of steamships. The taper bolt has the advantage of having no projecting head, and it may also be made a tight fit in the hole with less trouble than a parallel bolt. Bolts may also have hexagonal heads.

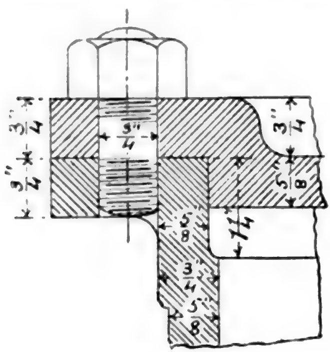


FIG. 15.

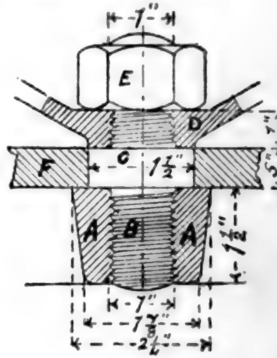


FIG. 16.

Studs, or *stud bolts*, are shown in figs. 15 and 16; that in fig. 15 is a *plain stud*, while that in fig. 16 has an intermediate collar forged upon it, and is therefore called a *collared stud.*

Proportions of Nuts and Bolt-heads.—In the hexagonal nut the diameter D across the flats is $1\frac{1}{2}d+\frac{1}{8}$, where d is the diameter of the bolt. The same rule gives the width of a square nut across the flats. A rule very commonly used in making drawings of hexagonal nuts is to make the diameter D_1 across the angles equal to $2d$. H, the height of the nut, is equal to the diameter of the bolt. In square and hexagonal headed bolts the height of the head varies from d to $\frac{7}{8}d$; the other dimensions are the same as for the corresponding nuts.

Washers are flat, circular, wrought-iron plates, having holes in their centres of the same diameter as the bolts on which they are used. The object of the washer is to give a smooth bearing surface for the nut to turn upon, and it is used when the surfaces of the pieces to be connected are rough, or when the bolt passes through a hole larger than itself, as shown in fig. 10. The diameter of the washer is a little more than the diameter of the nut across the angles, and its thickness about $\frac{1}{8}$ of the diameter of the bolt.

EXERCISE 12.—Draw, full size, the views shown in fig. 10 of an hexagonal nut and washer for a bolt $1\frac{1}{4}$ inches in diameter. The bolt passes through a hole $1\frac{3}{4} \times 1\frac{1}{4}$. All the dimensions are to be calculated from the rules which have just been given.

EXERCISE 13.—Draw, full size, the plan and elevation of the square nut and bolt with countersunk head shown in fig. 11, to the dimensions given.

EXERCISE 14.—Draw, full size, the elevation of the hook bolt with hexagonal nut shown in fig. 13 to the dimensions given, and show also a plan.

EXERCISE 15.—Draw, to a scale of 4 inches to a foot, the conical bolt for a marine shaft coupling shown in fig. 14. All the parts are of wrought iron.

EXERCISE 16.—Fig. 15 is a section of the mouth of a small steam-engine cylinder, showing how the cover is attached; draw this full size.

EXERCISE 17.—Fig. 16 shows the central portion of the india-rubber disc valve which is described on page 77. A is the central boss of the grating, into which is screwed the stud B, upon which is forged the collar C. The upper part of the stud is screwed, and carries the guard D and an hexagonal nut E. F is the india-rubber. The grating and guard are of brass. The stud and nut are of wrought iron. Draw full size the view shown.

Lock Nuts.—In order that a nut may turn freely upon a bolt, there is always a very small clearance space between the threads of the nut and those of the bolt. This clearance is shown exaggerated at (*a*), fig. 17, where A is a portion of a bolt within a nut B. Suppose that the bolt is stretched by a force W. When the nut B is screwed up, the upper surfaces of the projecting threads of the nut will press on the under surfaces of the threads of the bolt with a force P equal and opposite to W, as shown at (*b*), fig. 17. When in this condition the nut has no tendency to slacken back, because of the friction due to the pressure on the nut. Now suppose that the tension W on the bolt is momentarily diminished, then the friction which opposes the turning of the nut may be so much diminished that a vibration may cause it to slacken back through a small angle. If this is repeated a great many times the nut may slacken back so far as to become useless.

A very common arrangement for locking a nut is shown at (*a*), fig. 18. C is an ordinary nut, and B one having half the thickness of C. B is first screwed up tight so as to act on the bolt, as shown at (*b*), fig. 17. C is then screwed on top of B.

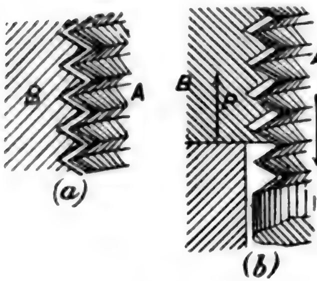


FIG. 17.

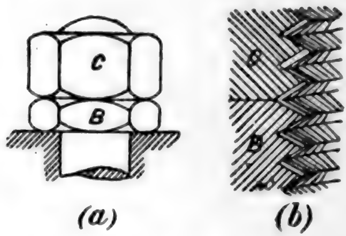


FIG. 18.

When C is almost as tight as it can be made, it is held by one spanner, while B is turned back through a small angle with another. The action of the nuts upon the bolt and upon one another is now as shown at (*b*), fig. 18. It will be seen that the nuts are wedged tight on to the bolt, and that this action is independent of the tension W in the bolt. The nuts will, therefore, remain tight after the tension in the bolt is removed.

It is evident that if the nuts are screwed up in the manner explained, the outer nut C will carry the whole load on the bolt : hence C should be the thicker of the two nuts. In practice, the thin nut, called the lock nut, is often placed on the outside, for the reason that ordinary spanners are too thick to act on the thin nut when placed under the other.

Another very common arrangement for locking a nut is shown in fig. 19. A is the bolt and B the nut, the lower part of which is turned circular. A groove C is also turned on the nut at this part. The circular part of the nut fits into a circular recess in one of the parts connected by the bolt. Through this part passes a set screw D, the point of which can be made to press on the nut at the bottom of the groove C. D is turned back when the nut B is being moved, and when B is tightened up, the set screw is screwed up so as to press hard on the bottom of the groove C. The nut B is thus prevented from slackening back. The screw thread is turned off the set screw at the point where it enters the groove on the nut.

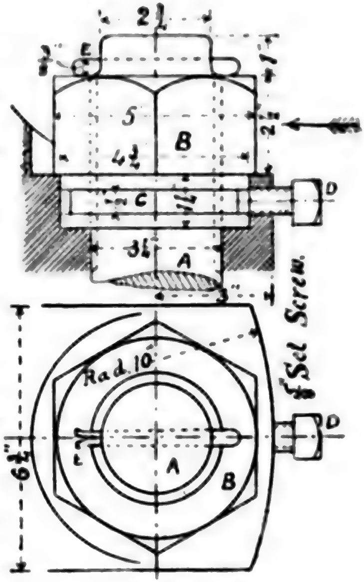


FIG. 19.

The use of the groove for receiving the point of the set screw is this: The point of the set screw indents the nut and raises a bur which would interfere with the free turning of the nut in the recess if the bur was not at the bottom of a groove. Additional security is obtained by drilling a hole through the point of the bolt, and fitting it with a split pin E.

Locking arrangements for nuts are exceedingly numerous, and many of them are very ingenious, but want of space prevents us describing them. We may point out, however, that many very good locking arrangements have the defect of only locking the nut at certain points of a revolution, say at every 30°. It will be noticed that the two arrangements which we have described are not open to this objection.

EXERCISE 18.—Draw, full size, a plan, front elevation, and side elevation of the arrangement of nuts shown in fig. 18, for a bolt $\frac{7}{8}$ inch diameter.

EXERCISE 19.—Draw the plan and elevation of the nut and locking arrangement shown in fig. 19. Make also an elevation looking in the direction of the arrow. Scale 6 inches to a foot.

EXERCISE 20: *Flanged Joint for Cast-iron Plates.*—Draw the views shown in fig. 20. Draw also a plan. The bolts and nuts must be shown in each view. The holes for the bolts are square, and the bolts have square necks. Scale half full size.

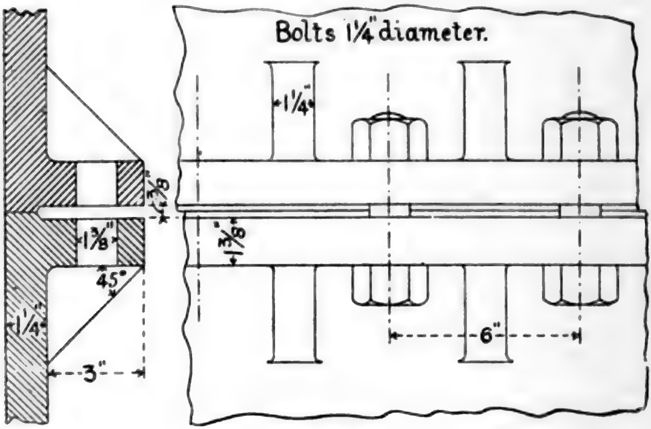


FIG. 20.

IV. KEYS.

Keys are wedges, generally rectangular in section, but sometimes circular; they are made of wrought iron or steel, and are used for securing wheels, pulleys, cranks, &c., to shafts.

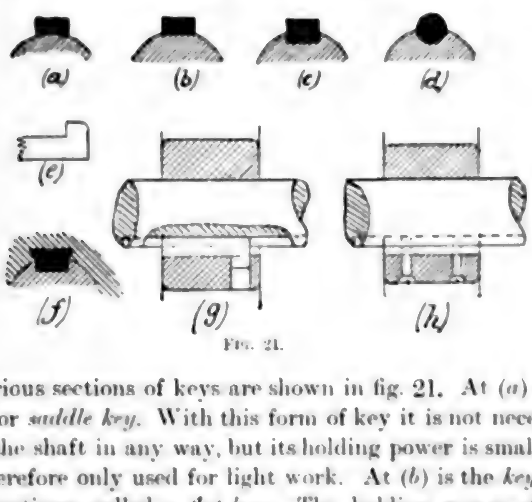


FIG. 21.

Various sections of keys are shown in fig. 21. At (*a*) is the *hollow* or *saddle key*. With this form of key it is not necessary to cut the shaft in any way, but its holding power is small, and it is therefore only used for light work. At (*b*) is the *key on a flat*, sometimes called a *flat key*. The holding power of this key is much greater than that of the saddle key. At (*c*) is the *sunk key*, a very secure and very common form.

The part of the shaft upon which a key rests is called the *key bed* or *key way*, and the recess in the boss of the wheel or pulley into which the key fits is called the *key way*; both are also called *key seats*. With saddle, flat, and sunk keys the key bed is parallel to the axis of the shaft; but the key way is deeper at one end than the other to accommodate the taper of the key. The sides of the key are parallel.

The *round key* or taper pin shown at (*d*) is in general only used for wheels or cranks which have been previously shrunk on to their shafts or forced on by great pressure. After the wheel or crank has been shrunk on, a hole is drilled, half into the shaft and half into the wheel or crank, to receive the pin.

When the point of a key is inaccessible the other end is provided with a *gib head* as shown at (*e*), to enable the key to be withdrawn.

A *sliding* or *feather key* secures a piece to a shaft so far as to prevent the one from rotating without the other, but allows of relative motion in the direction of the axis of the shaft. This form of key has no taper, and it is secured to the piece carried by the shaft, but is made a *sliding fit* in the key way of the shaft. In one form of feather key the part within the piece carried by the shaft is dovetailed as shown at (*f*). In another form the key has a round projecting pin forged upon it, which enters a corresponding hole as shown at (*g*). The feather key may also be secured to the piece carried by the shaft by means of one or more screws as shown at (*h*). The key way in the shaft is made long enough to permit of the necessary sliding motion.

Cone Keys.—These are sometimes fitted to pulleys, and are shown in fig. 42, page 46. In this case the eye of the pulley is tapered and is larger than the shaft. The space between the shaft and the boss of the pulley is filled with three *saddle* or *cone keys.* These keys are made of cast iron and are all cast together, and before being divided the casting is bored to fit the shaft and turned to fit the eye of the pulley. By this arrangement of keys the same pulley may be fixed on shafts of different diameters by using keys of different thicknesses ; also the pulley may be bored out large enough to pass over any boss which may be forged on the shaft.

Proportions of Keys.—The following rules are taken from Unwin's 'Machine Design,' Part I. pp. 170, 171.

Diameter of eye of wheel, or boss of shaft $= d$.
Width of key . . . . . $b. = \frac{1}{4} d + \frac{1}{8}$.
Mean thickness of sunk key . . $= \frac{1}{2} b$.
" key on flat . . $= \frac{1}{3} b$.

The following table gives dimensions agreeing with average practice.

Dimensions of Keys.

D = diameter of shaft.
B = breadth of key.
T = thickness of sunk key.
T_1 = thickness of flat key, also = thickness of saddle key. Taper of key $\frac{1}{8}$ inch per foot of length, *i.e.* 1 in 96.

D	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$
B	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1
T	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$
T_1	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$

D	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	7	8	9	10	11	12
B	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{5}{8}$	$2\frac{7}{8}$	$3\frac{1}{8}$
T	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{1}{4}$
T_1	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$

V. SHAFTING.

Shafting is nearly always cylindrical and made of wrought iron or steel. Cast iron is rarely used for shafting.

Axles are shafts which are subjected to bending without twisting.

The parts of a shaft or axle which rest upon the bearings or supports are called *journals*, *pivots*, or *collars*.

In journals the supporting pressure is at right angles to the axis of the shaft, while in pivots and collars the pressure is parallel to that axis.

Shafts may be solid or hollow. Hollow shafts are stronger than solid shafts for the same weight of material. Thus a hollow shaft having an external diameter of $10\frac{1}{2}$ inches and an internal diameter of 7 inches would have about the same weight as a solid shaft of the same material $7\frac{1}{2}$ inches in diameter, but the former would have about double the strength of the latter. Hollow shafts are also stiffer and yield less to bending action than solid shafts, which in some cases, as in propeller shafts, is an objection.

STRENGTH OF SHAFTS.[1]

Twisting Moment.—Let a shaft carry a lever, wheel, or pulley of radius R inches, and let a force of P lbs. act at the outer end of the radius, and at right angles to it. The force P produces a twisting action on the shaft, which is measured by the product $P \times R$. This product $P \times R$ is called the twisting moment or torque on the shaft; and if P is in lbs. and R in inches, the twisting moment is $P \times R$ inch-pounds. The twisting moment in foot-pounds is got by dividing the twisting moment in inch-pounds by 12.

If the shaft makes N revolutions per minute, the horse-power which is being transmitted is $\frac{2 \times R \times 3{\cdot}1416 \times P \times N}{12 \times 33000}$ or $\frac{2 \times 3{\cdot}1416 \times T \times N}{12 \times 33000}$, where T is the twisting moment in inch-pounds.

Resistance of Shafts to Torsion.—The resistance of a shaft to torsion is directly proportional to the cube of its diameter. Thus if the diameter be doubled, the strength is increased eight (*i.e.* 2^3) times. Let there be two shafts of the same material, and having diameters D_1 and D_2; and let the twisting moments which they support when strained to the same extent be T_1 and T_2 respectively; then $T_1 : T_2 :: D_1^3 : D_2^3$, or $T_1 D_2^3 = T_2 D_1^3$.

Moment of Resistance.—The stress produced in a shaft which is subjected to twisting is a shearing stress. This stress is not uniform, being greatest at the outside of the shaft and diminishing uniformly towards the centre, where it is nothing. Let f be the greatest shearing stress on the shaft and d its diameter. Then the moment of resistance of

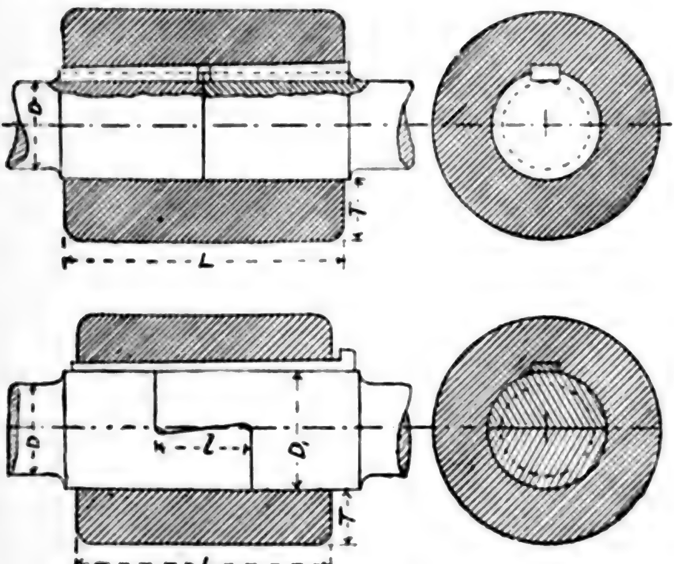
[1] From the author's 'Elementary Text-Book of Applied Mechanics.'

the shaft to torsion which balances the twisting moment is $\frac{3 \cdot 1416}{16} d^3 f$, so that $T = PR = \frac{3 \cdot 1416}{16} d^3 f$.

In determining the safe twisting moment for a mild steel shaft, f may be taken equal to 9000 lbs. per square inch.

VI. SHAFT COUPLINGS.

For convenience of making and handling, shafts used for transmitting power are generally made in lengths not exceeding 30 feet. These lengths are connected by couplings, of which we give several examples



Figs. 22 and 23.

Solid, Box, or Muff Couplings.—One form of box coupling is shown in fig. 22. Here the ends of the shafts to be connected butt against one another, meeting at the centre of the box, which is made of cast iron. The shafts are made to rotate as one by being secured to the box by two wrought-iron or steel keys, both driven from the same end of the box. A clearance space is left between the head of the forward key and the point of the hind one, to facilitate the driving of them out, as then only one key needs to be started at a time. Sometimes a single key the whole length of the box is used, in which case it is necessary that the key ways in the shafts be of exactly the same depth.

The half-lap coupling, introduced by Sir William Fairbairn, is shown in fig. 23. In this form of box coupling the ends of the shafts overlap within the box. It is evident that one shaft cannot rotate without the other so long as the box remains over the lap. To keep the box in its place it is fitted with a saddle key.

It will be noticed that the lap joint is sloped in such a way as to prevent the two lengths of shaft from being pulled asunder by forces acting in the direction of their length.

Half-lap couplings are not used for shafts above 5 inches in diameter.

It may here be pointed out that the half-lap coupling is expensive to make, and is now not much used.

As shafts are weakened by cutting key ways in them, very often the ends which carry couplings are enlarged in diameter, as shown in fig. 22, by an amount equal to the thickness of the key. An objection to this enlargement is that wheels and pulleys require either that their bosses be bored out large enough to pass over it, or that they be split into halves, which are bolted together after being placed on the shaft.

Dimensions of Box Couplings.

D = diameter of shaft.
T = thickness of metal in box.
L = length of box for butt coupling.
L_1 = length of box for lap coupling.
l = length of lap.
D_1 = diameter of shaft at lap.

D	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
T	1 1/8	1 3/16	1 1/4	1 3/8	1 1/2	2 1/8	2 3/16	2 1/4	2 3/8	2 1/2
L	5 3/4	7	8 1/4	9 1/2	10 3/4	12	13 1/4	14 1/2	15 3/4	17
L_1	4 1/2	5 1/4	6 3/4	7 1/2	8 1/2	9 3/4	10 3/4	12	—	—
l	1 5/16	1 1/2	2 1/16	2 1/4	3 1/16	3 1/2	4 1/16	4 1/2	—	—
D_1	2 5/16	3	3 11/16	4 3/8	5 1/16	5 3/4	6 7/16	7 1/8	—	—

Slope of lap 1 in 12.

EXERCISE 21: *Solid Butt Coupling.*—From the above table of dimensions make a longitudinal and a transverse section of a solid butt coupling for a shaft 2½ inches in diameter. Scale 6 inches to a foot.

EXERCISE 22: *Fairbairn's Half-Lap Coupling.*—Make the same views as in the last exercise of a half-lap coupling for a 3-inch shaft to the dimensions in the above table. Scale 6 inches to a foot.

Flange Couplings.—The form of coupling used for the shafts of marine engines is shown in fig. 24. The ends of the different lengths of shaft have flanges forged on them, which are turned along with the shaft. These flanges butt against one another, and are connected by bolts. These bolts may be parallel or tapered; generally they are tapered. A parallel bolt must have a head, but a tapered bolt will act without one. In fig. 24 the bolts are tapered, and also provided with heads. In fig. 14, page 17, is shown a tapered bolt without a head. The variation of diameter in tapered bolts is ⅜ of an inch per foot of length.

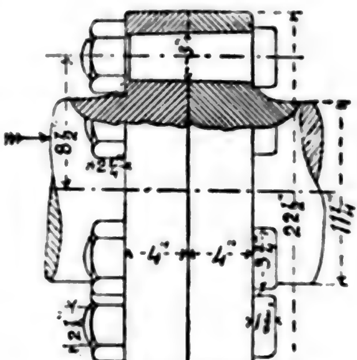


FIG. 24.

Sometimes a projection is formed on the centre of one flange which fits into a corresponding recess in the centre of the other, for the purpose of ensuring the shafts being in line.

Occasionally a cross-key is fitted in between the flanges, being sunk half into each, for the purpose of diminishing the shearing action on the bolts.

Exercise 23: *Marine Coupling.*—Draw the elevation and section of the coupling shown in fig. 24; also an elevation looking in the direction of the arrow. Scale 3 inches to a foot.

The following table gives the dimensions of a few marine couplings taken from actual practice.

Examples of Marine Couplings.

Diameter of shaft	$2\frac{3}{8}$	$9\frac{1}{4}$	$12\frac{5}{8}$	$16\frac{1}{2}$	$22\frac{1}{2}$	23
Diameter of flange . .	6	19	24	32	35	38
Thickness of flange .	1	$2\frac{3}{4}$	$3\frac{1}{8}$	$4\frac{1}{4}$	6	5
Diameter of bolts . .	$\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{11}{16}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{4}$
Number of bolts . .	3	6	6	8	9	8
Diameter of bolt circle .	$4\frac{1}{8}$	$14\frac{1}{8}$	$18\frac{13}{16}$	25	$28\frac{3}{4}$	$30\frac{3}{8}$

All the above dimensions are in inches.

Exercise 24.—Select one of the couplings from the above table, and make the necessary working drawings for it to a suitable scale.

The cast-iron flange coupling is shown in fig. 25. In this kind of coupling a cast-iron centre or boss provided with a flange is secured to the end of each shaft by a sunk key driven from the face of the flange. These flanges are then connected by bolts and nuts as in the marine coupling.

To ensure the shafts being in line the end of one projects into the flange of the other.

In order that the face of each flange may be exactly perpendicular to the axis of the shaft they should be 'faced' in the lathe, after being keyed on to the shaft.

If the coupling is in an exposed position, where the nuts and bolt-heads would be liable to catch the clothes of workmen or an idle driving band which might come in the way, the flanges should be made thicker, and be provided with recesses for the nuts and bolt-heads.

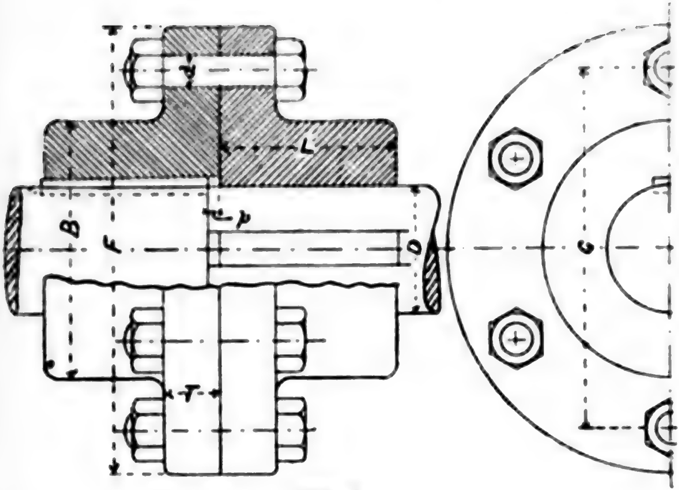


FIG. 25.

Dimensions of Cast-iron Flange Couplings.

Diameter of shaft D	Diameter of flange F	Thickness of flange T	Diameter of boss B	Depth at boss L	Number of bolts	Diameter of bolts d	Diameter of bolt circle C
1½	7¼	¾	3¼	2⅜	3	⅝	5¼
2	8½	$1\frac{1}{16}$	4⅛	$3\frac{3}{16}$	4	¾	6¾
2½	10⅛	1¼	$5\frac{5}{16}$	3¾	4	⅞	8¼
3	12⅜	$1\frac{7}{16}$	6[illegible]	$4\frac{5}{16}$	4	1	9[illegible]
3½	13⅛	1⅝	7½	4¼	4	1	$10\frac{5}{16}$
4	14	1¾	8	$5\frac{7}{16}$	6	1	11[illegible]
4½	15⅝	2	8⅞	6	6	1⅛	12¼
5	17⅛	2⅛	$9\frac{13}{16}$	6⅜	6	1¼	$13\frac{13}{16}$
5½	18[illegible]	$2\frac{5}{16}$	10[illegible]	7[illegible]	6	1¼	14⅞
6	19⅜	2[illegible]	11⅜	7¾	6	1⅜	16

The projection of the shaft *p* varies from ¼ inch in the small shafts to ½ inch in the large ones.

EXERCISE 25: *Cast-iron Flange Coupling.*—Draw the views shown in fig. 25 of a cast-iron flange coupling, for a shaft 4½ inches in diameter, to the dimensions given in the above table. Scale 4 inches to a foot.

EXERCISE 26: *Split Muff Coupling.*—Draw the views shown in fig. 26, and add a plan. Scale, half full size.

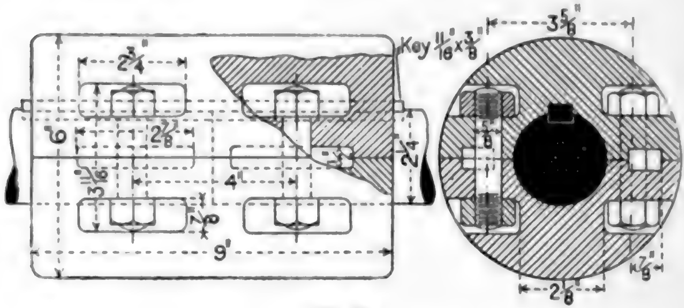


FIG. 26.

In making the split muff coupling, the faces for the joint between the two halves of the box are first planed. The bolt holes are then drilled, and the two halves bolted together with pieces of paper between them; then the muff is bored out to the exact size of the shaft. When the paper is removed, and the box put on the shaft and bolted up, the box grips the shaft firmly. The key has no taper, and should fit on the sides only.

VII. BEARINGS FOR SHAFTS.

An example of a very simple form of bearing is shown in fig. 27, which represents a brake shaft carrier of a locomotive tender. The bearing in this example is made of cast iron and in one piece. Through the oval-shaped flange two bolts pass for attaching the bearing to the wrought-iron framing of the tender. With this form of bearing there is no adjustment for wear, so that when it becomes worn it must be renewed.

EXERCISE 27 : *Brake Shaft Carrier.*—Draw the elevation and sectional plan of the bearing shown in fig. 27. Draw also a vertical section through the axis. The latter view to be projected from the first elevation. Scale 6 inches to a foot.

Pillow Block, Plummer Block, or Pedestal.—The ordinary form of plummer block is represented in fig. 28. A is the block proper, B the sole through which pass the holding-down bolts. C is the cap. Between the block and the cap is the brass bush, which is in halves, called *brasses* or *steps.* The bed for the steps in this example is cylindrical, and is prepared by the easy process of boring. The steps are not supported throughout their whole length, but at their ends only where fitting strips are provided as shown. As the wear on a step is generally greatest at the bottom, it is made thicker there than at the sides, except where the fitting strips come in. To prevent the steps turning within the block they are generally furnished with lugs, which enter corresponding recesses in the block and cover.

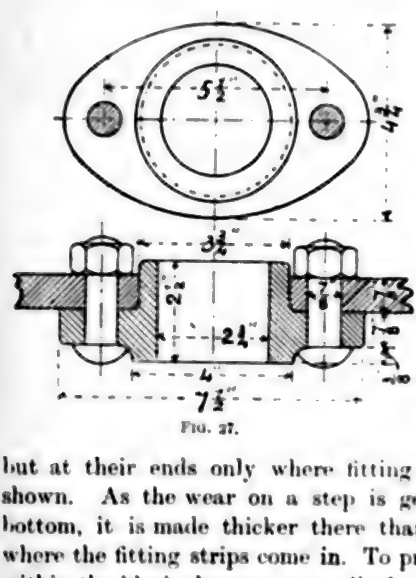


FIG. 27.

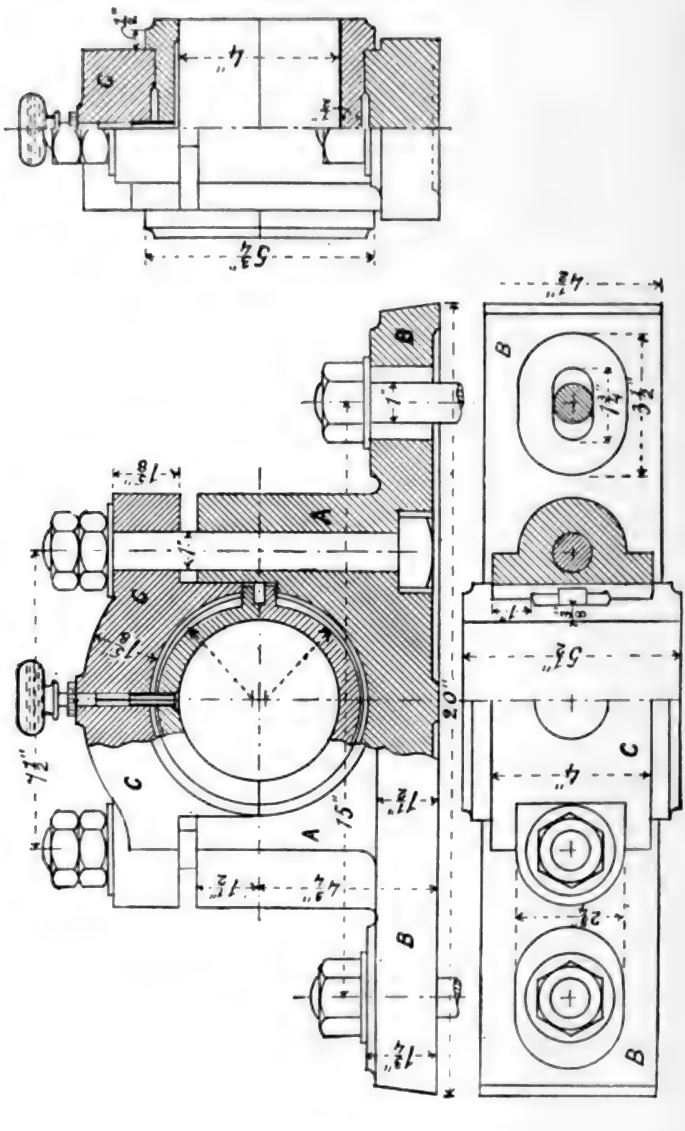


FIG. 28.

In the block illustrated the journal is lubricated by a *needle lubricator* ; this consists of an inverted glass bottle fitted with a wood stopper, through a hole in which passes a piece of wire, which has one end in the oil within the bottle, and the other resting on the journal of the shaft. The wire or needle does not fill the hole in the stopper, but if the needle is kept from vibrating the oil does not escape owing to capillary attraction. When, however, the shaft rotates, the needle begins to vibrate, and the oil runs down slowly on to the journal ; oil is therefore only used when the shaft is running.

EXERCISE 28 : *Pillow Block for a Four-inch Shaft.*—Draw the views shown of this block in fig. 28. Make also separate drawings, full size, of one of the steps. Scale 6 inches to a foot.

Proportions of Pillow Blocks.—The following rules may be used for proportioning pillow blocks for shafts up to 8 inches diameter. It should be remembered that the proportions used by different makers vary considerably, but the following rules represent average practice.

Diameter of journal	$= d$.
Length of journal	$= l$.
Height to centre	$= 1{\cdot}05\,d + {\cdot}5$.
Length of base	$= 3{\cdot}6\,d + 5$.
Width of base	$= {\cdot}8\,l$.
" block	$= {\cdot}7\,l$.
Thickness of base	$= {\cdot}3\,d + {\cdot}3$.
" cap	$= {\cdot}3\,d + {\cdot}4$.
Diameter of bolts	$= {\cdot}25\,d + {\cdot}25$.
Distance between centres of cap bolts	$= 1{\cdot}6\,d + 1{\cdot}5$.
" " base bolts	$= 2{\cdot}7\,d + 4{\cdot}2$.
Thickness of step at bottom	$= t = {\cdot}09\,d + {\cdot}15$.
" " sides	$= \frac{3}{4}\,t$.

The length of the journal varies very much in different cases, and depends upon the speed of the shaft, the load which it carries, the workmanship of the journal and bearing, and the method of lubrication. For ordinary shafting one rule is to make $l = d + 1$. Some makers use the rule $l = 1{\cdot}5d$; others make $l = 2d$.

EXERCISE 29: *Design for Pillow Block.*—Make the necessary working drawings for a pillow block for a shaft 5 inches in diameter, and having a journal 7 inches long.

Brackets.—When a pillow block has to be fixed to a wall or column a bracket such as that shown in figs. 29 and 30 may

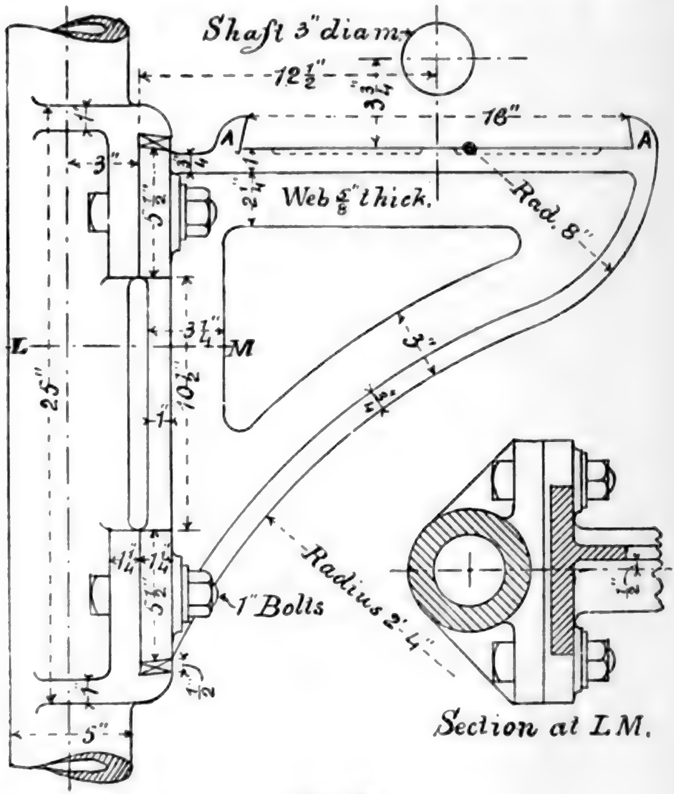


FIG. 29.

be used. The pillow block rests between the *joggles* A A, and is bolted down to the bracket and secured in addition with keys at the ends of the base of the block, in the same manner as is shown for the attachment of the bracket to the column.

EXERCISE 30: *Pillar Bracket.*—Fig. 29 shows a side elevation and part horizontal section, and fig. 30 shows an end elevation of a pillar bracket for carrying a pillow block for a 8-inch shaft. Draw these views *properly projected from one another*, showing the pillow block, which is to be proportioned by the rules given on page 35. Draw also a plan of the whole. Scale 4 inches to a foot.

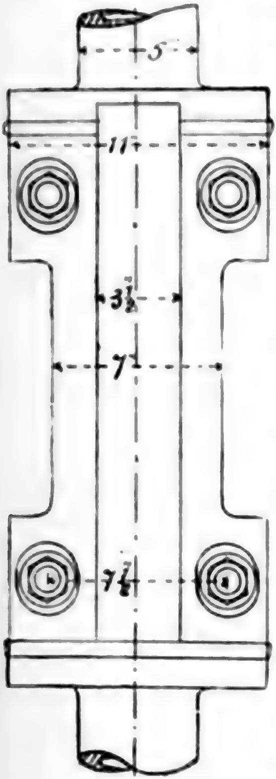


FIG. 30.

Hangers.—When a shaft is suspended from a ceiling it is carried by hangers, one form of which is shown in fig. 31, and which will be readily understood. The cap of the bearing, it will be noticed, is secured by means of a bolt, and also by a square key.

EXERCISE 31: *Shaft Hanger.*—Draw the two elevations shown in fig. 31, and also a sectional plan. The section to be taken at a point 5 inches above the centre of the shaft. Scale 6 inches to a foot.

Wall Boxes.—In passing from one part of a building to another a shaft may have to pass through a wall. In that case a neat appearance is given to the opening and a suitable support obtained for a pillow block by building into the wall a *wall box*, one form of which is shown in fig. 32.

EXERCISE 32: *Wall Box.*—Draw the views of the wall box shown in fig. 32, and also a sectional plan; the plane of section to pass through the box a little above the joggles for the pillow block. Scale 8 inches to a foot.

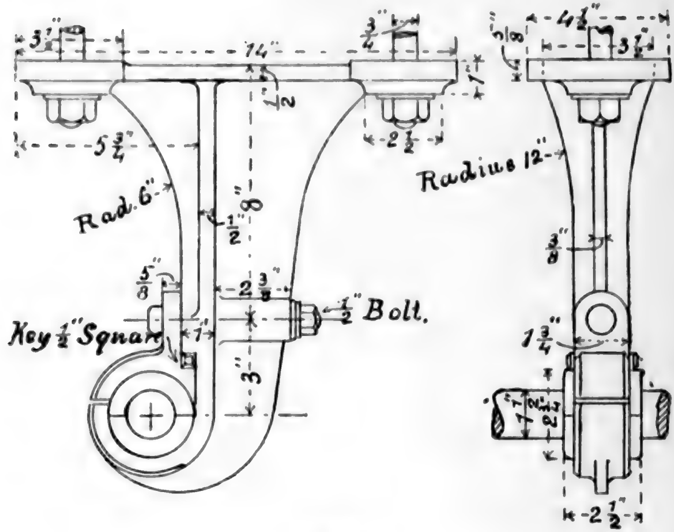

3 1/2"
14"
3/4"
4 1/2"
5/8
3 1/2"
1"
1/2
5 3/4"
2 1/2
Radius 12"
Rad. 6"
8"
1/2
3/8
5/8
2 3/8
1/2" Bolt.
Key 1/2" Square
1"
1 3/4
3"
2 1/2

FIG. 31.

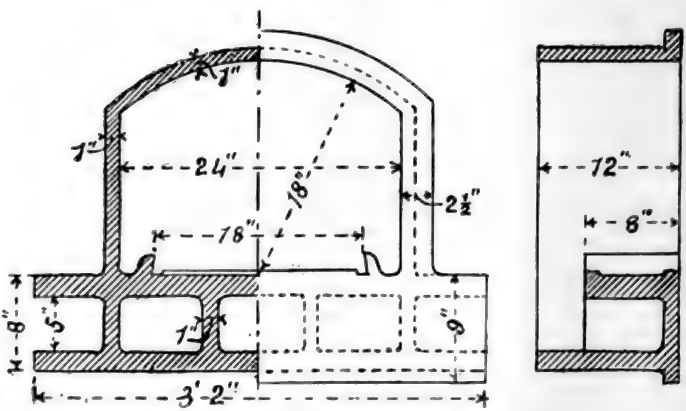

1"
1"
24"
18"
2 1/2"
18"
8"
5"
1"
9"
3'-2"
12"
8"

FIG. 32.

EXERCISE 33: *Sole Plate for a Pillow Block.*—Draw the views of a sole plate for a pillow block, shown in fig. 33. Draw also an end elevation. Scale half full size.

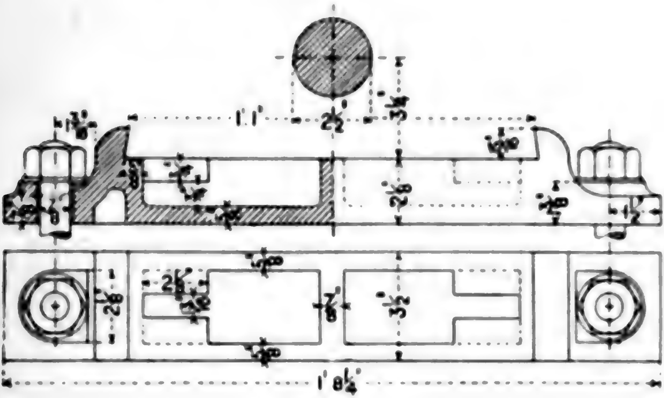


FIG. 33.

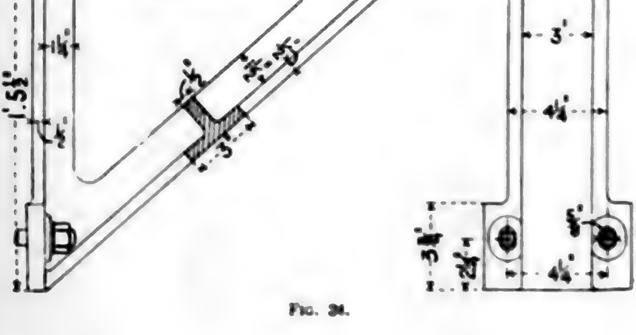


FIG. 34.

EXERCISE 34: *Bracket for Pillow Block.*—Draw, half full size, the side and end elevations of the bracket shown in fig. 34, and from the side elevation project a plan.

EXERCISE 35: *Pillar Bracket and Bearing.*—Draw, half full size, the elevations, partly in section, as shown below, and add a complete plan.

EXERCISE 36: (alternative to the preceding exercise).—Make complete working drawings of each separate part of the bracket and bearing shown below, by itself. Scale half full size.

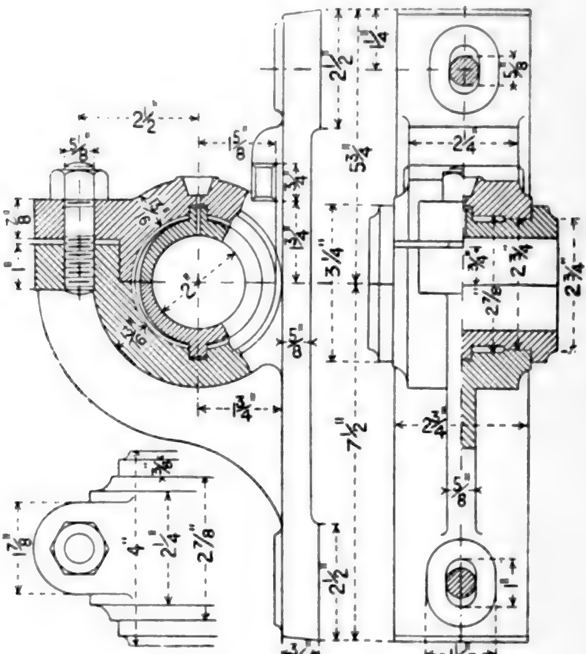


FIG. 35.

Exercise 37: *Pedestal and Bearing.*—Draw, half full size, the views shown in fig. 36; add also an end elevation and a plan.

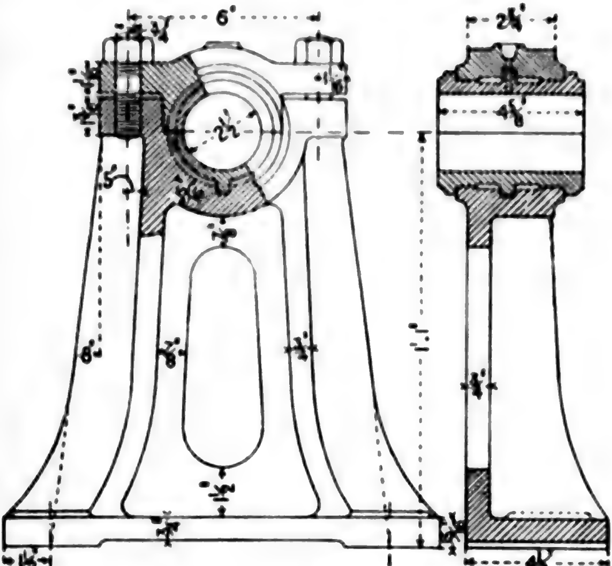


Fig. 36.

Exercise 38: *Pedestal for a Pillow Block.*—Draw the side elevation shown in fig. 37, also a plan and a sectional elevation, the plane of the section to be vertical and to contain the axis of the shaft. Scale 3 inches to a foot.

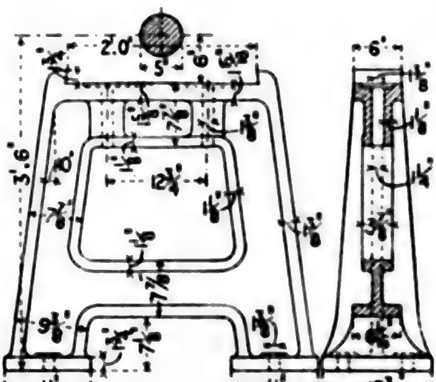


Fig. 37.

EXERCISE 39: *Shaft Hanger with Adjustable Bearing.*—The fig. below shows an excellent form of hanger and bearing for a shaft. The bearing is very long, and is held at the centre of its length on spherical seats, which are formed on the ends of the vertical adjusting screws. The spherical seats permit of a slight angular movement of the bearing, a movement which is necessary with such a long bearing, to ensure that the axis of the bearing coincides with the axis of the shaft. The bearing and the vertical adjusting screws are made of cast-iron.

Draw the side elevation, the cross sectional elevation, and the sectional plan (looking upwards) shown. Draw also a sectional plan looking downwards (section at AB), and an elevation looking in the direction B to A. Scale half full size.

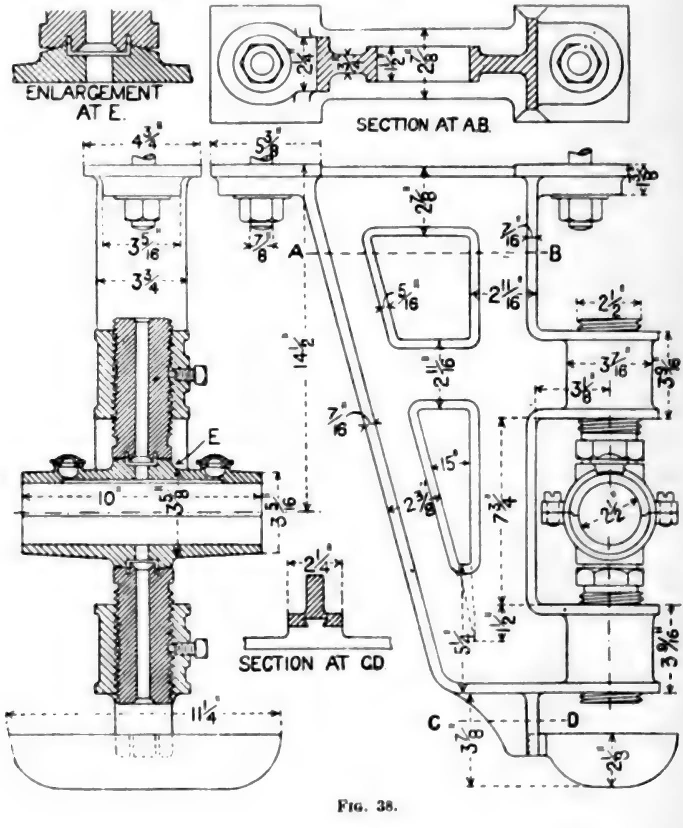


FIG. 38.

Exercise 40 : *Footstep for a Vertical Shaft*.—Draw the following views of the footstep bearing shown in fig. 39. A half-side elevation and half longitudinal section, a half end elevation and half cross section, and a plan. Scale 6 inches to a foot.

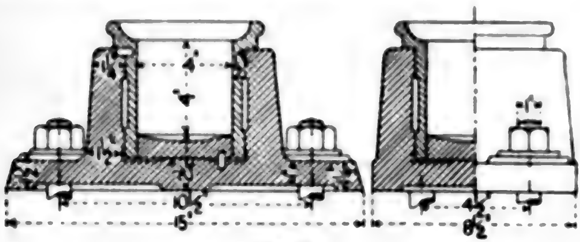


Fig. 39.

Exercise 41 : *Divided Footstep Bearing*.—Draw the views shown in fig. 40, and add a half end elevation and half cross section. Scale 4 inches to a foot.

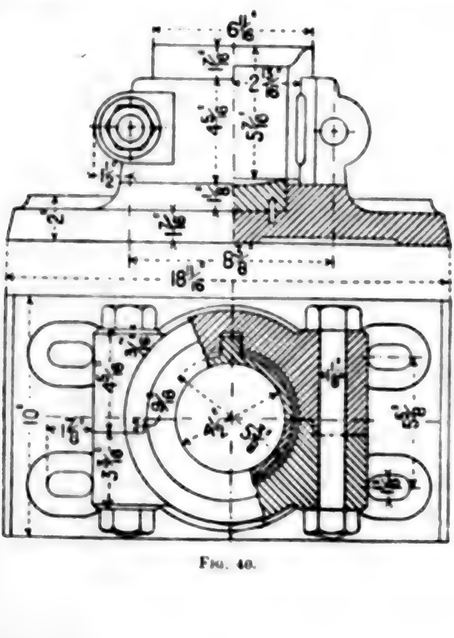


Fig. 40.

VIII. PULLEYS.

Velocity Ratio in Belt Gearing.—Let two pulleys A and B be connected by a belt, and let their diameters be D_1 and D_2; and let their speeds, in revolutions per minute, be N_1 and N_2 respectively. If there is no slipping, the speeds of the rims of the pulleys will be the same as that of the belt, and will therefore be equal. Now the speed of the rim of A is evidently $= D_1 \times 3{\cdot}1416 \times N_1$; while the speed of the rim of B is $= D_2 \times 3{\cdot}1416 \times N_2$. Hence $D_1 \times 3{\cdot}1416 \times N_1 = D_2 \times 3{\cdot}1416 \times N_2$,

and therefore $\dfrac{N_1}{N_2} = \dfrac{D_2}{D_1}$.

Pulleys for Flat Bands.—In cross section the rim of a pulley for carrying a flat band is generally curved as shown in figs. 41 and 42, but very often the cross section is straight. The curved cross section of the rim tends to keep the band from coming off as long as the pulley is rotating. Sometimes the rim of the pulley is provided with flanges which keep the band from falling off.

Pulleys are generally made entirely of cast iron, but a great many pulleys are now made in which the centre or nave only is of cast iron, the arms being of wrought iron cast into the nave, while the rim is of wrought sheet iron.

The arms of pulleys when made of wrought iron are invariably straight, but when made of cast iron they are very often curved. In fig. 41, which shows an arrangement of two cast-iron pulleys, the arms are straight; while in fig. 42, which shows another cast-iron pulley, the arms are curved. Through unequal cooling, and therefore unequal contraction of a cast-iron pulley in the mould, the arms are generally in a state of tension or compression; and if the arms are straight they are very unyielding, so that the result of this initial stress is often the breaking of an arm, or of the rim where it joins an arm. With the curved arm, however, its shape permits it to yield, and thus cause a diminution of the stress due to unequal contraction.

The cross section of the arms of cast-iron pulleys is generally elliptical.

EXERCISE 42: *Fast and Loose Pulleys.*—Fig. 41 shows an arrangement of fast and loose pulleys. A is the fast pulley, secured to the shaft C by a sunk key; B is the loose pulley, which turns freely upon the shaft. The loose pulley is prevented from coming off by a collar D, which is secured to the shaft by a tapered pin as shown. The nave or boss of the loose pulley is here fitted with a

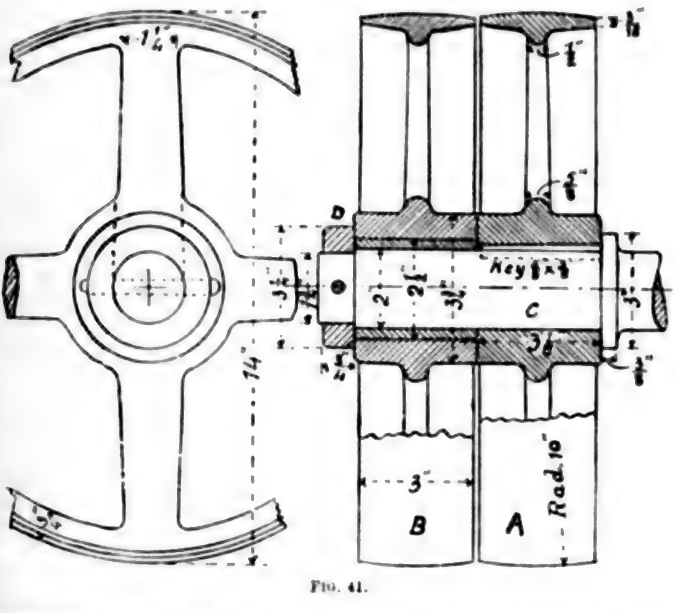


FIG. 41.

brass liner, which may be renewed when it becomes too much worn. Draw the elevations shown, completing the left-hand one. Scale 6 inches to a foot.

By the above arrangement of pulleys a machine may be stopped or set in motion at pleasure. When the driving band is on the loose pulley the machine is at rest, and when it is on the fast pulley the machine is in motion. The driving band is shifted from the one pulley to the other by pressing on that side of the band which is advancing towards the pulleys.

Exercise 43: *Cast-iron Pulley with Curved Arms and Cone Keys.*—Draw a complete side elevation and a complete cross section of the pulley represented in fig. 42 to a scale of 3 inches to a foot. In drawing the side elevation of the arms first draw the centre lines as shown; next draw three circles for each arm, one at each end and one in the middle; the centres of these circles being on the centre line of the arm, and their diameters equal to the widths of the arm at the ends and at the middle respectively. Arcs of circles are then drawn to touch these three circles. The centres and radii of

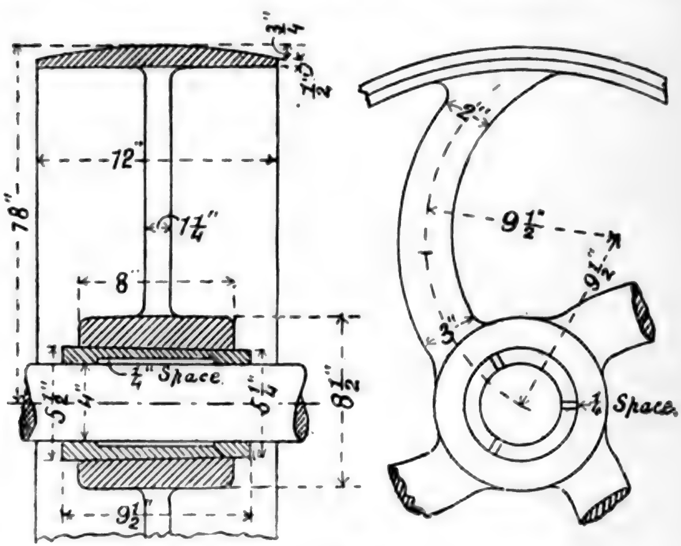


Fig. 42.

these arcs may be found by trial. The cone keys for securing the pulley to the shaft were described on p. 24.

Pulleys for Ropes.—Ropes made of hemp are now extensively used for transmitting power. These ropes vary in diameter from 1 inch to 2 inches, and are run at a speed of about 4,500 feet per minute. The pulleys for these ropes are made of cast iron, and have their rims grooved as shown in fig. 43, which is a cross section of the rim of a pulley carrying three ropes. The angle of the V is usually 45°, and the rope rests on the sides of the groove, and not on the bottom, so that it is wedged in, and has therefore a good hold of the pulley. The diameter of the pulley should not be less than 30 times the diameter of the rope. Two pulleys connected by ropes should not be less than thirty feet apart from centre to centre, but this distance may be as much as 100 feet.

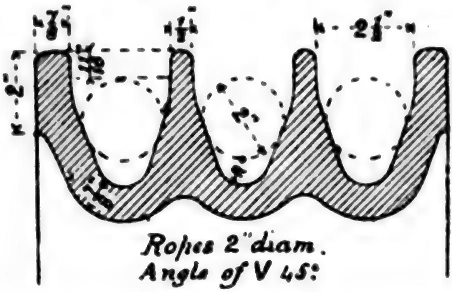


FIG. 43.

EXERCISE 44: *Section of Rim of Rope Pulley.*—Draw, half size, the section of the rim of a rope pulley shown in fig. 43.

IX. TOOTHED WHEELS.

Pitch Surfaces of Spur Wheels.—Let two smooth rollers be placed in contact with their axes parallel, and let one of them rotate about its axis; then if there is no slipping the other roller will rotate in the opposite direction with the same surface velocity; and if D_1, D_2 be the diameters of the rollers, and N_1, N_2 their speeds in revolutions per minute, it follows as in belt gearing that—

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}.$$

If there be considerable resistance to the motion of the follower slipping may take place, and it may stop. To prevent this the rollers may be provided with teeth; then they become *spur wheels*; and if the teeth be so shaped that the ratio of the speeds of the toothed rollers at any instant is the same as that of the smooth rollers, the surfaces of the latter are called the *pitch surfaces* of the former.

Pitch Circle.—A section of the pitch surface of a toothed wheel by a plane perpendicular to its axis is a circle, and is called a *pitch circle.* We may also say that the pitch circle is the edge of the pitch surface. The pitch circle is generally traced on the side of a toothed wheel, and is rather nearer the points of the teeth than the roots.

Pitch of Teeth.—The distance from the centre of one tooth to the centre of the next, or from the front of one to the front of the next, *measured at the pitch circle,* is called the *pitch of the teeth.* If D be the diameter of the pitch circle of a wheel, n the number of teeth, and p the pitch of the teeth, then $D \times 3{\cdot}1416 = n \times p$.

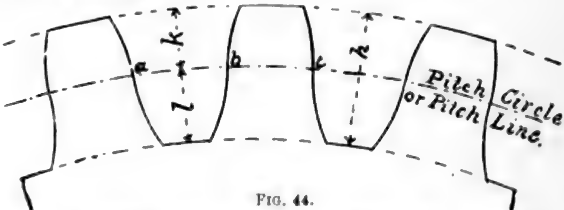


FIG. 44.

By the diameter of a wheel is meant the diameter of its pitch circle.

Form and Proportions of Teeth.—The ordinary form of wheel teeth is shown in fig. 44. The curves of the teeth should be cycloidal curves, although they are generally drawn in as arcs of circles. It does not fall within the scope of this work to discuss the correct forms of wheel teeth. The student will find the theory of the teeth of wheels clearly and fully explained in Goodeve's 'Elements of Mechanism,' and in Unwin's 'Machine Design.'[1]

The following proportions for the teeth of ordinary toothed wheels may be taken as representing average practice :—

Pitch of teeth	$= p =$ arc $a\,b\,c$ (fig. 44).
Thickness of tooth . . .	$= b\,c = {\cdot}48\,p$.
Width of space	$= a\,b = {\cdot}52\,p$.

[1] See also 'A Manual of Machine Drawing and Design,' by D. A. Low and A. W. Bevis.

Total height of tooth . . . $= h = \cdot 7\,p$.
Height of tooth above pitch line $= k = \cdot 3\,p$.
Depth of tooth below pitch line $= l = \cdot 4\,p$.
Width of tooth . . . . $= 2\,p$ to $3\,p$.

EXERCISE 45 : *Spur Wheel.*—Fig. 45 shows the elevation and sectional plan of a portion of a cast iron spur wheel. The diameter of the pitch circle is $23\frac{7}{8}$ inches, and the pitch of the teeth is $1\frac{1}{2}$ inches, so that there will be 50 teeth in the wheel. The wheel has

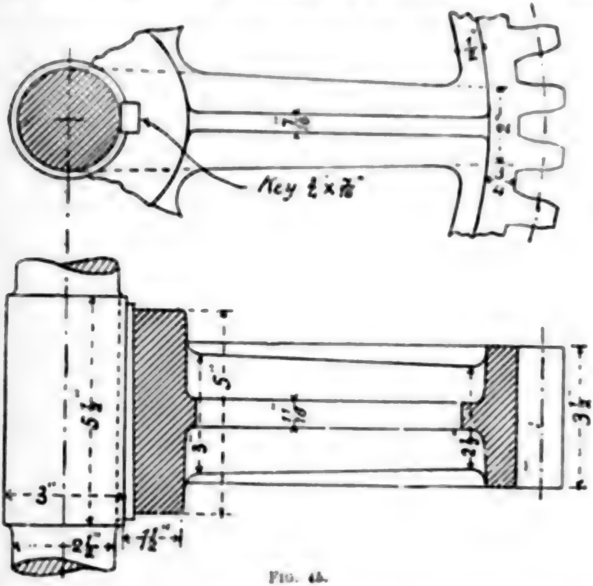


FIG. 45.

six arms. Draw a complete elevation of the wheel and a half sectional plan, also a half-plan without any section. Draw also a cross section of one arm. Scale 4 inches to a foot.

Mortise Wheels.—When two wheels gearing together run at a high speed the teeth of one are made of wood. These teeth, or cogs, as they are generally called, have tenons formed on them, which fit into mortises in the rim of the wheel. This wheel with the wooden teeth is called a *mortise wheel.* An example of a mortise wheel is shown in fig. 46.

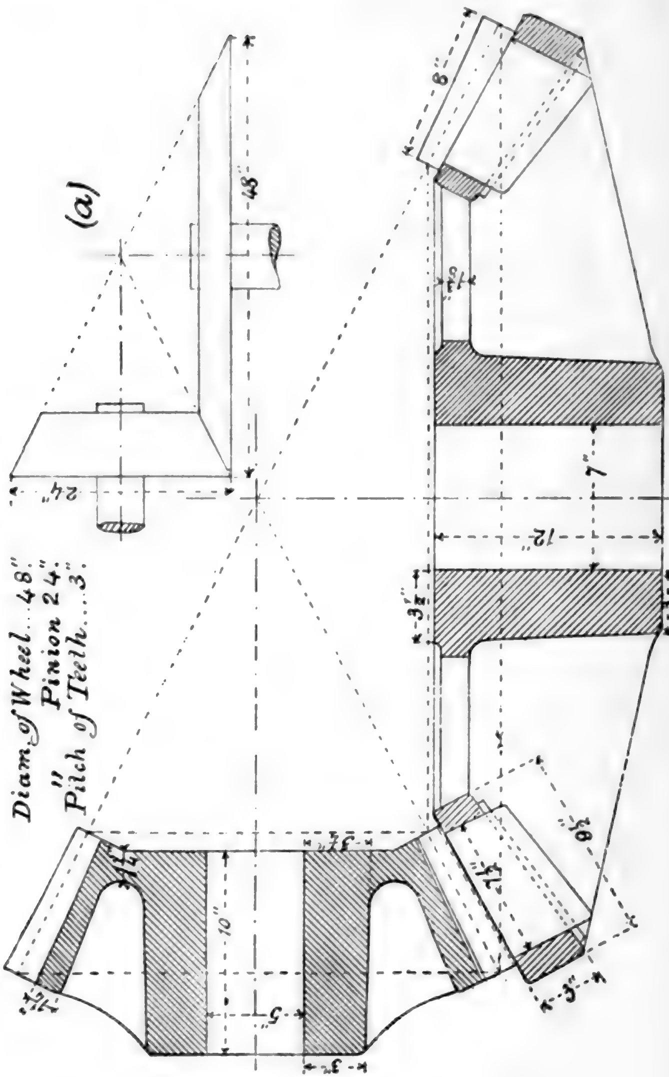


FIG. 46.

Bevil Wheels.—In bevil wheels the pitch surfaces are parts of cones. Bevil wheels are used to connect shafts which are inclined to one another, whereas spur wheels are used to connect parallel shafts. In fig. 46 is shown a pair of bevil wheels in gear, one of them being a mortise wheel. At (*a*) is a separate drawing, to a smaller scale, of the pitch cones. The pitch cones are shown on the drawing of the complete wheels by dotted lines.

The diameters of bevil wheels are the diameters of the bases of their pitch cones.

EXERCISE 46: *Pair of Bevil Wheels.*—Draw the sectional elevation of the bevil wheels shown in gear in fig. 46. Commence by drawing the centre lines of the shafts, which in this example are at right angles to one another; then draw the pitch cones shown by dotted lines. Next put in the teeth which come into the plane of the section, then complete the sections of the wheels. The pinion or smaller wheel has 25 teeth, and the wheel has 50 teeth, which makes the pitch a little over 3 inches. Each tooth of the mortise wheel is secured as shown by an iron pin $\frac{5}{16}$ inch diameter. Scale 3 inches to a foot.

X. CRANKS AND CRANKED SHAFTS.

The most important application of the crank is in the steam-engine, where the reciprocating rectilineal motion of the piston is converted into the rotary motion of the crank-shaft by means of the crank and connecting rod.

At one time steam-engine cranks were largely made of cast iron, now they are always made of wrought iron or steel. The crank is either forged in one piece with the shaft, or it is made separately and then keyed to it.

Overhung Crank.—Fig. 47 shows a wrought-iron overhung crank. A is the crank-shaft, B the crank arm, provided at one end with a boss C, which is bored out to fit the shaft; at the other end of the crank arm is a boss D, which is bored out to receive the crank-pin E, which works in one end of the connecting rod. The crank is secured to the shaft by the sunk key F. It is also good practice to *shrink* the crank on to the shaft. The process of shrinking consists of boring out the crank a little smaller than the shaft, and then heatingit, which causes it to expand sufficiently to go on to the shaft. As the crank cools, it shrinks and grips the shaft firmly. The crank may also be shrunk on to the crank-pin, the latter being then riveted over as shown in fig. 47.

A good plan to adopt in preference to the shrinking process is to force the parts together by hydraulic pressure. This

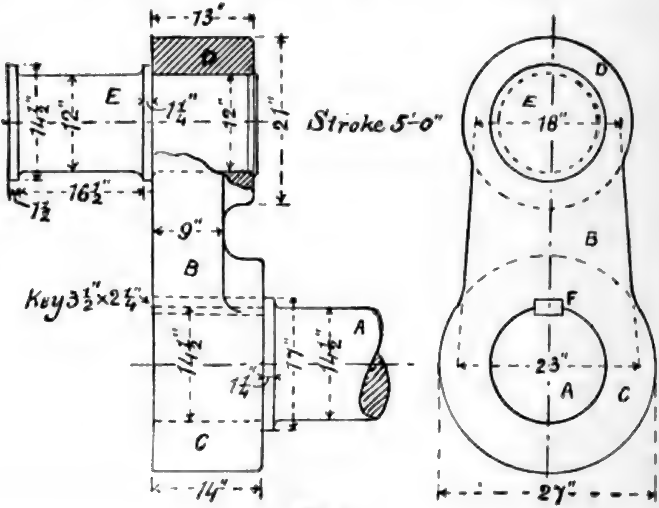


FIG. 47.

method is adopted for placing locomotive wheels on their axles, and for putting in crank-pins. As to the amount of pressure to be used, the practice is to allow a force of 10 tons for every inch of diameter of the pin, axle, or shaft.

Instead of being riveted in, the crank pin may be prolonged and screwed, and fitted with a nut. Another plan is to put a cotter through the crank and the crank-pin.

The distance from the centre of the crank-shaft to the centre of the crank-pin is called the radius of the crank. The *throw* of the crank is twice the radius. In a direct-acting engine the throw of the crank is equal to the stroke of the piston.

Exercise 47: *Wrought-iron Overhung Crank.*—Draw the two elevations shown in fig. 47, also a plan. Scale 1½ inches to a foot.

Proportions of Overhung Cranks.

D = diameter of shaft.
d = „ crank-pin.
Length of large boss = ·9 D.
Diameter „ = 1·8 D.
Length of small boss = 1·1 d.
Diameter „ = 1·8 d.
Width of crank arm at centre of shaft = 1·3 D.
„ „ crank-pin = 1·5 d.

The thickness of the crank arm may be roughly taken as = ·7 D.

Exercise 48.—Design a wrought-iron crank for an engine having a stroke of 4 feet. The crank-shaft is 9 inches in diameter, and the crank-pin is 4¾ inches in diameter and 6½ inches long.

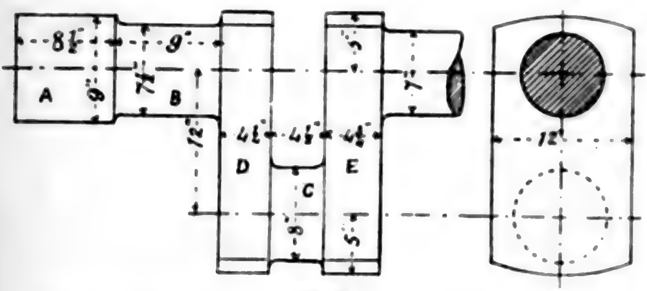


Fig. 48.

Locomotive Cranked Axle.—As an example of a cranked shaft we take the cranked axle for a locomotive with inside cylinders shown in fig. 48; here the crank and shaft or axle are forged in one piece. A is the wheel seat, B the journal, C the crank-pin, and D and E the crank arms. Only one half of the axle is shown in fig. 48, but the other half is exactly the same. The cranks on the two halves are, however, at right angles to one another. The ends of the crank arms are turned in the lathe, the crank-pin ends being turned at the same time as the axle, and the other ends at the same time as the crank-pin. This consideration determines the centres for the arcs shown in the end view.

EXERCISE 49.—Draw to a scale of 2 inches to a foot the side and end elevations of the locomotive cranked axle partly shown in fig. 48. The distance between the centre lines of the cylinders is 2 feet.

Built-up Cranks.—The form of cranked shaft shown in fig. 48 is largely used for marine engines, but for the very powerful engines now fitted in large ships this design of shaft is very unreliable, the built-up crank shown in fig. 49 being preferred, although it is much heavier than the other. It will be seen from the figure that the shaft, crank arms, and crank-pin are made separately. The arms are shrunk on to the pin and the shaft, and secured to the latter by sunk keys. These heavy shafts and cranks are generally made of steel.

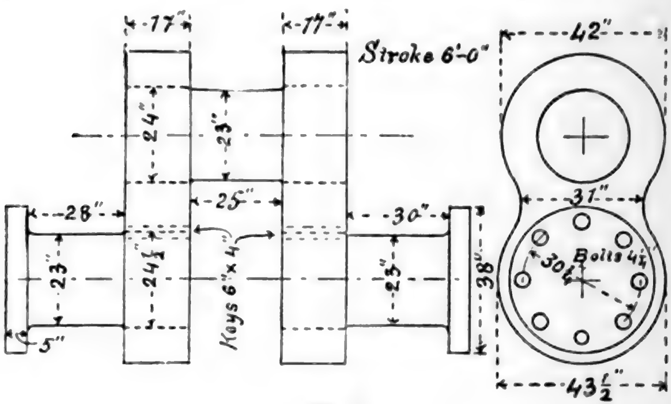


FIG. 49.

EXERCISE 50.—Keeping to the dimensions marked in fig. 49, draw the views there shown of a built-up crank-shaft for a marine engine. Scale ¾ inch to a foot.

XI. ECCENTRICS.

The *eccentric* is a particular form of crank, being a crank in which the crank-pin is large enough to embrace the crank shaft. In the eccentric what corresponds to the crank-pin is called the sheave or pulley. The advantage which an eccentric possesses over a crank is that the shaft does not require to be divided at the point where the eccentric is put on. The crank, however, has this advantage over the eccentric, namely, that it can be used for converting circular into reciprocating motion, or *vice versâ*, while the eccentric can only be used for converting circular into reciprocating motion. This is owing to the great leverage at which the friction of the eccentric acts.

The chief application of the eccentric is in the steam-engine, where it is used for working the valve gear.

To permit of the sheave being placed on the shaft without going over the end (which could not be done at all in the case of a cranked axle, and would be a troublesome operation in most cases) it is generally made in two pieces, as shown in fig. 50, which represents one of the eccentrics of a locomotive. The two parts of the sheave are connected by two cotter bolts. The part which embraces the sheave is called the eccentric strap, and corresponds to, and is, in fact, a connecting rod end: the rod proceeding from this is called the eccentric rod.

The distance from the centre of the sheave to the centre of the shaft is called the *radius* or *eccentricity* of the eccentric. The *throw* is twice the eccentricity.

The sheave is generally made of cast iron. The strap may be of brass, cast iron, or wrought iron; when the strap is made of wrought iron it is commonly lined with brass.

Exercise 51: *Locomotive Eccentric.*—In fig. 50 D E is the sheave, F H the strap, and K the eccentric rod. The sheave and strap are made of cast iron, and the eccentric rod is made of wrought iron. (*a*) is a vertical cross section through the oil-box of the strap; (*b*) is a plan of the end of the eccentric rod and part of the strap. All the nuts are locked by means of cotters. Draw first the elevation, partly in section as shown. Next draw two end

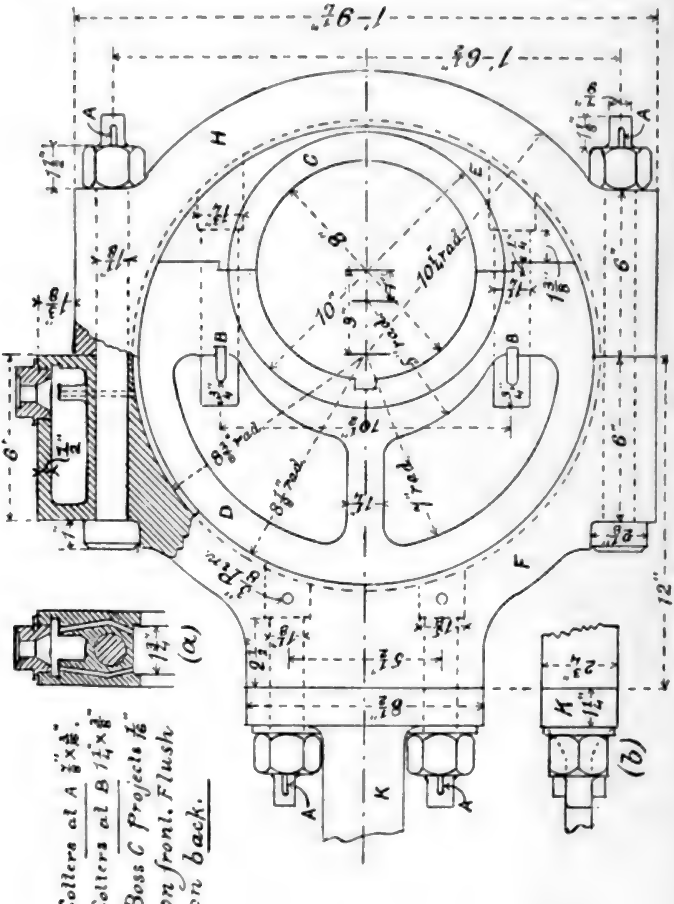


FIG. 50.

elevations, one looking each way. Afterwards draw a horizontal section through the centre, and also a plan. Scale 4 inches to a foot.

XII. CONNECTING RODS.

The most familiar example of the use of a connecting rod is in the steam-engine, where it is used to connect the rotating crank with the reciprocating piston. The rod itself is made of wrought iron or steel, and is generally circular or rectangular in section. The ends of the rod are fitted with steps, which are held together in a variety of ways.

Strap End.—A form of connecting rod end, which is not so common as it used to be, is shown in fig. 51. At (*a*) is shown a longitudinal section with all the parts put together, while at (*b*), (*c*), (*d*), and (*e*) the details are shown separately. A B is the end of the rod which butts against the brass bush C D, which is in two pieces. A *strap* E passes round the bush and on to the end of the rod as shown. The arms of the strap have rectangular holes in them, which are not quite opposite a similar hole in the rod when the parts are put together. If a wedge or *cotter* F be driven into these three holes they will tend to come into line, and the parts of the bush will be pressed together. To prevent the cotter opening out the strap, and to increase the sliding surface, a *gib* H is introduced. The gib is provided with horns at its ends to keep it in its place. Sometimes two gibs are used, one on each side of the cotter; this makes the sliding surface on both sides of the cotter the same. The cotter is secured by a set screw K. The unsectioned portion of fig. (*a*) to the right of the gib, or to the left of the cotter, is called the *clearance* or *draught*.

EXERCISE 52: *Connecting Rod End.*—Make the following views of the connecting rod end illustrated by fig. 51. First, a vertical section, the same as shown at (*a*). Second, a horizontal section. Third, side elevation. Fourth, a plan. Or the first and third views may be combined in a half vertical section and half elevation; and the second and fourth views may be combined in a half horizontal section and half plan.

All the dimensions are to be taken from the detail drawings (*b*), (*c*), (*d*), and (*e*), *but the details need not be drawn separately.* The brass bush is shown at (*d*) by half elevation, half vertical section.

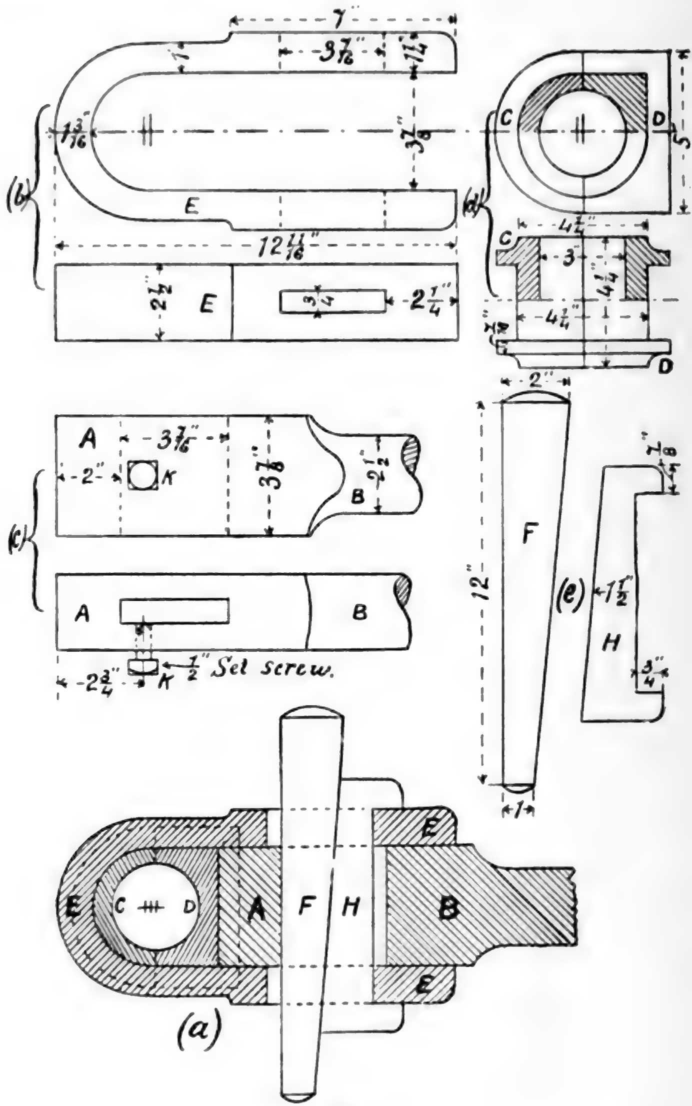


Fig. 51.

half plan, and half horizontal section. The draught or clearance is 7-16ths of an inch.

Box End.—At (*a*), fig. 52, is shown what is known as a box end for a connecting rod. The part which corresponds to the loose strap in the last example is here forged in one piece with the connecting rod. In this form the brass bush is provided with a flange all round on one side, but on the opposite side the flange is omitted except at one end; this is to allow of the bush being placed within the end of the rod. The construction of the bush will be understood by reference to the sketch shown at (*b*). The bush is in two parts, which are pressed tightly together by means of a cotter. This cotter is prevented from slackening back by two set screws. Each set screw is cut off square at the point, and presses on the flat bottom of a very shallow groove cut on the side of the cotter.

The top, bottom, and ends of this box end are turned in the lathe at the same time as the rod itself; this accounts for the curved sections of these parts.

It is clear from the construction of a box end that it is only suitable for an overhung crank.

Exercise 53: *Locomotive Connecting Rod.*—In fig. 52 is shown a connecting rod for an outside cylinder locomotive. (*a*) is the crank-pin end, and (*c*) the cross-head end. The end (*a*) has just been described under the head 'box end.' We may just add that in this particular example the brass bush is lined with white metal as shown, and that the construction of the oil-box is the same as that on the coupling rod end shown in fig. 54. The end (*c*) is forked, and through the prongs of the fork passes the cross-head pin, of which a separate dimensioned drawing is shown at (*d*). Observe that the tapered parts A and B of this pin are parts of the same cone. The rotation of the pin is prevented by a small key as shown. The cross-head pin need not be drawn separately, and the isometric projection of the bush at (*b*) may be omitted, but all the other views shown are to be drawn to a scale of 6 inches to a foot.

Marine Connecting Rod.—The form of connecting rod shown in fig. 53 is that used in marine engines, but it is also used extensively in land engines. A B is the crank-pin end, and C the cross-head end. The end A B is forged in one piece,

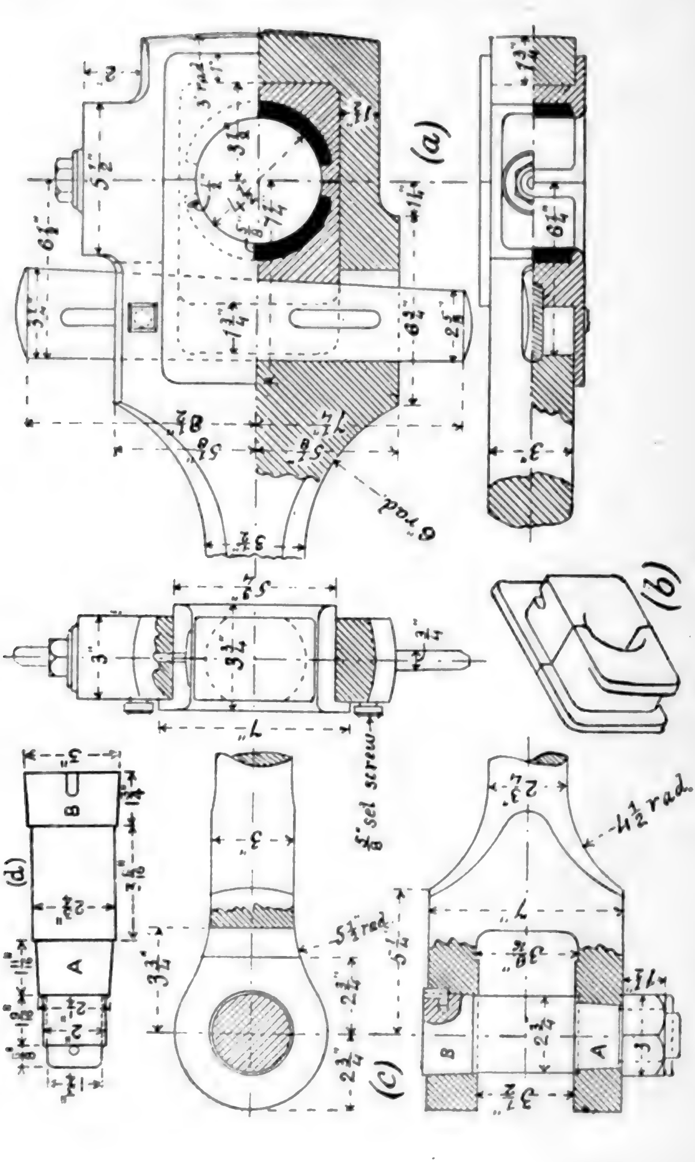


Fig. 52.

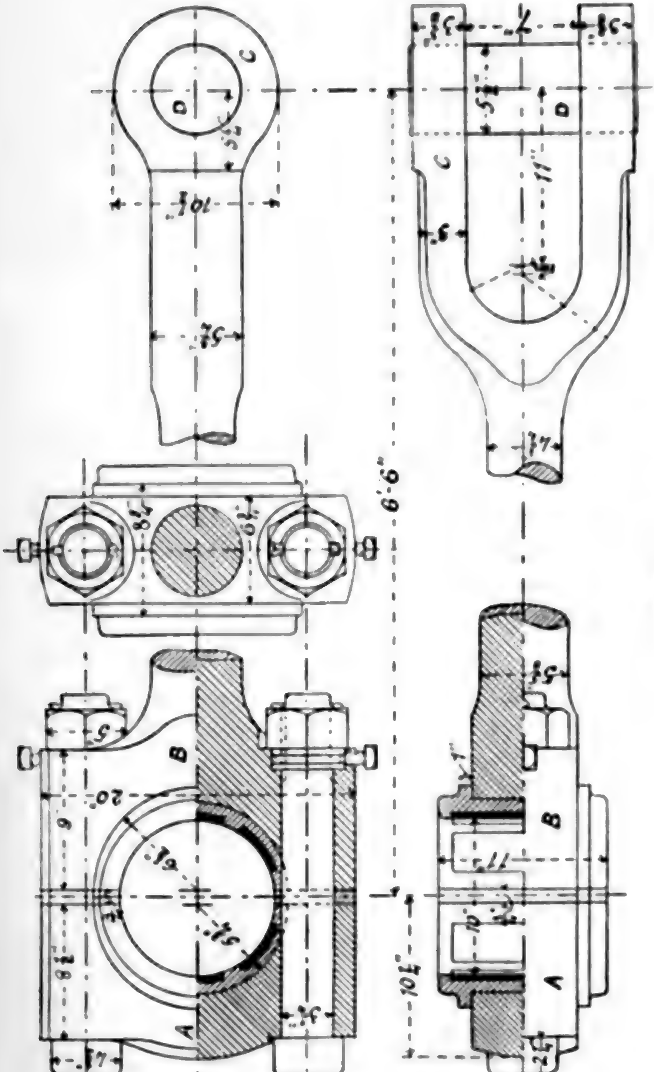


Fig. 32.

and after it is turned, planed, and bored it is slotted across, so as to cut off the cap A. The parts A and B are held together by two bolts as shown. This end of the rod is fitted with brass steps, which are lined with white metal. The cross-head end is forked, and through the prongs of the fork passes a pin D, which also passes through the cross-head, which is forged on to the piston rod or attached to it in some other way.

EXERCISE 54 : *Marine Connecting Rod.*—Draw all the views shown in fig. 53 of one form of marine connecting rod. For detail drawings of the locking arrangement for the nuts see fig. 19, page 21. Scale 4 inches to a foot.

Coupling Rods.—A rod used to transmit the motion of one crank to another is called a *coupling rod.* A familiar example of the use of coupling rods will be found in the locomotive. Coupling rods are made of wrought iron or steel, and are generally of rectangular section. The ends are now generally made solid and lined with solid brass bushes, *without any adjustment for wear.* This form of coupling rod end is found to answer very well in locomotive practice where the workmanship and arrangements for lubrication are excellent. When the brass bush becomes worn it is replaced by a new one.

Fig. 54 shows an example of a locomotive coupling rod end for an outside cylinder engine. In this case it is desirable to have the crank-pin bearings for the coupling rods as short as possible, for a connecting rod and coupling rod in this kind of engine work side by side on the same crank-pin, which, being overhung, should be as short as convenient for the sake of strength. The requisite bearing surface is obtained by having a pin of large diameter. The brass bush is prevented from rotating by means of the square key shown. The oil-box is cut out of the solid, and has a wrought-iron cover slightly dovetailed at the edges. This cover fits into a check round the top inner edge of the box, which is originally parallel, but is made to close on the dovetailed edges of the cover by riveting. A hole in the centre of this cover, which gives access to the oil-box, is fitted with a screwed brass plug. The brass plug has a screwed hole in the centre, through which oil may be introduced to the box. Dust is kept out of the oil-box by screwing into the hole in the brass plug a common cork. The oil is carried slowly but regularly from the oil-box over to the bearing by a piece of cotton wick.

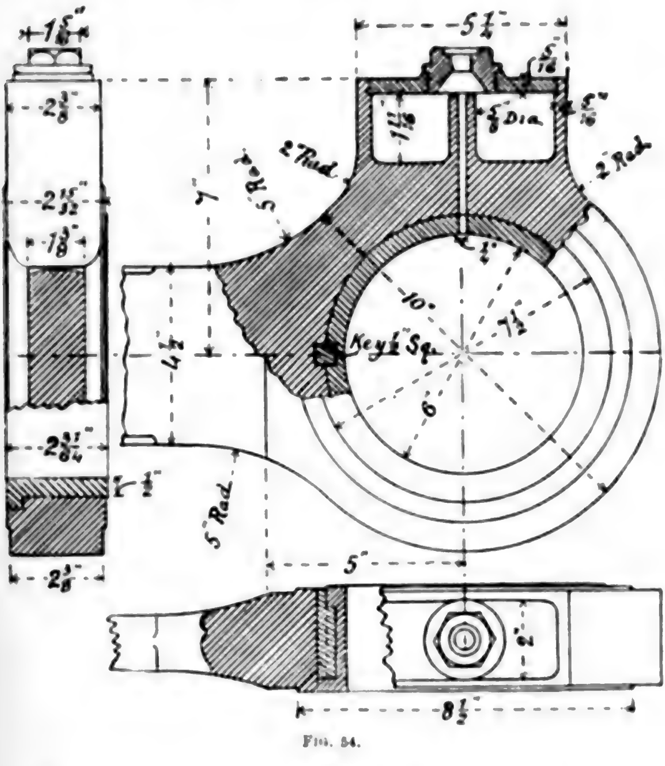


FIG. 54.

EXERCISE 55: *Coupling Rod End.* – Draw first the side elevation and plan, each partly in section as shown in fig. 54. Then instead of the view to the left, which is an end elevation partly in section, draw a complete end elevation looking to the right, and also a complete vertical cross section through the centre of the bearing. Scale 6 inches to a foot.

XIII. CROSS-HEADS.

An example of a steam-engine cross-head is shown in fig. 55. A is the end of the piston rod which has forged upon it the cross-head B. The cross-head pin shown at (*d*), fig. 52, and to which the connecting rod is attached, works in the bearing C. Projecting pieces D, forged on the top and bottom of the cross-head, carry the slide blocks E which work on the slide bars, and thus guide the motion of the piston rod.

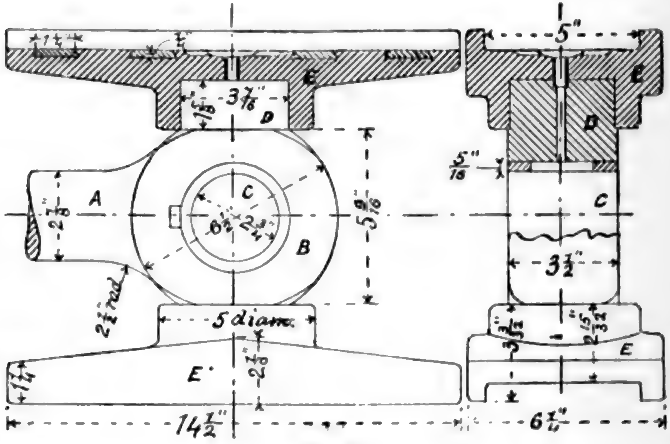


FIG. 55.

EXERCISE 56 : *Locomotive Cross-head.*—In fig. 55 are shown side and end elevations, partly in section, of the cross-head and slide blocks for an outside cylinder locomotive. Draw these views half size, showing also on the end elevation the cross-head pin and a vertical section of the connecting rod end from fig. 52. The bush in the cross-head which forms the bearing for the cross-head pin is of wrought iron, case-hardened, and is prevented from rotating by the key shown. The cross-head is of wrought iron, and the slide blocks are of cast iron, and are fitted with white metal strips as shown. A short brass tube leads oil from the upper slide block into a hole in the cross-head as shown, which carries it to a slot in the bush which distributes it over the cross-head pin.

XIV. PISTONS.

A *piston* is generally a cylindrical piece which slides backwards and forwards inside a hollow cylinder. The piston may be moved by the action of fluid pressure upon it as in a steam-engine, or it may be used to give motion to a fluid as in a pump.

A piston is usually attached to a rod, called a *piston rod*, which passes through the end of the cylinder inside which the piston works, and which serves to transmit the motion of the piston to some piece outside the cylinder, or *vice versâ*.

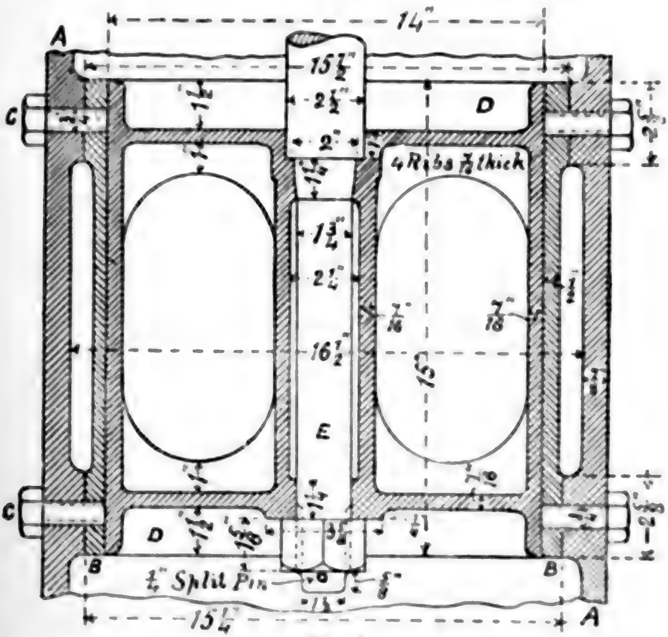


Fig. 36.

A *plunger* is a piston made in one piece with its piston rod, the piston and the rod being of the same diameter.

A piston which is provided with one or more valves which allow the fluid to pass through it from one side to the other is called a *bucket*.

Simple Piston.—The simplest form of piston is a plain cylinder fitting accurately another, inside which it moves. Such a piston works with very little friction, but as there is no adjustment for wear, such a piston is not suitable for a high fluid pressure if it has to work constantly. This simple form of piston is used in the steam-engine indicator, and also in pumps.

Fig. 56 shows the piston of the circulation pump of a marine engine. A is the cast-iron casing or barrel of the pump ; B is a brass liner fitting tightly into the former at its ends, and secured by eight screwed Muntz metal pins C, four at each end ; D is the piston, which is made of brass, and is attached to a Muntz metal piston rod E. The liner is bored out smooth and true from end to end, and the piston is turned so as to be a sliding fit to the liner. The wear in this form of piston is diminished by making the rubbing surface large.

EXERCISE 57 : *Piston for Circulating Pump.*—Draw the vertical sectional elevation of the piston, &c., shown in fig. 56, also a half plan and half horizontal section through the centre. Scale 4 inches to a foot.

Pump Bucket.—The next form of piston which we illustrate is shown in fig. 57. This represents the air-pump bucket of a marine engine. The bucket is made of brass, and is provided with six india-rubber disc valves. The rod is in this case made of Muntz metal. Air-pump rods for marine engines are very often made of wrought iron cased with brass. It will be observed that there is a wide groove around the bucket, which is filled with hempen rope or gasket. This gasket forms an elastic packing which prevents leakage. This is an old-fashioned form of packing, and is now only used for pump buckets.

EXERCISE 58 : *Air-pump Bucket.*—Draw the sectional elevation of the air-pump bucket shown in fig. 57. Also draw a half plan looking downwards and a half plan looking upwards. Scale 4 inches to a foot.

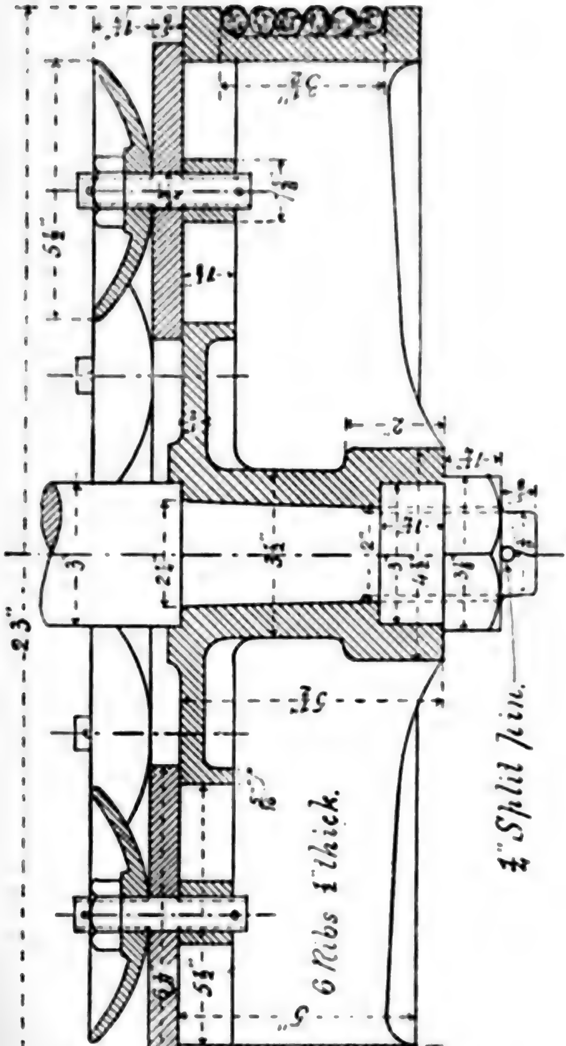


FIG. 33.

Ramsbottom's Packing.—The form of packing used in the air-pump bucket, fig. 57, is not suitable for steam pistons. For the latter the packing is now always metallic. The simplest form of metallic packing is that known as Ramsbottom's. This form is very largely used for locomotive pistons, and for small pistons in many kinds of engines besides. A locomotive piston for an 18-inch cylinder with Ramsbottom's packing is shown in fig. 58. The particular piston there illustrated is made of brass, and is secured to a wrought-iron piston rod by a brass nut. Two circumferential grooves of rectangular section are turned out of the piston, and into these fit two corresponding rings, which may be of brass, cast iron, or steel. In this example the rings are of cast iron. These rings are first turned a little larger in diameter than the bore of the cylinder (in this example $\frac{1}{2}$ inch), and then sprung over the piston into the groves prepared for them. Their own elasticity causes the rings to press outwards on the cylinder. At the point where a ring is split a leakage of steam will take place, but with quick-running pistons this leakage is unimportant. The points where the rings are cut should be placed diametrically opposite, so as to diminish the leakage of steam.

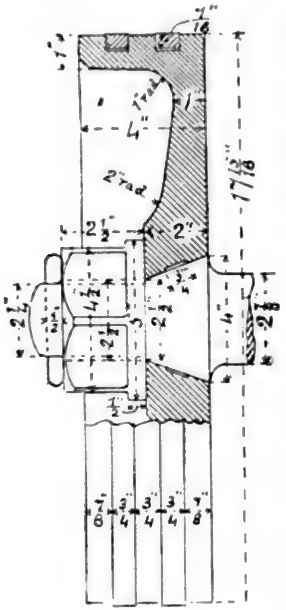


FIG. 58.

EXERCISE 59: *Locomotive Piston.*—A part elevation and part section of a locomotive piston, for a cylinder having a bore 18 inches in diameter, is shown in fig. 58. Draw this, and also a view looking on the nut in the direction of the axis of the piston rod. Scale 6 inches to a foot.

Note.—The reason why the part of the piston rod within the piston has such a quick taper is that the piston has to be taken off the rod while it is in the cylinder. The cross-head being forged on the end of the piston rod prevents the piston and piston rod being withdrawn together.

Large Pistons.—Pistons of large diameter are generally provided with two cast iron packing rings placed within the same groove. These rings are pressed outwards against the cylinder, and also against the sides of the groove by one or more springs. One form of this packing (Lancaster's) is shown in fig. 59. Here one spring only is used, and it is first made

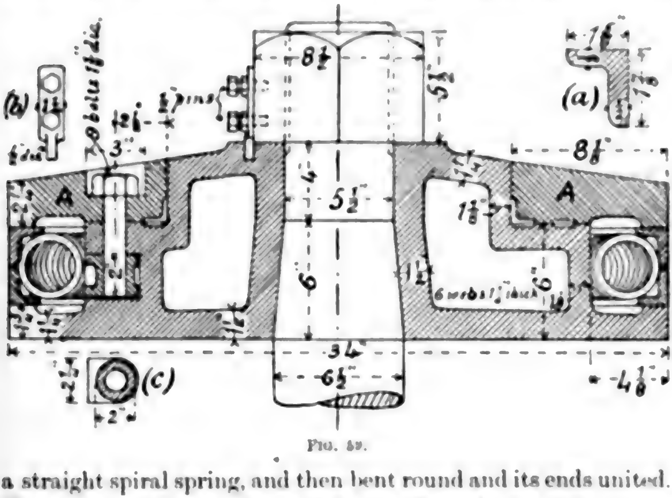


FIG. 59.

a straight spiral spring, and then bent round and its ends united. The action of the spring will be clearly understood from the illustration. For the purpose of admitting the packing rings the piston is divided into two parts, one the piston proper, and the other the *junk ring*. In fig. 59, A is the junk ring, which is secured to the piston by means of bolts as shown.

EXERCISE 60: *Marine Engine Piston.*—The piston illustrated by fig. 59 is for the high-pressure cylinder of a marine engine. The piston, junk ring, and packing rings are of cast iron. The piston rod and nut are of wrought iron, so also are the junk ring bolts. The nuts for the latter are of brass. The spiral spring is made from steel wire ⅜ inch diameter. An enlarged section of one of the packing rings is shown at (*a*). A front elevation of the locking arrangement for the piston rod nut is shown at (*b*). A sectional plan of one of the nuts for the junk ring bolts is shown at (*c*).

First draw the vertical section of this piston, next draw a plan, one-third of which is to show the piston complete, one-third to show the junk ring removed, and the remaining third to be a horizontal section through between the packing rings. The details (*a*) and (*c*) need not be drawn separately. Scale 3 inches to a foot.

Proportions of Marine Engine Pistons.—Mr. Seaton, in his 'Manual of Marine Engineering,' gives the following rules for designing marine engine pistons :—

D = diameter of piston in inches.

p = effective pressure in lbs. per square inch.

$x = \frac{D}{50} \times \sqrt{p} + 1.$

Thickness of front of piston near boss . .	$0{\cdot}2 \times x$.
„ „ „ rim . .	$0{\cdot}17 \times x$.
„ back of piston	$0{\cdot}18 \times x$.
„ boss around rod . . .	$0{\cdot}3 \times x$.
„ flange inside packing ring . .	$0{\cdot}23 \times x$.
„ „ at edge	$0{\cdot}25 \times x$.
„ junk ring at edge . . .	$0{\cdot}23 \times x$.
„ „ inside packing ring .	$0{\cdot}21 \times x$.
„ „ at bolt-holes . .	$0{\cdot}35 \times x$.
„ metal around piston edge . .	$0{\cdot}25 \times x$.
Breadth of packing ring	$0{\cdot}63 \times x$.
Depth of piston at centre	$1{\cdot}4 \times x$.
Lap of junk ring on piston	$0{\cdot}45 \times x$.
Space between piston body and packing ring	$0{\cdot}3 \times x$.
Diameter of junk-ring bolts	$0{\cdot}1 \times x + {\cdot}25$ inch.
Pitch of junk-ring bolts	10 diameters.
Number of webs in piston	$\frac{D+20}{12}$.
Thickness „	$0{\cdot}18 \times x$.

EXERCISE 61 : *Design for Marine Engine Piston.*—Calculate by Seaton's rules the dimensions for a marine engine piston 40 inches in diameter, and subjected to an effective pressure of 86 lbs. per square inch. Then make the necessary working drawings for this piston to a scale of, say, 3 inches to a foot.

Note.—Take the dimensions got by calculation to the nearest 1-16th of an inch.

Exercise 62: *Gas-engine Piston.* Draw the views (a), (b), and (c) of the gas-engine piston, gudgeon, and connecting-rod end, shown below. Scale 6 inches to a foot. (The two halves of the brass bush are pressed together by a brass set-screw, which has for a head a small spur-wheel, which gears with a pinion formed on a spindle, which is rotated by a spanner from the front end of the piston. The wheel has 24 teeth and the pinion 12 teeth.)

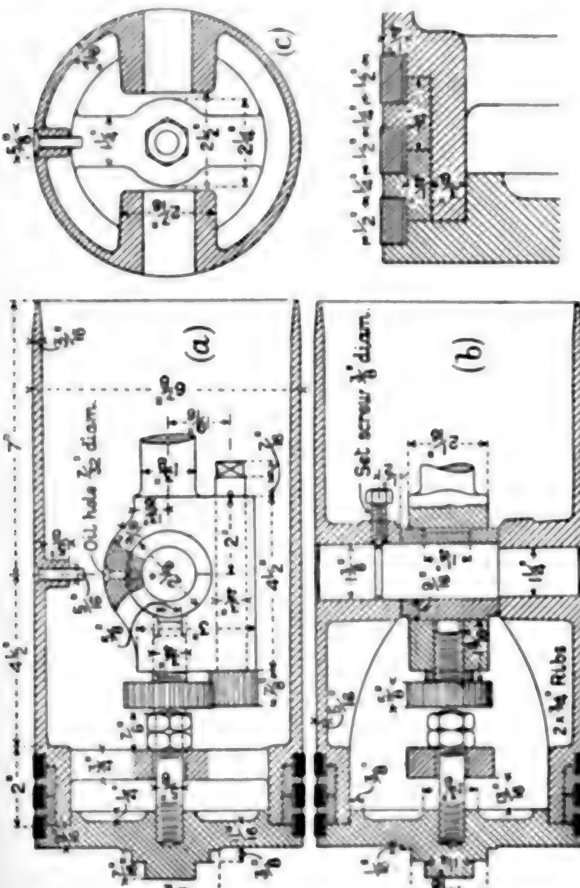


Fig. 60.

XV. STUFFING-BOXES.

In fig. 61 is shown a gland and stuffing-box for the piston rod of a vertical engine. A B is the piston rod, C D a portion of the cylinder cover, and E F the *stuffing-box*. Fitting into

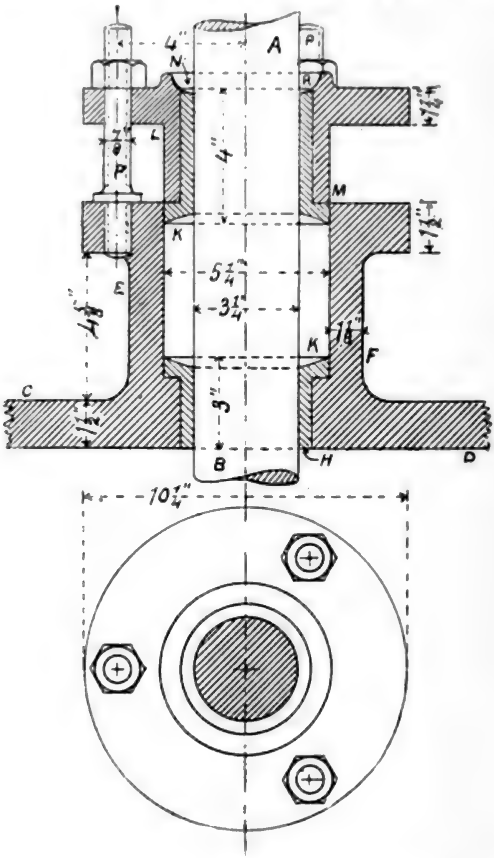


FIG. 61.

the bottom of the stuffing-box is a brass bush H. The space K around the rod A B is filled with *packing*, of which there is a variety of kinds, the simplest being greased hempen rope. The packing is compressed by screwing down the cast-iron gland L M, which is lined with a brass bush N. In this case the gland is screwed down by means of three stud-bolts P, which are screwed into a flange cast on the stuffing-box.

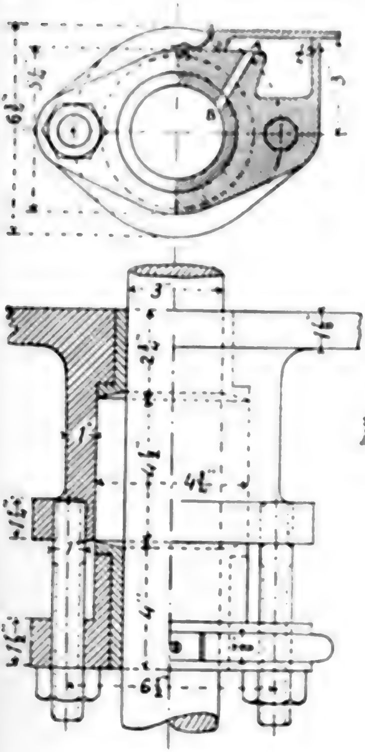


FIG. 62.

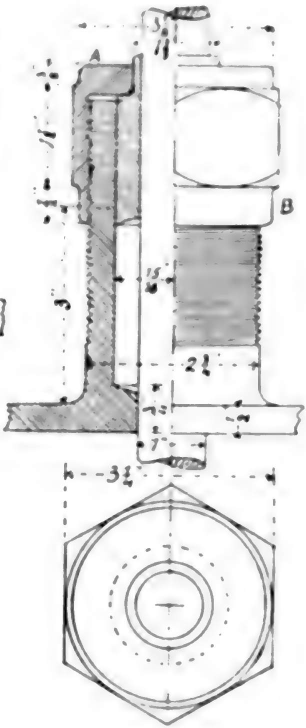


FIG. 63.

Surrounding the rod on the top of the gland there is a recess R for holding the lubricant.

The object of the gland and stuffing-box is to allow the piston rod to move backwards and forwards freely without any leakage of steam.

Fig. 62 shows a gland and stuffing-box for a horizontal rod. The essential difference between this example and the last is in the mode of lubrication. The gland flange has cast within it an oil-box which is covered by a lid; this lid is kept shut or open by the action of a small spring as shown. A piece of cotton wick (not shown in the figure) has one end trailing in the oil in the oil-box, while the other is carried over and passed down the hole A B. The wick acts as a siphon, and drops the oil gradually on to the rod. In this example only two bolts are used for screwing in the gland; and the flanges of the gland and stuffing-box are not circular, but oval-shaped.

In the case of small rods the gland is made entirely of brass, and no liner is then necessary. Fig. 63 shows a form of gland and stuffing-box sometimes used for small rods. The stuffing-box is screwed externally, and carries a nut A B which moves the gland.

Exercise 63: *Gland and Stuffing-box for a Vertical Rod.*—Draw the views shown in fig. 61 to the dimensions given. Scale 6 inches to a foot.

Exercise 64: *Gland and Stuffing-box for a Horizontal Rod.*—Fig. 62 shows a plan, half in section, and an elevation half of which is a section through the gland flange. Draw these to a scale of 6 inches to a foot, using the dimensions marked in the figure.

Exercise 65: *Screwed Gland and Stuffing-box.*—Draw, full size, the views shown in fig. 63 to the given dimensions.

A more elaborate form of gland and stuffing-box is shown in fig. 64. This is for a large marine engine with inverted cylinders, such as is used on board large ocean steamers. The stuffing-box is cast separate from the cylinder cover to which it is afterwards bolted. The lubricant is first introduced to the oil-boxes marked A, from which it passes to the recess B, where it comes in contact with the piston rod. To prevent the lubricant from being wasted by running down the rod, the main gland is provided with a shallow gland and stuffing-box which is filled with soft cotton packing, which soaks up the lubricant.

The main gland is screwed up by means of six bolts, and to prevent the gland from locking itself in the stuffing-box, it

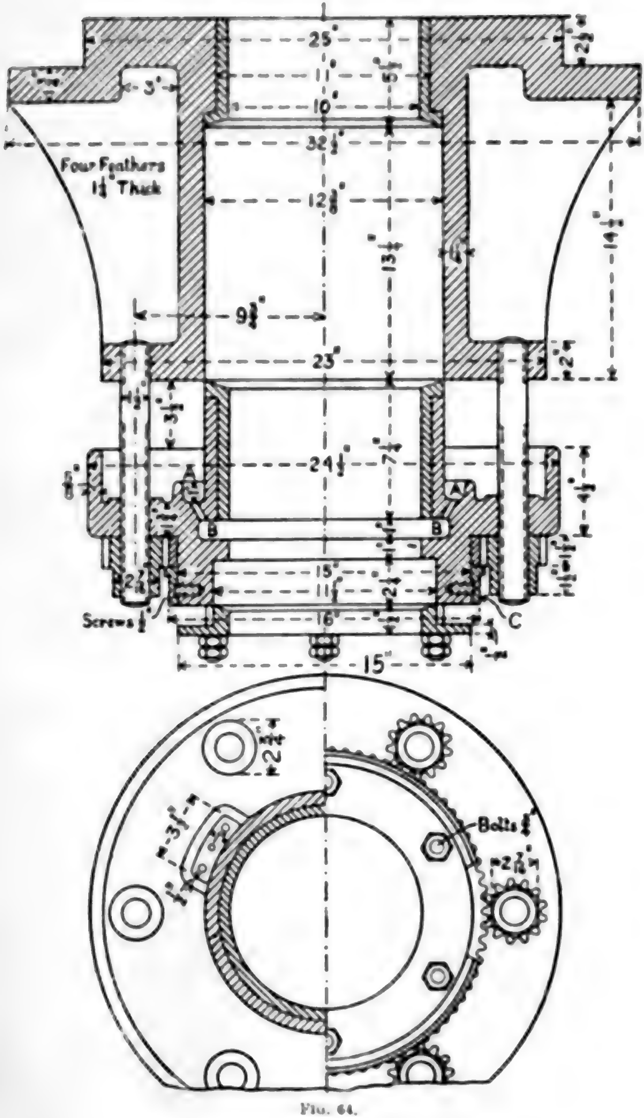


FIG. 64.

is necessary that the nuts should be turned together. This is done in a simple and ingenious manner. One-half of each nut is provided with teeth, and these gear with a toothed wheel which has a rim only ; this rim is held up by a ring C. When one nut is turned, all the rest follow in the same direction.

EXERCISE 66 : *Gland and Stuffing-box for Piston Rod of Large Inverted Cylinder Engine.*—The lower view in fig. 64 is a half plan looking upwards, and a half section of the gland looking downwards. The upper view is a vertical section. Complete all these views and add an elevation. Scale 8 inches to a foot.

Note.—The large nuts, the wheel, the supporting ring, and small gland are made of brass.

Dimensions of Stuffing-boxes and Glands.

d = diameter of rod.
d_1 = diameter of box (inside).
l = length of stuffing-box bush.
l_1 = length of packing space.
l_2 = length of gland.
t = thickness of metal in stuffing-box.
t_1 = thickness of stuffing-box flange.
t_2 = thickness of gland flange.
t_3 = thickness of bushes in box and gland.
d_2 = diameter of gland bolts.
n = number of bolts.

d	d_1	l	l_1	l_2	t	t_1	t_2	t_3	d_2	n
1	$1\frac{3}{4}$	$\frac{3}{4}$	2	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{1}{2}$	$t_2 = t$ when gland flange is made of cast iron, and $t_2 = t_1$ when gland flange is made of brass.	$\frac{3}{16}$	$\frac{7}{16}$	2
$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{5}{8}$	2	$\frac{9}{16}$	$\frac{11}{16}$		$\frac{1}{4}$	$\frac{5}{8}$	2
2	$3\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{1}{2}$	$\frac{11}{16}$	$\frac{7}{8}$		$\frac{5}{16}$	$\frac{3}{4}$	2
$2\frac{1}{2}$	$4\frac{1}{8}$	$2\frac{1}{4}$	$3\frac{7}{8}$	$2\frac{7}{8}$	$\frac{13}{16}$	$1\frac{1}{16}$		$\frac{5}{16}$	$\frac{7}{8}$	2
3	$4\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$3\frac{1}{4}$	$\frac{15}{16}$	$1\frac{1}{4}$		$\frac{3}{8}$	1	2
$3\frac{1}{2}$	$5\frac{1}{4}$	3	$5\frac{1}{8}$	$3\frac{5}{8}$	1	$1\frac{3}{8}$		$\frac{3}{8}$	1	2
4	$5\frac{7}{8}$	$3\frac{1}{4}$	$5\frac{3}{4}$	4	1	$1\frac{1}{2}$		$\frac{7}{16}$	1	2
$4\frac{1}{2}$	$6\frac{3}{8}$	$3\frac{1}{2}$	$6\frac{3}{8}$	$4\frac{3}{8}$	$1\frac{1}{16}$	$1\frac{9}{16}$		$\frac{7}{16}$	$\frac{7}{8}$	4
5	7	$3\frac{3}{4}$	7	$4\frac{5}{8}$	$1\frac{1}{16}$	$1\frac{9}{16}$		$\frac{7}{16}$	1	4
6	8	$4\frac{1}{4}$	$8\frac{1}{4}$	5	$1\frac{1}{8}$	$1\frac{11}{16}$		$\frac{1}{2}$	$1\frac{1}{4}$	4

The proportions of glands and stuffing-boxes vary considerably, but the above table represents average practice.

EXERCISE 67.—Make the necessary working drawings for a gland and stuffing-box for a locomotive engine piston rod $2\frac{1}{2}$ inches in diameter, to the dimensions given in the table.

XVI. VALVES.

Professor Unwin divides valves, according to their construction, into three classes as follows :—(1) flap valves, which bend or turn upon a hinge ; (2) lift valves, which rise perpendicularly to the seat ; (3) sliding valves, which move parallel to the seat.

Examples of flap valves are shown in figs. 65 and 66 ; two forms of lift valves are shown in figs. 67 and 68, and in figs. 69 and 70 are shown two forms of slide valve. The slide valve shown in fig. 69 moves in a straight line, while that shown in fig. 70 (called a cock) moves in circle.

India-rubber Valves.—In india-rubber valves there is a grating covered by a piece of india-rubber, which may be rectangular, but is generally circular, and which is held down along one edge if rectangular, or at the centre if circular. Water or other fluid can pass freely upwards through the grating, but when it attempts to return the elasticity of the india-rubber, and the pressure of the water upon it, cause it to lie close on the grating, and thus prevent the return of the water. The india-rubber is prevented from rising too high by a perforated guard. In fig. 65 is shown an example of an india-rubber disc valve. A is the grating, B the india-rubber, C the guard secured to the grating or seat by the stud D and nut E. The grating is held in position by bolts and nuts F. The grating and guard are generally of brass.

India-rubber disc valves are also shown on the air-pump bucket, fig. 57.

Exercise 68: *India-rubber Disc Valve.*—Fig. 65 shows a vertical section and a plan of an india-rubber disc valve. In the plan one-half of the guard and india-rubber are supposed to be removed, so as to show the grating or seat. Draw these views, and also an elevation. A detail drawing of the central stud is shown in fig. 16, page 18. In fig. 65 the elevation of the guard is drawn as it is usually drawn in practice, but if the student has a sufficient knowledge of descriptive geometry he should draw the elevation completely showing the perforations. Scale 6 inches to a foot.

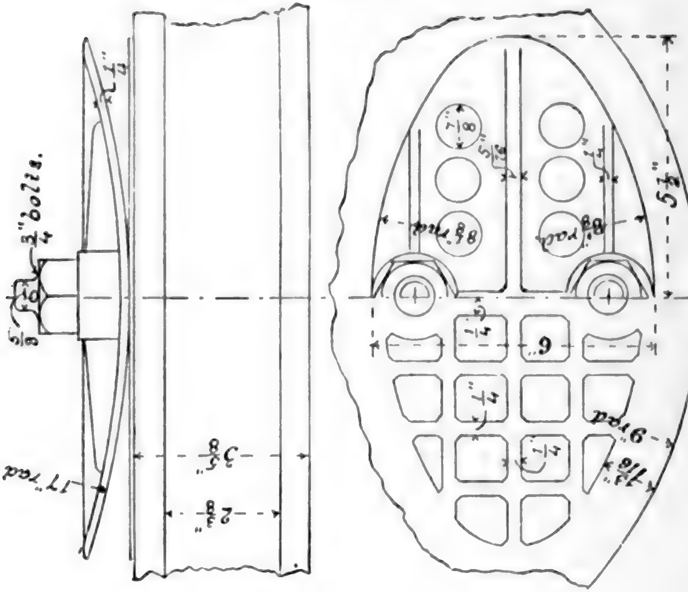


FIG. 66.

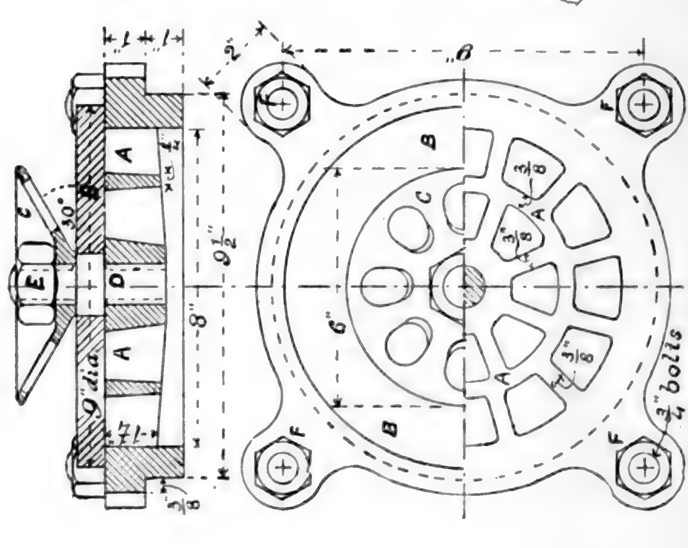


FIG. 65.

Kinghorn's Metallic Valve.—The action of this valve is the same as that of an india-rubber valve, but a thin sheet of metal (phosphor bronze) takes the place of the india-rubber.

This valve is now largely used in the pumps of marine engines, and is shown in fig. 66 as applied to an air-pump bucket. Three valves like the one shown are arranged round the bucket.

EXERCISE 69: *Kinghorn's Metallic Valve.*—Fig. 66 shows an elevation and plan of one form of this valve. In the plan one-half of the guard and metal sheet are supposed to be removed, so as to show the grating, which in this case is part of an air-pump bucket. Draw the views shown, and also a vertical section of the guard through the centres of the bolts. All the parts are of brass except the valve proper, which is of phosphor bronze. Scale 6 inches to a foot.

Conical Disc Valves.—A very common form of valve is that shown in figs. 67 and 68. This form of valve consists of a disc, the edge of which (called the face) is conical. The conical edge of this disc fits accurately on a corresponding seat. The angle which the valve face makes with its axis is generally 45°. If the disc is raised, either by the action of the fluid as in the india-rubber valve, or by other means, an opening is formed around the disc through which the fluid can pass. The valve is guided in rising and falling either by three feathers underneath it, as in fig. 67, or by a central spindle which moves freely through a hole in the centre of a bridge which stretches across the seat, as in fig. 68. The lift of the valve is limited by a stop above it, which forms part of the casing containing the valve. The lift should in no case exceed one-fourth of the diameter of the valve, and it is generally much less than this. The guiding feathers (fig. 67) are notched immediately under the disc for the purpose of making available the full circumferential opening of the valve for the passage of the fluid. These notches also prevent the feathers from interfering with the turning or scraping of the valve face.

Conical disc valves and their seats are nearly always made of brass.

Exercise 70: *Conical Disc Valves.*—Draw, half size, the plans and elevations shown in figs. 67 and 68. In fig. 68 the valve is shown open in the elevation, and in the plan it is removed altogether in order to show the seat with its guide bridge.

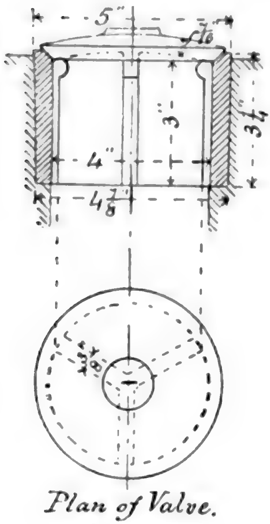


Fig. 67.

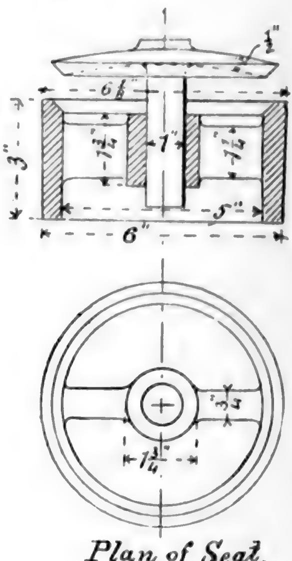


Fig. 68.

Simple Slide Valve.—The form of valve shown in fig. 69, often called the *locomotive slide valve*, is very largely used in all classes of steam-engines for distributing the steam in the steam cylinders. The valve is shown separately at (*d*), (*e*), and (*f*), while at (*a*), (*b*), and (*c*) is shown its connection with the steam cylinder.

It will be observed that the valve itself is in the shape of a box with one side open, the edges of the open side being flanged. When the valve is in its middle position, as shown at (*a*), two of these flanged edges completely cover two rectangular openings S_1 and S_2, called *steam ports*, while the hollow part of the valve is opposite to a third port E, called the *exhaust port*. As shown at (*a*) the piston P would be moving upwards and the valve downwards. By the time the piston has reached the top of its stroke the valve will have moved so far down as to partly uncover the steam port S_1, and admit steam from the valve casing C through S_1 and the passage P_1 to the top of the piston. The pressure of this steam on the top of the piston will force the latter down. While the above action has been going on, the port S_2 will have become uncovered, and the hollow part of the valve will be opposite both the steam port S_2 and the exhaust port E, so that the steam from the under side of the piston, and which forced the piston up, can now escape by the passage P_2, the steam port S_2, and the exhaust port E to the exhaust outlet O, and thence into the atmosphere, if it is a non-condensing engine, or into the condenser if it is a condensing engine, or into another cylinder if it is a compound engine. After the piston has performed a certain part of its downward stroke, the valve, which has been moving downwards, will commence to move upwards, and when it has reached a certain point it will cover the port S_1, and shut off the supply of steam to the top of the piston. It is generally arranged that the steam shall be cut off before the piston reaches the end of the stroke. When the piston reaches the bottom of its stroke the valve has moved far enough up to uncover the port S_2 and admit steam to the bottom of the piston, and to uncover the port S_1 and allow the steam to escape from the top of the piston through the passage P_1, the port S_1, the port E, and outlet O. In this way the piston is moved up and down in the cylinder.

The valve is attached to a valve spindle S by nuts as shown, the hole in the valve through which the spindle passes being oval-shaped to permit of the valve adjusting itself so as to always press on its seat.

When the valve is in its middle position it generally more than covers the steam ports. The amount which the valve projects over the steam port on the outside, the valve being in its middle position, is called the *outside lap* of the valve, and the amount which it projects on the inside is called the *inside lap*. When the term *lap* is used without any qualification, outside lap is to be understood. In fig. 69 it will be

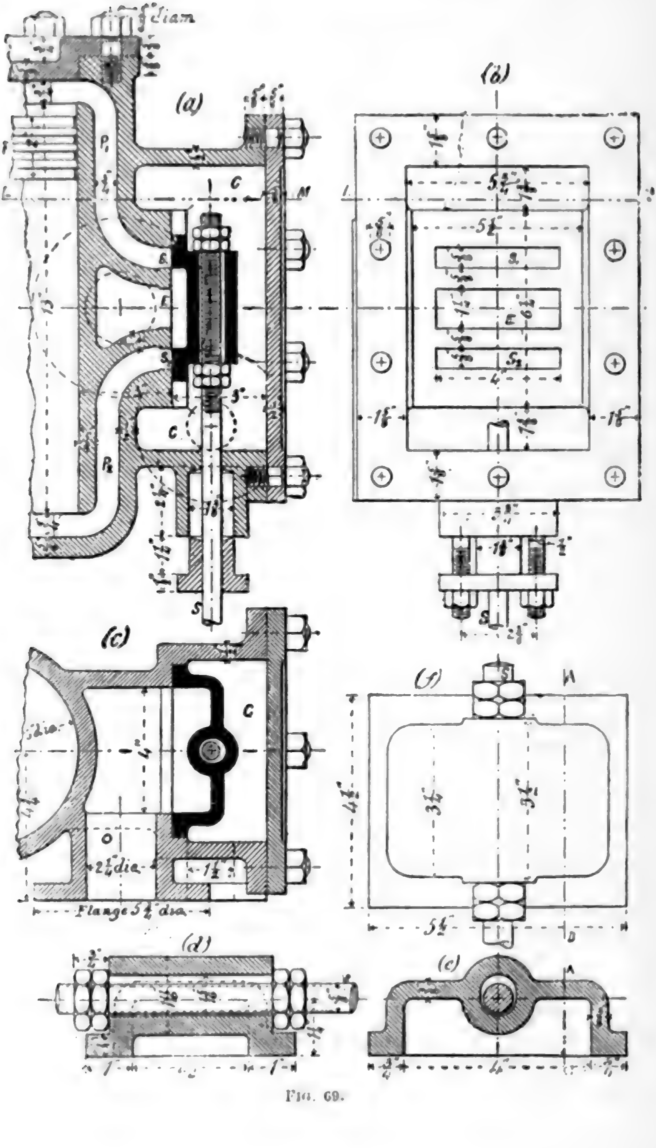


FIG. 69.

seen that the valve has no inside lap, and that the outside lap is three-eighths of an inch. The inside lap is generally small compared with the outside lap.

When the piston is at the beginning of its stroke the steam port is generally open by a small amount called the *lead* of the valve.

The reciprocating motion of the slide valve is nearly always derived from an eccentric fixed on the crank-shaft of the engine. Slide valves are generally made of brass, bronze, or cast iron.

EXERCISE 71 : *Simple Slide Valve.*—At (*d*), fig. 69, is shown a sectional elevation of a simple slide valve for a steam-engine, the section being taken through the centre line of the valve spindle, while at (*e*) is shown a cross section and elevation, and at (*f*) a plan of the same. Draw all these views full size, and also a sectional elevation at A B. The valve is made of brass, and the valve spindle and nuts of wrought iron.

EXERCISE 72 : *Slide Valve Casing, &c., for Steam-engine.*—Draw, half size, the views shown at (*a*), (*b*), and (*c*), fig. 69 ; also a sectional plan at L M. (*b*) is an elevation of the valve casing with the cover and the valve removed. (*a*) is a sectional elevation, the section being taken through the axes of the steam cylinder and valve spindle. (*c*) is a sectional plan, the section being a horizontal one through the centre of the exhaust port. The inlet and outlet for the steam are clearly shown in the sectional plan : in the sectional elevation their positions are shown by dotted circles.

The stroke of the piston is in this case 12 inches, so that from the dimensions given at (*a*) it must come within a quarter of an inch of each end of the cylinder ; this is called the *cylinder clearance.*

The piston has three Ramsbottom rings, a quarter of an inch wide and a quarter of an inch apart.

The steam cylinder and valve casing are made of cast iron.

Cocks.—A cock consists of a slightly conical plug which fits into a corresponding casing cast on a pipe. Through the plug is a hole which may be made by turning the plug to form a continuation of the hole in the pipe, and thus allow the fluid to pass, or it may be turned round so that the solid part of the plug lies across the hole in the pipe, and thus prevent the

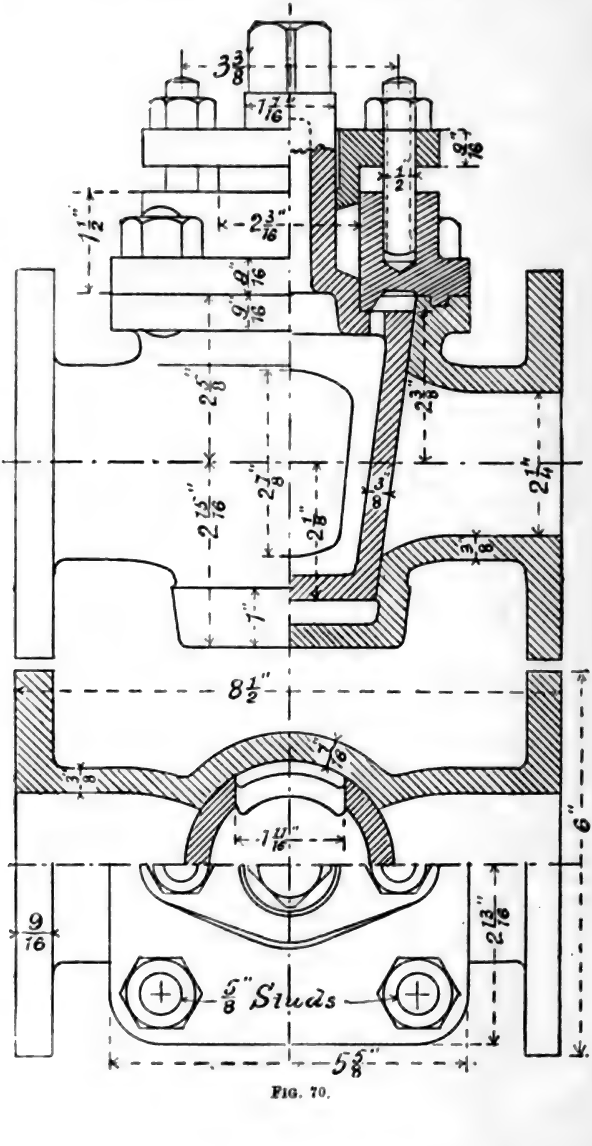

$3\frac{3}{8}$
$1\frac{7}{16}$
$\frac{9}{16}$
$\frac{1}{2}$
$1\frac{1}{2}''$
$2\frac{3}{16}''$
$\frac{9}{16}$
$\frac{9}{16}$
$2\frac{5}{8}''$
$2\frac{3}{8}''$
$2\frac{15}{16}''$
$2\frac{7}{8}''$
$2\frac{1}{8}''$
$\frac{3}{8}$
$2\frac{1}{4}''$
$\frac{3}{8}$
$1''$
$8\frac{1}{2}''$
$\frac{7}{16}$
$\frac{3}{8}$
$1\frac{11}{16}''$
$6''$
$\frac{9}{16}$
$2\frac{13}{16}''$
$\frac{5}{8}''$ Studs
$5\frac{5}{8}''$

FIG. 70.

fluid from passing. As the student will be quite familiar with the common water cock or tap such as is used in dwelling-houses we need not illustrate it here.

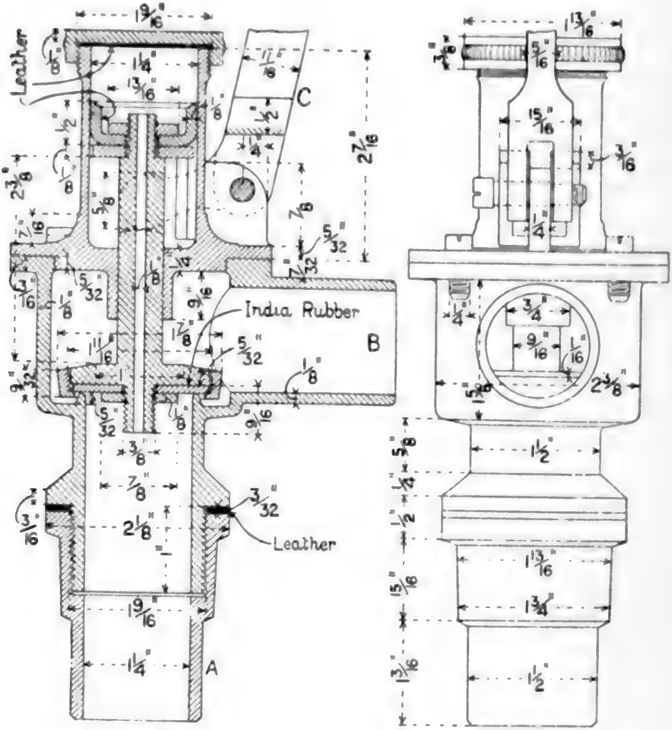
Fig. 70 shows a cock of considerable size, which may be used for water or steam under high pressure. The plug in this example is hollow, and is prevented from coming out by a cover which is secured to the casing by four stud bolts. An annular ridge of rectangular section projecting from the under side of the cover, and fitting into a corresponding recess on the top of the casing, serves to ensure that the cover and plug are concentric, and prevents leakage. Leakage at the neck of the plug is prevented by a gland and stuffing-box. The top end of the plug is made square to receive a handle for turning it. The size of a cock is taken from the bore of the pipe in which it is placed ; thus fig. 70 shows a 2½-inch cock.

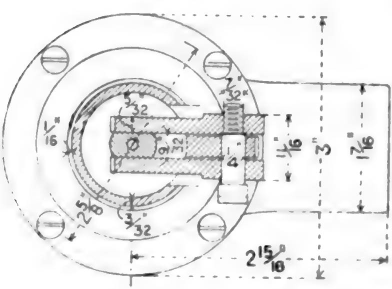
EXERCISE 73 : *2½-inch Steam or Water Cock.*—First draw the views of this cock shown in fig. 70 then draw a half end elevation and half cross section through the centre of the plug. Scale 6 inches to a foot.

Instead of drawing the parts of the pipe on the two sides of the plug in the same straight line as in fig. 70, one may be shown proceeding from the bottom of the casing, so that the fluid will have to pass through the bottom of the plug and through one side. This is a common arrangement.

All the parts of the valve and casing in this example are made of brass.

Equilibrium Ball Valve.—A valve for regulating the supply of water to a tank is called a ball valve when it is operated by a hollow ball which floats on the water in the tank. When the water in the tank rises to the highest level the ball is raised and the valve is closed, and when the water-level falls the ball is lowered, the valve opens and more water is admitted. Fig. 71 shows Underhay's equilibrium ball valve. The back end of the valve-spindle carries a piston which works in a cylinder. Through the spindle there is a hole which enables the water-pressure to act on the piston, and, as the area of the piston is the same as that of the valve, the latter is balanced, and only a small force is necessary to open or close it. A lead supply-pipe is soldered to the brass union A, and the water is delivered through B into the tank when the valve is open; C is a portion of the lever, to the outer end of which the ball is attached. The valve-spindle is usually horizontal.





EXERCISE 74: *Underhay's Equilibrium Ball Valve.*—Draw, full size, the views of this valve shown in fig. 71.

All the metal parts are made of brass.

FIG. 71.

Small Stop Valve (Figs. 72, 73, and 74).

A. Valve casing.

B. Hand-wheel attached to spindle.

C. Spindle.

D. Cap-nut forming a gland.

E. Screw for securing hand-wheel to spindle.

F. Cover on valve casing, which also forms a nut for screw on spindle.

H. Conical disc valve with four guiding-feathers underneath.

All the parts except the packing are made of gun-metal.

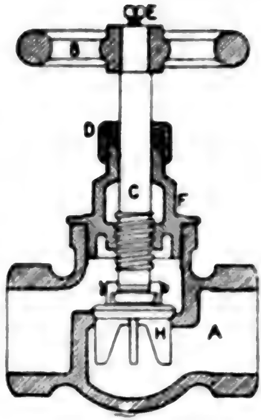


Fig. 72.

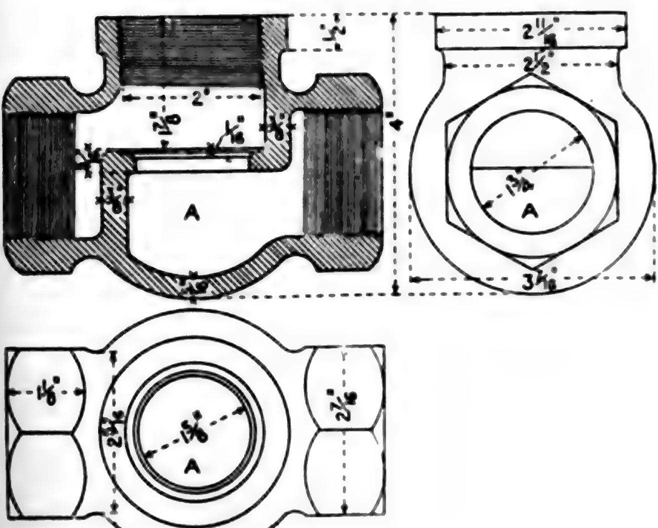


Fig. 73.

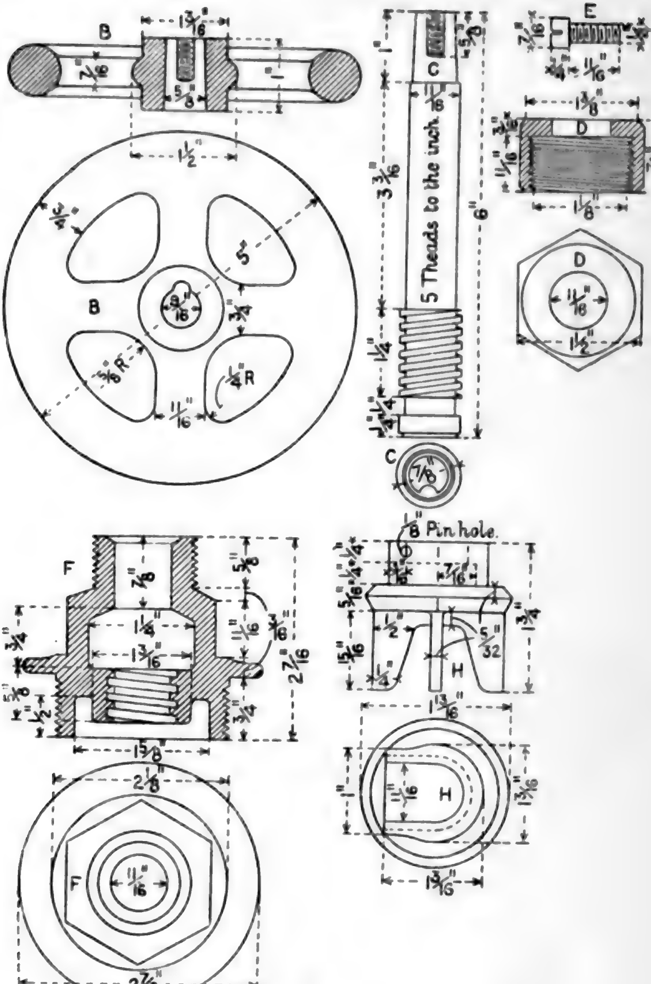


Fig. 74.

Exercise 75: *Small Stop-valve.*—Draw, full size, the following views of the small stop-valve shown in fig. 72:—(*a*) the sectional elevation shown in fig 72, (*b*) a plan, (*c*) an end elevation, (*d*) a cross-sectional elevation; the plane of the section to contain the axis of the spindle. All the dimensions are to be taken from the detail drawings shown in figs. 73 and 74.

XVII. MISCELLANEOUS EXERCISES.

The illustrations in this chapter are in most cases not drawn to scale; they are also in some parts incomplete, and in others some of the lines are purposely drawn wrong. The student must keep to the dimensions marked on the drawings, and where no sizes are given he must use his own judgment in proportioning the parts. All errors must be corrected, and any details required, but not shown completely in the illustrations, must be filled in.

Exercise 76: *Single Riveted Butt Joint with Tee-iron Cover Strap.*—Two views, one a side elevation and the other a sectional elevation, of a riveted joint are shown in fig. 75. Draw these views, and also a plan projected from one of them. Show the rivets completely in all the views. Scale 4 inches to a foot.

Exercise 77: *Girder Stay for Steam Boiler.*—The flat crown of the fire-box of locomotive and marine boilers is generally supported or stayed by means of girder stays, an example of which is shown in fig. 76. A B is the side elevation of a portion of one of these girders. Each girder is supported at its ends by the plates

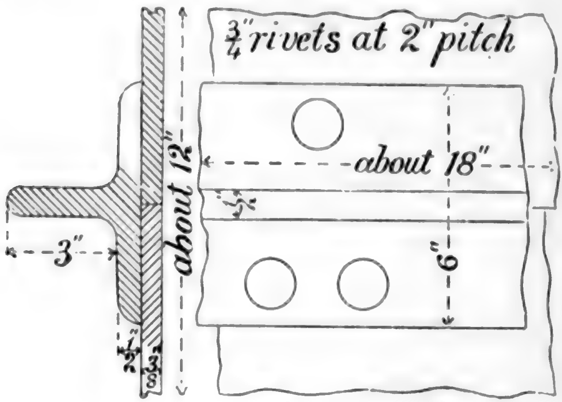


FIG. 75.

forming the vertical sides of the fire-box. The flat crown is bolted to the girders as shown. Observe that the girders are in contact

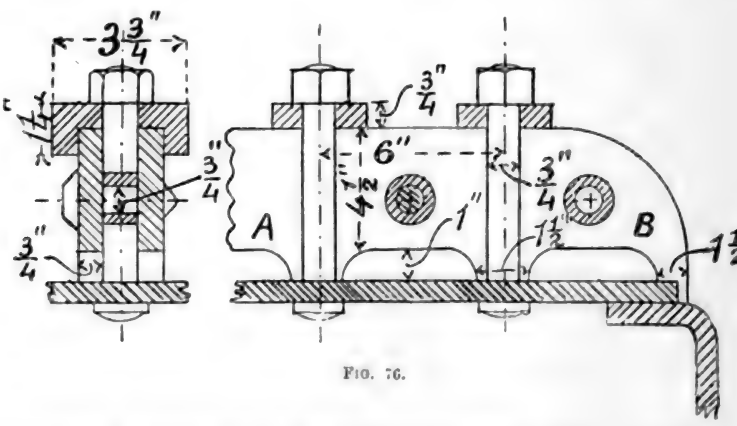


FIG. 76.

with the crown only in the neighbourhood of the bolts. Consider carefully this part of the design, and then answer the following questions: (1) What objections are there to supporting the girders at the ends only without the contact pieces at the bolts? (2) What objections are there to having the girders in contact with the crown plate of the fire-box throughout their whole length?

Draw the views shown in fig. 76, and from the right-hand one project a plan. Scale 4 inches to a foot.

EXERCISE 78: *End of Bar Stay for Steam Boiler.*—On page 12 one form of stay for supporting the flat end of a steam boiler is described. Another form of stay for the same purpose is shown in fig. 77. A B is a portion of the end of a steam boiler. C D is one

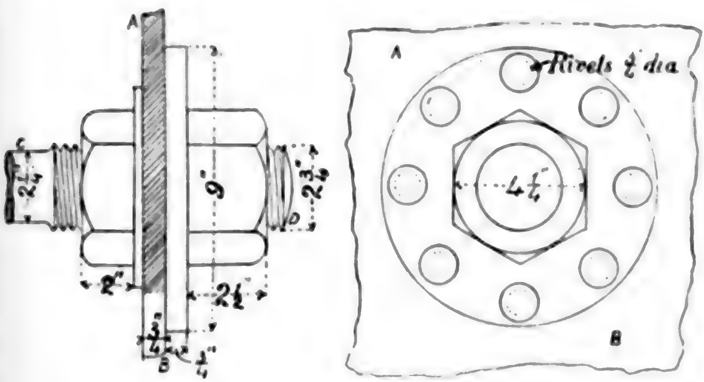


FIG. 77

end of a bar which extends from one end of the boiler to the other. The ends of this bar are screwed, and when the bar is of wrought iron the screwed parts are generally larger in diameter than the rest of the bar. When made of steel the bar is generally of uniform diameter throughout. In the case of wrought-iron bar stays the enlarged ends are welded on to the smaller parts. Welding is not so reliable with steel as with wrought iron. Write out answers to the following questions: (1) What is the advantage of having the screwed part of the bar larger in diameter than the rest? (2) Why are steel bar stays not generally enlarged at their screwed ends?

Draw the views shown in fig. 77, and project from one of them a third view. Scale 4 inches to a foot.

Exercise 79 : *Knuckle Joint.*—Draw the plan and elevation of this joint shown in fig. 78, and also draw an end elevation looking in the direction of the arrow. The parts at A and B are octagonal in cross section. Scale 4 inches to a foot.

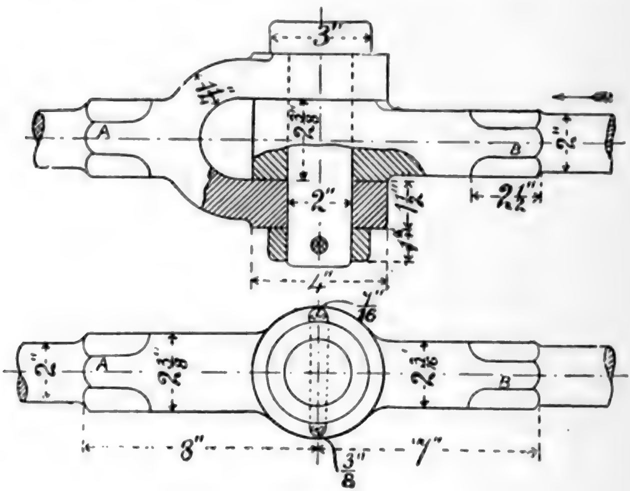


Fig 78.

Exercise 80 : *Locomotive Coupling Rod Ends.*—A form of knuckle joint used on locomotive coupling rods is shown in fig. 79.

In this case two rods meet and work on the same pin, as shown at (*a*) fig. 79. Draw, in addition to the views shown in fig. 79, a plan and a vertical section through the axis of the pin. Scale 6 inches to a foot.

Would it be practicable to replace the two rods A B and B C by a single rod working on the crank pins at A, B, and C ? Give reasons for your answer.

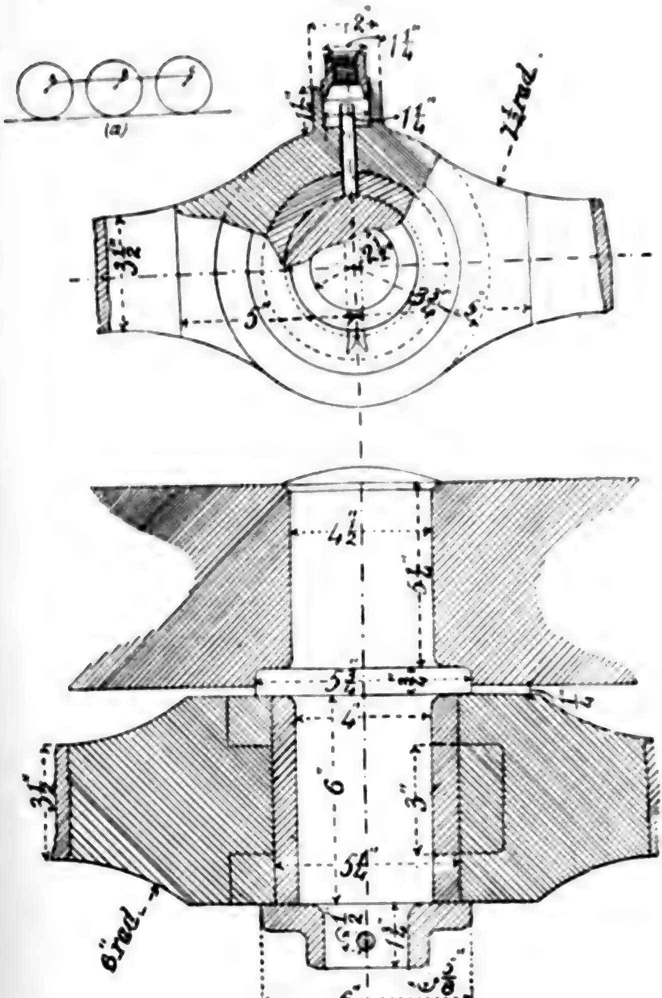


FIG. 78

Exercise 81 : *Bell Crank Lever.*—Draw the plan and elevation of the lever shown in fig. 80. Scale 6 inches to a foot.

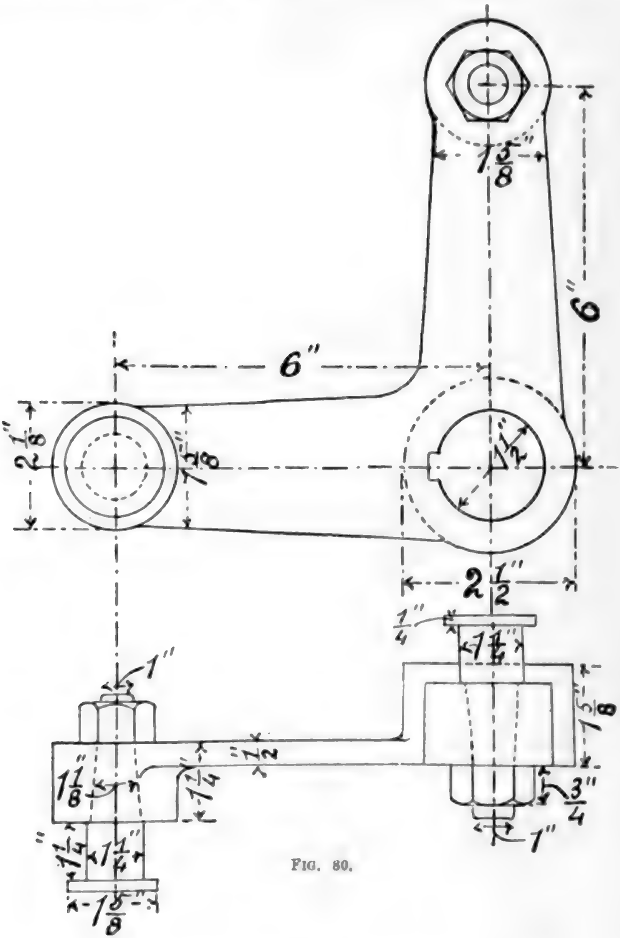


Fig. 80.

Exercise 82 : *Back Stay for Lathe.*—Draw a plan and two elevations of the stay shown in fig. 81. Make all necessary corrections and show all the details in each view. Scale full size.

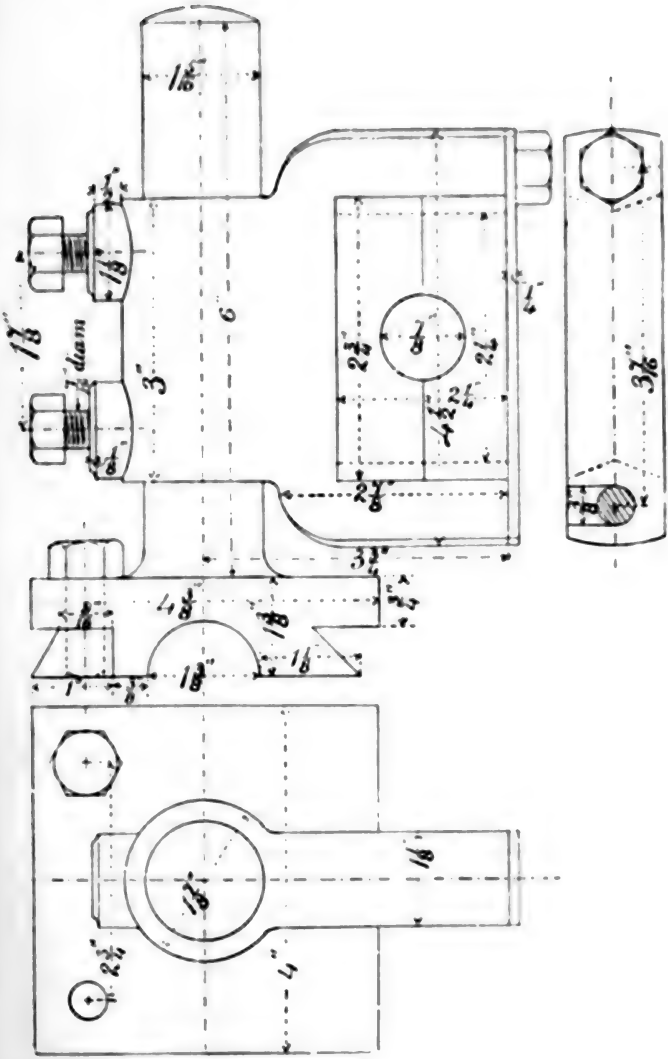


FIG. 81.

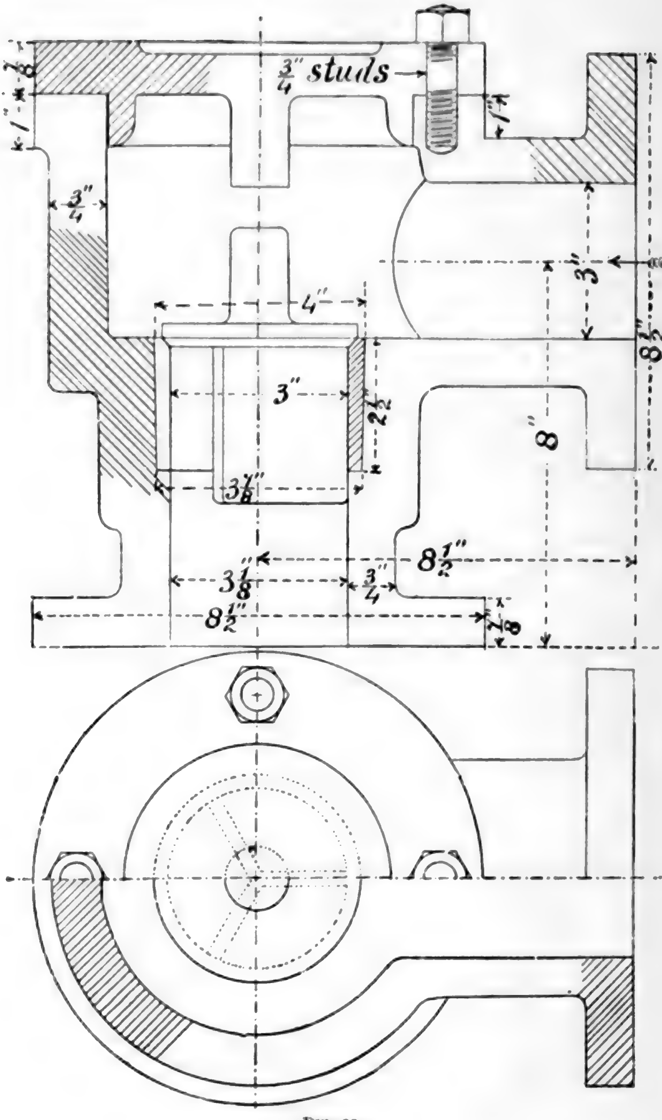


FIG. 82.

EXERCISE 83: *Conical Disc Valve and Casing.*—Draw, half size, the views shown in fig. 82 of the conical disc valve and casing, and also add an elevation looking in the direction of the arrow.

EXERCISE 84: *Connecting Rod End.*—The student should carefully compare this connecting rod end (fig. 83) with those illustrated on pages 58 and 60. The lower part of fig. 83 is a half plan and

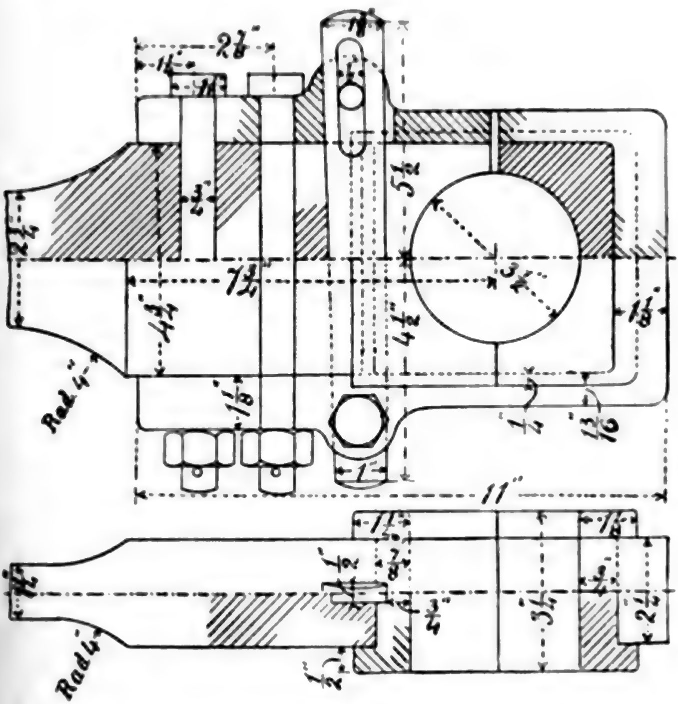
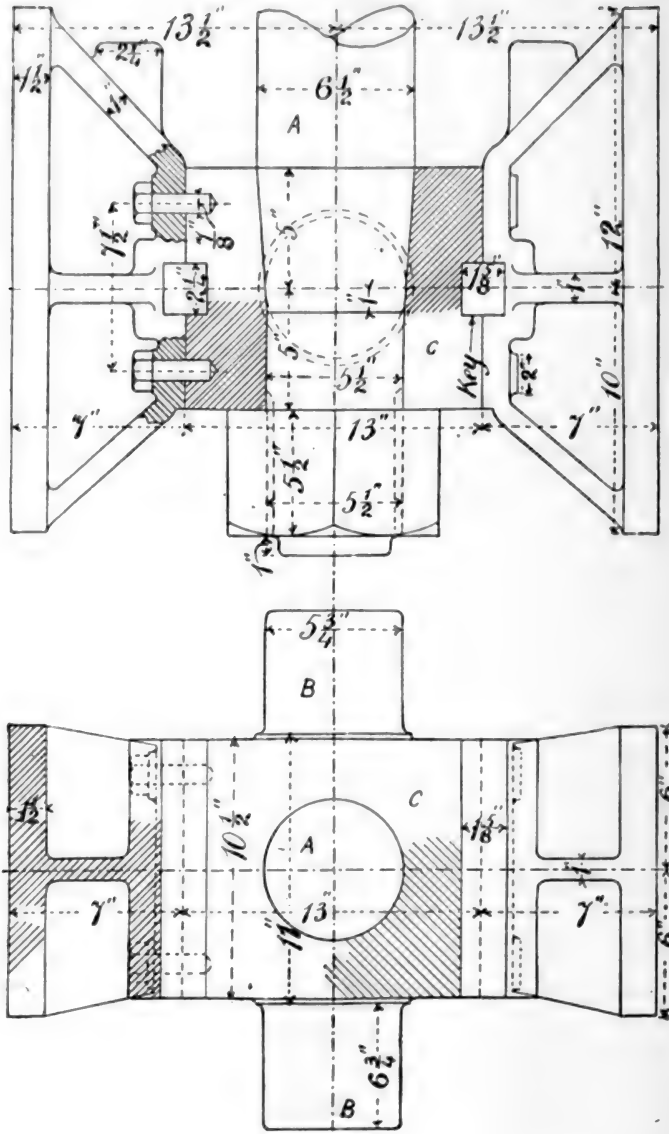


Fig. 83.

half horizontal section, and the upper part is a half side elevation and half vertical section. Draw these views and also an end elevation. Scale 6 inches to a foot.

EXERCISE 85: *Engine Cross-head.*—The cross-head shown in fig. 84 is for an inverted cylinder marine engine. A is the piston

(*Continued on* p. 103). H



13½"
13½"
2¼"
1½"
6½"
A
7½"
⅞"
5"
2¼"
1⅝"
1"
12"
5"
5½"
C
Key
2"
10"
7"
13"
7"
5½"
5½"
1"
5¾"
B
1½
10½"
C
1⅝"
A
1"
6"
7"
13"
7"
11"
6"
6¾"
B

FIG. 84.

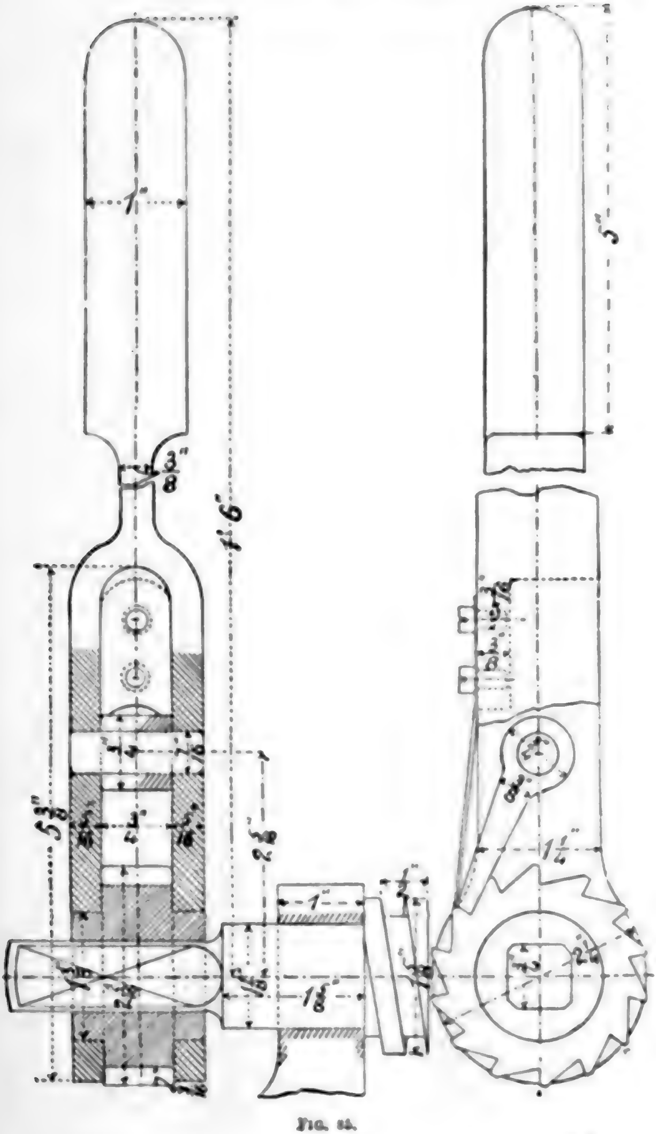


FIG. 88.

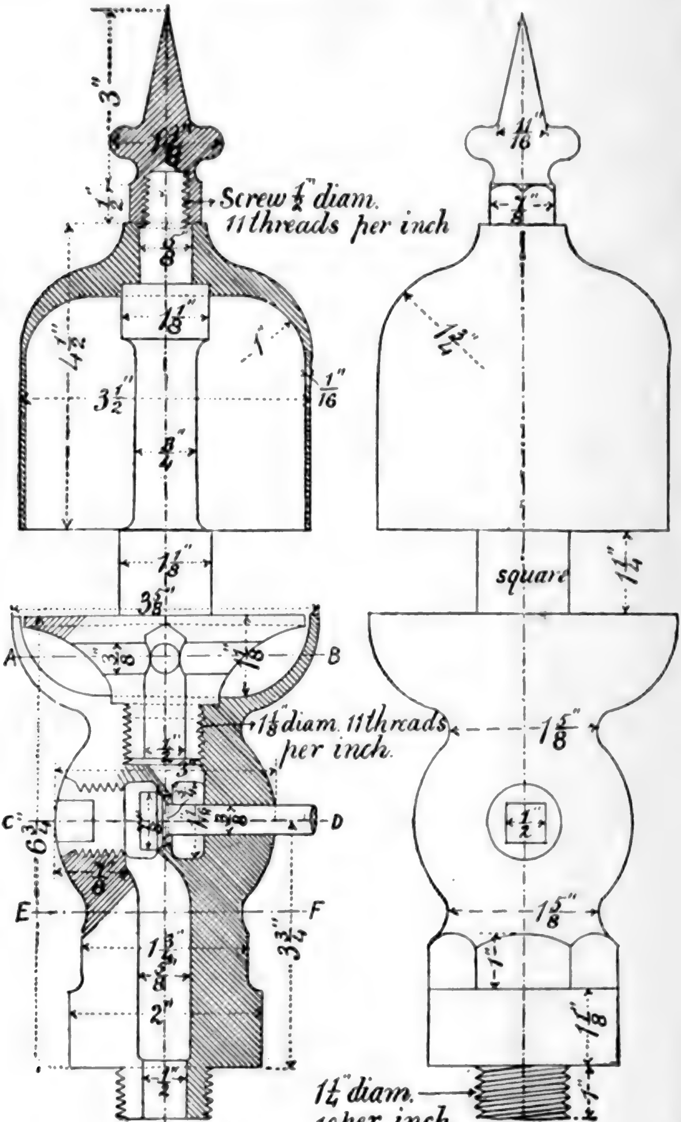

Screw ½" diam.
11 threads per inch
1⅛" diam. 11 threads per inch
1¼" diam.
10 per inch.
square
A
B
C
D
E
F

Fig. 86.

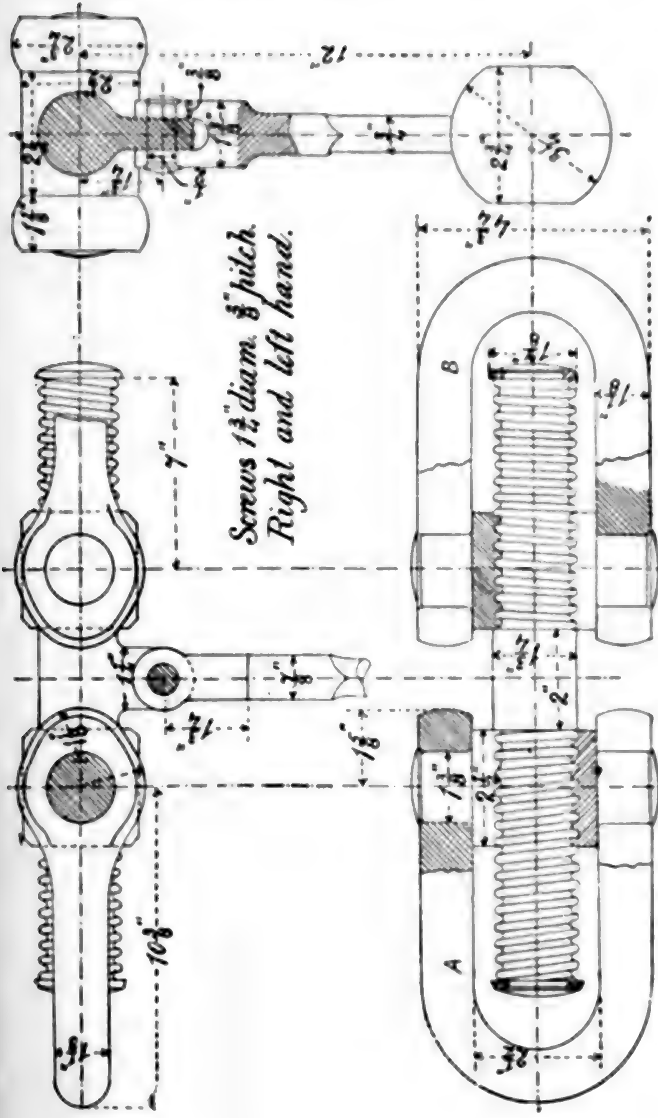


FIG. 87.

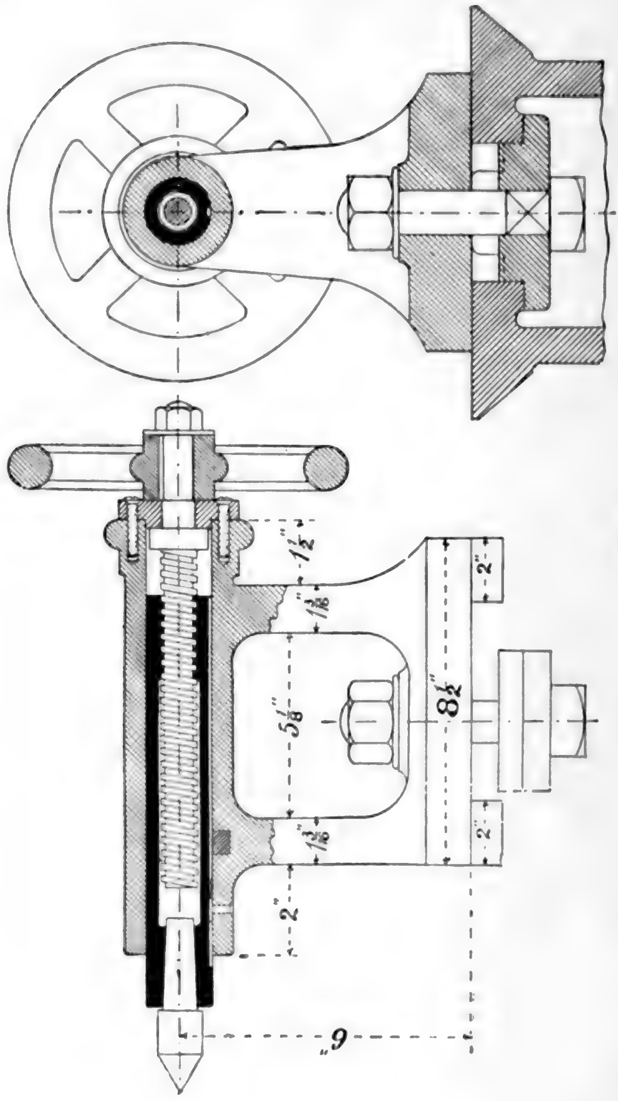


FIG. 88.

rod, and B B are pins, forged in one piece with C, to which the forked end of the connecting rod is attached. Draw the upper view with the central part in section as shown. Make the right-

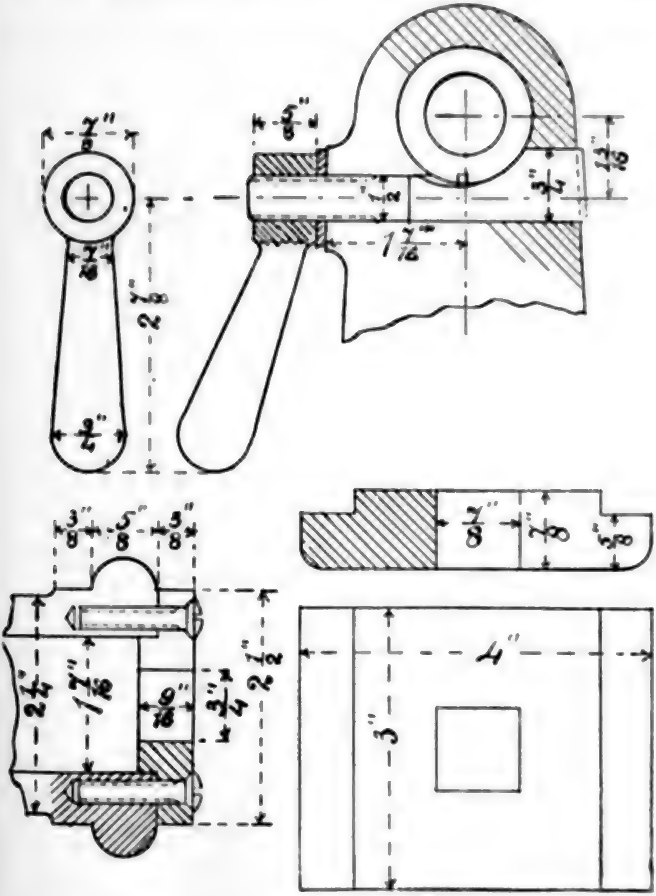


Fig. 89.

hand half of the lower view a plan without any section, and make the left-hand half a horizontal section through the axis of the pins B B. Scale 4 inches to a foot.

Exercise 86 : *Ratchet Lever.*—The lever shown in fig. 85 is used for turning the horizontal screw of a traversing screw jack. Draw the two views shown, and from one of them project a plan Scale full size.

Exercise 87 : *Steam Whistle.*—Draw, full size, the elevation and section of the steam whistle shown in fig. 86. Draw also horizontal sections at A B, C D, and E F.

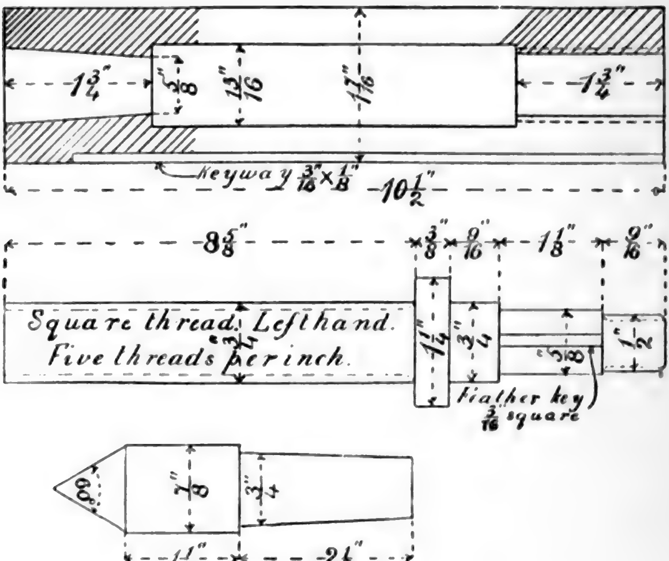


Fig. 90.

Exercise 88 : *Screw Coupling for Railway Carriages.*—Draw the three views of the screw coupling shown in fig. 87. Scale 6 inches to a foot.

If the link A is fixed, through what distance will the link B move for two turns of the lever ?

Exercise 89 : *Loose Headstock for a 6-inch Lathe.*—Two views of this headstock are shown in fig. 88. On one of these

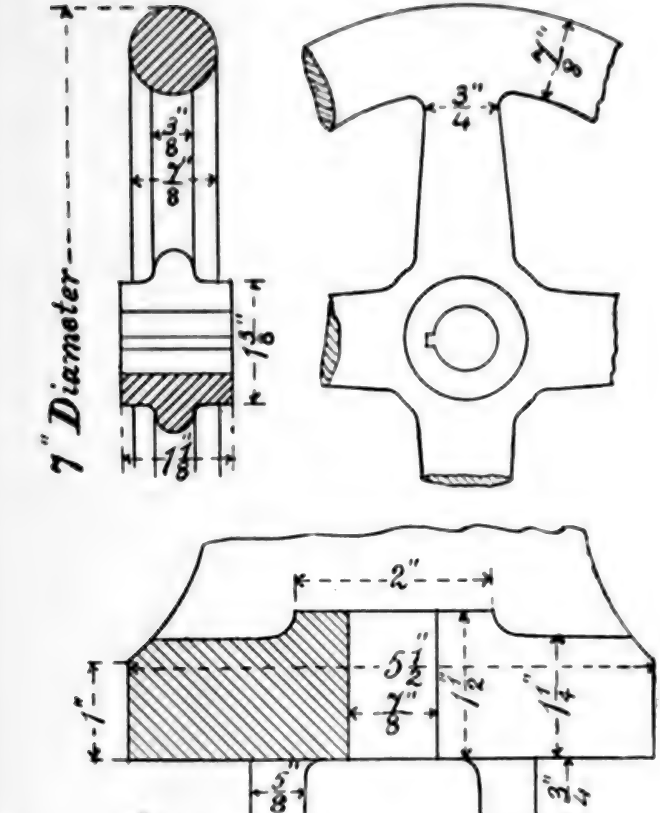

7" Diameter
$\frac{3}{8}$"
$\frac{7}{8}$"
$1\frac{3}{8}$"
$1\frac{1}{8}$"
$\frac{7}{8}$"
$\frac{3}{4}$"
2"
$5\frac{1}{2}$"
1"
$\frac{7}{8}$"
$1\frac{1}{2}$"
$1\frac{1}{4}$"
$\frac{5}{8}$"
$\frac{3}{4}$"
$2\frac{5}{8}$"
$\frac{7}{8}$"
3"
$\frac{7}{8}$"
$\frac{1}{2}$"
$\frac{3}{4}$"
$4\frac{3}{4}$"

FIG. 91

views a few of the chief dimensions are marked. The details, fully dimensioned, are shown separately in figs. 89, 90, and 91.

Explain clearly how the centre is moved backwards and forwards, and also how the spindle containing it is locked when it is not required to move.

Draw, half-size, the views shown in fig. 88, and from the left-hand view project a plan. Draw also the detail of the locking arrangement shown in fig. 89.

XVIII. MISCELLANEOUS EXERCISES *from Examination Papers set by the Department of Science and Art.*

Exercise 90: *Hooke's Coupling.*—Draw the three views shown (fig. 92), adding any omitted lines where the views are incomplete. Scale 3 inches to a foot.

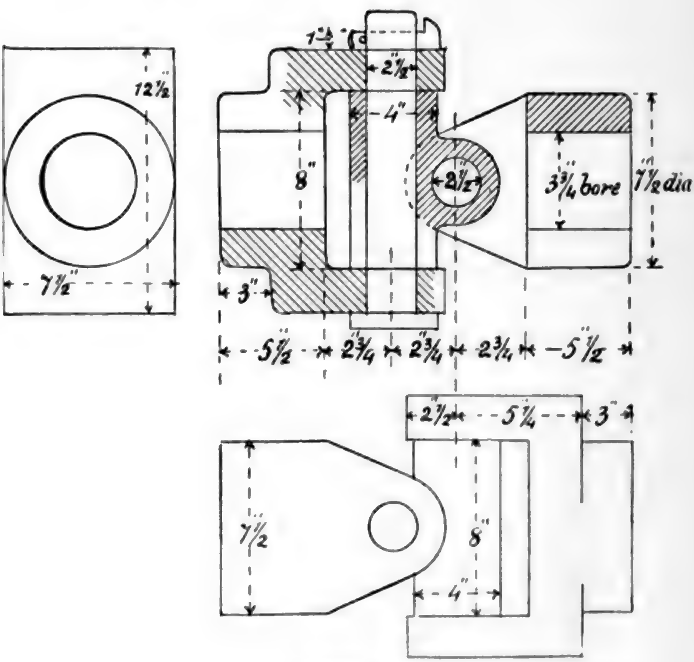


Fig. 92.

EXERCISE 91: *Eccentric and Rod.*—Draw and complete the elevation shown (fig. 93), and add a plan. Draw also a section of the strap and rim through A B. Scale three-eighths.

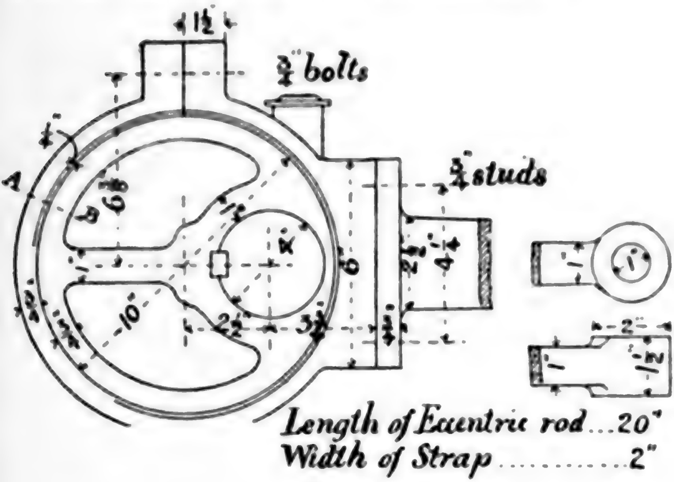


FIG. 93.

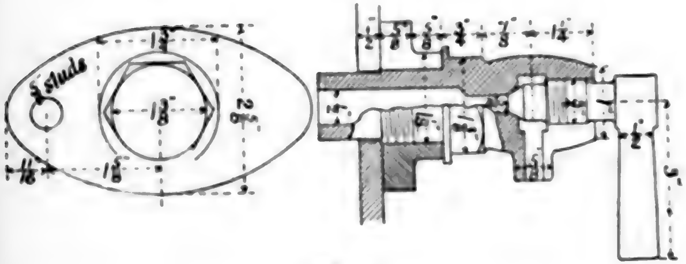


FIG. 94.

EXERCISE 92: *Water Gauge Cock for Steam Boiler.*—Draw and complete the views shown (fig. 94), also add a plan. Scale full size.

EXERCISE 93: *Ball Bearing for Tricycle.*—Draw, full size, the two views as shown, partly in section (fig. 95).

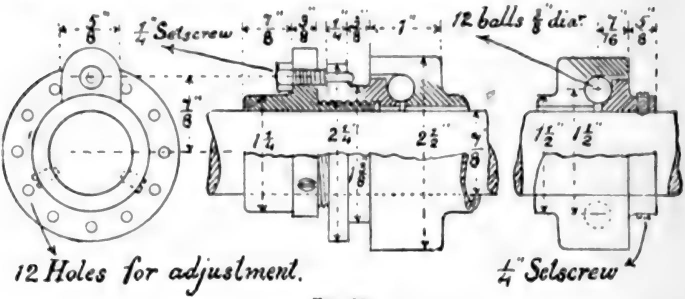


FIG. 95.

EXERCISE 94: *Ram of Slotting Machine.*—Draw and complete the two elevations shown (fig. 96). The tool-holders must be drawn in their proper positions in the ram, and not separate as in fig. 96. Scale quarter size.

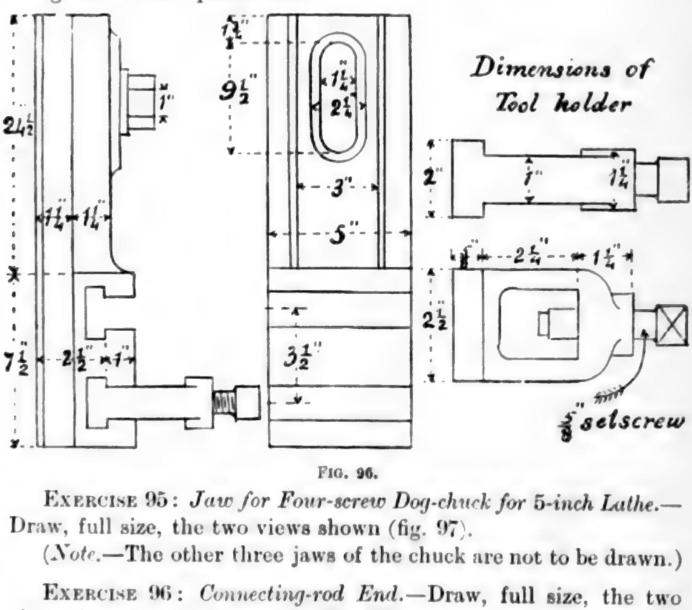
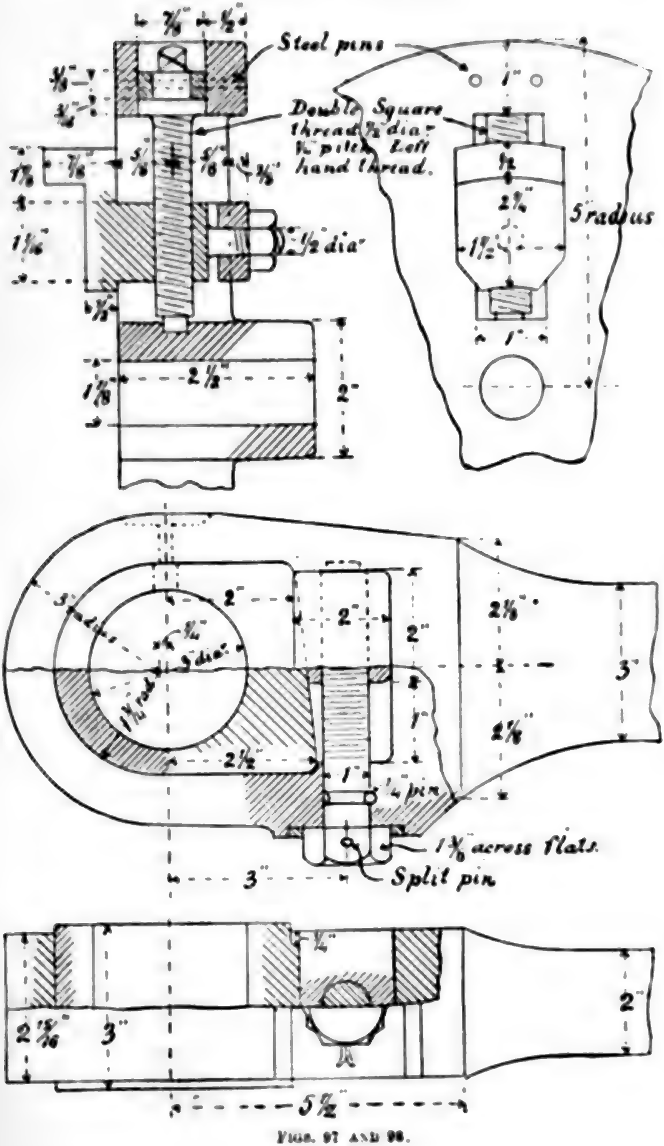


FIG. 96.

EXERCISE 95: *Jaw for Four-screw Dog-chuck for 5-inch Lathe.*—Draw, full size, the two views shown (fig. 97).

(*Note.*—The other three jaws of the chuck are not to be drawn.)

EXERCISE 96: *Connecting-rod End.*—Draw, full size, the two views shown, partly in section (fig. 98).



FIGS. 97 AND 98.

Exercise 97: *Valve-rod End for a Marine Engine.*—Draw and complete the three views, partly in section, as shown (fig. 99). Scale three-eighths.

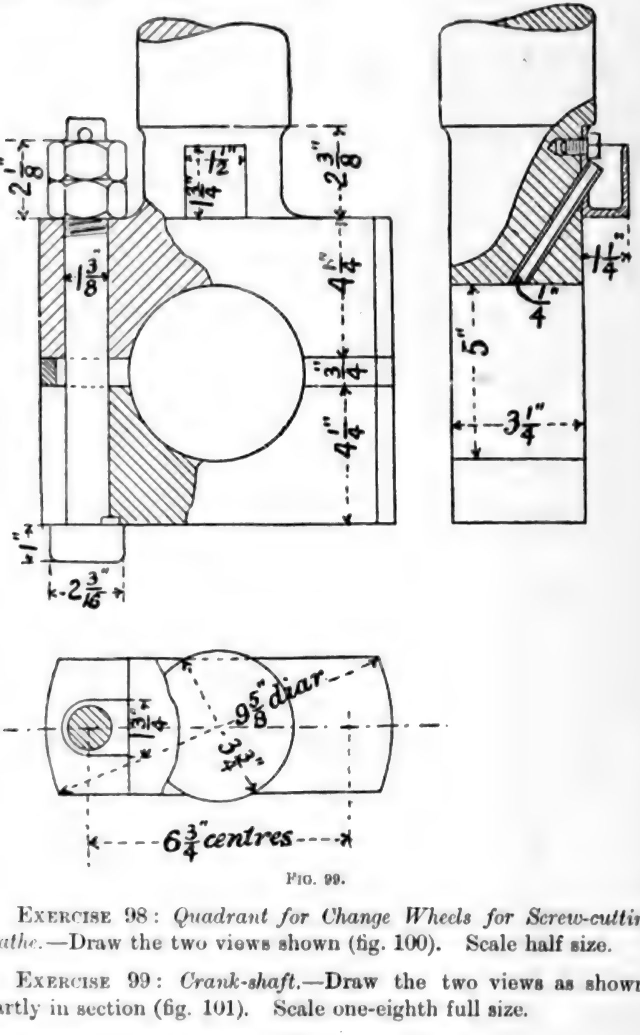
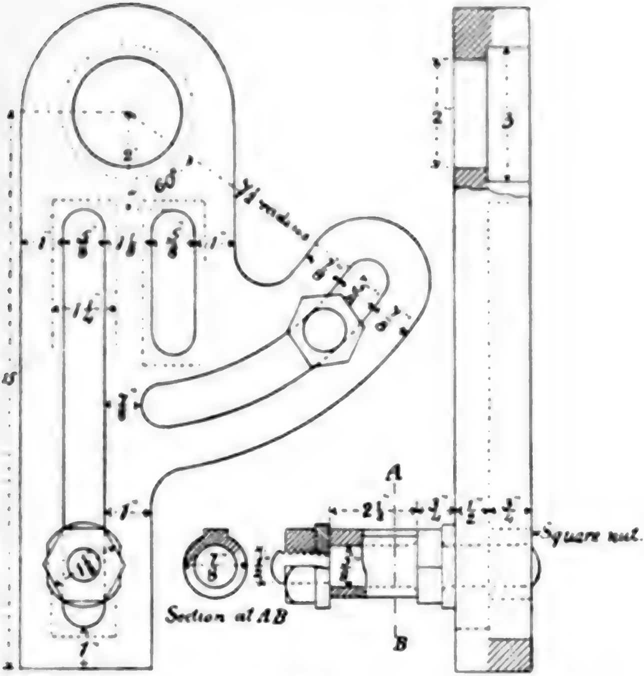
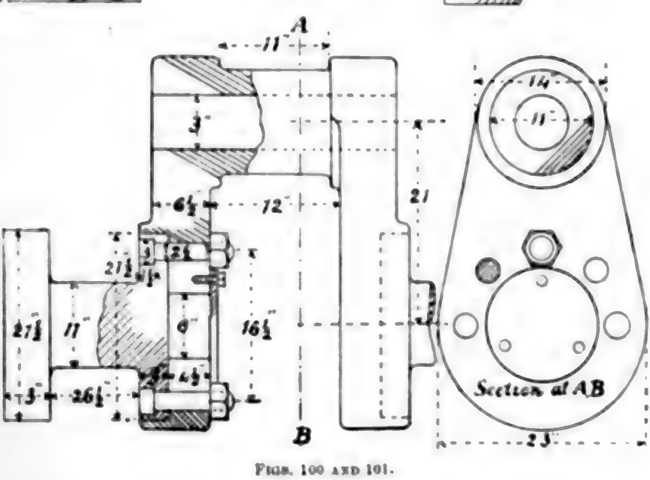


Fig. 99.

Exercise 98: *Quadrant for Change Wheels for Screw-cutting Lathe.*—Draw the two views shown (fig. 100). Scale half size.

Exercise 99: *Crank-shaft.*—Draw the two views as shown, partly in section (fig. 101). Scale one-eighth full size.





Figs. 100 and 101.

Exercise 100: *Hydraulic Pipe Joint for High Pressures.*—Draw and complete the two views shown (fig. 102), and add a plan. Scale half size.

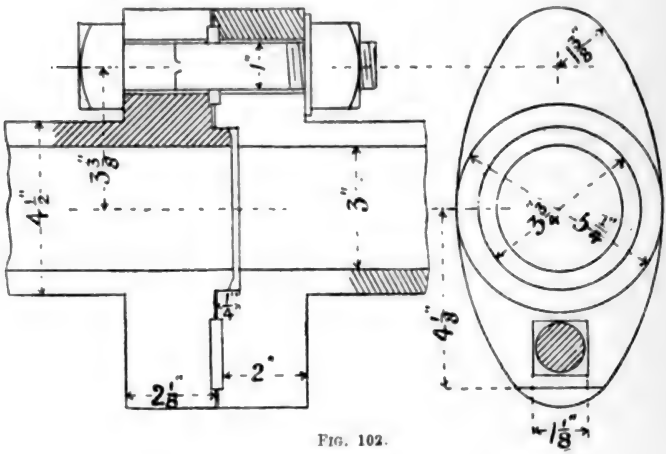
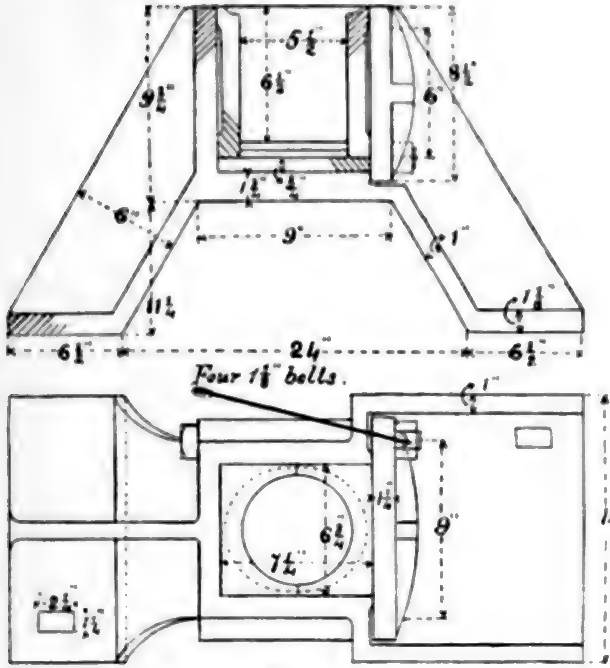
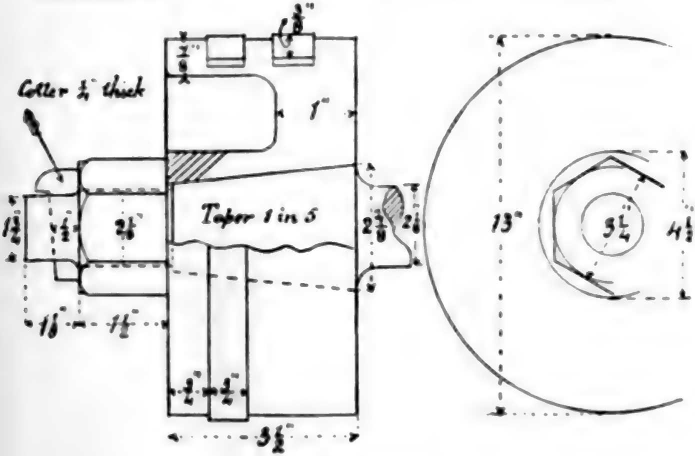


Fig. 102.

Exercise 101: *Plan and Sectional Elevation of a Footstep Bearing for an Upright Shaft.*—Draw and complete the views shown (fig. 103). Scale quarter size.

Exercise 102: *Piston for Steam Engine.*—Draw and complete the two views shown (fig. 104), the top half of the left-hand view to be in section. Scale half size.





FIGS. 103 AND 104.

Exercise 103 : *Mud-hole Mouthpiece for Lancashire Boiler.* — Draw and complete the two views shown (fig. 105). Scale three-eighths.

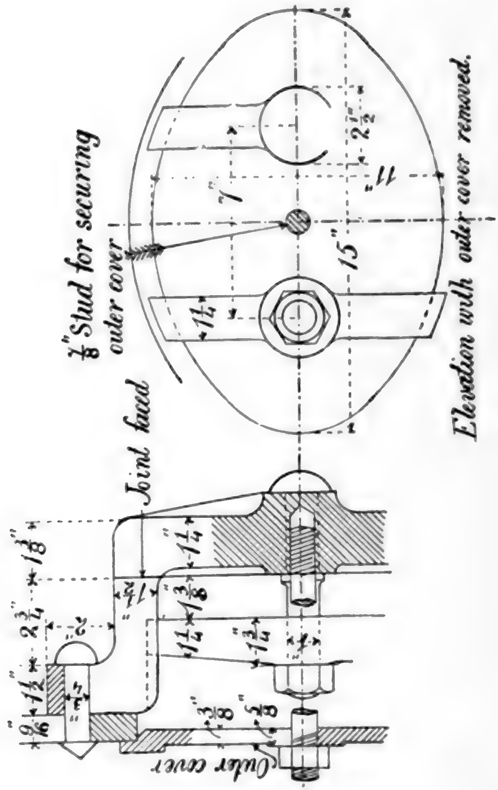


Fig. 105.

Exercise 104 : *Loaded Governor for small Gas Engine.* —Draw and complete the two views, partly in section, as shown (fig. 106). Scale full size.

Exercise 105 : *Joint for Segments of Large Spur Wheel.*—Draw and complete the views shown (fig. 107). Scale three-sixteenths.

Note.—As the radius of the wheel is too large for your instruments, the circumference at the joint may be set out straight, as in a rack.

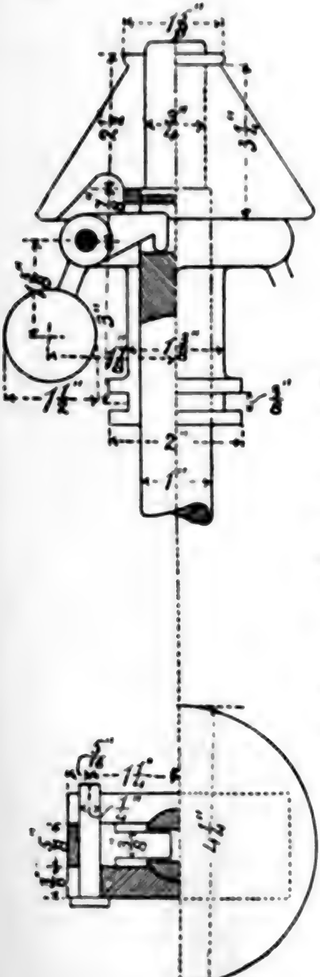


FIG. 106.

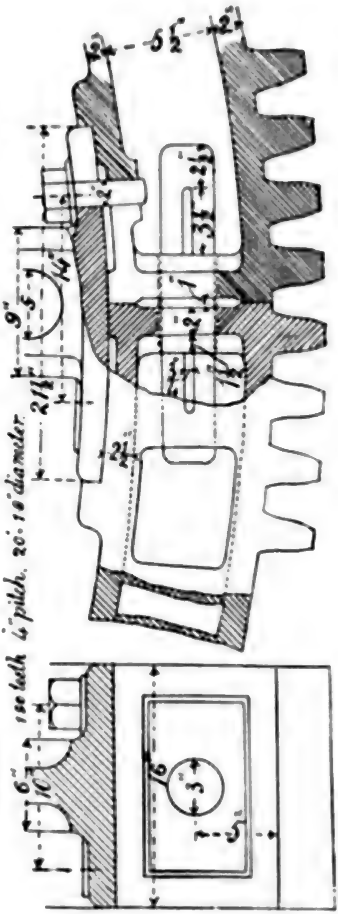


FIG. 107.

EXERCISE 106: *Coupling-rod End for Locomotive Engine.*—Draw and complete the two views, partly in section, as shown (fig. 108), and draw, projected from the elevation, an end view looking in the direction indicated by the arrow. Scale three-quarters.

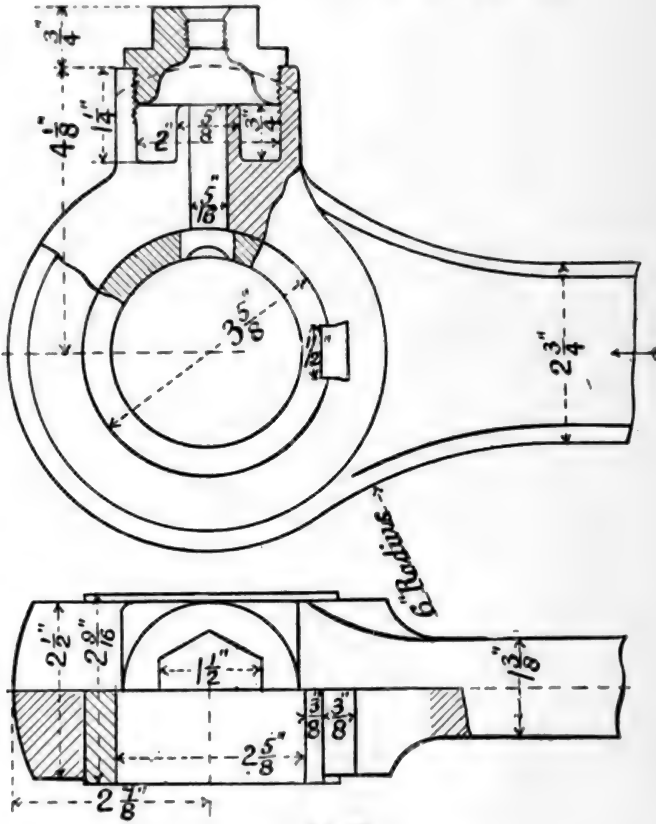


FIG. 108.

EXERCISE 107: *Wall Bracket.*—Draw and complete the two views, as shown (fig. 109), and add an end elevation properly projected. Scale one-quarter.

EXERCISE 108: *Gusset Stay for Boiler.*—The two views shown (fig. 110) are to be drawn and completed, all the rivets being properly set out and drawn in position in both views. Scale one-quarter.

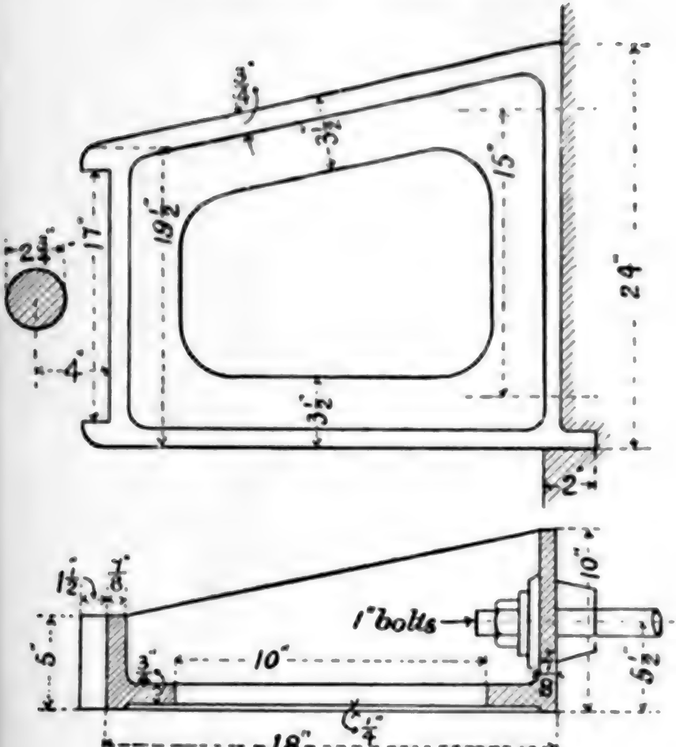


FIG. 109.

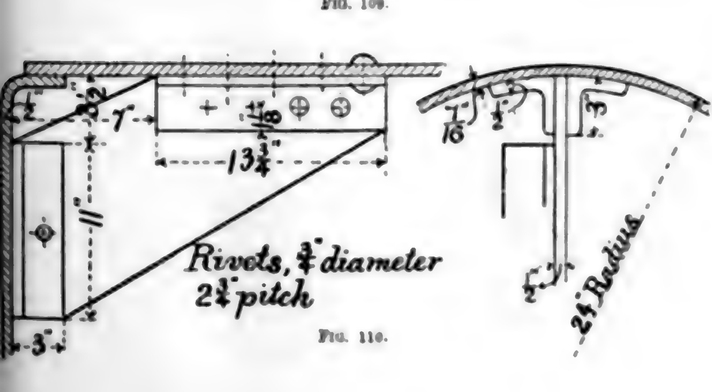


FIG. 110.

Exercise 109: *Fast Headstock and Spindle of a Lathe.*—Draw and complete the two elevations, one being partly in section, as shown (fig. 111). The plan is not required to be drawn, but dimensions for the other views are to be taken from it. The cone-pulleys and back-gear are not required to be drawn. Scale one-half.

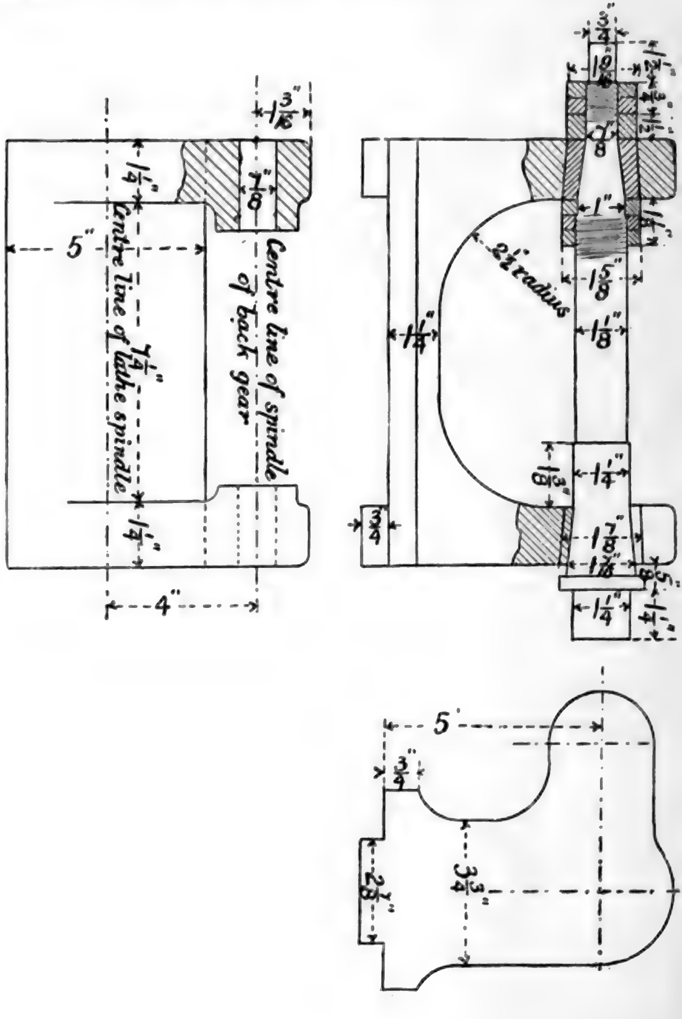


Fig. 111.

EXERCISE 110: *Bearing for a Turbine Shaft.*—Draw and complete the sectional elevation and half sectional plan, as shown (fig. 112). The weight of the shaft is supported by a collar-bearing, which is not shown, nor required to be drawn. Scale three-eighths.

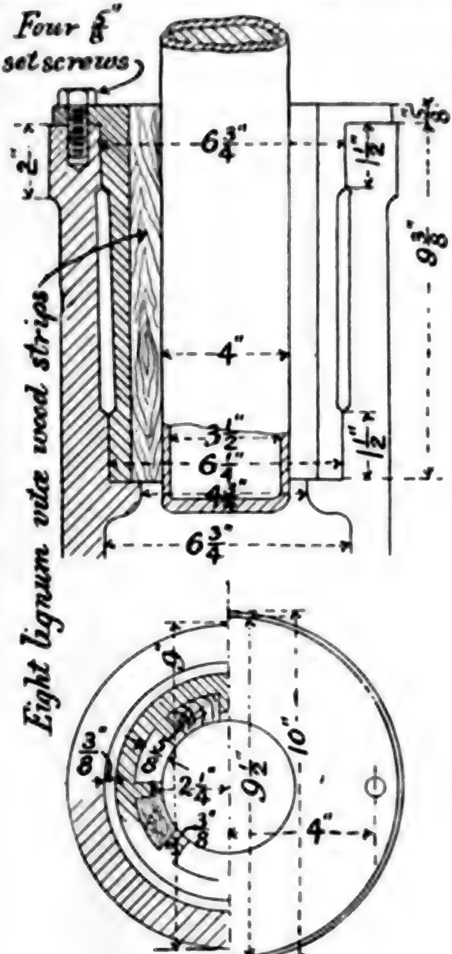


FIG. 112.

Exercise 111.—Draw to scale, full size, a bolt 1 inch diameter, 4 inches long. Make the head and shank of the bolt square, and the nut hexagonal; show a washer under the nut, and draw three threads of the screw more than are contained within the nut.

Draw also an end view looking on the nut.

A 1-inch bolt has eight threads per inch. The triangular threads may be drawn with the 60° set-square, and the projection of a helix may be represented by a straight line.

Exercise 112: *Force Pump.*—Three views, A, B, and C, are shown. View A is *not* to be drawn, but dimensions for the other views must be taken from it.

Draw the elevation B, showing the left-hand half of it in section, as in fig. 113, and the right-hand half not in section, but in outside elevation.

Draw and complete the plan C. Scale three-quarters.

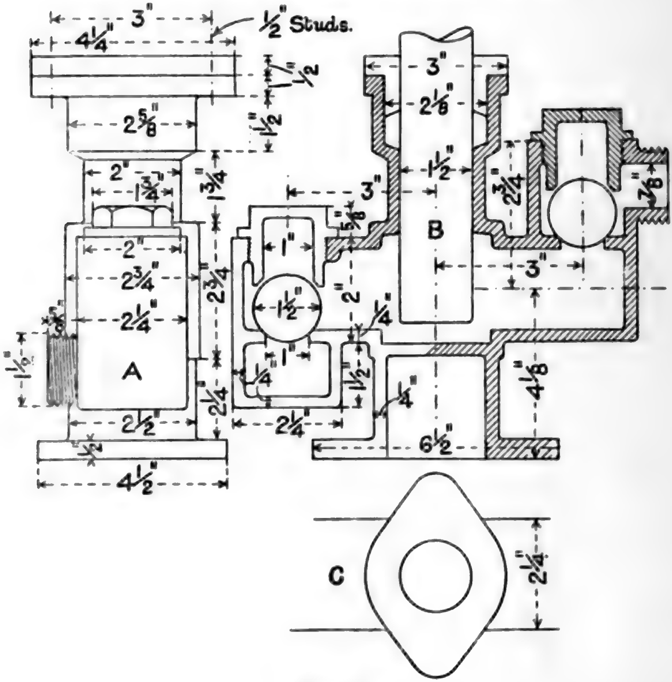


Fig. 113.

Exercise 113: *Union Joint for Pipe under Hydraulic Pressure.*—Draw the view A half in section, as shown, and draw also, projected from A, a plan and an end elevation looking in the direction of the arrow. Scale full size.

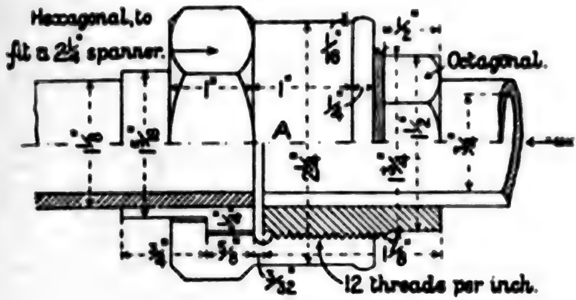


Fig. 114.

Exercise 114: *Piston-rod End and Guide-block of an Engine* (fig. 115).—Draw a sectional elevation taken through the centre line of the piston-rod.

Draw also, in projection from the above, a plan, and an end elevation looking from left to right in fig. 115.

The perspective view, as shown in fig. 115, is not to be drawn. Scale full size.

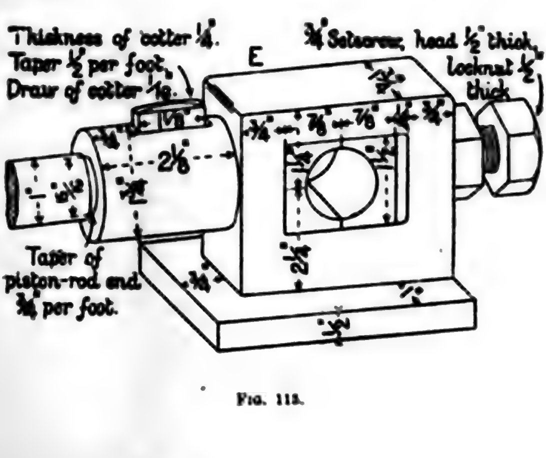


Fig. 115.

EXERCISE 115: *Combined Piston and Plunger for Hydraulic Pressure.*—Fig. 116 shows the piston and plunger, the packing on an enlarged scale, and the covers detached from the cylinder. Do *not* draw them detached, as in fig. 116, but in place relatively to one another, with the covers secured by studs and nuts.

Draw a longitudinal or side view, with the lower half in section and the upper half in outside elevation.

Draw also, in projection with the above, a view of the end L, the right half being drawn with the cover removed and the left half with the cover in place. Scale three-eighths.

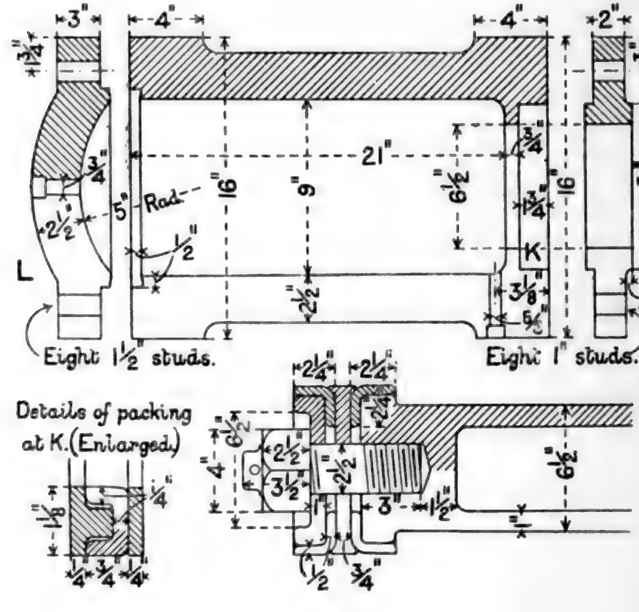


FIG. 116.

XIX. ADDITIONAL MISCELLANEOUS EXERCISES.

EXERCISE 116: *Gland and Stuffing-box.*—Make the necessary working drawings for a gland and stuffing-box for a vertical piston-rod. The chief dimensions to be as follows—

Diameter of rod	3	inches
Diameter of box (inside)	4¾	,,
Length of stuffing-box bush	2¾	,,
Length of packing space	4½	,,
Length of gland	3¼	,,
Thickness of metal in stuffing-box	⅝	,,
Thickness of stuffing-box flange	1¼	,,
Thickness of gland flange	1¼	,,
Diameter of bolts	1	,,
Number of bolts	two	

The gland to be fitted with a brass bush, and also to have an oil-cup formed on it.

EXERCISE 117 : *Ellington's Hydraulic Pipe Joint.*—Draw, half full size, the views shown below (fig. 117) of Ellington's hydraulic pipe joint. The packing ring is made of gutta-percha, and is shown as a black triangle in the longitudinal section of the pipes. A dimensioned drawing of a section of the ring when the joint is screwed up tight is shown at the top right-hand corner of fig. 117.

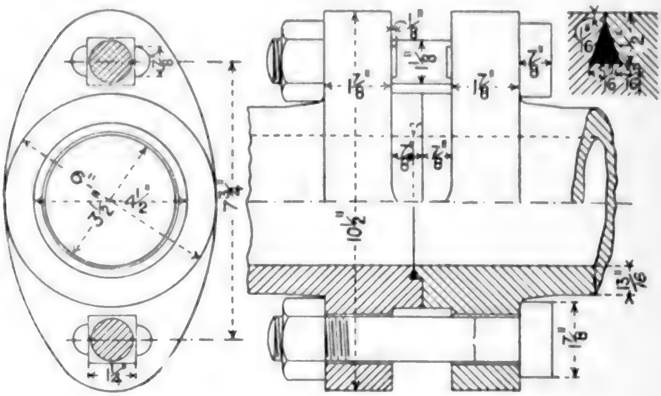


FIG. 117.

EXERCISE 118 : *Scribing Tool.*—First draw, full size, all the details separately, as shown in figs. 119 and 120 ; then draw, full size, the plan and two elevations of the tool complete, as shown in fig. 118.

F is the scriber which may be clamped at any part of the straight portion, between D and E. The scriber may also be placed at any angle to the horizontal, and the point at which it is clamped may be placed at any height from the base A within the limits of the upright K. D and E are carried by the clamp H, which embraces the upright K. By turning the milled nut J the scriber is fixed in position in relation to K. A fine vertical adjustment is obtained by rotating the milled nut B. After all adjustments have been made, K is locked in position by the set-screw C.

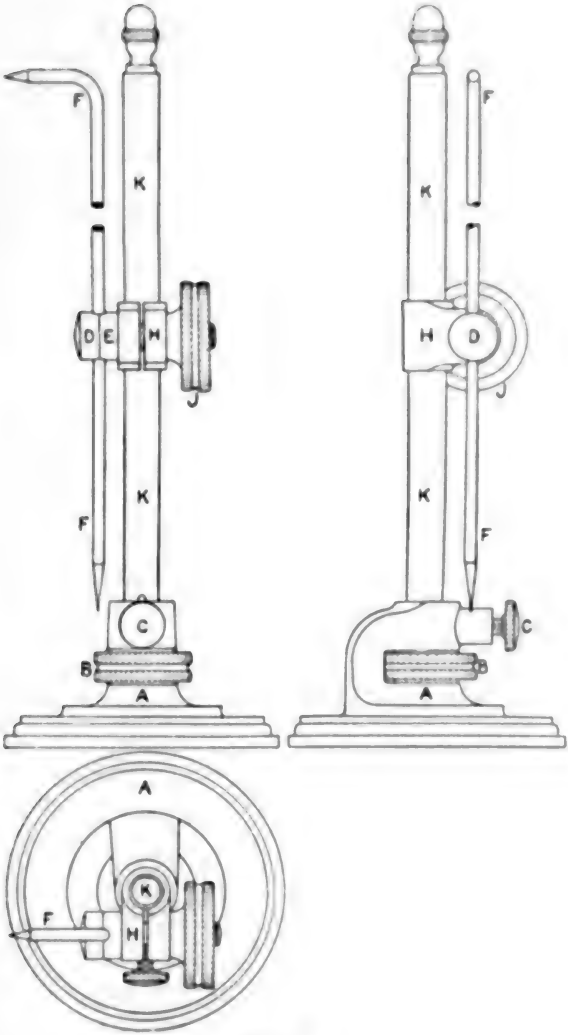


Fig. 118.

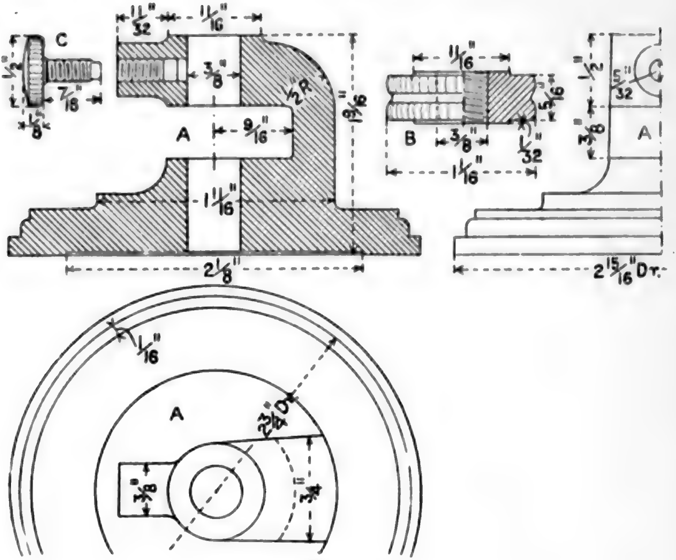


FIG. 119.

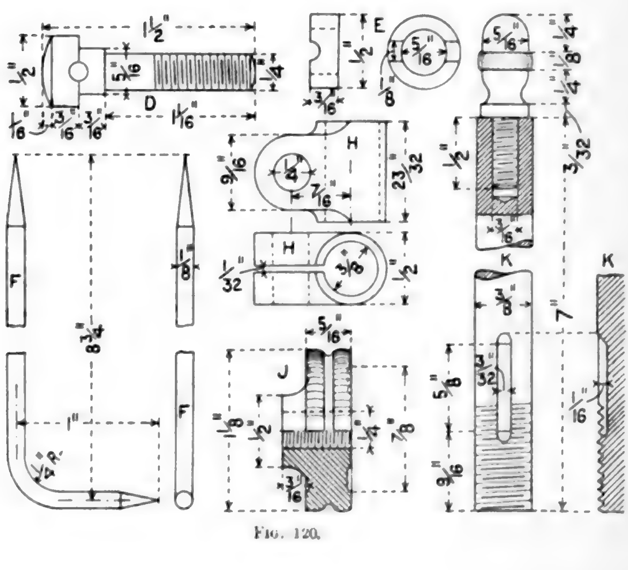


FIG. 120.

Exercise 119: *Simple Screw Jack to Lift 2½ Tons.*—From the half elevation and half section shown below make working drawings of the separate parts of the screw-jack, then draw the views shown below of the complete machine.

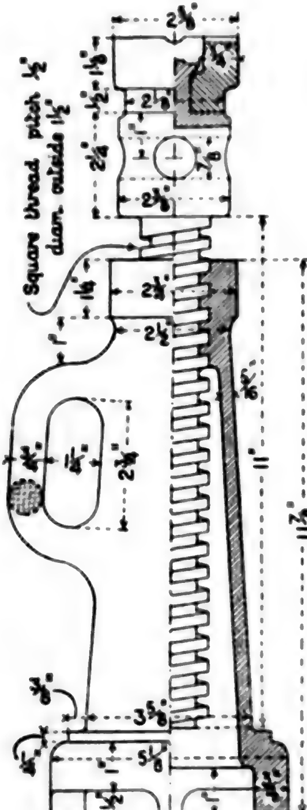


Fig. 121.

EXERCISE 120: *Four-jaw Dog Chuck.*—In fig. 122 the right-hand portion of the illustration shows a half front elevation, and a half back elevation of the chuck. The upper half of the left-hand portion shows a section by a plane containing the axis of the lathe-spindle and the axis of one of the jaw-screws, while the lower half

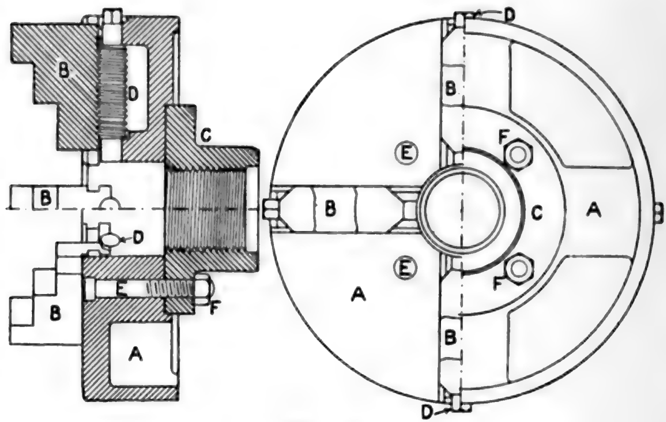


FIG. 122.

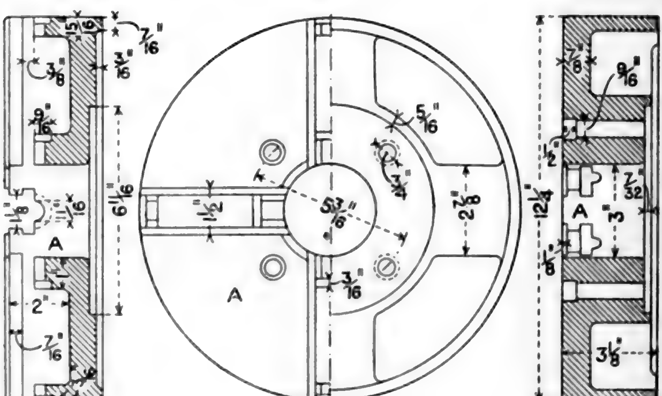


FIG. 123.

shows a sectional elevation on a plane containing the axis of the lathe-spindle and the axis of one of the bolts E.

Draw these views to a scale of 6 inches to a foot. All the dimensions are to be taken from figs. 123, 124, and 125.

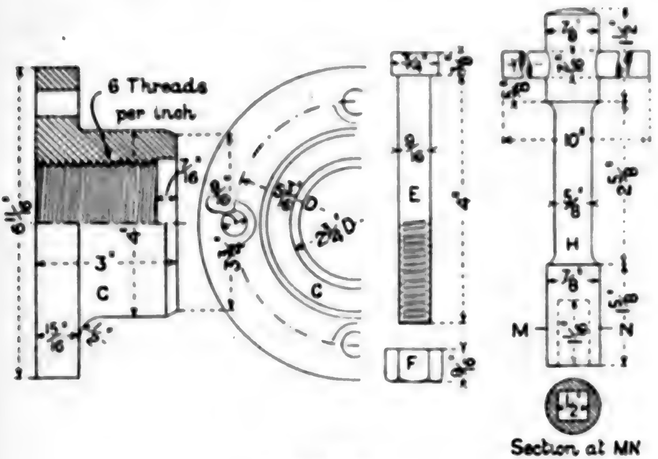


FIG. 124.

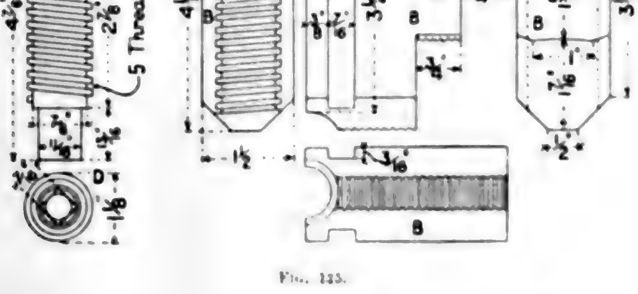


FIG. 125.

EXERCISE 121: *Reversible Ratchet Brace.*—Draw, full size, the views shown below of a reversible ratchet-brace. Draw also the details separately, as shown in fig. 127. All the dimensions are to be obtained from the detail drawings.

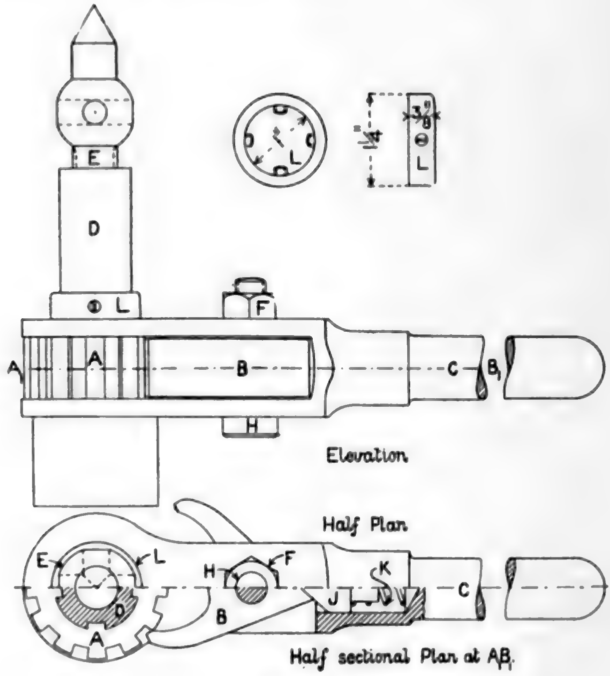


FIG. 126.

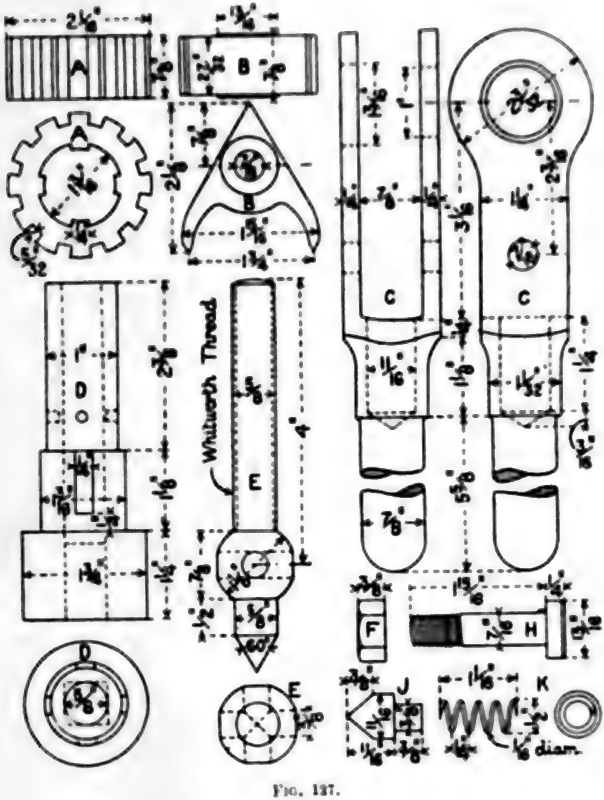


Fig. 137.

Exercise 122: *Taylor's Machine Vice.*—Draw, half full size, the views shown in fig. 129. The half end elevation and half cross-section to be projected from the side elevation instead of from the plan. Draw also a sectional elevation, the plane of section to contain the axis of the screw C. When not in use the steel faces of the jaws are slightly elevated by concealed springs, and when the work is inserted and the vice tightened up, the work slides downwards on to the base. Work which is not parallel can be held equally well, as the jaw B can swivel round.

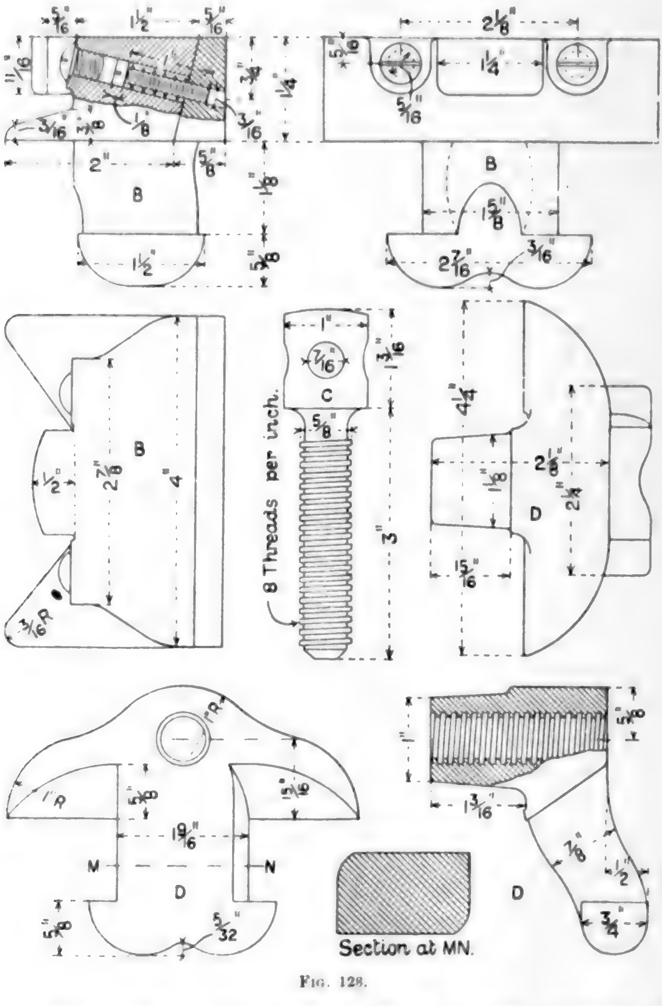


FIG. 128.

NOTE.—There is a slight error in the top left-hand portion of the above illustration. The sloping recess for the spiral spring should have a shoulder at the bottom for the spring to press against.

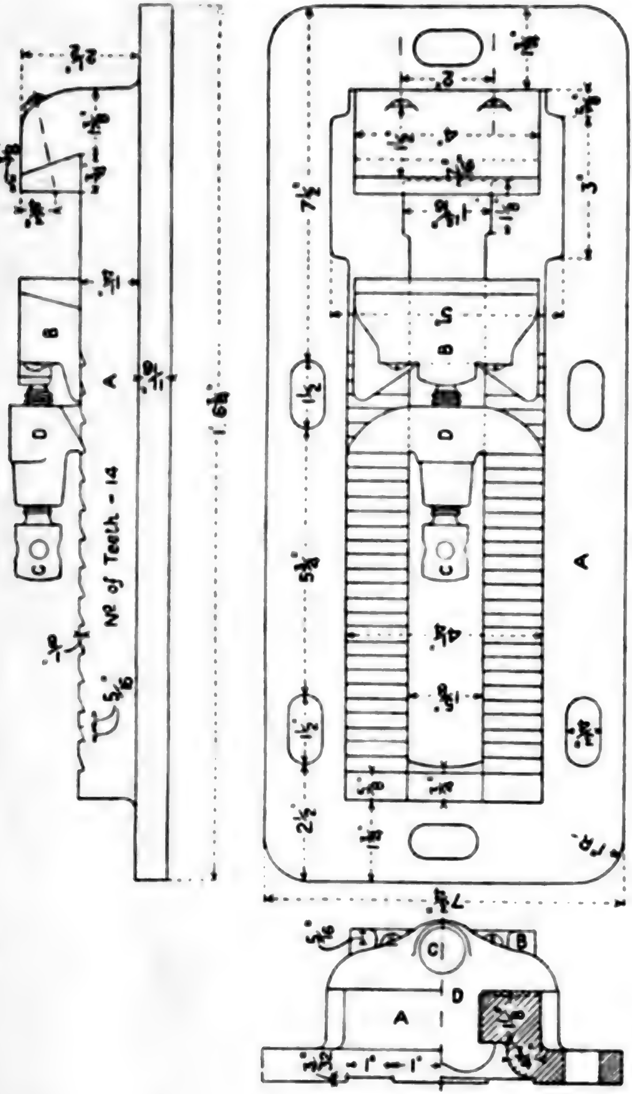


FIG. 139.

Exercise 123 : *Parkinson's Engineer's Vice.*—Draw the sectional elevation shown in fig. 131 ; also a side elevation, a front elevation, and a plan. Scale 6 inches to a foot. All the dimensions are to be taken from the illustrations of the separate details shown in figs. 130, 132, 133, and 134.

This vice has the advantages of the instantaneous grip vice, together with those of the ordinary screw vice. When the lever E is pushed over towards the screw M the nut L is lowered, and the movable jaw may be instantaneously moved out or in to suit the size of the work to be griped. After the lever E is released, the movable jaw is screwed up tight against the work as in an ordinary screw vice.

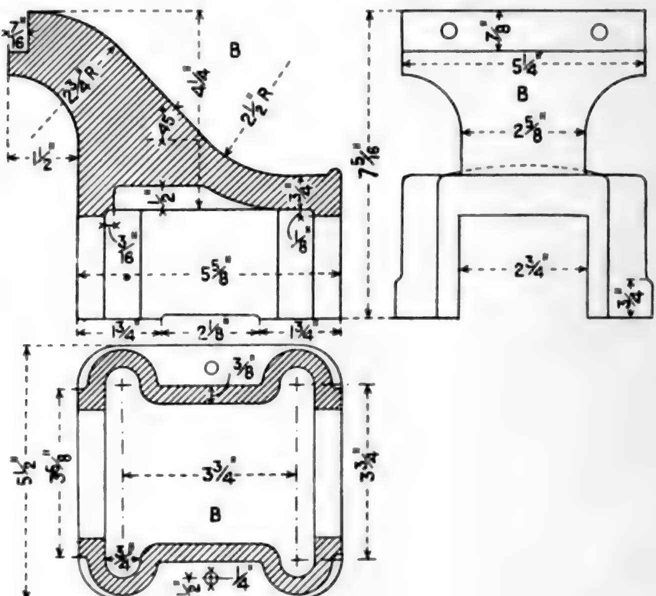


Fig. 130.

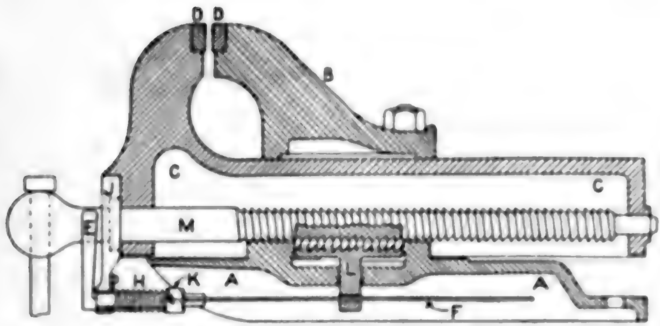


FIG. 131.

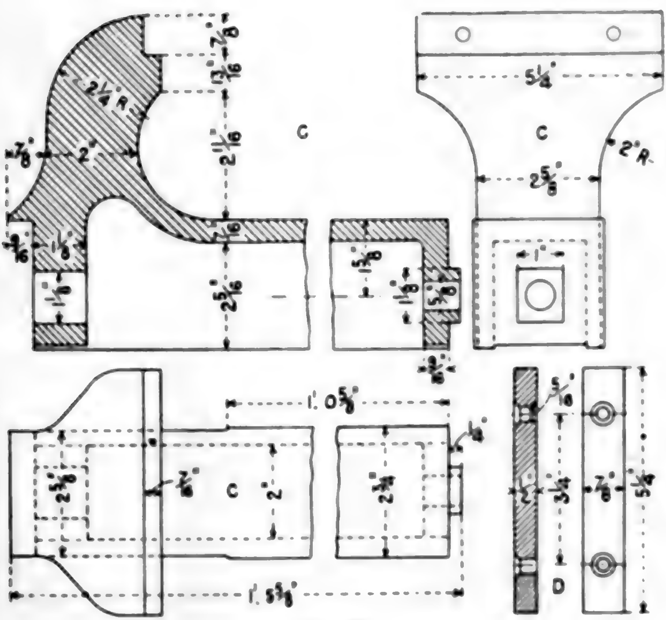


FIG. 132.

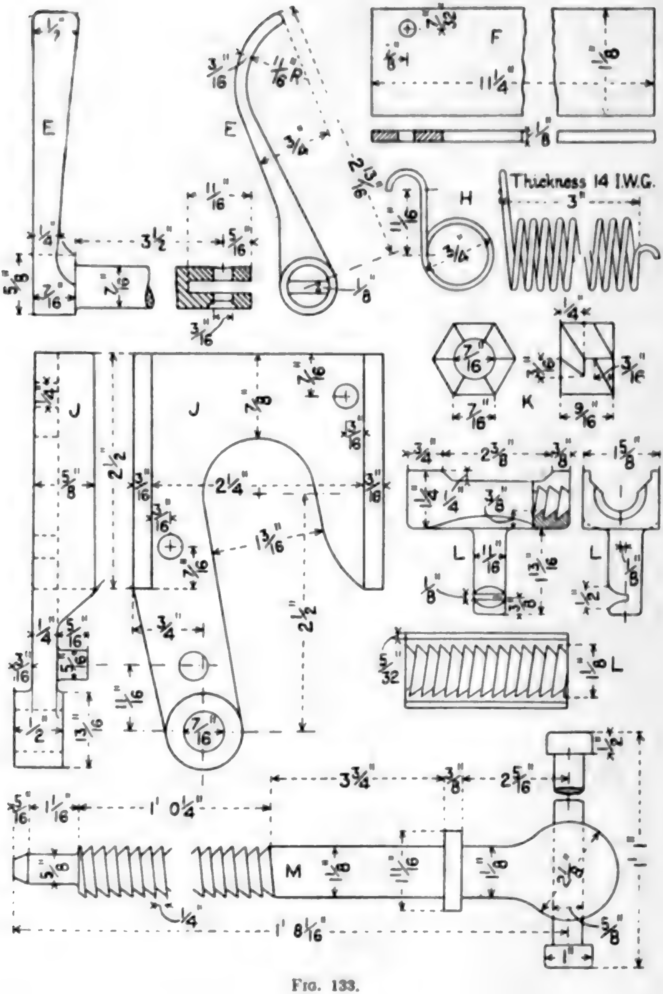


FIG. 133.

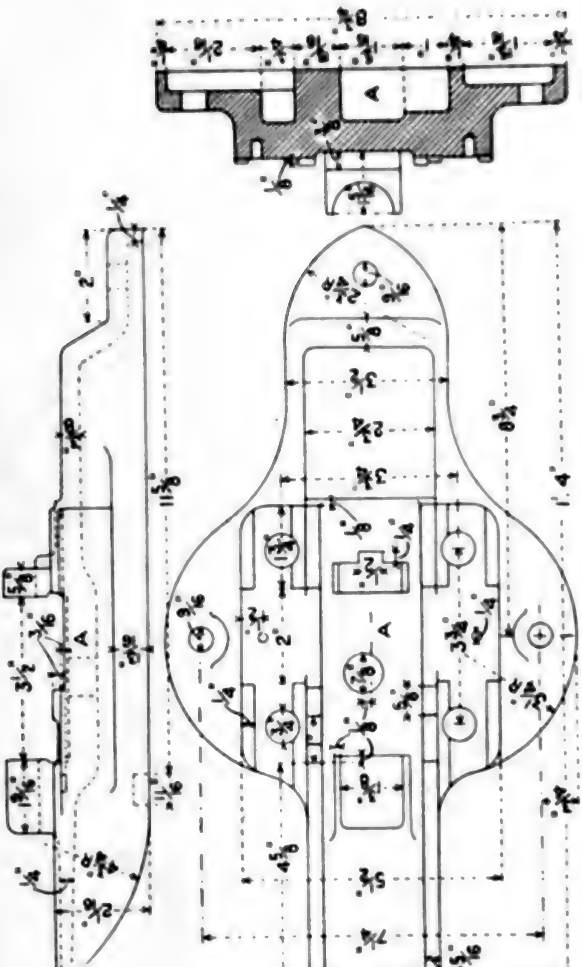


Fig. 134.

EXERCISE 124 : *Traversing Screw Jack.*—First draw all the details separately, as shown in figs. 135, 137, and 138 ; then draw the views of the complete machine, shown in fig. 136, also an end elevation. Scale half full size. (The separate drawings of the smaller details may be full size.)

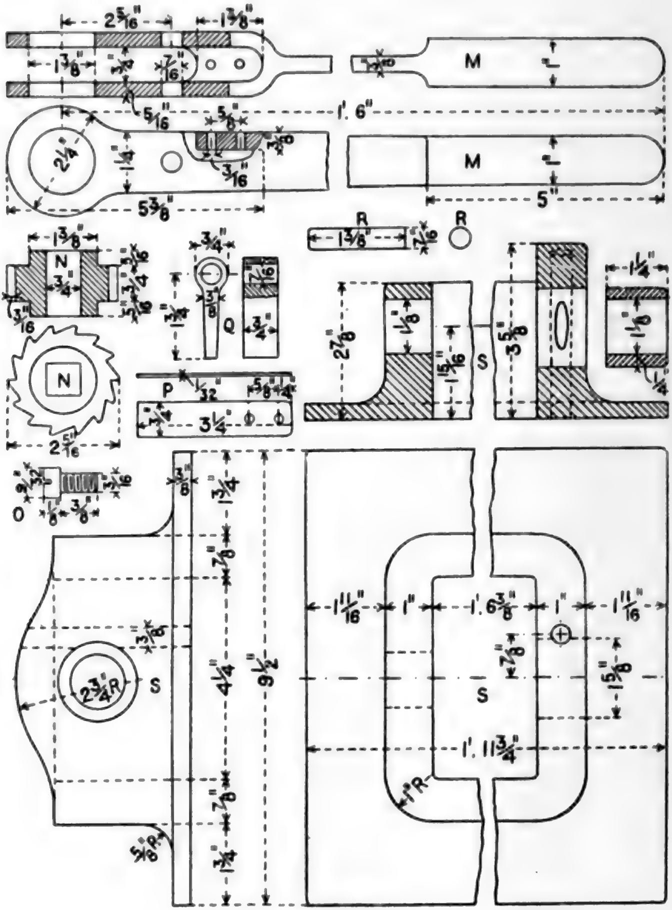


FIG. 135.

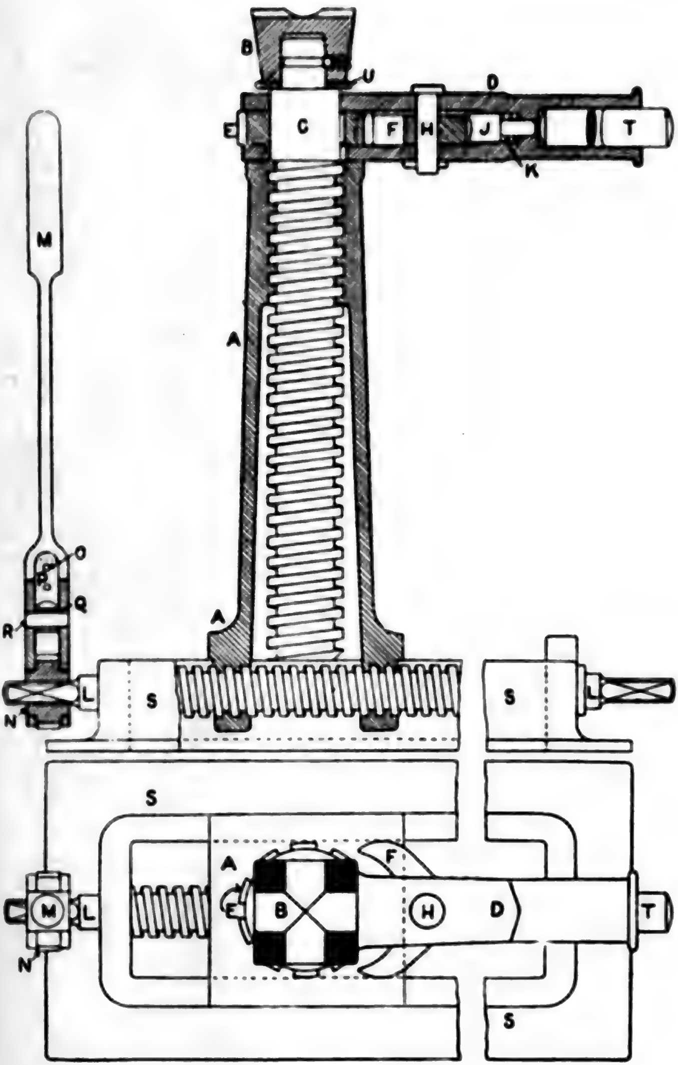


Fig. 136.

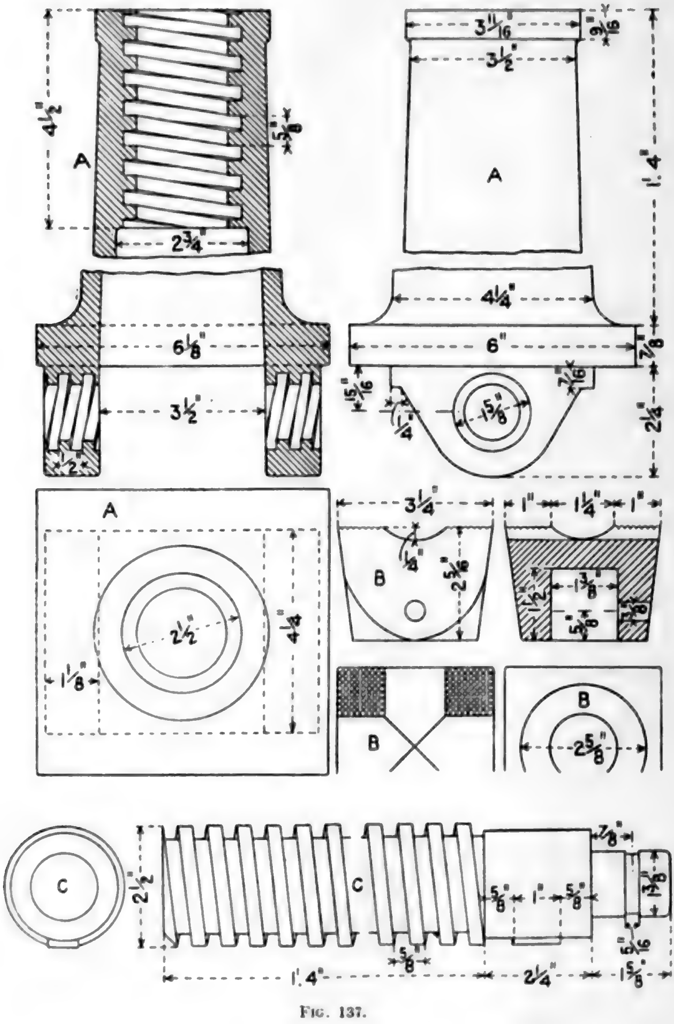

A
A
A
B
B
B
B
C
C
4½"
3 11/16"
9/16"
3½"
5/8"
1' 4"
2¾"
4¼"
6⅛"
6"
7/8"
3½"
15/16"
7/16"
1¼"
1⅝"
2¼"
½"
3¼"
1"
1¼"
1"
2 5/16"
1¼"
1⅜"
3/8"
5/8"
2½"
4¼"
1⅛"
2⅝"
7/8"
2½"
1⅜"
5/8"
1"
5/8"
5/16"
5/8"
1' 4"
2¼"
1⅝"

Fig. 137.

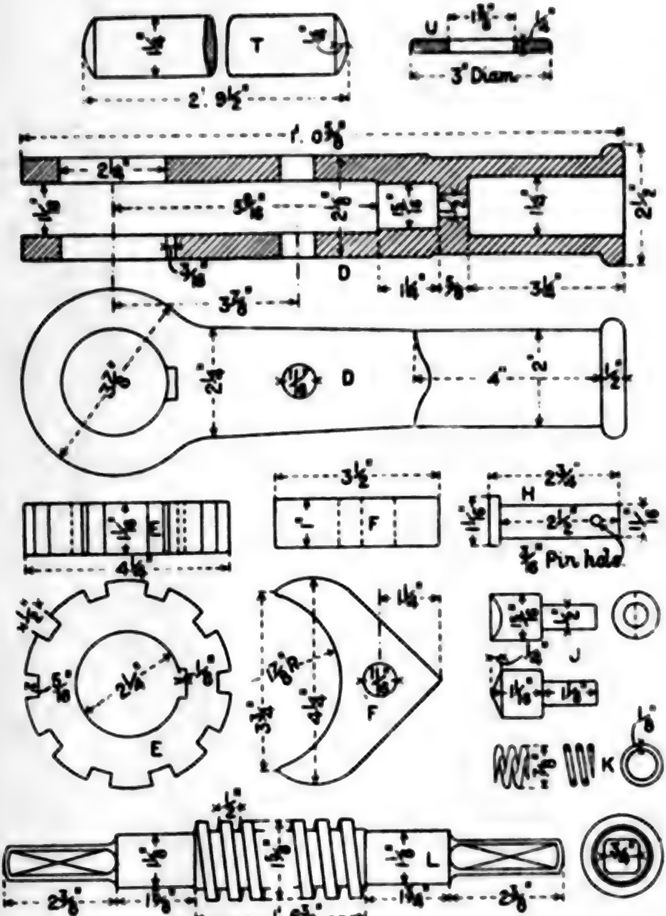


Fig. 138.

Exercise 125 : *Steam Engine Governor.*—Draw the half elevation and half section of the governor complete, as shown in fig. 141. Draw also a plan and an elevation looking in the direction of the arrow (*a*). Scale 6 inches to a foot. All the dimensions are to be taken from the illustrations of the details shown in figs. 139, 140, 142, and 143.

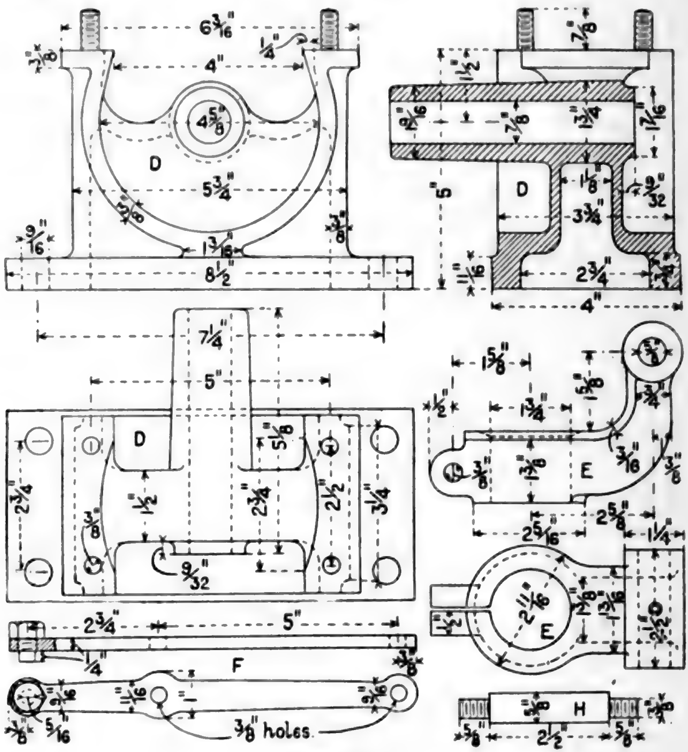


Fig. 139.

The particular governor here illustrated is used on an engine having a cylinder 8 inches in diameter, with a piston-stroke of 16 inches. The crank-shaft runs at about 110 revolutions per minute, and the governor-spindle is driven at three times the speed of the crank-shaft. The governor controls the expansion-valve. This type of governor is known as the "Porter" governor, from the name of its inventor.

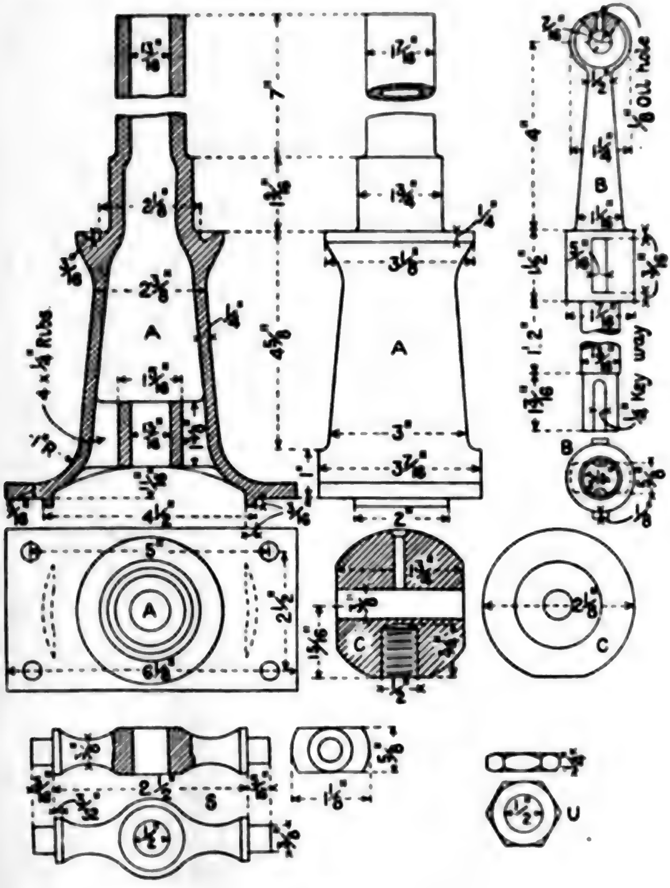


FIG. 140.

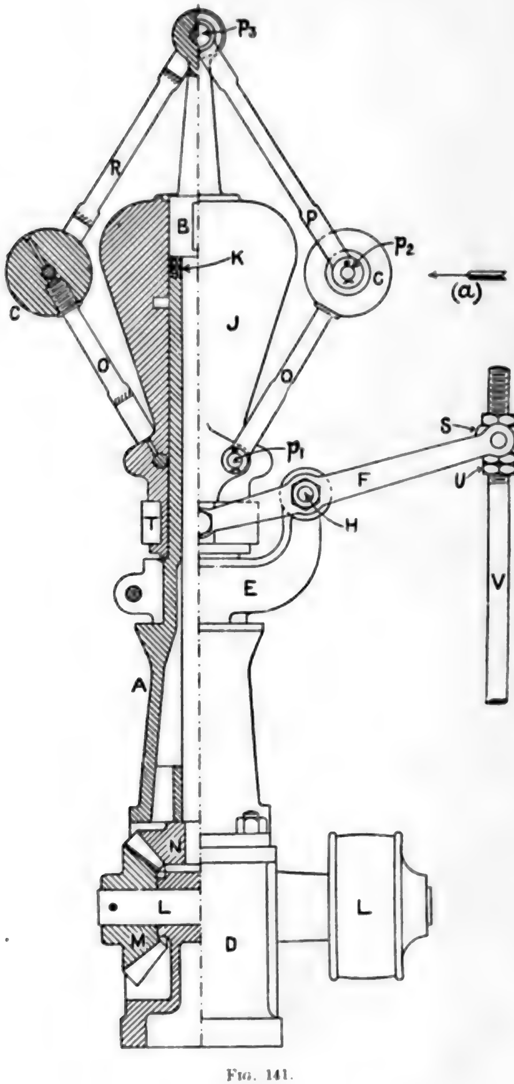


FIG. 141.

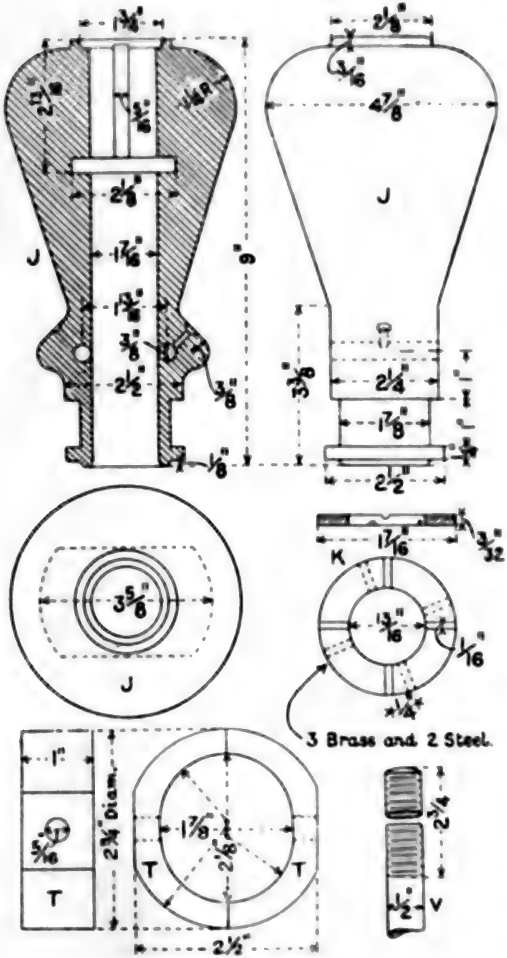


FIG. 142.

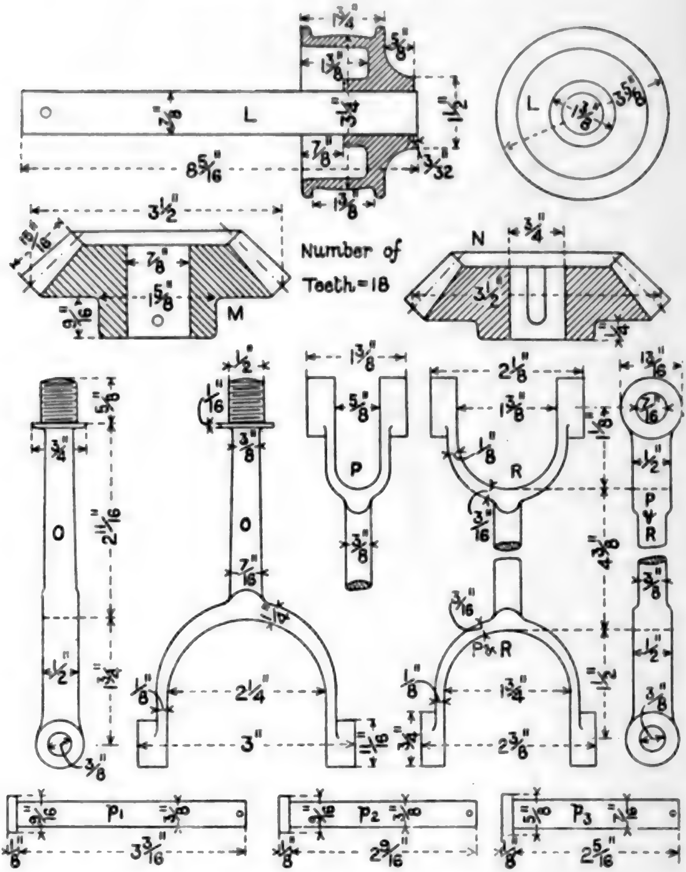


FIG. 143.

EXERCISE 126: *Gas Engine Governor.*—First draw the details A and B, half full size. Next draw the other details, full size. Lastly draw the plan and elevations of the complete governor shown on p. 148. The action of the governor is as follows: When the speed exceeds the normal speed the balls F fly further out, the sleeve K is raised higher, the lever D swings to the left (see left-hand elevation, p. 148) and pushes the disc G also to the left, so that it is no longer opposite to the cam on the cam-shaft M (this cam is not shown). When G is opposite to its cam the levers and spindle C C are moved at the proper time, and the valve which admits the gas to the engine is worked. But when G is moved away from its cam the gas-valve remains closed, and the motion of the engine is continued by the energy of the flywheel, and other moving parts, until the normal speed is again reached.

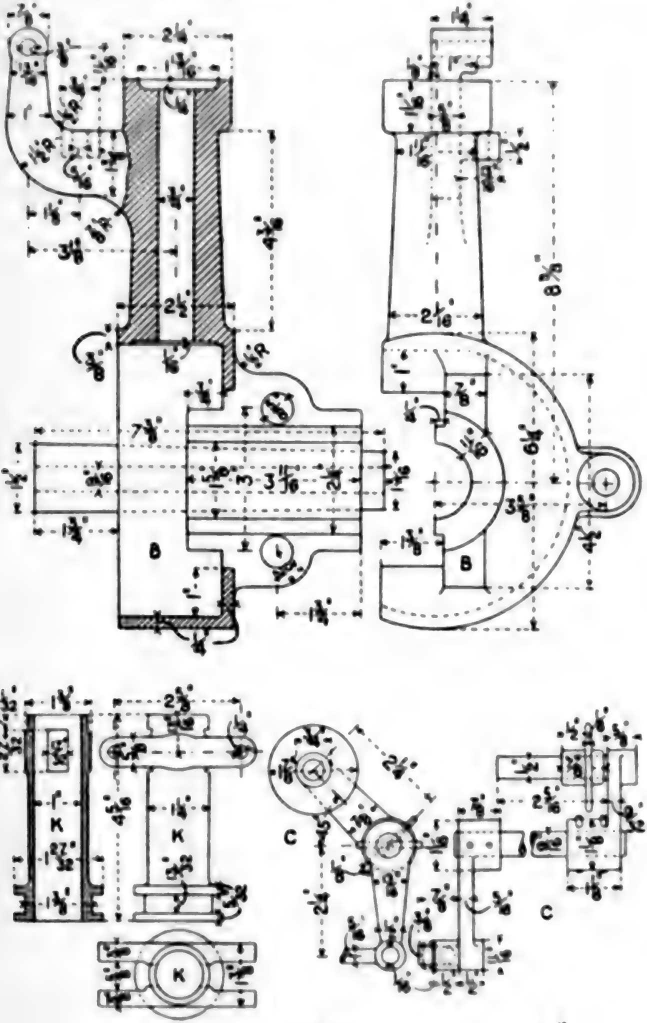


Fig. 144.

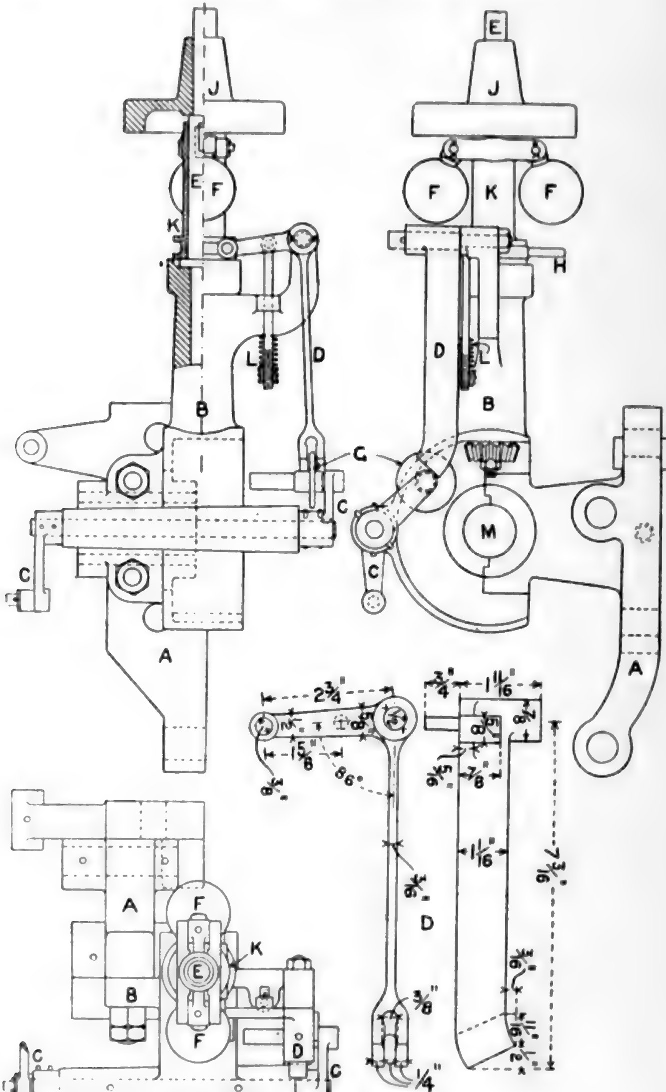


FIG. 145

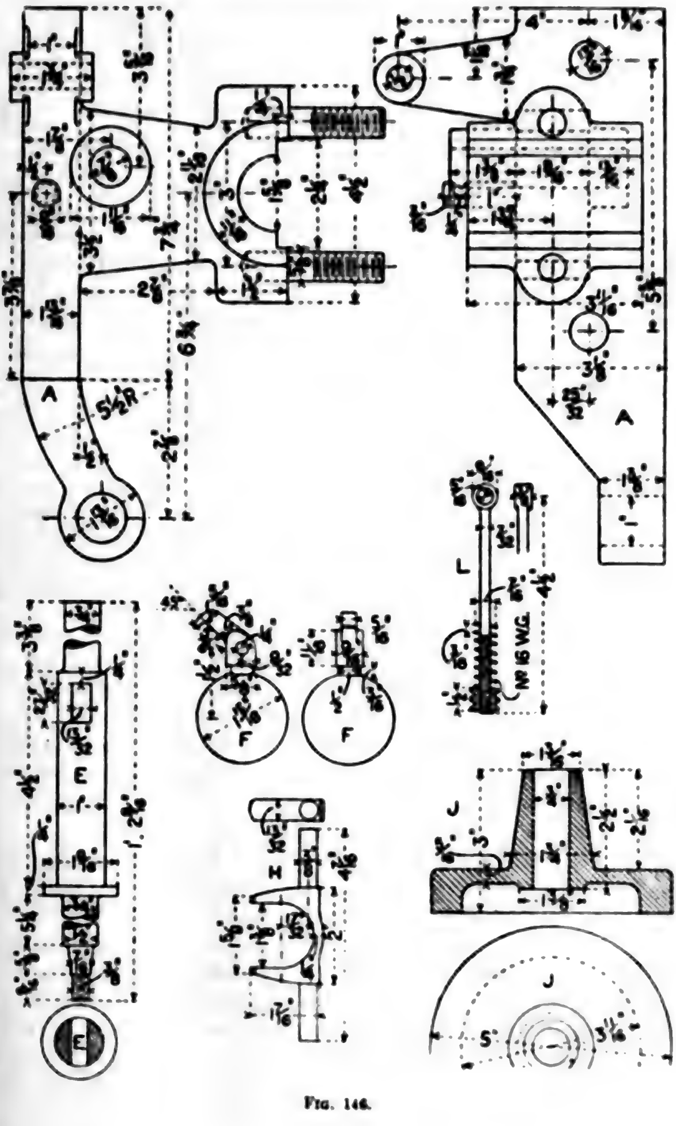


FIG. 146.

XX. MISCELLANEOUS QUESTIONS.

Chiefly from Examination Papers.

Sketches asked for should be drawn 'freehand.'

1. Describe with the aid of a sketch the operation of caulking a riveted joint. What is the object of caulking a riveted joint?

2. Sketch a simple single riveted lap joint, for $\frac{3}{8}$-inch plates and $\frac{3}{4}$-inch rivets, and dimension the overlap and pitch of rivets. Sketch also a $\frac{3}{4}$-inch rivet showing the usual form and proportions of the rivet head.

3. Give two views of a double riveted lap joint for boiler-plates.

4. Show by sketches a single riveted lap joint; a double riveted lap joint and a butt joint. What should be the least distance of the rivet holes from each other and from the edge of the plate and the least width of overlap?

5. Sketch sections of angle, tee, and channel iron. Give two views showing how two wrought-iron plates are connected together, at right angles to one another, by means of angle iron and rivets. What diameter of rivets would you use for $\frac{1}{2}''$ plates?

6. Show two ways of joining wrought-iron plates at right angles.

7. Describe in detail how any one of the rivets in fig. 110, p. 117, is put into place and riveted. Explain the use of a gusset stay.

8. Show by sketches the forms of triangular, square, and buttress screw threads.

9. Show the form of the Whitworth screw thread by drawing to scale a part section of two or three threads taking a pitch of $1\frac{1}{2}$ inches. Figure the dimensions on the sketch. How many threads to the inch are used on an inch bolt?

10. Sketch a bolt with square head, and hexagon nut. Supposing the bolt to be $1''$ in diameter, mark the usual dimensions of the nut and bolt head.

11. Sketch the end of a foundation bolt, showing how to fix it by a cotter and cast-iron plate below the masonry.

12. Sketch a form of bolt used for securing a machine to a stone foundation, and explain how the bolt is fixed in the stone.

13. Make a sketch of a stud, describe how it is screwed into place, and state some circumstances under which it is used in preference to a bolt.

14. What is a set-screw? Give an example of the use of a set-screw.

15. Show by sketches some method of preventing a nut from working loose. State the advantage due to the use of a hexagonal nut as compared with a square one.

16. Mention some instances in machine construction in which it has been found necessary to provide means to prevent nuts from working loose, and other cases in which such a provision is unnecessary. With the aid of sketches show two methods employed to prevent unscrewing.

17. Sketch and describe a construction in which by means of a right- and left-handed screw a rod may be adjusted in length; *or* sketch and describe any alternative method by which the length may be adjusted. Mention one example in which such an adjustment may be necessary.

18. Sketch and explain the modes of fixing a wheel or pulley by a sunk key, by cone keys, and by staking on.

19. Show by sketches how a wheel is fixed on a shaft by means of a sunk key. Explain how the key may be withdrawn when it cannot be driven from the point end.

20. A fly-wheel is required to be secured to a shaft by means of a sunk key. On one side, in contact with the wheel, the shaft has a collar, and on the other side the shaft is supported in a bearing. Show how to construct the wheel seating, the key and key-way, so that the key may be readily driven tight and removed when necessary.

21. Distinguish between a key and a cotter. Draw an example of each, stating the purpose for which each is employed.

22. Give two views in projection with one another, showing how the parts of a machine are united by a cotter. By reference to the sketches explain what is meant by the draw of a cotter and show how it is provided for.

23. Show two methods by which a cotter may be prevented from slacking back.

24. How much stronger is a 4-inch wrought-iron shaft than a 2-inch wrought-iron shaft to transmit work to machines?

25. Give sketches showing how the separate lengths of a line of shafting may be connected together.

26. Sketch the brasses for a bearing, and show how they are prevented from turning in the pedestal.

27. Give sketches of a pedestal to be carried by the bracket in fig. 109, p. 117, to support the shaft shown in section.

28. What is the object of using conical bearings for the lathe spindle shown in fig. 111, p. 118? Describe how adjustment is made for wear. Show by sketches how the headstock is secured to the bed of the lathe.

29. Sketch one form of hanger suitable for supporting mill-shafting.

30. Under what circumstances is such a bearing used as is shown in fig. 112, p. 119? Is it necessary to lubricate such a bearing? Why is a covering or sleeve provided for the shaft?

31. A shaft running at 100 revolutions per minute drives another by a leather belt. Pulley on first shaft 18 inches diameter; pulley on second shaft 30 inches diameter. Find the speed of the second shaft. Suppose the same belt is to drive the second shaft at 40 revolutions per minute. Find the diameters of the two pulleys.

32. By means of sketches and a description show how the two ends of a leather belt are united. Describe also how a belt in motion is shifted from the fast to the loose pulley.

33. Explain why the diameter of a belt pulley is often made greater at the centre than at the edges. Give the reason why the arms of cast-iron pulleys are often curved.

34. The pitch circle of a spur wheel is 2 feet in diameter and the wheel has 80 teeth. Calculate the pitch of the teeth.

35. What must be the diameter of the pitch circle of a spur wheel which has 95 teeth of 2 inches pitch?

36. A spur wheel has teeth of 3 inches pitch. Sketch a tooth and mark on it the thickness of the pitch line, and the height above and below the pitch line.

37. Show by a sketch what is meant by clearance of wheel teeth.

38. Show what is meant by a mortice wheel, and show how the teeth are fixed in the wheel rim.

39. Show by sketches how the segments of a spur fly wheel or other large wheel may be joined.

40. Describe how the parts of the spur wheel in fig. 107, p. 115, are put together, and explain why the wheel is made in segments.

41. Sketch in section a pair of bevil wheels in gear with one another. The centre lines of the shafts and the form of the pitch surfaces of the wheels are required to be carefully shown.

42. Show two ways of securing a crank pin to a crank arm.

43. By means of a sketch and description show how the two parts of an eccentric sheave are joined together when the sheave cannot be passed over the end of the shaft.

44. When the eccentric strap shown in fig. 93, p. 107, becomes loose by wear, how is it adjusted? What is the travel of the slide valve, the spindle of which is connected directly to the end of the eccentric rod?

45. Sketch a connecting rod end, with strap, gib, and cotter. Explain the use of the gib.

46. Give sketches of a connecting rod for a steam engine, and explain how the exact length of the rod may be maintained whilst adjustment is made for the wear of the brasses.

47. Explain the object of the construction of the connecting rod end shown in fig. 98, p. 109. Describe how the adjustment must be made and how it is locked.

48. In fig. 99, p. 110, describe how adjustment is made for wear; state why two nuts are used on each bolt; explain the use of the feather adjoining the round head of the bolt.

49. Sketch two views of the end of a connecting rod suitable for attachment to the piston rod end and guide block shown in fig. 115, p. 121, showing how the pin is fitted. What prevents the steps from working out sideways?

50. Describe how the lubricator shown in fig. 108, p. 116, is enabled to supply oil in a continuous manner. Explain the use of a locomotive coupling-rod.

51. Explain how the piston rings in fig. 104, p. 113, are made so that the piston may work steam-tight in the cylinder. How are these rings got into place?

52. Give sketches showing how a piston rod is secured to a piston.

53. With the aid of sketches explain how a piston rod is made to work steam-tight through the end of the cylinder.

54. Sketch a conical or puppet valve, showing how it is guided in lifting.

55. Give sketches showing one method of attaching the valve rod to an ordinary slide valve.

56. Sketch a slide valve in mid position to the following dimensions. Exhaust port 3″ wide; bars 1″ wide; steamports 2″ wide; outside lap $1\frac{1}{2}$ inches. Sketch also the same valve at the beginning of the piston stroke with $\frac{1}{2}$-inch

lead. The valve need not be drawn to scale, but may be sketched and the dimensions marked on it.

57. What is the use of the water-gauge cock shown in fig. 94, p. 107? State exactly where it is placed on the boiler.

58. With the aid of sketches describe how a steam-tight joint is made between the cylinder and cylinder cover of a steam engine. If the cylinder cover carries a stuffing-box for the piston rod, show how the cover is fitted so that the centre line of the rod must exactly coincide with the centre line of the cylinder.

59. In fig. 116, p. 122, explain how the high pressure water used in the cylinder is prevented from escaping past the piston, and between the plunger and cylinder cover. Describe also how you would make a tight joint between the cylinder and the cover at the end L.

60. Describe the working of the pump shown in fig. 113, p. 120.

61. With the aid of sketches describe how to make a steam-tight joint between two flanges. Explain under what circumstances studs are used instead of bolts.

62. Describe with sketches two methods by which the joints are made in connecting lengths of cast-iron pipes.

63. Sketch, partly in section, a union nut and joint for connecting two lengths of small piping.

64. How is the joint shown in fig. 102, p. 112, made water-tight? How are the bolts prevented from turning in the bolt-holes when screwing up the nuts?

65. What is the object of using chipping or facing strips in fitting up machine parts? Give one or two examples.

66. Describe in detail how the mud-hole door in fig. 105, p. 114, is removed for the purpose of cleaning the boiler and how it is replaced and the joint made steam-tight.

67. Sketch and describe a method of connecting together two lengths of a long tie rod of round *or* flat iron.

68. Explain the action of the governor shown in fig. 106, p. 115.

69. Explain the use of the quadrant for change wheels for a screw-cutting lathe shown in fig. 100, p. 111, by making a sketch showing it in place on a lathe with wheels in gear.

70. Make a sketch showing how the adjustment is made in the sliding parts of machine tools; as, for example, in the slide rest of a lathe.

71. Give sketches showing how you would grip and drive a round iron bar for the purpose of turning it between the centres of a lathe.

72. Describe in sequence how to secure and adjust a piece of a machine in a four-jawed dog-chuck so that it may run as truly as possible in a lathe.

73. Give sketches showing how the cutting tool of a lathe or other machine is secured in place.

74. Explain how the slotting machine ram in fig. 96, p. 108, may be made to move up and down when at work. How is the length of the stroke altered, and what is the object of the slotway in the upper part of the ram?

75. By means of sketches and a description show how you would secure a wheel or pulley to the table of a slotting machine for the purpose of cutting a key way, and how you would make the adjustment which is necessary when the key way is to be suitable for a taper key. Show by sketches the form of the cutting tool you would use.

76. Name the material you would employ in the construction of (1) a lathe bed; (2) the plunger of a water pump; (3) a steam boiler. In each case give reasons for your answer by referring to the characteristic properties of the metal used.

77. With the aid of sketches describe how the following four kinds of fastenings are used in connecting together parts of machines, and quote one example for each fastening, in which it is preferable to use that kind of fastening rather than one of the others, giving the reasons :—(1) a bolt and nut; (2) a rivet; (3) a cotter; (4) a key.

XXI. MATERIALS USED IN MACHINE CONSTRUCTION.

Cast Iron.—The essential constituents of cast iron are iron and carbon, the latter forming from 2 to 5 per cent. of the total weight. Cast iron, however, usually contains varying small amounts of silicon, sulphur, phosphorus, and manganese.

In cast iron the carbon may exist partly in the free state and partly in chemical combination with the iron.

In *white cast iron* the whole of the carbon is in chemical combination with the iron, while in *grey cast iron* the carbon is principally in the free state, that is, simply mixed mechanically with the iron. It is the free carbon which gives the grey iron its dark appearance. A mixture of the white and grey varieties of cast iron when melted produces *mottled cast iron.* The greater the amount of carbon chemically combined with the iron, the whiter, harder, and more brittle does it become.

The white cast iron is stronger than the grey, but being more brittle it is not so suitable for resisting suddenly applied loads. White iron melts at a lower temperature than grey iron, but after melting it does not flow so well, or is not so liquid as the grey iron. White iron contracts while grey iron expands on solidifying. The grey iron, therefore, makes finer castings than the white. Castings after solidifying contract in cooling about $\frac{1}{8}$ of an inch per foot. Castings possessing various degrees of strength and hardness are produced by melting mixtures of various proportions of white and grey cast irons. White cast iron has a higher specific gravity than grey cast iron.

Cast iron gives little or no warning before breaking. The thickness of the metal throughout a casting in cast iron should be as uniform as possible, so that it may cool and therefore contract uniformly throughout ; otherwise some parts may be in a state of initial strain after the casting has cooled, and will therefore be easier to fracture. Re-entrant angles should be avoided ; such should be rounded out with fillets.

The presence of phosphorus in cast iron makes it more fusible, and also more brittle. The presence of sulphur diminishes the strength considerably.

The grey varieties of cast iron are called *foundry irons* or *foundry pigs*, while the white varieties are called *forge irons* or *forge pigs*, from the fact that they are used for conversion into wrought iron.

Amongst iron manufacturers the different varieties of cast iron are designated by the numbers 1, 2, 3, &c., the lowest number being applied to the greyest variety.

Chilled Castings.—When grey cast iron is melted a portion of the free carbon combines chemically with the iron; this, however, separates out again if the iron is allowed to cool slowly; but if it is suddenly cooled a greater amount of the carbon remains in chemical combination, and a whiter and harder iron is produced. Advantage is taken of this in making *chilled castings.* In this process the whole or a part of the mould is lined with cast iron, which, being a comparatively good conductor of heat, chills a portion of the melted metal next to it, changing it into a hard white iron to a depth varying from $\frac{1}{8}$ to $\frac{1}{2}$ an inch. To protect the cast-iron lining of the mould from the molten metal it is painted with loam.

Malleable Cast Iron.—This is prepared by imbedding a casting in powdered red hematite (an oxide of iron), and keeping it at a bright red heat for a length of time varying from several hours to several days according to the size of the casting. By this process a portion of the carbon in the casting is removed, and the strength and toughness of the latter become more like the strength and toughness of wrought or malleable iron.

Wrought or Malleable Iron.—This is nearly pure iron, and is made from cast iron by the puddling process, which consists chiefly of raising the cast iron to a high temperature in a reverberatory furnace in the presence of air, which unites with the carbon and passes off as gas. In other words the carbon is burned out. The iron is removed from the puddling furnace in soft spongy masses called *blooms*, which are subjected to a process of squeezing or hammering called *shingling*. These shingled blooms still contain enough heat to enable them to be rolled into rough *puddled bars.* These puddled bars are of very inferior quality, having less than half the strength of good wrought iron. The puddled bars are cut into pieces which are piled together, reheated, and again rolled into bars, which are called *merchant bars.* This process of piling, reheating, and re-rolling may be repeated several times, depending on the quality of iron required. Up to a certain point the quality of the iron is improved by reheating and rolling or hammering, but beyond that a repetition of the process diminishes the strength of the iron.

The process of piling and rolling gives wrought iron a fibrous structure. When subjected to vibrations for a long time, the structure becomes crystalline and the iron brittle. The crystalline structure induced in this way may be removed by the process of *annealing*, which consists in heating the iron in a furnace, and then allowing it to cool slowly.

Forging and Welding.—The process of pressing or hammering wrought iron when at a red or white heat into any desired shape is called *forging*. If at a white heat two pieces of wrought iron be brought together, their surfaces being clean, they may be pressed or hammered together, so as to form one piece. This is called *welding*, and is a very valuable property of wrought iron.

Steel.—This is a compound of iron with a small per-centage of carbon, and is made either by adding carbon to wrought iron, or by removing some of the carbon from cast iron.

In the *cementation* process, bars of wrought iron are imbedded in powdered charcoal in a fireclay trough, and kept at a high temperature in a furnace for several days. The iron combines with a portion of the carbon to form *blister steel*, so named because of the blisters which are found on the surface of the bars when they are removed from the furnace.

The bars of blister steel are broken into pieces about 18 inches long, and tied together in bundles by strong steel wire. These bundles are raised to a welding heat in a furnace, and then hammered or rolled into bars of *shear steel*.

To form *cast steel* the bars of blister steel are broken into pieces and melted into crucibles.

In the *Siemens-Martin* process for making steel, cast and wrought iron are melted together on the hearth of a regenerative gas-furnace.

Bessemer steel is made by pouring melted cast iron into a vessel called a converter, through which a blast of air is then urged. By this means the carbon is burned out, and comparatively pure iron remains. To this is added a certain quantity of 'spiegeleisen,' which is a compound of iron, carbon, and manganese.

Hardening and Tempering of Steel.—Steel, if heated to redness and cooled suddenly, as by immersion in water, is *hardened*. The degree of hardness produced varies with the rate of cooling; the more rapidly the heated steel is cooled, the harder does it become. Hardened steel is softened by the process of *annealing*, which consists in heating the hardened steel to redness, and then allowing it to cool slowly. Hardened steel is *tempered*, or has its degree of hardness lowered, by being heated to a temperature considerably below that of a red heat, and then cooling suddenly. The higher the temperature the hardened steel is raised to, the lower does its 'temper' become.

Case-hardening.—This is the name given to the process by which the surfaces of articles made of wrought iron are converted into steel, and consists in heating the articles in contact with substances rich in carbon, such as bone-dust, horn shavings, or yellow prussiate of potash. This process is generally applied to the articles after they are completely finished by the machine tools or by hand. The coating of steel produced on the article by this process is hardened by cooling the article suddenly in water.

Copper.—This metal has a reddish brown colour, and when pure is very malleable and ductile, either when cold or hot, so that it may be rolled or hammered into thin plates, or drawn into wire. Slight traces of impurities cause brittleness, although from 2 to 4 per cent. of phosphorus increases its tenacity and fluidity. Copper is a good conductor of heat and of electricity. Copper is largely used for making alloys.

Alloys.—*Brass* contains two parts by weight of copper to one of zinc. *Muntz metal* consists of three parts of copper to two of zinc. Alloys consisting of copper and tin are called *bronze* or *gun-metal*. Bronze is harder the greater the proportion of tin which it contains; five parts of copper to one of tin produce a very hard bronze, and ten of copper to one of tin is the composition of a soft bronze. *Phosphor bronze* contains copper and tin with a little phosphorus; it has this advantage over ordinary bronze, that it may be remelted without deteriorating in quality. This alloy also has the advantage that it may be made to possess great strength accompanied with hardness, or less strength with a high degree of toughness.

Wood.—In the early days of machines wood was largely used in their construction, but it is now used to a very limited extent in that direction. *Beech* and *hornbeam* are used for the cogs of mortise wheels. *Yellow pine* is much used by pattern-makers. *Box*, a heavy, hard, yellow-coloured wood, is used for the sheaves of pulley blocks, and sometimes for bearings in machines. *Lignum-vitæ* is a very hard dark-coloured wood, and remarkable for its high specific gravity, being $1\frac{1}{3}$ times the weight of the same volume of water. This wood is much used for bearings of machines which are under water.

TABLES OF STRENGTH OF MATERIALS.

ULTIMATE TENSILE STRENGTH.

Approximate average values in tons per square inch.

Cast-iron	8	Zinc, cast	1·5
Wrought-iron—		„ sheet	7
Bars, good quality	23	Bronze (Gun-metal)—	
Bars, superior quality	27	Copper, 92; tin, 8	13
Forgings	21	Copper, 90; tin, 10	17
Plates, good quality—		Phosphor-bronze	20
Along the grain	21	Manganese-bronze	28
Across „	19	Brass, yellow	12
Plates, superior quality—		Muntz-metal	22
Along the grain	23·5	Naval brass	24
Across „	21	Delta-metal, cast	20
Steel—		„ „ rolled	30
Castings	30	Wood (along the fibres)—	
Forgings	30	Ash	7
Mild steel bars	28	Beech	5·4
Mild steel plates	28	Elm	5·8
Copper—		Fir and pine	5·1
Cast	10	Mahogany	7
Forged	15	Lignum-vitæ	5
Sheet	13.5	Oak	7
Tin, cast	1·5	Teak	7

ORDINARY WORKING STRESSES (FOR A STEADY OR DEAD LOAD).

In lbs. per square inch.

TENSION.

Cast-iron	4,000	Gun-metal	6,000
Wrought-iron—		Phosphor-bronze	10,000
Bars or forgings	14,000	Manganese-bronze	12,000
Plates, along the grain	14,000	Brass	4,000
" across "	12,000	Muntz-metal	7,000
Steel—		Naval brass	8,000
Castings or forgings	20,000	Delta-metal, cast	10,000
Mild steel	18,000	" rolled	13,000
Copper, cast	4,000	Wood	2,000
" forged	6,000	Leather	800
" sheet	5,000		

COMPRESSION.

Cast-iron	16,000	Copper	6,000
Wrought-iron	14,000	Gun-metal	6,000
Steel—		Phosphor-bronze	10,000
Castings or forgings	20,000	Brass	3,000
Mild steel	18,000	Wood	1,300

SHEARING.

Cast-iron	3,000	Copper, rolled	2,300
Wrought-iron	11,000	Wood, across the grain	500
Mild steel	14,000	" along "	100

For a live load which produces a stress always of the same kind or in the same direction, the working stress may be taken at two-thirds of the working stress for a steady or dead load.

For a live load which produces equal stresses in opposite directions, the working stress may be taken at one third of the working stress for a steady or dead load.

APPENDIX A.

DEPARTMENT OF SCIENCE AND ART, SOUTH KENSINGTON.

SYLLABUS.

SUBJECT II.—MACHINE CONSTRUCTION AND DRAWING.

THIS subject includes a knowledge of the form of the parts of machines, the physical characteristics of the materials used in machine construction, the various workshop processes employed in giving the materials the required shape and size, the magnitude of the straining actions to which they are exposed, and the methods of estimating the dimensions necessary to withstand those straining actions.

In addition to this knowledge, the possession of which may be shown by means of written descriptions, freehand sketches and calculations, a candidate for examination in this subject will be required to be able to draw neatly to scale, the whole or part of a machine either from dimensioned sketches, by measurement of an actual machine or model, or from his own design.

IN THE ELEMENTARY STAGE.

A candidate will be required to draw in simple or orthographic projection neatly in pencil to a given scale, two or more views (sectional or outside) of a simple portion of a machine in common use. The sketches from which the drawings are to be produced will be given. They will in general be incomplete, and be drawn purposely somewhat out of proportion, and the candidate will be required to set off, correctly to scale, dimensions, some of which are given on the view he is drawing, the remainder being obtained from the other views. He will be expected to add parts which are omitted from some of the sketches but shown in shape and size in others. He will further be expected to draw from his own knowledge the fastenings which are suitable for connecting together the machine parts which are the subject of the example, and, in sectional views, to draw lines neatly by freehand to indicate parts cut by the planes of section, taking care to slope the lines on all the parts of the same piece in the same direction, and of contiguous pieces in directions or characters which differ from one another.

In some cases an additional new view (outside or sectional), which is not shown in the sketches, will be required to be drawn, and details which are shown in separate detached sketches will be required to be inserted in their proper places in the general drawing.

The various views required must be placed in position so as to project from one another, in order to show that the candidate appreciates the fact that he is producing a representation of a solid piece of machinery, and not merely copying a sketch. No credit whatever will be given unless the candidate shows some knowledge of projection by drawing two views of at least one subject in their proper relative situations.

Teachers are enjoined not to rely too much on drawings in giving instruction to their classes, but to make use also of actual simple machine parts or models of them.

It is desirable that centre lines should be shown distinctly, and the parts of other lines continued too far, and not needed in the finished drawing, should be rubbed out.

In order to save time during the examination the drawings should not be inked in, nor should the figured dimensions be inserted.

The following list of examples which have been set in previous years will give a general indication of what may be expected and prepared for :—

Parts of an Engine.—Piston. Hydraulic piston and plunger. Piston rod end and guide block. Cross-head. Connecting-rod. Crank-shaft. Eccentric and rod. Valve-rod end. Spring-loaded steam-valve. Guide bracket for slide-valve rod. Simple form of loaded governor.

Parts of a Boiler.—Gusset-stay. Mud-hole door. Water-gauge cock. Simple feed-pump.

Portions of Machine Tools.—Fast headstock and spindle of a lathe. Tumbler bearing and bracket for the back shaft of a long lathe. Rest for a hand-tool for a lathe. Jaw of a dog-chuck for a lathe. Quadrant for carrying change-wheels for a lathe. Ram of a slotting machine. Parallel-jaw vice.

Mill Work.—Footstep-bearing for an upright shaft. Joint for segments of large spur-wheel. Bearing for turbine shaft. Wall bracket.

General Fittings.—Hooke's coupling. Ball-bearing for a tricycle. Hydraulic pipe-joint. Union joint.

Besides making Drawings, Candidates will be required to answer some of a Number of Questions on Machine Construction, and illustrate those answers by sketches. Unless specially instructed to the contrary, the sketches should be drawn freehand. The capability of making freehand sketches of parts of machines from memory is of the greatest value to an engineer, and when the sketches are drawn to a tolerable proportion they will be estimated by the examiners at at least as high a value as those drawn more accurately by means of instruments with a much larger expenditure of time.

The details of this portion of the subject may be classified as follows :—

The Formation of the Parts of Machines which are in Moving Contact :—

Constructions suitable to permit of *turning* and *swinging* motions.

Simplest form without special means for refitting after wear, as in fork or knuckle-joint. Use of bushes to facilitate renewal after wear. Use of steps or brasses with caps to facilitate adjustment of the cylindrical surface for wear in one direction. Methods of preventing end motion by pin and groove, collars and recesses as in shafts and eccentric-straps and by simple forms of footstep and pivot bearings.

Method of providing cylindrical and end adjustment together by the use of cones as in lathe.

Constructions suitable for *sliding* motions. Forms of cross section employed for piston-rod guides and in the lathe, planing, shaping, drilling and slotting machines.

Helical or Screw Motion.—Construction of a helical curve. Meaning of the terms pitch and angle of thread.

Surfaces suitable for Rolling Contact.—Cylinders, frustums of cones and spheres.

Surfaces for a Combination of Rolling and Sliding Contact.—Elementary information relative to the forms of spur and bevil wheels.

CONSTRUCTIONS TO PERMIT OF THE APPLICATION OF THE URGING FORCES AND THE WORKING RESISTANCES TO THE MOVING PARTS AND THE REGULATION OF THOSE FORCES.

For the Application of Pushing Forces by means of steam, air, or water pressure:—Simple forms of pistons, plungers, and stuffing boxes. Use of leather in hydraulic work. Simple forms of slide, lift, and screw-down valves, and two-way turn cocks.

For the Application of Pulling Forces by means of belts and ropes:—Forms of pulleys of simple construction with radial and curved arms. Forms of periphery to retain belt or rope by rims, barrel-shaped surface and grooves, also by the use of forked guides. Methods of connecting the ends of a belt or rope.

Use of an idle or loose pulley and shifting fork for the purpose of ceasing the pulling force.

METHOD OF CONSTRUCTION OF THE PORTIONS OF A MACHINE IN PARTS TO FACILITATE THE MANUFACTURE AND REFITTING AFTER WEAR, AND THE USE OF FASTENINGS TO JOIN THE PARTS TOGETHER:—

By the Use of Rivets.—Forms of rivets. Junction of plates by single and double riveting in chain and zigzag with lap and butt joints. Process of closing the rivet, and caulking the joint. Use of iron and steel of angle, tee, and channel sections to strengthen and stiffen plates, and to unite plates.

By the Use of Screws.—Bolts with various forms of heads and nuts. Studs and screws. Use of washers. The Whitworth and square form of screw threads. Raised threads. Right and left-handed threads. Methods of preventing nuts from working loose. Prevention of bolts from turning when screwing up the nut. Forms of spanners.

By the Use of Cotters.—Draw of cotter and clearance. Use of gib. Methods of preventing cotters from working loose.

By the Use of Keys.—Sunk, saddle, and feather keys. Methods of withdrawing keys.

METHODS OF CONSTRUCTION BY PARTS OF THE FOLLOWING PORTIONS OF MACHINES:—

The Frame of a Machine.—Use of chipping strips when two or more parts of a frame have to be united. Simple forms of pedestals, and methods of securing them to frame. Simple forms of hangers, brackets, and wall boxes, the structure of the building itself being a part of the frame. Methods of securing frames to foundations.

Elementary knowledge of the construction of a boiler and the necessary fittings. Gusset and bar stays. Methods of making the joints of pipes for conveying steam and water under pressure. Flange, socket, and union joints. Use of a centring ring in a cylinder cover.

The Primary Pieces of a Machine.—Connection of the parts of a shaft. Crank-pin to crank-arm and arm to shaft. Box and flange couplings. Connection of the two parts of an eccentric sheave. Meaning of terms eccentric radius and travel of valve. Connection of the parts of sliding pieces. Piston to rod, rod to crosshead or guide-block, and slide-valve to valve-rod.

Secondary Pieces.—Parts of a connecting-rod. Construction of an eccentric-strap and rod.

Physical Characteristics of the Common Materials used in Machine Construction.—Elementary information as to the relative strength, durability under wear, resistance to corrosion, and capability of being cast or forged of iron, steel, brass, and copper. Any question which may be set on the strength and proportions of machine parts will be of a very elementary character.

Workshop Processes.—Elementary information of the processes by which the desired shape is given to machine parts, including the use of the lathe, the planing, shaping, slotting, and drilling machines.

APPENDIX B.

EXAMINATION PAPERS SET BY THE DEPARTMENT OF SCIENCE AND ART.

SUBJECT II.—MACHINE CONSTRUCTION AND DRAWING.

Examiners, PROF. T. A. HEARSON, M.Inst.C.E., and J. HARRISON, ESQ., M.Inst.M.E., Assoc. M.Inst.C.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are expected to prove your knowledge of machinery, as well as your power of drawing neatly to scale. You are therefore to supply details omitted in the sketches, to fill in parts left incomplete, and to indicate, by diagonal lines, parts cut by planes of section.

No credit will be given unless some knowledge of projection is shown, so that at least two views of the example will be required properly projected one from the other. The centre lines should be clearly drawn. The figured dimensions need not be inserted.

Your answers should be clearly and cleanly drawn in pencil. No extra marks will be allowed for inking in.

In the Elementary and Advanced Stages the answers to the questions as well as the drawings must be made on the single numbered sheet of drawing-paper supplied, for no second sheet will be allowed.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

A single accent (′) signifies *feet*; a double accent (″) *inches*.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination. 1896.

INSTRUCTIONS.

Read the General Instructions on p. 167.

Draw one, but not both, of the examples shown in figs. 147 and 148. The example should be drawn on the side of the paper on which the candidate's number is printed.

Answer briefly any three, but not more than three, of the following questions.

Foolscap paper must *not* be used for this stage. No credit will be given for any work in this stage on foolscap paper.

EXAMPLES.

Only one to be drawn.

1. Eccentric for a steam-engine (fig. 147).

The diagram shows the two portions of the sheave and strap disconnected from one another. You are required to draw the parts fitted together, and to include the strap end of the eccentric rod. Place the centre line of the rod lengthways of your paper, with the eccentric radius in line with the rod.

Three views are required: one, E, as seen when looking in a direction parallel to the crank shaft, and the other two as viewed in directions at right angles to the first. Let the end view be as seen from the right, and be placed on the right-hand side of view E, and the other view be placed below E. In view E draw the upper half in section so as to show one of each of the 3 pairs of bolts and studs, and the lower half in outside elevation. No credit whatever will be given for drawing the parts of this example detached from one another.

Scale ⅓. (70.)

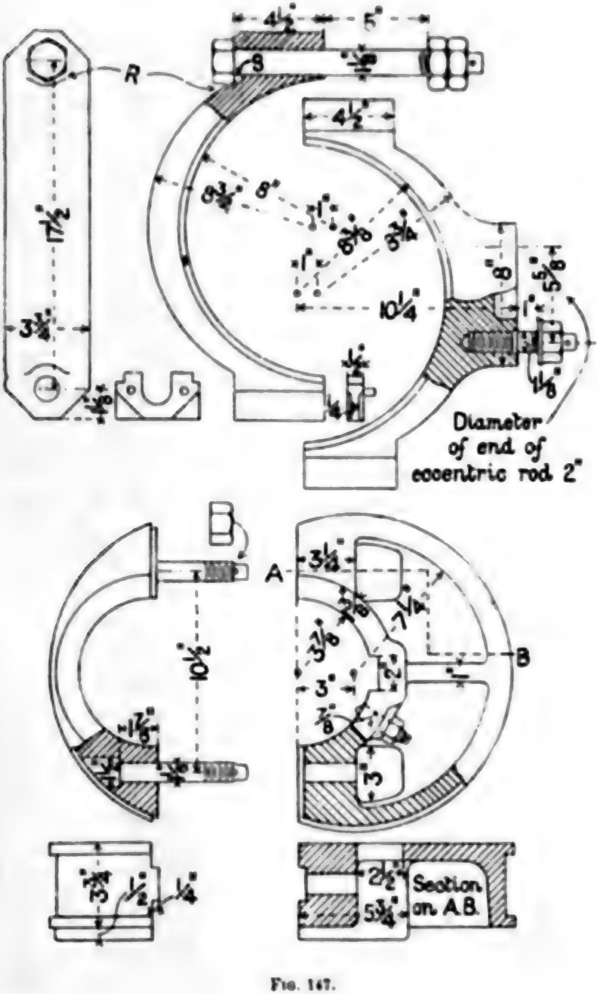


FIG. 167.

2. Tumbler bearing and bracket for the back shaft of a long lathe (fig. 148).

A portion of the lathe-bed is shown on the diagram for information, but it is not required to be drawn in any of the views.

Draw and complete the two views shown.

Draw also a plan projected from the left-hand view.

Scale $\frac{3}{4}$. (70.)

Note.—Dotted lines representing hidden parts are not required to be drawn in either example; nor should the figured dimensions be inserted.

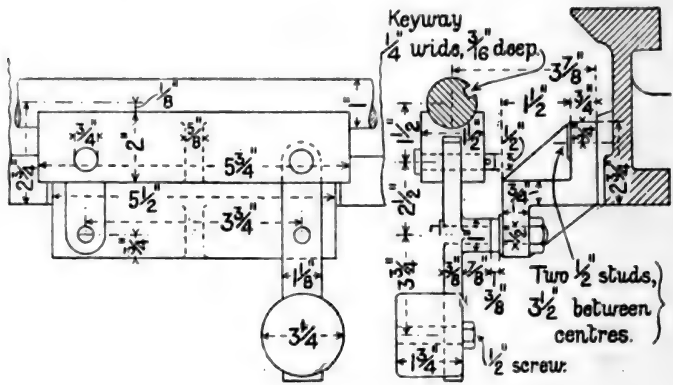


FIG. 148.

Questions, only three to be answered.

The sketches in answer to these questions should be drawn freehand.

(*a.*) Sketch an example of the use of a cotter together with a gib, and another example of a cotter without a gib, and explain the advantage due to the use of the gib in the first example. (10.)

(*b.*) It is required to extend a length of shafting through a brick wall, and support it by means of the wall. With the aid of sketches describe the construction of the wall box which you would use. The pedestal which carries the shaft need not be shown. (10.)

(*c.*) Describe with a sketch some form of automatic lubricator which will give a regular supply of oil to a bearing.

Explain its action and point out any special advantage which it may possess. (10.)

(*d*.) Describe with sketches some form of spanner which is adjustable to fit various sizes of nuts. (10.)

(*e*.) Supposing that, during the operation of turning a pin between the centres of a lathe, the revolving centre is out of truth, point out the resulting inaccuracy in the work. State under what circumstances the fault would be of no consequence, and when it is important to avoid the fault. Describe also the effect produced by the fixed centre being out of the line of the revolving spindle of the lathe. (10.)

(*f*.) Explain the use of the stop S under the head of the bolt which connects the two halves of the strap of the eccentric in fig. 147. Describe how it is attached to the bolt, and how the recess, into which it fits, is made. Describe also the process of knifing out the recess R to receive the head of the bolt, and show by sketches the form of the tool by which the operation is performed. (10.)

First Stage or Elementary Examination. 1897.

INSTRUCTIONS.

Read the General Instructions on p. 167.

Draw one, but not both, of the examples shown in figs. 149, 150, and 151. The example should be drawn on the side of the paper on which the candidate's number is printed.

Answer briefly any three, but not more than three, of the following questions.

Foolscap paper must *not* be used for this stage. No credit will be given for any work in this stage on foolscap paper.

EXAMPLES.

Only one to be drawn.

1. Pedestal-bearing for a shaft (figs. 149 and 150).

The diagram shows the parts detached from one another. In your drawing you are required to show them in place relatively to one another just as they would be when in use. No credit will be given for drawings in which the several parts are shown separated.

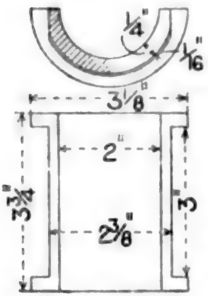


FIG. 149.

Three views are required, viz. :—

A front elevation as seen when looking in a direction parallel to the axis of the shaft. In this the left-hand portion is required to show a section through the centres of the bolt-holes, and the right-hand portion an outside view ;

A plan, the left-hand portion of which is required to show a section through the axis of the shaft, the right-hand portion being an outside view ; and

An end elevation, which is required to be an outside view entirely.

Scale, full size. (70.)

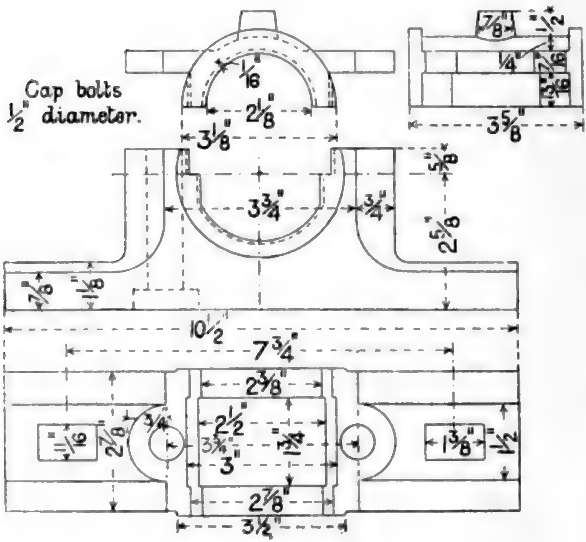


FIG. 150.

2. **Piston with connecting-rod end for a gas engine** (fig. 151).

The diagram shows the connecting-rod end detached from the pin on which it works. In the drawing you are required to show them connected together. No credit

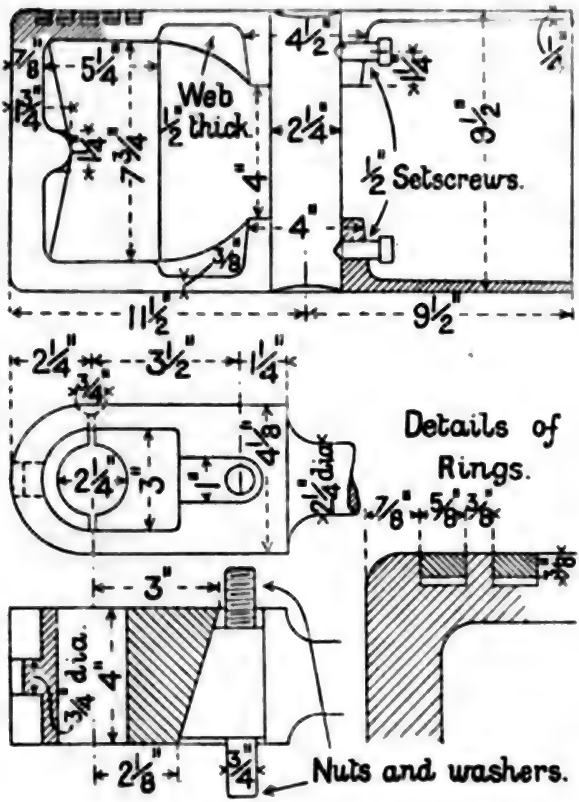


FIG. 151.

will be given for a separated drawing of the connecting-rod end, nor for a separate enlarged view of the piston rings.

Three views are required, viz. :—

A sectional plan taken through the axis of the piston, but in which neither the connecting-rod end nor the pin on which it works is to be shown in section ;

A side elevation, in which the upper half is to show a section taken through the axis of the cylinder, and the lower half an outside view of the piston ; and—

An end elevation looking into the open end of the piston.

Scale, half-size. (70.)

Note.—Dotted lines representing hidden parts are not required to be drawn in either example ; nor should the figured dimensions be inserted.

Questions, only three to be answered.

The sketches in answer to these questions should be drawn freehand.

(*a.*) Select a special example of each of the following two kinds of fastenings. Sketch the forms of the fastenings and the forms of the pieces united, in the locality of the fastenings, and for each state the reasons which cause that form of fastening to be preferred to the other.
(1) a rivet ; (2) a bolt and nut. (10.)

(*b.*) Sketch in section a stuffing box and gland with bolts or studs, in the construction of which cast iron, wrought iron or mild steel, and brass are all employed. Explain why these different materials are used for the various parts. (10.)

(*c.*) With the aid of sketches, describe the construction of the portion of the slide-rest of a lathe, by means of which the tightness of fit of the sliding portion may be adjusted after wear. (10.)

(*d.*) Make sketches showing the construction of a scribing-block, and describe one example of its use. (10.)

(*e.*) State under what circumstances it would be appropriate to use the pedestal bearing shown in figs. 149 and 150, in which only one brass step is provided. What are the uses of the shell-cap? Describe the means available for adjusting this bearing to the desired position of the shaft which it is required to support. (10.)

(*f.*) Describe how the piston rings shown in fig. 151 are made, and how they are placed in position. With the aid of a sketch, describe how they are prevented from turning. (10.)

First Stage or Elementary Examination. 1898.

INSTRUCTIONS.

Read the General Instructions on p. 167.

Draw one, but not both, of the examples shown in figs. 152 and 153. The example should be drawn on the side of the paper on which the Candidate's number is printed.

Also answer briefly any three, but not more than three, of the questions which follow.

Foolscap paper must *not* be used for this stage. No credit will be given for any work in this stage on foolscap paper.

EXAMPLES.

Only one to be drawn.

Locomotive crank shaft (fig. 152).

The diagram shows one end of the crank shaft, the crank arm, and one of a pair of eccentric sheaves of an outside cylinder narrow-gauge locomotive in which there are three pairs of driving wheels coupled together.

Do not draw the parts separated from one another as in the diagram, but draw one end of the shaft with the crank arm and *one* of the eccentric sheaves in place.

Three views are required as follows :—

(*s.*) An end view showing the crank arm placed vertically downwards and so much of the nearer eccentric sheave as is not hidden by the crank arm, the eccentric sheave being in its correct angular position.

(*t.*) In projection with (*s*), and to the right of it, draw an elevation with the crank on the left side of this view.

(*u.*) Also draw a plan projected from (*t*).

Scale, ½. (60.)

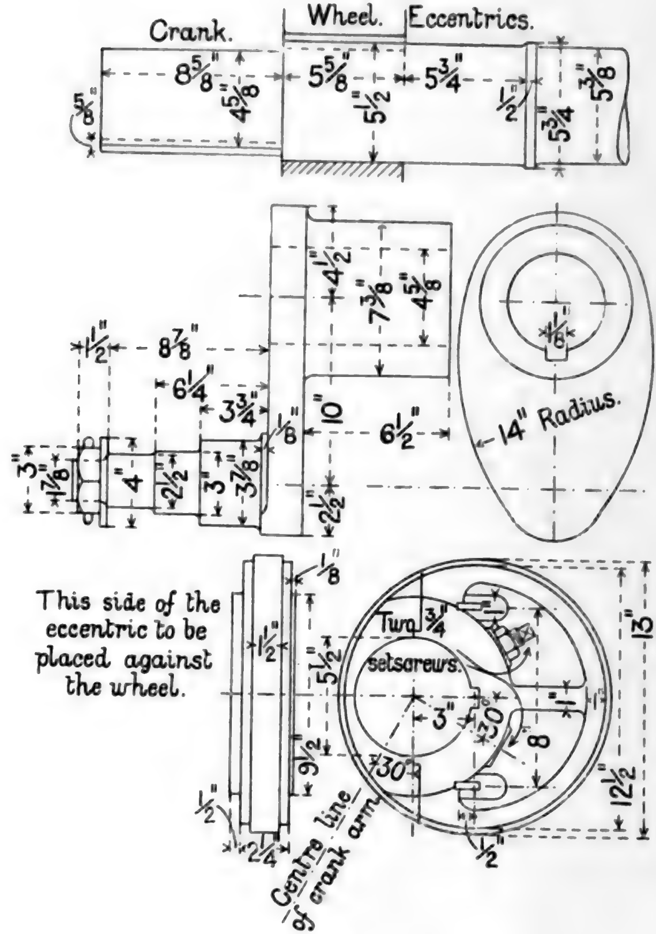

Crank.
Wheel.
Eccentrics.
14" Radius.
This side of the eccentric to be placed against the wheel.
Two 3/4" setscrews.
Centre line of crank arm

Fig. 152.

2. Tool rest of a planing machine (fig. 153).

The diagram shows three views, *V*, *W*, *Z*, of the tool rest together with a separate enlarged view of one of a pair of tool holders.

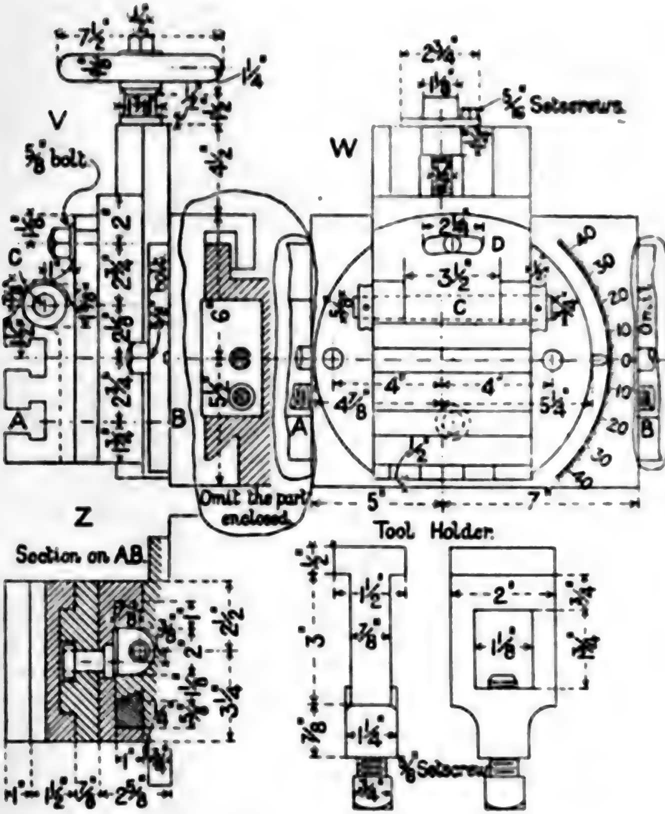


FIG. 153.

The sectional plan *Z* is given for information only, and is *not* to be drawn.

Draw and complete the two views *V* and *W*, placing one tool holder in the tool box (the upper one).

By the diagram you are instructed to omit a marked portion of the slide rest in both views. This portion should not be drawn.

Scale, half size. (70.)

Note.—Dotted lines representing hidden parts are not required to be drawn in either example, nor should the figured dimensions be inserted.

Questions, only three to be answered.

The sketches in answer to these questions should be drawn freehand.

(*a.*) Give sketches and a description of an eccentric strap and rod, and explain why each portion of it is made separately from the rest. (10.)

(*b.*) Sketch (freehand) three views of a fork or pin-joint to as good a proportion as you can judge by the eye. The views must be placed so that each one projects from another. (10.)

(*c.*) A cylinder cover is to be secured to a cylinder by $\frac{7}{8}''$ studs; what would be the size of the holes you would drill in the cover? Describe in detail how you would mark off, drill, and tap with accuracy the holes required in the cylinder flange. Describe also how you would screw the studs tightly in place, and how you would remove them if required to do so. (10.)

(*d.*) With the aid of sketches describe one form of lift or disc valve. In your sketches show how the valve is guided in its movement, and how the height of the lift of the valve is limited. (10.)

(*e.*) Give sketches and a description of a belt-shifting arrangement for ceasing and setting in action the pulling force of a belt on a machine by means of loose and fast pulleys. (10.)

(*f.*) Explain why the tool rest shown in Example 2, fig. 153, is pivoted at *C*, and describe how this joint is adjusted for wear. Explain also the use of the slot at *D*; and state under what circumstances the graduated arc would be used. (10.)

Elementary Stage. 1899.

EXAMPLES.

Only one to be drawn.

1. Valve-rod-end and link-block.

The diagram shows the details of the end of a valve rod (Fig. 154), which is to be coupled to a block also shown (Fig. 155), designed to fit a double-bar link.

Do not draw the parts separated from one another as in the diagram, but draw all the parts in their proper relative working positions.

Three views are required as follows :—

(*a.*) A front elevation, the right half of which is to be a section through the axis of the valve rod, and the left half an outside view.

(*b.*) In projection with (*a*), and to the right of it, draw a side elevation, the right half of which is to be a section also through the axis of the valve rod, and the left half an outside view.

(*c.*) Draw a plan projected from (*a*).

Scale, ½ (70.)

2. Bearing for a shaft.

Figs. 156 and 157 show the details of a swivelling bearing for a shaft. A perspective view of the complete bearing is added for information.

Do not draw the parts separated from one another as in the diagram, but draw them in their proper relative working positions as indicated in the perspective view. The perspective view is not to be drawn.

Three views are required as follows :—

(*d.*) An elevation, as seen when looking in a direction at right angles to the shaft, the right half of which is to be a section taken through the axis of the shaft, and the left half an outside view.

(*e.*) In projection with (*d*), and to the right of it, draw an end elevation, the right half of which is to be a section taken through the centre of the bearing, and the left half as seen from outside.

(*Continued on p.* 184). N 2

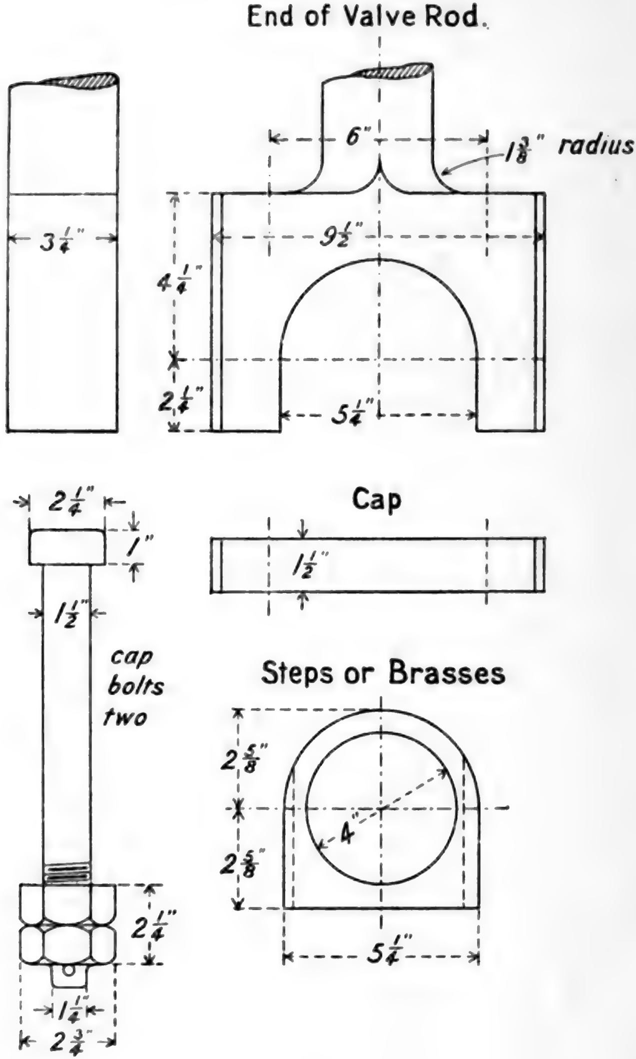

End of Valve Rod.
6"
1⅜" radius
3¼"
9½"
4¼"
2¼"
5¼"
Cap
2¼"
1"
1½"
1½"
cap
bolts
two
Steps or Brasses
2⅝"
2⅝"
4"
2¼"
1¼"
2¾"
5¼"

FIG. 154.

Link Block.

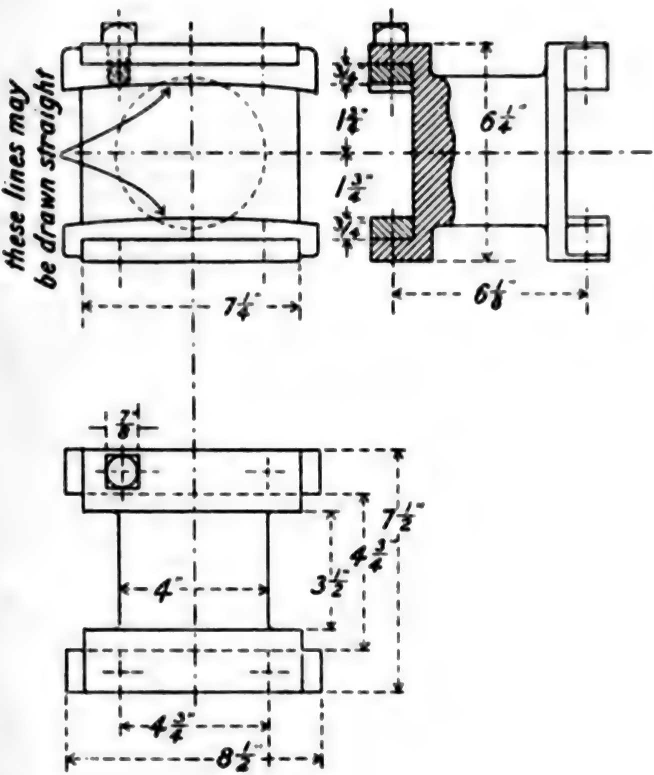


FIG. 152.

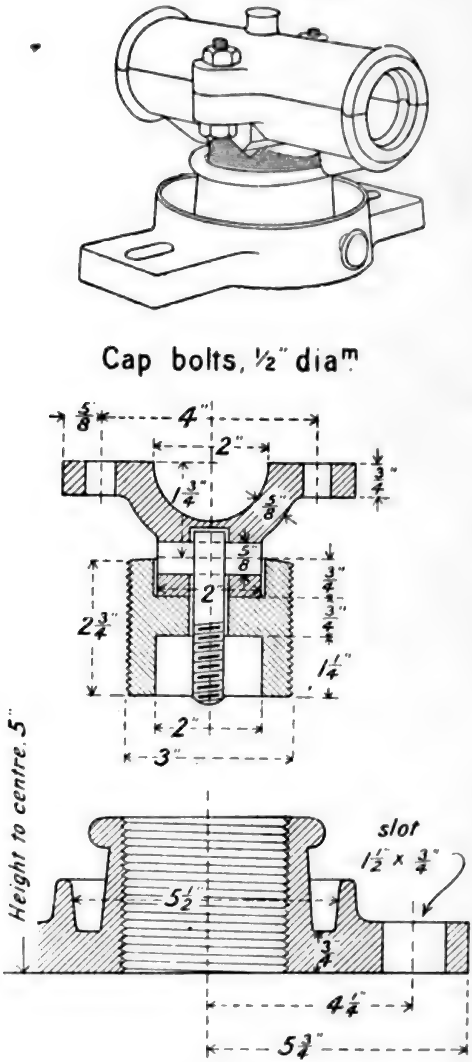

Cap bolts, ½" diam.
5/8
4"
2"
3/4"
1 3/4"
5/8"
5/8"
2"
2 3/4"
3/4"
3/4"
1 1/4"
2"
3"
Height to centre, 5"
slot
1½" × ¾"
5½"
¾"
4¼"
5¾"

Fig. 156.

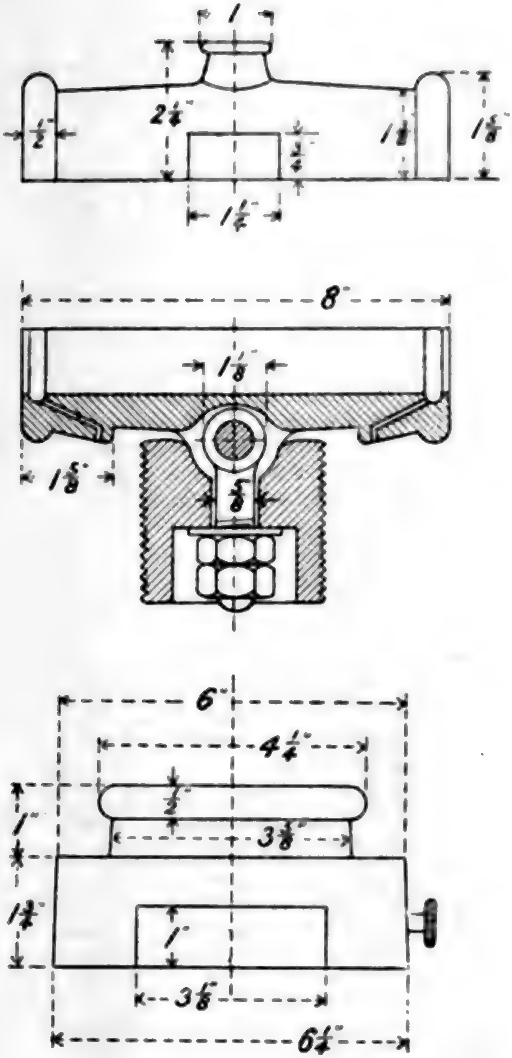


Fig. 167.

(*f.*) Draw a plan projected from (*e*).

Scale, $\frac{3}{8}$. (70.)

Note.—Dotted lines representing hidden parts are not required to be drawn in either example, nor should the figured dimensions be inserted.

Questions, only three to be answered.

The sketches in answer to these questions should be drawn freehand.

(*g.*) In the bearing shown in Example 2, Figs. 156 and 157, explain how the adjustment is made—
(1) for the lateral position of the shaft;
(2) for the height of the shaft; and
(3) for the angular position of the shaft. (10.)

(*h.*) Draw a section and an end view of a simple form of stuffing-box, suitable for a valve rod, so made that neither studs nor bolts are required for the purpose of tightening the gland. This section is to be shown as taken through the axis of the valve rod. (10.)

(*k.*) Sketch and describe three distinct ways by which a flat belt may be retained on the surface of a pulley when running. (10.)

(*l.*) Draw two views of a double riveted lap-joint, *first* when the rivets are arranged zig-zag, and *second* when they are placed in chain. Point out the advantage of the former arrangement. (10.)

(*m.*) Give sketches showing the various ways of constructing and fitting a key to prevent the relative rotation of a shaft and a piece which is mounted on it. Quote an example of the use of each method of fitting, mentioning the difference in the circumstances of each. (10.)

(*n.*) Describe in detail each step of the process of turning in a lathe with a slide rest a bar to a uniform diameter of $\frac{7}{8}''$ and length 5″ from a rough forging, the dimensions of which are only a little greater. Explain how you would ascertain whether or not the bar was being made taper, and, if so, how you would adjust the lathe. (10.)

APPENDIX C.

REPORT OF THE EXAMINERS ON THE EXAMINATION IN MACHINE CONSTRUCTION AND DRAWING, 1890.

In reporting on the examination in Machine Construction and Drawing, we are sorry to have to state that in the Elementary Stage a smaller proportion of candidates than usual succeeded.

Teachers who have studied the examination papers of successive years will have observed that our aim has been to require year by year more knowledge of construction and of ability to understand the drawings. We have repeatedly noticed with dissatisfaction that candidates, often in large classes, are sent in for examination who have been shown merely the method of setting off to scale the various dimensions given on a figured drawing, and who have been taught little or nothing of machine construction, and frequently appear to have no idea that the different views shown are related to one another and represent a solid piece of machinery. As an example of the result of unsatisfactory teaching may be mentioned a class of 94 candidates, of whom only 3 obtained a first class, and 59 failed entirely; for comparison with this may be quoted a class of 108 candidates, of whom 40 obtained a first class, and only 16 failed.

Ability to draw machines to scale is useful only to those who also know something about their construction, therefore, in order to pass, we have made it essential that the candidate must be able to do something more than merely copy to scale.

Besides being taught to take from one view dimensions which are necessary for the drawing of another, the student should be instructed to show the relation of one view to the other by placing them to project one from the other. A very considerable proportion of drawings are sent in with the different views of the examples placed indiscriminately on the sheet, as if they were independent objects. In accordance with the general instructions on the first page of the examination paper, such papers are cancelled.

Provided some knowledge of projection is shown on the paper, a displaced second view of an example is not entirely discredited if the displacement is due to the candidate not having left sufficient room for drawing it in the right place; but a considerable deduction is made for the fault of bad arrangement.

In some cases, whilst the notion of projection had been imparted, projection lines being drawn, yet the student had utterly failed to realise from the sketches the form of the object he was drawing, absurd additions being made to the views shown, and the added view often ludicrously impossible. It is suggested that teachers would do well in making more use in their teaching of models of machine details.

In setting the examples to be drawn, only sufficient is shown on the diagram to make clear and determinate the shape and dimensions of the piece of machinery represented. In completing the views which are commenced, and in producing a third view when required, the student has the greatest opportunity of showing his knowledge of machine construction. Such extra drawing is highly marked. It should include details shown in one view of the copy, but omitted in the other. In the sections, diagonal lines should be drawn on the parts which are cut by planes of sections, and on those parts only. It is a very common error to find two separated portions of a section of the same piece to be crossed by section lines sloping in opposite directions, as if they were distinct pieces. Another frequent fault is for the section lines to be drawn in the same direction in continuous lines over adjacent separate pieces, no distinction between the parts being made at all, and often portions are sectioned which can only be in elevation. More care on the part of some of the teachers in instructing their students in the proper use of section lines would, we believe, lessen the frequency of these faults. It is advisable to note that these section lines are not required to be drawn with mathematical precision, but only with neatness.

Candidates should be advised not to spend too much time in showing by dotted lines details of the construction which are not apparent on the face of the view.

In the event of the candidate not happening to be familiar with one or more of the examples which are set to be drawn, he has still a large opportunity of showing some knowledge of machinery by answering some of the questions which precede the examples. An inadequate attention is often paid to this part of the paper in the elementary stage. A large proportion of the candidates ignore it altogether, another large proportion treat it in a cursory way, and a few elaborate their answers unduly, and use up the time wanted for drawing the examples.

The sketches required in answer to these questions should be neatly drawn by freehand, both for the sake of saving time and for the purpose of exhibiting a kind of skill of great value.

It would be advisable for teachers to draw the attention of their students to the general instructions which are repeated year by year in the examination paper. A large proportion of candidates always disobey these instructions, and suffer, more or less severely, thereby.

There are a number of drawings sent in in which the wrong scale has been adopted. It is impossible to do anything else than cancel these drawings.

Only loss, and no gain, follows from attempting too many questions or examples. What the student does not require to have examined he should cross out.

Inking-in, inserting figured dimensions, and shading, though more or less desirable in class work, are not required in the examination, and receive no marks.

It is not advantageous for the student to construct his own scale; it occupies time, and introduces an additional element of error.

Neither the questions nor examples call for much special comment. All conceivable answers, right and wrong, found expression. As cases of frequently recurring faults, it may be mentioned that the pedestal, frequently well sketched in answer to question (*b*), was one suitable for bolting to a horizontal plate, and not to the vertical plate of the wall bracket of example 2.

The frequent answer to the question (*d*) why the arms of cast-iron pulleys are often curved, 'because they are stronger,' did not score any marks; full marks were given for such answers as 'less liability to crack in the mould while cooling.'

The attempts at example 3 were very few as compared with examples 1 and 2, but relatively were more successful.

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