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MACHINE CONSTRUCTION AND DRAWING

FRANK CASTLE



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MACHINE CONSTRUCTION AND DRAWING

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PREFACE.

A LONG experience of teaching Machine Construction and Drawing to students of many conclusion that in order to be able to produce in a reasonable time a working drawing or an engine detail, a student must know thoroughly certain fundamental facts. He must be familiar with the proportions usually adopted for such simple details as rivets, bolts, keys, &c.

The plan followed in this book has been first to describe these details briefly, and then to give the usual empirical proportions—which are obtainable without calculation—in which these simple machine details occur, the dimensions have to be determined from the empirical proportions previously given. In this way the student gains unconsciously a complete familiarity with the commonly occurring proportions. In special cases, of course, calculations are necessary, and the results obtained by the student for particular instances must be utilised. The student is shown, by numerous examples, how to perform these calculations.

An examination of the contents of the volume will, it is believed, show that an unusual as well as a great variety of machine and engine details have been brought together. It should be understood, however, that no attempt has been made to include every essential detail. Every machine draughtsman should be acquainted with the details given.

After the first three chapters have been mastered, the various sections may be taken in the order the teacher finds most convenient. Students working alone may find it the best plan to take the easier examples first after studying the first three chapters—to deal only with the easier examples which are given, reserving the remaining exercises for a subsequent perusal of the book.

It is almost impossible to acknowledge each one of the many sources from which material has been obtained in preparing the book, but reference must be made gratefully to the work of Prof. Unwin. Numerous examples have been taken from examination papers, the University of London, the Board of Education, and permission to do this has been given by the Controller of Education. These questions are recognised easily by the letters B.E. attached in each case.

I am indebted to Mr. C. P. Butler for several photographs reproduced in this book. I am also indebted to the Council of the Institution of Mechanical Engineers for kind permission to use material from their publications.

The work of preparing the MSS. and of seeing the book through the press has been greatly aided and dealt with by the kindly advice and experienced criticism received from Sir Richard Gregor. Much trouble has been saved by the excellent way in which the printing has been done by MacLehose & Co. Ltd.

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CHAPTER I.

INTRODUCTORY.

Introductory. Although in some subjects, such as Freehand or Model Drawing, it is possible to draw straight and curved lines without the aid of mathematical instruments, this is not the case in Engineering Drawing. In making the drawings with which the reader of this book is concerned, mathematical instruments are continually required, and it therefore becomes necessary at the outset to indicate the really necessary instruments, and also to explain how, when these have been obtained, they may be maintained in an efficient condition.

The few necessary instruments should be as far as possible of the best quality. One of the mistakes too often made by the beginner is to substitute *quantity* for *quality*, the result being a box containing a number of instruments the majority of which are probably of little or no use. If to commence with it is impossible to purchase a good and fairly complete set, it will be better and cheaper for the student in the long run to obtain those instruments which are absolutely necessary and afterwards to add others gradually to his stock.

Pencils. Pencils should be neither too hard nor too soft; with the former, grooves are frequently made in the paper; while with the latter, it is a difficult matter to draw lines sufficiently fine for accurate work, as well as to preserve a uniform thickness of line throughout. In using soft pencils, also, a portion of the lead is easily rubbed off by the friction of the set squares and this is deposited on the surface of the paper in the form of dust, which tends to give the drawing a smeared and dirty appearance.

Probably the best pencil for general work will be found to be an **HH** or **H**, although **HHH** or **HHHH** may be used with advantage. Such pencils are used most conveniently when sharpened to a chisel point, along the edges of the T-square and the set squares. With this form

the edge is easily maintained by occasionally rubbing on a piece of *fine sand paper*. A softer pencil may be used for sketching or for general purposes and a round point (Fig. 2).



FIG. 2.

Compasses. One pair of 6-inch compasses will be required. The legs of one terminating in a round point, or arranged to carry a needle, the other an inking-pen.

When a needle is used it should be as firm as possible. To effect different methods of fastening adopted, and of these that shown in Fig. 3. The joint at J may be tightened or released by means of a small steel key. A small flat piece of steel with two pins or projections fitting the compass. The adjustment just referred to is frequently necessary. Thus, if the compass is not sufficiently firm, an alteration may occur during the process of transferring one place to another.

Dividers. Two forms of dividers are shown at A and B (Fig. 4). That

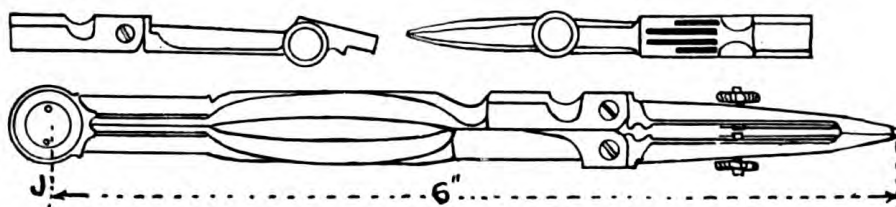


FIG. 3.—6" Compasses.

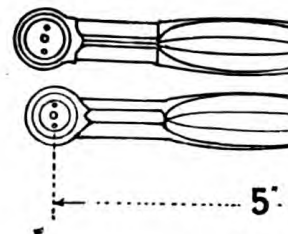


FIG. 4.

than that at A, is provided with a screw adjustment. In this case rotation right or left enables the point to which it is attached to be opened or closed.

Smaller compasses, pen and pencil, of about the size shown in Fig. 5, are suitable have two joints, as shown at J and K. In the case of the pen compass K is indispensable for good work.

Drawing pen. There are many varieties of drawing pens. One of the most useful is (Fig. 6). The pen should be of good quality, and the handle is usually made of ivory or similar material.

Spring bows. Comparatively small dimensions, and especially small circles, are most readily drawn by what are known as *spring bows* (Fig. 7). These may be obtained either separately, or in a small box in which they may be kept when not in use.

Drawing board and T-square. The size of the drawing board obviously will depend on the size of paper to be used. A comparatively large sheet of paper will require a corresponding large board, and although a small drawing could be made on a small board it is far from convenient. Suitable sizes are known as *Imperial*, 30" x 22", and

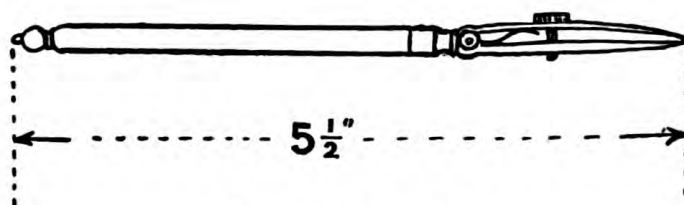


FIG. 6.—Drawing Pen.

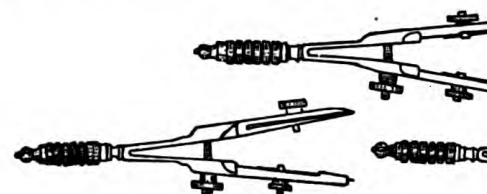


FIG. 7.—Spring Bows

known as *Half-Imperial*. Though the former will be found useful sometimes, the latter is more serviceable for the majority of purposes, and is suitable for most of the exercises given.

The drawing board should be made of well-seasoned yellow pine and be free from warp. It should be provided with cross-bars or battens at the back to prevent the board from warping.

T-square. The blade **AB** of the T-square should be equal in length to the drawing material for it is mahogany with an ebony working edge. Such T-squares are sometimes made of pear wood, but those made of pear wood are frequently used. The blade of the square should be firmly set in the stock, but not sunk into it. The edge of the blade in time becomes uneven owing to use of pen and pencil, and it becomes necessary to remove the blade from time to time

rectifying the edge by means of a plane. To ensure that, when replaced, the angle of the stock is unaltered, a pair of dowels, or pins, are usually used, as at *d d* (Fig. 8), and the blade is turned in the blade.

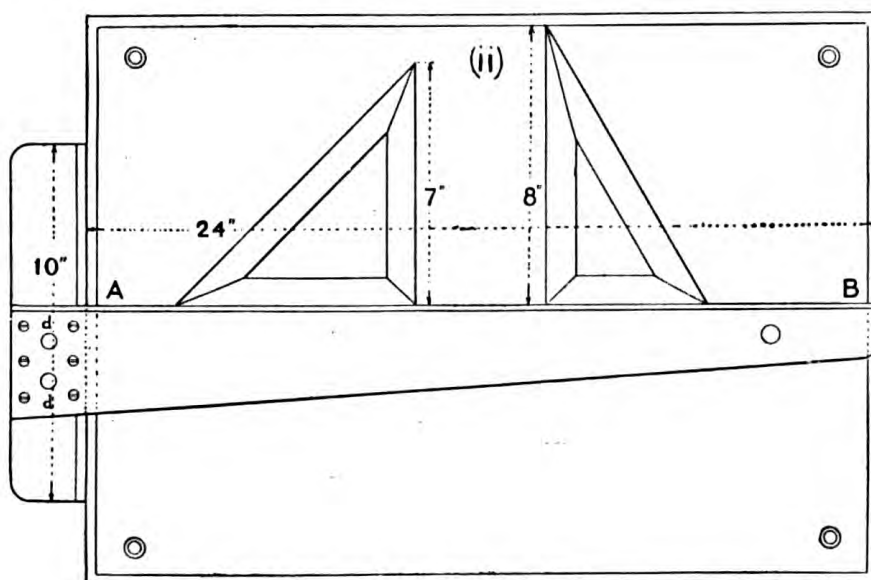


FIG. 8.—Drawing Board and Set Squares.

paper is next damped with a sponge or cloth and the turned down portion is coated with thin glue, or gum; next, the glued edges are pressed carefully to the board, and when dry the paper presents a smooth surface.

Set squares. Two set squares, one 60° , the other 45° , of about the dimensions given in Fig. 8, are required. They may be obtained either of the form shown in Fig. 9 or (ii) (Fig. 8). The latter forms are known as framed set squares. Both kinds are made of a variety of materials, such as pear wood, sycamore, vulcanite, celluloid, etc. The framed set squares are easier to handle, and when made of pear wood or sycamore they are not so liable to alter their shape as those illustrated in Fig. 9.

Drawing pins. The exercise work and for work fastened to the drawing board, drawing pins, one at each corner, by this method the paper is held in the heads of the drawing pins, free motion of the T-square. To avoid the latter objection, the paper is secured by the use of a wax. The paper on which the drawing is to be made, or on which the drawing is to be made, is to be made. This is done by turning down a portion of the paper wide all round the paper.



French curves. What are called French curves are usually made use of to draw the curves the compasses are not applicable. Such curves are made of various materials, sizes, and

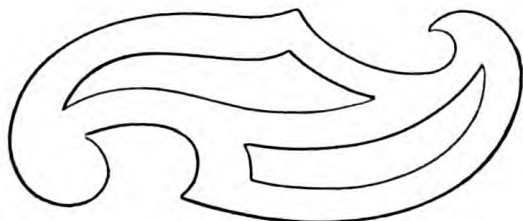


FIG. 10.—French Curve.

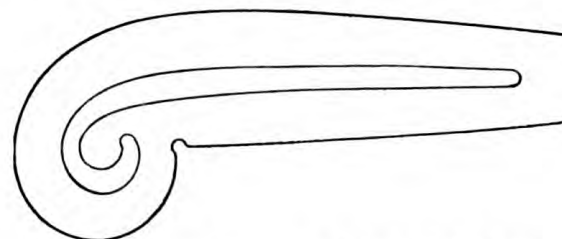


FIG. 11.—Scale-graded Curve.

curves made of pear wood or celluloid are, however, very convenient for use, and are obtained of different forms. A useful form is shown in Fig. 10, but Harrison's scale-graded curves, shown in Fig. 11, are the best for all purposes.

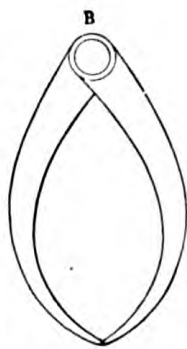


FIG. 12.—Inside and Outside Calipers.

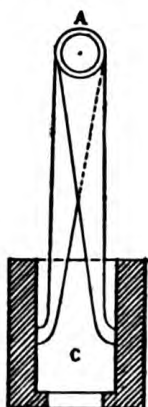


FIG. 13.

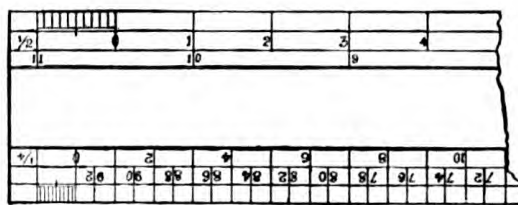


FIG. 14.



Calipers. To obtain the dimensions of round objects, etc., two pairs of calipers, called *inside* and *outside* calipers, are necessary. The former are shown at **A** (Fig. 12), and are used to measure the diameter or width of a cylindrical cavity has to be measured. The *outside calipers*, **B**, (Fig. 12), are used to measure a dimension such as the diameter of a sphere. When the dimensions have been obtained, the calipers may be applied to a rule or scale, and the magnitude of the dimensions

been obtained, the calipers may be applied to a rule or scale, and the magnitude of the dimensions

Scales. An ordinary two-foot rule or steel scale is used usually with the calipers.

what is called an open-divided scale is useful. Such a scale is generally 8 or 12 in. long and made of boxwood. The section of such a scale may be either of the forms shown in the illustrations. In either of these forms the scale may be applied directly to the drawing, thus avoiding the use of dividers or compasses. The use of dividers or compasses on such a scale rapidly obliterates the divisions.

An open-divided scale usually shows scales of $\frac{1}{12}$, $\frac{1}{3}$, $\frac{3}{4}$, $\frac{3}{16}$ inch on the one side, and $\frac{1}{2}$, and 1 inch on the other.

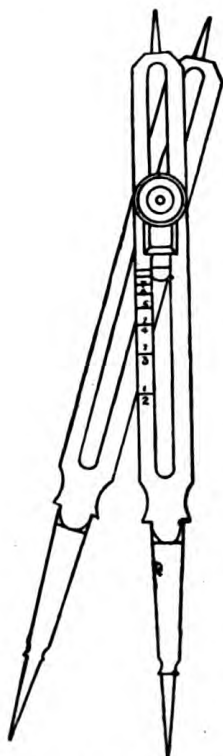


FIG. 15.—Proportional Compasses.

Printing. The title or description of a drawing may be either written or printed. If the former plan is employed, a clear bold handwriting should be used. If the latter results are obtained in printing when the letters are drawn freehand. In the majority of cases, *stencilling apparatus* is used. *Stencil plates* are made of copper or zinc, in which the various letters and figures are cut. Brushes are supplied with the apparatus. The setting of each letter is done by a brush. If a line is drawn on the stencil plate at the base of each letter, a clear print is obtained.

Enlarging or reducing drawings. It is sometimes necessary to enlarge or reduce a drawing. This process may be effected in several different ways. One method is to draw the surface of the paper on which the drawing is made into a large square and by means of another sheet, on which the squares are larger than those on the first sheet, the drawing is enlarged or reduced as required.

Another method is to employ an instrument called a *pantograph*. It consists of a series of jointed levers carrying a tracing point and a pencil or pen. When a convenient point, the tracing point is carried round the outline of the original figure, the tracing point is again reached. The pencil or pen in the meantime has drawn a reduced copy of the figure. The pantograph is of great use to draughtsmen, etc., but is not used much in machine drawing.

Proportional compasses. In dealing with the enlargement or reduction of drawings, proportional compasses may be used in preference to either of the two methods just described. The instrument consists of two limbs, having at each end rounded points as in a pair of dividers. The distance between the limbs is made by means of a pivot which can be placed at any position on the limbs.

USE OF INSTRUMENTS

The instrument is marked so that when the two points at one end are set to any distance between the points at the other will be $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, etc., of it.

Use of instruments. It is not only of the utmost importance to be able to make but also to work rapidly and easily so as to complete a drawing in a reasonable facility in handling drawing instruments must be acquired, and this is possible only by

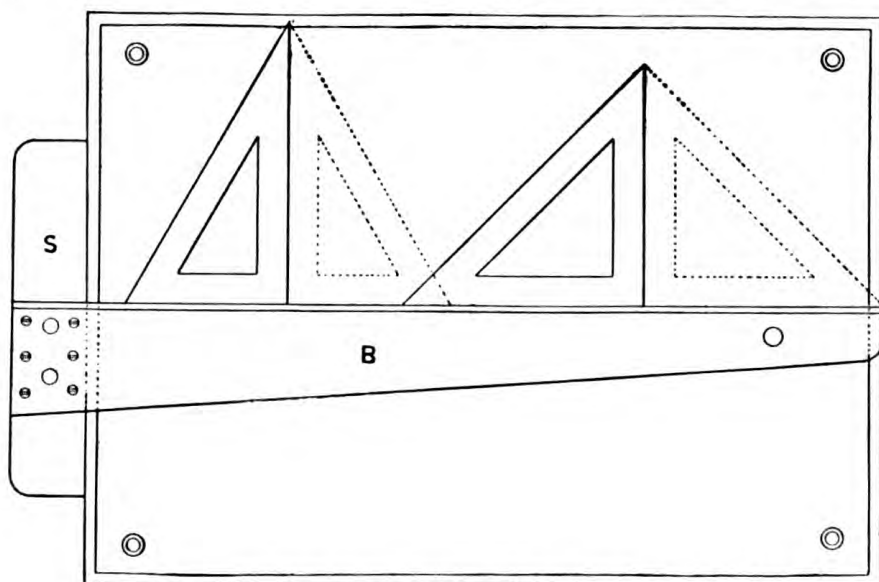


FIG. 16.—Tests of Right Angles of Set Squares.

To ensure that all instruments are maintained in an efficient condition, the following receive careful attention.

Use of T-square. The T-square should be placed on the board in the position shown. The stock, **S**, should be allowed only to slide along the left hand edge of the board and be used on the other edges. The left hand edge of the board and the stock, **S**, and blade should be tested by means of a straight edge, and if they are not straight they should be tested by means of a *trying-plane* before being used.

Use of set squares. Set squares should be tested by placing them in the position and drawing vertical lines. If, when the squares are reversed (as indicated by the dotted line), the edges of the set squares do not agree with the lines already drawn, the edges should be drawn in the two positions coincide.

The angle of 45° may be tested by drawing an angle of 45° , and obtaining the angle of the set square and the line already drawn when the set square is reversed.

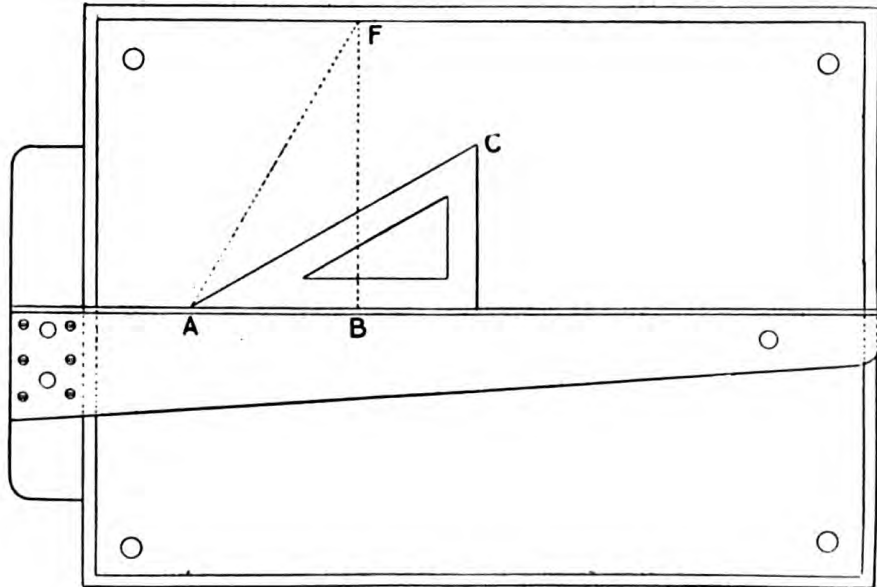


FIG. 17.—Test of the Angles of a Set Square.

The 60° and 30° angles of the remaining set square may be tested by drawing a line perpendicular to the horizontal line AB, and reversing the set square to obtain an angle equal to 60° with the set square, and reversing the set square to obtain an angle equal to 30° . The T-square may be made to coincide with AC, and if the set square is inserted in the position of the dotted line, it should coincide with AF. If it does not, the necessary adjustment must be made.

A convenient method of drawing parallel and perpendicular lines is to slide one set square on another. Lines perpendicular to the parallel lines drawn in this manner are called perpendicular lines.

the set square (Fig. 18). These methods of drawing lines parallel and perpendicular of great use in practice.

Clinograph. One of the most useful instruments for drawing inclined lines and lines perpendicular to them is *Harrison's Clinograph* (Fig. 19). The edge **B** is made to slide along the edge of the

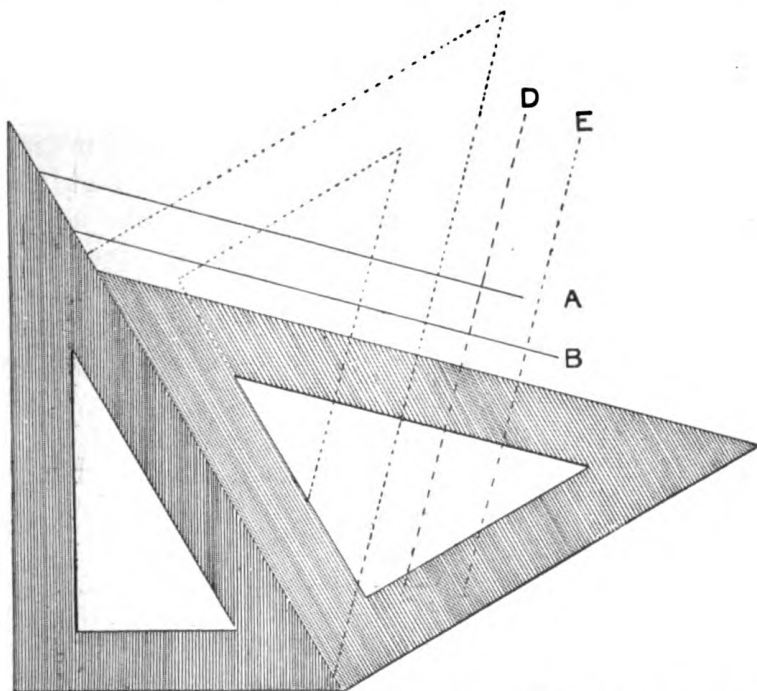


FIG. 18.—Parallel and Perpendicular Lines by Use of Set Squares.

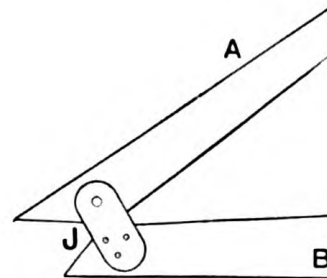


FIG. 19.—The Clinograph.

joint at **J** is sufficiently rigid to enable any number of parallel lines to be drawn. When the instrument is reversed, a line at the same inclination to the horizon, but sloping in the opposite direction, can be drawn.

Setting a drawing pen. A drawing pen of good material will be serviceable usually for a long time before it is necessary to reset it. In some cases, however, the pen, after comparatively

attention. When necessary, the two nibs of the pen should be brought into contact **S** (Fig. 20); then, holding the pen in a vertical position, the nibs are made of the

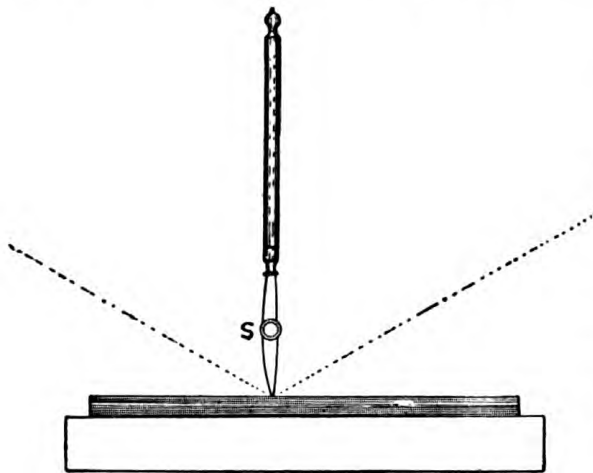


FIG. 20.—Setting a Drawing Pen.

the end of the pen on an oilstone. The nibs must not be flat but carefully rounded. This is done by moving the pen from side to side during the rubbing, as indicated by the dotted lines in Fig. 20. Afterwards each nib is worked up to a good point, rounded by slightly rocking the pen between the fingers while rubbing. The inclination at which the pen is held varies as the rubbing proceeds, and care must be taken to keep a sharp edge; to ensure this the edge should be rubbed at intervals. When finished, each nib should be looked at end-on, and should, when looked at end-on, show a sharp point. After carefully wiping the nibs to get rid of the oil, the pen should be tried by using it to draw a line. If the pen is too sharp it may be put right by rubbing it on cartridge paper.

The compass pen is adjusted in a similar manner. The inside surfaces of the nibs must not be sharpened. If a slight burr is found it may be removed by using a small piece of smooth emery paper, or better by a fine file.

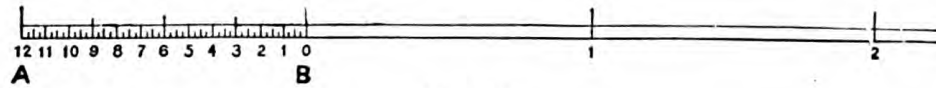


FIG. 21.



Drawing to scale. The student who has used cycling or other maps is already familiar with the fact that the distance between two places on a map gives no information as to the actual distance.

places themselves unless the scale to which the map is drawn is specified. Thus, the distance between two places may be known to be 30 miles; if on the map this distance is represented by a line one inch long, the distance between two other towns one inch apart on the same map would be 10 miles. The map would be said to be drawn to a *scale of 10 miles to an inch*. In a similar manner, if a distance of 4 inches represents 1 foot, the scale would be $4'' = 1'$ or $\frac{1}{4}$ full size. Although a scale can be obtained cheaply it is often necessary to be able to make one. Such a scale should be made as large as possible and be made either on thick cartridge paper or on thin cardboard. Scales should be made without creases for future use.

Example. Make a scale of $4'' = 1'$ or $\frac{1}{4}$ full size.

Draw two lines about an eighth or three sixteenths of an inch apart. Measure a line $AB = 4''$ (Fig. 21); this length represents 1 ft. or 12 in. and may be divided into 12 equal parts, and these may be subdivided further into half or quarter inches. Finally, as many feet as may be necessary are marked off from left to right, and the scale is complete.

Dimensions. The dimensions of an object are usually indicated by dotted lines. The dimension heads at the end of the lines should be put in neatly and should join close up to the lines. The dimensions are taken. In Fig. 22 the length of the rectangle is 1 foot 2 inches, and this is expressed by $1' 2''$; the width is $6\frac{1}{2}''$ inches and is denoted by $6\frac{1}{2}''$.

Angular measurements. Abbreviations are used also to denote angular measurements. Thus, an angle of thirty degrees, twenty minutes, ten seconds, is written $30^\circ 20' 10''$. To understand clearly what such a measurement implies, the beginner may consider the motion of a pointer, such as a movable radius of a circle, or the minute hand of a clock, capable of moving about an axis or centre **A** (Fig. 23). If such a line, as **AC**, moves in the opposite direction to the hands of a clock, then the amount of rotation of the line may be expressed by the angle **DAC**. This angle may be indicated either by the number of degrees or radians in it.

Measurement in degrees. Assuming the circumference of a circle to be divided into 360 equal parts, then any two consecutive points joined to the centre will enclose an angle. A line **AC₂** (Fig. 23) perpendicular to **AC** will be one-fourth part of 360° or 90° .

If a point C_3 be taken, such that the arc CC_3 is $\frac{1}{6}$ th a semicircle, then the arc AC_3 is $\frac{1}{3}$ th a semicircle. If C_1 is the middle point of the arc CC_2 , then C_1 joined to A , will denote an angle of 30° .

Radian measure. The radian measure of an angle denotes the ratio $\frac{\text{arc}}{\text{radius}}$. It is obtained by taking an arc CD (Fig. 23) equal to the radius AC ; by joining D to A , the angle CAD equal to one radian $= 57^\circ.3$ approximately—is obtained.

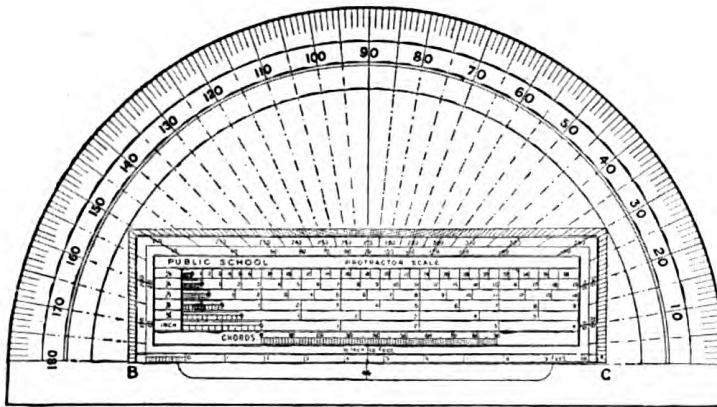


FIG. 24.—Protractors.

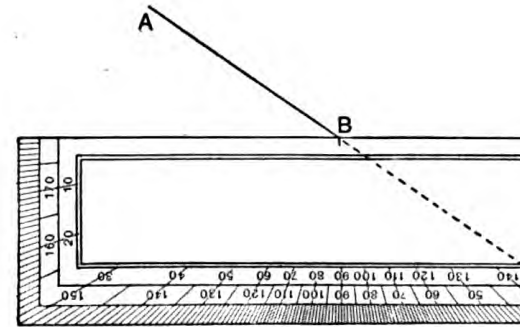


FIG. 25.—Use of P

Protractor. The angles 30° , 45° , 60° , and 90° , may be set out by means of a protractor. Submultiples of these may be obtained by bisection and by the process of addition. But any angle (including those referred to) can be set out at once by means of a protractor. The instrument is usually made either in the form of a circle, a semicircle, or rectangle, as shown in Fig. 24.

Use of protractor. At the point B in the line, AC , to make an angle of 30° . Mark on the protractor immediately below the division marked 90° coincident

the division corresponding to 35° on the line **AC**. Using the edge of the protractor the line **BD**. Then **DBC** is an angle of 35° required.

Conversely, to measure the magnitude of a given angle: put the mark on the protractor at the vertex of the angle and the edge of the protractor coincident with one of the lines forming the angle; then the magnitude of the angle can be read off at the point where the remaining line crosses the divided edge of the protractor.

Table of chords. Ordinary protractors are rarely trustworthy, and it frequently happens that expensive instruments are more or less inaccurate. Probably the most accurate method of setting out a required angle is by means of a *table of chords*.

Example. To set out an angle of 43° .

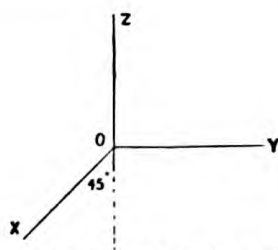
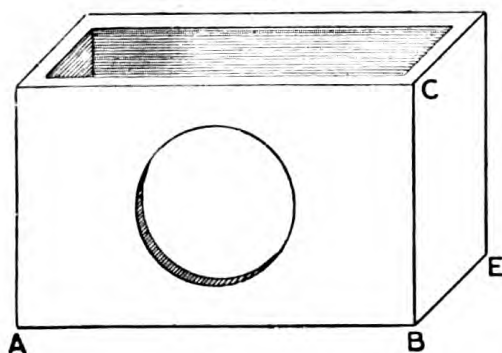


FIG. 27.—Metric Projection.

On any convenient scale make **PM** equal to the chord of 43° . With **P** as centre and **PM** as radius, describe an arc. In Table IV. (p. 243), we find corresponding to 43° a chord of 7.33, and multiplying this by 10 we obtain 73.3. With **P** as centre and radius 73.3, describe an arc intersecting the first arc at **N**. Join **N** to **P**, then **MPN** is an angle of 43° .

Projection. As an easy example of projection we will show the representation of a simple box such as that shown in Fig. 27. The dimensions are as follows: Length, 2 ft. 6 in.; depth, 1 ft. 6 in.; thickness, 2 in. A hole 12 in. in diameter is cut in one of the longer sides. These dimensions, as indicated, are 2' 6", 1' 3", 1' 6", respectively.

As the representation of such an object may be made in different ways it may be desirable to ascertain briefly the advantages and disadvantages of these methods of representation.

A *photograph* of the box would show the real object as it appears.

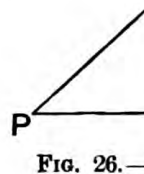


FIG. 26.—

direction of **Oy** or **Oz** to true size and the dimensions in the direction **Ox** to half size. **AB** and **BC** are made 2' 6" and 1' 6" respectively, but **BE** is made $\frac{1}{2} \times 1' 3''$ or 7 $\frac{1}{2}$ ". Fig. 28 shows a small crosshead drawn half size in metric projection.

Orthographic projection. The usual method adopted by engineers and others to represent objects such as occur in machines and machine details, is called *orthographic projection*. Unless the object is of the simplest form, two or more views properly projected from each other are required. Various names are given to these views, such as *elevation*, *plan*, *section*, *sectional plan*, *end view*, and *sectional elevation*. Using as a model an empty rectangular box (such as a cigar box without a lid), it will be an easy matter to verify the projections shown in Fig. 29. These projections should be drawn carefully to scale as follows:

Commence by drawing an indefinite line and marking off to scale the two points **a** and **b** (Fig. 29) equal to 2' 6". Draw vertical lines at **a** and **b**, making **bc** equal to 1' 6", and draw **cd** parallel to **ab**. Obtain **O**, the centre of the face **abcd**. With **O** as centre and radius 6", describe a circle. Then the elevation of the box is completed by drawing dotted lines parallel to **ab**, **bc**, and **ad**, and at a distance of 2" from them. These lines represent the thickness of the box. By the set square project the edges **bc** and **ad**. Draw a line **ef** and make **eh** = 1' 3"; also draw **hg** parallel to **ef**. Mark off from **ef** and **eh** equal distances of 2", and draw the lines **ef** and **eh**. The two rectangles shown represent the plan of the box.

The end view is projected from the elevation and the width obtained from the plan.

Sections and sectioning. In the drawings of machines and machine details, the elevation and end view, are not always sufficient to show clearly the whole arrangement, particularly the internal parts. *Dotted lines* may be used for the purpose, but these are in many cases difficult to interpret. It is therefore assumed, consequently, to be cut by *section planes* in such a manner that the

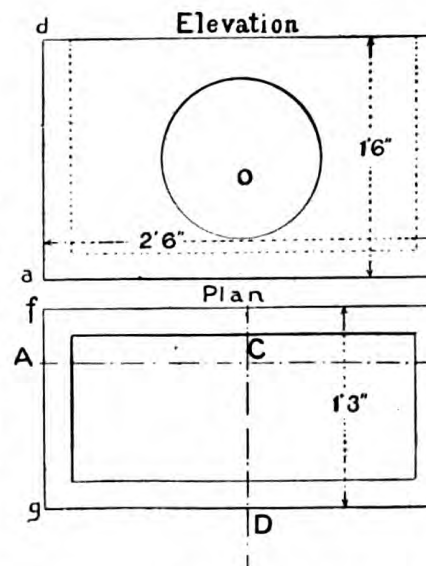


FIG. 29.—Orthographic

various parts can be clearly seen. If sections of the box along lines such as A then views corresponding to *sectional elevations* are obtained, as in Fig. 29. The lines of section are indicated by one of the following methods. The first plan is to cut at about 45°, either freehand or more accurately with the 45° set square. Such sections may be put in much more rapidly with a brush, using a suitable colour for the purpose.

A flat wash of colour applied to those parts which are in section may also be used.

In each of the colour methods there is the distinct advantage that the materials made can be seen at once from the drawing.

The colours used by engineers and indicated in the following table may be in the form of *dry* or *moist* colours. Dry colours are obtainable in *cakes* or *half-cakes* and with a small quantity of water in a suitable dish or saucer. Moist colours are obtained in *pans* or in *soft metal tubes* and only require the addition of water to render them suitable. The conventional colours used by engineers for machine drawings are given in the following table.

MATERIAL.	COLOUR.
Cast iron,	Payne's grey or neutral tint.
Wrought iron,	Prussian blue.
Steel,	Purple (may be obtained by mixing prussian blue and crimson).
Brass,	Gamboge or Indian Lake.
Brickwork,	Crimson Lake.
Wood,	Burnt Sienna.
Stone,	Bistre.
Earth,	Sepia.

Conventional arrangements. Bolts, nuts, screws, rivets, and pins, which occur in machine drawings, are not usually shown in section except when they are cut by a section plane in a direction parallel to their length, *i.e.* in a transverse direction.

Sectioning. When it is inconvenient or impossible to denote the materials used in machine detail by suitable colours, the materials may be indicated by suitable alternate hatching.

adopted. A list of the materials in common use, together with the form of sectioning to designate them, is given in Fig. 30. In the majority of cases, however, the nature may be easily inferred from the drawing, or, if not, a description may be written on it.

Saucers and brushes. The difficulty with regard to sectioning is removed by the use of saucers to designate the various materials. A list of colours is given on p. 16. Porcelain dishes in the form of a "nest" consisting of four or more dishes fitting one above the other (Fig. 31) are used to hold the colours.

The brushes may be either of camel hair or sable. Sable, although more expensive, is preferred to camel hair. When filled with colour the brush should terminate in a fine point.

Inking in. A good black ink is obtained by rubbing a stick of Chinese or Indian ink on a piece of white paper. The colour may be tested from time to time as the rubbing proceeds by dipping a brush in the ink and smearing it on a piece of white paper. There are many kinds of *fluid* (Chinese and

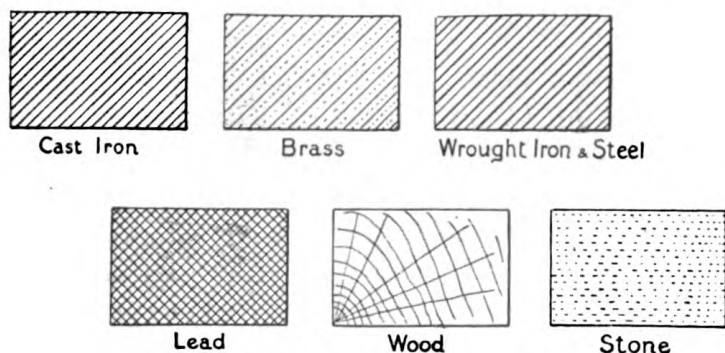


FIG. 30.—Conventional Sectioning.



FIG. 31.

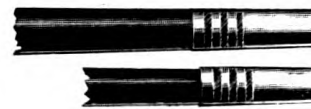


FIG. 32.

obtained, but in many cases the lines made by these are, when dry, of a dark brown color. But by the process of rubbing a deep black ink may be obtained, the lines made dry, of a glossy appearance.

As a rule it will be found to be easier to draw straight lines touching curves than the converse operation; hence, when inking in, it is advisable to commence by inserting all

of circles in the drawing. When this has been done the horizontal lines may be drawn with the T-square, and the remaining lines by means of the set squares. The drawing is complete, with the possible exception of perhaps a little cleaning by means of a soft piece of india-rubber.

Sections of bars. In the drawings of machines and machine details it often becomes necessary to show a portion of the length of a bar, and thus "breaks" occur. The

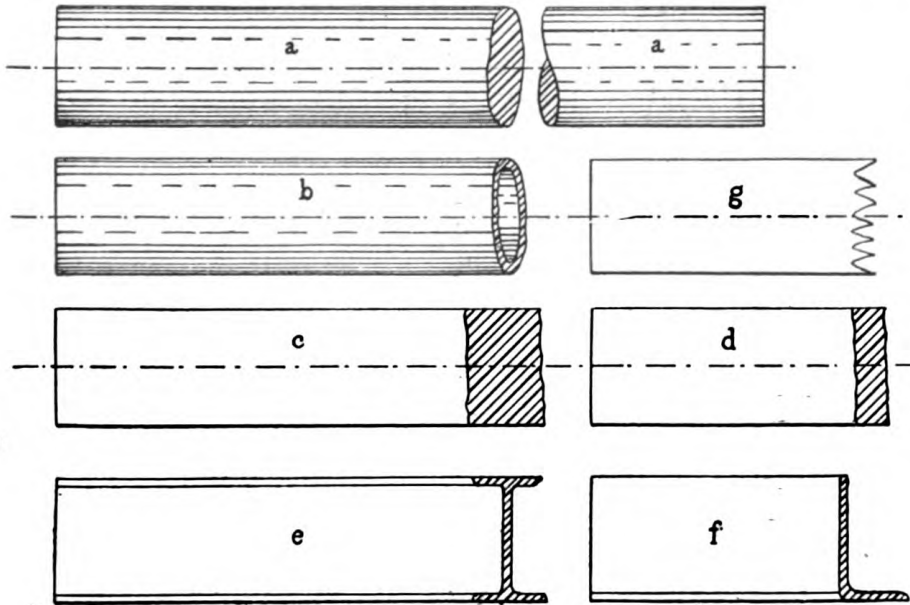


FIG. 33.—Sections of Bars.

form of *prints*. Such prints are either what are called *blue-prints*, i.e. white lines on a black and white, i.e. black or dark brown on a white ground.

The printing frame necessary to obtain such prints simply consists of a frame in which the paper is placed close to a transparent sheet of glass. Behind the tracing is placed a sheet of paper, and in front of this a strip of felt or cloth to prevent light from entering except at the front. After the paper is taken out and washed in water, and when dry is fit for use.

with little trouble as a glance the form of the stock by iron merchant. Thus, at (a), the section at (b), a hollow round at (d), a rectangular section; at (f), an angle useful conventional break in a piece of tin.

Standard forms. The cross-sections of the forms in stock by iron merchant.

Working drawing usually need not be in common method is to drawing in *pencil*, and *tracing* in ink. The to obtain as many copies

that occur may be indicated by diagonal section lines. The same process may also be a and white." Or, the outline only need be shown, the colours indicating any sections be

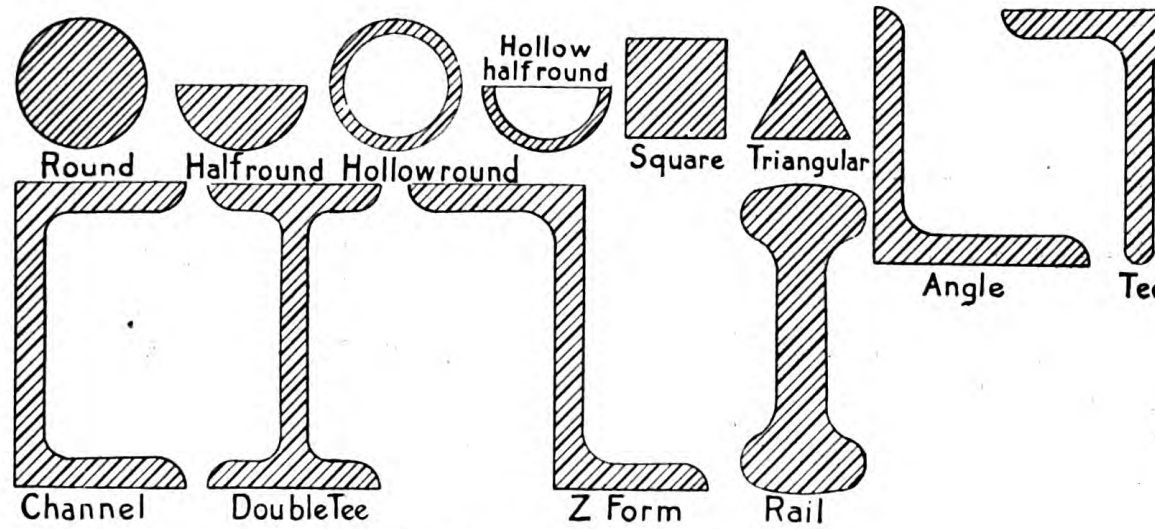


FIG. 34.—Cross-sections of Standard Forms of Bars.

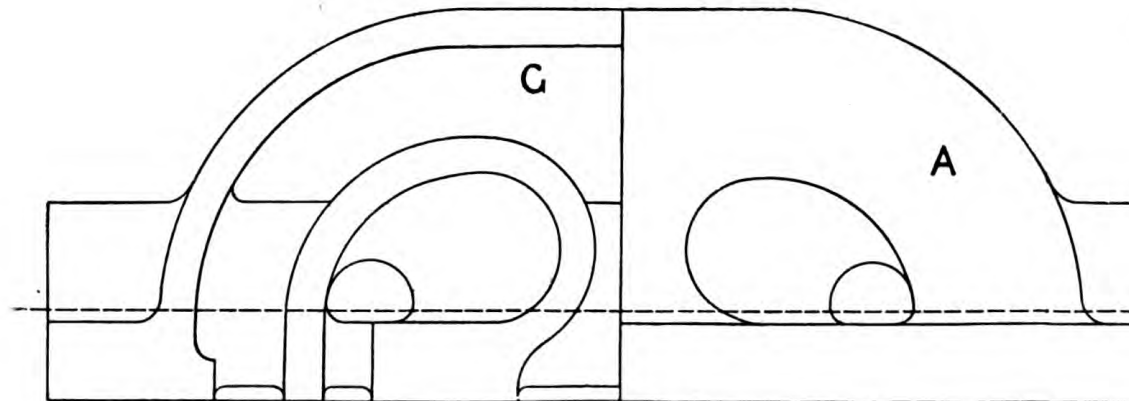


FIG. 35.

Tracings. In making a tracing, what is called *tracing paper* or *tracing cloth* is placed over the drawing and fastened to the drawing board by means of lines show clearly through the transparent paper, a copy can be made in ink. C the lines are not too thin, and also that they are throughout uniform in thickness in the following chapters may be used for this purpose.

Example. Make a tracing of the diagram shown in Fig. 35.

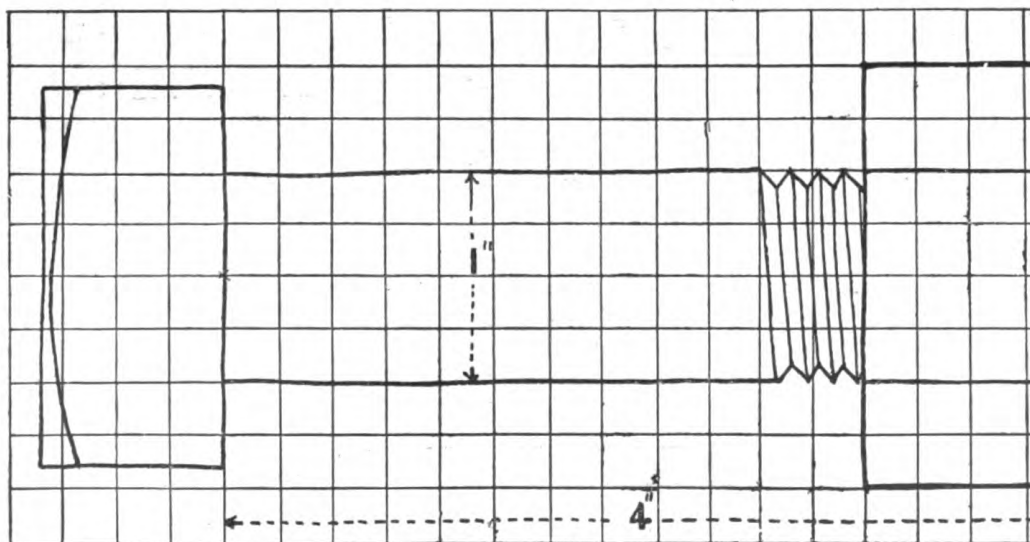


FIG. 36.

Hand sketching. It is of the utmost importance to a student to be able to machine details. The various parts should be inserted in fairly good proportions. Important dimensions should be indicated. For the purpose of such sketches, squares is very suitable; the lines forming the squares are usually of a faint color so as not to interfere with the lines of the sketch. Sketches may be made readily to full size. Figs. 36 and 37 show two sketches; the former is full size and the latter is $\frac{1}{4}$ -size.

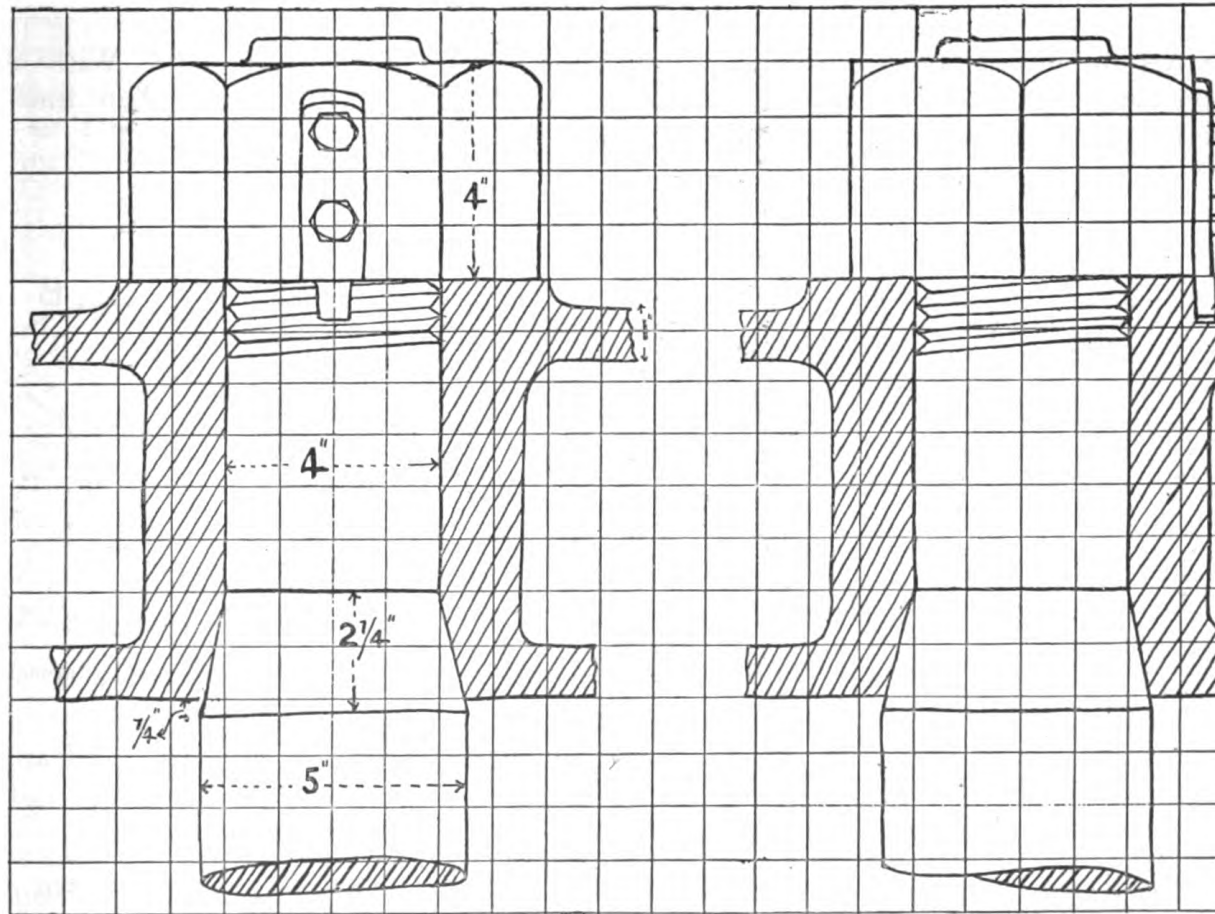


FIG. 37.

Simple geometrical constructions. The following simple but important geometrical constructions should be noted carefully :

To bisect a line AB by a line perpendicular to it. Let AB be the given line, with A and B as centres, and any convenient radius, describe arcs intersecting at C and D (Fig. 38). The line CD, the line of intersection, is perpendicular to and bisects AB.

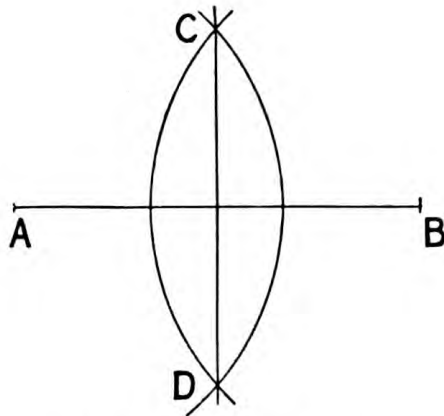


FIG. 38.—Bisection of a line.

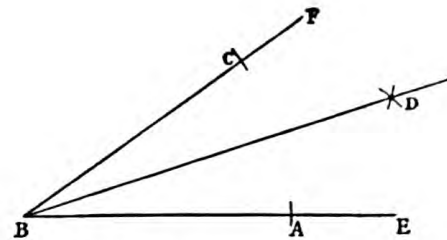


FIG. 39.—To bisect an angle.



FIG. 40.—To find the center of a circle.

To bisect a given angle. Let EBF (Fig. 39) be the given angle. With B as centre and any convenient length, mark off equal distances BA and BC. With centres A and C, and any convenient radius, describe arcs intersecting in a point D. Join D to B. Then DB is the required bisector.

To describe a circle passing through three given points. Let A, B, and C be the three given points. With A and B, and B and C, as centres, describe intersecting arcs (Fig. 40). Join the intersection points and produce the lines to intersect at a point O. Then O is the centre required.

To find the centre of a circle or circular arc. This exercise is only a repetition of the preceding case. Take three points in the circle or circular arc, and, as in the preceding case,

Join the points of intersection, and produce until they intersect at a point. This point is the centre required.

To describe a circle of given radius touching a given straight line and a given circle. Let AB be the given line and C the given circle (Fig. 41). As a simple example we may assume the given circle to be 1". It is obvious that as the circle has to touch the line AB , its centre will be some point on a line EF parallel to AB and 1" from it. Similarly, the centre will

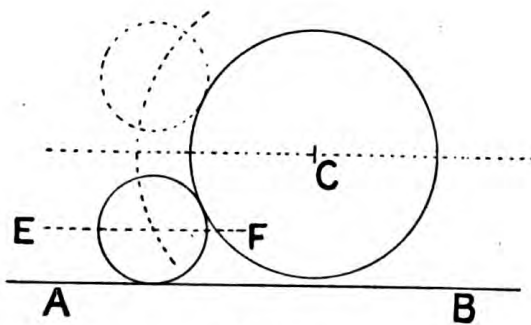


FIG. 41.

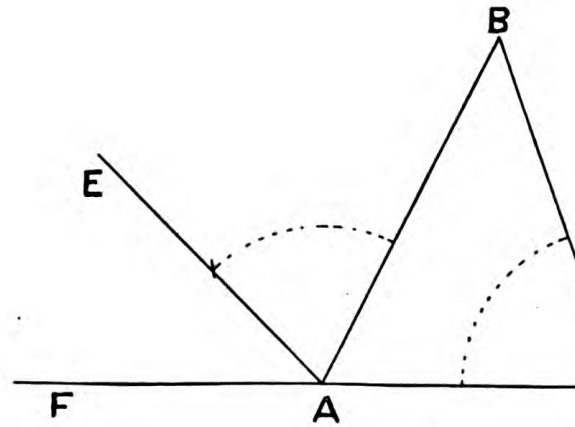


FIG. 42.

circle of centre C and at a distance of 1" from the circumference. The intersection of the line EF is the centre required.

The three angles of a triangle are together equal to two right angles. This important geometric theorem may be verified by several methods. An experimental verification is as follows:

Draw any triangle, ABC (Fig. 42). Denote the three angles by A , B , and C . To the angle A , then an angle such as CAE is obtained; finally, add the angle B . The angle CAF , i.e. the line CA produced.

Regular polygon. When the sides or edges of a polygon are equal in length, and

equal, the figure is called a *regular polygon*. The following table gives the number of sides of the most important regular polygons. The table should be committed to memory:

3 sides,	-	equilateral triangle.	7 sides,
4 „	-	square.	8 „
5 „	-	pentagon.	9 „
6 „	-	hexagon.	10 „

To construct a regular polygon, given the length of one of its sides.

Equilateral triangle. Let **AB** denote the length of the given side (Fig. 43). The equilateral triangle may be obtained by using the 60° set square. Or, with **A** as centre, and radius **AB**, describe an arc; with **B** as centre and the same radius, describe another arc intersecting the former in **C**; join **C** to **A** and **B**; then **BAC** is the required equilateral triangle.

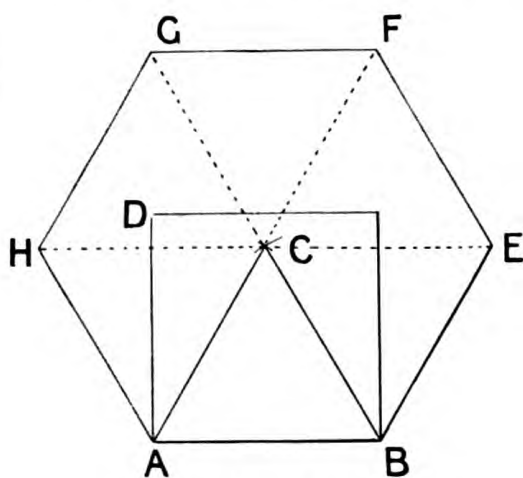


FIG. 43.

Square. A square may be constructed by using the 45° set square and a line equal to **AB**, and drawing lines parallel to **AB** and **AC**.

Hexagon. Draw the line **AH** with the 60° set square, making **AH = AB**; reverse the set square and draw **BE** making **BE = AB**. This procedure forms one half of the hexagon; the other half is completed by using the 60° set square and the line **AB**.

Octagon. An octagon may be constructed by using the 45° set square and a line equal to **AB**, and drawing lines parallel to **AB** and **AC**.

If all the angular points, **ABE...**, of a regular polygon are equidistant from the centre **C** (Fig. 43), the number of triangles formed at the centre is equal to the number of sides in the figure. For example, in a square the angles formed at the centre is 4 right angles.

to obtain the magnitude of the angle in a regular polygon we may use the following rule: *the number of sides in the figure, subtract four, multiply the remainder by 90° , divide the product by the number of sides in the figure.*

SIMPLE GEOMETRICAL CONSTRUCTIONS

Example. Find the angle between any two sides in a regular (α) hexagon,

(a) Here double the number of sides is 12.

Also
$$\frac{(12-4)90}{6} = 120^\circ.$$

(b)
$$\frac{(10-4)90}{5} = 108^\circ.$$

Another method which depends only on construction is as follows:

With **A** as centre and radius **AB** describe a semicircle; divide the semicircle into equal parts as the number of sides in the figure, and number these 1, 2, 3, ...; join **A** to 2; then **BA** and **AE** are two sides of the required figure (Fig. 44).

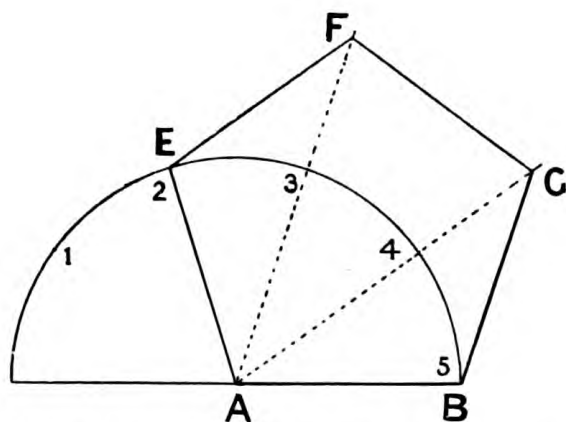


FIG. 44.—Construction of a Regular Pentagon.

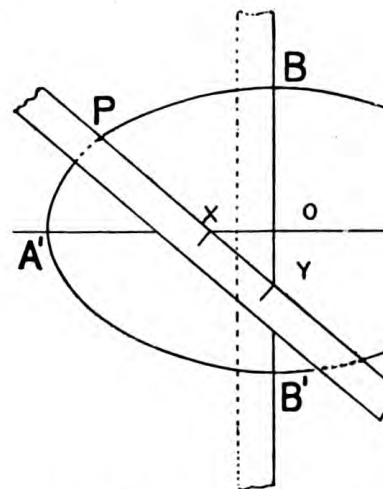


FIG. 45.—Construction of an angle.

Example. Construct a regular pentagon, length of side $1\frac{1}{2}$ ".

Make **AB** (Fig. 44) equal to $1\frac{1}{2}$ " and with **A** as centre and **AB** as radius describe a semicircle; divide the semicircle into five equal parts. Join **A** to 2; then **EA**, **AB**, are two sides of the required figure.

pentagon. Join **A** to 3 and to 4 and produce the lines; the polygon is complete and equal to **AB**.

Ellipse. If **O** is the centre of an ellipse (Fig. 45), the lines **AA'**, **BB'** at right angles and passing through **O** are the *axes of the ellipse*. The longer axis **AA'** is called the *major axis*, the shorter **BB'** the *minor axis*.

To obtain points on the curve we may use a straight strip of paper in the following manner. On the strip mark off lengths **YP** equal to **OA'**, and **XP** equal to **OB**. If the points **X**

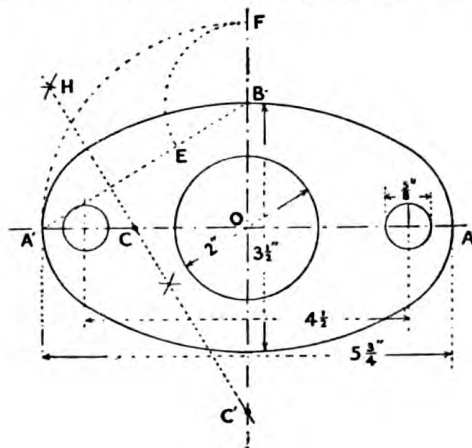


FIG. 46.

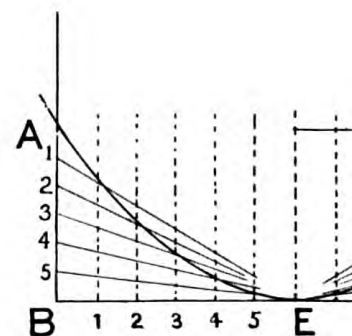


FIG. 47.—Construction of an ellipse.

along the lines **AA'** and **BB'**, and the successive positions of **P** are marked, a series of points are obtained. The curve may be put in neatly by freehand; or, if necessary, the paper may be pasted to a piece of celluloid, thin wood, or zinc, and a template may be made by cutting out the shape as possible, finishing the edge by a smooth file or a piece of glass paper. In making the template, one quarter or one half the curve is necessary.

An ellipse, or some approximation to it, is usually the form adopted for small glands, flanges, of pipes and other cases where two bolts are used. An approximation is as follows. Let **OF = OA'**, and **BE = BF** (Fig. 46). The line **HC'**, bisecting **A'E** at right angles, determines the point **C'**; **C** being the centre for the circular arc forming one end of the ellipse, while **C'** is the centre for the other part of the curve.

Parabola. A simple method of drawing a portion of a parabola—a modification of the method of drawing an ellipse—is to obtain a series of points on the curve by using either a rectangle or a triangle.

Thus, to inscribe a parabola in the rectangle **ABCD** (Fig. 47) we may proceed as follows: divide the base **BC** at **E**; divide **BE** and **BA** each into the same number of equal parts; 1, 2, ... 5 draw lines parallel to **BA**; join the points 1, 2, 3, 4, 5, on **AB**, to **E**; the points of intersection of these lines with the lines already drawn give a series of points on the curve required.

The portion of the curve to the right of the point **E** is obtained in a similar manner. The curve may be drawn either freehand or by means of a French curve.

EXERCISES I

1. Draw scales of (a) $\frac{3}{4}$ " to 1', and (b) $1\frac{1}{2}$ " to 1', each to be long enough to measure to tenths of an inch, and (b) to eighths of an inch.

2. Set out an angle of $43^\circ 20'$. Bisect the angle and draw two circles touching the sides of the angle. The diameter of the smaller circle is to be 1".

3. The base of a triangle is 3.58" long, and the angles adjacent to it are 45° and 60° . Draw the triangle and measure the two sides and remaining angle. State the magnitude of the angles in radians. Draw a circle passing through the angular points of the triangle.

4. Construct a regular heptagon of side 2".

5. Draw an ellipse with axes 4" and 2" respectively.

6. Inscribe a parabola in a rectangle of sides 3" and 1" respectively.

7. Draw a line 7" long and divide it into nine equal parts. Construct a triangle with sides 3, 4, and 5 of these parts. Measure the angles of the triangle and find their sum. Draw a circle passing through the three sides of the triangle.

8. Sketch, full size, the following cross-sections: (i) angle iron $2'' \times 3'' \times \frac{3}{8}''$, (ii) channel iron $3'' \times 3'' \times \frac{3}{8}''$, (iii) tee iron $3'' \times 3'' \times \frac{3}{8}''$, (iv) double tee or rolled steel joist, flanges $5'' \times 0.6''$, web $0.6''$.

CHAPTER II.

RIVETS AND RIVETED JOINTS.

Joints. The joint between two plates or between the parts of a machine may be made by a similar process, by rivets, or by bolts. The process of *riveting* furnishes a rigid fastening cheaper and simpler than that obtained by using bolts. Riveting is commonly used in boilers, in cylinders, in cisterns, etc., may be made in a riveted joint when once made can only be disconnected by the removal of the rivets, thus destroying the fastening. Those joints which are disconnected at intervals for renewals or repairs are known as *removable joints*.

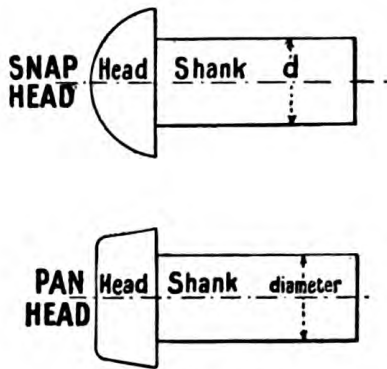


FIG. 48.—Rivets.

Rivets. A rivet is a round bar of iron, steel, or other metal, being enlarged to form what is called the *head* of the rivet. The smaller portion is called the *shank*, or *diameter*, of the rivet. The point of the rivet to the head is called the *point* of the rivet.

Riveting. The two general methods of riveting are *machine riveting* and *hand riveting*. In *hand riveting* the point of the rivet is heated in a clear charcoal fire or oil furnace; the rivet is then placed in the joint.

The rivet is then placed in the joint, with a sufficient length of metal projecting to form the remaining head. The rivet is held in place by means of a heavy weight, whilst the second head is formed. The second head may be made conical. The rivets are more easily worked in a red hot state. The contraction due to cooling tends, moreover, to draw the plates closer together, and makes the joint stronger than would otherwise be the case.

In machine riveting the head of the rivet is held firmly in one jaw of a hydraulic press, whilst the other forms the remaining head. In this process great pressure is available.

usually about 80 tons on each rivet of 1 in. diameter, and about 60 tons on each in boilers, all rivets, wherever possible, are closed in this manner by hydraulic machinery, hand riveting only being allowed where it is impossible to apply machinery.

Lap joint. In the *lap joint* the two plates overlap each other and are secured by one or more rows of rivets.

Butt joint. The name *butt joint* is given to the joint in which the two plates meet or butt against each other, and the joint is made by using one or two cover plates or *butt straps*.

Pitch. The pitch of the rivets is the distance from the centre of one rivet to the centre of the next. This distance will be denoted in this book by the letter *p*.

In a single riveted lap joint there is one row or line of rivets, and two rows in a double riveted joint (Fig. 49).

Margin. The term *margin* is applied to the distance from the edge of the rivet hole to the edge of the plate. The minimum distance is the diameter of the rivet. The margin is usually a little greater than this, and the distance from the centre of the rivet to the edge of the plate is consequently a little greater than one and a half times the diameter of the rivet.

Forms of rivet heads. Some forms of rivet

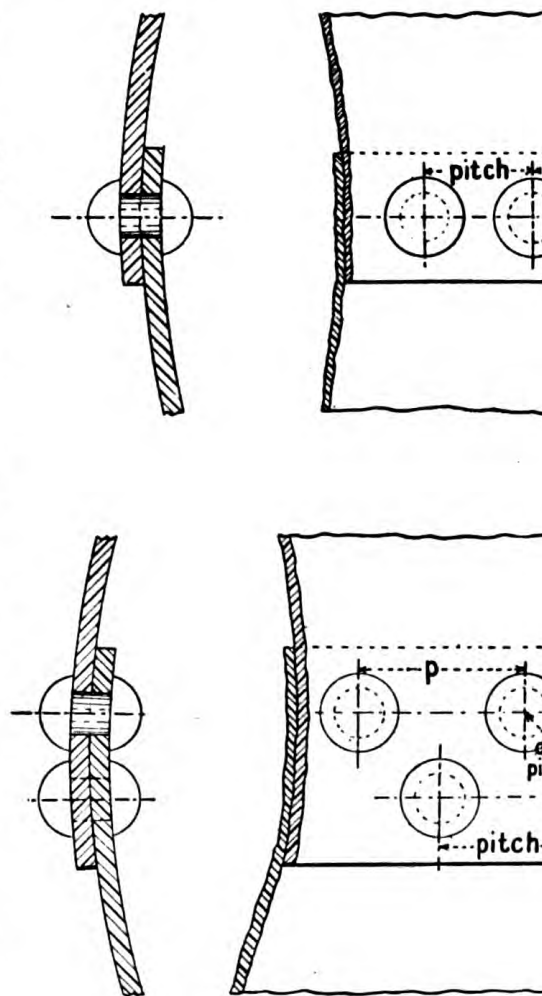


FIG. 49.—Single and Double Riveted Lap Joints.

heads are shown in Fig. 50, and are known as (I) a *snap head*; (II) a *conical countersunk head*.

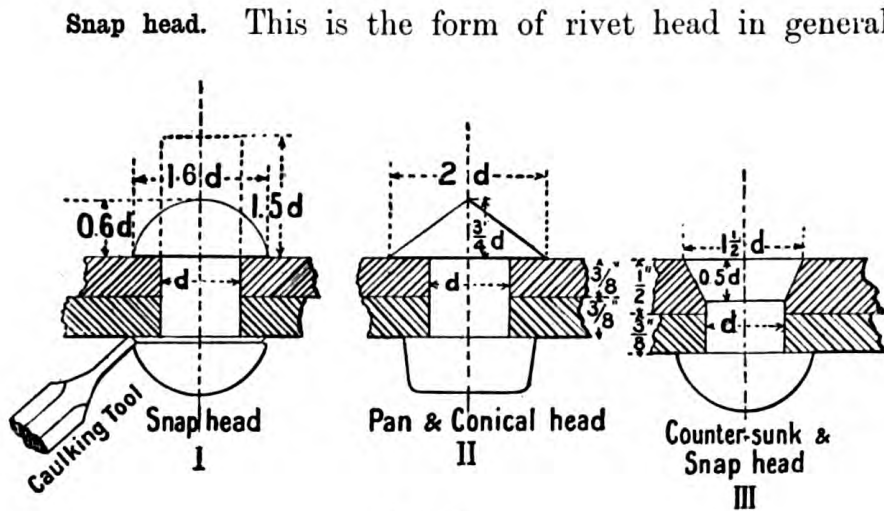


FIG. 50.

only used when the surface of the plate must be free from projections. The indicated at III, Fig. 50.

Drawing a rivet head. From the proportions of the rivet head (Fig. 50) in any given case to calculate its dimensions. It is, however, much better to obtain a graphic method as follows: At one extremity of the diameter **AB**, draw a line **AF** (Fig. 51). With **B** as centre, draw an arc of a circle touching the line **AF** at centre line at **D**.

Mark off **CD = BE**, then the head is drawn by using the centre **C** and radius **BE**.

Diameter of rivet. A rough rule sometimes employed is to make the diameter twice the thickness of the plates when the plates are less than $\frac{1}{2}$ inch in thickness,

The proportions add to Fig. 50, the unit being rivet. Thus, the *spread* rivet head is $1.7d$ and to $0.7d$. The thickness greater in boiler than in

Conical head. A form sionally used in hand head shown at (II) (Fig. diameter, of the head is the rivet and the height diameter.

Countersunk head. The the plate through which trustworthy as either of projections. The

RIVETS AND RIVETED JOINTS

half times the thickness of the plate when the thickness of the plate is $\frac{1}{2}$ inch and under. The empirical rule is given by the equation

$$d = 1.2\sqrt{t},$$

where d is the diameter of the rivet, and t the thickness of the plate.

Example. Find the diameter of the rivets suitable for plates $\frac{9}{16}$ " thick.

$$d = 1.2\sqrt{\frac{9}{16}} = 0.9".$$

The rough rule mentioned above would give

$$\frac{3}{2} \times \frac{9}{16} = 0.84375".$$

As values of t are usually fractional, frequently a little manipulation will simplify the calculation. Thus, if $t = \frac{9}{16}$, the value of d can be found by extracting the square root of $\frac{9}{16}$ and multiplying one by the other. Instead of performing this laborious operation, we may multiply numerator and denominator by 16, so that the numerator becomes 24, and it is only necessary to divide 24 by 8. The work is carried out readily in this and four-figure logarithms or by the slide rule.

Single riveted lap joint. This form of joint is shown in Fig. 52. The length of the joint will be simply the aggregate of all the pitches, which the joint may be assumed to be divided, it is only necessary to draw a strip equal in length to twice the pitch.

In working drawings, the rivet heads are shown usually in elevation (Fig. 52); but, in the case of the plan, instead of representing the heads of the rivets, it is usual to draw circles to the rivets and to section as shown.

In girder work, and in other cases where a comparison of rivets occur, one or two rivets only are shown, the center of the rivets being indicated simply by small crosses.

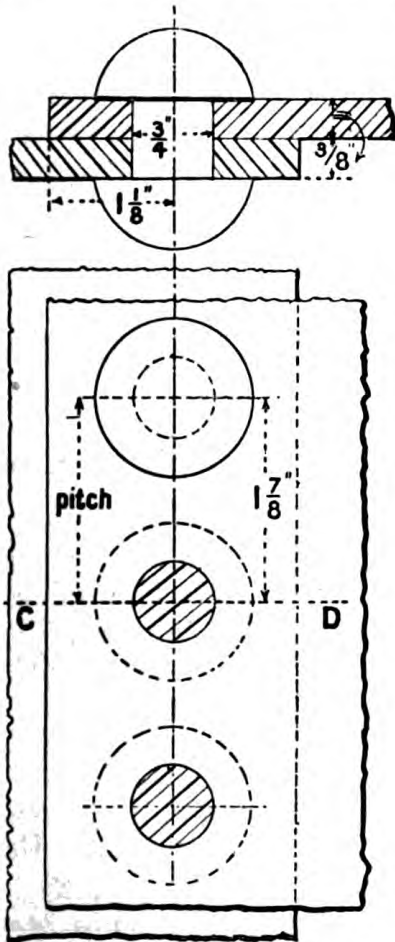


FIG. 52.—Single Riveted Lap Joint.

Caulking and fullering. The edges of the plates forming the joints of a boiler are treated by the processes of *caulking* and *fullering* to ensure that the two plates are in contact at the edges of the joint. Caulking is indicated at (I) (Fig. 50), and consists in burring down the edges of the plates close to the edge of the plate. Fullering is the better method, and is carried out by using a fullering tool, the thickness of which is equal to that of the plates to be joined.

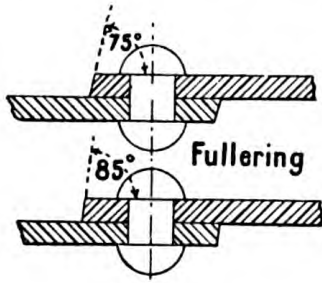


FIG. 53.

The edges of the plates are planed usually to an angle of about 85°, as in Fig. 53. In this manner the edges are brought into close contact in any slack places which might otherwise occur, ensuring a tight joint.

In the design of a riveted joint, when the thickness of the plates is small, the diameter of the rivet may be obtained from $d = 1.2 \sqrt{p}$, where p is the assumed value of f_s or f_t , the numerical value of the pitch of the rivets. A rough rule for a single riveted lap-joint is to add $1\frac{1}{8}$ " to the thickness of the plates, a fact which is expressed by the relation $p = d + 1\frac{1}{8}$ ".

Example. Draw the projections of a single riveted lap joint; thickness of plates, $\frac{3}{8}$ ". Scale full size.

Commence by drawing a horizontal line and two lines parallel to and $\frac{3}{8}$ " from the centre line and mark off on each side of it the radius of the rivet. Complete the plan of the rivet by drawing the heads of the rivet. Mark off, on each side of the plan, the margin, and complete the sectional elevation by drawing the rivet. The elevation can now be drawn. The elevation represents the joint (Fig. 52). The pitch is given by $p = \frac{3}{4}" + 1\frac{1}{8}" = 1\frac{7}{8}"$.

Double riveted lap joint. A double riveted lap joint will be best understood by drawing the steps necessary to draw full size a sectional elevation and plan of a double riveted lap joint with $\frac{3}{8}$ " plates and $\frac{3}{4}$ " rivets.

Commence by drawing a horizontal line and two lines at $\frac{3}{8}$ " from it. Draw the

making the distance from the centre of the rivet to the edge of the plate $1\frac{1}{2}d$, where d is the diameter of the rivet.

To obtain the plan, commence by drawing a circle **C** of $\frac{3}{4}$ " diameter. Measure off a distance equal to the pitch $p = d + 2\frac{1}{4}$ ", and draw the circle representing the second rivet. To obtain the centre line of the second row of rivets, the diagonal pitch p_1 is made equal to $\frac{2p + d}{3}$; or roughly, draw a vertical line parallel to the former and at a distance $2d$ from it. When the circles denoting the second row of rivets have been inserted, the elevation can be obtained by projection. As any section plane, such as that indicated by the line **AB** (Fig. 54), does not pass through these rivets, they are indicated in elevation by dotted lines.

The pitch p is obtained by substituting the values in

$$p = d + 2\frac{1}{4} = \frac{3}{4} + 2\frac{1}{4} = 3".$$

The diagonal pitch is obtained from

$$p_1 = \frac{2p + d}{3} = \frac{6\frac{3}{4}}{3} = 2\frac{1}{4}."$$

Hence, with a radius $2\frac{1}{4}$ " and with centres **C** and **F** (Fig. 54), describe arcs of circles intersecting at a point **D**. **D** is the centre required, and a circle with centre **D** and radius $\frac{3}{8}$ " denotes the plan of the rivet.

The elevation of the rivet is determined by projection. The elevation and plan of the riveted joint are completed as shown.

The horizontal width w between the two centres is 1.68 ", though the rough rule $w = 2d$ would give 1.5 ".

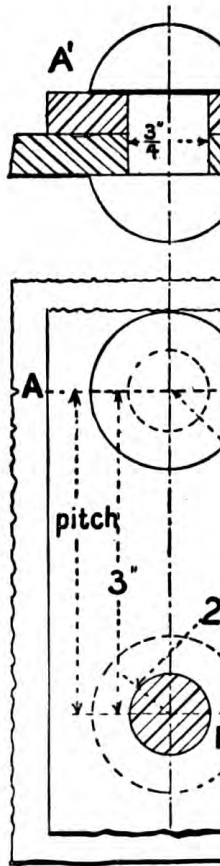


FIG. 54.—Double riveted butt joint.

Butt joint. In a butt joint the connection between the two plates may be made by means of a single butt strap (or *butt strap* as it is frequently termed), or by means of two butt straps, one on each side of the joint.

C.M.C

C

below the two plates to be joined. The former arrangement is shown at **A** (Fig. 54). The latter is the better arrangement of the two.

When a single cover plate is used, the thickness of the plate is made about equal to the thickness of one of the plates. When two plates are employed the thickness of each is made equal to the thickness of one of the plates.

Example. In a butt riveted joint (Fig. 55) the plates are $\frac{3}{8}$ " thick and the rivets are $\frac{1}{2}$ " diameter. Draw a sectional elevation and plan of the joint, (a) using a single cover plate. Scale full size.

Combined lap and butt joint. A joint sometimes used in locomotive boilers is known as a combined lap and butt joint. In this case there are three rows of rivets in the outer rows being twice that in the middle row. The peculiar arrangement makes the joint a somewhat expensive one to produce.

Example. Draw two views of a combined lap and butt riveted joint (Fig. 56) using rivets $\frac{1}{2}$ " diameter, pitch of the outer rows of rivets 4", and of the inner row 3".

Resistance of a riveted joint to fracture. In considering the strength of a riveted joint, such as the joint in a boiler shell subjected to tensile force, it is only necessary to consider a strip of plate of width equal to the pitch. The consideration of the whole length of the joint is that of the aggregate of all such strips. Such a strip might fracture in any of the four ways at (i), (ii), (iii), and (iv) (Fig. 57).

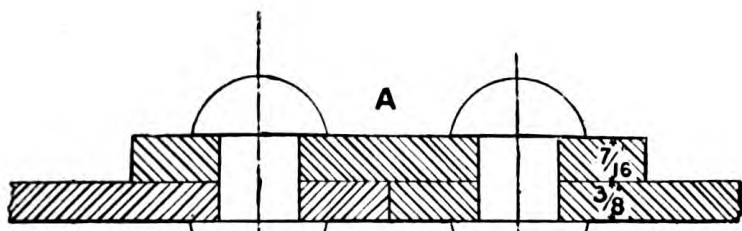
Let p denote the pitch, t the thickness of the plates, and d the diameter of the rivets.

(i) The joint might fracture by the tearing across of the plates at the rivets (Fig. 57).

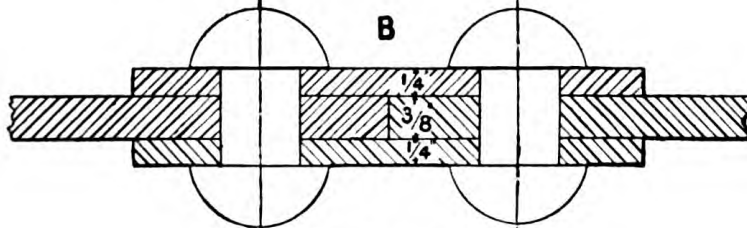
Area of section at $em = (p - d)t$.

If f_t denotes the tensile strength of the plates,

$\therefore$ resistance of strip $= (p - d)tf_t$



Butt joint. One cover plate or butt strap.



Butt joint Two cover plates

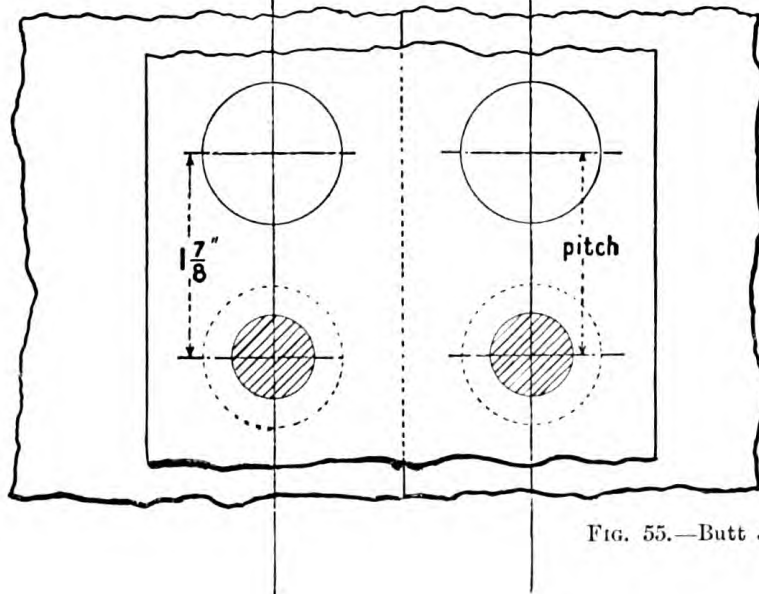


FIG. 55.—Butt Joint.

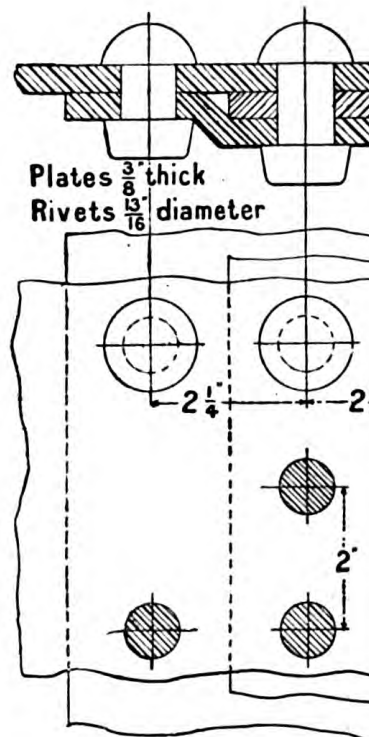


FIG. 56.—Combined Lap

(ii) The joint might fracture by the shearing of the rivets as at (ii) (Fig. 57)

Modes of fracture of a single riveted lap joint.

The resistance to shearing of the rivet multiplied by the area of the rivet multiplied of the material.

$$\therefore \frac{\pi}{4} d^2 \times f_s,$$

where f_s denotes the shearing stress.

The joint will have a maximum resistance to tearing is equal to Hence, equating the tearing and have

$$(p - d) t f_t = \frac{\pi}{4} d^2 f_s$$

From (3), when t is known value of p can be obtained from f_t . In many actual cases f_s is Assuming the two to be equal, $f_s = f_t$

$$(p - d) t = \frac{\pi}{4} d^2$$

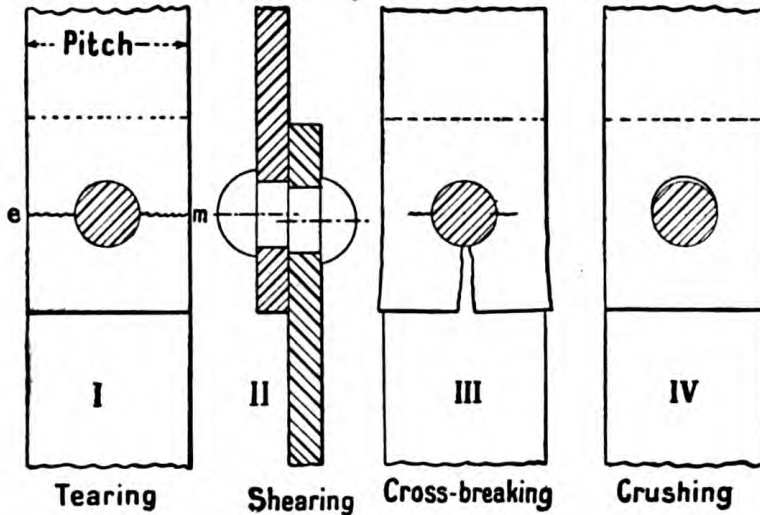


FIG. 57.

Example. In a single riveted lap joint the plates are $\frac{3}{8}$ " thick. Find the pitch of the rivets. Assuming $f_s = f_t$,

$$d = 1.2\sqrt{t} = 1.2\sqrt{\frac{3}{8}}.$$

$$\log d = \log 1.2 + \frac{1}{2}(\log 3 - \log 8) = \log 1.8662$$

$$\therefore d = 0.7348''.$$

The rough rule $d = 2t$ would give $d = 0.75''$.

$$(p - d) f_t t = \frac{\pi}{4} d^2 f_s;$$

$$\therefore p = \frac{\pi d^2}{4t} + d = 0.36\pi + 1.2\sqrt{t} = 1.8658''.$$

The rough rule $p = d + 1\frac{1}{8}''$ would give

$$p = \frac{3}{4} + 1\frac{1}{8} = 1.87.$$

Two other modes of fracture are shown at (iii) and (iv) (Fig. 57). The third form is due to the breaking of the plate in front of the rivet, and may be provided for by allowing a margin of the plate.

The fracture shown at (iv) is due to the crushing of the plate and the rivet. The first-named methods of fracture are of the utmost importance in the design of a riveted joint.

Efficiency of joint. The ratio of the strength of the joint to the strength of the plates is called the efficiency of the joint.

$$\therefore E = \frac{(p-d)tf_t}{ptf_t}, \text{ or } \frac{\pi}{4} \frac{d^2f_s}{ptf_t},$$

where E denotes the efficiency.

Example. Given $p = 1\frac{7}{8}''$, $t = \frac{3}{8}''$, $d = \frac{3}{4}''$, find E .

$$E = \frac{p-d}{p} = \frac{1\frac{7}{8} - \frac{3}{4}}{1\frac{7}{8}} = 0.6 \text{ or } 60\%.$$

In the case of a double riveted lap joint the shearing resistance is doubled, and we have

$$(p-d)tf_t = 2 \times \frac{\pi}{4} d^2 f_s.$$

Example. In a double riveted lap joint the plates are $\frac{3}{8}''$ thick. Find the pitch of the rivets. Assume $f_s = f_t$.

$$d = 1.2\sqrt{\frac{3}{8}} = 0.7348'',$$

$$(p-d)tf_t = \frac{\pi}{2} d^2 f_s;$$

$$\therefore p-d = \frac{\pi d^2}{2t},$$

or

$$p = \frac{\pi \times d^2}{2t} + d$$

$$= 0.72\pi + 1.2\sqrt{\frac{3}{8}} = 2.996''.$$

The rough rule $p = d + 2\frac{1}{4}''$ gives $p = 3''$.

Design for a joint. A common practical method of designing a joint for a boiler

Let P denote the pressure of the steam in lbs. per sq. in.; D the diameter of the shell plates in inches. Assuming a working stress of about 5 tons per sq. in. the thickness of the plate t may be calculated from $t = \frac{PD}{2fE}$, where E denotes the efficiency usually taken to be from 60 to 80 per cent.

Having obtained the thickness of the plate, the diameter of the rivet is obtained. d denotes the diameter of the rivet. The pitch p is obtained from $E = \frac{p-d}{p}$. The f_s is obtained from $f_t(p-d)t = n \times \frac{\pi}{4}d^2f_s$, usually $\frac{f_s}{f_t} = \frac{23}{27}$.

It is not necessary to consider the crushing of the rivet, provided that the pitch is not less than five times the diameter of the rivet for single row rivets, nor less than five times the diameter of the rivet for double rows, or seven times the diameter of the rivet for triple rows, since f_c may be neglected.

Riveting in bridge and girder work. In bridge and girder work, instead of the empirical rule $d = 1.2\sqrt{t}$, the diameter of the rivet is fixed by considerations of strength required. The thickness of plate is made so that the bearing stress on the metal is from 8 to 10 tons per sq. in.

For bridge work, the diameter of the rivet is seldom made less than $\frac{7}{8}$ " for the main angles, flanges, attachment of diagonal bracings to booms, etc.

In the case of work which does not carry the rolling load, such as floor plates, the diameter may be $\frac{3}{4}$ " or $\frac{5}{8}$ ".

The diameter d is not changed by amounts less than $\frac{1}{8}$ ". Common values are $\frac{3}{4}$ ", $1\frac{1}{8}$ ", $1\frac{1}{4}$ ", $1\frac{3}{8}$ ". The rivet holes are drilled usually about $\frac{1}{16}$ " larger than the free entry of the hot rivet, and also for any slight deviation of the alignment. Assuming the riveting to be carefully carried out, a rivet $\frac{3}{4}$ " diameter would be $\frac{13}{16}$ " in diameter.

Flat bars, angle irons, etc. In the case of flat bars, etc., the relation of the width of the bar is given by $w = 4d$, where w denotes the width of the plate and d the diameter of the rivet.

In angle irons, the distance S_1 (Fig. 58) is not less than $1\frac{1}{4}$ " for $\frac{7}{8}$ " rivets, and the distance S_2 is not less than d .

As already indicated, the size of the rivet is calculated from considerations of the

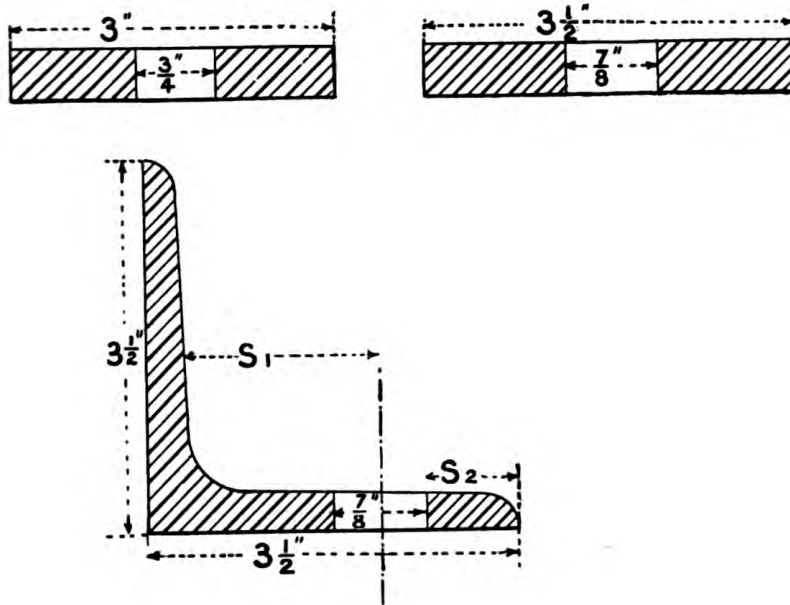


FIG. 58.

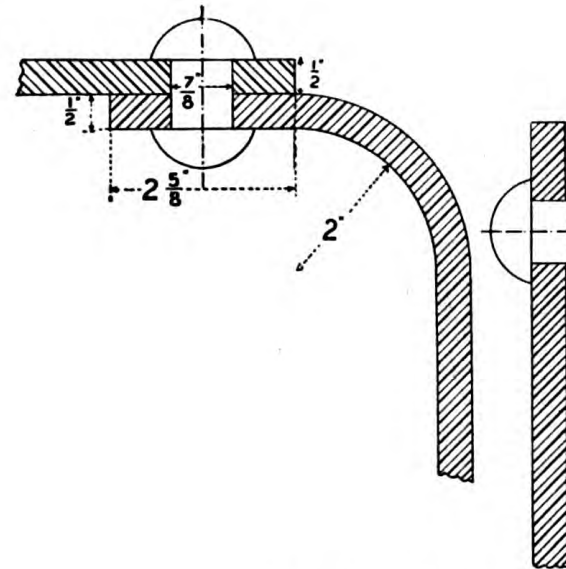


FIG. 59.—Plates at right angles.

areas. In shear, the net area of the rivet in the plane of shear is made equal to $1\frac{1}{2}$ times the area of the plate. For a single riveted lap joint, we obtain

$$(p - d)t = \frac{2}{3}\frac{\pi}{4}d^2.$$

Plates at right angles. The joint between two plates at right angles to each other is made by bending one of the plates, or by using an angle iron. The two methods (Fig. 59) are used at the front and the back end respectively of a boiler. The joint obtained by bending is called a

and that when an angle iron is used, an *angle iron joint*. In the former, the radius of the plate is bent should not be less than 4 times the thickness of the plates.

Flue joints. Plain furnace flues, such as those generally used in Lancashire, are liable to comparatively great alterations in length, due to changes of temperature.

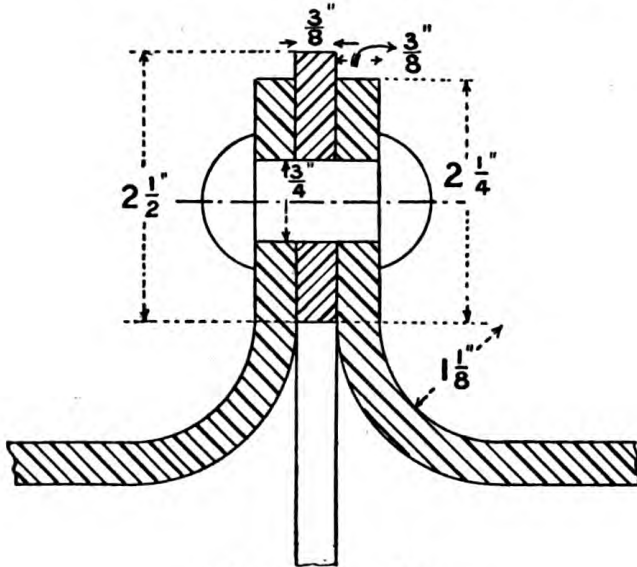


FIG. 60.—Flanged Seam.

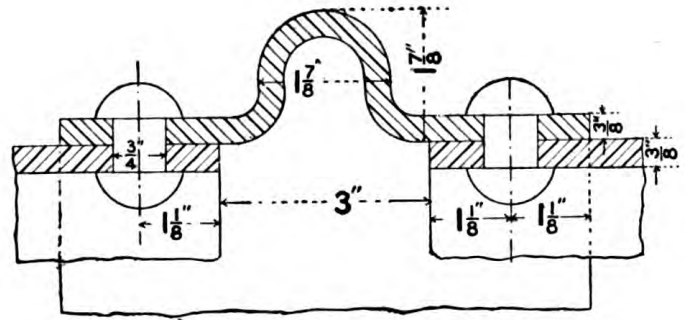


FIG. 61.—Bowling Hoop.

of the flues are fixed in the ends of the boiler it is necessary to provide a form of joint to allow of an alteration of length to take place. Of the forms of joints which may be used for such purposes the *Adamson Ring*, or *Flanged Seam*, is usually considered to be the best joint. It is shown that the ends of the flue sheets are flanged and riveted to a ring inserted between them. The ring is effected to a radius 2 to 3 times the thickness of the plates. This construction prevents longitudinal expansion, and also facilitates the process of making and maintaining the flue. It is noticed that in this arrangement the heads of the rivets are not subjected to the action of the steam.

Example. Draw the flanged seam (Fig. 60). Scale full size.

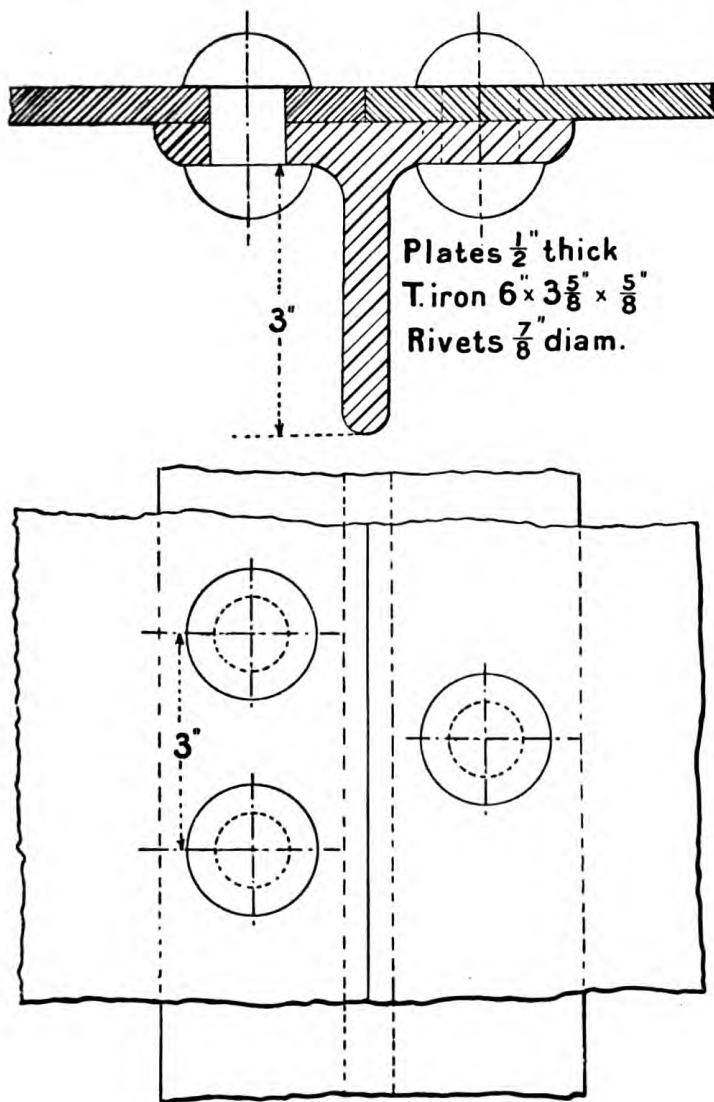


FIG. 62.

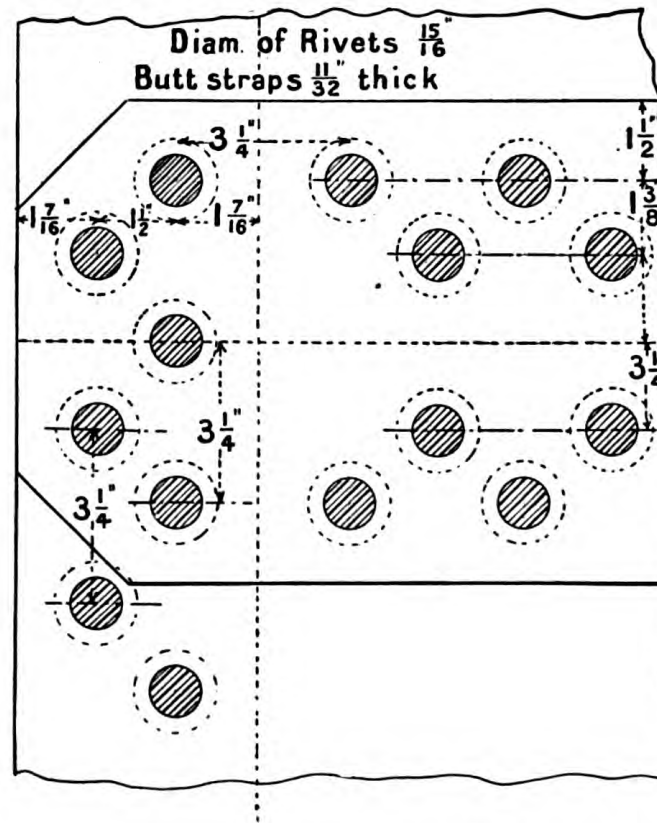


FIG. 63.

Example. Riveted joint. Angle irons $3'' \times 3'' \times \frac{5}{8}''$. Rivets $\frac{7}{8}''$ diam $\frac{1}{2}''$ thick. Draw to scale $\frac{1}{2}$ size (Fig. 61).

Example. Tee-iron joint. T-iron $6'' \times 3\frac{5}{8}'' \times \frac{5}{8}''$. Plates $\frac{1}{2}''$ thick. $3''$ pitch. Draw half size (Fig. 62).

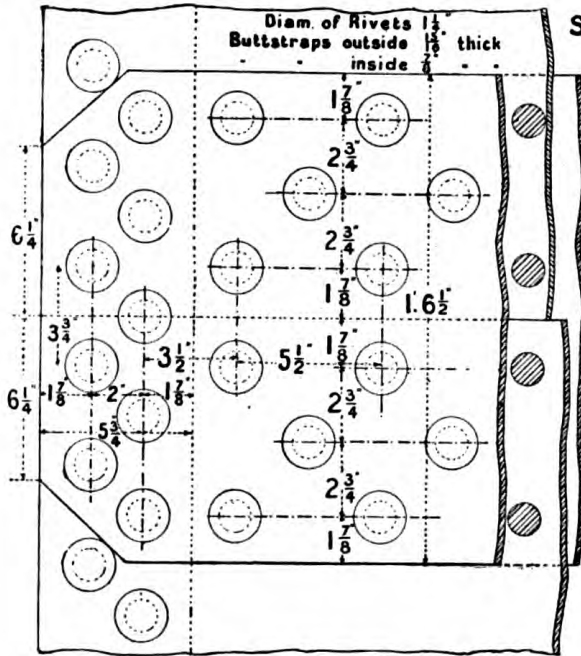


FIG. 64.

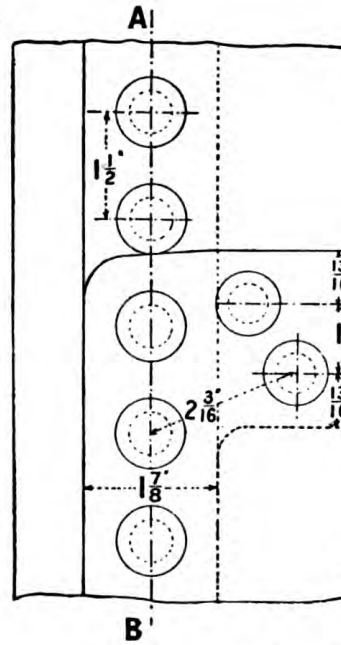
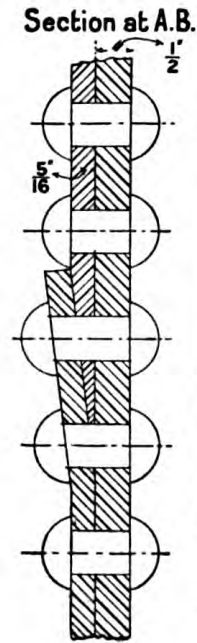
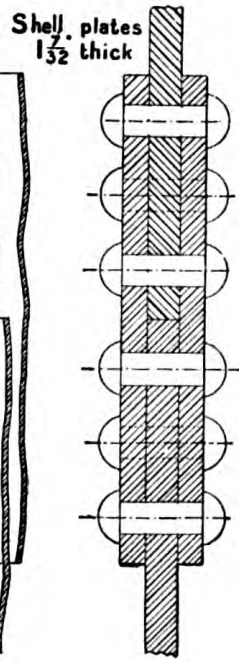


FIG. 65.

Examples of boiler joints. (i) Draw the two views of a double riveted joint of a ring and longitudinal joint (Fig. 63). Shell plates $\frac{9}{16}''$. Butt straps full size. Find the efficiency of the joint and also the safe working pressure of the boiler being $8' 4''$. $f_t = 5$ tons per sq. in.;

[Ans. 71 per cent., 89 lb. per sq. in.]

RIVETS AND RIVETED JOINTS

- (ii) Draw the two views shown (Fig. 64). Shell plates $1\frac{7}{8}$ ". Butt straps, Rivets $1\frac{1}{4}$ " diameter. Scale full size. Find the efficiency of the joint. If boiler is $16' 4''$, what will be the safe working pressure? $f_t = 7.2$ tons per sq. in.
[Ans. 77.3 per cent. 155 lb. per sq. in.]

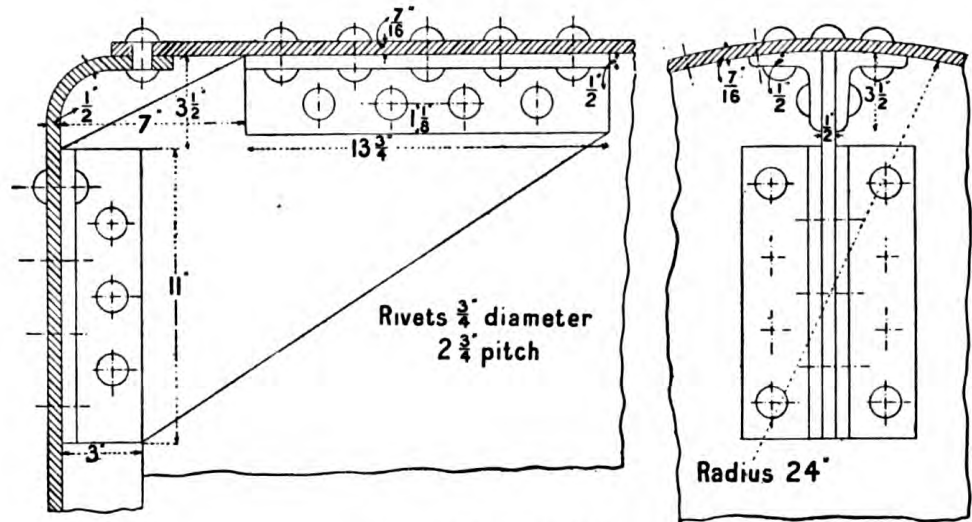


FIG. 66.—Gusset Stay.

- (iii) Two views of a boiler joint at the junction of a ring and a longitudinal plate. Draw full size. Shell plates $\frac{5}{16}$ " and $\frac{1}{2}$ ". Rivets $\frac{5}{8}$ ". Find the efficiency of the joint. If the boiler is $3' 4''$, and the working pressure 140 lbs. per sq. in., what is the working stress adopted?

[Ans. 66.7 per cent., 6 tons per sq. in.]

Gusset stays. The flat ends of a boiler are strengthened or stayed by means of gusset stays (Fig. 66). These stays connect the shell plates to the flat end.

Example. Draw and complete the two views of the gusset stay (Fig. 66).

EXERCISES. II.

1. Sketch a $\frac{3}{4}$ " rivet, showing the form and proportions of the rivet head.
2. Show by sketches the method of joining the plates of a cylindrical boiler longitudinal joint meets a ring joint. Explain why the longitudinal joints are so constructed from that of the transverse or ring joints.
3. Show by sketches a single riveted, and a double riveted lap joint, also for plates $\frac{3}{8}$ " thick. What in each case is (i) the least width of overlap, and (ii) the distance between rivet holes from each other and from the edge of the plate?
4. Draw a section and plan of a double riveted butt joint with $\frac{3}{4}$ " plates, $1\frac{1}{8}$ " thick, pitch 4". Scale half size.
5. Give dimensioned sketches of a double riveted lap joint suitable for $\frac{1}{2}$ " plates. In the sketch the width of overlap and margin, assuming $f_s = f_t$.
6. Sketch with dimensions a double riveted butt joint with two butt straps suitable for a joint in a steel boiler with $\frac{5}{8}$ " plates. Explain how one of the rivets is put in place.
7. Draw two views of a double riveted lap joint, first, when the rivets are staggered (Fig. 55); and secondly, when they are placed in chain, *i.e.* when all the rivets are in line with each other. Point out the advantage due to the former arrangement.
8. Show by a sketch a flanged seam used for a furnace flue in a Lancashire boiler.
9. Sketch in section common forms of wrought iron and mild steel used in a built-up girder the web plate is connected to the flanges. What size rivets would be used?
10. Show three methods of connecting together parallel plates such as are used in a built-up girder.
11. Give a section through a T-iron joint showing the construction.
12. Show by sketches how two plates at right angles to each other may be joined by means of angle irons and rivets.
13. Show by sketches the methods of strengthening a boiler by means of (a) a gusset stay, (b) a gusset stay. [B.E.]

14. In a single riveted lap joint the plates are $\frac{1}{2}$ " thick, rivets $\frac{7}{8}$ " diameter, pitch 2". Calculate the tensile resistance of the plates to be equal to the shearing resistance of the rivets. The joint will fracture by tearing or by shearing.

15. Show the different ways in which a riveted joint may fracture. In a single riveted lap joint the plates are $\frac{1}{2}$ " thick and the rivets $\frac{7}{8}$ " diameter, calculate the pitch for the greatest resistance. The shearing resistance of the rivet is $\frac{3}{4}$ the tensile resistance of the plate per square inch.

16. In a single riveted lap joint the plates are $\frac{5}{8}$ " thick, rivets 1" diameter, and pitch 2". Calculate whether the joint will yield by shearing or by tearing, the plates being 10 per cent. stronger than the rivets in shear, per square inch of section. [B.E.]

17. Sketch a single riveted lap joint for $\frac{1}{2}$ " plates, using $\frac{7}{8}$ " rivets. Show how the joint may fracture.

Calculate the pitch, (i) assuming the tearing resistance of the plates and the shearing resistance of the rivets to be equal.

(ii) When the safe shearing strength is 7800 lbs. per sq. in., and the safe tensile strength of the plates is 30,000 lbs. per sq. in.

18. A treble-riveted lap joint has twice as many rivets in the middle row as in the outer rows. Plates $\frac{3}{4}$ " thick. Rivets 1" diameter. Pitch of outer rows $4\frac{1}{2}$ ".

Draw cross section and plan. Scale $\frac{1}{2}$ ".

19. In a single riveted lap joint the plates are $\frac{5}{8}$ " thick, rivets 1" diameter and pitch 2". Calculate the efficiency of the joint.

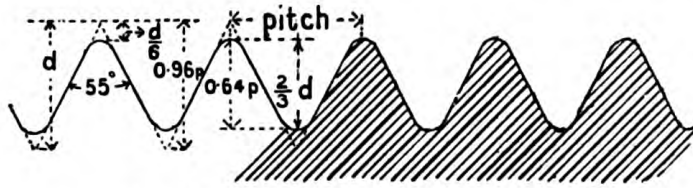
20. In a double riveted lap joint for $\frac{1}{2}$ " plates, the rivets are $\frac{7}{8}$ " diameter, the longitudinal pitch is 2", and the diagonal pitch is $2\frac{1}{8}$ ", and the overlap is $4\frac{1}{4}$ ". Sketch this joint to scale, full size, showing two views, one being in section.

21. In a single riveted lap joint the plates are $\frac{3}{8}$ " thick, rivets $\frac{3}{4}$ " diameter. Assume the tensile resistance of the plates to be 30 tons per sq. in. and the ultimate shearing strength of the rivets to be 30 tons per sq. in., find the pitch. Make a dimensioned sketch of the joint.

CHAPTER III.

SCREWS, BOLTS AND NUTS.

Screw threads. The usual form of screw thread in use by engineers is the *Whitworth V-thread*. Other forms, such as *gas* threads, are employed for special purposes.



Section of Whitworth V-thread.

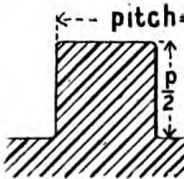
FIG. 67.

Vee thread. What is called the *vee thread* is shown in Fig. 67. It will be seen that the threads are inclined at an angle of 55°; they have a sharp edge, but are rounded off at the root a distance equal to $\frac{1}{6}$ of the depth.

Pitch. The pitch of a single thread is the distance between two consecutive ridges, or the amount by which the distance between the bolt and its nut would increase or diminish for one rotation of the screw.

For any diameter of bolt in ordinary use the pitch may be obtained from tables, such as Table V., p. 243. Thus, on a bolt of 1 inch diameter there are 8 threads in an inch of its length, and hence the pitch is $\frac{1}{8}$ ". It is convenient to express all the proportions of a screw thread in terms of the pitch.

Square thread. Another common form of screw thread is the *square thread*, a section of which is shown in Fig. 68. The pitch of a square thread is usually twice that of the corresponding triangular thread.



Section of square thread.

an inch bolt with a Whitworth triangular thread would have 8 threads per inch length, bolt of the same diameter would have 4 threads per inch.

Comparing the two forms of thread, it will be seen that more material is in a square thread than in making a triangular thread of the same diameter. The triangular thread is stronger than the square thread. The triangular thread is used for holding down purposes where strength is required. In this form of thread the direction of the force between the bolt and nut is inclined to the axis of the screw, this not only increases the friction between the bolt and nut, but also gives a tendency to burst the nut.

In the square thread, the direction of the mutual force between the bolt and nut is nearly parallel to the axis of the bolt. Hence this form is used for a variety of purposes, such as in book presses, etc., in which the transmission of motion is concerned.

The edges of a square threaded screw are slightly rounded off, an expedient which not only makes it safer and easier to handle, but also renders it less liable to damage.

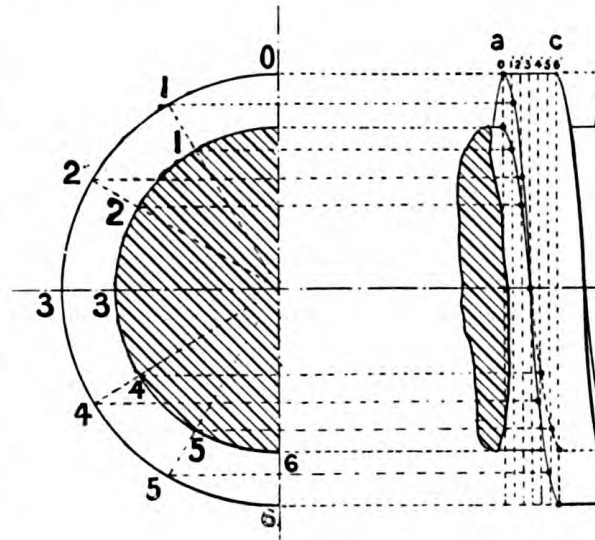


FIG. 69.—Projection of a Square

Screw thread or helix. In many cases, such as in screws of comparatively large size, in spiral springs, etc., it is necessary to be able to approach to accuracy the form of a screw thread. The method may be shown by an example.

Example. Draw a square threaded screw, using the following dimensions; inside diameter, 3"; pitch, 1".

Commence by drawing two semi-circles with radii of 2" and $1\frac{1}{2}$ " respectively **A** and **B**, i.e. 4" apart (Fig. 69). Divide the semi-circle into any convenient number these as shown. Mark off a distance *ac* denoting half the pitch, and divide into the same number of equal parts as the semi-circle. Draw the vertical lines

points on the required curve are obtained by projections from the points on the corresponding lines $0'$, $1'$, $2'$... $6'$. The points obtained in this manner may be used to draw the curve.

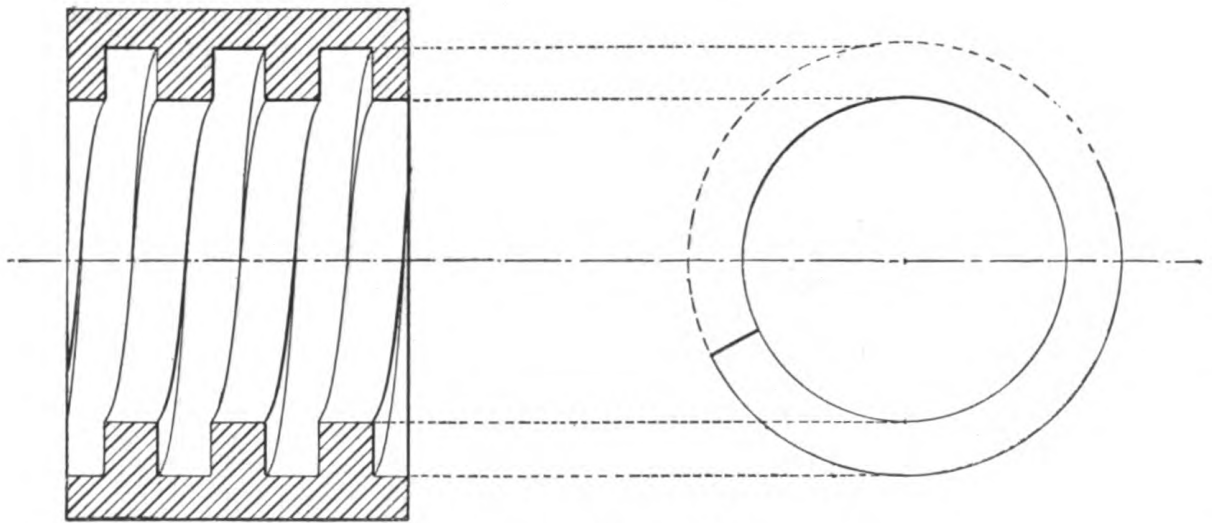


FIG. 70.—Section of Nut.

In a similar manner, the curve showing the inner edge of the screw thread may be drawn.

A section of a nut suitable for the screw just drawn is shown in Fig. 70. The curves showing the inner and outer edges of the screw thread are obtained in the same manner as before.

Conventional methods of representing screw threads. In the majority of cases in machine drawings, the bolts are not only of small size, but, in addition, the screws are of small size, and therefore the attempt to draw the true shape of a screw thread would serve no purpose. In such cases the screws are usually drawn in a conventional manner. Some of the methods are indicated in Fig. 71. Thus, at (I), a triangular screw is represented by a line drawn using for the purpose the 60° set square.

As one turn of the screw corresponds to a distance equal to the pitch, it is convenient to draw the threads by a series of parallel lines.

vertical line, and to mark off a distance on one side of it equal to half the pitch. When this is done the two series of triangles on the upper and lower edges respectively can be drawn, and the delineation of the screw thread is completed by joining the angular points of the triangles by straight lines.

In a similar manner, we may obtain the square thread shown at (II) (Fig. 71). This thread consists of a series of small squares joined by straight lines. Another method frequently adopted, for all except comparatively large screws, is indicated at (III). It will be seen that the screw thread is indicated by straight lines drawn at a suitable inclination—the shorter lines denoting roughly the bottom of the thread may be made slightly thicker than the longer lines.

Two other methods are indicated at (IV) and (V) (Fig. 71). In (V) the thread is denoted by dotted lines and in (IV) by two thick lines.

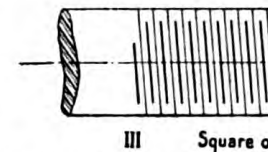
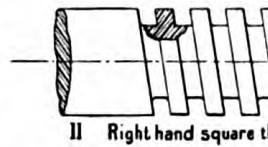
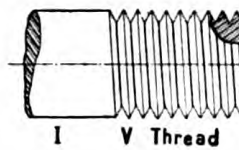
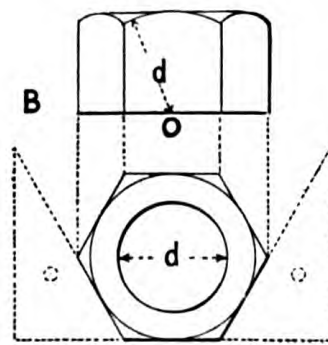
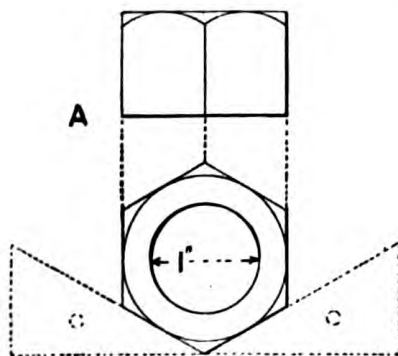


FIG. 71.—Conventional Screw

Projection of a nut. If a careful examination of a hexagonal nut



Projections of a Hexagonal Nut

FIG. 72.

C.M.C.

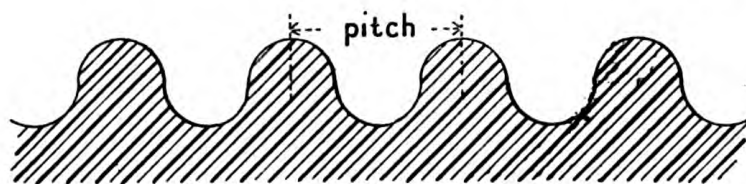
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is made before proceeding to draw it, it will be experienced in realising that the projection of a nut may be shown as at A and B. The elevation at A shows two flat sides of the nut and the elevation at B shows the nut from corner to corner.

To draw the projections of a 1 inch diameter, proceed as follows:—drawing a circle 1" diameter, in the centre draw another circle the diameter of which is the width of the nut $= 1\frac{1}{2}d + \frac{1}{8}"$. Using the 30° T-square, draw the sides of the nut.

the circle as at **A** (Fig. 72). In a similar manner, using the 60° set square, draw the nut as at **B**.

The chamfering of the edges of the nut may be indicated by drawing an arc of small radius and radius equal to the diameter of the thread, and completed by drawing two smaller arcs of the same radius in Fig. 72.



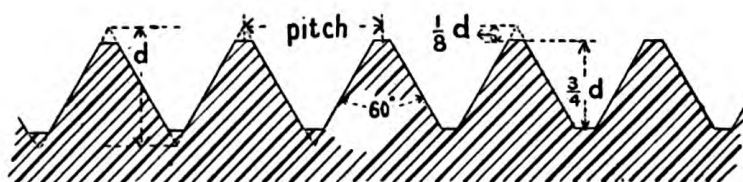
Section of Knuckle Thread

FIG. 73.

Knuckle thread. When a screw is subjected to rough usage, the pitch may be that shown in Fig. 73, which is known as a *knuckle thread*.

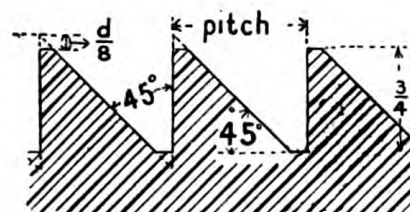
Seller's thread. A section of it is shown in Fig. 74. It will be noticed that the angle of the thread is 60° and that one eighth of the depth is taken off at the top and at the bottom.

Buttress thread. As already indicated, the amount of material removed in forming the buttress thread renders the screw thread much weaker than the corresponding triangular thread, in which a small amount is removed.



Section of Sellers thread.

FIG. 74.



Section of Buttress thread.

FIG. 75.

A successful attempt to combine the advantages of the *V-thread* has been made in what is called a *buttress thread*, shown in Fig. 75. In this thread one side is vertical and the other inclined at an angle of 45° . One eighth of the depth is cut off at the top and at the bottom.

Proportions of bolts and nuts. The names given to the various parts of a bolt and nut are shown in Fig. 76.

The sizes of the head and of the nut of a bolt may be obtained from Table V. when the diameter of the bolt is known. Bolts and nuts are, however, of such frequent occurrence in all mechanical drawings that it is desirable that the draughtsman should be able to draw them without reference to a table.

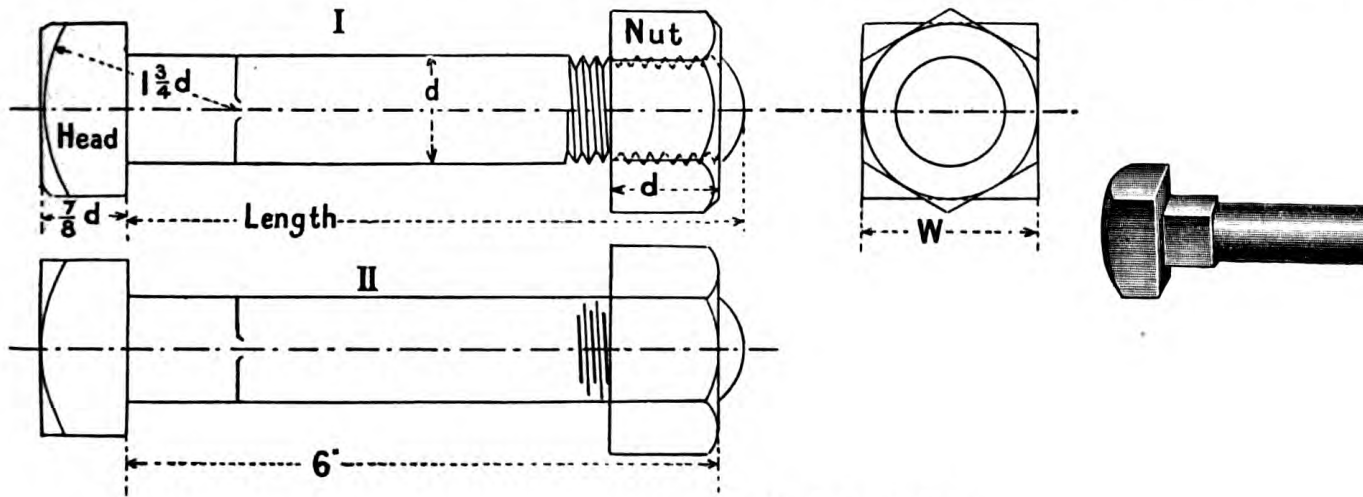


FIG. 76.—Bolt and Nut.

details that it is desirable, when the diameter of a bolt is known, to be able, without reference to a table, to draw it. The following proportions of bolt heads and nuts—which represent fairly average proportions—may be committed to memory.

Thickness of bolt head	$= \frac{7}{8}d.$
Thickness of nut	$= d.$
Width, W , across flat sides	$= 1\frac{1}{2}d + \frac{1}{8}''.$
Distance from corner to corner	$= 1\frac{3}{4}d + \frac{1}{8}''.$

When the head of the bolt is made square, as in Fig. 76, the side of the square is equal to the diameter of the bolt. When the head is circular this proportion also gives the diameter of the circle.

The drawings in which bolts and nuts occur are frequently made to a small scale, and in such cases the proportion $1\frac{1}{2}d + \frac{1}{8}''$ is used to replace $1\frac{1}{2}d$. When this replacement is made it is only necessary to draw the bolt and nut to the same scale as the rest of the drawing.

side of the centre line a distance $\frac{7}{8}d$, also the distance from corner to corner is m are obtained easily from the drawing.

The conventional methods of drawing a bolt and nut are shown at **I** and **II** (

Example. Draw the elevation, end view, and plan, of a bolt and nut 4" long. Write on the drawing the usual dimensions adopted for the

Fracture of bolts. A bolt may fracture

- (1) by tearing ;
- (2) by the stripping of the thread ;
- (3) by the bolt head giving way.

Of these, the first is the most important, and in this case the diameter of a bolt is related to the load by the relation

$$(\text{area of bolt}) \times (\text{safe stress}) = \text{load} ; \text{ or,}$$

$$\frac{\pi}{4} d_1^2 \times f = P,$$

where d_1 is the diameter of the bolt at the bottom of the thread, and the relation between d_1 and the diameter d is given in Table V., or by $d_1 = 0.84d$ approximately. f may be taken to allow for stresses due to screwing tightly.

Example. A cylinder of 12" diameter is to be designed. Pressure of steam is 100 lbs. per sq. in. Find the size and the number of bolts in the cylinder cover.

$$\text{Area of cylinder} = 12^2 \times 0.7854 = 113 \text{ sq. in.}$$

$$P = 113 \times 100 = 11300 \text{ lbs.,}$$

$$\therefore \text{ bolt area} = \frac{11300}{3000} = 3.767.$$

$$\text{If } \frac{3}{4}" \text{ bolts are used, then } n = \frac{3.767}{0.3039} = 12 \text{ bolts.}$$

$$\text{If } \frac{7}{8}" \text{ bolts are used, then } n = \frac{3.767}{0.422} = 9 \text{ bolts.}$$

To ensure tight joints, the pitch of the bolts is usually about $5d$, where d is the diameter. With the spanners in general use, no bolts less than $\frac{3}{4}$ " diameter are used for joints.

Gas threads. Wrought iron pipes of comparatively small size used for the conveyance of gas and water may be fastened together by what are called *nipples* or *couplings* (Fig. 76). To form such a connection, the pipes have a screw thread cut either on the outside or on the inside of the pipe. The depth of the Whitworth thread renders it unsuitable for such purpose, and the thread used, called a *gas thread*, is finer in pitch and of smaller depth than the Whitworth thread. Thus, the screwed portion of a pipe $\frac{3}{4}$ " internal diameter and $\frac{1}{2}$ " external diameter would have 14 threads per inch of length, or a pitch of $\frac{1}{14}$ " instead of $\frac{1}{8}$ ".

Prevention of rotation of bolt. To prevent the rotation of the bolt during the turning of the nut, a small portion of the bolt close to the bolt head is usually left square. This fits somewhat loosely into a square hole in one of the pieces to be joined. Another method is to provide a small pin or *snug* immediately under the head of the bolt, and this fits a corresponding hole made to receive it. Such an arrangement is shown in Fig. 77.

Forms of bolts and screws.

When a bolt and nut cannot be used, other forms of fasteners receive special names, such as *tap bolts*, *set screws*, etc., are used. A set screw is a screw, or bolt, which presses on a piece so as to prevent the sliding or rotation of that piece, as in Figs. 90, 118, 136, etc.

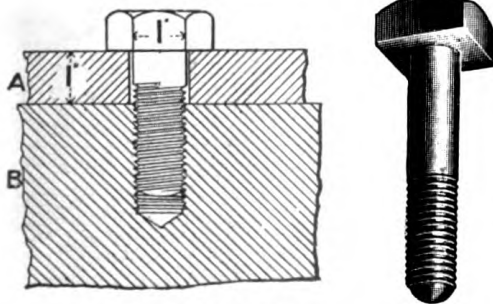


FIG. 78.—Tap Bolt.

Tap bolt. In this form a screw thread is made all the way through the piece, as in the arrangement in Fig. 78. It will be noted that the bolt passes loosely through one piece *A* and is screwed into the other piece in which a hole has been made to receive it.

The heads of **tap bolts**, as in bolts, are of various forms, hexagonal, hemispherical, cylindrical, etc.

In some cases, as in Fig. 100, a hole large enough to receive the cylindrical head of the screw is made in one piece, and the screw may be rotated by a driver fitting a rectangular hole in the head of the screw.

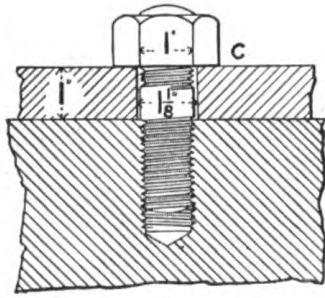


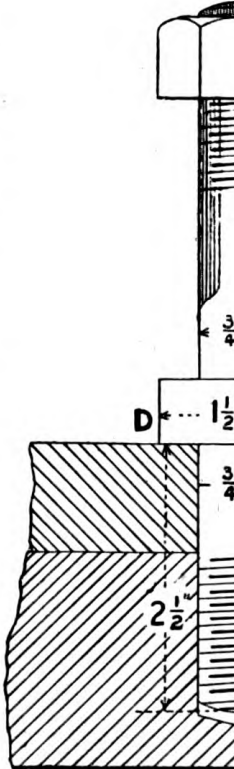
FIG. 79.—Stud.

Studs. A stud, in its simplest form, as at **C** (Fig. 79), is a piece of metal (iron, steel, brass, copper etc.), at each end of which a thread is formed. The intermediate portion is used to grip the metal into which it is to be screwed firmly into its place. To facilitate this the stud is in many cases made square in cross-section, as at **D** (Fig. 80). The stud is screwed into metal usually for a distance $1\frac{1}{4}d$ to $1\frac{1}{2}d$, where d is the diameter of the stud.

Special bolts. Bolts of special shapes are used in machine tools and for other purposes. Three of these are shown at (a), (b), (c) in Fig. 81. The first is called a *hook bolt* from the peculiar hook form given to the head. At (b), another form called an *eye-bolt* is shown, and at (c) a *tee-headed bolt*. In the last, the projections forming the head of the bolt are only present on two sides of it.

Rag bolt. When a machine is to be secured to stonework, its own weight is not always sufficient to keep it rigidly in position, and some means of fastening it to the stone must be provided. Two forms of bolt frequently used for this purpose are known as *Rag* and *Lewis* bolts. In the former, the lower part of the bolt is made with the tapering sides, and these are usually indented as indicated in Fig. 82. When placed in position, in a corresponding taper hole, the space between the sides of the bolt and the stone in which it is fitted is filled with molten lead. The objections to this form of bolt are the use of the molten lead for fixing and the difficulty of removing the bolt if required to do so.

Lewis bolt. In the Lewis bolt one side of the head of the



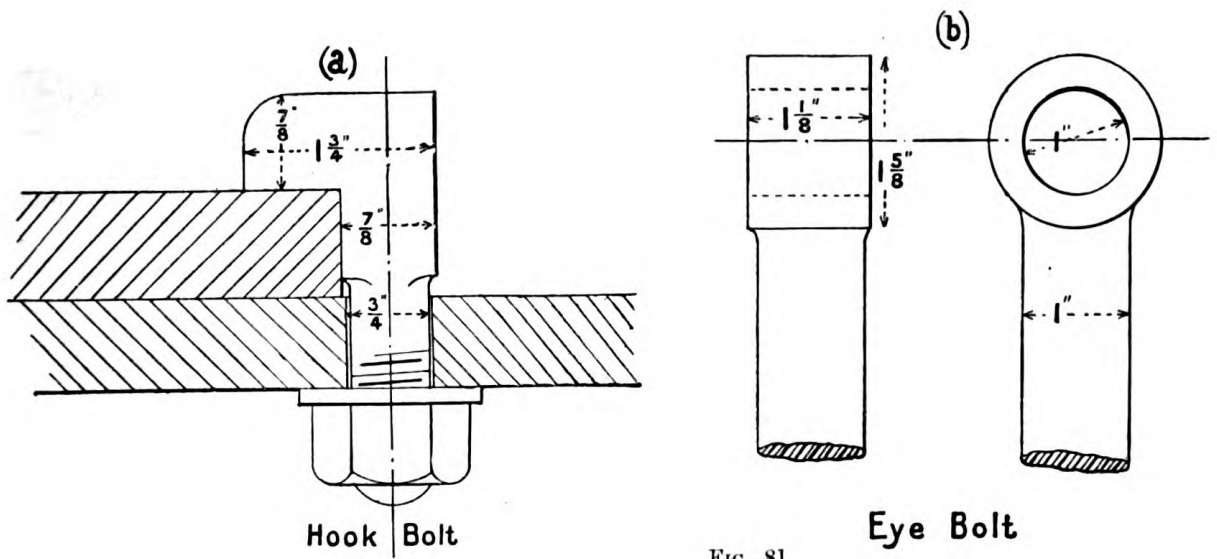


FIG. 81.

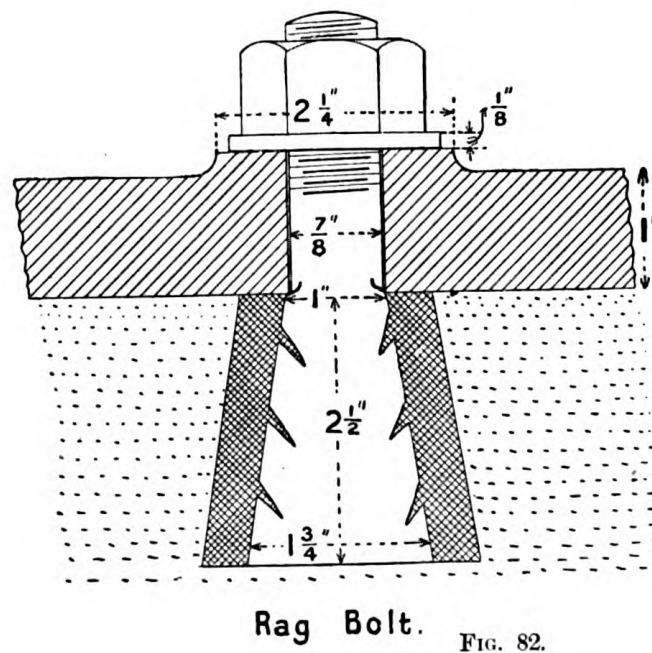
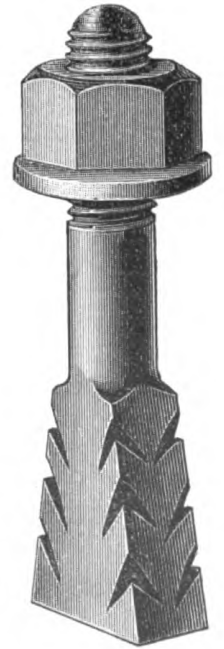
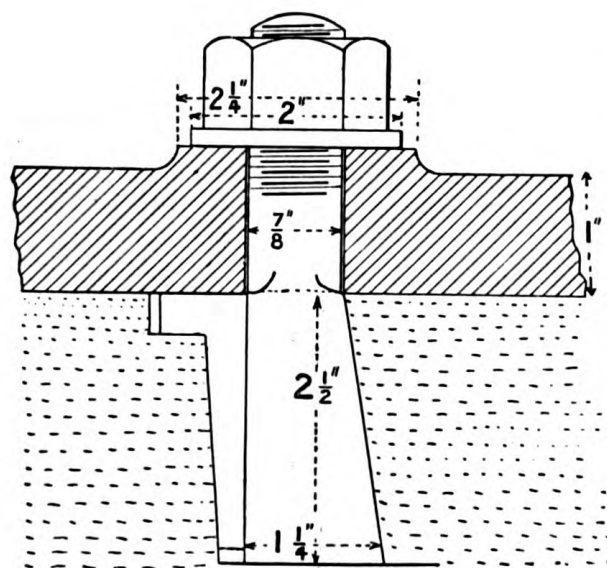


FIG. 82.



bolt is made of a taper form and the other straight, as shown in Fig. 83. The to receive the head, which is secured by a cotter as shown.



Lewis Bolt.

FIG. 83.



FIG.

Cotter bolt. In a so-called *cotter bolt*, a rectangular hole is made in the One form of such a bolt is shown in Fig. 84, and consists of a comparatively brickwork or masonry. At some convenient place, a hole is made in the bri enough to allow a cast-iron washer to be threaded on to the bolt. The washer

for the cotter. Rotation of the bolt during the process of turning the nut may be prevented by the formation of a groove on the washer into which the cotter fits. The bolt can rotate only by rotation of the washer. As the washer is of comparatively large size and rests against a rough surface, this prevents the rotation during the process of screwing or unscrewing the nut.

Stay bolt. What are known as *bar stays* or *stay bolts* are used to strengthen

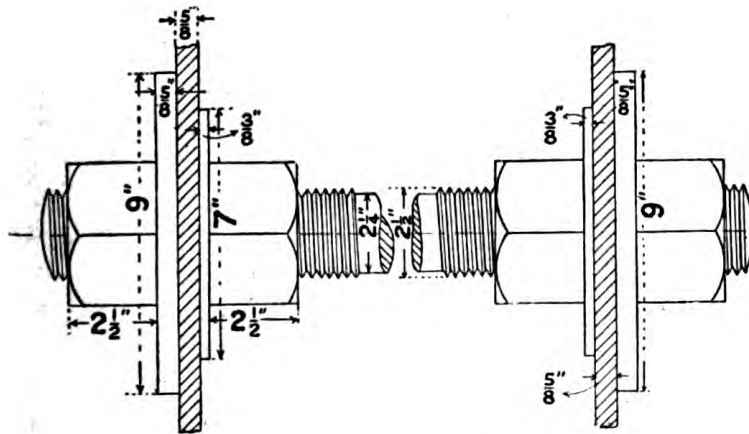


FIG. 85.—Stay Bolt.

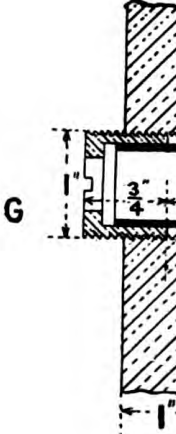
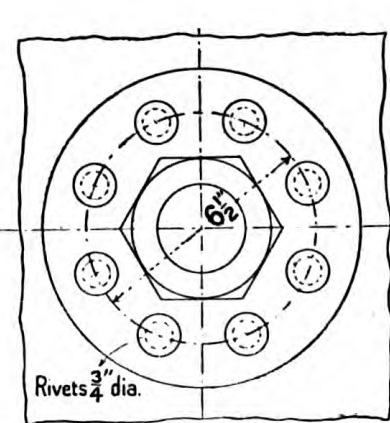


FIG. 86.

cylindrical boiler. These consist of long bolts passing from one flat end to the other. Stay bolts have the ends enlarged (Fig. 85), the diameter of the bolt being equal to the diameter of the thread. A raised screw thread of this kind is known as a *plus thread*.

Condenser tubes. The tubes are $\frac{5}{8}$ " or $\frac{3}{4}$ " external diameter and about $\frac{1}{20}$ " thick. To make them watertight in the tube plates, a small screwed ferrule or gland **G** (Fig. 86) is used. This is used to compress packing placed around the end of the tube.

Screwed stays. The flat sides and back of combustion chambers are stayed by diameter. These screws are screwed through the plates, and are either riveted or n

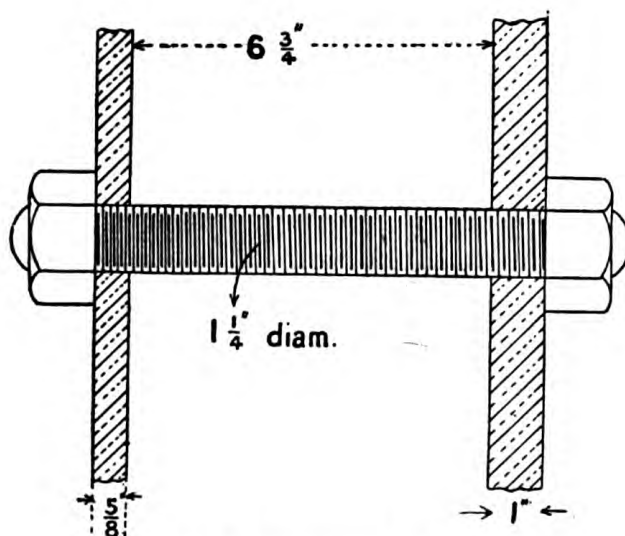


FIG. 87.—Screwed Stay.

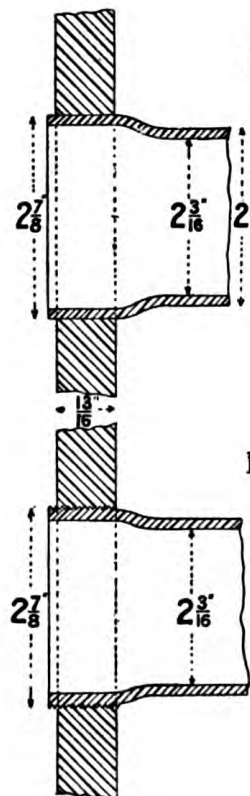


FIG. 88.—Sta

Stay tubes. These stay tubes were formerly made of brass, but are now made of steel. *tube I* (Fig. 88) is $2\frac{1}{2}$ " external diameter. It is made to fit well in the hole of the plate and is slightly enlarged at the ends by a tube expander to prevent leakage. The tube is slightly enlarged

facilitate insertion or withdrawal. The *stay tube II* is thickened at the ends to allow raised or plus thread. The threads are of the same pitch, so as to allow the tube to be inserted simultaneously into the two plates. One end is enlarged to enable the smaller end to be inserted into the hole in the outer tube plate.

Example. Draw the two views of (a) Bar stay, Fig. 85, (b) Stay tubes, Fig. 86.

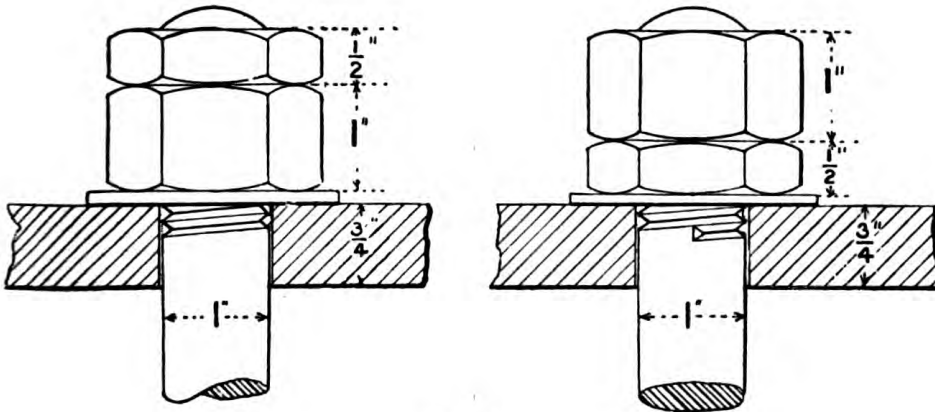


FIG. 89.

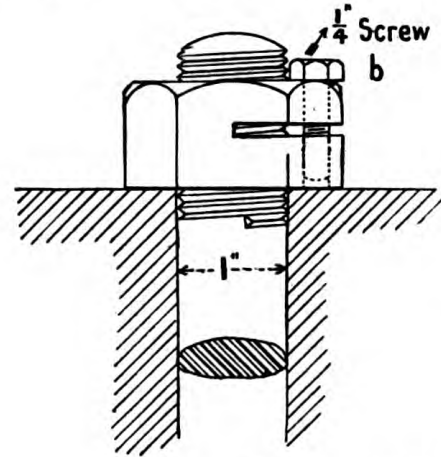


FIG. 90.—Locking

Locking arrangements. There is always a tendency for the nuts of the moving parts to unscrew owing to the vibration. Several methods have been devised to prevent this, and the general use are indicated in Figs. 89, 90, 91. One of the most common is by means of a locking nut. The first nut is screwed up as tight as is necessary, and the outer nut is brought in until it touches the first. Finally, whilst the upper one is held firmly by a spanner, the lower one is turned in through a short distance, so that the two nuts are firmly wedged together.

The usual arrangement is to place the thicker nut below and the thinner one above. This allows an ordinary spanner, which is usually thicker than the thinner nut, to be used. It is better to place the thicker nut on the outside. A plan sometimes adopted is to increase the diameter of the bolt and to use two nuts of ordinary thickness.

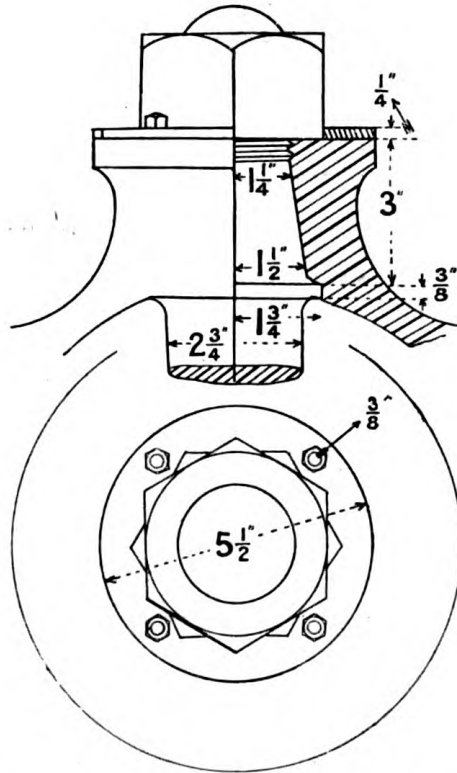


FIG. 91.—Locking Arrangement for Piston Rod.

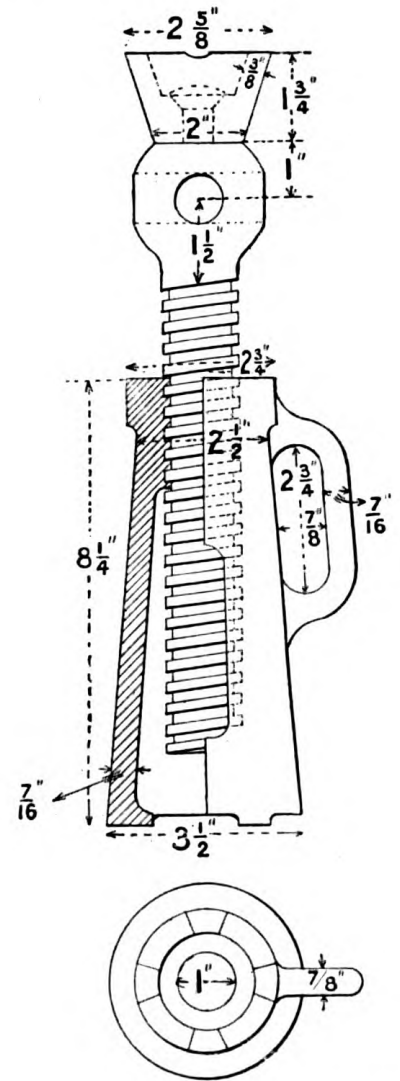


FIG. 92.—2-ton Screw Jack.

Two arrangements sometimes adopted for comparatively large nuts are shown at (b) and (c). In that indicated at (c), the lower part of the nut is made cylindrical and can be locked by means of a small set screw.

A simple arrangement consists of a small split pin inserted near the end of the bolt through the nut, as in Fig. 106, p. 77. The disadvantage of such an arrangement is that the pin is always in the same position.

A plan frequently adopted is to place what is called a *guard plate* in the space between the nuts. The plate is kept in position by one or more small set screws, and these, together with the nuts, must be removed before rotation of the nuts can take place. One arrangement of this kind in recent practice for marine pistons is shown in Fig. 176. The thickness of the plate varies according to the size of the nut, and the studs range from $\frac{3}{8}$ " to $\frac{3}{4}$ " diameter.

The nut at the end of a piston rod may be secured by means of a plate. This plate is secured by two or more studs and nuts. To tighten the nut, the plate is removed, and may be replaced. The nut is rotated through one-twelfth of a revolution. The arrangement is shown in Fig. 91.

Example. Draw full size the locking arrangement at the end of a piston rod.

Spring washers. Split washers of various kind are in use. These washers are bent so that they require considerable force to straighten them. One of these is placed underneath a nut to give resistance due to compression during the tightening of the nut, but, in addition, if any tendency to rotate occurs, the sharp end of the cut portion of the washer enters the undersurface of the nut and prevents rotation.

Example. 2 ton screw jack. Draw the two views (Fig. 92). Scale full size. Draw end view, diameter of screw $1\frac{1}{2}$ ", 3 threads per inch.

Example. Complete two views of the studs and tap bolts shown (Figs. 78, 79). Scale full size. Draw a plan. What is the advantage of having square necks on the studs?

Example. Draw the two ends of a stay bolt (Fig. 85). Scale half size. Also draw a plan.

Example. Draw full size one end of a condenser tube (Fig. 86).

Example. Draw full size the two views of a spanner (Fig. 93).

Example. Girder stay for a boiler. Draw half size (Fig. 94).

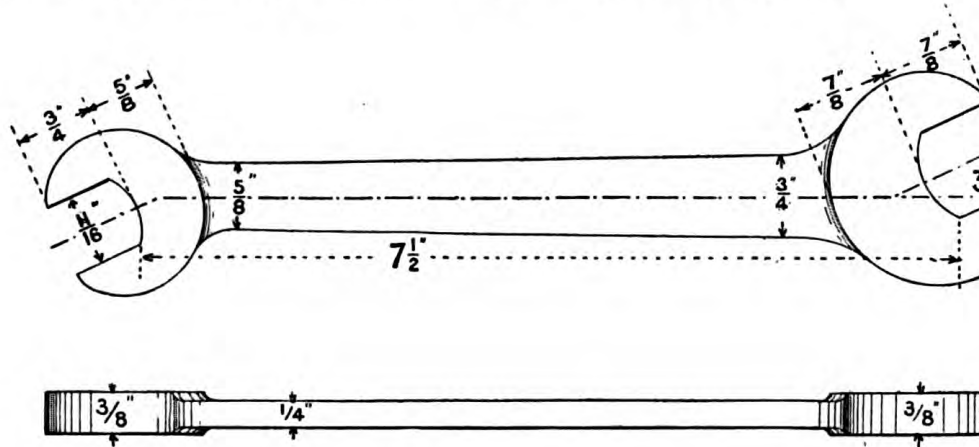


FIG. 93.—Spanner.

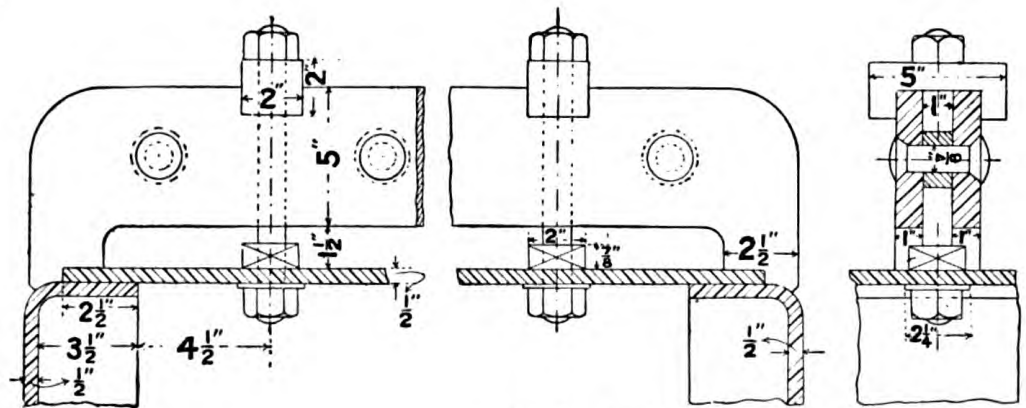


FIG. 94.—Girder Stay.

Knuckle joint. What is called a knuckle joint is shown in Fig. 95. The proportions are given in terms of the diameter of the pin. When this is known or assumed the remaining proportions can be determined.

Example. Draw full size the two views of a knuckle joint (Fig. 95). Also

PROPORTIONS OF KNUCKLE JOINTS.

Let D denote the diameter of the rod.

Width of rod,	$R = 1\frac{1}{8}D.$
Thickness of forks,	$T = \frac{3}{4}D, T_1 = \frac{5}{8}D.$
Width between forks,	$W = 1\frac{1}{4}D.$
Diameter of bosses,	$B = 2D.$
„ „ pin,	$d = D.$
„ „ pin head,	$D_1 = 1\frac{1}{2}D.$
Thickness of pin head,	$t = \frac{3}{8}D.$
Diameter of collar,	$C = 1\frac{1}{2}D.$

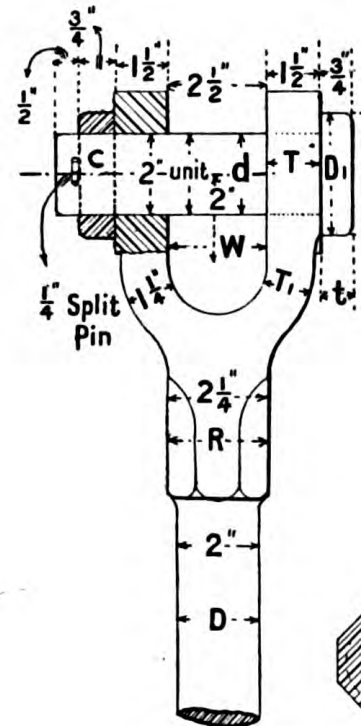


FIG. 95.—Knuckle joint.

Example. Calculate from the above table the dimensions of a knuckle joint. Draw sectional elevation, end view, and plan. Full size.

Cotter joints for tie rods. A form of joint suitable for tie rods is shown. The tie rods pass into a sleeve and are fastened by cotters. The proportions are given in terms of d , the diameter of the rod.

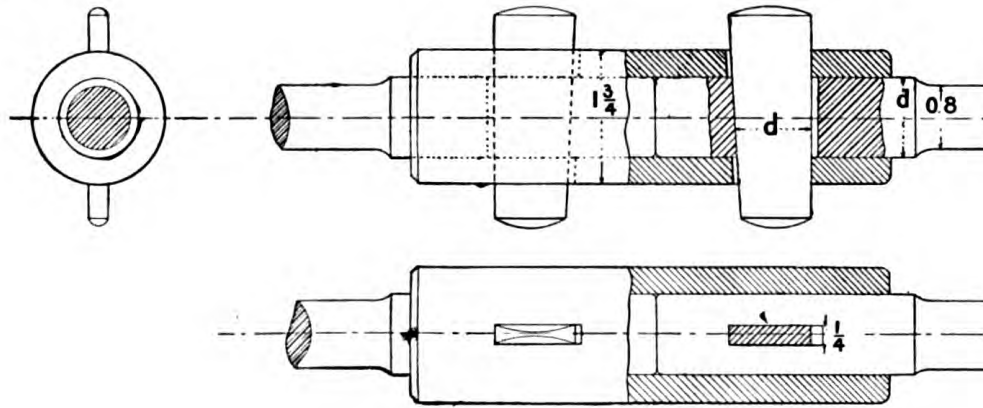


FIG. 96.—Cotter Joint.

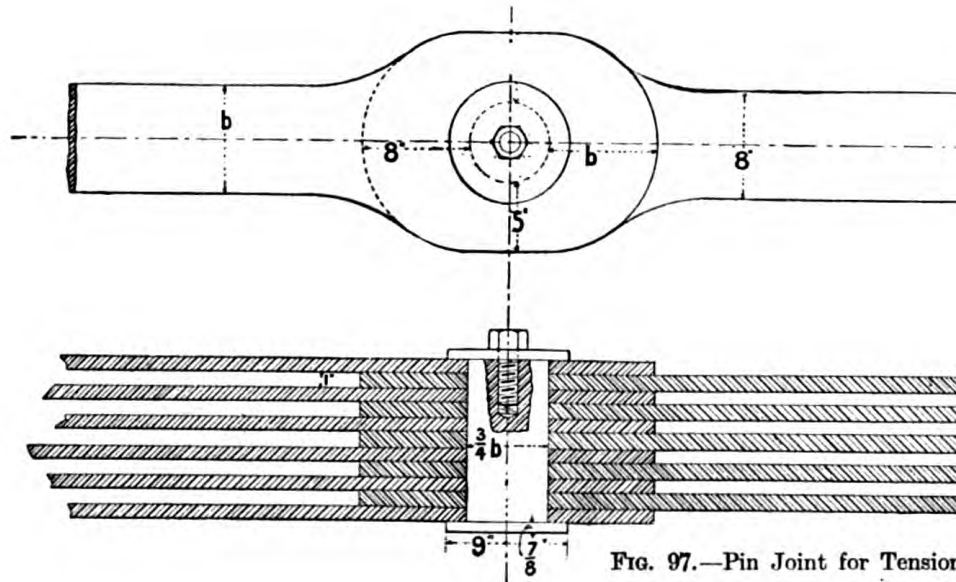


FIG. 97.—Pin Joint for Tension.

Example. Assuming the diameter of each of two tie rods to be 2", calculate the dimensions and draw the joint. Scale full size.

Pin joint for tension bars. A joint which may be used to connect together a series of bars (as in the links of the chain of a suspension bridge) is indicated in Fig. 97. The end view is enlarged as shown. The proportional unit is b , the breadth of each tie bar.

Example. Assuming the breadth of the tie bars to be 8" and thickness 1", calculate the dimensions and draw the two views of the joint (Fig. 97). Scale $\frac{1}{4}$.

EXERCISES. III.

1. Sketch a bolt with a square head, and a hexagonal nut. Supposing the bolt to be of the usual dimensions of the nut and bolt head. How many threads to the inch are used?
2. Make a sketch of a stud. Describe how it is screwed into place and state a case in which it may be used in preference to a bolt. [B.E.]
3. Sketch the profiles of the various forms of screw threads commonly employed in engineering. State the proportions adopted. Point out the relative merits of the various forms. State the advantage due to the use of a hexagonal nut as compared with a square nut.
4. Sketch a form of bolt used for securing a machine to a stone foundation, and explain how it is fixed in the stone. [B.E.]
5. Show by sketches the various forms of bolts, studs, screws and nuts which are commonly used in securing together the parts of a machine.
6. Sketch the end of a foundation bolt, showing how to fix it by a cotter and nut in the masonry.
7. Draw full size (i) a Tee head bolt, (ii) Hook bolt, (iii) Eye bolt, (iv) Rag bolt, (v) Cotter bolt. Diameter of bolt $\frac{7}{8}$ ". Give any example in which each may be used.
8. Draw, full size, about 4 turns of a square thread for a screw of $1\frac{1}{2}$ " pitch; outside diameter 4", inside diameter $2\frac{1}{2}$ ".

C.M.C.

9. A rectangular water tank is built up of flanged cast-iron plates. Sketch corner where three plates meet.

10. Show, by sketches, Whitworth's and Seller's standard forms of screw thread of 1", put on your sketches the remaining dimensions.

11. Sketch two or three methods which are in use to prevent a nut working.

12. Select a special example of each of the following two kinds of fastenings, fastenings and the forms of the pieces united in the locality of the fastening, which cause that form of fastening to be preferred to the other.

(a) A rivet. (b) A bolt. [B.E.]

13. Give an example of the use of both a right and left handed screw thread, describe how it is used.

14. Show the form of the Whitworth screw thread by drawing a section on a cylinder for a length of two inches. Draw five times full size, using a pitch of $\frac{1}{4}$ ". [B.E.]

15. Describe with sketches some form of spanner which is adjustable to fit various sizes.

16. Sketch and describe how the flat end plate of a boiler is strengthened by longitudinal bar stay.

17. Point out the various ways in which a screwed bolt and nut may yield, and how they are subjected.

18. The cover of a hydraulic cylinder is secured by two bolts. If the water pressure is 1000 lbs. per sq. inch, and the cylinder $1\frac{3}{4}$ in. diameter, find the diameter of the bolts. Safe stress, 6000 lbs. per sq. in.

19. Find the diameter of the screwed end of a piston rod, diameter of the cylinder 4 in., steam pressure 80 lbs. per sq. in. Safe stress, 6000 lbs. per sq. in.

Give dimensioned sketches of the nut.

20. The longitudinal bar stays of a short boiler are 16 inches apart, horizontal, steam pressure is 135 lbs. per sq. in. Find the diameter, the material being mild steel, safe stress 8000 lbs. per sq. in.

21. The chain of a suspension bridge is made up of links having a rectangular cross-section. Sketch with dimensions a pin joint suitable for connecting the links.

22. Give dimensioned sketches of a knuckle or fork joint suitable for connecting two rods.

23. A tie rod of $1\frac{1}{4}$ " round iron is made in two lengths, connected by a sleeve. Sketch the joint and insert suitable dimensions.

24. If d is the diameter of a bolt, p the pitch of the screw thread, n the number of threads per inch, and d_1 the diameter at the bottom of the thread, calculate values of p , n , and d_1 when $d = 1$ inch.

(i) Vee thread $p = 0.08d + 0.045$, $d_1 = 0.845d$.

(ii) Square thread $p = 0.16d + 0.9$, $d_1 = d - p$, $n = 1 \div p$.

25. Find the diameter of the screwed stays, each of which supports an area of boiler equal to a square of 4" side, steam pressure 150 lbs. per sq. in., safe stress 4000 lbs. per sq. in.

26. A flat surface in a marine boiler is constructed of $\frac{5}{8}$ " plates, with wrought iron stays. Steam pressure 120 lbs. per sq. in. Show how to fix the stays. Also determine their diameter.

27. The square thread in a screw jack is $1\frac{1}{2}$ " diameter, pitch $\frac{1}{3}$ " (p. 61). If the steam pressure is 150 lbs. per sq. in., find the load that can be raised.

28. A cylinder is 12 in. diameter, pressure of steam 100 lbs. per sq. in. Find the number of bolts in the cylinder cover if 12 bolts are used. Safe stress 3000 lbs. per sq. in.

CHAPTER IV.

SHAFTING, KEYS AND COUPLINGS.

Keys. What are known as *keys* consist either of wedge-shaped, or parallel, or steel. They are used to connect rigidly wheels, cranks, pulleys, etc., to shafts. In general use are shown at (a), (b), (c), (d) and (e) in Fig. 98. In each case one

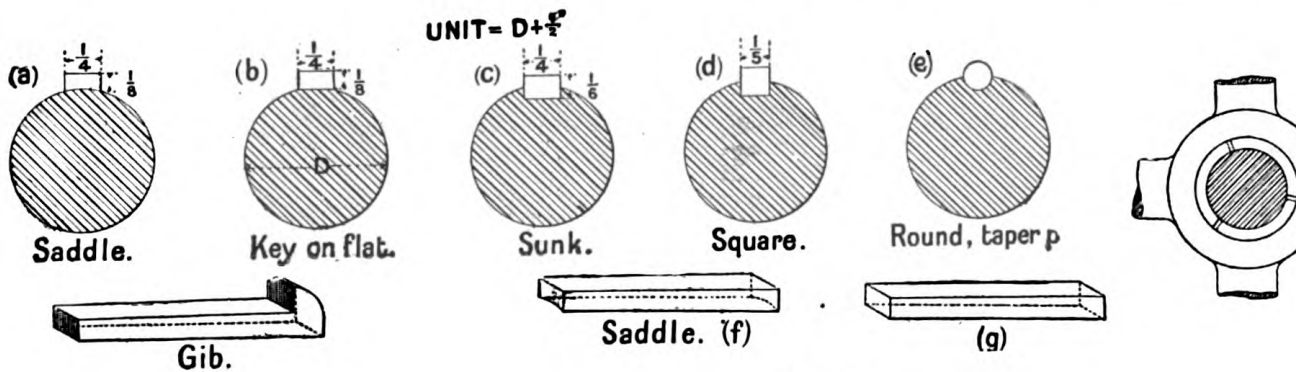


FIG. 98.

head is made slightly thicker than the opposite end, called the *point of the head*. When a key is fitted into suitable grooves in a wheel, or in a pulley, the friction set up forms a rigid connection, and rotation of one ensures the rotation of the other. The resistance to motion depends to some extent upon the shape of the key and the surface on which it is used. In light pulleys and wheels, where the resistance to motion is comparatively small, as in light pulleys and wheels, where a **key** (Fig. 98 (a)) may be used. The under surface of a saddle key is made hollow in this manner a wheel, or pulley, can be fixed in any desired position along a shaft.

The resistance to slipping is increased when the under surface of the key (b) is of the form of key is that at (c), called a *sunk key*, in which one-half the key is sunk in the remaining half in the wheel or pulley.

In certain cases, as in some machine tools, a square key, as at (e) (Fig. 98), is parallel from end to end, and some means must be adopted to prevent the key moving in one direction during the rotation of the shaft. In many cases this endlong motion is prevented by a plate, or washer, fastened by a set screw to the end of the shaft.

Proportions of keys. When the diameter of a shaft is known, it is important to know the dimensions of a suitable key. These dimensions may be obtained by calculation; or, such as the following, may be used and should be committed to memory.

The proportional unit is obtained first by adding $\frac{1}{2}$ " to the diameter of the shaft. The depth of the key are then expressed as fractional parts of the unit, as follows:

Saddle and key on flat: breadth $\frac{1}{4}$, depth $\frac{1}{8}$.

Sunk key: breadth $\frac{1}{4}$, depth $\frac{1}{6}$.

The practical method is to increase the diameter of the shaft by half an inch over that to which the shaft has been drawn and then to take $\frac{1}{4}$, and $\frac{1}{8}$ or $\frac{1}{6}$ th of the distance so obtained.

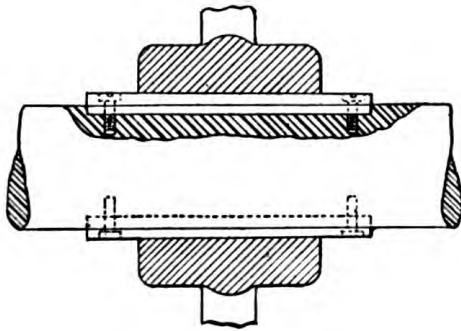
Example. Find the dimensions of the key for a shaft $3\frac{1}{2}$ " diameter (a) for a saddle, or key on flat, (b) for a sunk key.

Adding $\frac{1}{2}$ " to the given diameter the unit becomes 4".

$\therefore$ (a) = 1" and $\frac{1}{2}$ ", (b) = 1" and $\frac{2}{3}$ " are the breadth and depth respectively.

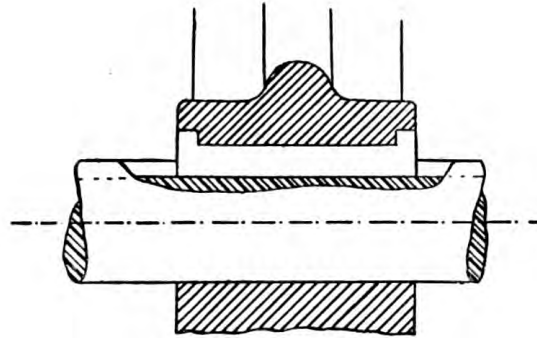
Gib key. To dislodge a key of the form shown at (f) and (g) (Fig. 98) it is necessary to be able to drive it in a backward direction from the point end of the key. In some cases, a projection on the shaft may occur as at (Fig. 99), and the point of the key is inaccessible. In such circumstances what is called a *gib key* may be used, since this form of key may be released, if necessary, by inserting a pin, marked S.

Sliding keys. A wheel, or pulley, is sometimes required not only to turn with the shaft but also to slide in the direction of the length of the shaft. In such a case the key is made square in cross-section as at (d) (Fig. 98). Such a key may be fastened to the shaft with screws, as indicated in Fig. 100. Another arrangement is shown in Fig. 101, in which the key is fastened to the wheel, or pulley.



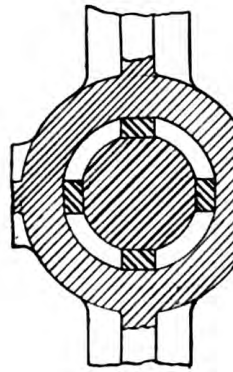
Sliding Keys.

FIG. 100.



Key fixed to Wheel.

FIG. 101.



S

Staking on. In the case of large wheels and pulleys the hole is sometimes made larger than the diameter of the shaft, and the two are fastened together by four taper keys (Fig. 102) as *staking on*.

Taper of a key. The taper of a key varies from $\frac{1}{8}$ " to $\frac{3}{16}$ " per foot of its length. A fraction corresponding to a taper of 1 in 96 is used.

Cone keys. To enable a wheel, or pulley, to pass over projections such as a keyway in the shaft, the hole is made larger than the shaft, and also what are known as *cone keys* are used between the shaft and the pulley. Cone keys are usually made of cast iron and are in the form of a hollow cylinder; the inner surface is bored to fit the shaft and the outside is turned to form to fit the hole in the pulley, or wheel. When this has been done, the cast

or four equal portions, as in Fig. 98A. The pulley, or wheel, is secured to the shaft keys firmly into place.

In another arrangement, a screw thread is formed on the outside of the cone thread on the inner surface of the wheel, or pulley. Holding the cone keys at rest, as tightly as is necessary to secure it firmly to the shaft. The direction of rotation resistance of the belt on the pulley tends still further to increase the grip.

Shafting. The material generally used for shafting is either wrought iron or mild steel, rarely, if ever, employed for such a purpose. The cross-section is usually circular. Except by such special cases as the shafting used in some overhead travelling cranes in which square shafts are used.

The strength of a circular shaft to transmit force depends upon the cube of its diameter. The strength of two shafts of the same material, and 2" and 3" diameter respectively, would be in the ratio of the cubes of the diameters, or as 8 to 27, or as 1 to 3.4. Whilst the weights of equal lengths of the shafts are proportional to the squares of the diameters, or as 4 to 9, or nearly 1 to 2. Hence, if the weight of a given length of shafting being retained, its strength may be increased by making the shaft hollow. Thus, for example, a hollow shaft in which the external diameter is 20" and the internal diameter 14", would weigh about the same as a solid shaft 20¾" diameter, but would be about double the strength.

The torsional strength of a circular solid shaft is given by

$$T = \frac{\pi}{16} f d^3, \dots\dots\dots$$

where T is the twisting moment in lbs. inches, d is the diameter of the shaft in inches, and f is a constant depending upon the material of the shaft. Thus, f for wrought iron is usually 8,000 lbs. per sq. in. and f for steel about 13,500 lbs. per sq. in.

In the case of a hollow steel shaft, of external diameter D , and of internal diameter d , the formula becomes

$$T = \frac{\pi}{16} f \left(\frac{D^4 - d^4}{D} \right), \dots\dots\dots$$

where f has the same value as before.

When the numerical value of T is known, the diameter of a shaft may be obtained by calculation from (i) or (ii).

The twisting moment that can be transmitted safely by a shaft of diameter d , or of external diameter D and internal diameter d , can be obtained easily by calculation from (i) or (ii).

If l is the length, and b the width of a key, then if l is known, b can be found

$$lb f \times \frac{d}{2} = \frac{\pi}{16} d^3 f.$$

For convenience in handling and in manufacture, shafts used in factories, and made in convenient lengths of from 20 to 30 feet. These separate lengths are joined by suitable couplings. These couplings, may, as in marine shafts, be made in one piece or made separately and afterwards fastened to the shafts by means of keys.

Shaft couplings. The couplings used in connecting together lengths of shafting are divided into two classes, viz.: *fast*, and *loose or disengaging* couplings. Of the fast couplings, those of renewal or repair, rarely require to be disconnected. The couplings in general are *box or muff*, *half-lap*, and *flange* couplings.

Loose or disengaging couplings are of many different forms. Thus, one coupling consists of projections fitting into corresponding recesses of the other (Fig. 107, p. 78). Such couplings are used for slowly moving shafts; but for shafts moving more quickly some form of friction coupling is used, the wedging action between two conical surfaces, which may be forced together or released by means of a wedge actuated by a screw. When the wedge is forced into the coupling, due to the expansion of the ring, are held together firmly without slipping, one shaft ensures the rotation of the other. When the wedge is withdrawn, the shafts are free to rotate independently, one shaft, rotates freely without giving motion to the other.

Box or muff coupling. A *box or muff coupling* is shown in Fig. 103. It consists of a box B , in the centre of which the two shafts S_1 and S_2 meet. The coupling is fixed to one shaft, say S_1 , by placing a key in position. The other shaft S_2 is then placed in position, and the coupling is fixed to it until the centre of the coupling coincides with the ends of the two shafts. The coupling is then generally to fasten each end of the shaft to the coupling.

It will be seen from Fig. 103 that the point end of one key is not in contact with the other, but the two are separated by a short interval. This device enables the firm

used as a driver to release the second key. In this manner the loosening and re-assembly is facilitated.

In some cases only one key is used, and this is the full length of the coupling. This arrangement requires that the key ways in the ends of the two shafts shall be exactly the same and is not so good an arrangement as the preceding one.

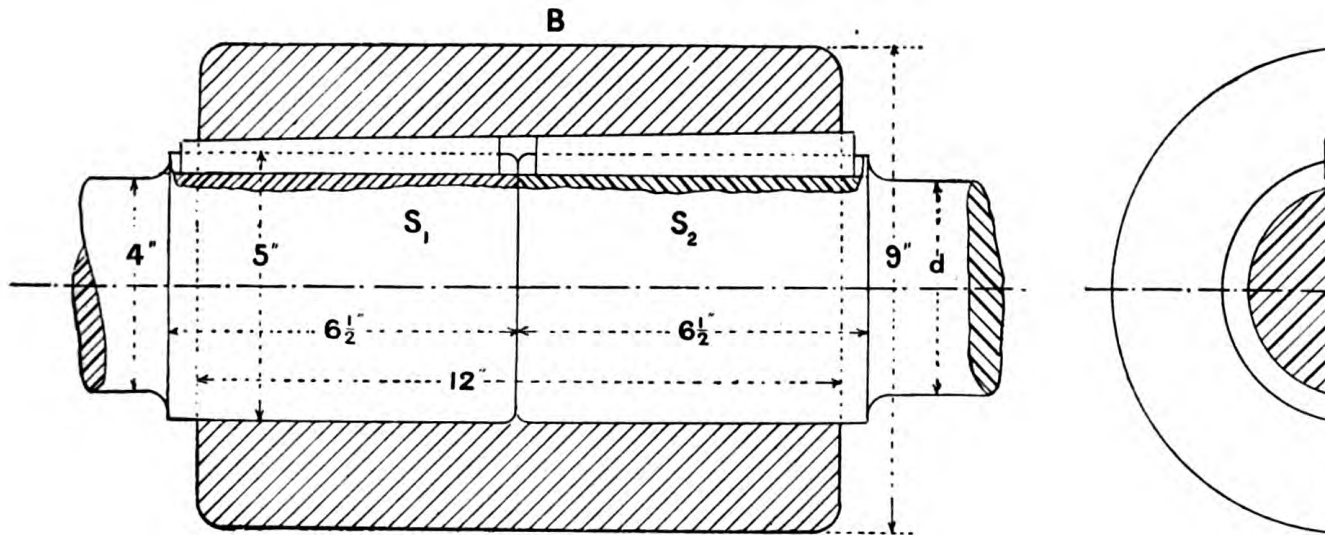


FIG. 103.—Box or Muff Coupling.

The following proportions may be used to determine the dimensions of a box coupling.

Length of coupling = $3d$

Diameter „ = $2\frac{1}{4}d$

Diameter of enlarged portion of shaft = $1\frac{1}{4}d$,

where d denotes the diameter of the shaft.

The following table gives some dimensions of couplings suitable for shafts up

BOX OR MUFF COUPLINGS.

Diameter of shaft, -	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	
„ „ coupling, -	$4\frac{1}{2}$	$5\frac{5}{8}$	$6\frac{3}{4}$	$7\frac{7}{8}$	9	$10\frac{1}{8}$	1
Length of coupling, -	6	$7\frac{1}{2}$	9	$10\frac{1}{2}$	12	$13\frac{1}{2}$	1

Example. Draw half size the two views of a box coupling (Fig. 103).

Half-lap coupling. In the *half-lap coupling*, introduced by Sir William Fairbairn, shafts are made to overlap each other and are usually fastened by a key as in Fig. 102. The taper of the half lap prevents the separation of the two shafts due to any pull length of a shaft. The taper is about 1" per foot or 1 in 12. Couplings of this kind are made and are therefore not often used.

The dimensions of a half-lap coupling for a given diameter d of shaft are the following proportions :

Length of coupling = $2d$. Diameter of coupling = $2\frac{1}{4}d$. Diameter of enlargement = $2\frac{1}{2}d$.

Oldham's Coupling, Fig. 104a, may be used when the axes of the shafts are parallel, but the shafts are not in line. A flange F with two projecting pieces at right angles to one another, fit recesses in the shafts. Draw half size.

Example. Draw half size the two views of a half-lap coupling (Fig. 102).

Flange couplings. A flange coupling, or a *face plate coupling*, is usually made in two halves of the coupling are turned in the lathe, the holes bored to fit the shaft

The parts are then keyed to the shafts, the head of the key in each case being at the end. When this has been done, each shaft is again put into the lathe centres and the two flanges which fit together, are made perpendicular to the axis of the shaft. The rotation of the process of turning the nuts is prevented by making the bolts fit the holes in the flange or, a small pin or snug may be inserted close to the head of the bolt for the same purpose.

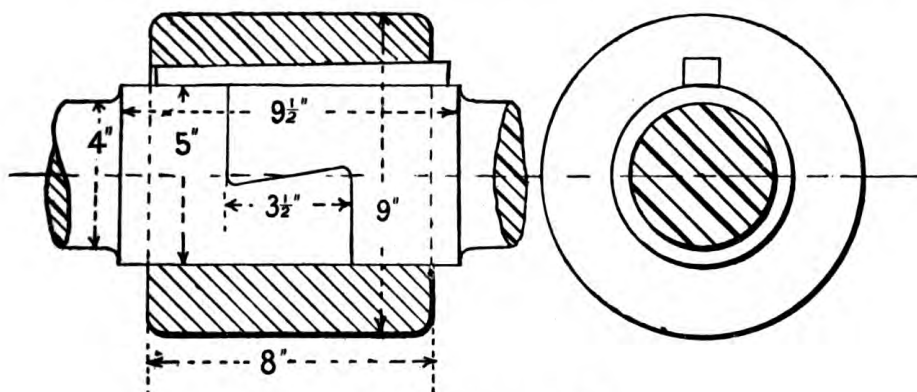


FIG. 104.—Half-lap Coupling.

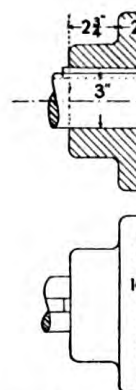


FIG. 104A.—C

One coupling is made to enter a short distance, $\frac{1}{4}$ " or $\frac{3}{8}$ ", into the other. This prevents the couplings from being in line with each other. When necessary the flanges of the couplings are made of sufficient thickness to allow recesses to be formed for the bolt heads and the nuts as in Fig. 108.

The dimensions of a *flange coupling* for shafts of diameter d may be found from the following:

Diameter of boss = $2d$, thickness of flange = $\frac{1}{2}d$

Length of flange and boss = $1\frac{3}{4}d$.

Example. Draw half size the two views of a flange coupling (Fig. 105). A

Coupling for marine shafts. In the shafts for marine engines, the flanges are usually cast with the shaft and are secured by bolts. For this purpose taper bolts—which are tapered at the ends—are employed. The number of bolts used is generally 6, 8, 9, or 12. The

shafting are filleted into one another to keep them in line, or the flanges are each to receive a steel disc. The bolts are made with heads, as shown in Fig. 106. The following table gives particulars of some couplings taken from actual practice (the

MARINE FLANGE COUPLINGS.

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

Example. Draw two views, half sectional elevation and end view of Scale half size. Also draw a plan.

Example. Draw two views of a coupling for a marine shaft $16\frac{1}{2}$ " diam preceding table.

Claw, or disengaging coupling. In the forms of couplings, shown in Fig. 107, one ha to one shaft S_1 by means of a *sunk key*; the other part **D** is connected to the shaft S_2

By means of a suitable lever, centred outside the axis of the shaft and having the coupling **D** can be brought into contact with, or moved away from, the par

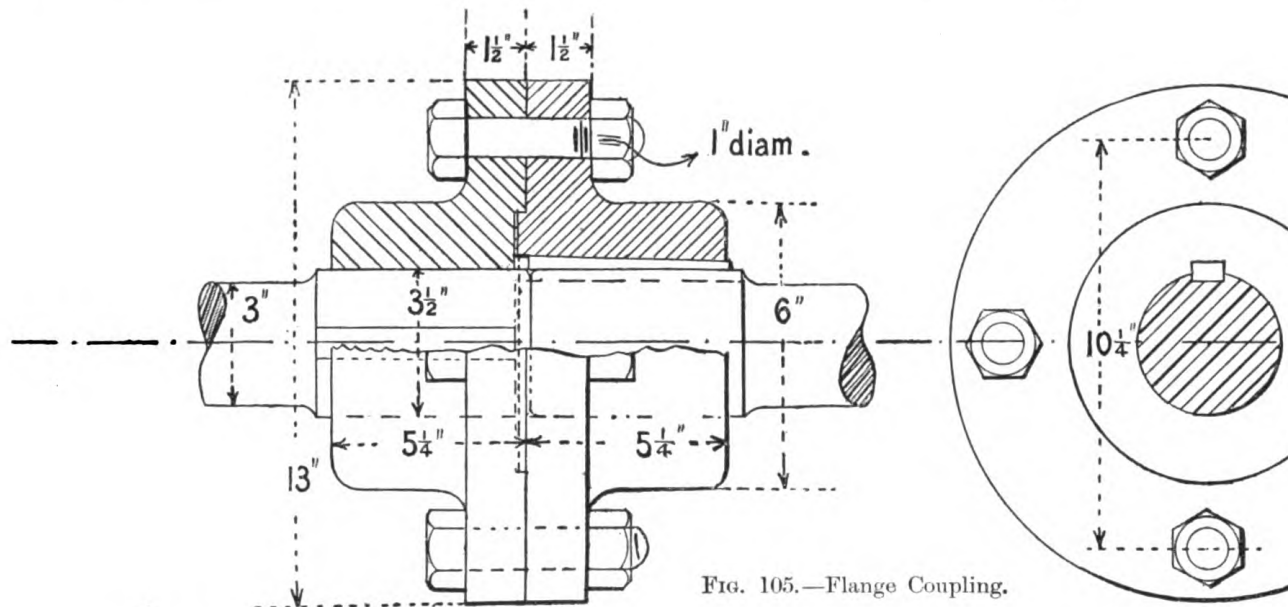


FIG. 105.—Flange Coupling.

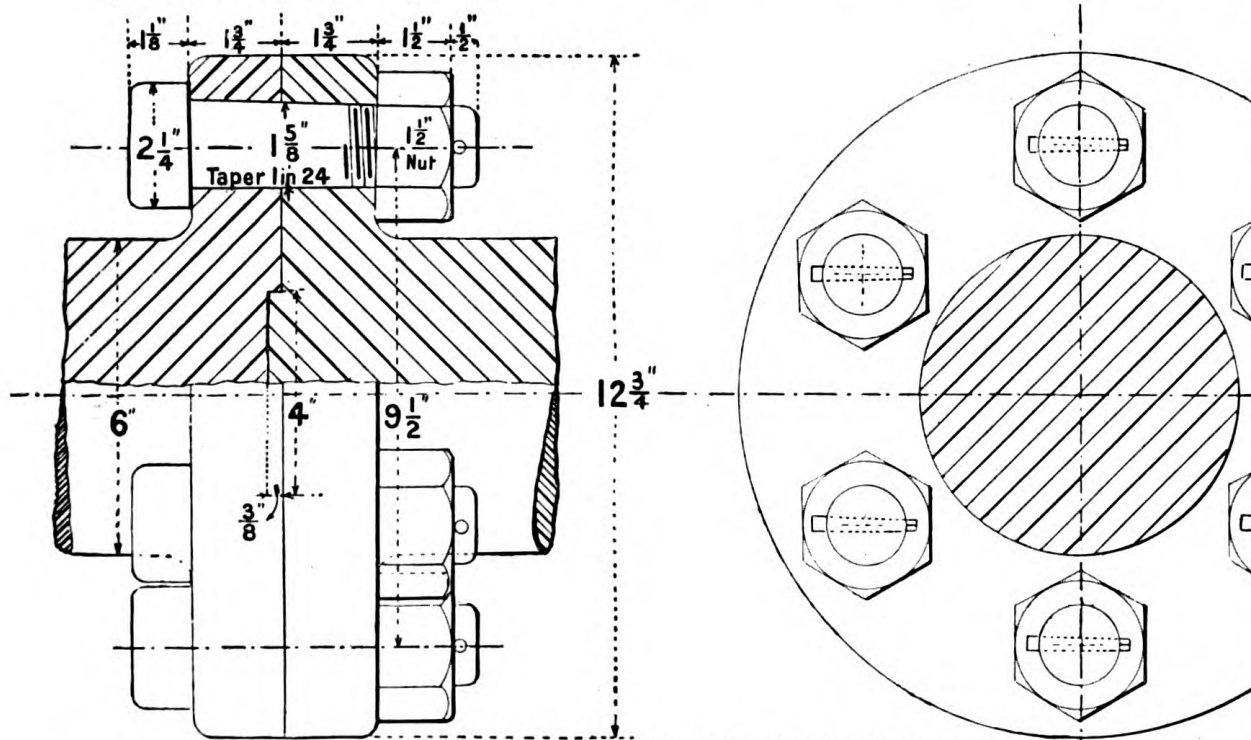


FIG. 106.—Coupling for Marine Shaft.

the driver it follows that when the two couplings are in gear, the shaft to which but when **D** is drawn out of gear with **B**, then **B** will remain at rest.

Example. Draw the disengaging coupling (Fig. 107). Scale half size.

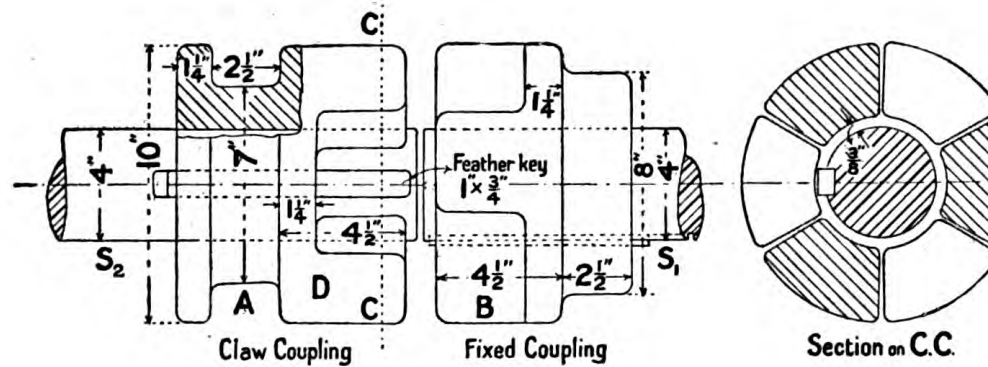


FIG. 107.—Disengaging Coupling.

Friction cone coupling. This coupling (Fig 108) closely resembles externally a flange coupling. The keys are bored to fit the shaft and the outside turned taper to fit corresponding holes in the halves of the coupling are drawn together by means of the bolts, the sloping surfaces of these very tightly against the shaft, and in this manner rotation of one ensures the rotation of the other.

Hooke's Joint or Universal Coupling is used to connect two shafts the axes of which intersect at a point so that the angle between the shafts may alter while they are in motion (Fig. 108A).

Example. Draw half size the sectional elevation and end view of the coupling.

Flexible coupling. In the preceding types of coupling the object throughout is rigidity; the turning of one shaft must give the same definite motion to the other. In no yielding or slipping of the couplings is supposed to occur. There are many cases in machinery, especially where sudden shocks, or where twisting forces, are suddenly applied, where a shaft may fracture (e.g., a shaft). In such cases the shaft must be sufficiently rigid to transmit

must also be flexible enough to yield to any sudden shock without fracture. Such as a *flexible coupling*, and may consist of two parts resembling a flange coupling, one to one shaft and the other half to the other shaft. But the two halves, instead of bei

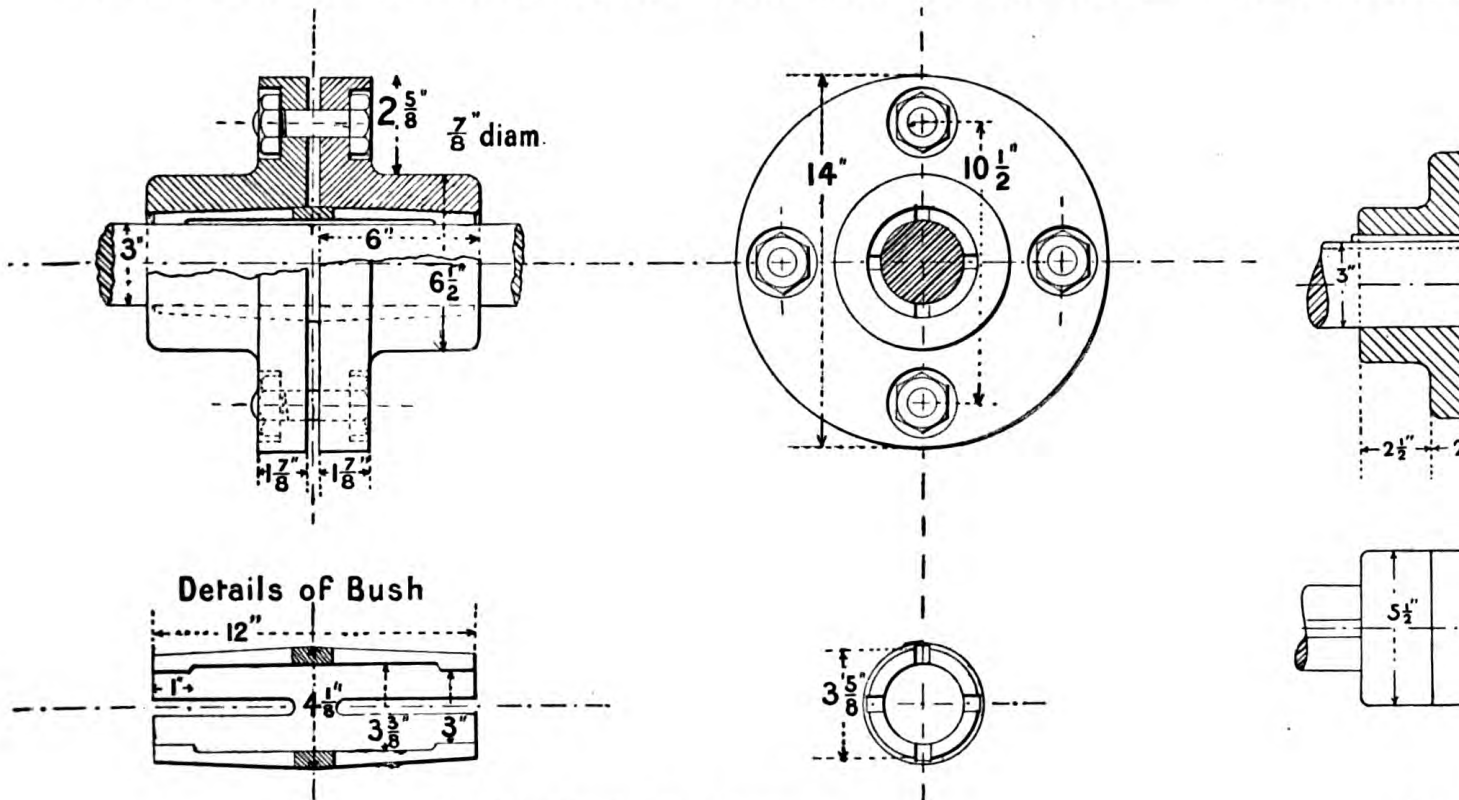


FIG. 108.—Friction Cone Coupling.

a rigid bolt connection, are connected by steel springs, as in Perry's Transmission Dyn disc or ring of leather, as in Fig. 109, where, as shown by a zig-zag section, a ring of leather means of 6 screws to the coupling A and also to the coupling B. In such an arrangement action is allowed for by the flexibility of the steel springs, or the leather.

Example. Draw half size the two views of the flexible coupling (Fig.

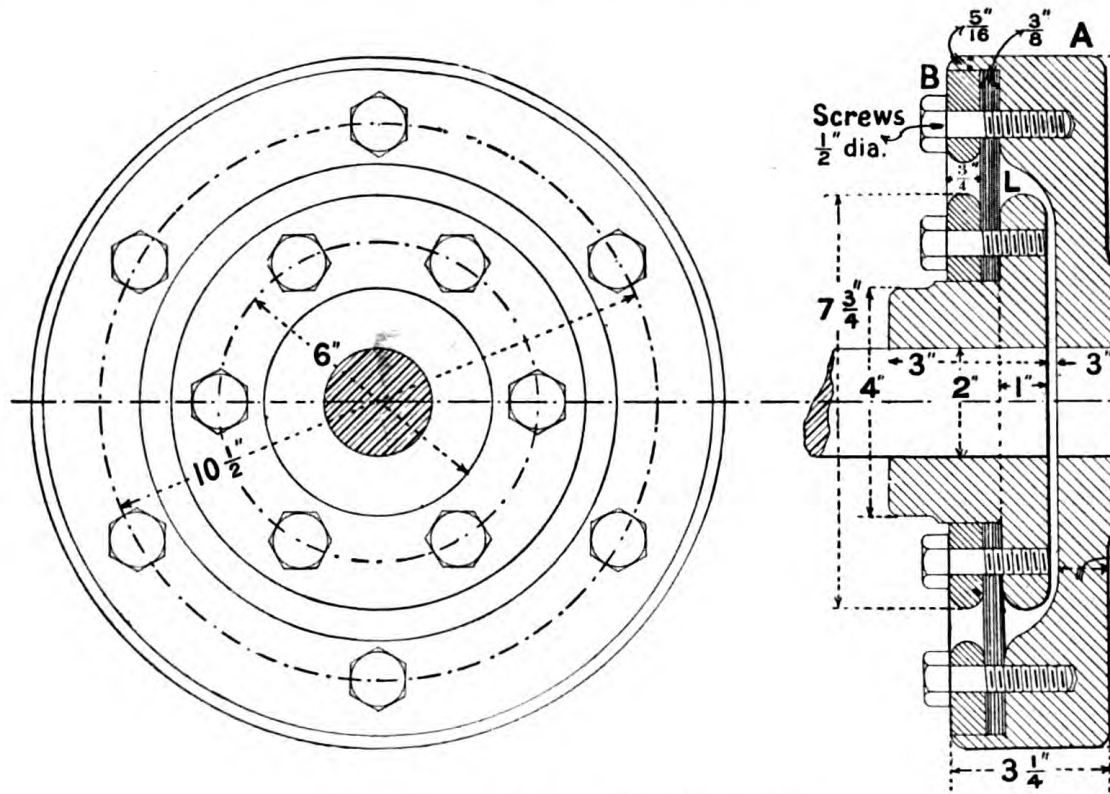


FIG. 109.—Flexible Coupling.

EXERCISES. IV.

1. Show by sketches some of the various methods of fitting a key to prevent shaft and a piece which is mounted on it. Quote an example of the use of mentioning the difference in the circumstances of each.

2. Describe a coupling for shafting on which there are no projecting bolt heads, nuts or washers.
3. Of what material is shafting usually made. Show by means of a sketch the use of a loose collar on a neck or journal. Explain the use of loose collars.
4. In some forms of flange couplings the bolt heads and nuts are placed in circular projections. Sketch some form of box-key or spanner which may be used for tightening such couplings.
5. Sketch two or three forms of coupling suitable for mill shafting.
6. What is the object of using cone keys for fastening pulleys to shafts?
7. Two shafts of 2" diameter are connected by a muff or box coupling. Draw a side elevation and plan. (Scale half size.)
8. Show by sketches how a wheel is fixed on a shaft by means of a sunk key. Show also a method by which the key may be withdrawn when it cannot be driven from the point end.
9. Give sketches showing how the separate lengths of a line of shafting may be connected.
10. Show by sketches a claw or disengaging coupling (or friction clutch). Explain how it is put in and out of gear whilst the shaft is running.
11. Describe with sketches (a) how you would proceed to cut a parallel and square key in a pulley or wheel; (b) how you would proceed to fit such a key; (c) state the advantages of a feather or sliding key so as to permit a pulley or wheel to be moved endways along the shaft.
12. Sketch and explain the modes of fixing a wheel or pulley by means of a key, by a pin, by a screw, by keys, and by staking on. In each case give suitable dimensions for a shaft $3\frac{1}{2}$ " diameter.
13. Sketch a butt or muff coupling and a half lap and a flange coupling, suitable for mill shafting. State any circumstances when one may be used in preference to the others. Give suitable dimensions.
14. With the aid of sketches describe how the following four kinds of fastening are used together parts of machines—quote one example of each fastening, in which it is the best kind of fastening rather than one of the others: (a) a bolt and nut, (b) a rivet, (c) a cotter pin, (d) a screw.

CHAPTER V.

BELT AND ROPE PULLEYS.

Belt pulleys. If **A** and **B** represent two shafts on each of which a pulley is fastened, and a belt is run round them, so that the rotation of one shaft will cause the rotation of the other. If **A** is the driver, and **B** is driven by it (usually called the *follower*), then when an open belt is used, **B** will revolve in the same direction as **A**, and in the opposite direction when the belt is crossed (Fig. 110). The speed of **B** with that of **A** will depend upon the sizes of the pulleys on **A** and **B**.

Let **N** denote the number of revolutions made by **A** in a given time, and **n** that of **B** in the same time; also let **D** denote the diameter of the pulley on **A**, and **d** that on **B**.

If no slipping occurs between the belt and the rim of the pulley, the speed of **B** will be the same as that of the belt.

Speed of rim of **A** = $D \times \pi \times N$, and this must be the same as the speed of **B** = $d \times \pi \times n$.

$$\therefore D\pi N = d\pi n$$

$$\text{or } \frac{n}{N} = \frac{D}{d} \dots\dots\dots$$

It follows that when the diameters of the pulleys are the same, the number of revolutions of **B** will be the same as **A**.

Example. Let the pulley on **A** be 36" diameter, and make 100 revolutions per min. If the pulley on **B** is 12" diam.,

$$\text{Speed of } \mathbf{B} = \frac{36 \times 100}{12} = 300 \text{ revol. per min.}$$

Length of Belt. A good approximation to the length of belt required may be obtained by the following construction. Let **A** and **B** (Fig. 110) denote the two pulleys. Draw **CF** the common tangent to the two circles, then one-half the length required is obviously the arc **DC**, the length **CF** and the length **FE**. Divide the arc **CD** into four equal parts so that **Cb** is $\frac{1}{4}$ **CD**. With **C** as centre and **Cb** as radius, describe an arc cutting **FC** produced in **R**. Then with **R** as centre and **RD** as radius, describe an arc

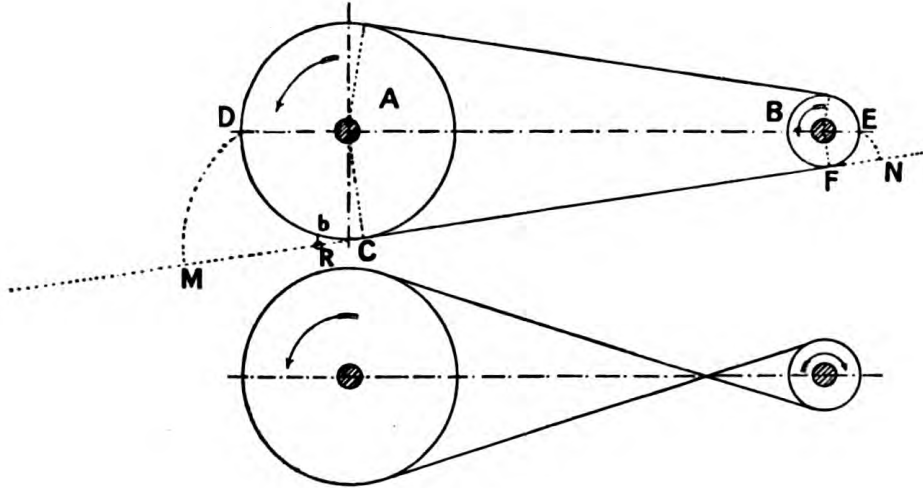


FIG. 110.

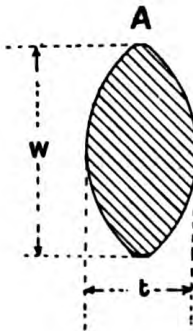


FIG. 111.—A

in **M**. The length **CM** is equal to the arc **CD**. In a similar manner, obtain the point **N**. The length **MN** is the length of belt required.

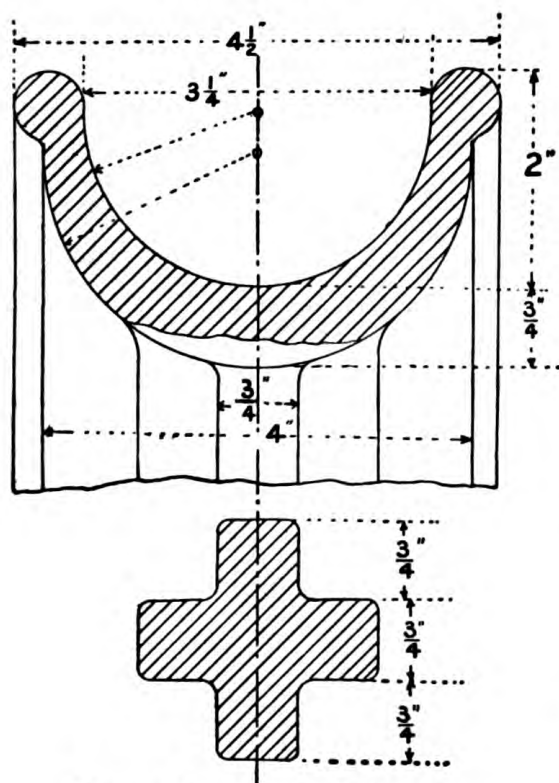
Pulleys made of cast iron are commonly used for comparatively low speeds, but are not sufficiently trustworthy or safe in the case of high speeds. For such high speeds the pulley is made of cast iron, the rim and arms are either wrought iron or mild steel. Pulleys made of steel have less weight than those of cast iron and are more trustworthy.

Arms of pulleys. The arms of pulleys when made of cast iron may be *segmental* or *elliptical* as at **B**, or *cross-shaped* as shown in Fig. 114. The thickness **t** (Fig. 111) is

When the arms are made of wrought iron the cross-section is circular, one end being made taper to fit a corresponding taper hole in the cast iron boss of the pulley. The other end fits into the rim, which is usually provided with a collar pressing against the rim as in Fig. 112.

By releasing the joint in the rim and also the four bolts at the centre, the pulley can be placed in position on the shaft. The hole is made slightly smaller than the shaft, and the pulley is secured to the shaft by tightening the bolts in the boss.

Rope Pulley



Cross Section of Arms.

FIG. 114.

Example. Draw the wrought iron pulley (Fig. 112). Scale $\frac{1}{3}$. Make any necessary section in the right-hand view.

Rims of pulleys. The rim of a pulley for a belt may be either *flat* or *convex*. The convex tends to keep the belt in the middle of the pulley as in Fig. 113, are sometimes provided for the same purpose. This form of pulley is known as a *flanged pulley*, or *sheave*. Various forms of rims for various pulleys are shown in Figs. 115, and 116.

Rim for rope pulley (Fig. 114). The rope lies in the groove.

Example. Draw the section of the rim of a rope pulley Fig. 114. Scale half size.

Rim for wire rope. To prevent injury to the rope the rims of pulleys for wire ropes are made so wide that the rope does not press against the sides of the groove, but is merely supported by the rounded bottom of the groove. To prevent the rapid wear of the iron, the bottom of the groove is lined with wood or leather. The leather is made in pieces of the shape of the groove.

hammered in. When a wood lining is used, the pieces are inserted through an opening in the rim, and when the lining is completed the opening is closed by using a metal plate. The form of rim is shown in Fig. 115.

Rim for chain pulley. In differential pulley blocks, in cranes, etc., in which chain is used, the rim is of the form shown in Fig. 116.

Use of curved arms. Various practical methods are adopted to ensure uniformity in the process of casting a pulley. One plan is to uncover the thicker parts of the pulley near the centre—and to leave the thinner portions—such as the rim and arms—covered.

But even when this precaution is adopted, when the arms of the pulley cool, and in consequence unequal contraction, introduces unknown initial stresses, it tends to produce fracture—usually at or near the junction of the arm and the rim.

When the arms are curved as in Fig. 117, the initial stresses are lessened by curving the arms to straighten during cooling. Three forms of arms are shown in Fig. 117, respectively as a *straight arm*, as a *curved arm*, and as an *S-armed* pulley. The *S-armed* pulley (as indicated) is obtained by using the 30° and 60° set square. This plan gives a mean thickness of the arm is slightly less near the rim than it is near the centre, two centres may be obtained by setting off half the thickness of the rim on each side of the

S-armed pulley. To obtain the mean centres for the curves, make $CD = \frac{2}{3}CE$ at 45° with CB , and Ca perpendicular, thus obtaining the mean centre. Set off equal distances on each side for the respective centres. The centre for the remaining curve is obtained at E by drawing BE perpendicular to Da to meet aD produced in E .

Fast and loose pulleys. A common arrangement in a shop or factory is to have on one engine one or more shafts called *main driving* or *line* shafts. These, by means of belts, transmit motion to smaller shafts called *counter shafts* placed in convenient positions at intervals to be driven. Any of these machines may require to be stopped at intervals, or restarted without disturbing the remainder. An arrangement of fast and loose pulleys is used for this purpose. This arrangement consists of two pulleys of equal size, one of which is fastened to the

BELT AND ROPE PULLEYS

Wire Rope Pulley.

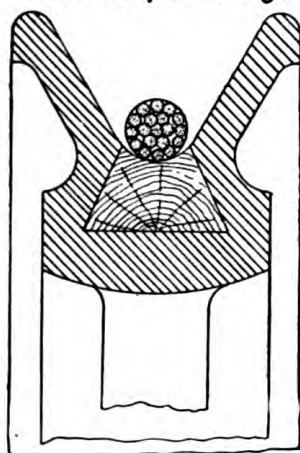


FIG. 115.

Chain Pulley.

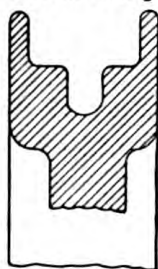


FIG. 116.

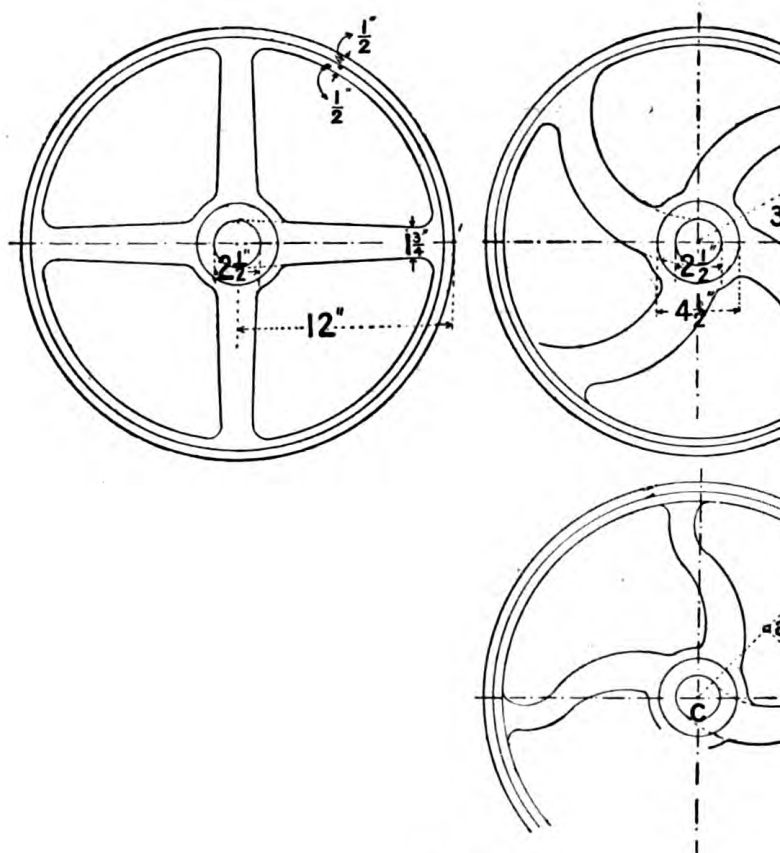


FIG. 117.

a key or a set screw; the other can rotate freely, but any motion in the direction of the shaft is prevented by means of a collar as at **C** (Fig. 118).

Example. Draw $\frac{1}{4}$ size the two views of fast and loose pulleys (Fig. 118).

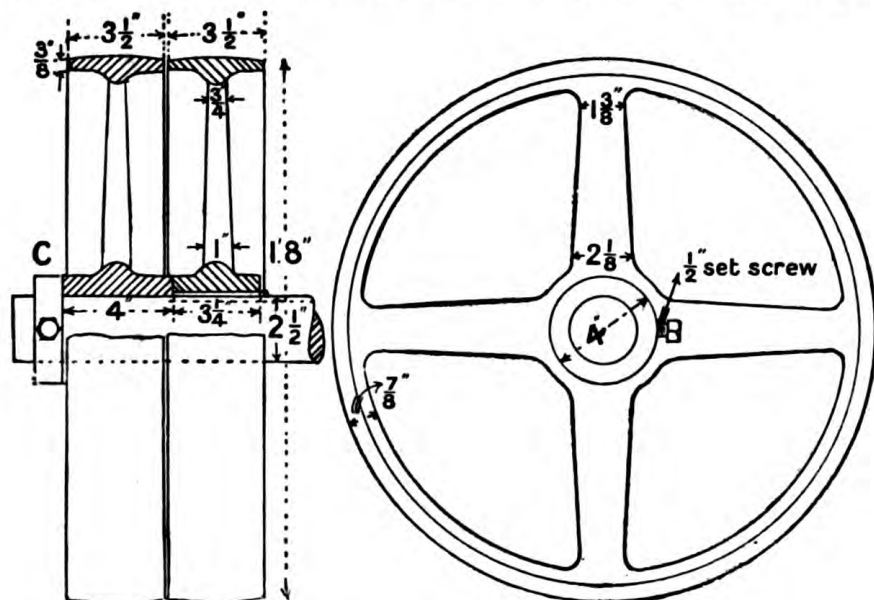


FIG. 118.—Fast and Loose Pulleys.

Speed cones. *Speed cones* are used in machine tools and for many other purposes at different rates of speed. A counter shaft carries—in addition to a fast and loose speed cone (Fig. 119). This cone by means of a belt gives motion to a similar cone and arranged as indicated. The diameter of **A** is 20" and that of **D** is 10". Intermediate pulleys may be found by drawing a line from **A** to **D**.

Example. (a) Draw the three views of the speed cones, Fig. 119. See

(b) If the axes of the two shafts are 15 feet apart, find the length of

(c) If the upper speed cone makes 100 revolutions per minute, find the speed of the lower cone for all positions of the belt.

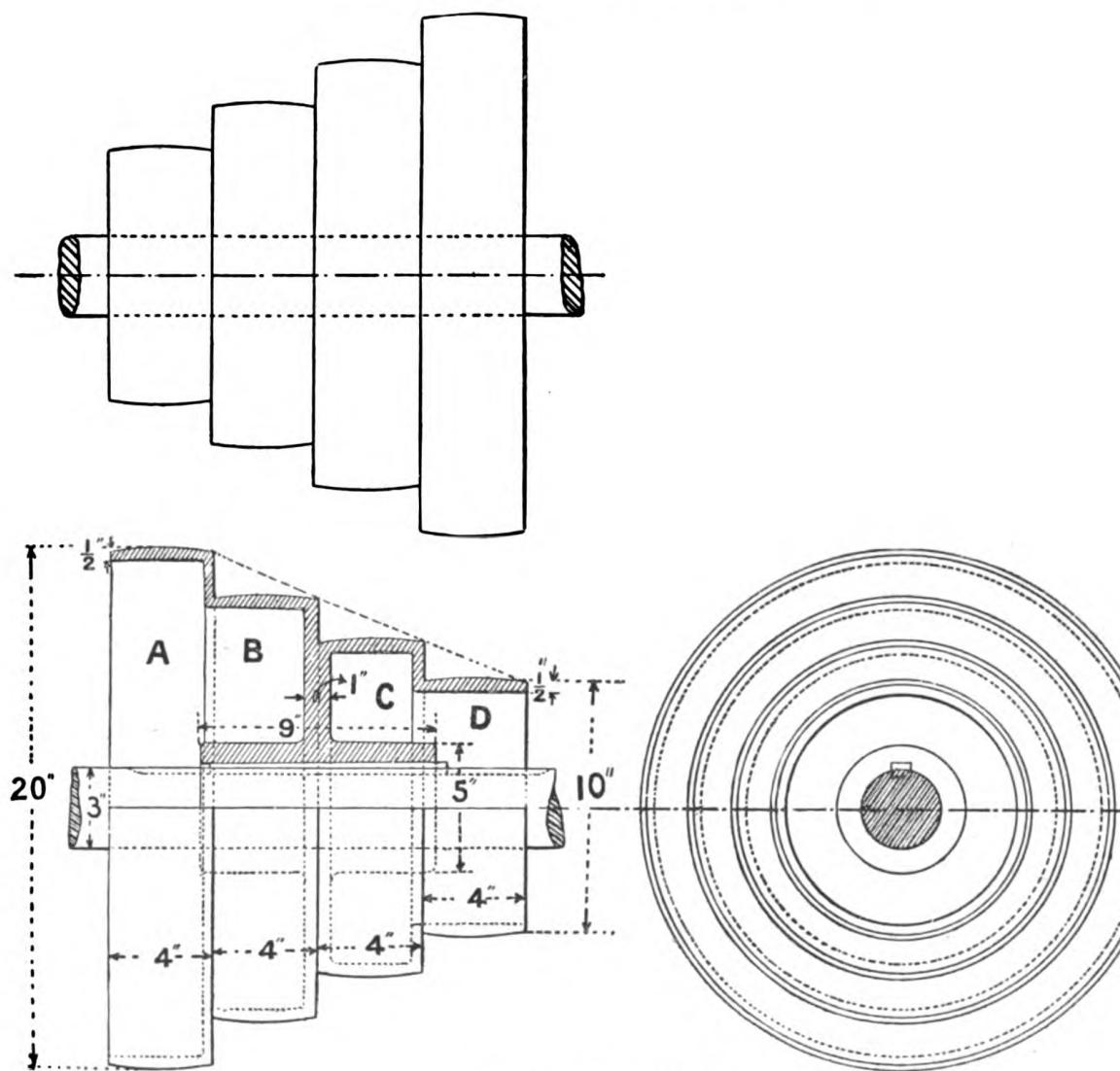


FIG. 119.—Speed Cones.

ords and pulleys shown in Fig. 121. Suitable stops, S, S, prevent the striking bar too far in either direction.

Rope pulleys. Flat belts are not suitable for the main driving pulleys in large works on account of the tendency to slip, and also the liability to total stoppage in the Spur gearing may be used, but rope driving offers many advantages over either b

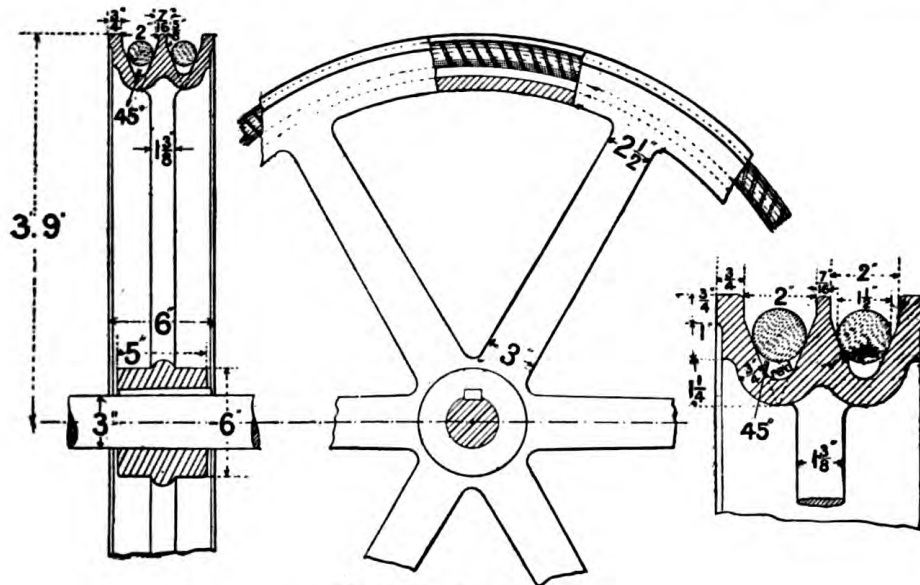


FIG. 122.—Rope Pulley.

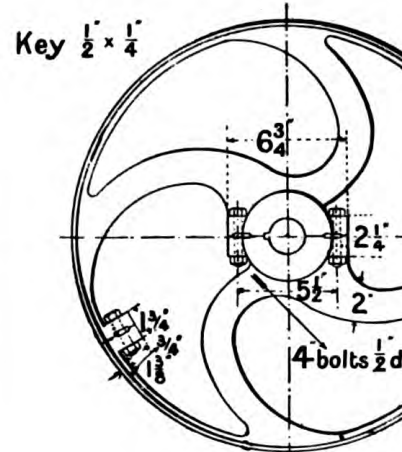


FIG. 123.—Curved

Formerly the ropes used were made from Manilla or Russian hemp, but *cotton* is v The ropes vary in diameter from $\frac{3}{4}$ " to 2". The pulleys are usually of cast iron, and suit the ropes.

One form of the rim is shown in Fig. 122. It will be noticed that the rope r the groove and not on the bottom. The diameter of the pulley used is generally not le diameter of the rope, and the horizontal distance between the pulleys not less than 100 feet. The driving side of the rope should be on the lower part of the pulleys and

The speed of the rope varies considerably. Speeds of 2000 ft. per minute the usual speed is about 4000 ft. per minute. The number of grooves in the rope is determined by the power to be transmitted. When this power is considerable, the number may be 6 or 8, depending upwards of 4000 H.P.

The width of the pulley face can be found by multiplying the number of grooves by the thickness of the flanges, adding to the product the thickness of the outer flanges.

Example. Draw, to a scale of $\frac{1}{4}$ full size, a sectional elevation and end view of a pulley (Fig. 122). Diameter of pulley, 3 ft. 9 in.

Example. Draw half size the two views of a curved arm split pulley.

EXERCISES. V.

1. Give any reasons you can why the rims and arms of cast iron pulleys are the objections to straight armed pulleys and how are these overcome?
2. Show, by sketches, an arrangement of fast and loose pulleys. In what circumstances would such an arrangement be used?
3. Show the cross sections of two forms of arms used for cast iron pulleys.
4. Show, by sketches, the construction of a speed or stepped cone pulley, and in what circumstances such a pulley is used.
5. Sketch and describe three distinct ways by which a flat belt may be run over a pulley when running. [B.E.]
6. Show, by sketches, the construction of a belt-pulley having a light malleable iron rim, in such a way that it may be fixed to the shaft without threading it over the end of the shaft.
7. With the aid of a graphical construction determine the length of a crossed belt drive between either of two pairs of pulleys which are mounted on parallel shafts 3' 6" apart. The smaller shaft is 8" diameter and the velocity ratio at the higher speed is to be four times the lower speed.

8. A shaft running at 100 revolutions per minute drives another by a leather belt. The first shaft is 18" diameter; the pulley on the second shaft is 30" diameter. Sketch the arrangement and find the speed of the second shaft. If the same belt is to drive the second shaft at 100 revolutions per minute, find the diameters of the two pulleys.

9. Sketch in section the rims of pulleys suitable for (1) leather belting, (2) wire rope.

10. Show, by sketches, the construction of a split pulley for a line of shafting. How the pulley is secured to the shaft.

11. The section of the rim of a pulley, 24 in. diameter, is given (Fig. 114). The hub is 5½ in. long bored out to 3 in. diameter. It has six arms of the cross section shown. Draw the complete section and elevation. Scale ¼".

12. A pulley, 5 ft. diameter, rotating at 120 revolutions per minute, is connected to a smaller pulley, 2 ft. diameter, on a main shaft. On the main shaft a pulley, 3 ft. diameter, is connected by means of a belt to one of 1 ft. 9 in. diameter on a counter-shaft. On the counter-shaft, the largest and smallest diameters being respectively 12 in. and 6 in.; these drive a pair of speed cones on the spindle of a lathe. Find the highest and lowest speeds at which the spindle can revolve. Sketch the arrangement.

13. A fly-wheel, 6 ft. diameter, revolves 150 times per minute; find the speed in revolutions per second. A belt connects the fly-wheel to a pulley, 2 ft. 6 in. diameter, on another shaft. If the slip of the belt is 2 per cent., find the speed of the driven shaft.

14. The speeds of a driving pulley and the follower are 140 and 80 revolutions per minute respectively, and the sum of their diameters is 66 in. Find the diameters of the driver and follower.

CHAPTER VI.

WHEELS.

Linear and angular velocity. If two cylinders, **A** and **B** (Fig. 124), the axes pressed tightly in contact, then when one rotates the adhesion of the surfaces to the other. If no slipping occurs, the surface of one will move at the same speed as

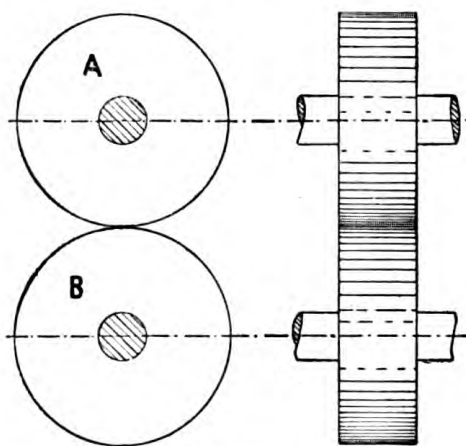


FIG. 124.

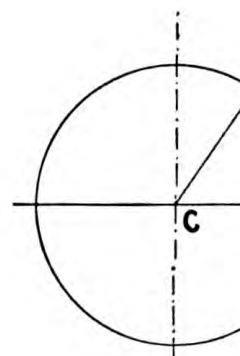


FIG. 125.

surface speed is called *linear velocity*, and is usually estimated by the number of units of time by a point in the rim.

Angular velocity. Another method of estimating the speed is by *angular* rotation, the angle moved through by any radius, such as **CB**, would be 360° of

indicates an angle such that the length of the arc **AB** (Fig. 125) is equal to the radius. We say the angle **ACB** is $180^\circ \div \pi$ or **57°·3**.

The relation between linear and angular velocity is given by

$$\mathbf{v} = \omega \mathbf{r} \dots\dots\dots$$

where $\mathbf{v}$ is the velocity of $\mathbf{B}$ in feet per second, r the distance in feet of $\mathbf{B}$ from the axis of rotation, and ω denotes the angular velocity in radians per second.

If the two cylinders are of equal size, they will each make the same number of turns in the unit of time. If one cylinder is twice as large as the other, the smaller cylinder will make two revolutions whilst the larger makes one. If one cylinder is three times the size of the other, then one will make three revolutions whilst the other makes one, and so on. These facts may be expressed readily by using symbols. If n revolutions are made in unit time, then $\omega = 2\pi n$.

Also, from (1), $v = 2\pi nr$. Thus, $n = \frac{v}{2\pi r}$.

From this result it is seen easily that for the same surface speed, as r increases n diminishes. Thus if r is doubled, n is one-half its previous value.

Example. A cylinder 6 ft. diameter makes 30 revolutions per second. What is its angular velocity? Also what is the linear speed of a point in its rim?

Here $\omega = 2\pi n = 60\pi$ radians

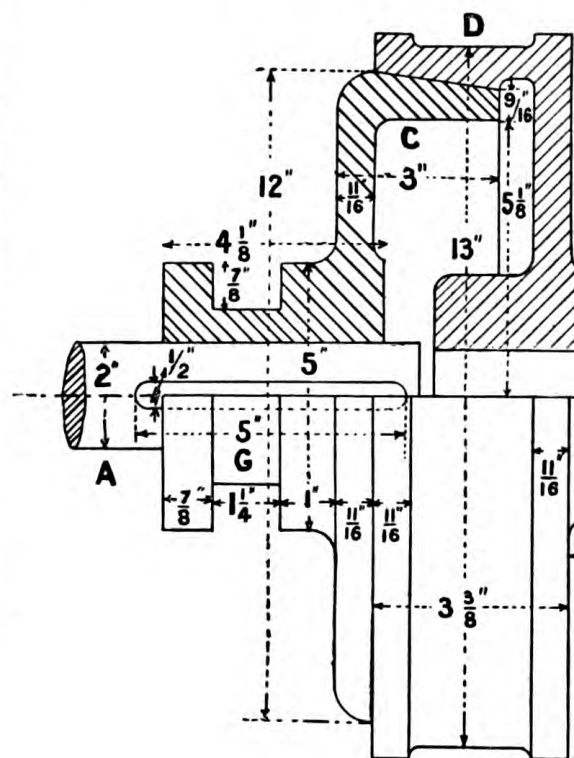
$$v = \omega r = 360\pi \text{ ft. per sec.}$$


FIG. 126.—Friction Clutch.

Friction clutches. The arrangement illustrated in Fig. 124 is used in modified forms in so-called *friction grips* or *clutches*, one of which is shown in Fig. 125. In these devices **A** is the driving shaft on which a friction clutch is mounted, rotating with the shaft

suitable lever operating in the groove **G**, the clutch can be moved backwards or forwards. When in this manner the two inclined surfaces of **C** and **D** are pressed tightly together, they ensure rotation of **B**, and **B** will remain at rest when the clutch **C** is not in contact.

Example. Draw the sectional elevation of the friction clutch shown in Fig. 123, in plan and an end view. Scale half size.

Teeth of wheels. The method shown in Fig. 124, although useful for many wheels, etc., is not always suitable for the transmission of force, for even when the teeth are made together resistances to motion may produce slipping. In order to prevent slipping, teeth are provided on each cylinder, and by this means the rotation of one shaft can be transmitted to the other, the motion being the same as if two cylinders were in contact. The surfaces are called *pitch surfaces*, and the two circles representing the circumferences are called *pitch circles* of the wheels. Such circles are always assumed to exist in every pair of meshing wheels. It is important in wheels gearing together so to shape the teeth that the pitch circles will mesh together without any slipping.

The length of the line or arc joining the centres of two consecutive teeth, as measured along the pitch circle, is called the *pitch of the teeth*, or simply the *pitch*. The various parts of the tooth of a wheel are shown in Fig. 125. The distance the tooth projects above the pitch circle is called the *addendum*. The distance the tooth projects below the pitch circle is called the *dedendum*. The distance the tooth projects above the pitch circle is called the *addendum*. The distance the tooth projects below the pitch circle is called the *dedendum*. The thickness of the tooth, which is measured on the pitch circle, is called the *thickness*. The width of the space between the teeth is called the *space width*, and is denoted by **S**, and the thickness of the rim by **R** (Fig. 127). All the dimensions are given in terms of the pitch, and therefore are found easily when the pitch **p** is known. The proportions represent fairly average values:

H = height of tooth above pitch circle	= 0·3 p.
D = depth below pitch circle	= 0·4 p.
T = thickness of tooth	= 0·48 p.
S = width of space	= 0·52 p.
R = thickness of rim	= 0·48 p.

Other proportional numbers are given in Fig. 128.

Proportions not quite so exact as the preceding are as follows: Divide the pitch (127), and take 8 for the width of space **S**, 7 for **T**; also make **H** = 5 and **D** = 6 of

That is, $S = \frac{8}{15}p$, $T = \frac{7}{15}p$, $H = \frac{5}{15}p$, $D = \frac{6}{15}p$.

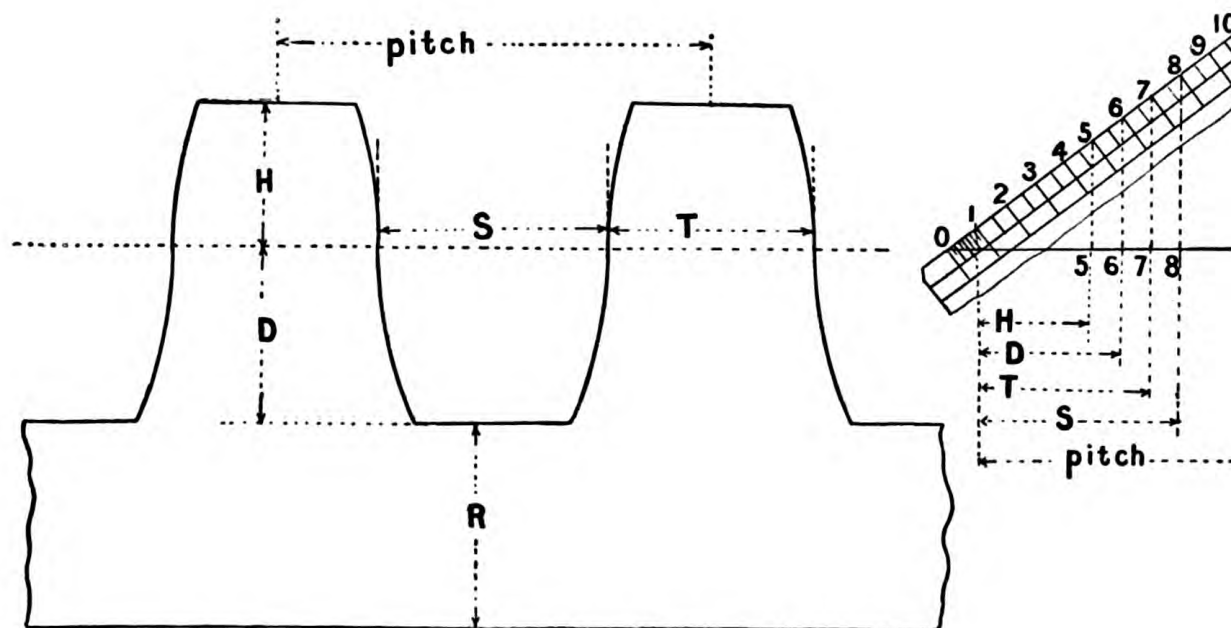


FIG. 127.

C.M.C.

G

When the teeth are made accurately, as in machine moulded wheels and also in the above proportions may be modified, *i.e.* the thickness **T** may be increased slightly and **S** diminished slightly.

For more detailed information reference should be made to works dealing with

The beginner should notice carefully that the fractional parts of the pitch denominator when added together, equal to **p**.

The proportions which may be adopted for the arms of a wheel can also be expressed as in Fig. 128.

It will be found to be a good plan to make drawings of wheel teeth on cardboard afterwards to cut these out as carefully as possible. Then, by placing them in gear, to test the accuracy of his work.

It will be obvious from the preceding definition of *pitch* that the number of teeth multiplied by the pitch will give the circumference of the pitch circle. But this circumference is the diameter of the pitch circle multiplied by π . Hence, we have the relation,

$$\text{Diameter of pitch circle} \times \pi = \text{Number of teeth} \times \text{pitch},$$

$$\pi d = np.$$

where **d** denotes diameter, **n** the number of teeth, and **p** the pitch.

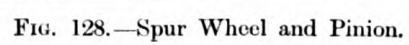
From this relation, when any two of the three terms **n**, **p**, and **d** are given, the third may be obtained. The value of π is usually taken to be $\frac{22}{7}$ or 3.1416. The former value is sufficiently accurate, and the latter when expressed in the form 3.142 is very convenient for four-figure logarithms.

Example 1. A wheel has 30 teeth of 2" pitch. Find the diameter of the wheel.

$$d = \frac{30 \times 2}{\pi}$$

$$\log d = \log 60 - \log \pi = 1.2810;$$

$$\therefore d = 19.1 \text{ inches.}$$



Example 2. The pitch of the teeth of a wheel is to be 3" and the pitch circle as nearly as possible equal to 4 ft. Find the number of teeth.

$$n = \frac{48 \times \pi}{3} = 16\pi,$$

$$\log n = \log 16 + \log \pi = 1.7013;$$

$$\therefore n = 50.27.$$

It is obvious that there cannot be a fractional part of a tooth in a wheel. 50 is the nearest whole number for the number of teeth, and calculate the diameter.

$$d = \frac{50 \times 3}{\pi} = \frac{150}{\pi},$$

$$\log d = \log 150 - \log \pi = 1.6789;$$

$$\therefore d = 47.74.$$

Rack. The circumference of a circle approaches nearer and nearer to a straight line as the radius of the circle is increased. When the radius is considered to be infinitely long, the circumference becomes a straight line, the proportions adopted for the teeth obviously remain unaltered.

Wheels and pinions. When two wheels of unequal size are in gear, the larger is called a *wheel* and the smaller as a *pinion*.

In Fig. 128 the elevation and section of a **spur wheel and pinion in gear** is shown. The wheel has 30 teeth of 2" pitch and the pinion 15 teeth of 2" pitch.

The diameter of the pitch circle of the wheel is given by $d = \frac{30 \times 2}{\pi} = 19.1$.

The diameter of the pitch circle of the pinion = $\frac{15 \times 2}{\pi} = 9.55$.

Draw a circle 19.1 diameter and divide the circumference into 30 equal parts for the teeth, draw a line **AB** equal to the pitch and divide this, as in Fig. 128, into 30 equal parts. Make the thickness of the tooth 7 of these parts, width of the space between teeth 6 of these parts, and **D** = 6 parts.

The curves for the teeth are usually drawn with centres on the pitch circle and a pitch. The flanks of the pinion may be made radial, *i.e.* drawn to the centre of the pitch circle.

Example. Draw the given wheel and pinion (Fig. 128). Scale half full size.

Forms of the teeth. It is beyond the scope of a book of this kind to enter into details of the various forms which are adopted for the curved portions of the teeth of wheels. The form adopted is usually a *cycloid*. Such a curve is formed by a point in the periphery of a cylinder or disc rolling on a straight surface; it is called an *epicycloid* when the disc referred to rolls on the *outside* of a circle, and a *hypocycloid* when it rolls on the *inside*. The disc is usually called the *rolling circle*.

It is instructive to obtain these curves not only by the usual geometrical method, but also practically. Thus, a sector of a circle representing a portion of the pitch circle may be made of thin wood, sheet zinc, etc., and the rolling circles may consist of small discs of wood or metal.

A convenient method is as follows: Draw the circle representing the pitch circle on a piece of tracing paper a smaller or rolling circle; make a mark on the circumference of the rolling circle and a corresponding mark on the tracing paper; put the two circles touching each other at the point marked; then, inserting a pricker, or the needle point of a pair of dividers, roll the smaller circle round the larger one, marking successive positions of the point. In this manner the two curves of the upper part or *face*, and the lower part or *flank* of a tooth may be obtained.¹

Rolling circle. The diameter of the rolling circle is usually made equal to the diameter of the pitch circle. An exception to this rule is furnished by a set of change wheels for a lathe, in which the diameter of the smallest wheel in the set are made *radial*, *i.e.* the diameter of the rolling circle is made equal to the radius of the pitch circle of the smallest wheel of the set.

Conventional methods. In working drawings it is customary to draw the pitch circles and to write on the drawing the necessary particulars, such as number of teeth, pitch, and so on. The arms, boss and shaft may be shown.

Spur and bevel wheels. When the axes of two shafts are parallel and a suitable gear is required, they may be connected by *spur wheels*. When the axes meet at an angle, *bevel wheels* are used. The surfaces in the first case are cylinders, those of the latter are *cones* and are called *pitch surfaces*.

¹The curve traced out by the end of a piece of flexible string unwound from a circle and kept tight is a cycloid, and is usually better adapted than curves of a cycloidal form.

In drawing bevel wheels, a conventional method frequently adopted is to

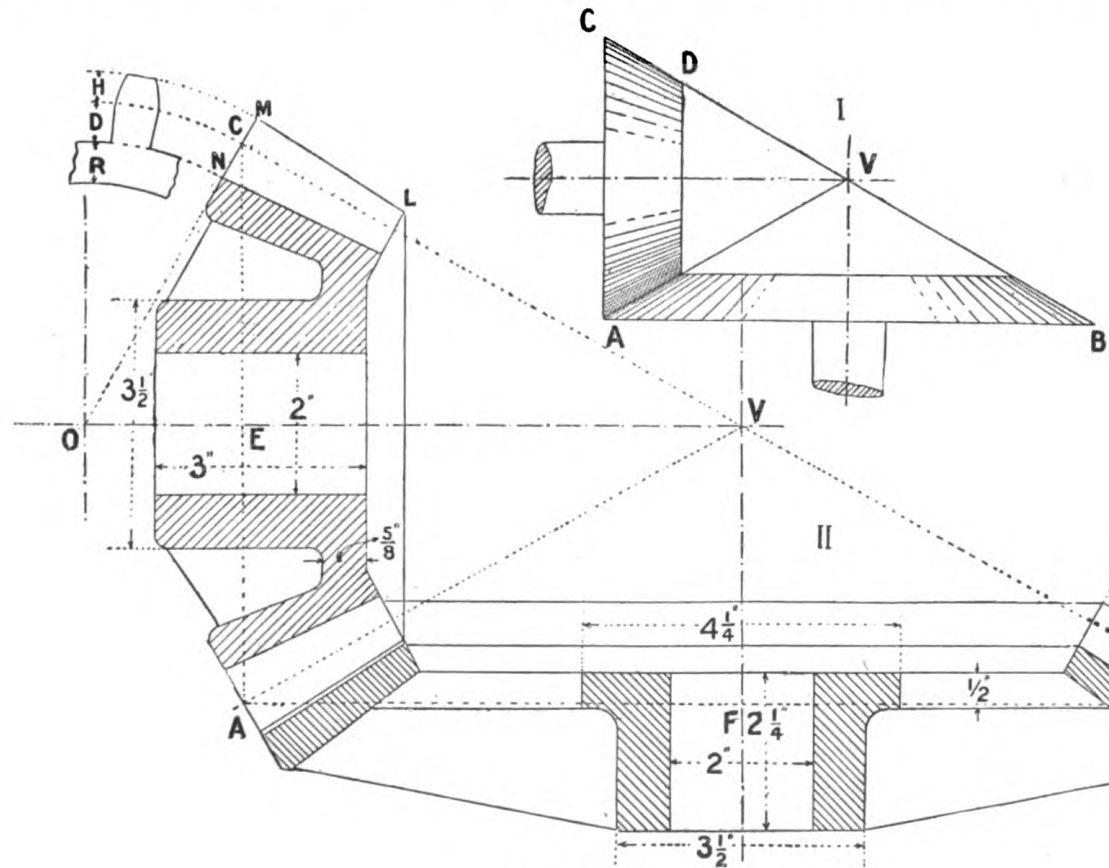


FIG. 129.—Bevel Wheels.

portions of the two pitch cones and to write on the drawing the number of teeth and any necessary information.

Another method is to draw the wheels in section; only two teeth, drawn and any necessary data not indicated by the drawing may be written on it.

Mitre wheels. When the two bevel wheels which gear together are of equal *mitre wheels*, and the *pitch cones* of the wheels can be shown when the diameters of the wheels are known. In this instance, as in the case of two wheels of unequal diameters, the pitch circle of either wheel can be obtained when the number of teeth and the pitch are given. The simple necessary calculation may be seen from the following case of

Example. (a) Draw the projection of two bevel wheels having 20 and 36 teeth and $1\frac{1}{4}$ " pitch. (b) Draw a sectional elevation and end view of the smaller wheel and a plan of one tooth. Width of face $2\frac{1}{2}$ ".

From the relation $\pi \times \text{diameter} = \text{No. of teeth} \times \text{pitch}$

we have, $\text{diameter of large wheel} = \frac{36 \times 1\frac{1}{4}}{\pi} = 14''\cdot32,$

$\text{diameter of smaller wheel} = \frac{20 \times 1\frac{1}{4}}{\pi} = 7''\cdot96.$

(a) These wheels would in many cases be shown in a conventional manner, as in Fig. 128. The centre lines **AB** and **AC**, are drawn at right angles to each other; **AC** is made equal to $7''\cdot96$, the diameter of the smaller wheel; and **AB** equal to $14\cdot32''$, the diameter of the larger wheel. The centre lines are drawn. Join **C**, **A**, and **B** to **V**; then **VCA**, and **VAB** will represent the pitch cones. Mark off **CD** equal to the width of face, and the conventional drawing may be completed. In addition, lines roughly indicating the teeth may be drawn, as shown.

(b) The two wheels may be shown in section as in Fig. 129. To draw the development of the smaller wheel we may proceed as follows:

Obtain **V** the common vertex of the two cones, as in the preceding drawing, and draw a line **CO** at right angles to **CV** and meeting **VE** produced in **O**. With **O** as centre and **OC** as radius, describe an arc of a circle denoting the pitch circle of the pinion. Set off **OD** the depth **D** of the tooth. With **O** as centre obtain the points **M** and **N**; draw a line **ML** and cut off a distance **ML** = width of face = $2\frac{1}{2}$ ". Complete the sections of the wheel to the dimensions given. Scale full size.

Skew bevel wheels. It will be obvious that when the axes of the two shafts, at a point, one shaft may be of any desired length in either direction, but the other it reaches the common centre **V**.

In many cases, to provide suitable bearing surfaces and for other purposes, the shafts shall be made to pass each other, and what are called *skew bevels* are used, in which the axis of each shaft, does not when produced pass through a point **V** but on one side of it.

Familiar examples of wheels of this kind are to be found in "Engineers' drills,"

Arms of wheels. The shape adopted for the arms of a wheel depends chiefly upon the nature of the work to be done.

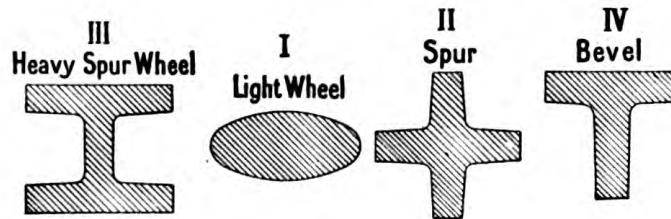


FIG. 130.—Sections of Arms of Wheels.

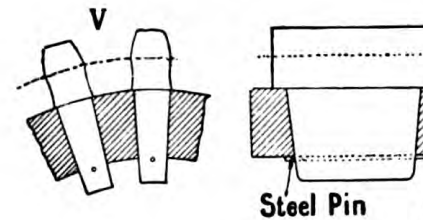


FIG. 131.—Rims of Mortise Wheels.

For wheels, the cross section may be an ellipse, or a cross, as at **I** and **II** (Fig. 130). For a double tee shape as at **III**, and for bevel wheels, a tee form shown at **IV** may be used.

Mortise wheels. The noise and vibration caused by two wheels in gear, which is considerably diminished when one of the wheels is provided with wooden teeth, is known as a *mortise wheel*. In addition, the wear chiefly occurs on the wooden teeth, which may be replaced readily when worn. Such a wheel, usually made of cast iron, is cast with holes in the rim; into each of these openings wooden blocks are fitted tightly, and are fastened by means of pins passing through each tooth on the under side of the rim, or wooden wedges (as at **VI**, Fig. 131) are inserted for the same purpose. The form of a bevel wheel is shown at **VII**, Fig. 132.

When the wooden blocks are fitted to the rim, the wheel is put into the lathe and turned on the face and edges. Finally the blocks are cut to the required shape either by hand or by machine.

Shrouded wheels. In small wheels, such as in the pinions, used in cranes, etc. rim is frequently made wider than the teeth and of a size to reach to the full height

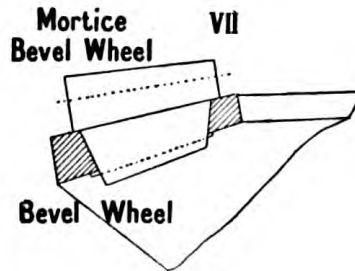


FIG. 132.

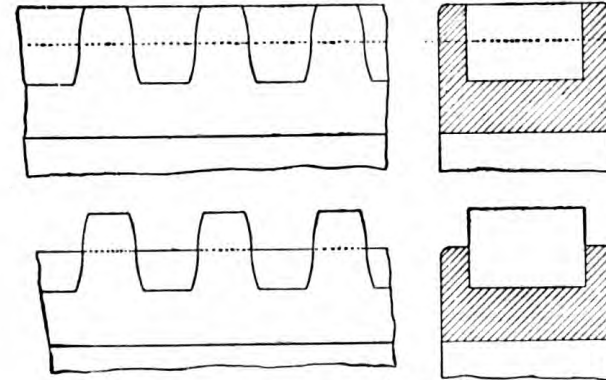


FIG. 133.—Shrouding.

of the tooth on one or both sides of a tooth (Fig. 133). This plan is called *shrouding*, strengthen the teeth.

EXERCISES. VI.

1. What is the meaning of the terms pitch, breadth of face, thickness of tooth, pitch line, rim, arm, and boss as applied in toothed gearing?
2. A spur wheel has teeth of 3 inches pitch. Sketch a tooth and mark on it pitch line, and the height above and depth below the pitch line. What names are given to these parts?
3. Show by a sketch what is meant by the clearance of wheel teeth.
4. Give sketches of a mortise open wheel showing the form of the rim and of method of fixing the latter. In what circumstances would mortise wheels be used?
5. Two shafts intersect at right angles and are connected by bevel wheels with

respectively of 1" pitch. Draw the pitch surfaces of the wheels, and find the surfaces on which the shapes of the ends of the teeth are set out.

6. Sketch in section a pair of bevel wheels in gear with one another. The pitch surfaces are to be shown.

7. Two bevel wheels connecting shafts at right angles have respectively 12 and 24 teeth, the pitch being 2". The width of face is 4". Set out the pitch surfaces of the wheels. Set out one tooth of the smaller wheel, the flanks being radial and the diameter of the pitch circle equal to twice the pitch. [B.E.]

8. Draw to scale, full size, one tooth of a pinion which has 12 teeth of pitch 2". The describing circle for the teeth being 4.3 times the diameter.

9. A spur wheel has a pitch circle 30 inches diameter with pitch of teeth 2". Set out a full size tooth for this, and insert all the necessary dimensions.

10. Make a sketch of 4 teeth for a rack, 3" pitch. Write on your sketch the dimensions.

11. Write down ordinary proportions, in terms of the pitch, for the teeth of a rack. Draw the correct form of a tooth for a spur pinion of 10 teeth 2" pitch, the rolling circle being 4.3 times the pitch, and radial flanks.

12. Set out to scale a cycloid, the diameter of the rolling circle being 2". Set out a full size tooth of 1" pitch, the faces and flanks of the teeth being portions of the above cycloid.

13. Draw full size two views of one tooth of a mitre wheel of 16 teeth, 1 1/2" pitch, the diameter of the rolling circle being such that the teeth have radial flanks.

14. Describe how the parts of a large spur wheel are put together, and how the teeth are made in segments.

15. Describe the construction of a mortise spur wheel. (a) In what circumstances can it be used with advantage? (b) What kind of wood is used for the teeth? (c) Describe the method of making such a wheel.

16. A pinion of 12 teeth, 2" pitch, gears with a rack. Draw, full size, one tooth of the pinion, the rolling circle to be such as to give radial flanks to the teeth of the pinion.

CHAPTER VII.

BEARINGS.

Bearings. All rotating shafts and bearings require to be supported at lengths. These supports or *bearings*, in the case of a spindle or shaft which rota

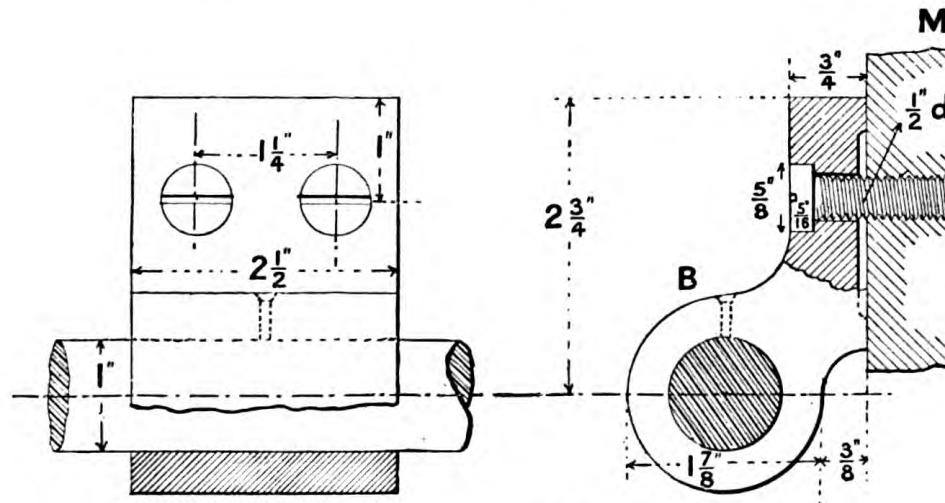


FIG. 135.—Small Bracket.

may be of simple form. A simple form of bearing may consist of some kind of a hole is bored to fit the shaft. Such brackets are made in a variety of forms for which they are intended. A simple bracket, **B**, which may be fastened to on

means of the tap bolts indicated, is shown in Fig. 135. The hole is bored to fit the shaft for adjustment for wear.

Example. Draw the two views of a simple bracket (Fig. 135). Scale full size.

Another form of bracket is shown in Fig. 136. In this case, the hole in the bracket is larger than the shaft, and the space between the bracket and the shaft is filled by a brass cylinder. The outside of the brass bush is made to fit the hole in the bracket tightly, and the inside is bored to fit the shaft. A small screw, having one half its diameter in the bracket and the other half in the bush, is usually inserted to prevent rotation of the bush.

In this arrangement not only is the friction between the shaft and its bearing reduced by the use of the softer metal, but, in addition, the bush, when worn, can be readily replaced.

Example. Draw the two views of the bracket (Fig. 136). Scale full size. Also draw an end view.

Pedestal. When a brass bush, as in Fig. 137, is made in two parts and means provided so that, as wear takes place, the two parts can be drawn closer together, we obtain an arrangement in which compensation for wear can be made. The *pedestal*, or *plummer block*, one form of which is shown in Fig. 137, consists of a cast-iron block, **B**, and a cast-iron cap, **C**, made to fit the block. Two brass steps, **S**, are fitted to the block, the parts on the steps marked **a, a**, fit the corresponding parts on the block, and the halves of the steps can be drawn together by means of two bolts, one of which is shown in Fig. 137. This allows for slight irregularities in the casting. In a similar manner the hole in the block is bored to fit the shaft.

The holes both in the block and the cap are somewhat larger than the diameter of the shaft in Fig. 137. This allows for slight irregularities in the casting. In a similar manner the hole in the block is bored to fit the shaft.

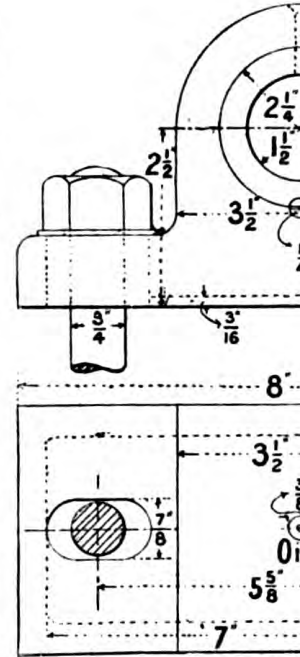


FIG. 136.—

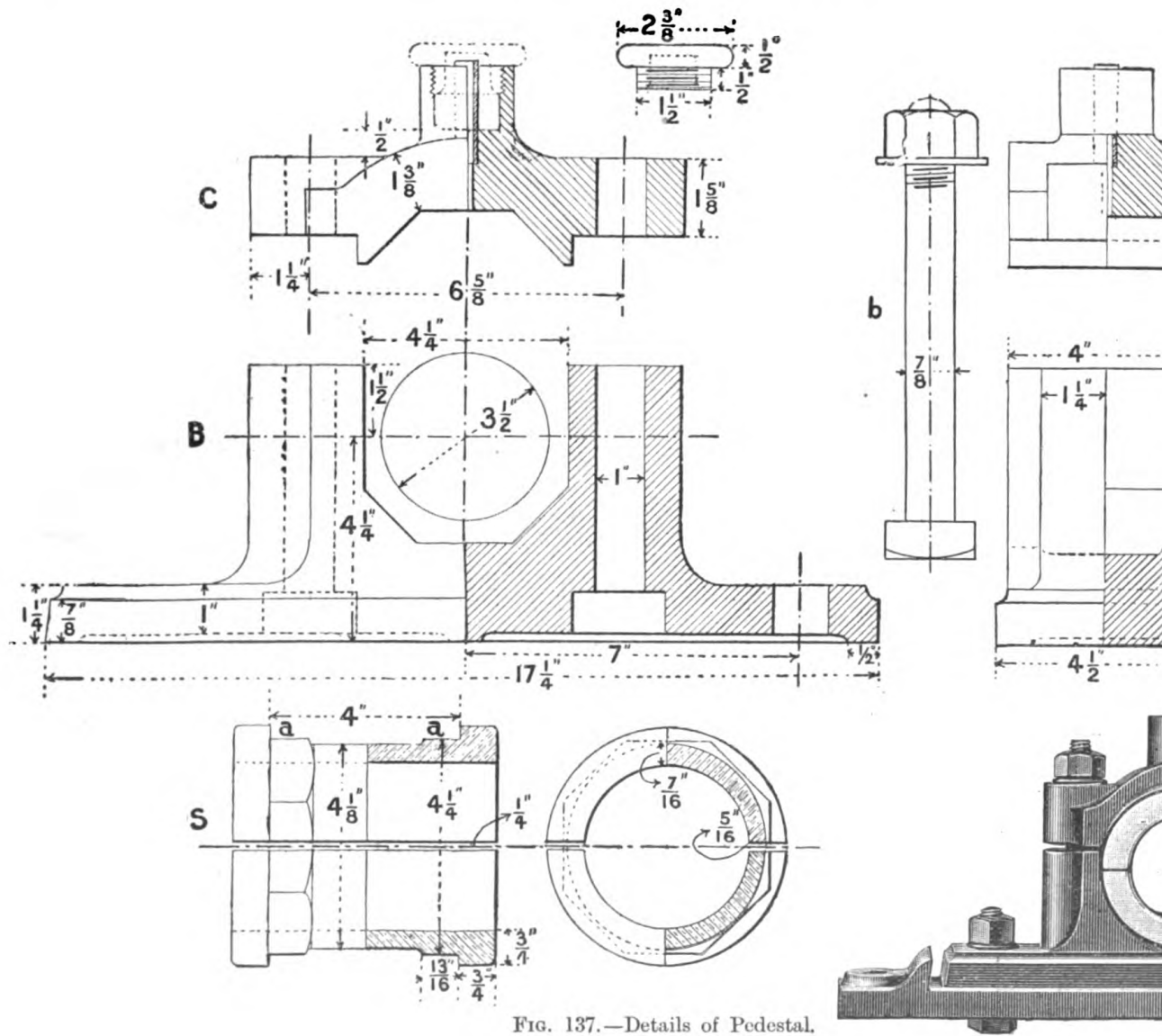


FIG. 137.—Details of Pedestal.

Example. Draw the details of the pedestal (Fig. 137). Also draw a section view and plan, with all the details inserted in place in the pedestal and showing the wall plate (Fig. 138). Bolts, $\frac{7}{8}$ " diameter. Scale, 6"=1'.

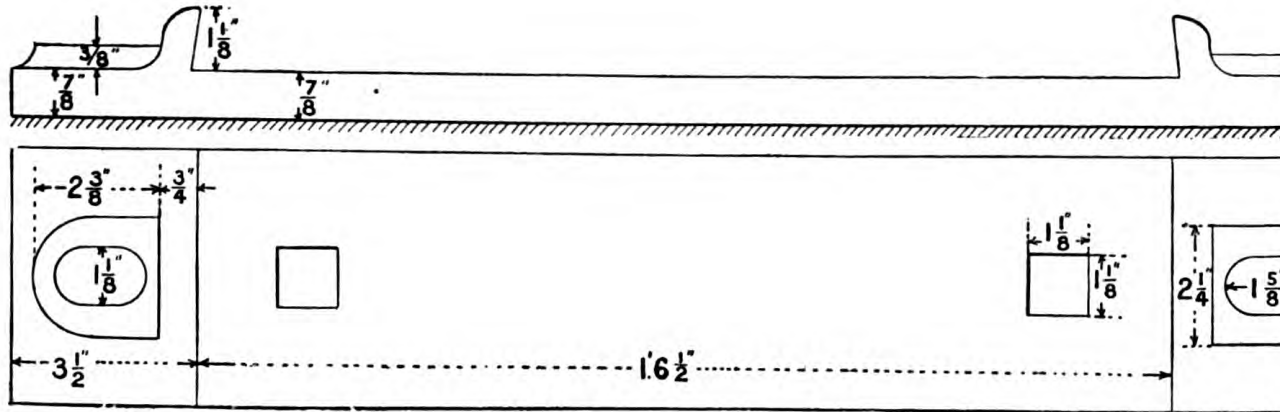


FIG. 138.—Wall Plate.

Hangers. When a shaft is supported from the ceiling of a room, the bearing may take the form shown in Fig. 139. In this arrangement, a suitable cavity is provided, in the central part of the hanger, in which one of the brass steps is fitted. The other step is fitted to the cap, and the whole bolted together.

Various methods are in use to prevent the rotation of the steps, or brasses. Thus, the steps which are made to fit corresponding parts of the hanger and cap may be made octagonal or circular in form. The first is indicated in Fig. 137. When of a circular form a suitable key is used to prevent rotation.

It is only possible to refer to a few of the many kinds of hangers, or brackets, in general.

instead of the pedestal base being bent round and upwards and fastened on both sides as in Fig. 139, it may be fastened on one side only and is then known as a *Hanger*.

Example. Draw the two views of the hanger. Scale 4" to 1'. (Fig. 139.)

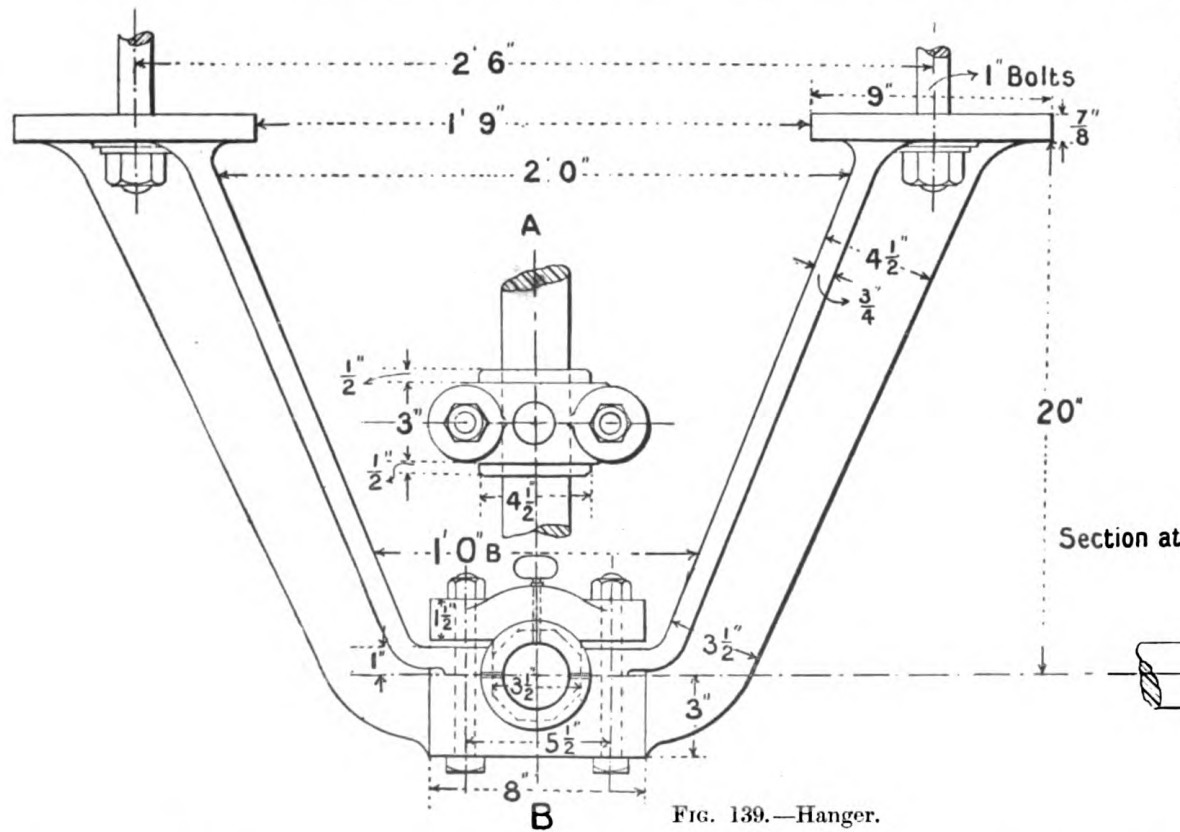


FIG. 139.—Hanger.

A form usually fastened to one side of a pillar and known as a *Pillar Bracket*. Another form known as a *Wall Bracket*, used for supporting a horizontal shaft at a distance from, a wall is shown in Fig. 141.

Example. Draw the two views of the bracket (Fig. 140). Scale 6" to 1'.

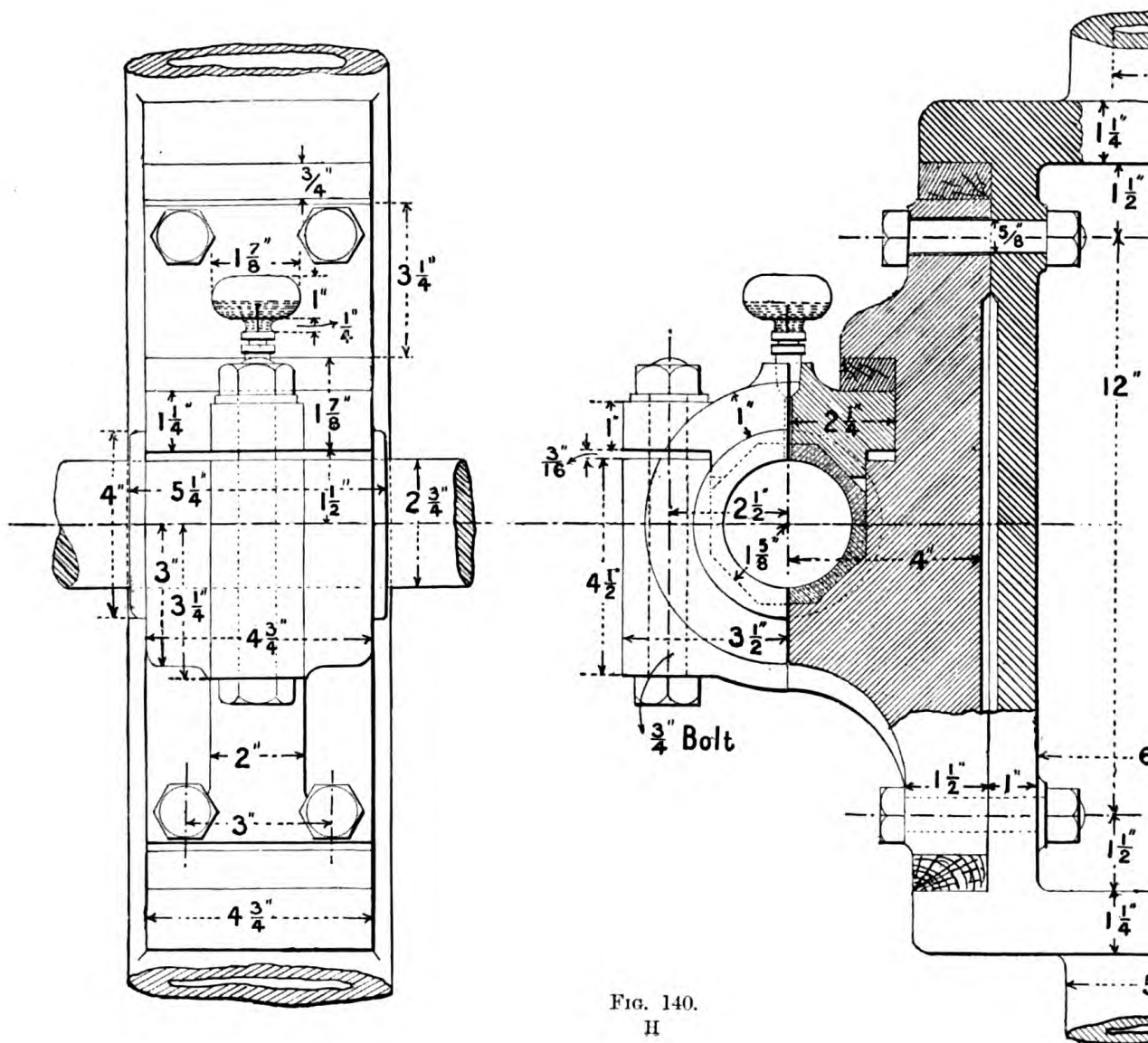
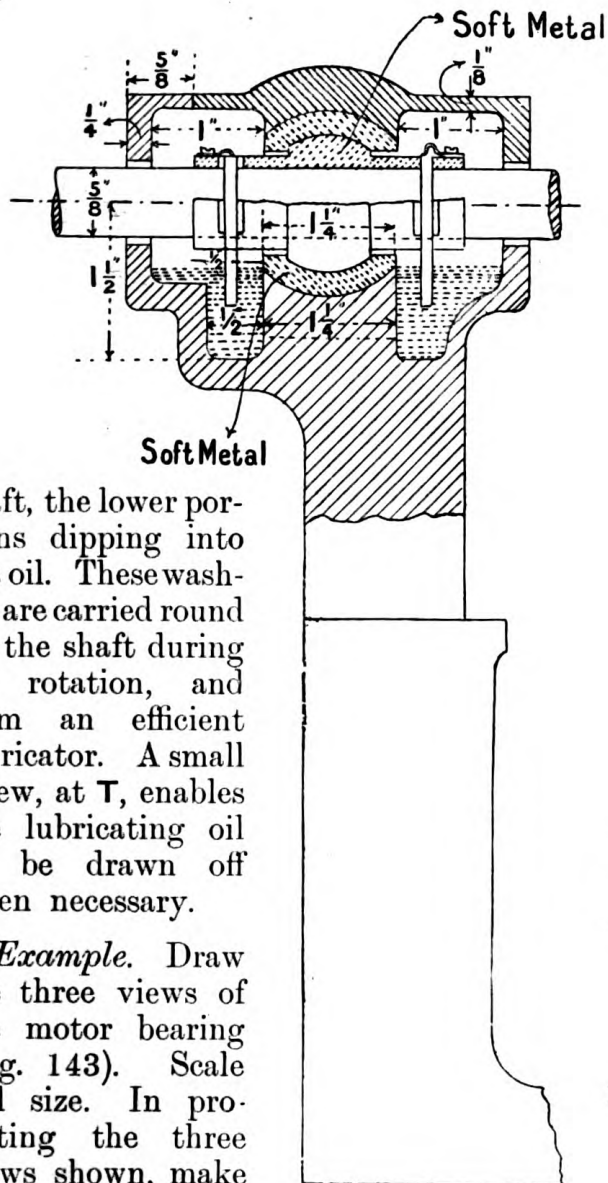


FIG. 140.
H

BEARINGS



shaft, the lower portions dipping into the oil. These washers are carried round by the shaft during its rotation, and form an efficient lubricator. A small screw, at T, enables the lubricating oil to be drawn off when necessary.

Example. Draw the three views of the motor bearing (Fig. 143). Scale full size. In projecting the three views shown, make any corrections that may be necessary.

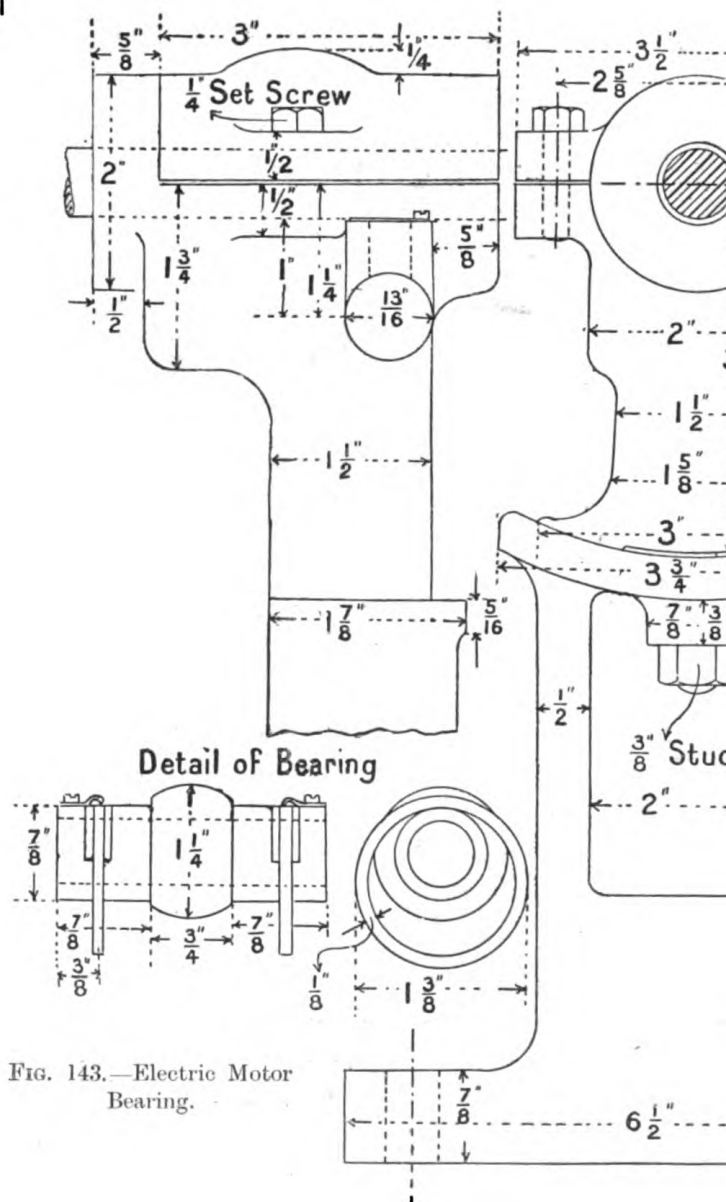


FIG. 143.—Electric Motor Bearing.

Footstep. When a shaft is vertical, what is called a *footstep bearing* is used. bearing is shown in Fig. 145, and consists of a cast-iron block, B, into which a bras

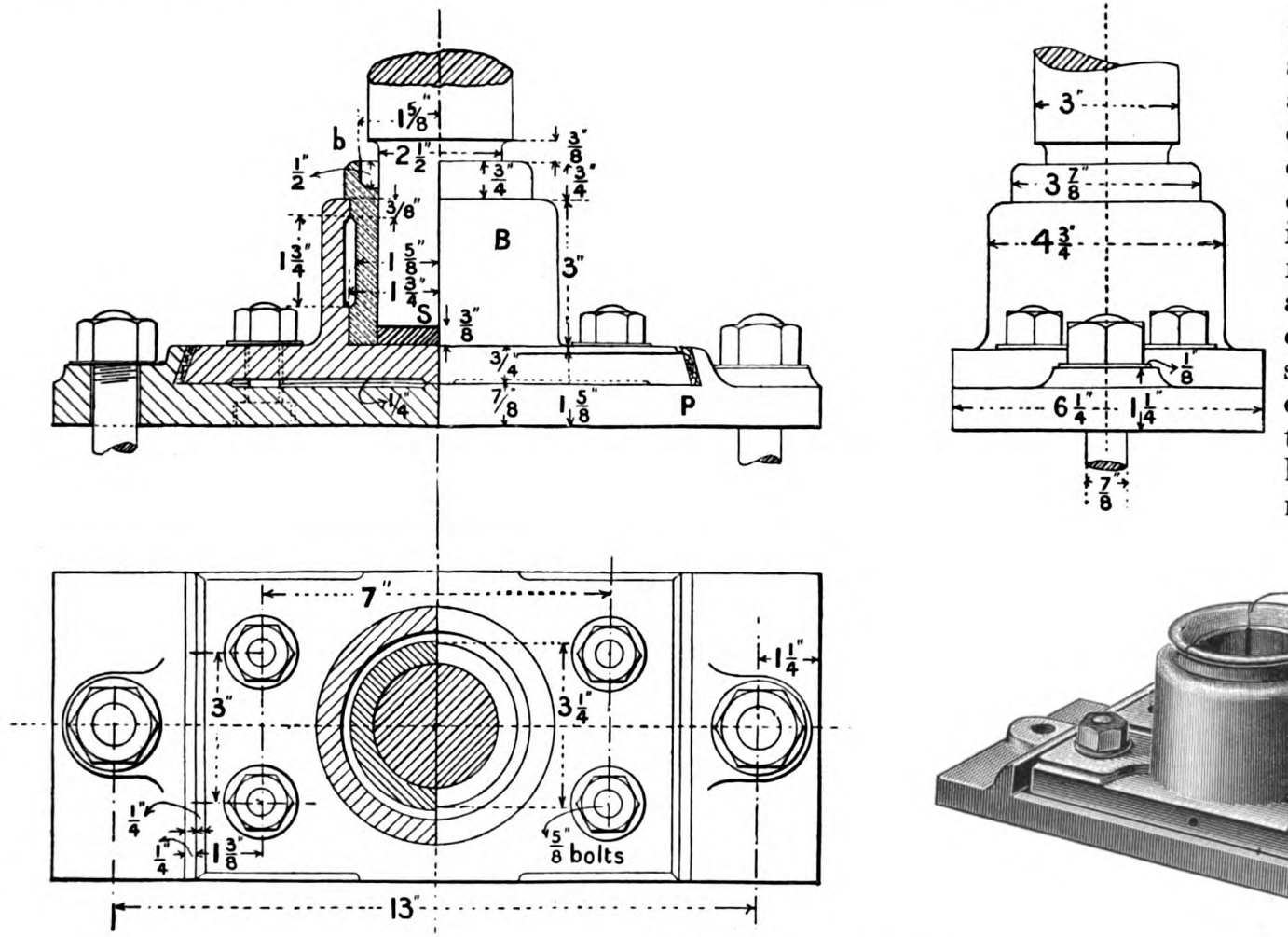


FIG. 145.—Footstep Bearing.

washer, **S**. This washer may be replaced readily when worn. The rotation of the means of a small steel pin of $\frac{1}{2}$ " diameter.

The bush, as indicated at **C**, is hollowed out to receive and to retain the oil u block, **B**, and the base plate, **P**, on which it rests, are both provided with chipping holes allow for adjustment. When the adjustment has been made, wooden blocks ends of the block and between the projections on the base plate. The perspective to show the relations of the parts **B**, **C**, and **P**.

Example. Draw and complete the two views of a footstep bearing (end view. Scale 6" to 1' Make any necessary corrections in the plan.

Ball bearings. In ball bearings a number of hard and accurately formed steel in suitable channels. The radius of the section of such a channel is about two-thirds Such bearings can carry comparatively heavy loads, and the friction is much le bearings already described. The wear of the balls and the friction is very sma bearing is shown in Fig. 146.¹

Example. Draw the two views of the ball bearing (Fig. 146). Scale

EXERCISES. VII.

1. Sketch the brasses for a bearing, and show how they are prevented from turni
2. Sketch one form of hanger suitable for supporting mill shafting. [B.E.]
3. A length of shafting is to be carried through a brick wall. Sketch a suita pose of supporting the shaft. What is the object in using chipping or facing str
4. Make a sketch of a simple form of bearing for supporting shafting. Show prevented from turning. Describe some form of automatic lubricator which will oil to the bearing. Explain its action and point out any special advantage which

¹ Hopkinson, "Electric Lighting Works," *Proc. Inst. of Mech. Eng.*, July 1894.

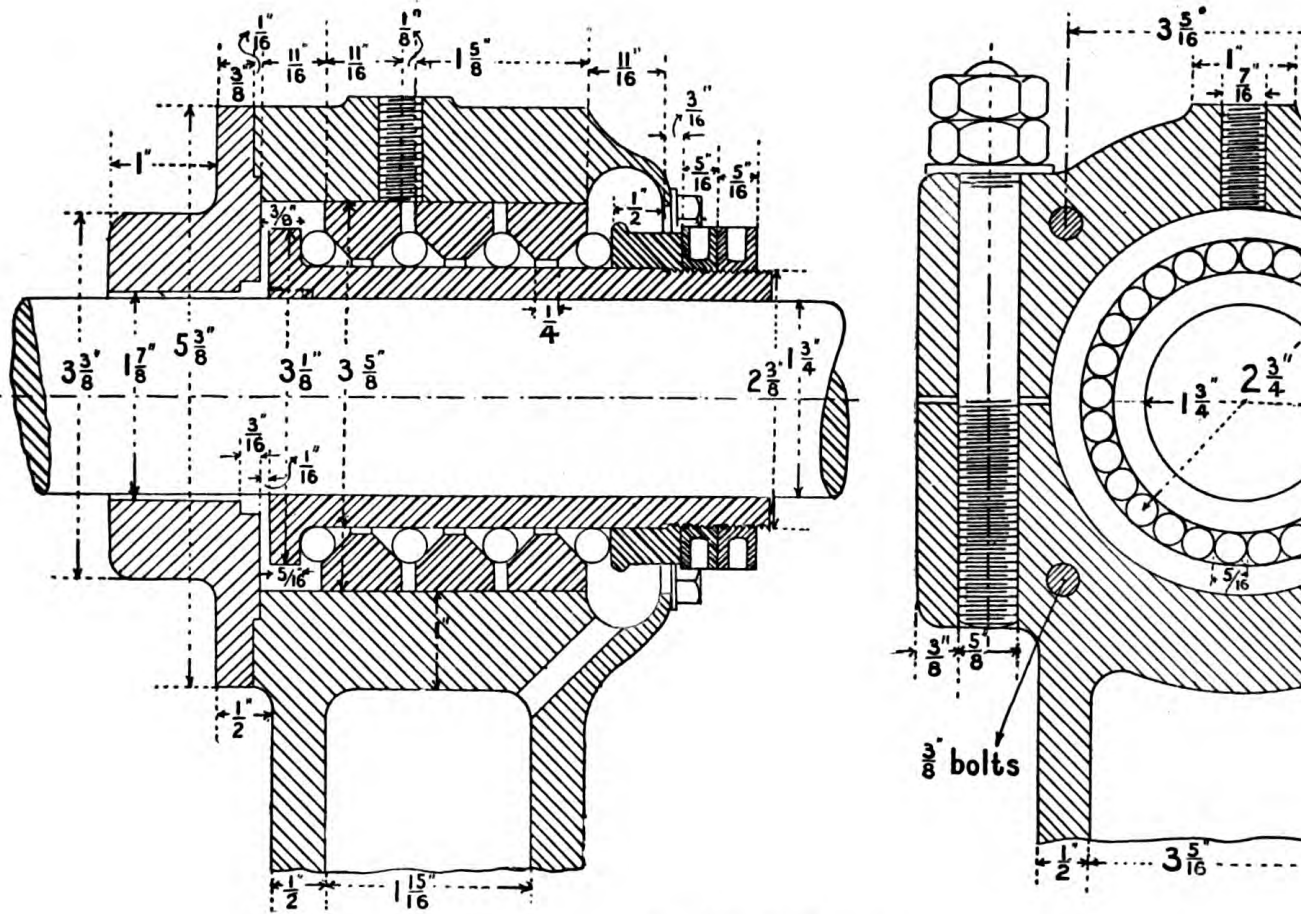


FIG. 146.—Ball Bearing.

5. Sketch and give a description of a bearing suitable for a shaft working under two cases in which such a bearing would be used.
6. Sketch two views of a swivel bearing, and state any advantage of this bearing.

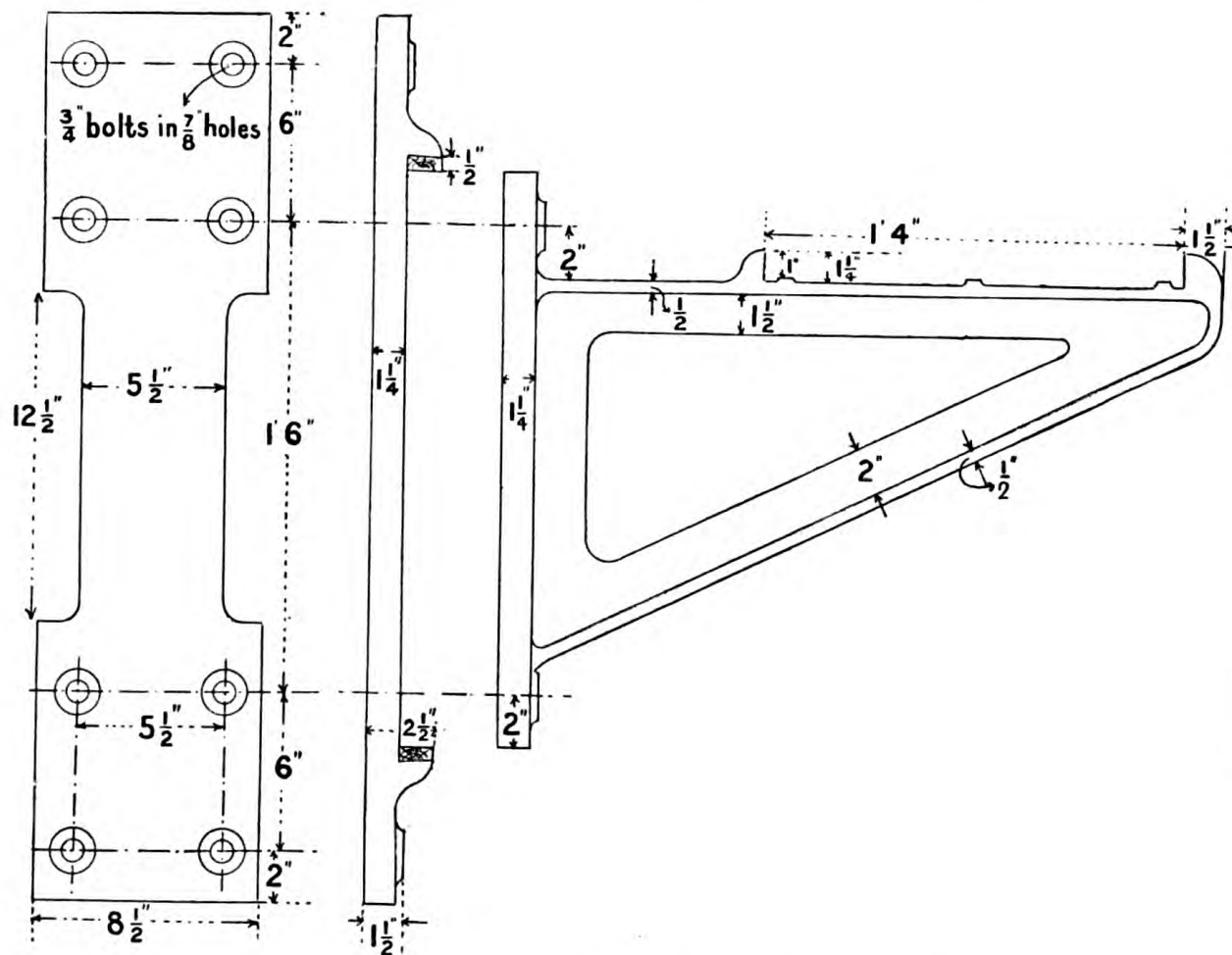


FIG. 147.—Hanger and Wall Plate.

7. Sketch and explain the construction of any form of thrust bearing, showing how for lubrication.

8. Sketch and describe a form of bearing suitable for the crank shaft of a horizontal engine, complete provision being made for adjustment.

9. Explain by the aid of sketches a method of automatically lubricating: (i) a pedestal for a line shaft; (ii) the end of a small connecting rod; (iii) a footstep bearing.

10. Sketch a footstep bearing suitable for a vertical shaft. Mark on the sketch the materials employed for the various parts.

11. Show, by sketches, a wall bracket. Show how such a bracket may be attached to the wall of a workshop.

12. 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 any suitable form of wall box.

13. Show the construction of a crank shaft bearing, provided with means of adjustment for horizontal and vertical wear. [B.E.]

14. Details of a hanger and wall plate are given (Fig. 147). Do not draw these details separately, but in their respective positions fastened to a brick wall 14" thick. Scale $\frac{1}{3}$.

15. Small bracket. Draw the two views shown (Fig. 148), also draw a plan. Scale

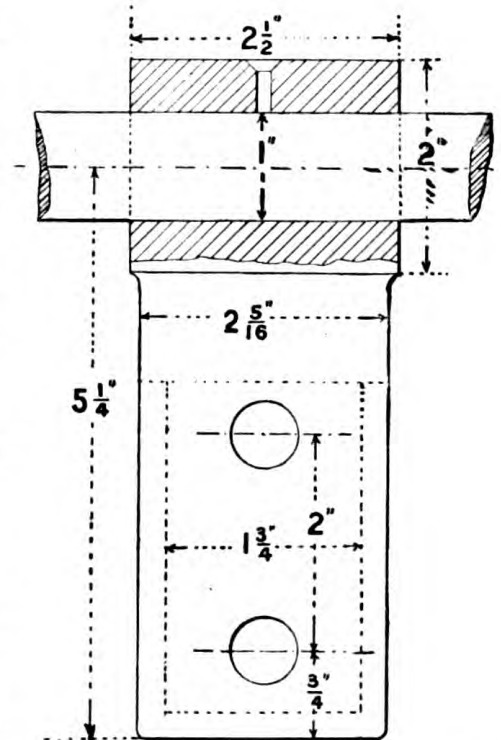


FIG. 148.—Small Bracket

16. Wall box. Complete the two views shown (Fig. 149). Scale 3" to 1'.

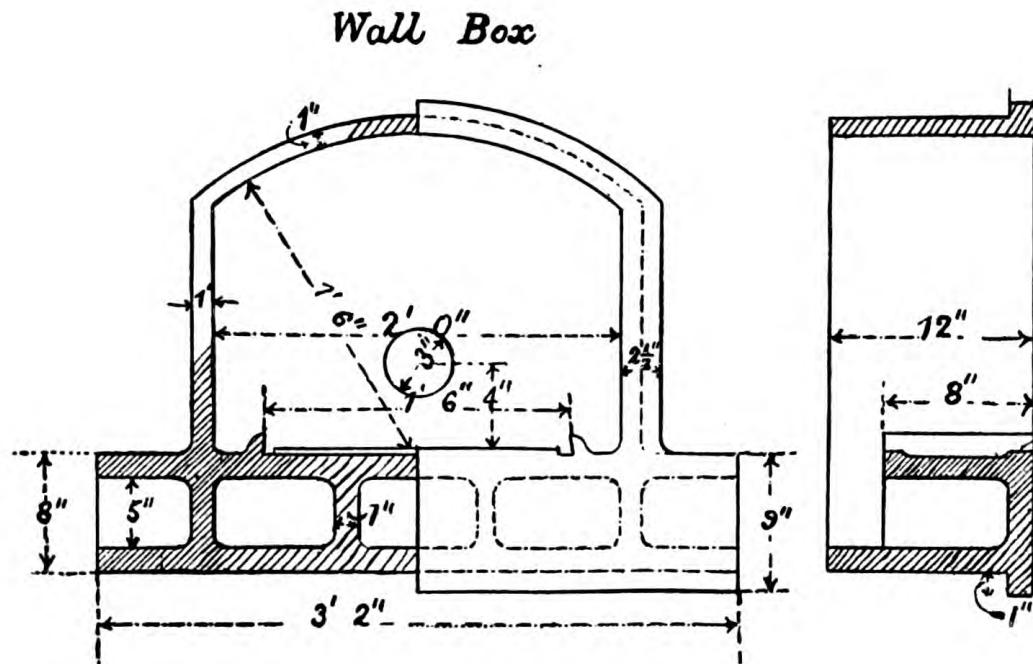


FIG. 149.—Wall Box.

18. Pedestal. Draw elevation, plan, and end view of the pedestal (Fig. 151), their respective places. Scale full size. [B.E.]

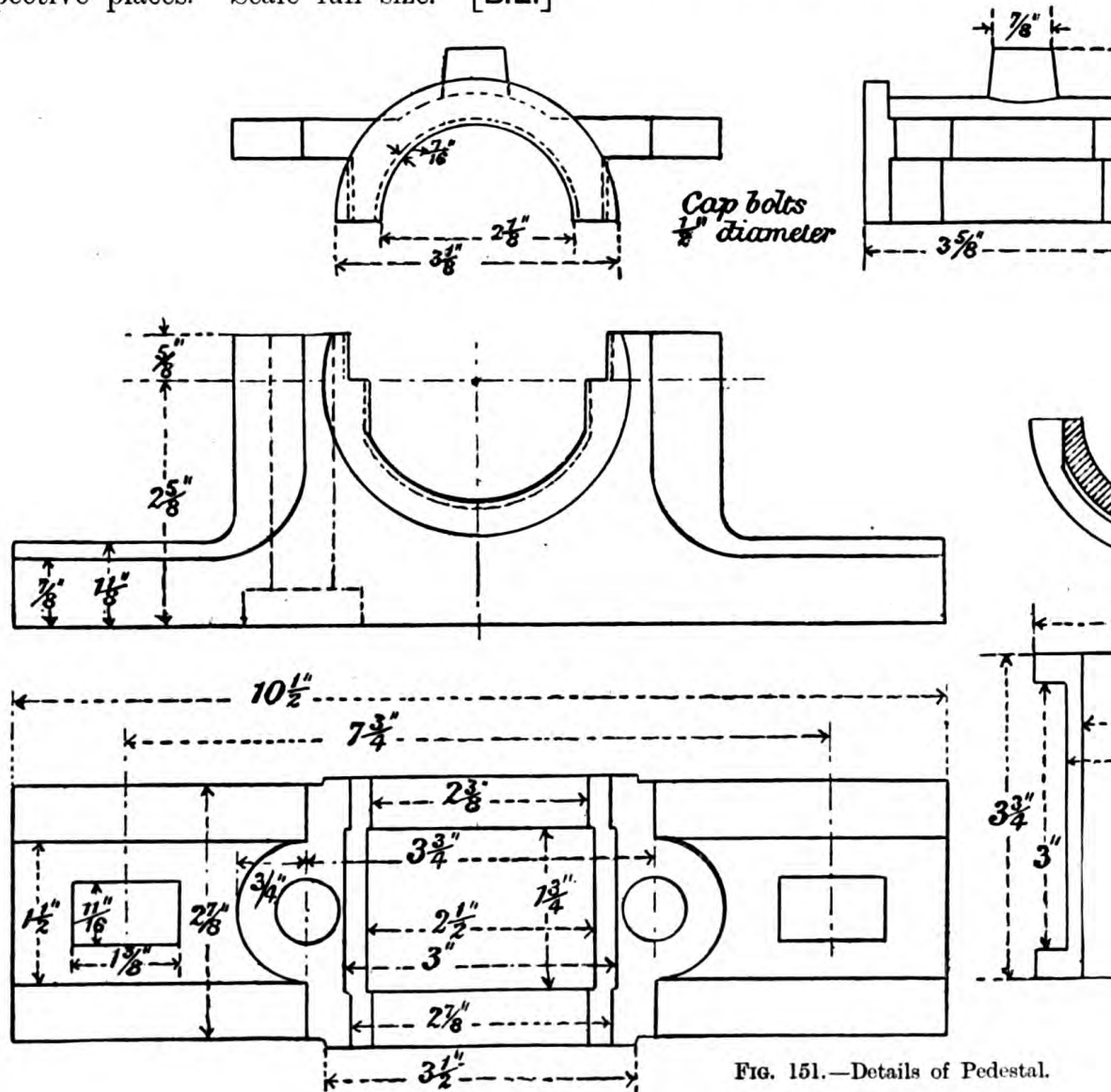
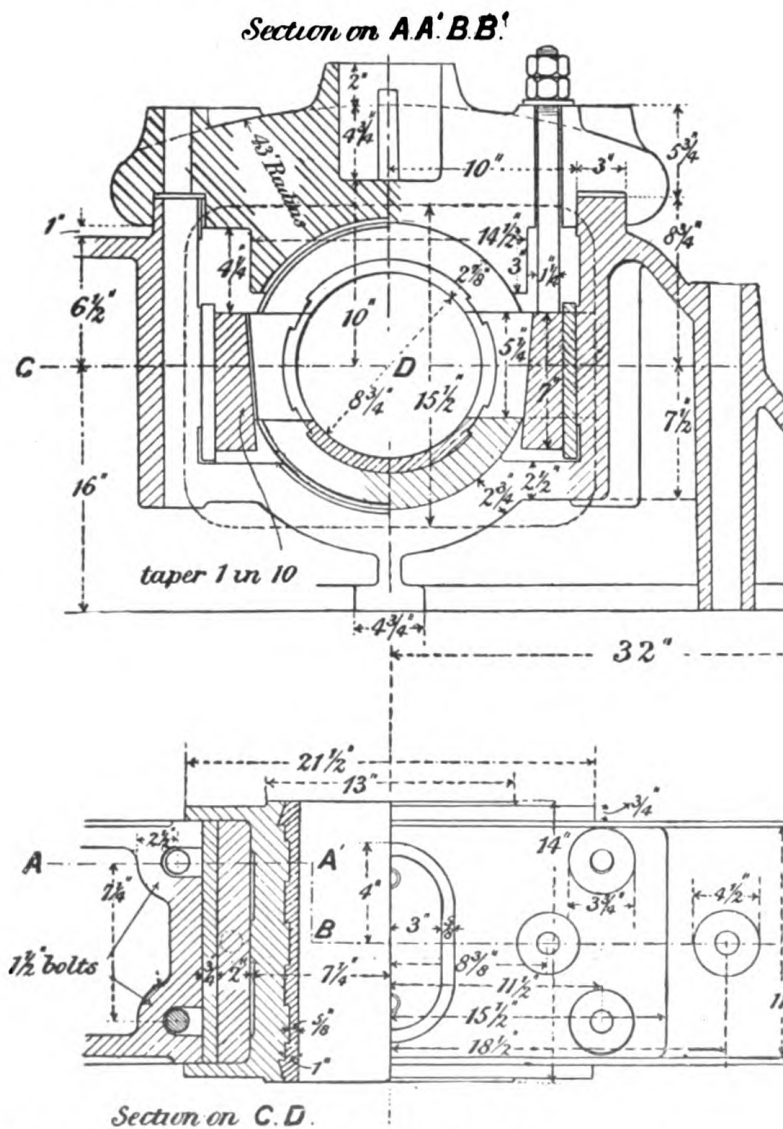


FIG. 151.—Details of Pedestal.

20. Crank shaft bearing.
Two views of a crank shaft bearing with horizontal and vertical adjustment are given in Fig. 153. Draw to a scale 3" to 1'.



21. Bearing for a shaft. Draw elevation, plan, and end view of the bearing (Fig. 154). So

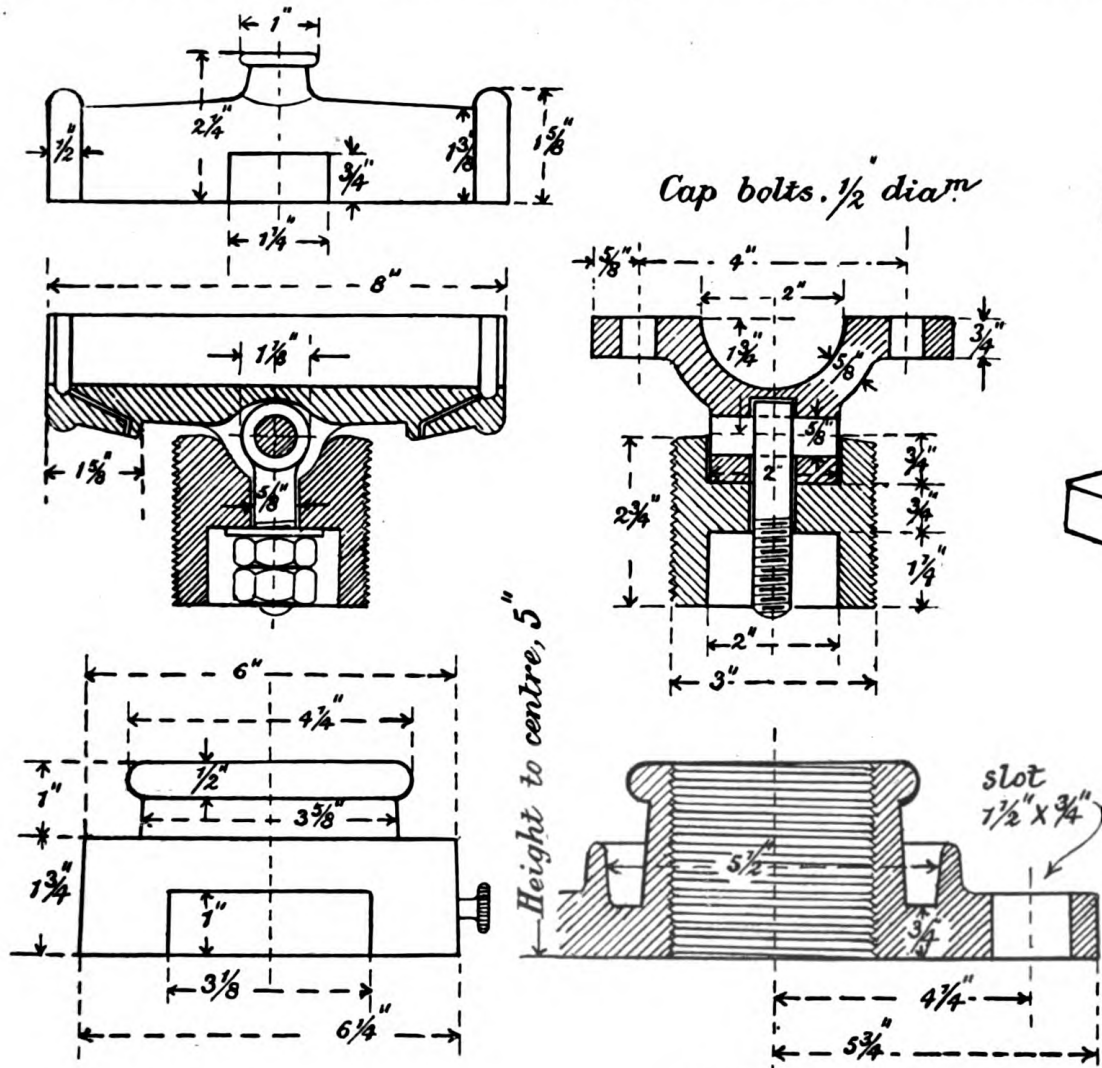


FIG. 154.—Bearing.

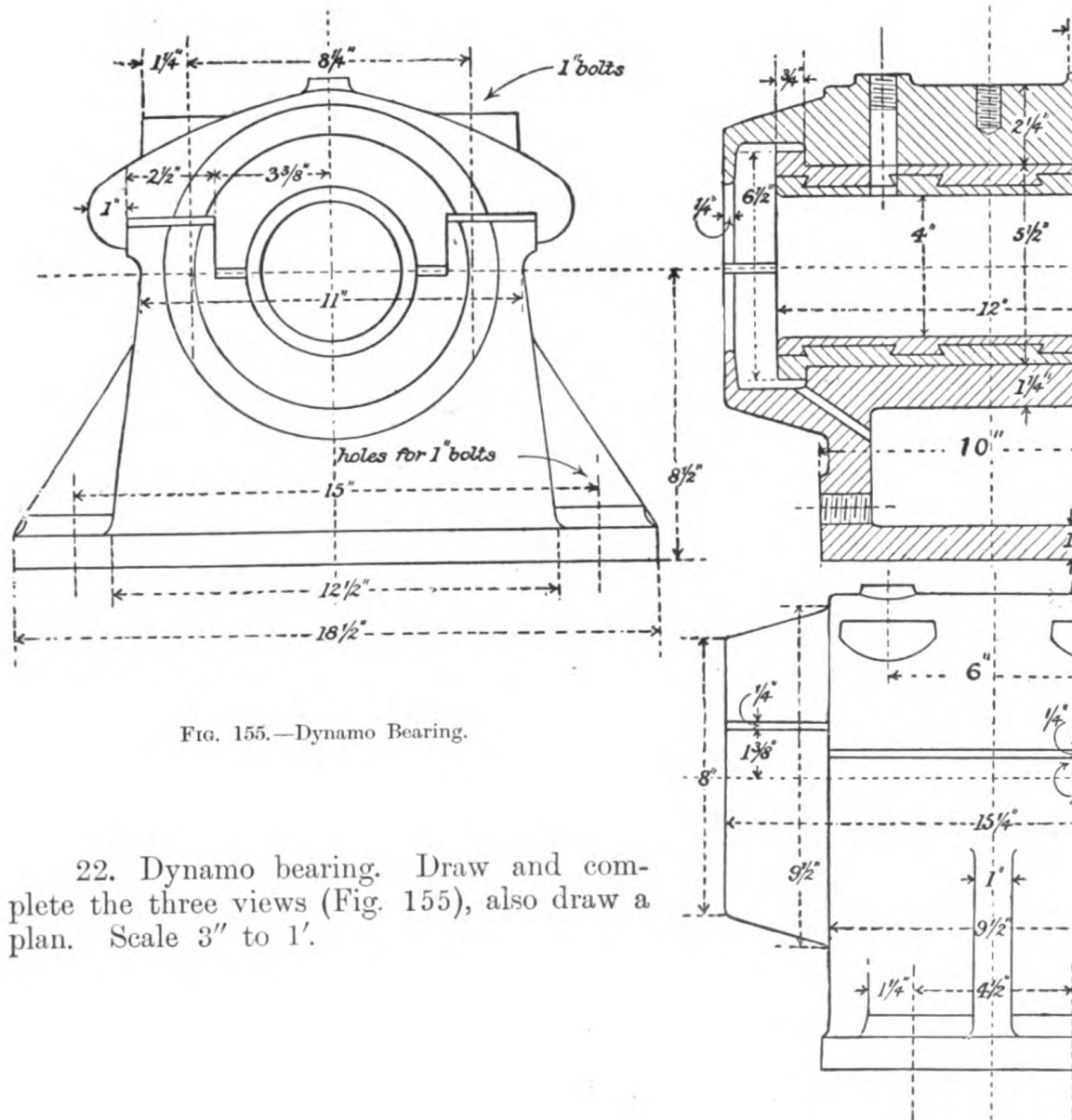


FIG. 155.—Dynamo Bearing.

22. Dynamo bearing. Draw and complete the three views (Fig. 155), also draw a plan. Scale 3" to 1'.

CHAPTER VIII.

PIPES AND PIPE JOINTS.

Pipes and pipe joints. The materials used for pipes include cast iron, wrought iron, and lead. For convenience in manufacture and in handling, a long length of piping is made of a series of comparatively short lengths, and these separate lengths are fastened together by different kinds of joints. The joint used in any case depends not only on the material but also on the pressure for which the pipe is to be used.

Cast-iron pipes are made easily and cheaply to any desired form; they are made in lengths of from 8 to 12 feet. Two forms of joint in general use are the *flange-joint* and the *socket-joint*. The flange-joint is stronger and easier to connect or disconnect than the socket joint. The flexibility in the latter form of joint makes it suitable for pipes laid in the ground in which some settlement may occur owing to unequal settlement of the soil, etc.

Wrought iron pipes are used to convey gas, water, and steam. They are obtained in standard sizes of internal diameter; the separate lengths may be fastened together by means of one of the joints shown in Fig. 159.

Steel is generally used for ordinary and high pressure steam pipes, the longitudinal joints being welded. The plates are not less than $\frac{1}{4}$ " and are usually $\frac{5}{16}$ " thick with $\frac{5}{8}$ " rivets. Cast iron is used for bends and elbows but copper is better and is used in marine and in the best work. Copper pipes usually consist of hard brass and are brazed to the pipe.

Fig. 156 shows an ordinary form of flange-joint. The ends of the pipes are usually rounded and for this purpose a *facing*, as shown, may be provided. This facing is usually about $\frac{1}{8}$ " thick and about $\frac{1}{2}$ " wide. The joint is made by inserting a ring of india-rubber, millboard, or lead smeared with red lead, the flanges being forced together finally by means of bolts or studs. In some cases a portion of the bolt close to the bolt head is made square and is made to

square hole in the flange somewhat loosely, the object being to prevent the rotation of the nut during the process of screwing, or unscrewing, the nuts.

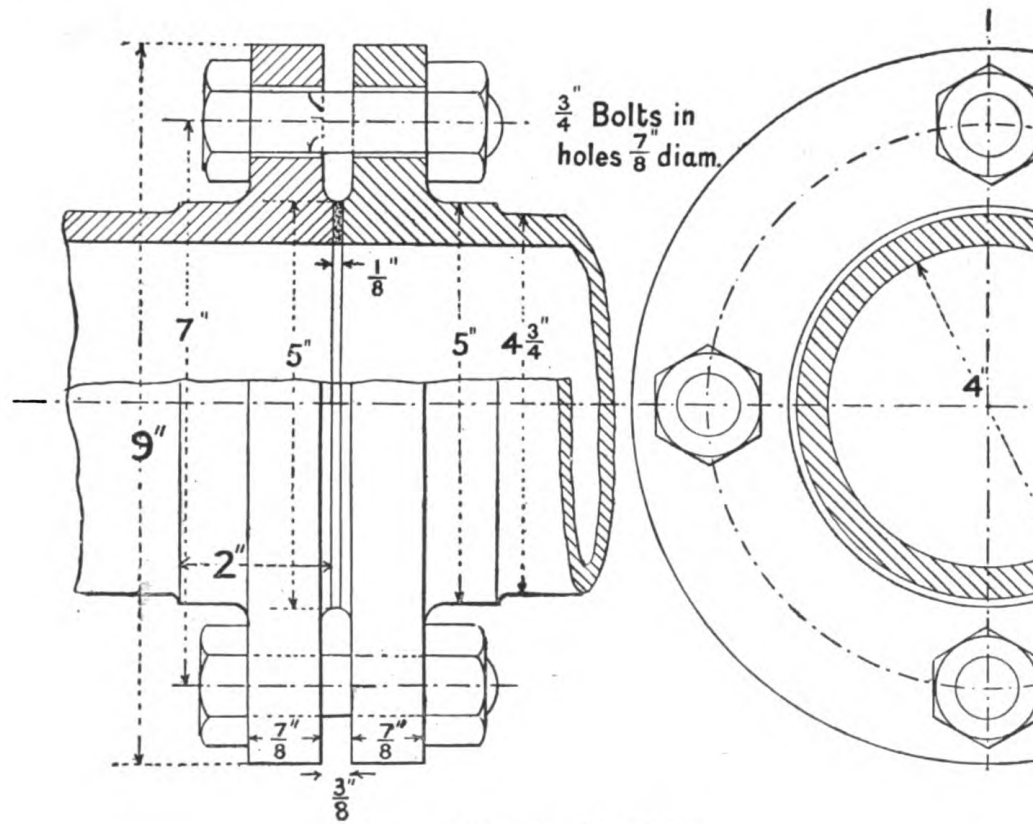


FIG. 156.—Pipe Joint.

Example. Draw full size the sectional elevation and end view of a flange

Example. Draw full size the sectional elevation of the pipe joint (I end view).

Pipe Joint

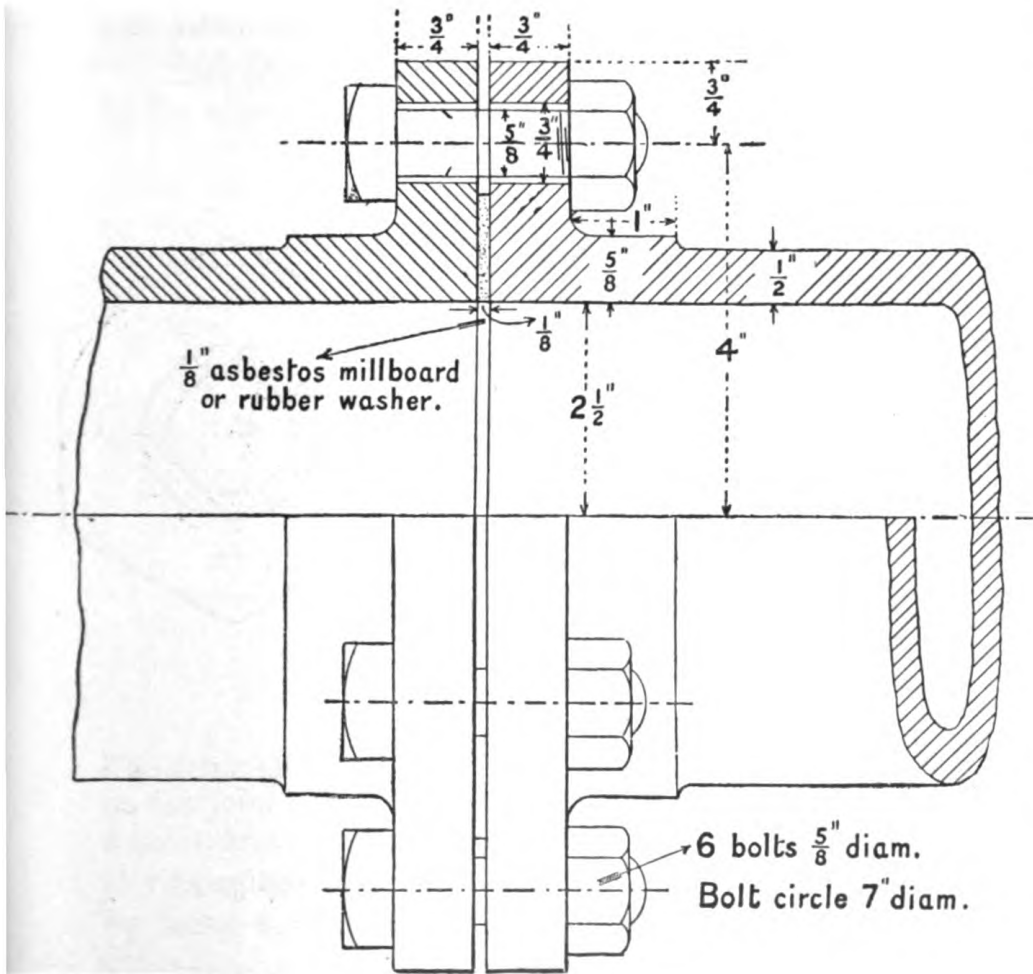


FIG. 157.—Pipe Joint.

Socket and spigot. In one pipe is made to enter the other a certain distance as at I (Fig. 158). The joint is made by threading several turns of lead around the pipe and by pouring molten lead into the space provided between the two flanges. When the lead is sufficiently cooled, the joint may be broken up with a hammer and chisel.

Another form of joint (Fig. 158), in which a facing is made slightly taper and to fit the facing in the socket end. The joint is made by smearing the surfaces with lead and forcing them together.

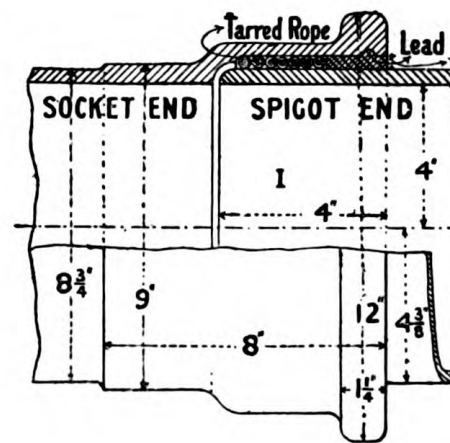


FIG. 158.—Socket and Spigot Joint.

Wrought-iron pipes. In wrought-iron pipes of comparatively small size the screwing what is called a *coupling*, shown at **C** (Fig. 159), on the end of one other into it. In some cases it is important that the surface of the pipe shall and a *nipple* **N** (Fig. 159) may be used. The ends of the pipes are screwed to meet at the centre. The objection to this form of joint is that when the pipe is

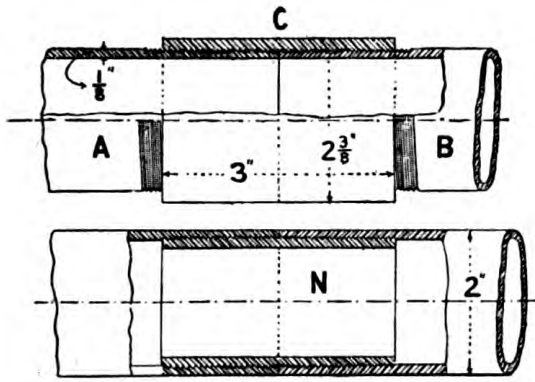


FIG. 159.—Wrought-iron Pipes.

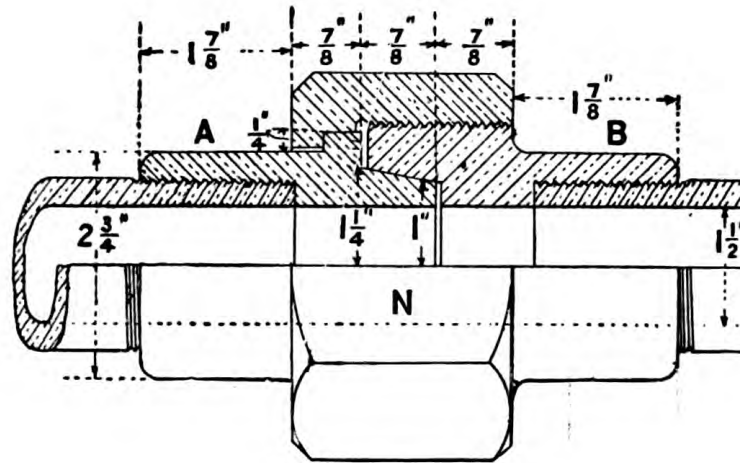


FIG. 160.—Union Joint.

other fluid the projecting surface of the nipple may cause a partial stoppage. A cast-iron flange may be riveted on to the end of each pipe.

Union joint. A *union joint* is a very useful and handy joint for steam or other small size, since it is easily connected or disconnected and makes a steam-tight joint.

The two parts, **A** and **B**, (Fig. 160) are screwed to the end of the pipes; the flange **A** is ground to fit accurately a corresponding inclined surface on **B**. A hollow hexagonal

the part **A** and fits an external screw on **B**. The two cone surfaces may be drawn together by rotating the nut **N**, thus forming a steam or water-tight joint.

Example. Draw full size the two views of the union joint (Fig. 160). Also

Lead pipes. The joints used in lead pipes are generally either a *wiped joint* (Fig. 161) or a *blown joint*. In the wiped joint the end of one pipe is opened, or *tamped out*, and the end of the other *rasped*

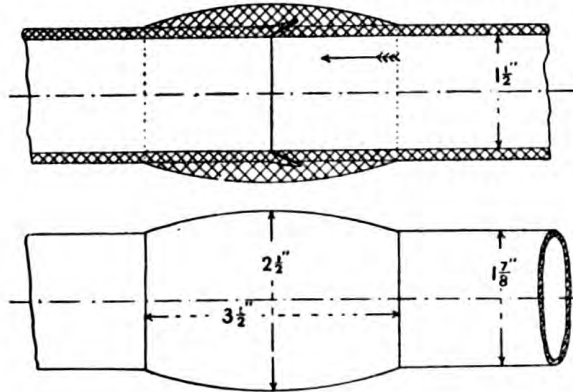


FIG. 161.—“Wiped Joint” for Lead Pipes.

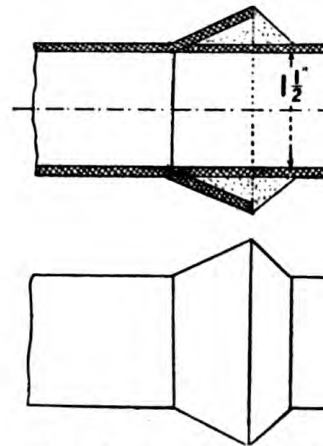


FIG. 162.—“Blown Joint” for Lead Pipes.

The pipes are fitted together and the two ends *shaved* bright for a distance of about $1\frac{1}{2}$ in. Moisture is applied to the joint and the joint wiped with a piece of greased cloth; the solder adheres to the bright surfaces, forming a sharp line round the pipe. The arrow denotes the direction of the flow.

In a blown joint the end of one pipe is enlarged to receive the end of the other and is made tight by using a *blow-pipe*.

Hydraulic pipe joint. The joints already described would be entirely useless for transmitting water at high pressure necessary in hydraulic work. Thus, for general hydraulic purposes

the water may be 700 lbs. per square inch and in the case of machine tools sq. in. One form of joint which is suitable for cast-iron pipes is shown in Fig. 163.

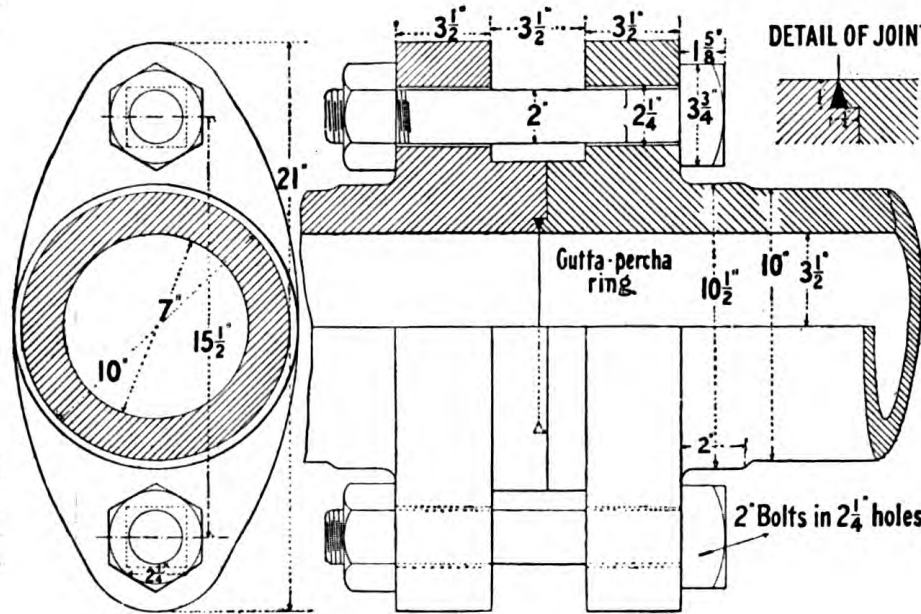


FIG. 163.—Hydraulic Pipe Joint.

At the end of each pipe there is a strong elliptical flange with two bolt holes. for a short distance, forming a dove-tailed recess, and the joint is made by a gutta-

Example. Draw the sectional elevation and end view of the hydraulic Scale 6" to 1'. Also draw a plan.

The preceding arrangement is modified in the case of wrought iron or steel supply water to machine tools. The ends of the pipes are screwed to a gas three flanges are screwed on.

Example. Draw the two views of the hydraulic pipe joint (Fig. 164). Also 6" to 1'.

Hydraulic joint for wrought iron pipes.

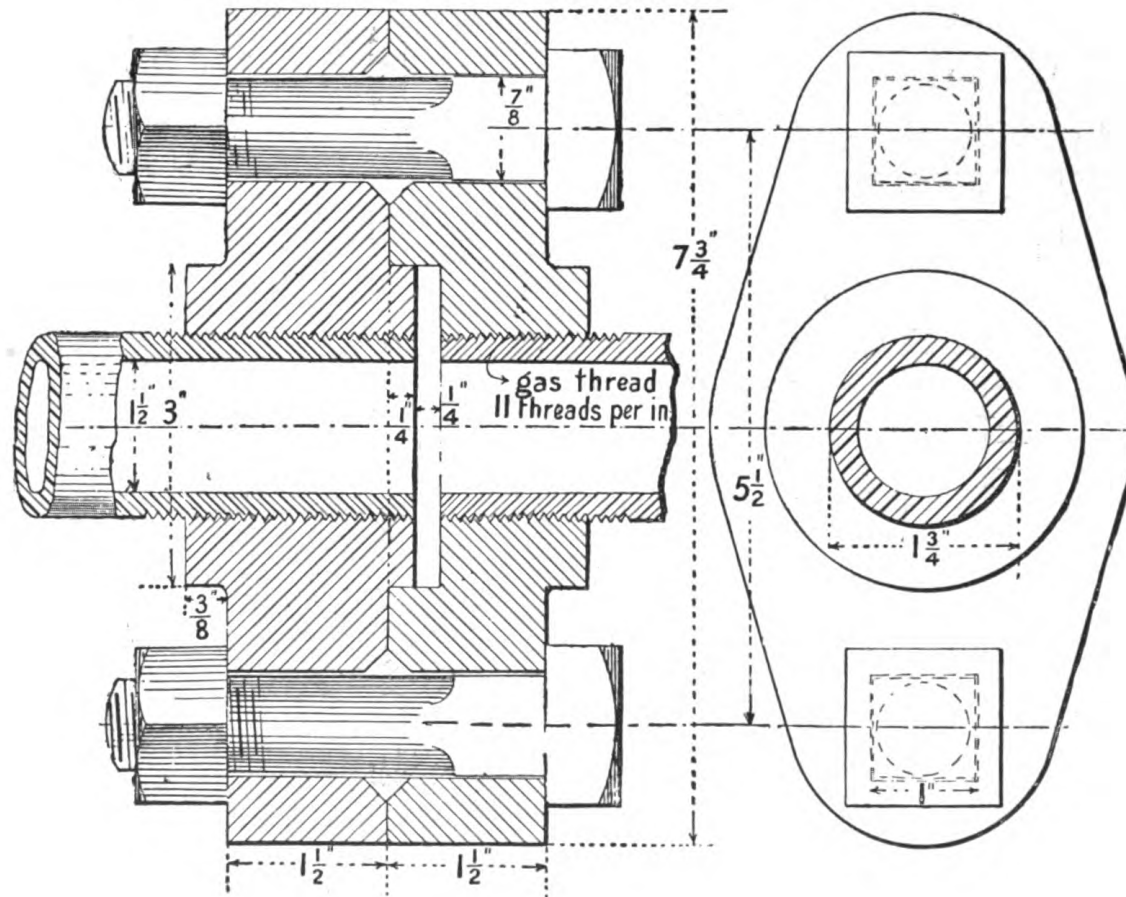


FIG. 164.

Fig. 165 shows a sectional elevation of a *steel steam pipe joint*. The ends of a gas thread and two collars **BB** are screwed on and afterwards brazed. The copper ring pressed tightly against the pipe is secured by a series of bolts passing through two iron collars **CC**.

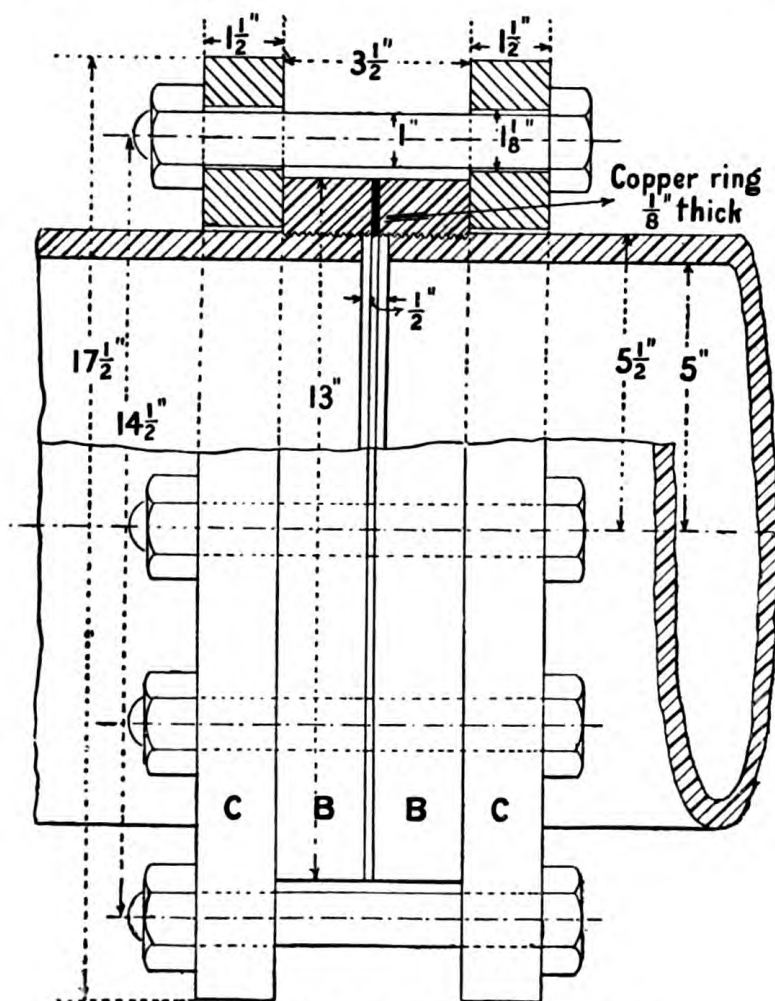


FIG. 165.—Hydraulic Pipe Joint (Steel Pipes).

Example. Draw a view of the pipe joint (I).

Tank joint. Two forms of are shown (Fig. 166) at A,

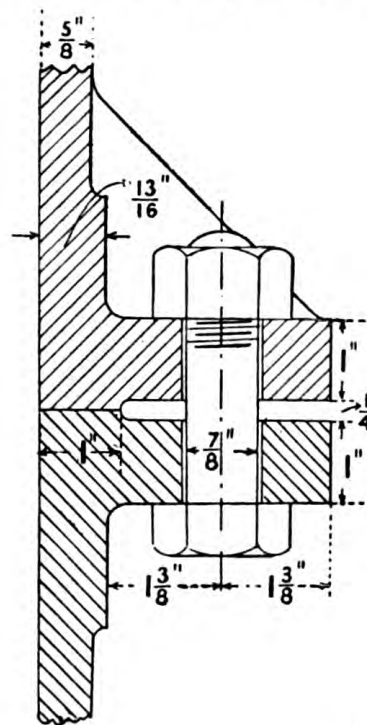


FIG.

two flanges is filled with iron borings mixed with sal ammonia and rammed tightly into the joint. This method is called a *rust joint*. At **B** the joint is made by using a strip of asbestos or millboard, sometimes stiffened by ribs or gussets, as shown in Fig. 166. Thickness $1.1t$, where t is thickness of flange.

Expansion joints. Metal pipes expand and contract with variations in temperature. It is found that pipes are found to alter in length about 1 inch in 50 feet, the range of temperature being about 100°. Various forms of expansion joints are used to allow for this movement.

As indicated in Fig. 167, a brass liner may be fitted to one end of one pipe and tapers to fit the other end of the other pipe. The liner slides easily in a form of stuffing box. Leakage at the joint is prevented by packing inserted in the space **P**. This packing is forced against the sliding surfaces by means of the bolts shown.

The stuffing box would be of simpler form for pipes of comparatively small size and a brass liner would not be used.

Example. Draw the sectional elevation of an expansion joint, Fig. 167. Also draw an end view. Scale half size.

Strength of cylinders. In pipes and cylinders in which the thickness of the metal is comparatively small, as in the shell of a steam boiler, the relation made use of is $p \times d = 2f \times t$, where p denotes the internal pressure in lbs. per sq. in., d the diameter of the cylinder in inches, f the tensile strength of the material in pounds per square inch, and t the thickness in inches. The preceding formula is not applicable in the case of the cylinders employed for hydraulic pressures and usually called *thick cylinders*.

If R is the external and r the internal radius of such a cylinder, p the internal

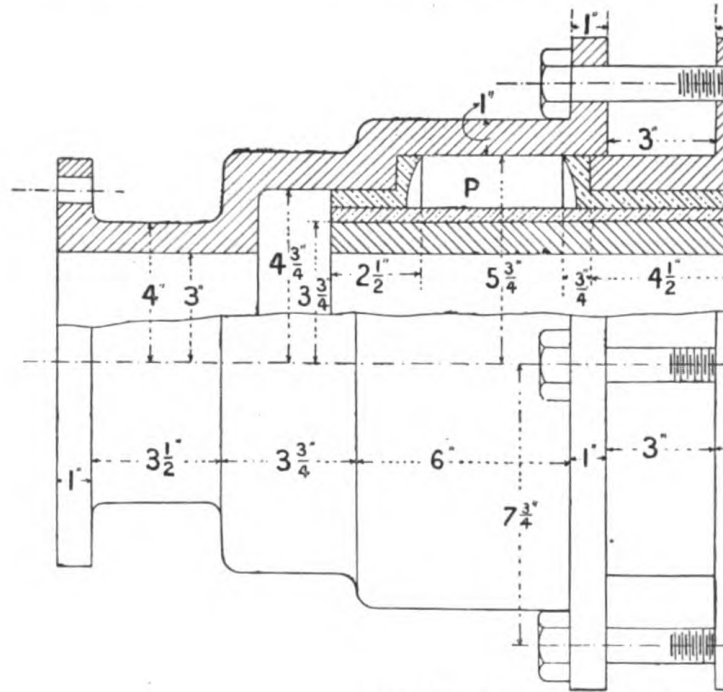


FIG. 167.—Expansion Joint.

safe working stress of the material = 2700 lbs. per sq. in. for cast iron, then R and relation

$$R = r \sqrt{\frac{f+p}{f-p}};$$

when r is known, R can be calculated.

Example. In a hydraulic accumulator r is $4\frac{3}{4}$ ". The internal pressure

$$R = 4\frac{3}{4} \sqrt{\frac{2700 + 1000}{2700 - 1000}} = 7".$$

Hence, the thickness of metal is $7 - 4.75 = 2\frac{1}{4}$ ".

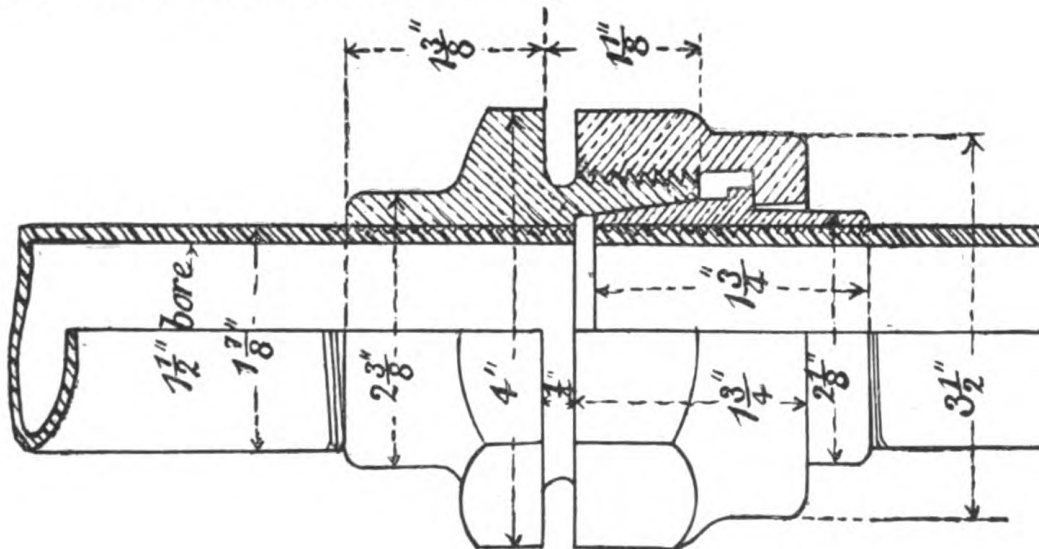


FIG. 168.—Pipe Joint.

EXERCISES. VIII.

1. Union nut and joint for connecting two lengths of small piping, Fig. 168. a plan. [B.E.]
2. With the aid of sketches, describe how to make a steam-tight joint between what circumstances studs are used instead of bolts. [B.E.]

3. Show, by sketches, the methods of constructing the ends of wrought iron or steel pipes and their connection. [B.E.]

4. Describe with a sketch how the joints in hydraulic pipes are made to resist, with high pressures used.

5. Show, by sketches, two methods of joining wrought-iron and cast-iron pipes.

6. Show, by sketches, the construction of a socket joint suitable for connecting lengths of piping.

7. Name the principal materials of which pipes such as are usually employed by engineers are made.

8. Hydraulic pipe joint, Fig. 169. Draw full size, also draw a plan. Explain how the joint is made water-tight. How are the bolts prevented from turning in the bolt holes? [B.E.]

9. Find the thickness of the steel shell plates of a steam boiler; diam., 7 ft. 6 in., pressure, 125 lbs. per sq. in.; tensile strength of material, 30 tons per sq. in.; factor of safety, 5; efficiency of joint.

10. A cast-iron pipe is jointed by means of flanges 10 in. diameter, 1 in. thick. internal diameter and is $\frac{3}{4}$ in. thick. Each joint has five $\frac{7}{8}$ in. bolts joining the two flanges and an end view of the joint. Scale $\frac{1}{2}$.

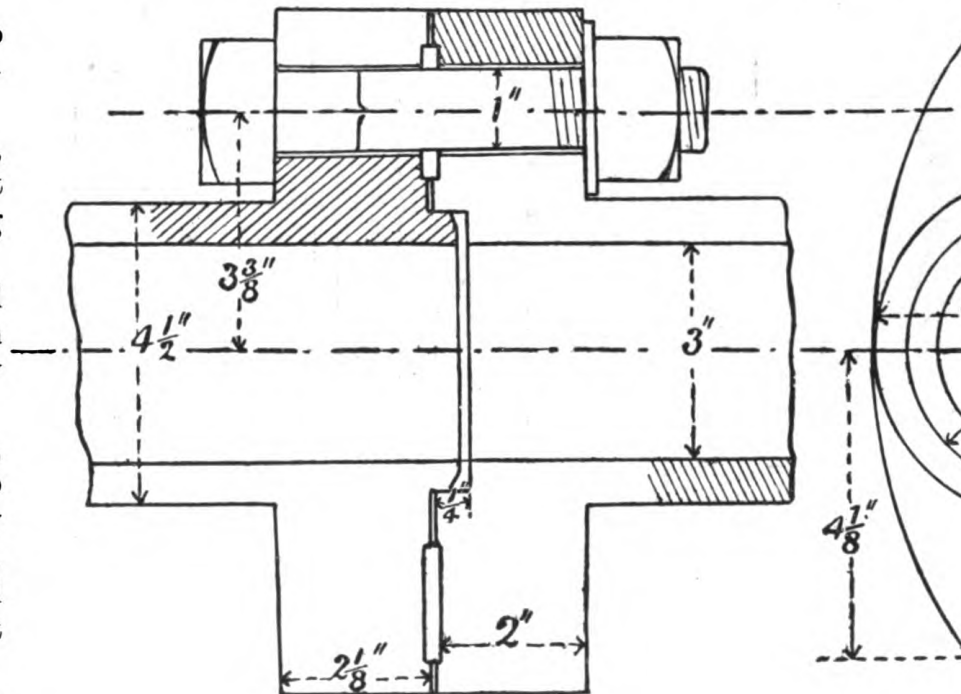


FIG. 169.—Hydraulic Pipe Joint.

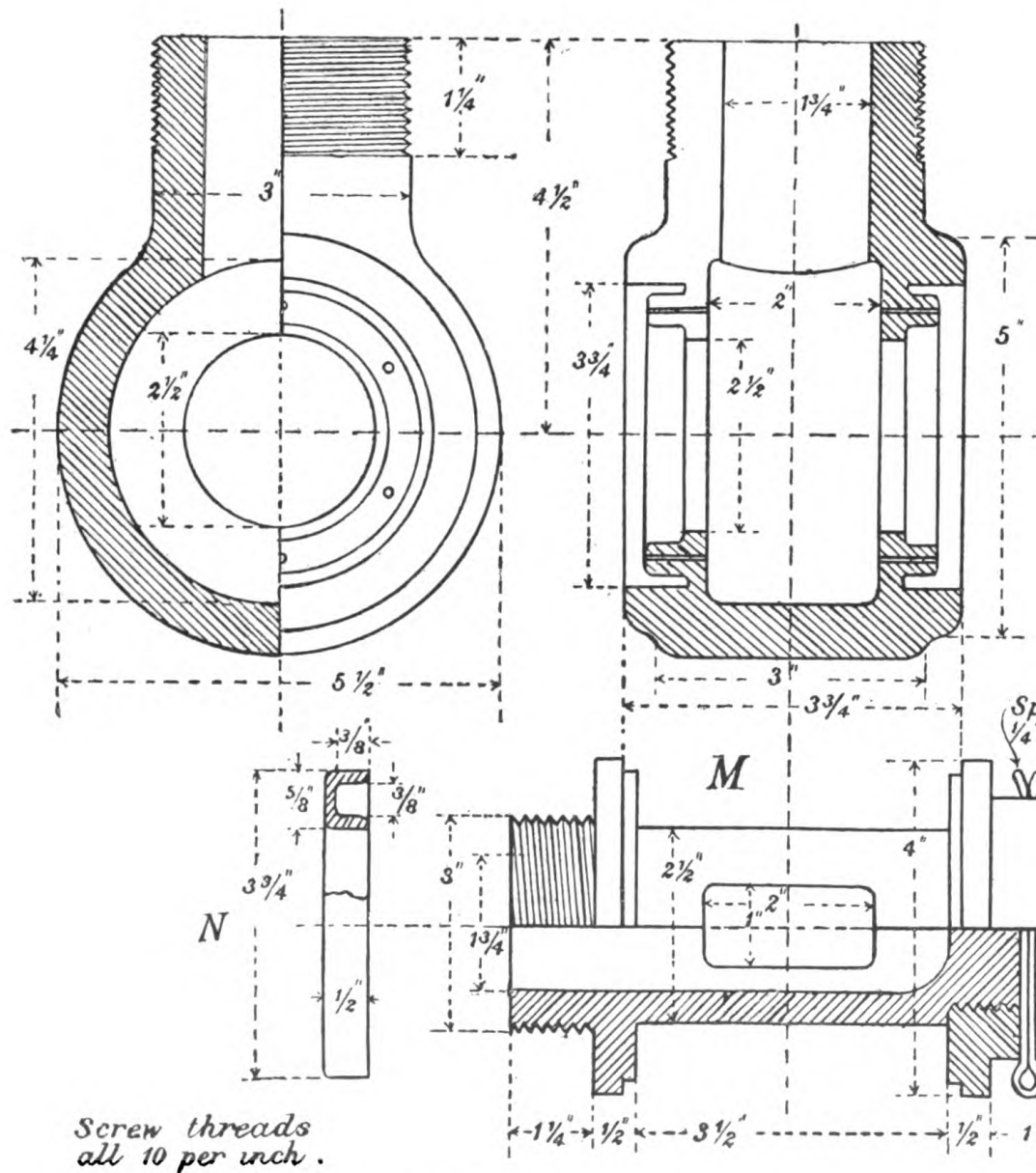


FIG. 170.—Hydraulic Pivot Joint.

11. Give sketches and a description of some method of providing for the expansion of a long length of steam pipe. [B.E.]

12. With the aid of sketches, describe how to make a steam-tight joint between pipes. What are the conditions used to determine the most suitable diameter and number of bolts to use?

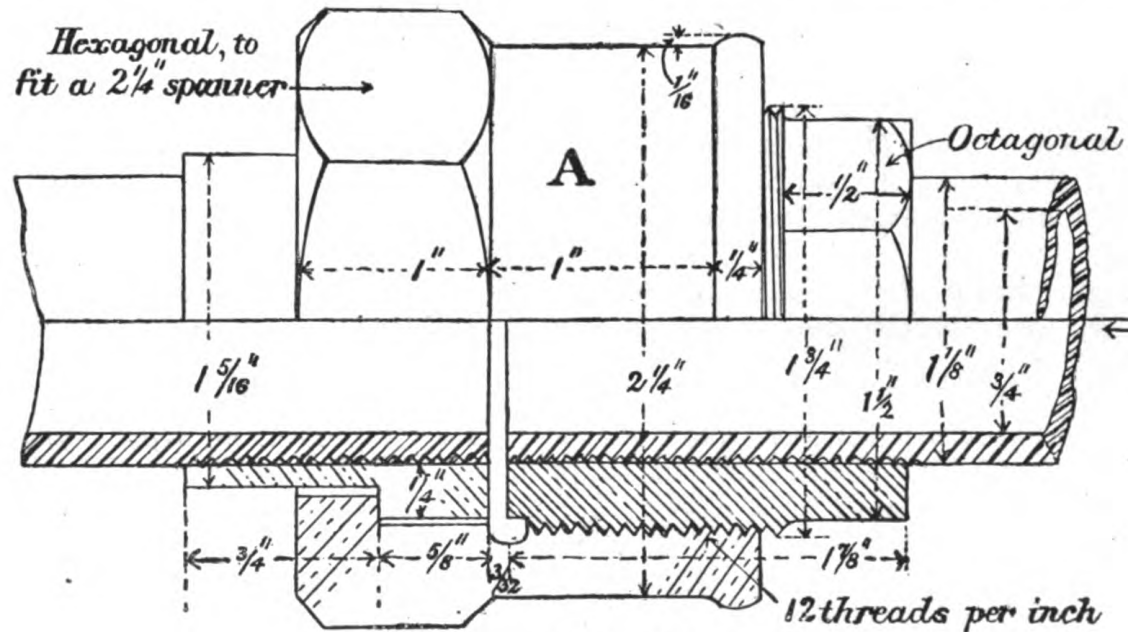


FIG. 171.—Union Joint for Hydraulic Pipes.

13. Give sketches showing two ways of constructing pipes from rolled steel plates. How may they be readily connected with a water-tight joint.

14. Draw the sectional elevation of the hydraulic pivot joint in Fig. 170. Scale full size. **M** shows the plug and retaining nut half in section, and **N** is a cup-leather.

15. Fig. 171 shows a form of union joint suitable for hydraulic piping. Draw two views. Scale full size. Also draw a plan projected from **A**. [B.E.]

CHAPTER IX.

ENGINE DETAILS. PISTONS.

Engine details. In considering the details of an engine, it is important to consider each single detail to the whole. One of the simplest forms of engine is a horizontal steam engine. In Fig. 172 it will be seen that the piston rod is fastened at one end to the piston and at the other to the crosshead, the connection between the crosshead and the crank is made by the connecting rod.

The pressure of the steam acting on alternate sides of the piston gives a reciprocating motion to the piston in the cylinder, and this rectilinear motion causes rotation of the crank which it is fastened to.

The piston rod, connecting rod, and crank, are all in one line when the piston is at its extreme position to the right, or to the left; these positions or points are known as *dead points* in each revolution of the crank. Means have to be provided to enable the mechanism to pass through these points, and this is effected by means of a fly-wheel, *i.e.* a wheel of comparatively small diameter with a heavy rim. When a fly-wheel is not admissible, two cylinders are provided and the crank is turned to two cranks mutually at right angles. A similar arrangement is used also in engines which are reversed, such as in locomotives, portable engines, etc.

A most instructive exercise for those who have not access to an engine of their own is to make a simple skeleton model in wood or cardboard.

The admission of steam to one side or other of the piston is effected by means of a valve.

The distance moved through by the piston from one end of the cylinder to the other is called the *stroke*, or *the travel* of the piston. This distance is obviously *twice* the *throw* of the crank, given to the distance between the centres of the crank pin and the crank shaft.

The crosshead is made to move in a straight line parallel to the axis of the cylinder by means of suitable *guides* or *guide bars*. These guides may form a segment of a circle as in the case of a

in Fig. 190. Only one such surface is necessary in an engine in which the crank shaft rotates in one direction only. When the crank shaft rotates in both directions, as in all reversing engines, etc., two surfaces, one on the upper and the other on the lower, must be provided.

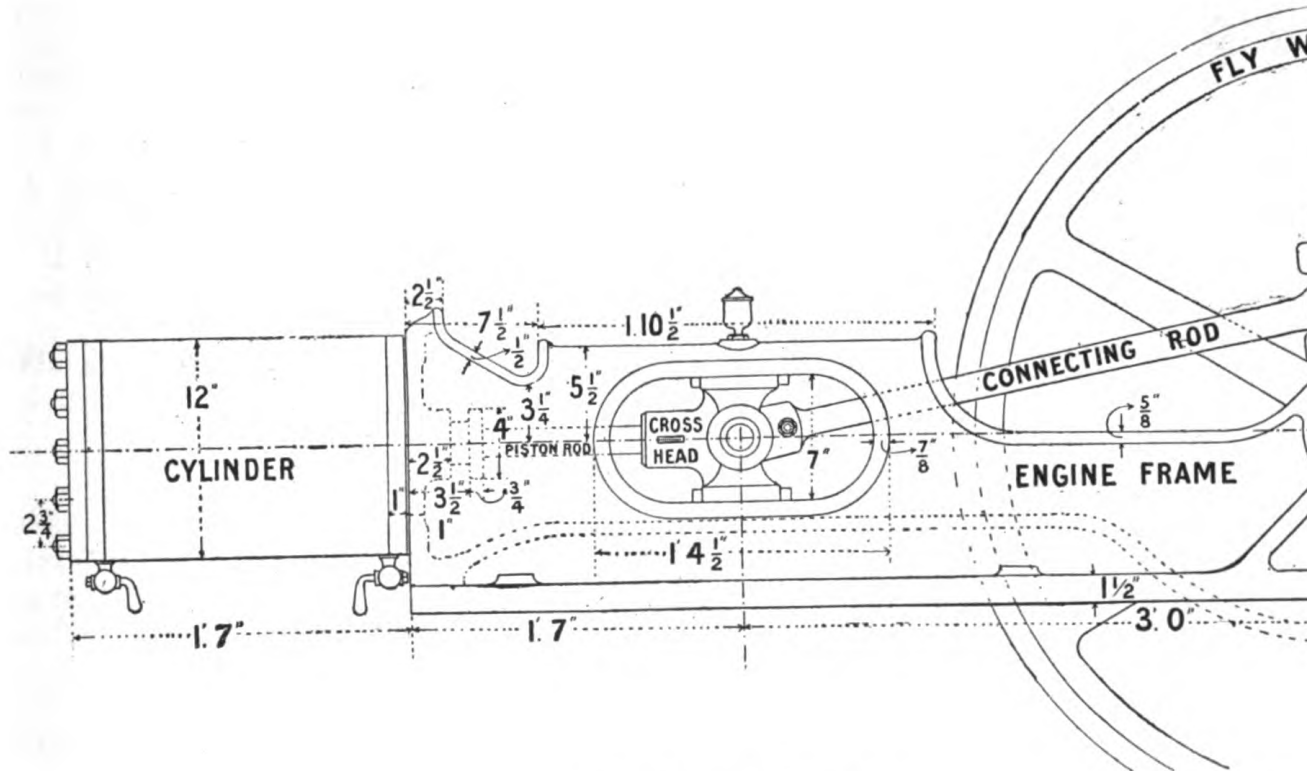


FIG. 172.—Horizontal Engine.

Example. Draw the elevation of the horizontal engine (Fig. 172). Some of the dimensions are given in the diagram. Details of the *connecting rod*, *connecting rod ends*, *crank shaft* bearing, are given in Figs. 202, 192, 144.

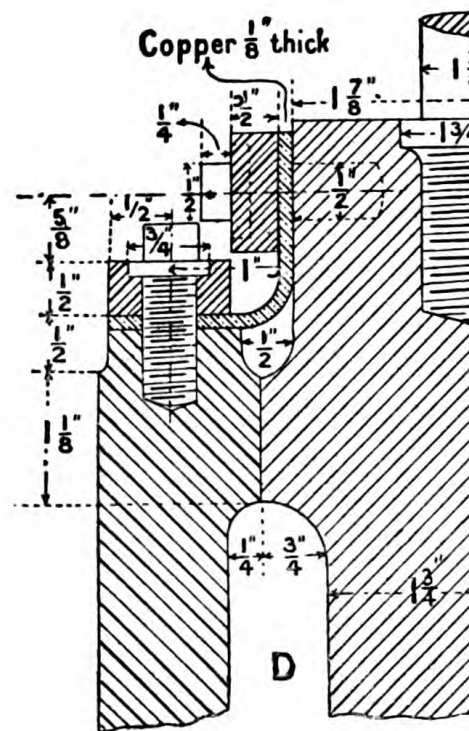
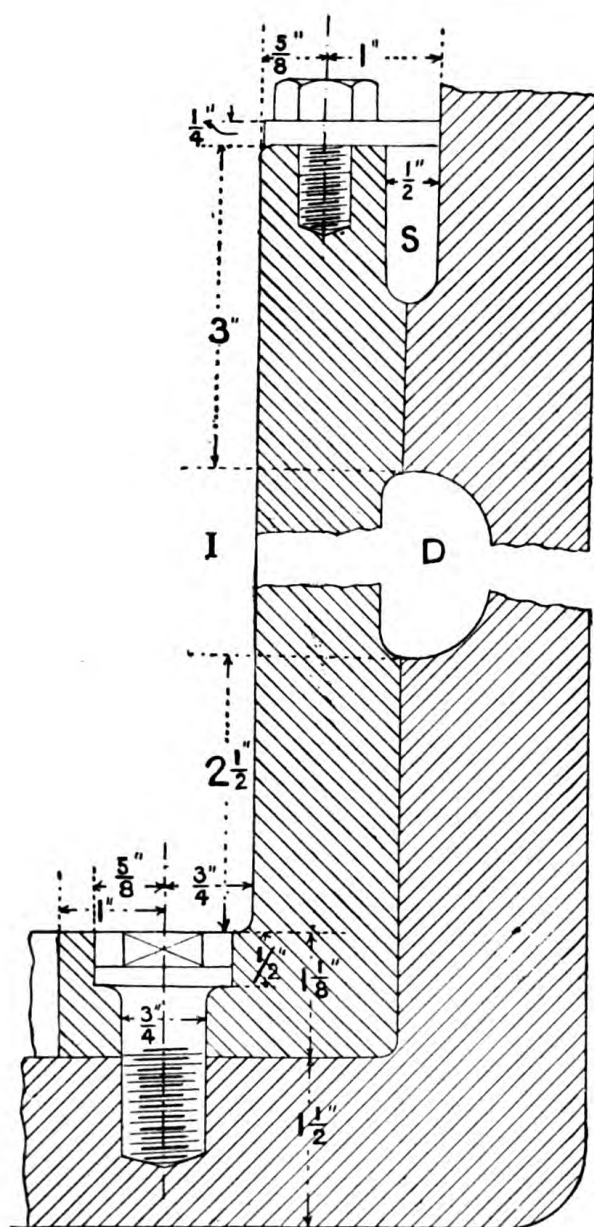


FIG. 173.—Cylinder and

Cylinders. The internal surface of a cylinder should present a hard and smooth surface; that this is the case, what is called a *liner* is frequently used, especially in cylinders of large size. Such liners have been made of steel, but hard close-grained cast iron is usually preferred for purpose. Arrangements have to be made not only to secure the liner to the cylinder for expansion. The liner may be secured to the cylinder by bolts passing through a flange, the bolts being recessed into the flange. The joint between the liner and the cylinder, or the cylinder cover, must be kept steam tight and must also allow for expansion. For the arrangement adopted may be that shown at **I** or at **II** (Fig. 173).

In **I** a small stuffing box **S** is used, and this box when packed with asbestos or other material makes a steam-tight joint. The lower part of the liner is flanged and secured to the cylinder by set screws with square heads.

In **II** a copper ring is used, and this is fastened to the liner and cylinder by set screws.

It will be noticed that the liner is made to fit the cylinder for a comparatively short distance at each end only, and this reduces the labour and expense in machining. The space **D** between the liner and the cylinder varies from $\frac{3}{4}$ " to $1\frac{1}{4}$ " in depth, and is usually kept filled with steam jacket.

Example. Draw the sections of the liner and the cylinder shown in Fig. 173.

Pistons. A piston is usually cylindrical in form on account of the ease and accuracy with which a cylindrical cylinder can be produced by means of workshop tools. As already indicated, the piston moves forwards and backwards in a hollow cylinder, giving rotary motion to the crank shaft by means of the connecting rod, crosshead, connecting rod, and crank. In this to and fro motion, whether the drive is by steam, gas, oil, or water-pressure, the arrangement must be such as to prevent leakage from one piston to the other.

In the cylinder of a steam, gas, or oil engine, the leakage may be prevented by means of packing of metallic packing.

In the cylinder of a hydraulic engine, in which water under comparatively great pressure is used, form of leather packing is necessary. The packing is usually made in the form of a ring or rings in form (Fig. 178).

Ramsbottom's packing. One of the simplest forms of metallic packing, which is used in steam engines, is Ramsbottom's packing.

C.M.C.

K

In the locomotive piston shown in Fig. 175, there are two cast-iron packing rings $\frac{3}{4}$ apart. The end of the piston rod, as indicated in the detail at I, is made in the form of a T, and this expedient enables the piston to be removed readily when necessary.

Example. Draw the section of the locomotive piston (Fig. 175). Draw also the front view. Scale half size.

Steel piston. For many purposes, and especially in marine engines in which the cylinder is large, it is necessary not only that the piston shall be of sufficient strength, but also that its weight shall be as much as possible. These ends are effected by making the piston of cast steel, and, being much stronger (p. 227), the piston may be made about one-third lighter than if made of cast iron. The piston, as in Fig. 176, is made in a conical form. This shape not only makes it easy to cast, but gives strength and rigidity to it.

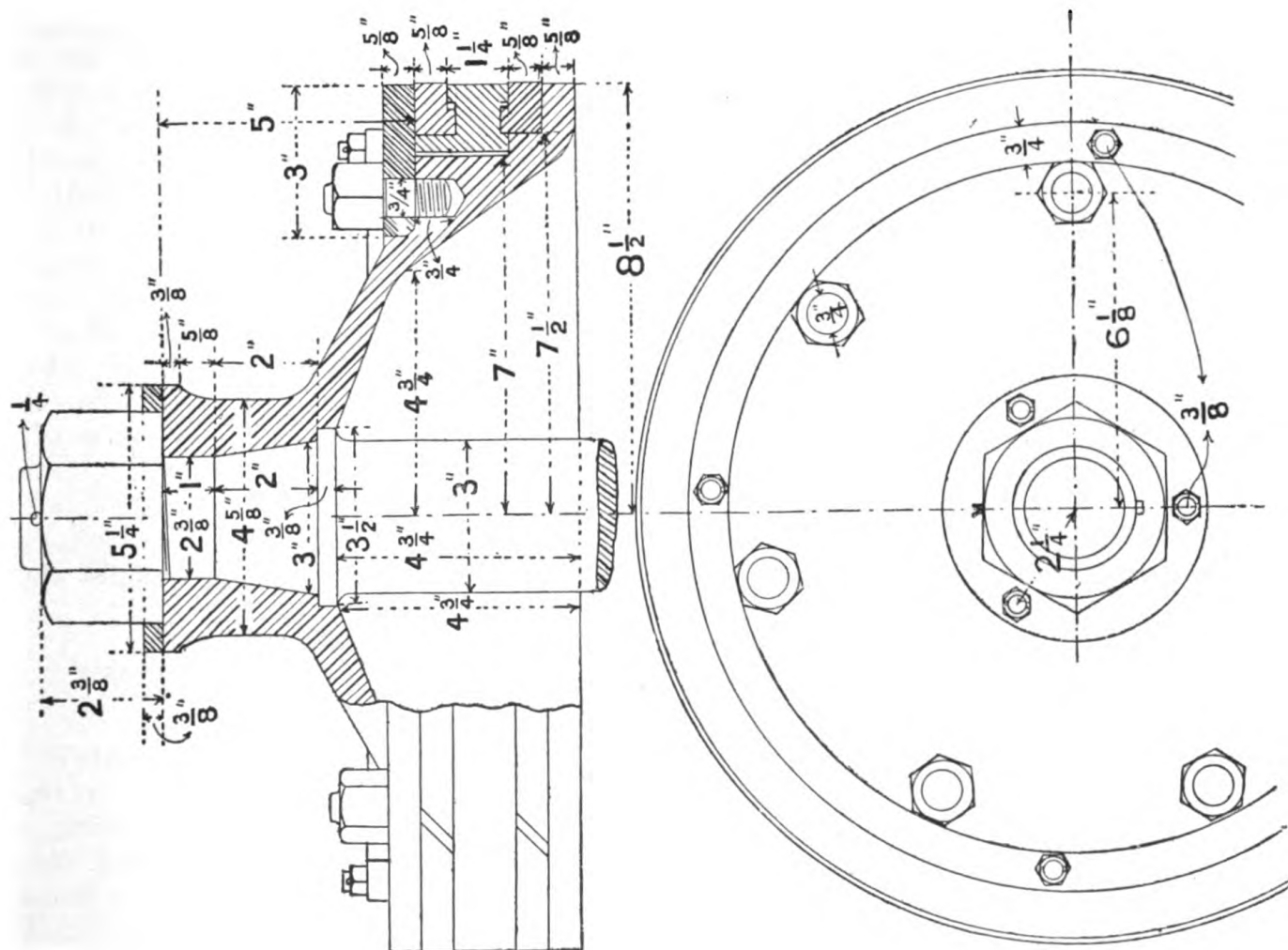
The taper of the piston rod in the boss of the piston is usually from 1 in 3 to 1 in 4. The rings are pressed out by means of suitable springs, so that the pressure against the surface of the cylinder is from 3 to 5 lbs. per sq. in. The split in the piston ring is cut in an oblique direction so that it may not score or cut the surface of the cylinder. Leakage at the split is prevented by a garter spring, which is fixed to one end of the ring by screws.

The packing rings are held in position by a ring called a *junk ring*; this ring is secured to the piston either by studs and nuts or by set screws. The screws or nuts are secured from slacking back by various locking arrangements. The usual method, as in Fig. 177, is to use a *securing* or *guard ring*, which is made to bear against the flat faces of the head of the piston, and is fastened to the piston by means of studs and nuts, the latter being secured by split pins. The usual arrangement, when set screws or bolts are used, is to screw these into nuts or into the metal of the piston. This plan avoids the danger of the bolts rusting and becoming fast in place. The plugs, moreover, can be renewed easily when defective.

The bolt heads are sometimes sunk into the ring instead of standing above it. When using the securing ring the "slacking-back" of the nuts may be prevented by using a split pin.

The nut at the end of the piston rod is secured by means of a locking plate, as in Fig. 178, by three or more small studs, the nuts being fixed by split pins.

ENGINE DETAILS. PISTONS



Hydraulic piston. When water under pressure is used in the cylinder of an engine, the form of the piston is different from the preceding examples. One form is shown in Fig. 178. In this case the cylinder and piston are of brass, and the end of the steel piston rod in contact with the piston is made in a spherical form, for since the rod is throughout the stroke in a state of compression, it is not necessary to fasten the rod and piston together. The water-tight packing is furnished by a *hat leather* as shown. This leather is held in place by a washer and nut, while a small split pin prevents the slacking back of the nut.

In this form of hydraulic piston for what is known as a *single-acting* engine, the water pressure only acts on one side of the piston. The arrangement of the three pistons in an engine of this type is shown in Fig. 182.

A double leather packing is used when the water pressure acts alternately on each side of the piston. One form of piston adopted is shown in Fig. 181.

Example. Draw full size the three views of a single-acting hydraulic piston and cylinder (Fig. 178).

Water-pump bucket. Fig. 179 shows a piston or pump bucket with a hat-leather arrangement for preventing leakage. The water pressure acts alternately on each side of the flexible leather and is found to make a good joint for any pressure.

Example. Draw the two views of the hat-leather arrangement shown in Fig. 179 also draw an end view. Scale 6" to 1'.

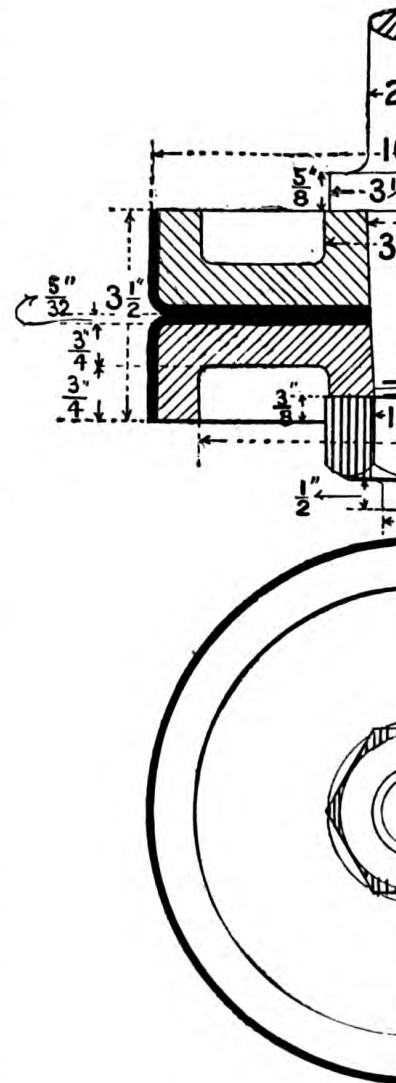


FIG. 179.—Water-p

EXERCISES. IX.

1. Explain how piston rings are made so that the piston may work steam-tight in the cylinder. How are these rings put into place?

2. Explain, by means of a sketch, the manner in which a piston rod is made to move in the cylinder so that the axis of the rod coincides with the axis of the cylinder.

3. Show, by sketches, the construction of a hydraulic piston suitable for high pressure.

4. Sketch and explain how a ram is made to work water-tight in the cylinder of a hydraulic press.

5. Sketch and describe one form of piston suitable for a steam engine and one suitable for a gas engine. State the reasons for the difference in construction in the two cases, and also the materials used in the construction of the piston.

6. Give sketches showing two or more methods of fastening the piston rod to the piston.

7. State the essential points to be secured in the design of a piston for a steam engine. Illustrate your answer by sketching any good form of piston.

8. Explain the advantages of providing a separate piece for the liner of a steam engine cylinder. Aid of sketches describe how the liner is fitted at each end of the cylinder.

9. Fig. 180 shows the piston with connecting rod end for a gas engine. Draw half of the piston showing which the parts are properly connected together. (i) A side elevation in which the upper half is a section taken through the axis of the cylinder, and lower half an outside view of the piston. (ii) A plan taken through the axis of the piston. (iii) An end elevation looking into the open end of the piston.
[B.E.]

10. The diagram (Fig. 181) shows a piston and plunger for hydraulic pressure. together, the covers to be secured by studs and nuts. Draw a sectional elevation L; the right half with the cover removed, and the left half with the cover in place

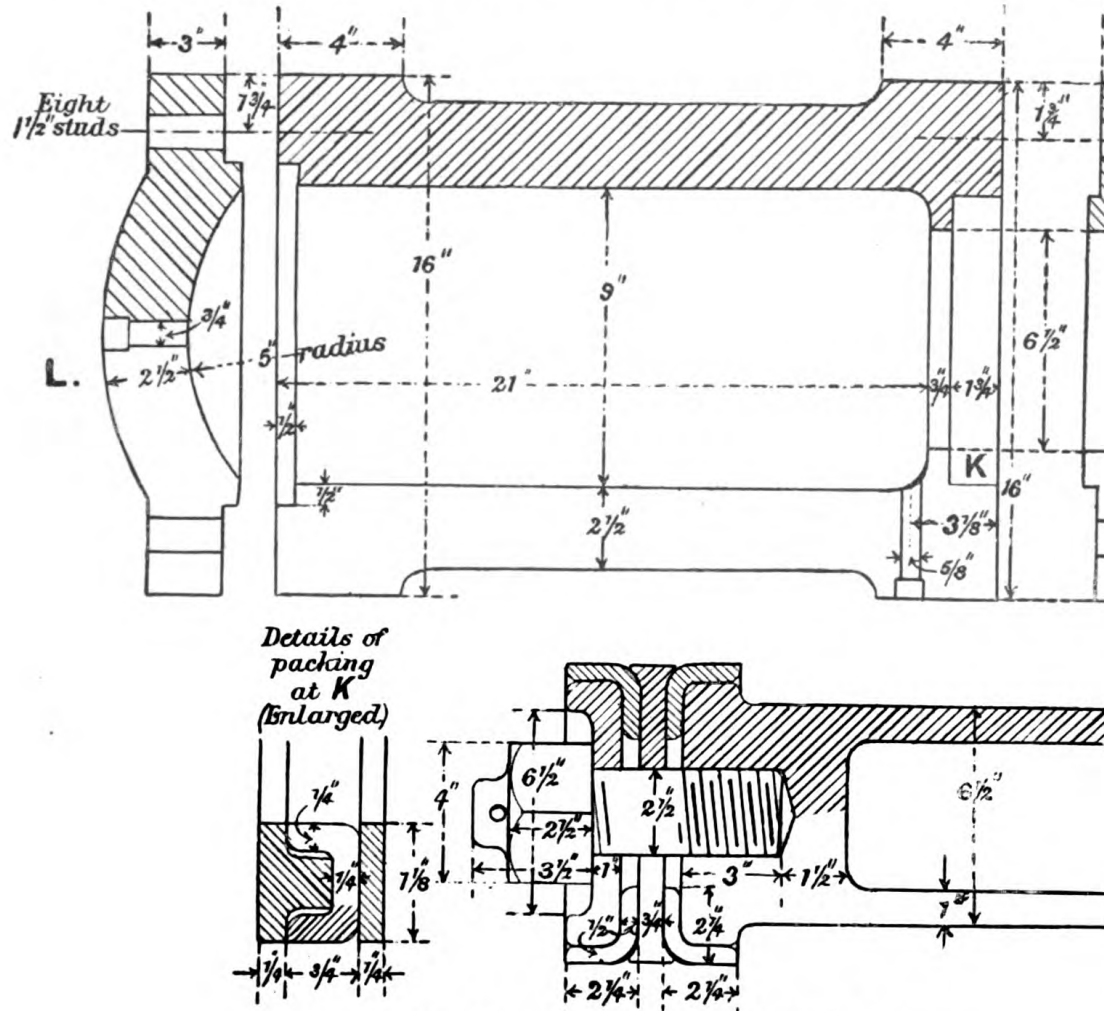


FIG. 181.—Piston and Plunger for Hydraulic Pressure.

IX.]

ENGINE DETAILS. PISTONS

11. Draw the two views shown of the three-cylinder Hydraulic Engine (Fig. 182). is 700 lbs. per sq. in. Find the size of the two bolts for the cover, and show the Scale half size. [B.E.]

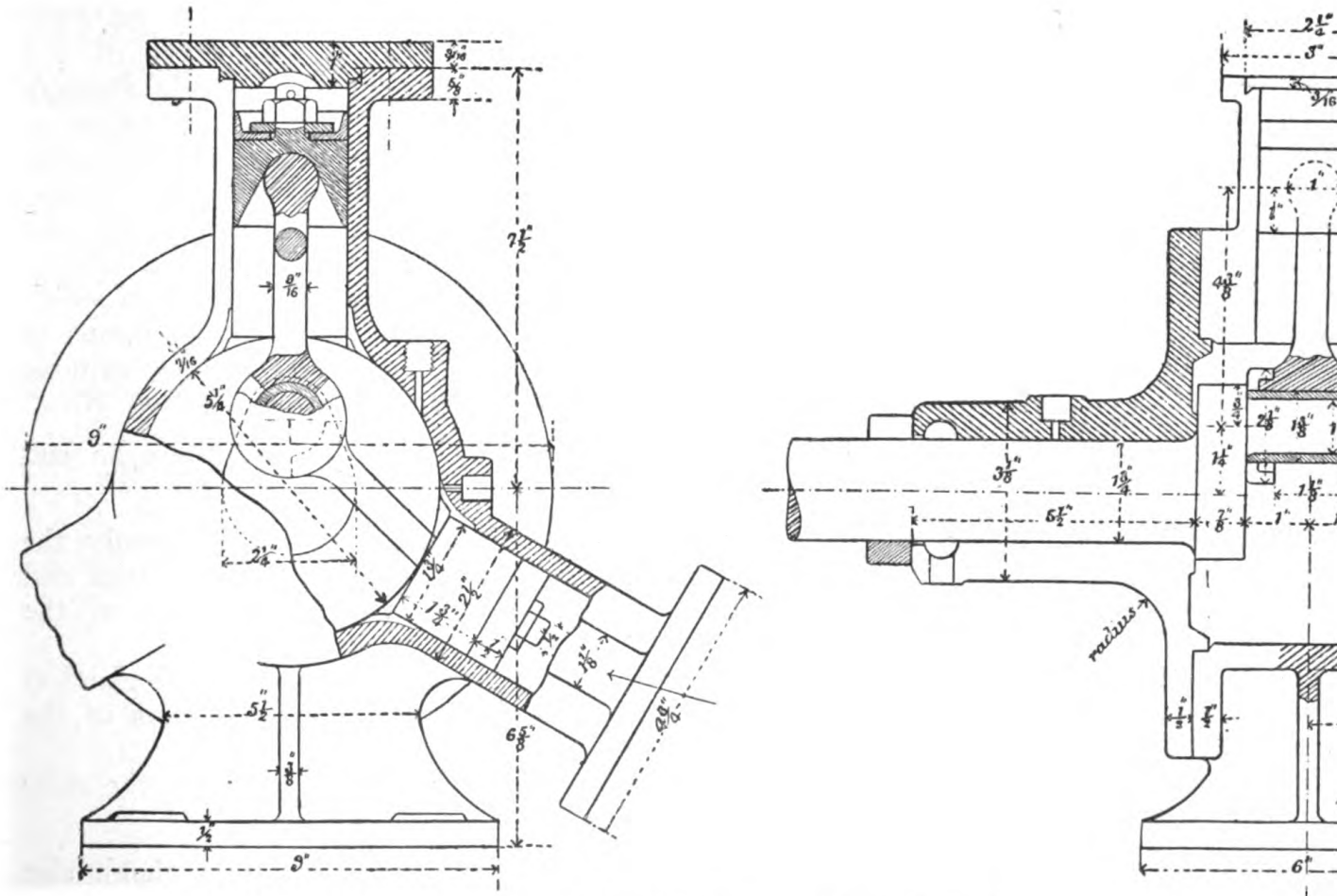


FIG. 182.—Three Cylinder Hydraulic Engine.

CHAPTER X.

STUFFING BOXES AND GLANDS

Gland and stuffing box. The piston rod of a steam, gas, or other engine passes through the cylinder cover of the engine, and there must be no leakage past the rod during its motion. Such leakage is prevented by using a *stuffing box*, which consists of a hollow cylindrical box, in which asbestos or other suitable material is placed. The stuffing box also acts as a guide, so that the axis of the rod always coincides with the axis of the cylinder. The wear on the rod and the stuffing box is lessened by using a suitable alloy for the rubbing surfaces.

Fig. 183 shows a simple form of stuffing box, which consists of a cylindrical box, in which a screw thread is formed; a gland, **G**, is made to fit the box and can be forced against it by a hexagonal nut, **N**. The lower part of the stuffing box is bored to fit the rod. The packing inserted in the space **P** is compressed and forced tightly against the rod by the gland.

Example. Draw the two views of the stuffing box and gland (Fig. 183). Scale full size.

In the form just described, all the parts—the box, gland, etc.—are of brass or gunmetal, except the case when it is of comparatively small size. In larger sizes, the box and gland are of cast iron; the rubbing surfaces are provided by brass bushes inserted in the gland and in the stuffing box.

In Fig. 184 a gland and stuffing box for a vertical engine are shown. The gland and stuffing box are of cast iron; a brass bush which tightly fits the gland and another bush inserted in the stuffing box, form the rubbing surfaces.

A steam-tight joint is obtained by suitable packing placed in the space **P** around the piston rod by means of the three studs shown.

Example. Draw to a scale 6" to 1' the two views shown of a stuffing box and gland (Fig. 184). Draw an end view.

STUFFING BOXES AND GLANDS

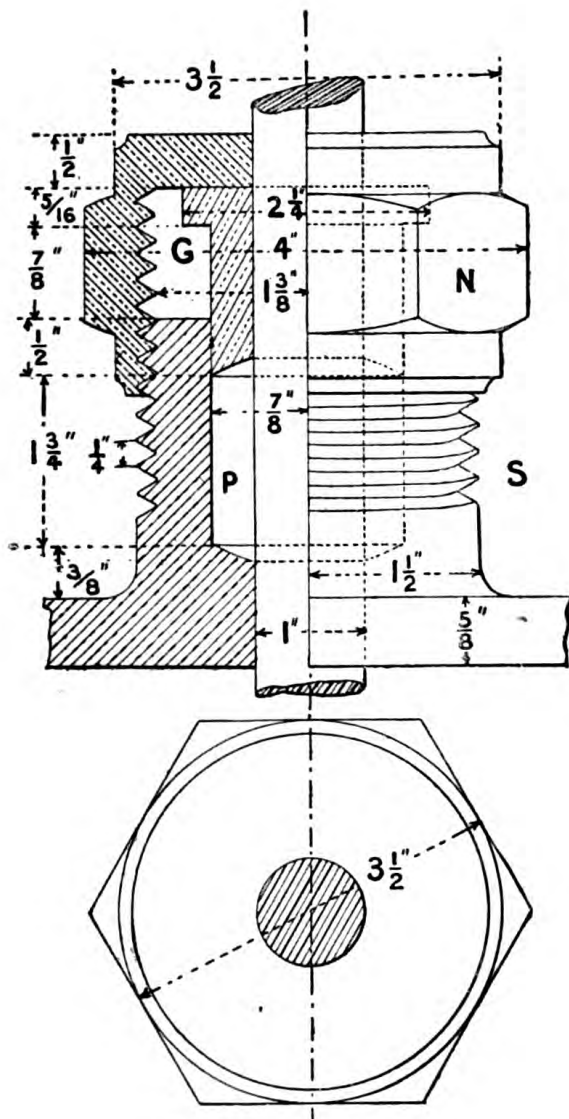


FIG. 183.—Stuffing Box.

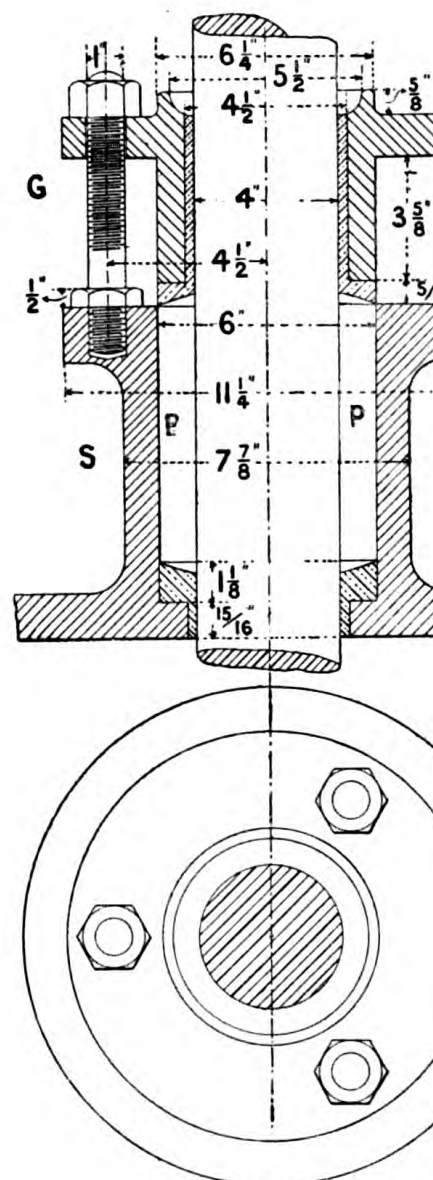
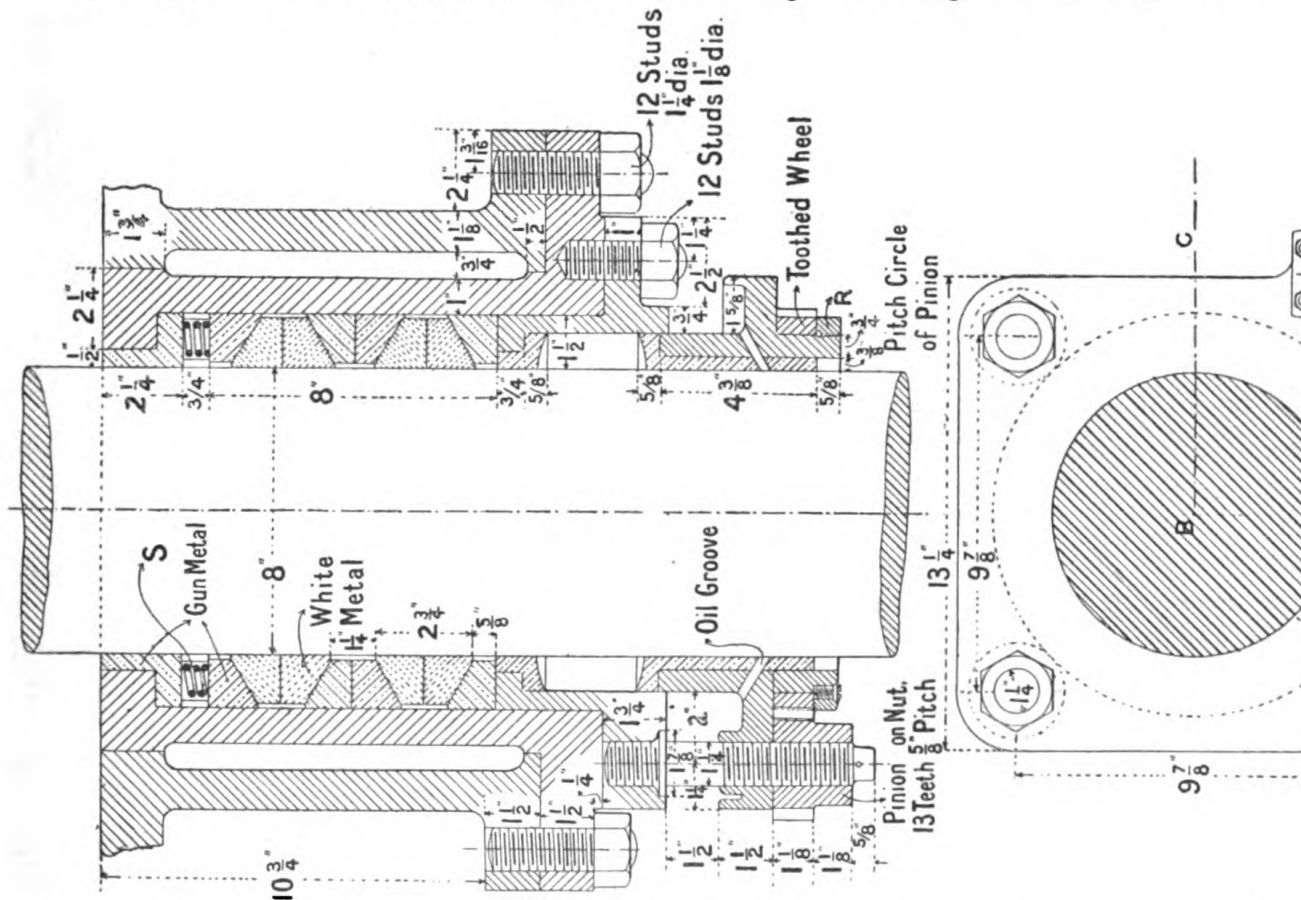


FIG. 184.—Stuffing Box and Gland.

STUFFING BOXES AND GLANDS

Example. Draw, to scale 6" to 1', the stuffing box and gland for the piston rod



Hydraulic packing. Leather packing—in the forms known as *cup-leather* or *hat-leather*—packing consists of a leather washer moulded into the form of an annular ring (Fig. 10). It may be placed in a recess or chamber formed in the side of the cylinder. When under pressure leaks past the ram, *R*, into the chamber *C*, and acting on the inside of the leather tightly against the sides of the ram, thus ensuring a tight joint. The tight

increases with the increase in the pressure. Some difficulty may be experienced in Fig. 187 in placing the leather in position; this difficulty may be avoided, however, by the arrangement shown in Fig. 188.

Double cup-leather. In the case of the piston of a hydraulic engine, there is a cup-leather on one side of the piston or on both sides. In the former case, a single cup-leather, as in the Brotherhood engine (Fig. 182), may be used, and in the latter a double cup-leather would be required.

EXERCISES. X.

1. Describe how a steam-tight joint is made between the cylinder and the piston of a steam engine. Show how a piston rod is enabled to work steam-tight through a cylinder. An alternative plan could be adopted when water is the pressure fluid used instead of steam.
2. Sketch in section a stuffing box and gland, with bolts or studs, in the case where cast iron, wrought iron, and brass are employed. Explain why these different materials are used for the various parts. [B.E.]
3. Draw a section of a simple form of stuffing box suitable for a valve rod where no studs nor bolts are required for tightening the gland.
4. What is packing? Name the principal materials of which it is made. What is the purpose of the packing in a stuffing box to prevent leakage of steam? Sketch two methods of tightening the gland when it becomes worn.
5. Show, by sketches, how cup-leather packing is used to prevent leakage of water from steam presses.
6. Describe how the lubrication is provided for in the stuffing box and the gland.
7. Describe an arrangement for screwing up simultaneously the several nuts of the gland of a stuffing box. [B.E.]
8. Explain, with sketches, one form of metallic gland packing for the piston rod of a steam engine. State the advantages due to the use of metallic packing as compared with other forms of packing.
9. A stuffing box and gland are shown in Fig. 189. Draw the two views shown in the figure. Scale half size. [B.E.]

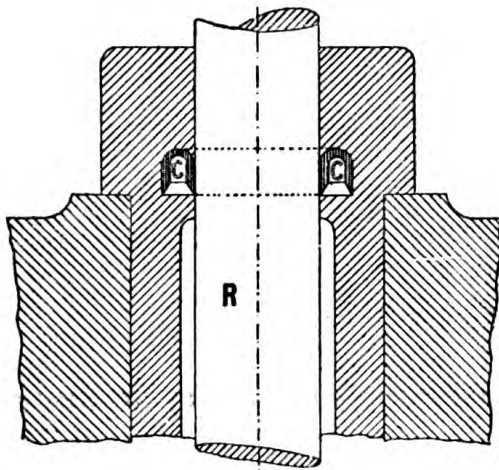


FIG. 187.—Hydraulic Packing.

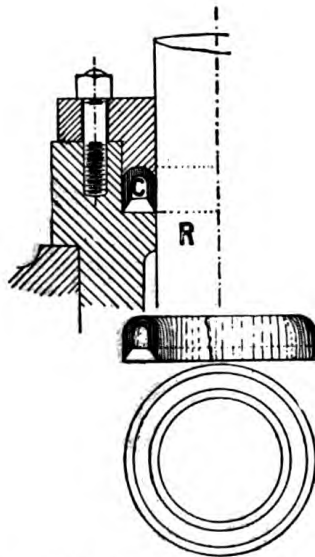
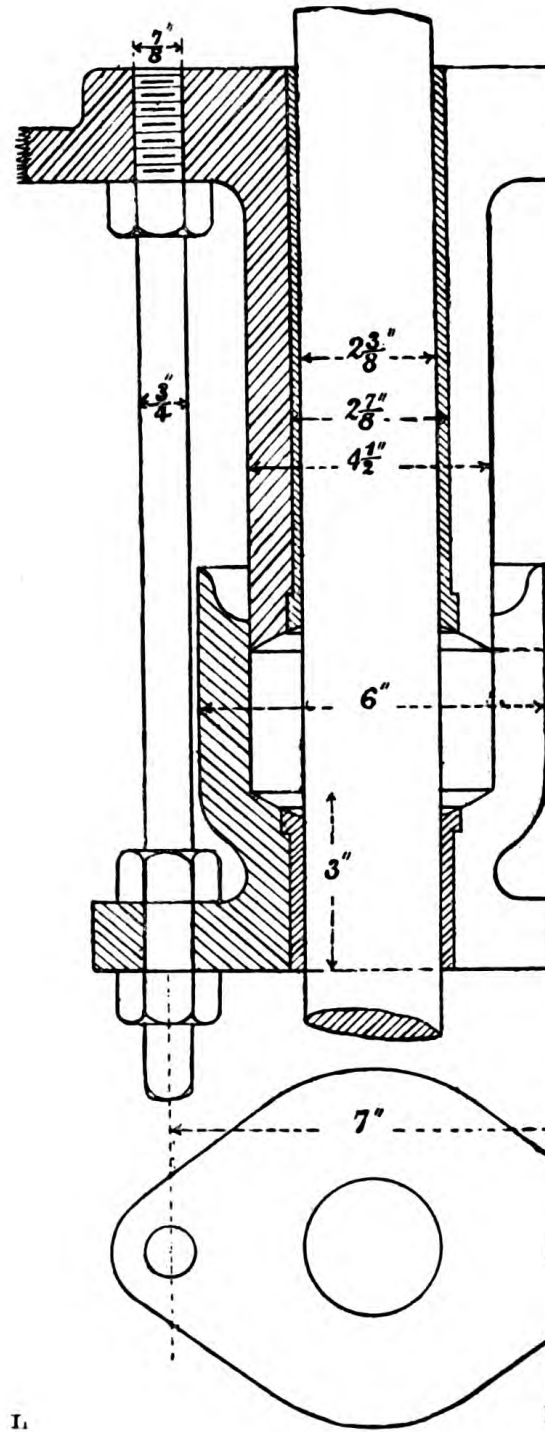


FIG. 188.—Cup Leather Packing.

C.M.C.



I.

CHAPTER XI.

CROSSHEADS AND SLIDE BARS.

Crosshead and slides. The connection between a piston rod and a connecting of a crosshead. One form of crosshead is shown in Fig. 190.

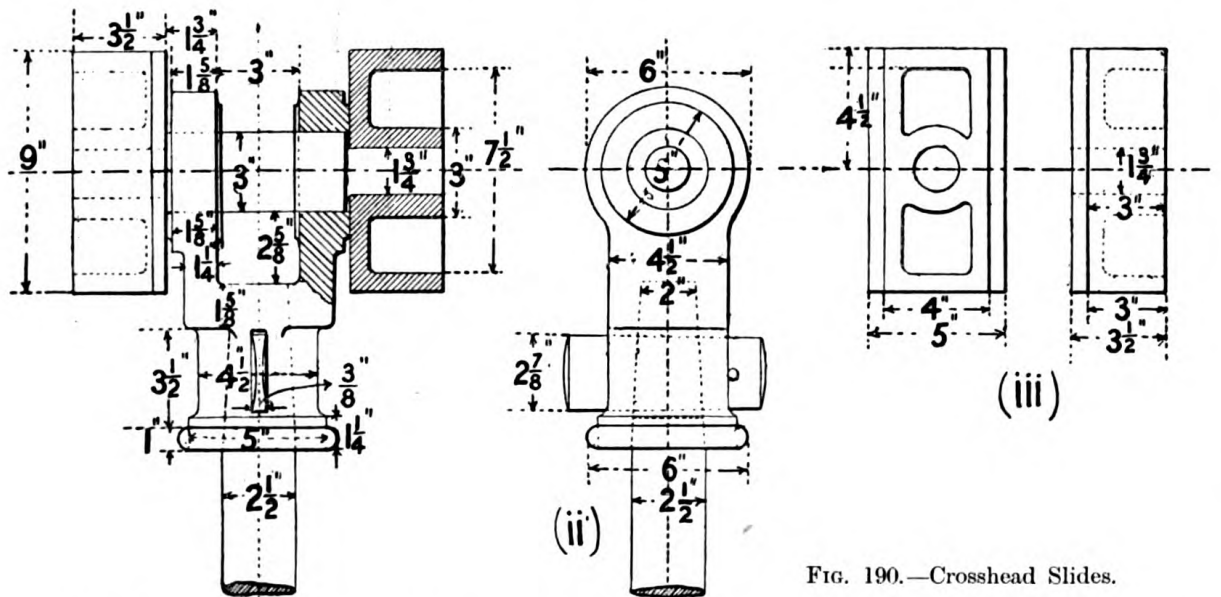


FIG. 190.—Crosshead Slides.

Detailed drawings of the end of the piston rod and slides are given at (ii) and (iii). It will be seen that the end of the rod is made of a taper form, and is secured by a cotter.

CROSSHEADS AND SLIDE BARS

The dimensions and general form of the crosshead and slides may be seen from the

Example. Draw the details of the crosshead and slide bars (Fig. 190). Scale

Guide bars. The two slides (Fig. 190) move backwards and forwards, the centre moving in a horizontal line. This motion is ensured by means of guide bars, a pair of in Fig. 191.

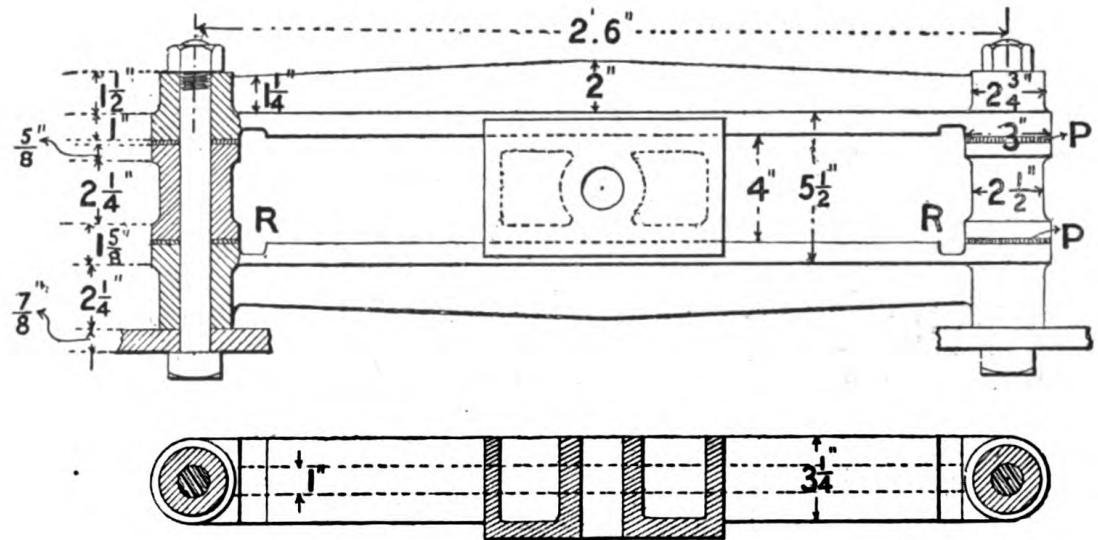


FIG. 191.—Guide Bars.

It will be noticed that small recesses, **R, R**, are made at each end of the guide bars. The slides entering these recesses during each to and fro motion of the crosshead prevents a ridge, which would otherwise occur owing to the wear of the slides.

Adjustment for wear may be made by means of *distance pieces*, **PP**, which are inserted at the ends of the guide bars.

Example. Draw the two views of the guide bars shown in Fig. 191. Also in positions the crosshead and slides of Fig. 190.

Forged steel crosshead for marine engine. Fig. 194 shows a form of crosshead engine. The rubbing surfaces are of white metal, which is placed in suitable grooves.

Example. Draw the two views of crosshead (Fig. 194). Scale half size.

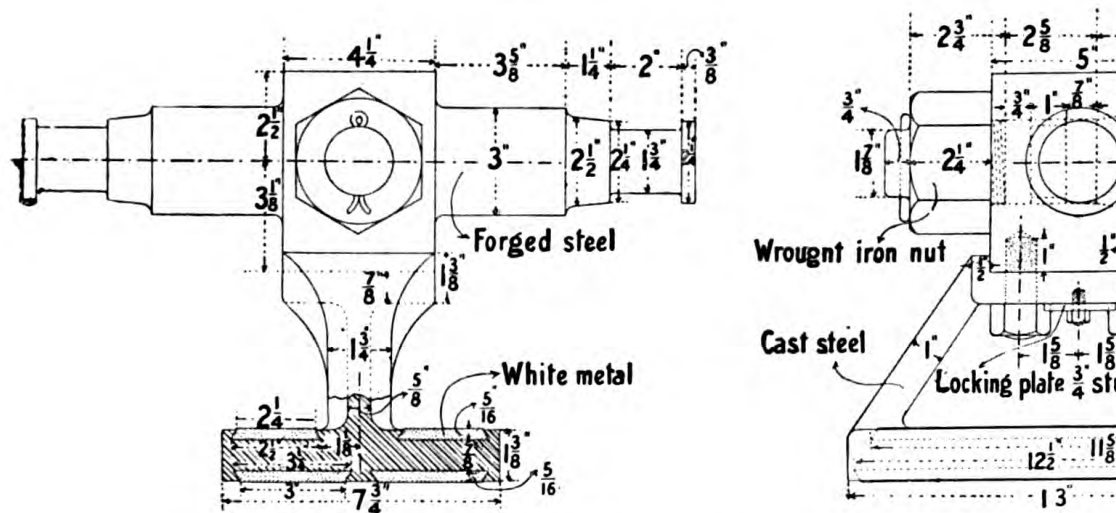


FIG. 194.—Forged Steel Crosshead.

Some of the remaining forms of crossheads and guide blocks used are shown in Fig. 197 adjustment for wear can be made by means of the set screw shown; the crosshead to press against a steel plate. In Fig. 199 two views of a crosshead and slide block and piston rod are shown.

4. Complete the two views of the crosshead (Fig. 198). Also draw a plan. S

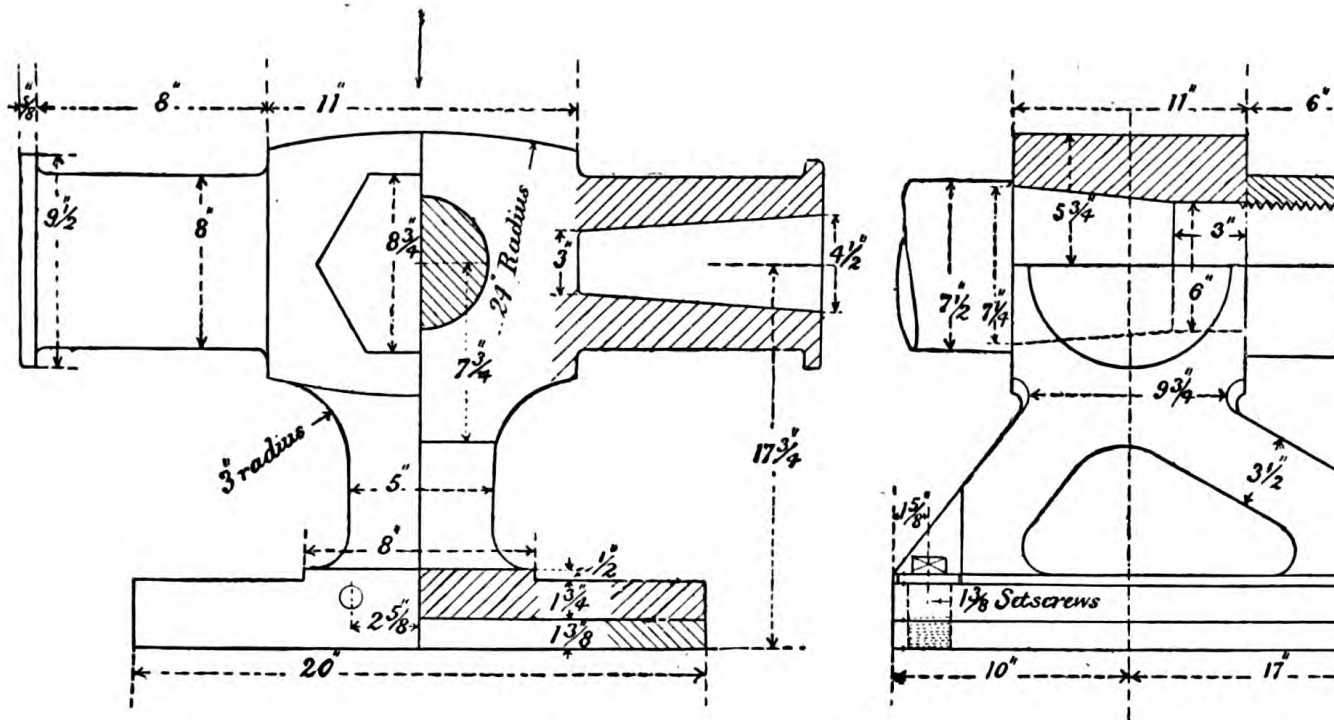


FIG. 198.

5. The diagram (Fig. 199) shows two views of a crosshead and slide block for a rod. Draw these views and add a plan and a sectional elevation on the line **AB**.

$\frac{7}{8}$ " studs with
lock nuts & split pin.

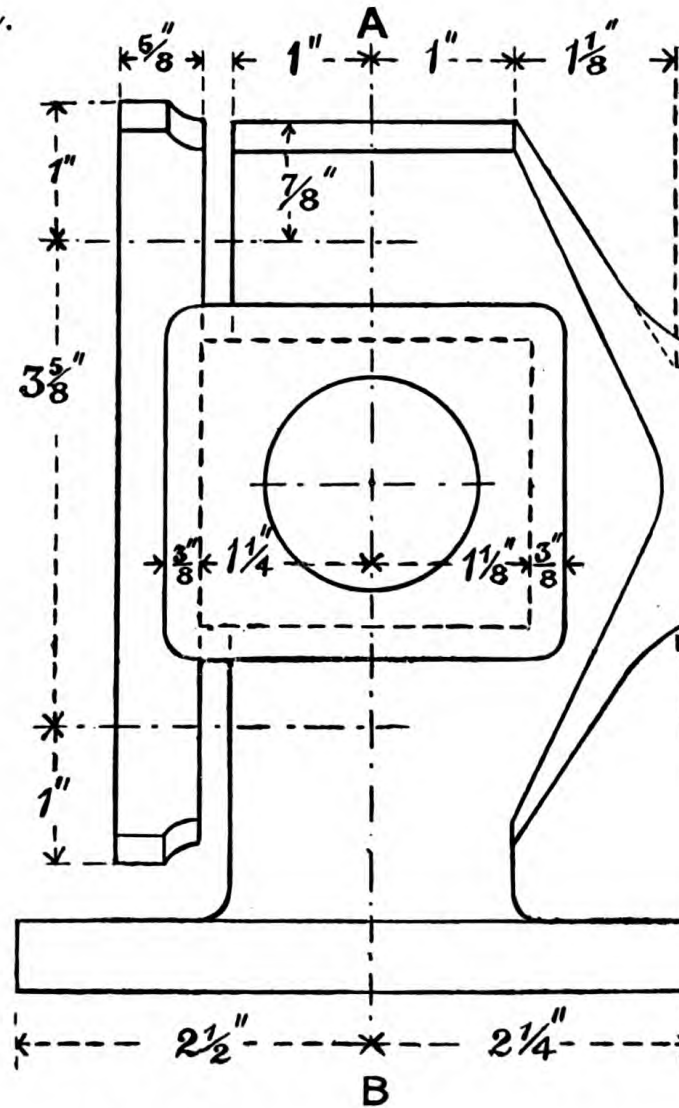
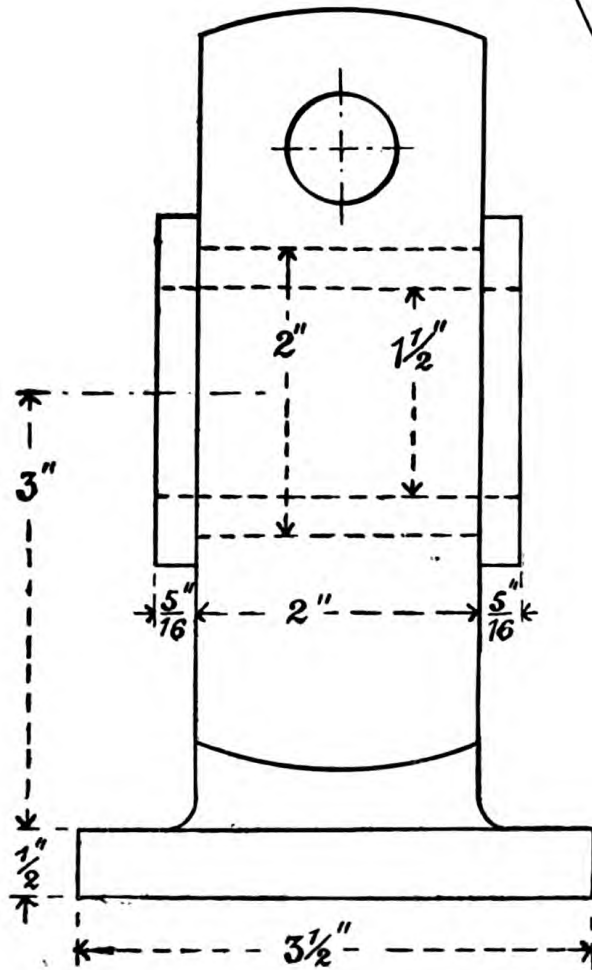
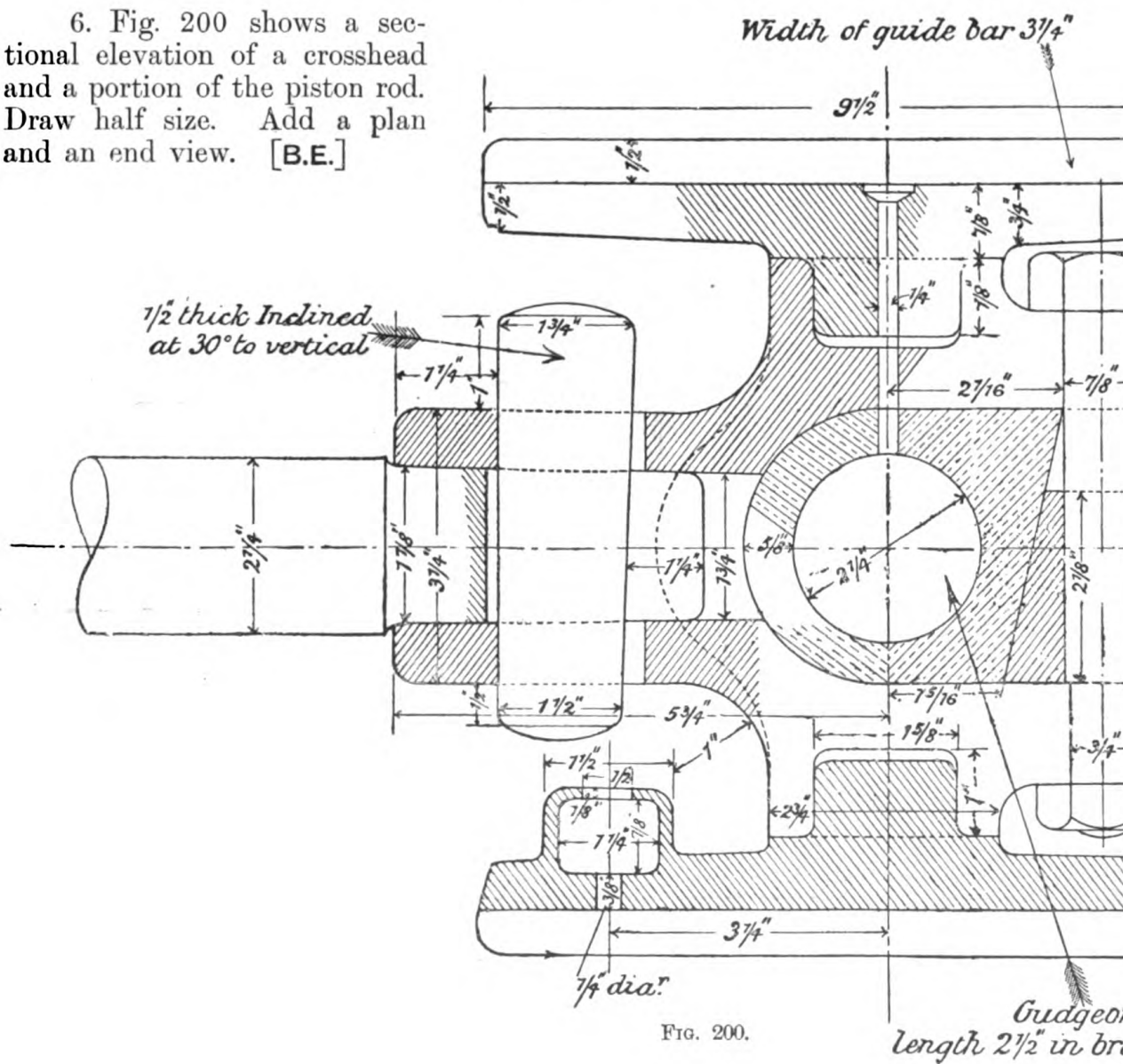


FIG. 199.

6. Fig. 200 shows a sectional elevation of a crosshead and a portion of the piston rod. Draw half size. Add a plan and an end view. [B.E.]



CHAPTER XII.

CONNECTING RODS.

Connecting rod. The connection between the crosshead and the crank pin of an engine is made by what is known as a *connecting rod*. The material used for such a rod is either mild steel or wrought iron of good quality.

The ends of the rod are usually referred to as the *small end* and the *large end* respectively. The former embraces the crosshead pin and the latter the crank pin.

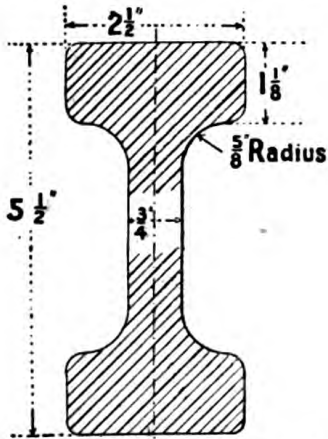


FIG. 201.—Cross Section of a Connecting Rod.

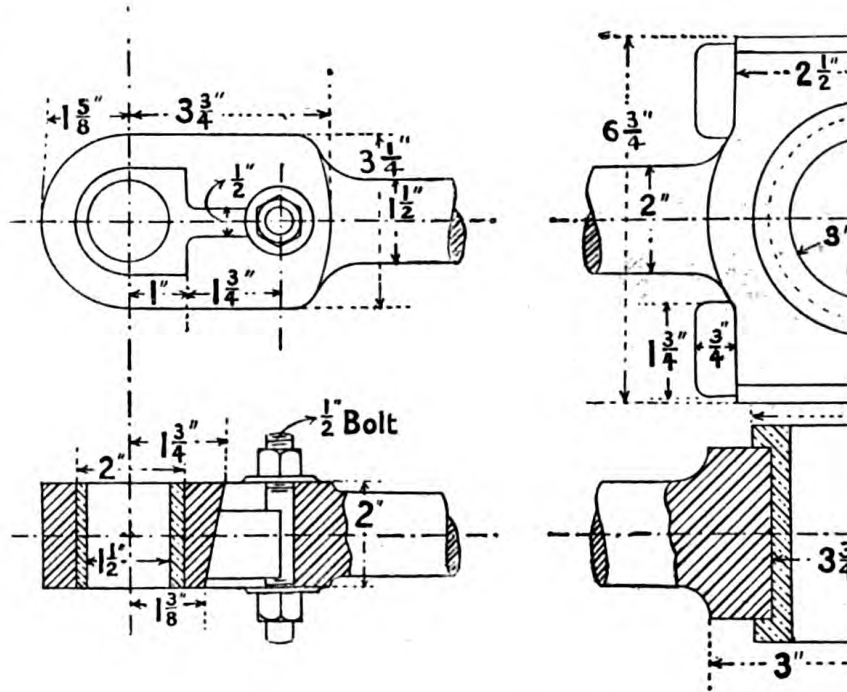


FIG. 202.—Details of Connecting Rod.

Example. Draw, full size, the cross section of a locomotive connecting rod.

Example. Details of the ends of the connecting rod of the horizontal engine shown in Fig. 202. Draw full size.

In slow moving engines the rod is frequently made of a circular form in moving engines—locomotives, etc.—the rod usually consists of a tapering bar, or a section as in Fig. 204. It may be I-shaped as in Fig. 201, which shows the cross connecting rod, the distances between the centres being 10 ft.

Strap and cotter connecting rod end. In this form, the end of the connecting rod is of a rectangular section. A strap of mild steel, or wrought iron, is made to fit this

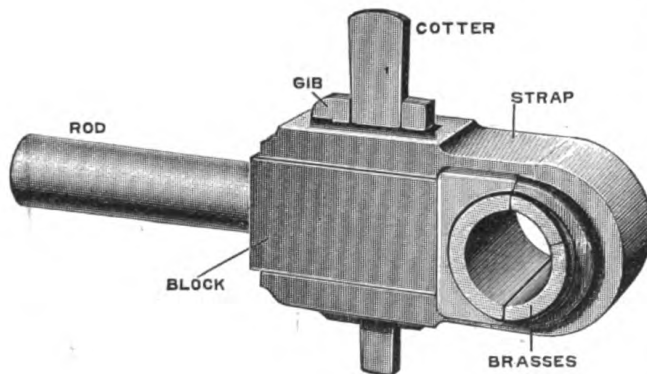


FIG. 203.

Fig. 203, and this strap also carries the bearing. The strap may be secured by cotters. The arrangement of such a form may be seen by reference to Fig. 204.

In Fig. 204 the large and small ends of the rod are shown. In the small end shown the strap are held by means of two gibs, *G*, and the cotter *C*. The lubricator is with the upper part of the strap. The cotter is prevented by means of two set screws to prevent injury to the cotter, shallow grooves to receive the ends of the set screws.

The preceding arrangement is modified in the same connecting rod shown at II.

fixed by two well-fitting bolts; the back of the cotter is made in the form of a corresponding recess in the end of the rod. This recess is bored out to receive the cotter. The cotter is bolted in position. The taper of the cotter is from 1 in 18 to 1 in 24, and there is a shallow groove in the steel wedge, *W*. In addition to providing means of adjustment, *W*, simplifies the fitting of the brasses.

As in the small end, the lubricator is forged solid with the upper part of the block. The back of the cotter is prevented by means of small set screws as shown.

Example. Draw the sectional elevation and plan of the ends of a connecting rod (Fig. 204). Scale $\frac{1}{4}$. Also draw, to a scale of $\frac{1}{6}$ full size, a sectional elevation of the rod and ends. The complete distance between the centres is 6' 6".

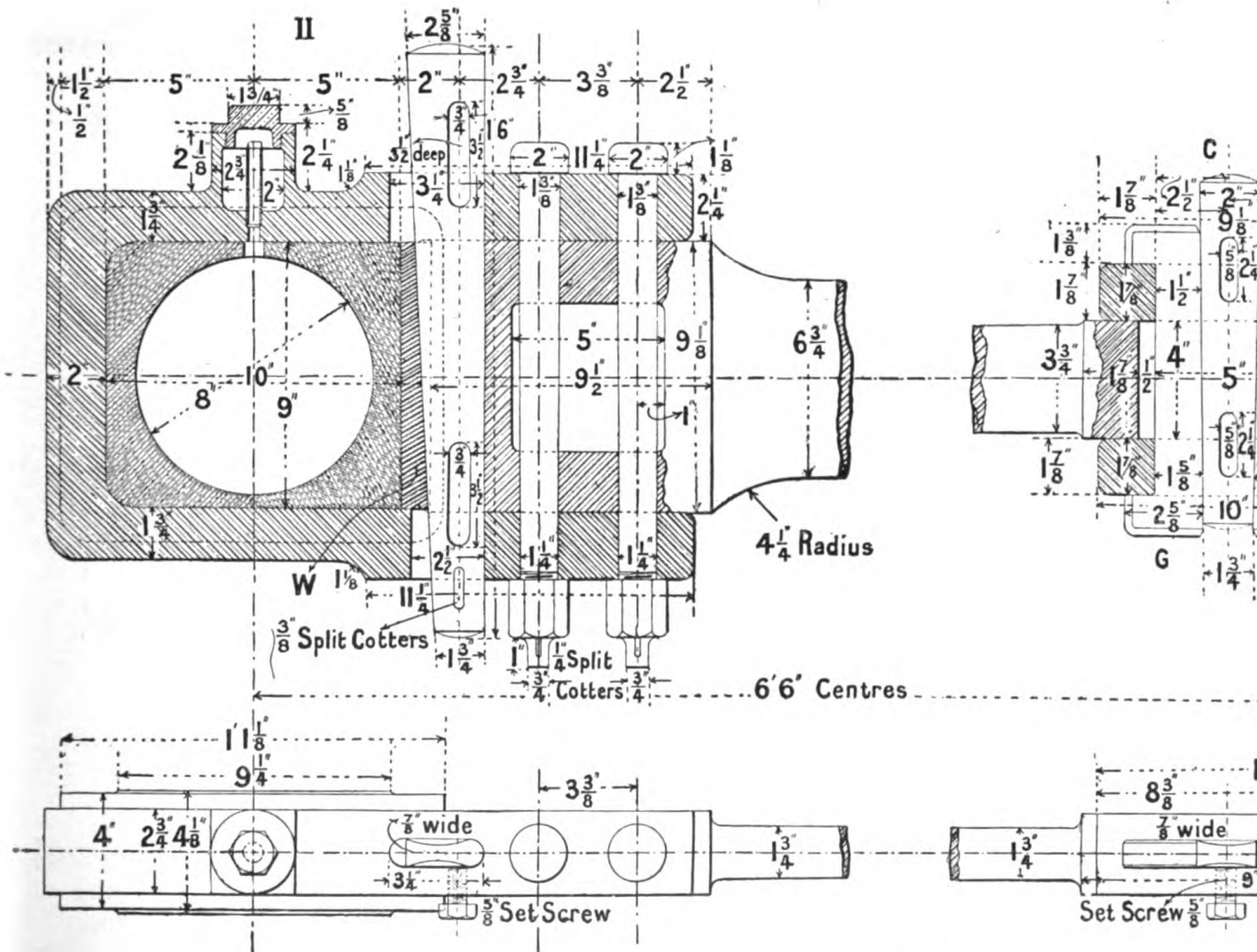


FIG. 204.—Locomotive Connecting Rod.

Box-end. In the preceding form of connecting rod end, there is the liability may slacken back. To avoid this, the end of the rod carrying the brasses may

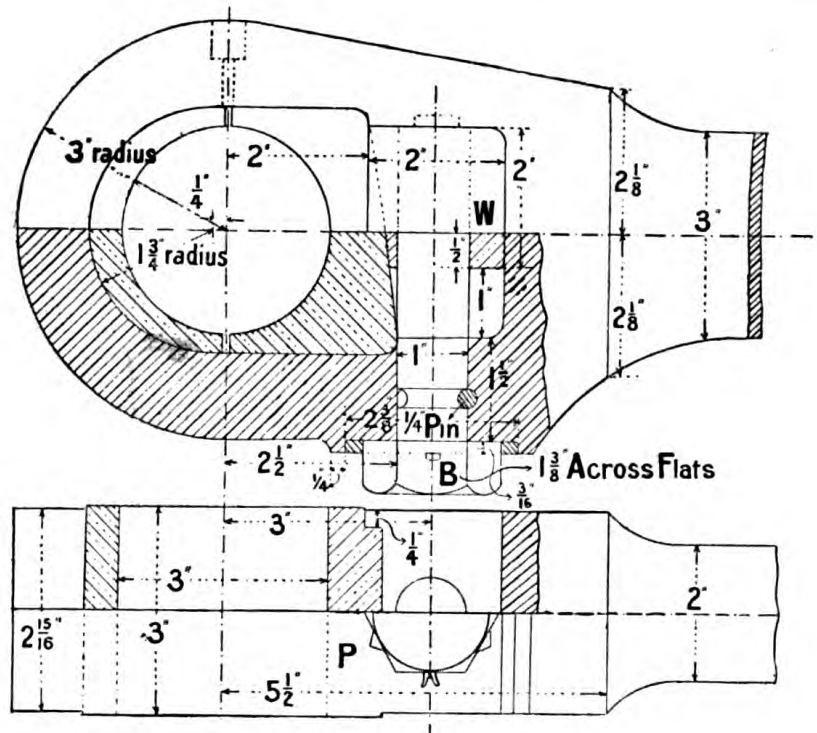


FIG. 205.—Box-end Connecting Rod.

piece with the connecting rod. The form thus obtained is known as the *box-end* no separate strap is required. The brasses are machined on the outside to fit the inside to fit the crank or crosshead pin. Rotation of the bolt, **B**, will force release them by means of the inclined surface of the wedge, **W**. The bolt is secured by **P**, and a split pin.

Adjustment for wear. To adjust for wear the split pin and plate must be removed and drawn up by means of a spanner. These are replaced when the adjustment is effected.

Example. Draw, full size, the two views of a connecting rod (Fig. 205). Also
Instead of the preceding arrangement, a modified type of "marine" end may be used

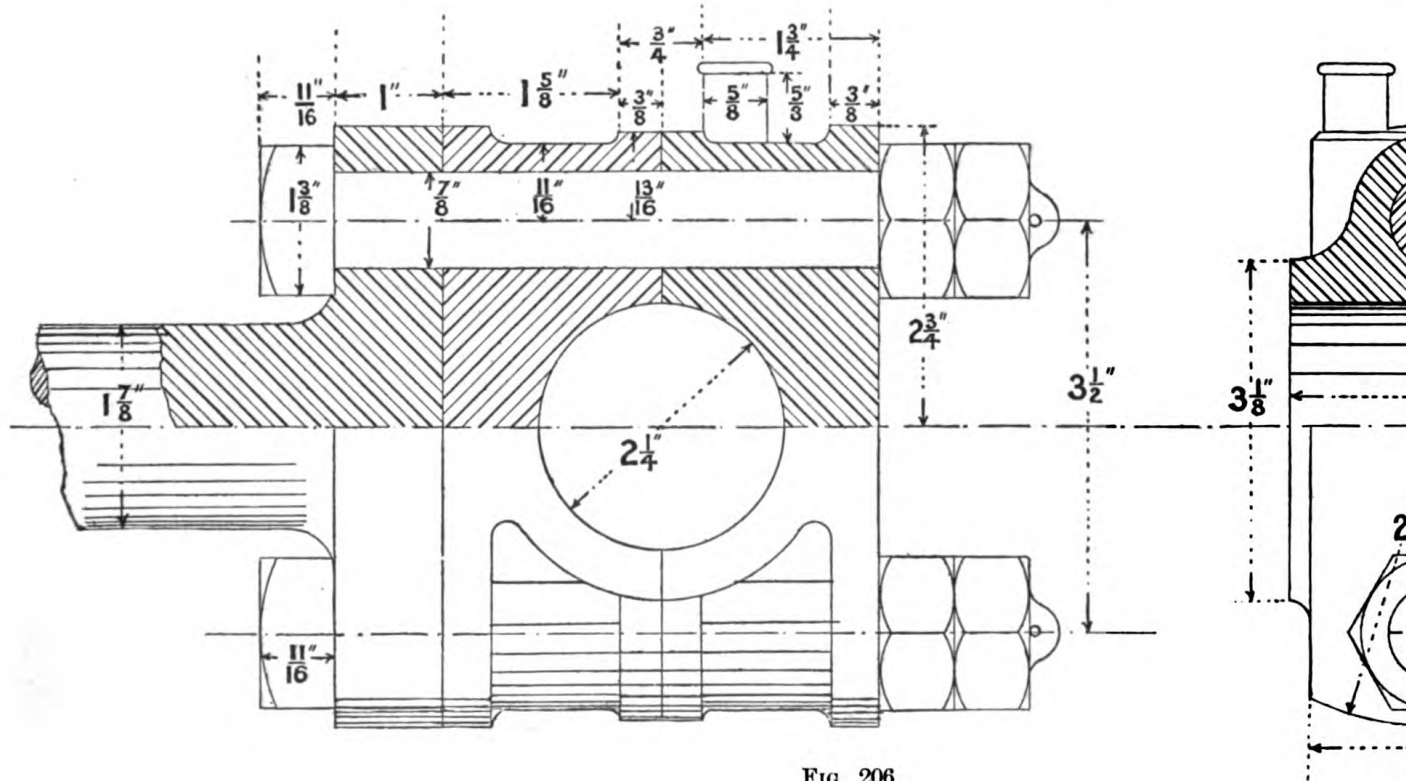


FIG. 206.

Fig. 206. The rod end is forged with a solid strap end and the brasses are secured by two straps which pass through the rod end and cap not only serve to secure the brasses, but also pe

Example. Draw, full size, the two views of a connecting rod end (Fig. 206).

C.M.C.

M

Example. Draw the sectional elevation and plan of the two ends of a
The dimensions are given in millimetres.

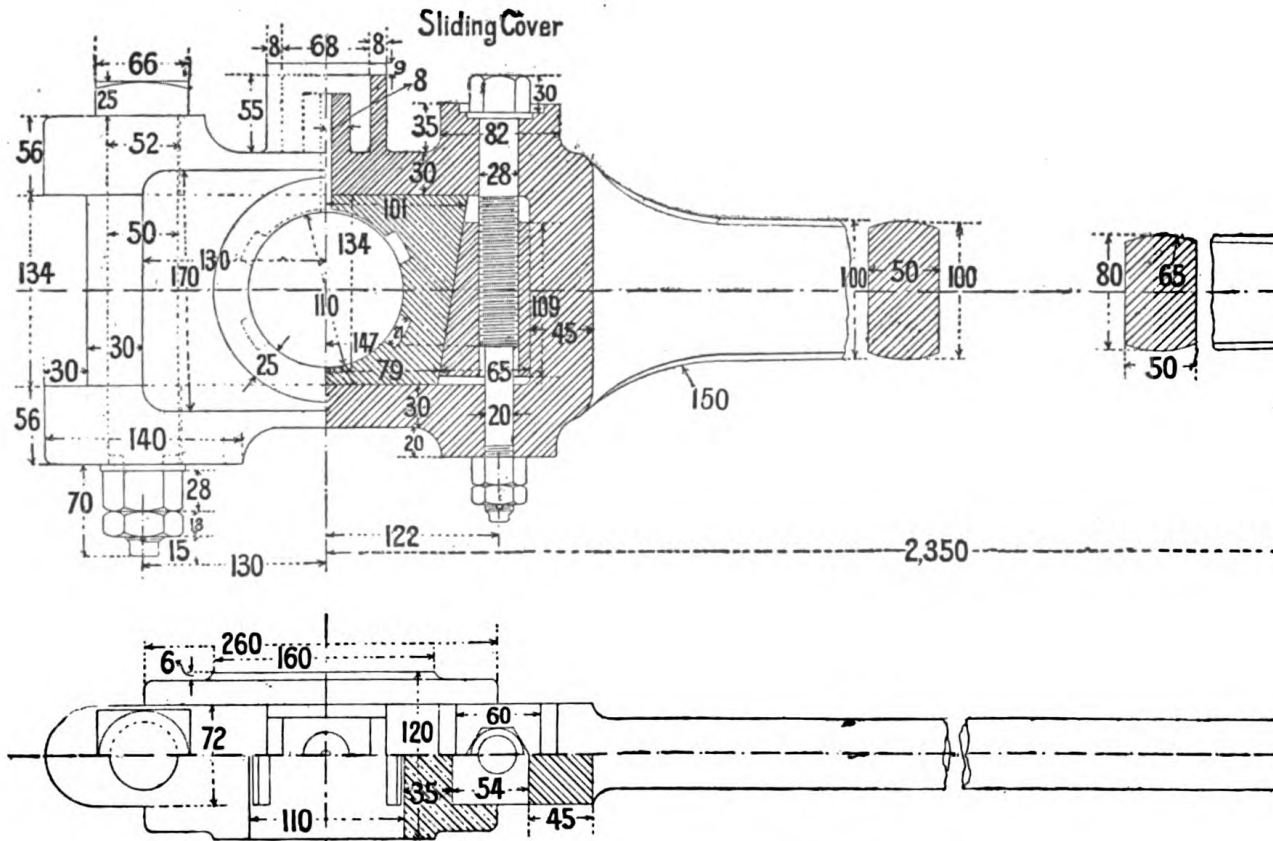


FIG. 207.

The two brasses are bored to fit the crank pin and machined along the rod end and cap. These are fastened together by means of two bolts passing through the end of the rod, the brasses, and the cap.

These bolts are prevented from rotating by means of snugs, one of which is

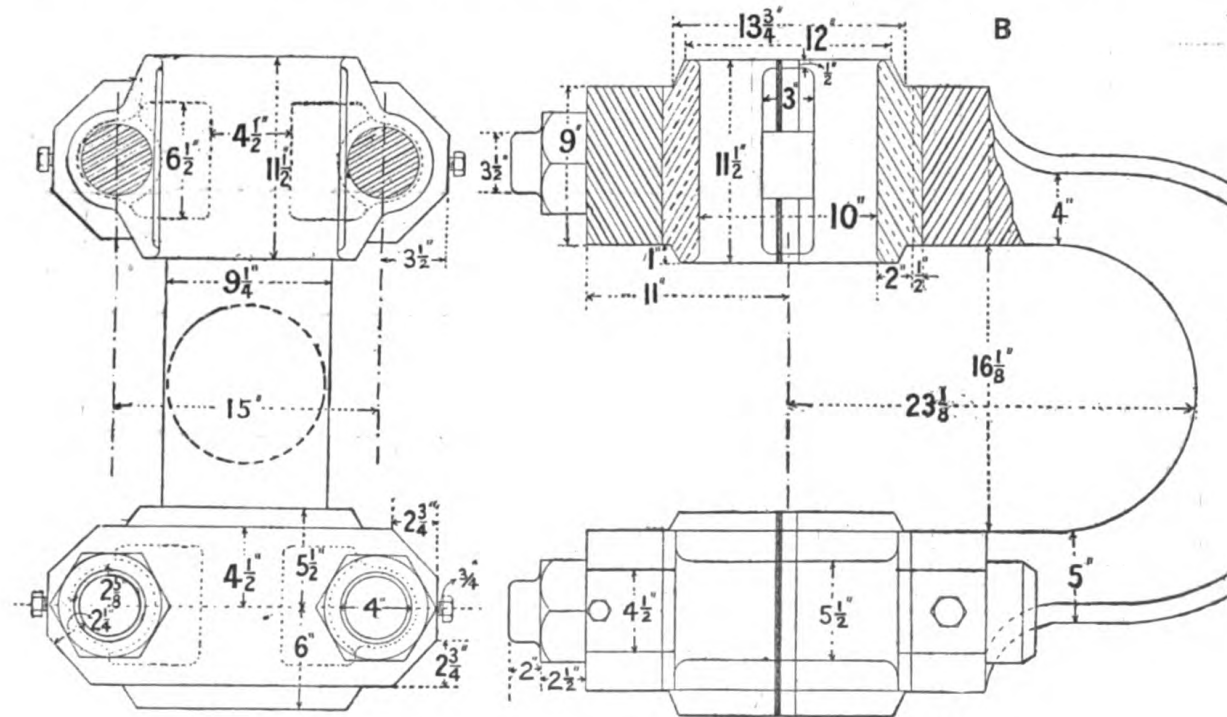


FIG. 209.—Connecting Rod End.

Small set screws passing through the end of the rod prevent the bolts from rotating in a similar manner, set screws, passing through the cap, form locking arrangements for the split pins are inserted. The weight of the brasses is reduced by hollowing out the middle.

Example. Draw, $\frac{1}{4}$ size, the sectional elevations and plans of the connecting rod (Figs. 208, 209, 210).

EXERCISES. XII.

1. Sketch two or three methods by which a cotter may be prevented from slackening.
2. Distinguish between a key and a cotter. Draw an example of each, stating which it is employed. Also state the amount of taper in each case. What is meant by the "draw of a cotter"?
3. Explain the advantage due to the use of a gib. Show by sketches the use of a cotter and a gib, also a cotter without a gib.
4. Show, by sketches, two forms of connecting rod ends. Explain how adjustment is made for the wear of the brasses.
5. Explain how the exact length of a connecting rod may be maintained whilst adjustment is made for the wear of the brasses.
6. Show, by sketches, the construction of a coupling rod end suitable for a locomotive.
7. Show, by sketches, a connecting rod end suitable for (i) a marine engine, (ii) a locomotive engine.
8. Sketch a connecting rod end with strap, gib, and cotter. Explain the use of the gib.
9. Fig. 211 shows one end of a coupling rod for a locomotive. Draw, full size, the other end, also draw an end view. [B.E.]
10. Two views of a simple form of "box-end" are given in Fig. 212. Draw half view.

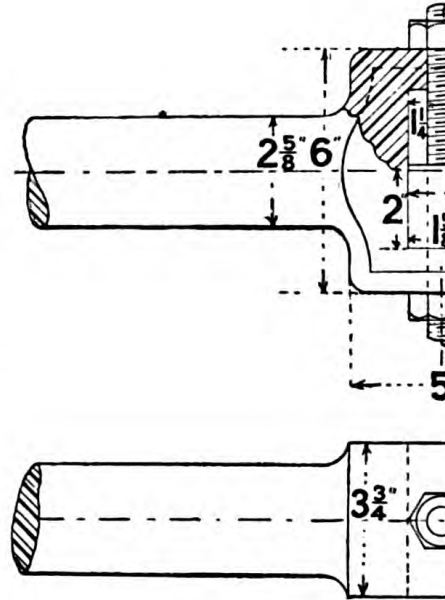


FIG. 212.—"Box-end"

CONNECTING RODS

12. A valve rod end for a marine engine is shown in Fig. 214. Draw half size. [B.E.]

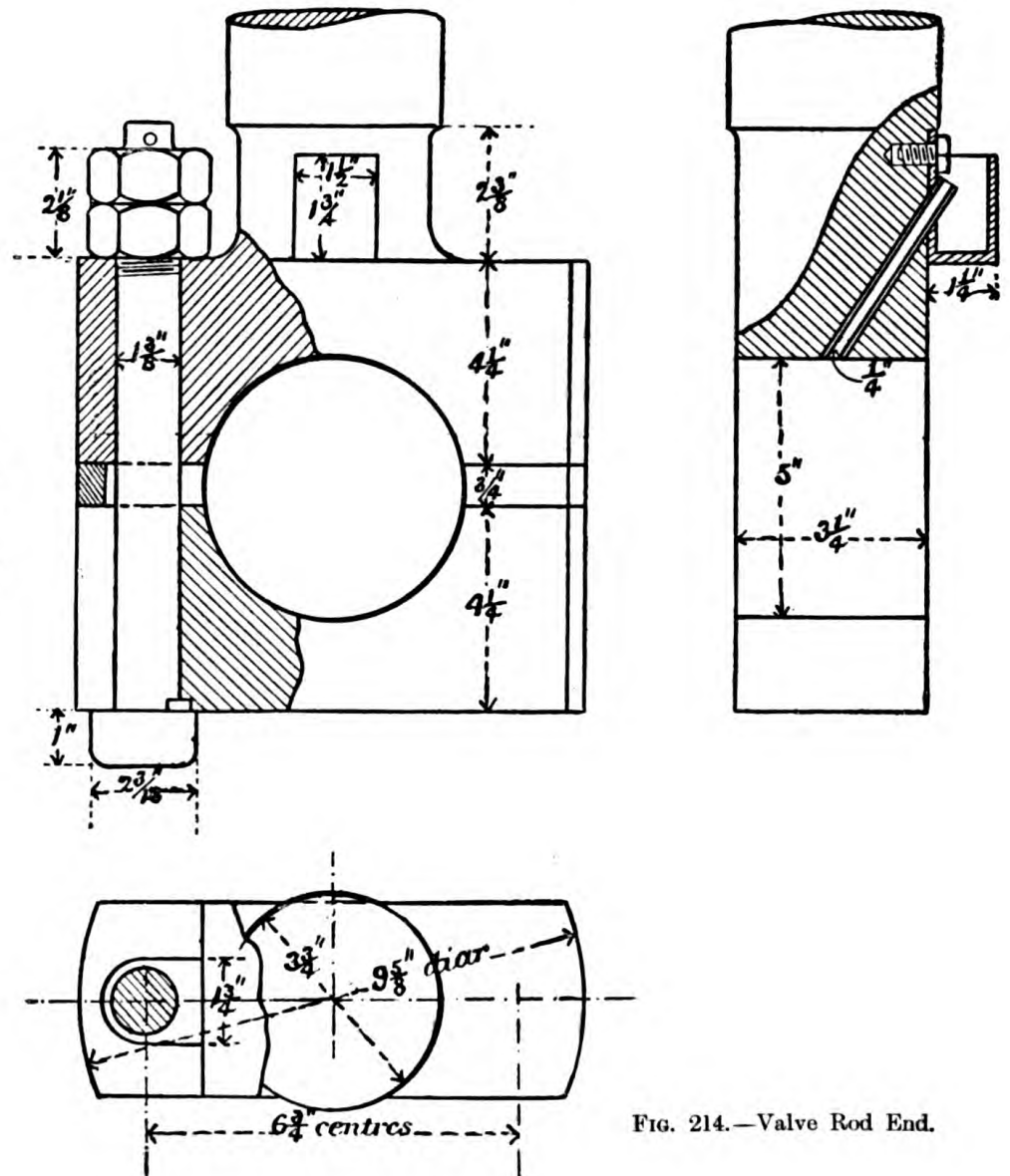


FIG. 214.—Valve Rod End.

CHAPTER XIII.

CRANKS AND ECCENTRICS.

Cranks. The forward and backward motion of the piston of an engine is produced by the circular motion of the crank shaft by means of some form of *crank*. The material may be cast iron, mild steel, or wrought iron. Of these the two named last are

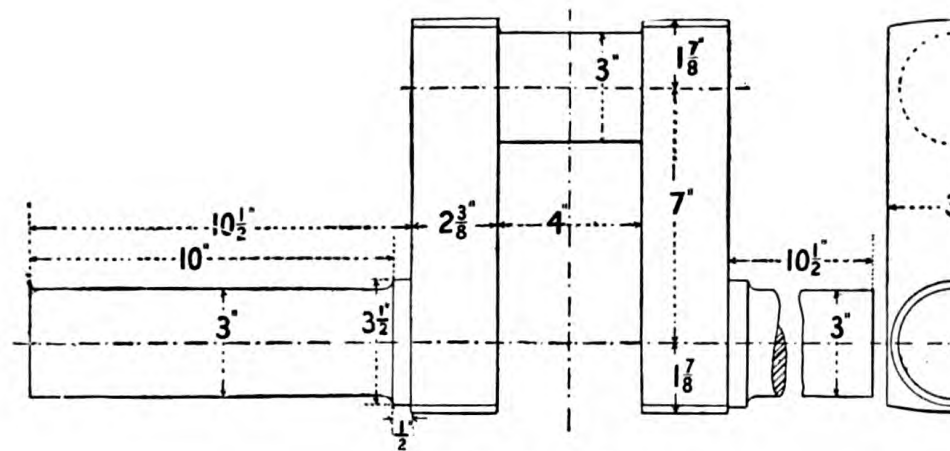


FIG. 215.—Crank Shaft.

Fig. 215 shows a simple form of crank suitable for a small gas engine. The crank pin is to be formed on each side of the crank pin.

Example. Draw the two views, half size, of the crank (Fig. 215).

CRANKS AND ECCENTRICS

In Fig. 216 two views of a crank shaft suitable for a portable engine, etc., are shown. The crank pin are formed by bending the crank shaft. This plan, like that in the preceding case, is to be formed on each side of the crank pin.

Example. Draw, half size, the two views of the crank shaft (Fig. 216). Als

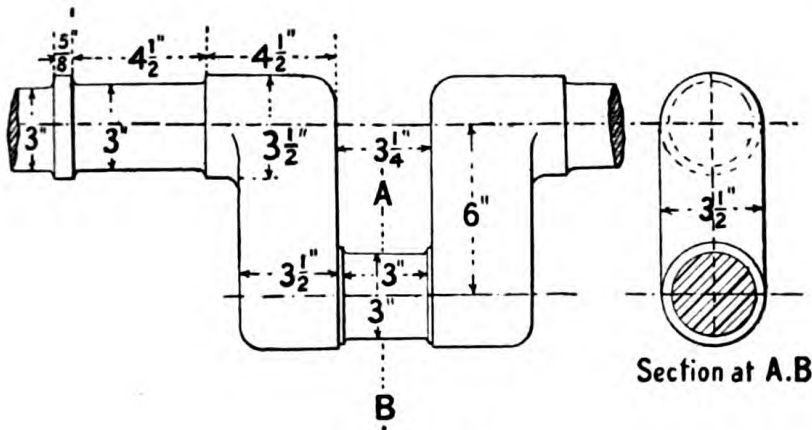


FIG. 216.

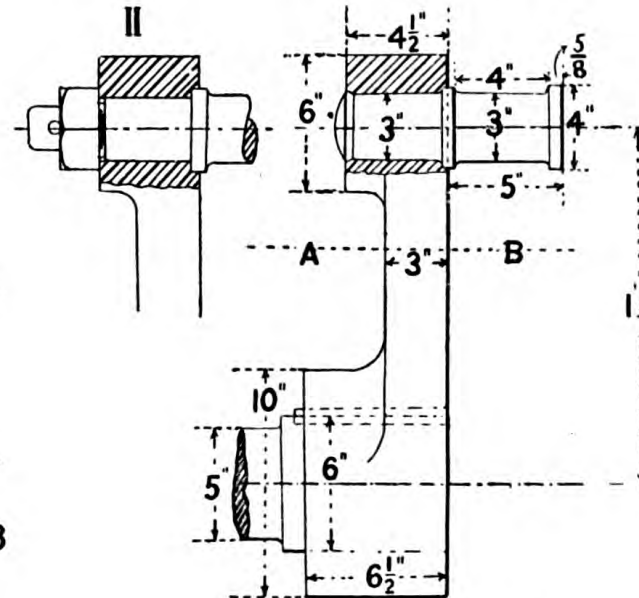


FIG. 217.

Cranks of larger size usually consist of forgings which are fastened to the crank shaft by a key. The method of fastening commonly used for the purpose are known as *forcing* and *shrinking*. In the first method a hole in the crank is bored slightly smaller than the crank shaft, the key-ways are cut in the shaft and the crank, and the crank is then forced to its place by hydraulic pressure. The second method is applied to the crank in a similar manner.

Example. Draw, $\frac{1}{3}$ full size, the two views of the overhung crank (Fig. 217) plan along the line **AB**.

In the second method, advantage is taken of the expansion that metals undergo before, the hole is made slightly smaller than the shaft, then, when heated, the place, care being taken to keep the key-ways in line during the process of cooling.

shaft is gripped firmly. A key is fitted carefully in place.

The crank pin may be tapered and, in addition, it may be tapered in Fig. 217.

A better method than the preceding is to increase the length of the hole in the crank, and make it large enough to receive a thin key. Instead of the preceding method, the crank may be made taper and tapered cotter, as in Fig. 218.

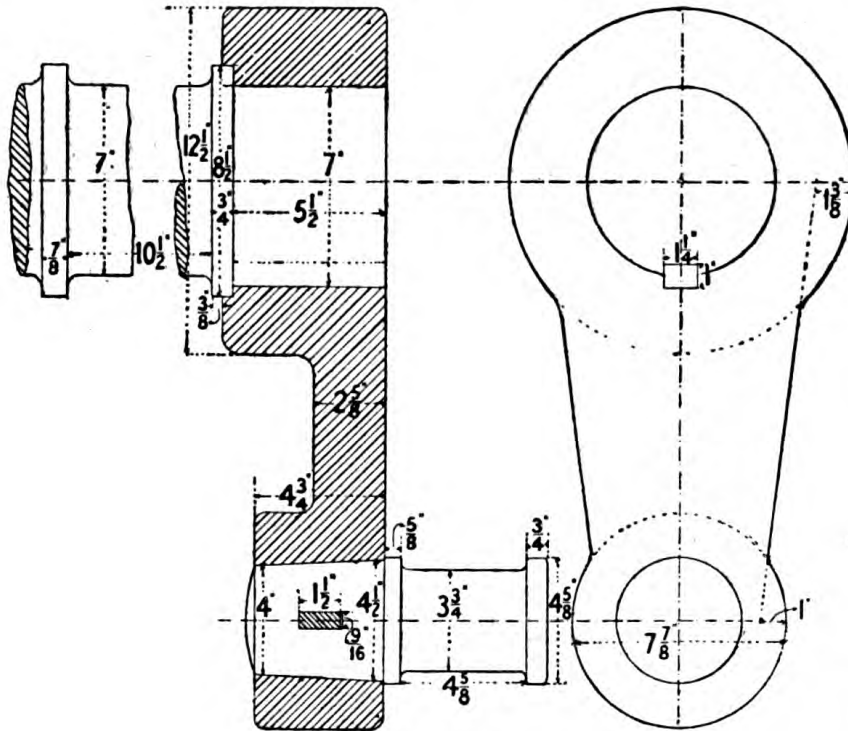


FIG. 218.

tance in those moving at a comparatively high rate of speed, and give rise to avoid these disturbances, various plans of balancing are adopted. One method is beyond the crank shaft.

Another plan is to place a weight between two arms of a wheel to which the the balance weight between two arms of the driving wheel of a locomotive. A

Example. Draw of the crank (Fig. 218) crank shaft to center

In the overhung crank evident that a considerable the crank is on one side of hence unbalanced forces may in the case of large cranks be negligible in slow mov

CRANKS AND ECCENTRICS

cast-iron disc in which a weight, **W**, can be placed along the line joining the centres of the crank shaft produced. Two views of such an arrangement are shown in Fig. 219.

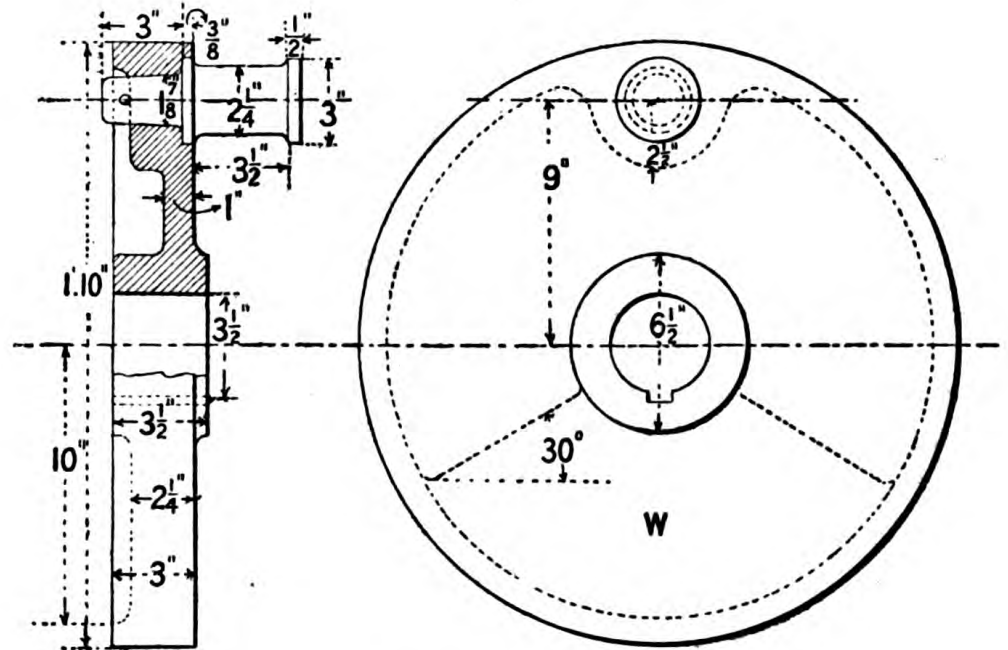


FIG. 219.—Disc Crank.

of mild steel, $3\frac{1}{2}$ " diameter, the hole bored out to a slight taper, and the disc is then forced on with considerable pressure, and further secured by a sunk key. The crank pin is made of mild steel, $\frac{1}{2}$ " diameter, and is secured by a taper pin, $\frac{1}{2}$ " diameter.

Example. Draw, to a scale of 4" to 1', the two views of a disc crank (Fig. 219) as a plan.

Two methods adopted for lubricating a crank pin are shown at **I** and **II** (Fig. 220) in the direction of the length of the pin and outwards, as shown, to the bearing.

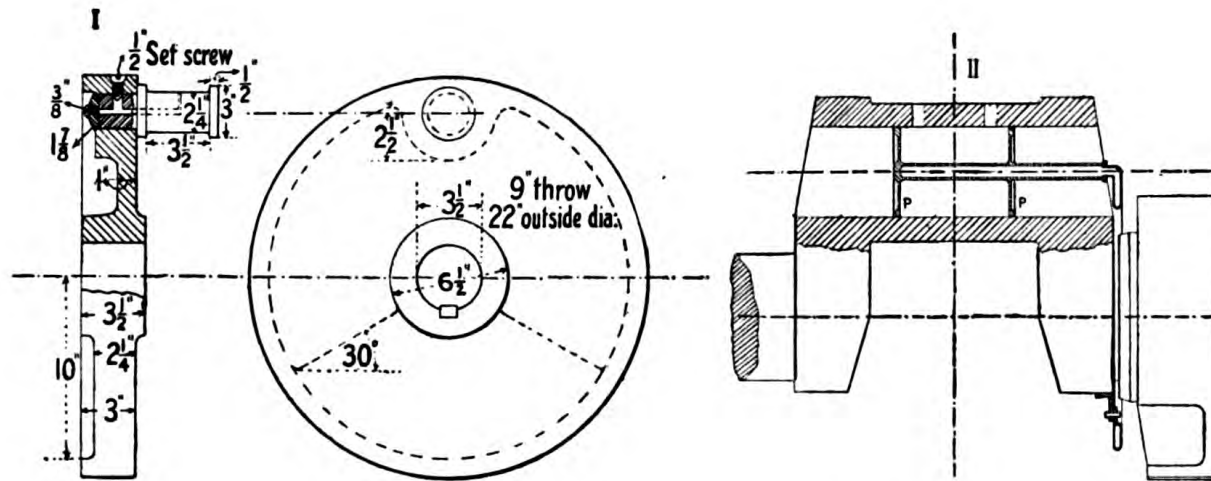


FIG. 220.—Lubricating Crank Pin.

is forced along the pipe shown, and passes through the two holes indicated; escape of oil from the crank pin is prevented by the two small pistons depicted at **P, P**, in the diagram.

Built-up crank shafts. Built-up crank shafts are generally used for the compound engines of the mercantile marine. The two webs—or crank arms—crank pin, and the two bearings are made separately and afterwards fastened together. The material may be forged or cast by hydraulic presses. The holes in the webs are punched and afterwards forged closed. The method of fastening the parts together is briefly as follows. One of the webs, **A** or **B**, (see Fig. 221) of the crank shaft, care being taken to keep the key-ways in line; after cooling, a

tightly into place; instead of a key, a hole for a pin may be drilled and then the pin inserted into place.

The remaining web is secured in like manner. The two holes for the crank pin are drilled and heated, and whilst hot the crank pin is inserted.

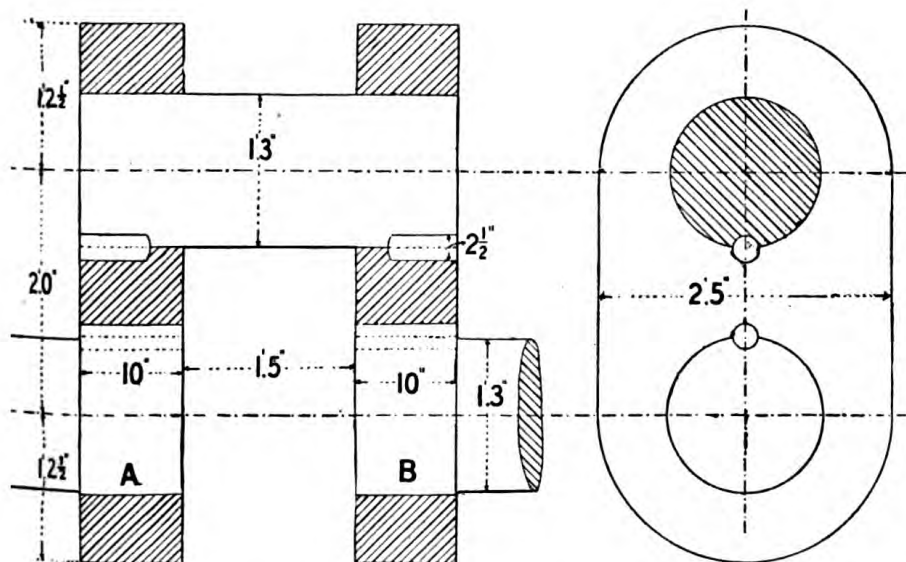


FIG. 221.—Built-up Crank Shaft.

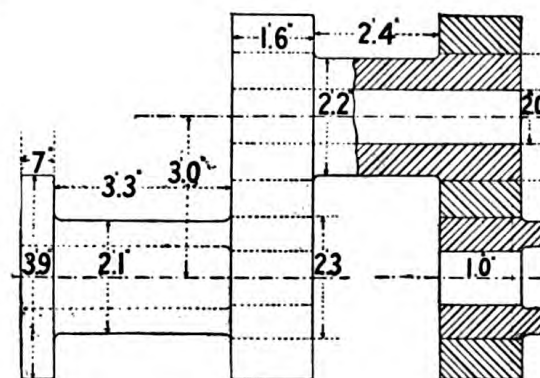


FIG. 222.

Example. Draw, half size, the two views of a built-up crank shaft (Fig. 221).

Example. Draw, $\frac{1}{3}$ full size, the two views of one of the crank shafts for Fig. 222, also draw a plan (Fig. 222).

Eccentric. When a crank is used, the crank shaft must be divided to enable one end of which is fastened to the crank pin—to pass the centre of the crank. unnecessary when an eccentric—which may be described as a particular form of crank pin is made large enough to include the crank shaft—is used.

Thus, let **A** (Fig. 223) denote the centre of the crank pin, and **B** the centre of the eccentric. With **A** as centre and a radius large enough to include the crank shaft, draw a circle which corresponds to what is called the *sheave of an eccentric*. This sheave, when encircled by a suitable strap may be made to give a valve or other reciprocating piece.

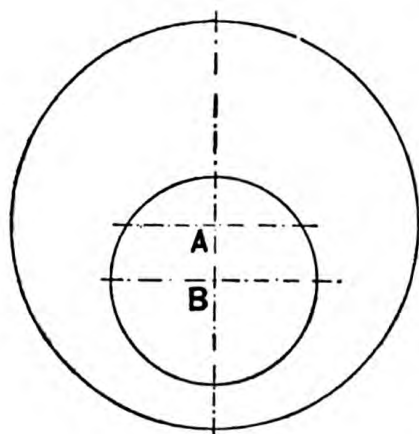


FIG. 223.

The sheave may be made either in one or in two parts. In the latter case it must be passed over the end of a shaft; and, in such cases, the projections, may be difficult or impossible. In such cases the sheave is made in two parts and fastened together by bolts or studs.

The sheave is fastened temporarily in position on the crank shaft by one or more set screws. Afterwards, when its position is definitely fixed, it is keyed fast to the crank shaft.

The eccentric, unlike the crank, cannot be used to convert reciprocating into circular motion; but it is of great use in converting circular into reciprocating motion. A familiar example is the conversion of the circular motion of the eccentric into the reciprocating motion of the slide valve. The materials used are generally

cast iron or steel, and friction is reduced by using a brass liner.

A common form of eccentric is shown in Fig. 224. The sheave and strap are made of brass. The sheave is made in two parts, fastened together by means of bolts. The halves of the strap are connected by bolts and the unscrewing of the nuts. In addition, small split pins are inserted near the end of each bolt.

Distance pieces, **P, P**, are provided for adjustment. These may be made of gun-metal, etc., and the adjustment is made by reducing their thickness.

EXERCISES. XIII.

1. For what purpose are cranks used? Indicate by sketches two forms of crank shaft engine.

2. State the process by which a wrought-iron crank is fastened to the crank shaft and the crank pin is fastened to the crank.

3. Explain, by sketches, the chief difference between a crank and an eccentric. What is an eccentric?

4. Show, by sketches, a wrought-iron overhung crank and a disc crank. What advantage is gained by using the latter?

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

6. Sketch in section the construction of an eccentric sheave, strap, and rod, the sheave and rod in two parts. Show how the sheave is fixed to the shaft and explain why each portion is made separately from the rest.

7. When the eccentric strap shown in Fig. 227 becomes loose by wear, how is it refitted? What is the travel of the slide valve, the spindle of which is connected directly to the end of the rod? [B.E.]

8. With the aid of sketches, describe how you would fix the portions of the eccentric strap in a lathe for the purpose of turning the interior surface. Also point out where the strap will wear most rapidly and describe how it may be refitted when worn.

C.M.C.

N

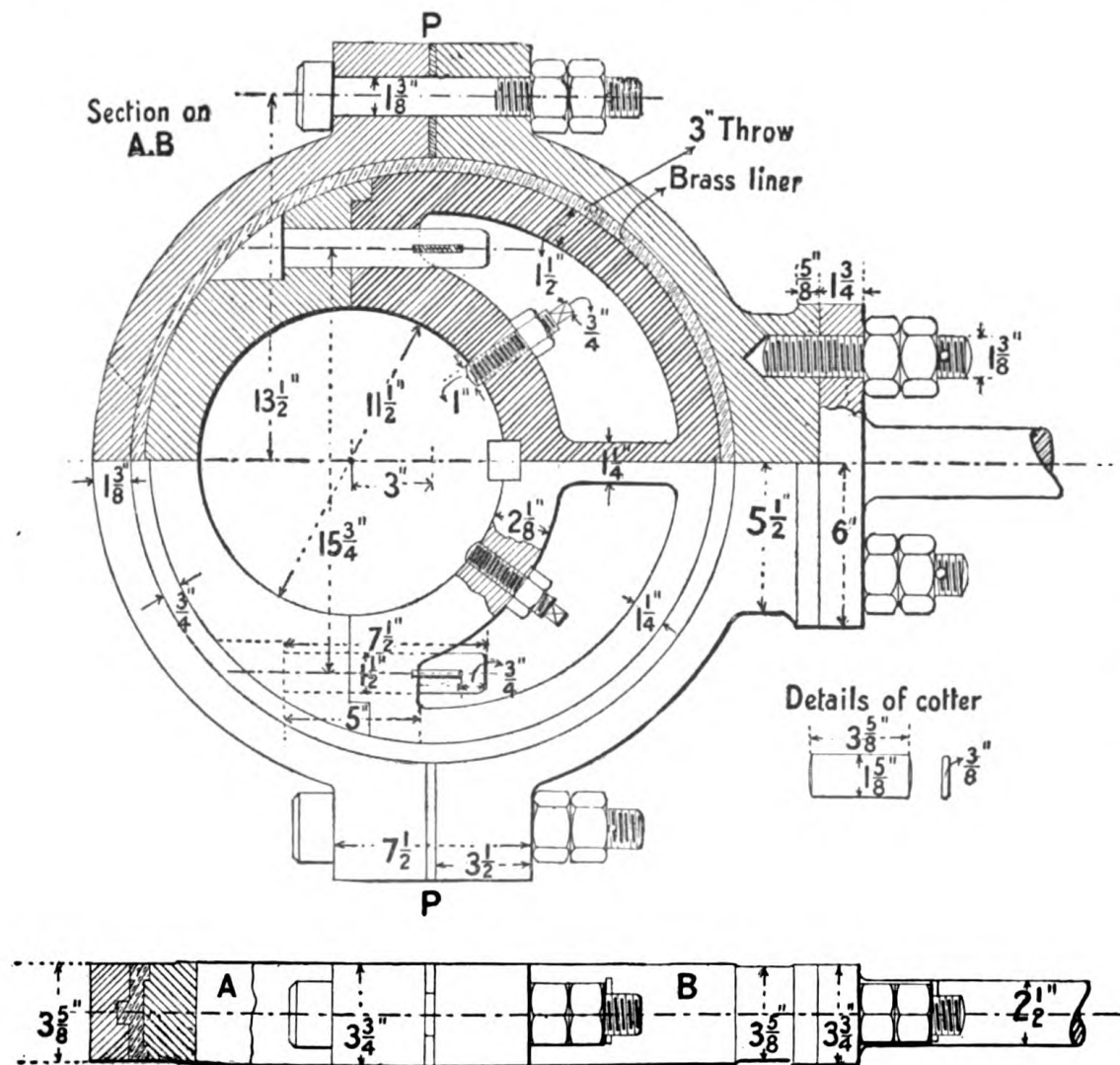
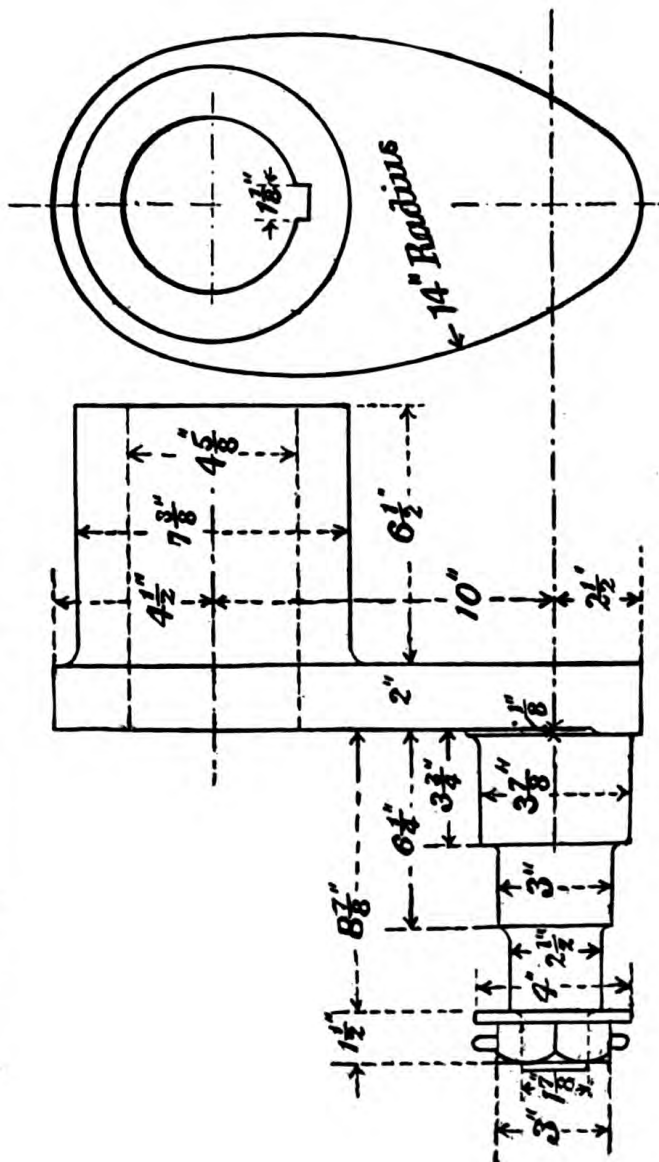
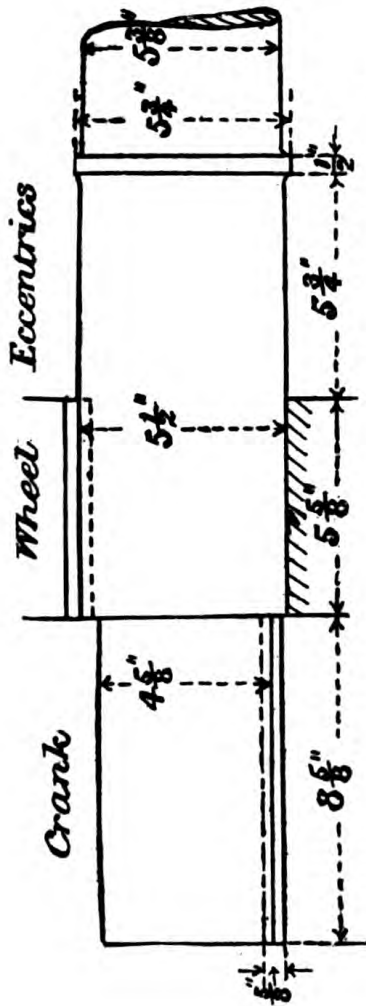


FIG. 224.—Eccentric.

8a.
elevation
(Fig. 22)

9.
crank sh
separate
the dia
of the
and the
Scale ha

CRANKS AND ECCENTRICS



This side of the eccentric to be placed against the wheel.

11. Eccentric. The diagram (Fig. 227) shows the various portions of an eccentric. elevation and plan of the parts fitted together. Scale half size. [B.E.]

CHAPTER XIV.

VALVES. SLIDE VALVE. SAFETY VALVE.

Valves. The object of a valve is usually to open or close a passage through which fluid can pass from one place to another. The fixed part, or seating on which the valve usually sits, is usually in the passage, especially in the case of small brass valves. In larger valves the valve is made separately; the outside of the seating is then made slightly taper and fitted against a corresponding taper opening in the passage. This method of fixing allows the valve to be made of brass, though the passage in which it is placed may be made of cast iron.

Valves of various kinds are used so largely by engineers, and there are so many different kinds, that it is a difficult matter to make a suitable selection, and it is only possible to refer to a few. Roughly, they may be divided into three classes, viz. :

- (1) Those opened and closed by hand.
- (2) Valves which are opened and closed by self-acting mechanism.
- (3) Valves opened and closed by the pressure of a fluid.

An example of the first kind is furnished by the ordinary stop, or throttle valve, or ordinary straight-way cock, etc. (Fig. 228). A familiar instance of the second kind is the valve of an engine and in regulating or throttle valves (Fig. 241). India-rubber valves are of the third kind as well as being instances of non-return valves.

Example. Draw, half size, the two views of a 3" stop valve (Fig. 228).

The lift of a valve is usually made equal to one-quarter of the diameter of the valve. The diameter of the stop valve on a boiler is usually the same as the diameter of the pipe. The maximum lift of the valve is equal to one-fourth its diameter.

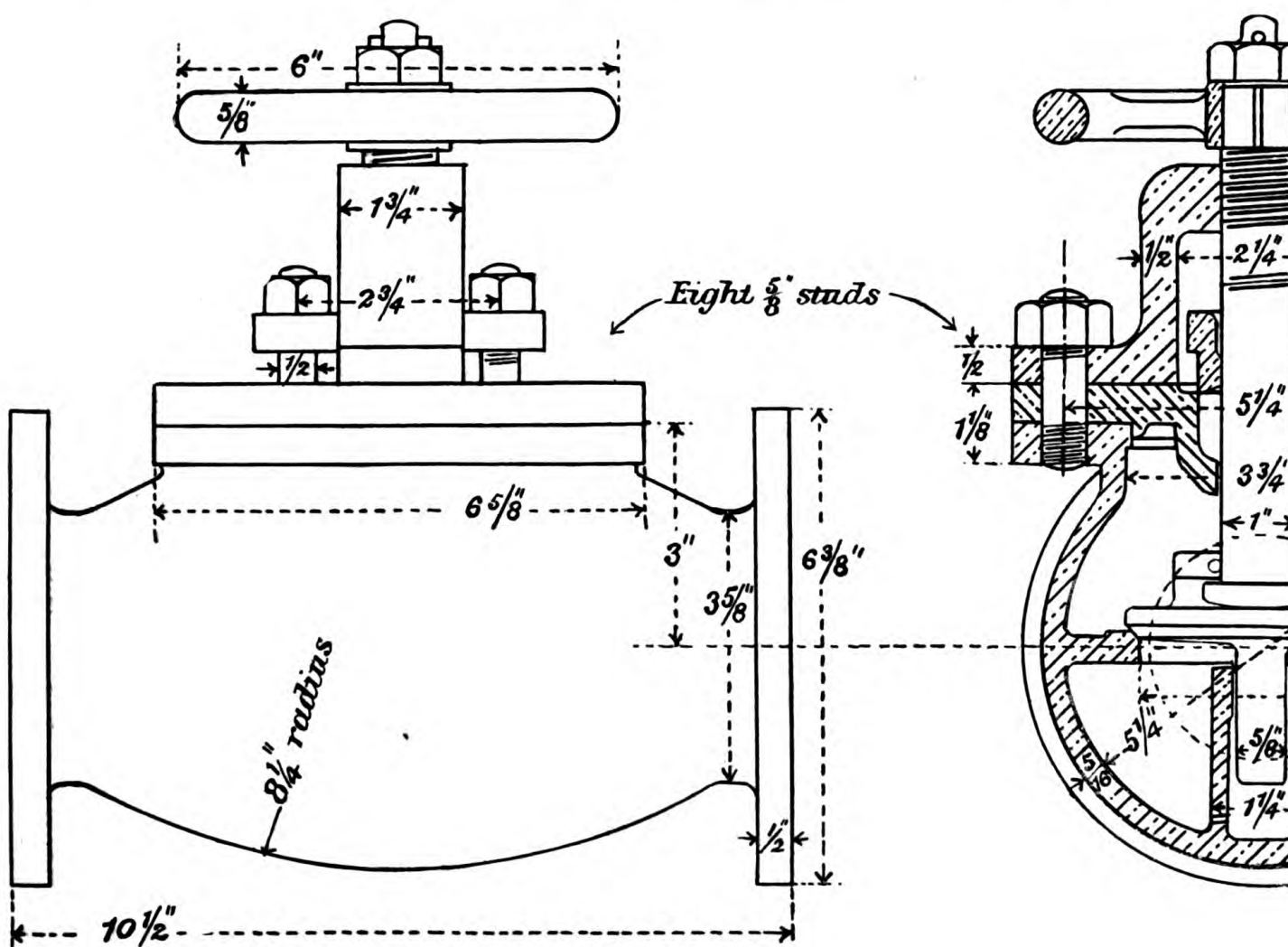


FIG. 228.—Stop Valve.

Let d denote the diameter and x the lift of the valve. The cylindrical area of the valve which is opened a distance x , is πxd , and this must be equal to the area of the orifice, or bore, of the pipe, i.e. to $\frac{\pi}{4}d^2$.

$$\text{Hence } \pi xd = \frac{\pi}{4}d^2$$

$$\therefore x = \frac{d}{4}$$

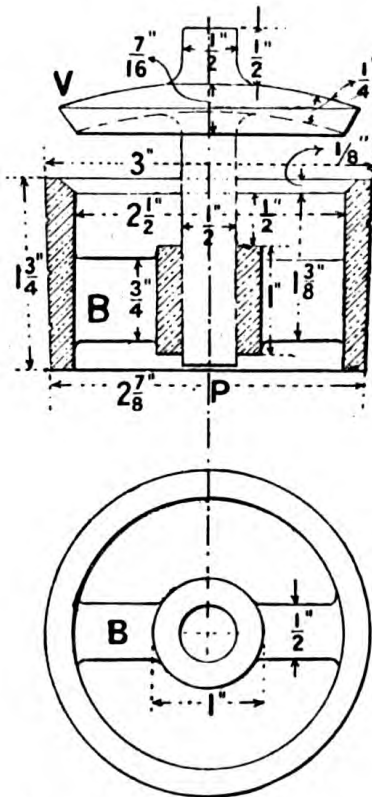


FIG. 229.—Conical Disc Valve.

Conical disc valve. In Figs. 229, 230, examples of *wing valves* are shown. The essential difference between the two is in which the valve V is guided during its rise and fall. In the fixed part of the valve called the *seat* or *sealing* forming part of the seating, passes across the centre; a bar, a hole of the size of the pin is made. This forms a guide in which the pin P moves freely. The under surface of the valve is conical, the inclination being about 45° , and fits into a corresponding conical seating. The width of the conical part is small, not exceeding the thickness of the valve.

The valve and seating, when of comparatively small size, are of brass. To reduce the weight of the valve, the under surface is turned out in a manner indicated by the dotted curves of Fig. 229.

Another method of guiding the valve is shown in Fig. 230, in which three *wings* or *feathers*, radiating from the centre of the valve, are turned in the lathe so that they fit quite easily and loosely into the seating. The notches, shown at N at the junction of the feathers, and the feathered edges, allow a better opening for steam or water when the valve is lifted, but also prevent the lathe tools during the process of turning and the preparation of the surfaces in the seating.

In all cases suitable stops are provided to prevent the valves rising too far.

VALVES. SLIDE VALVE. SAFETY VALVE

Example. Draw the sectional elevations and plans of the two disc valve Full size.

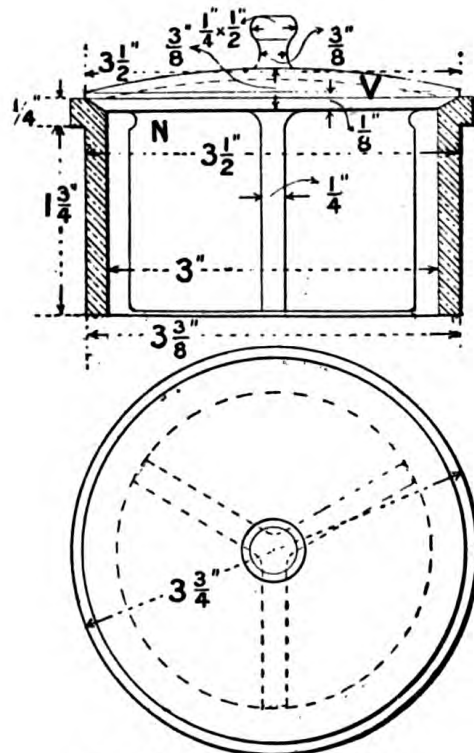


FIG. 230.—Conical Disc Valve.

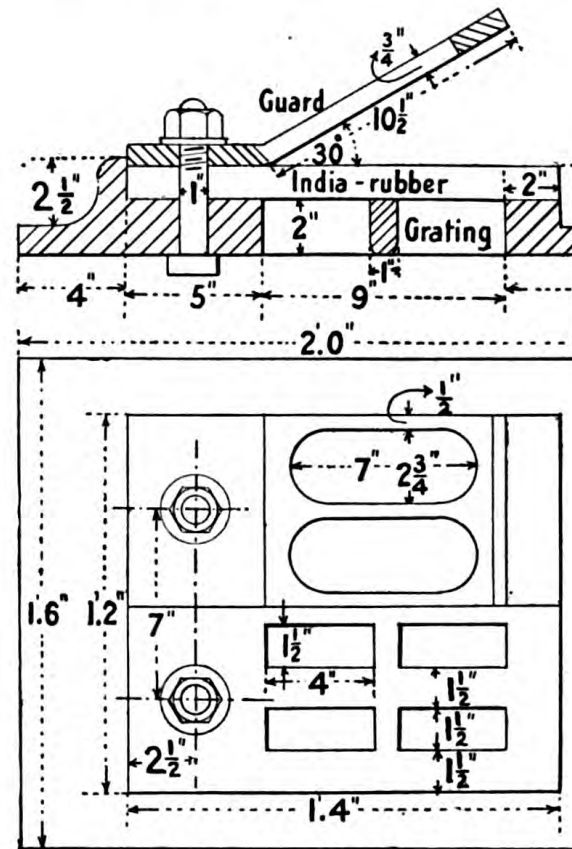


FIG. 231.—India-rubber Flap Valve.

India-rubber flap valve. In this form of valve, a rectangular piece of india-rubber is used as indicated in Fig. 231. In the plan shown, one-half the guard is removed to show the valve. The object of the guard is to prevent the india-rubber from rising too far.

Example. Draw the two views of the valve (Fig. 231). Also draw an end

Slide valve. In its simplest form, the slide valve consists of a box-shaped ca
A, A are planed accurately and made to slide backwards and forwards on a similar
 steam chest. This surface contains three passages, or *ports*, as they are called, the t

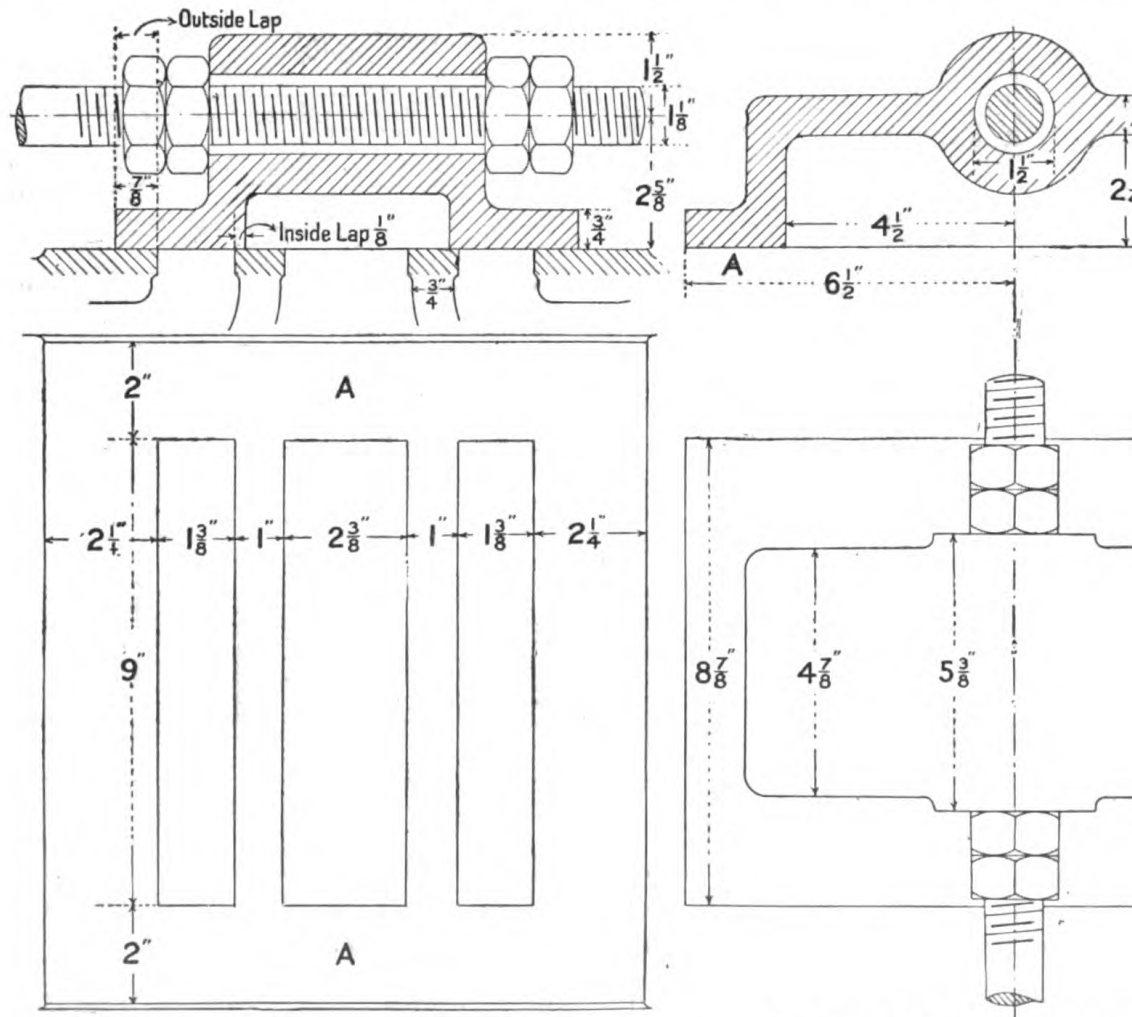


FIG. 232.—Slide Valves and Ports

leading to the ends of the cylinder, whilst the inner, or *exhaust port*, simply allows either to the condenser or to the atmosphere.

When the valve is placed in its mid-position, as in Fig. 232, the face of the openings, or steam ports, and the exhaust is covered by the hollow part of the valve.

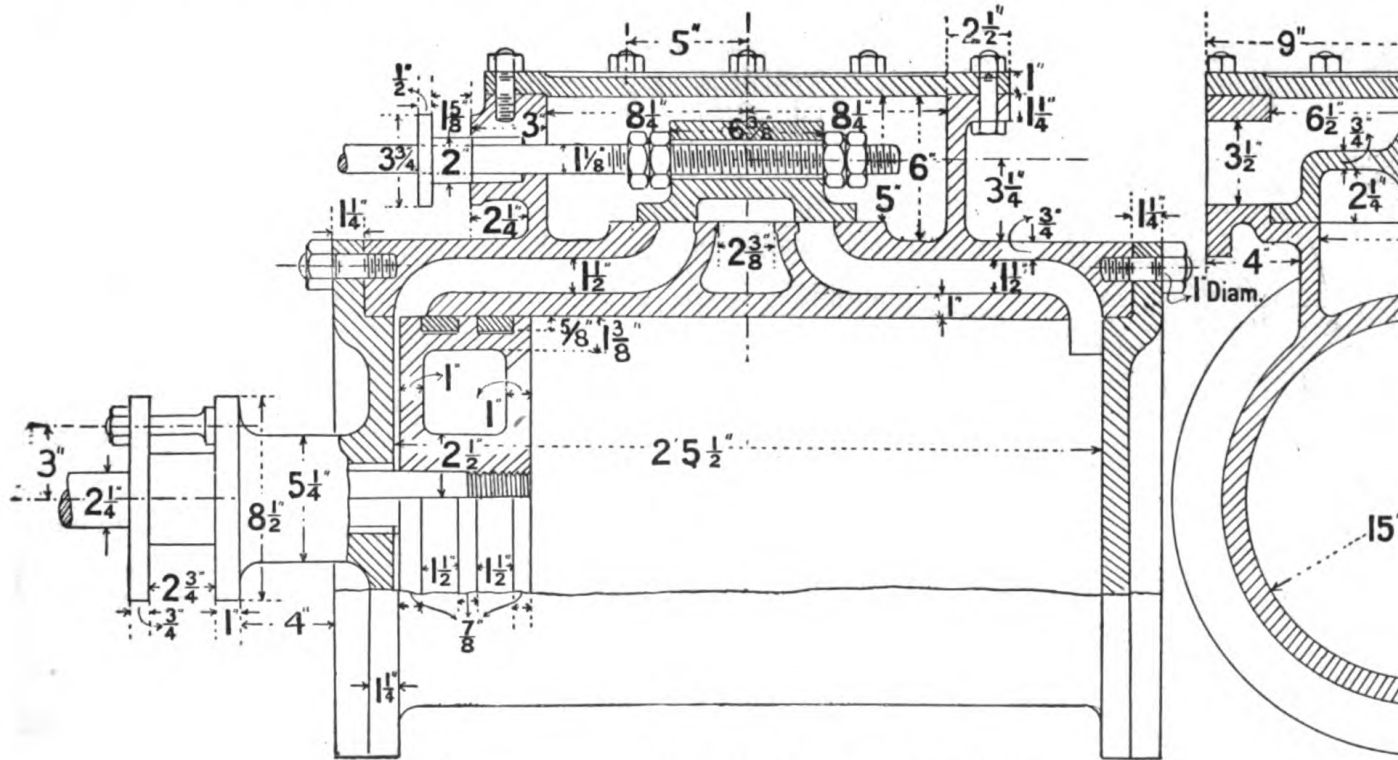


FIG. 233.—Cylinder and Slide Valve.

Example. Fig. 233 shows a sectional elevation of the cylinder, piston, valve, and a horizontal engine. Draw, $\frac{1}{4}$ full size, and complete the views shown. The valve are given in Fig. 232.

Lap. It will be noticed that the edge of the valve is not coincident with the edge of the port, but projects some distance beyond. This prolongation, or projection, is called the **lap**, or simply the **lap**. In a simple form of valve gear, referred to, the lap is usually the same for both valves.

In vertical engines, the lap of the exhaust valve is frequently slightly greater than that of the steam valve.

The distance that the inner edge of the valve overlaps the inner edge of the port is called the **inside lap**.

The object in providing outside lap is to keep the valve working. Thus, if there is no outside lap, the valve remains open, and steam is admitted to the cylinder of the piston. With lap, the steam is cut off during a part of the stroke, and the cylinder is furnished by the expansion of the steam.

The object of inside lap is to keep the valve closed before the end of the stroke.

The volume of steam, which remains in the cylinder, is compressed by the piston, and is called **cushioning**.

Lead of a valve. When the piston is at one end of the stroke, the distance between the edge of the steam port and the edge of the valve is called the **lead**. Thus, in Fig. 234, as the valve is moving in the direction of the arrow, the valve has moved from its mid-position a distance of $\frac{3}{16}$ " together with a distance of $\frac{7}{8}$ ", or distance from mid-position = $\frac{7}{8}$ " + $\frac{3}{16}$ " = $1\frac{1}{16}$ ". Draw a horizontal line through **O** in a horizontal position; make **OD** = lap + lead and draw a perpendicular **DB**. Join **OB**. The position of the eccentric crank. The eccentric is thus 90° + the angle **EOB** ahead of the crank. The angle **EOB** is called the **angle of advance**.

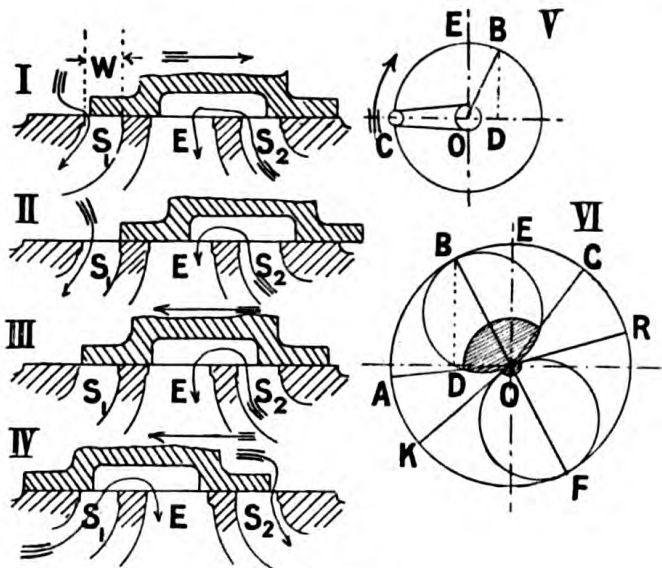


FIG. 234.

Successive positions of the slide valve are shown at **I...IV** (Fig. 234).

At **I**, steam is entering the cylinder through the port S_1 , the piston moving from the left; steam from the opposite end of the cylinder is escaping to the exhaust through the port S_2 .

The edge of the valve may uncover the steam port to a distance $0.7w$ to $1w$, where w is the width of the port.

At **II**, the valve is shown in the extreme position to the right. At **III**, the valve is moving to left, as indicated by the arrow, just covers the port S_1 ; this point of the stroke is called **cut off**.

At **IV**, the port S_2 is open an amount equal to the lead, the piston being at the end of the cylinder. Steam is escaping to the exhaust through the port S_1 .

Zeuner's valve diagram. The motion of the eccentric relative to the crank is made a diagram shown at **VI** (Fig. 234). This diagram is constructed as follows:—Draw a circle representing the **travel of the valve**, and set off the angle of advance, **EOB**, on the opposite side of the circle as shown.

Produce **BO** to **F**, and on **OB** and **OF** as diameters describe two circles. With **O** as centre and radius equal to the *outside lap*, describe an arc of a circle. Join **O** to **D** the point of intersection, and produce to cut the circle at **A**; **A** is the position of the crank when admission of steam takes place. Similarly, **C** is the position of the crank when steam is shut off.

In a similar manner, with centre **O** and radius equal to *inside lap*, describe an arc of a circle. Join **O** to the points of intersection and producing to cut the circle, determine two points **R** and **P**. **R** is the position of the crank when the valve is just opening to exhaust, and therefore **R** is called **point of release**. At **P** the valve is just closing, and this is called the *point of compression*. The four points: **admission**, **cut off**, **release**, and **compression** may be clearly made out by drawing the diagram to scale.

Air pump valves. Air pump valves are made frequently of india-rubber. They are prepared specially to resist the action of the mineral oil used for lubricating purposes.

Sheet metal is also used largely for the purpose. In this form the valves may be made of any shape, and they have the advantage that they are not affected by grease. Valves of this form are shown in Fig. 237.

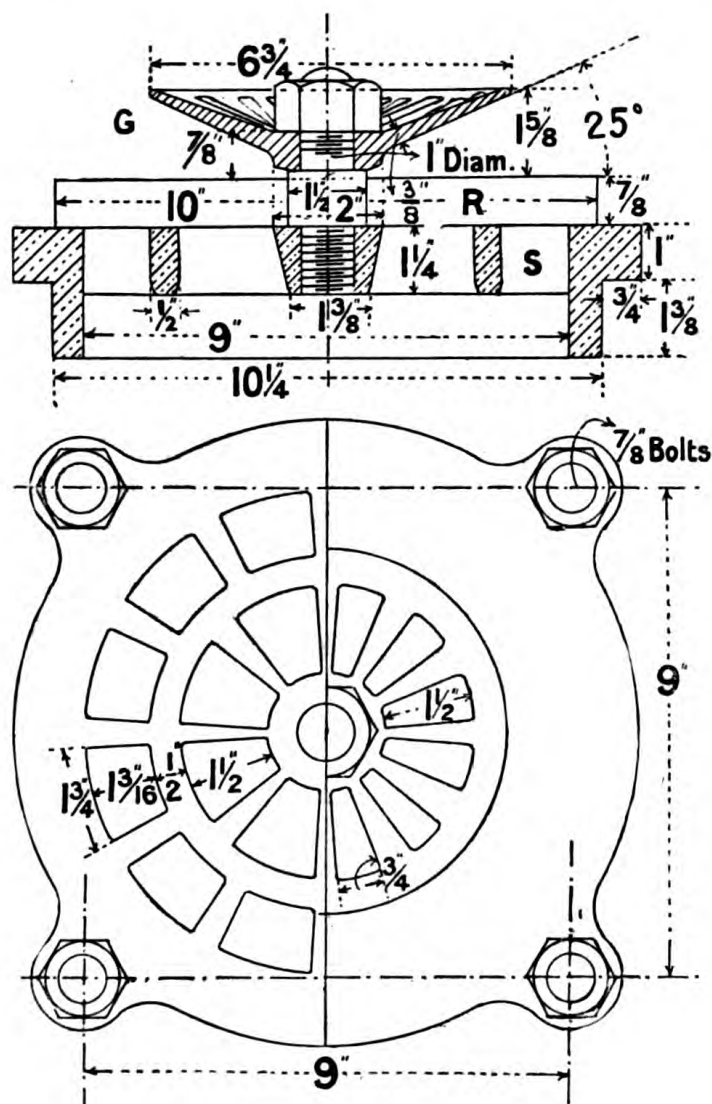


FIG. 235.—India-rubber Disc Valve.

India-rubber disc valve. This form is shown in Fig. 235. It consists of a flat cylindrical disc R, resting on a perforated seating surface S. The guard G will allow the india-rubber disc to move a definite distance; thus the pressure of the fluid on the india-rubber disc will cause it to move against the guard. On the return direction causes the disc to assume its original position and thus to close the opening. The disc is not forced through the opening, and thus to close the opening. The disc is kind open and close quietly.

Example. Draw the two views of the india-rubber disc valve (Fig. 235).

Metal flap valve. This type may be seen in Fig. 236. The valve is placed in a pipe. It will allow water or other fluid to pass in one direction, but will prevent effectually its return. The valve is a rectangular brass plate resting on a ball. The valve is held in position by wooden wedges. The valve is in an enlarged portion of the pipe, in which is called a *valve box*. A cover is provided for the valve box for renewals or repairs.

Example. Draw the three views of the metal flap valve (Fig. 236). Scale half size.

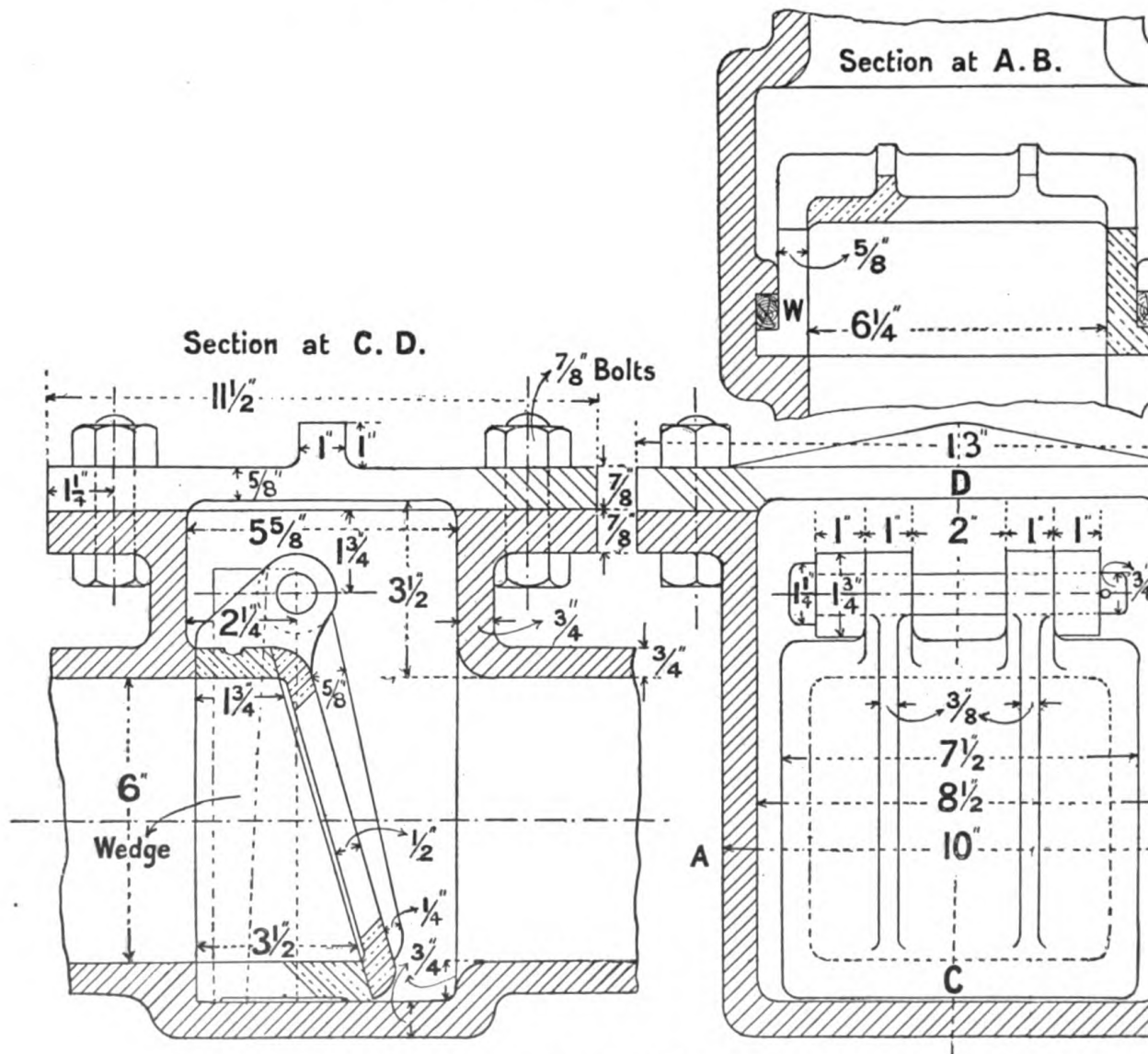
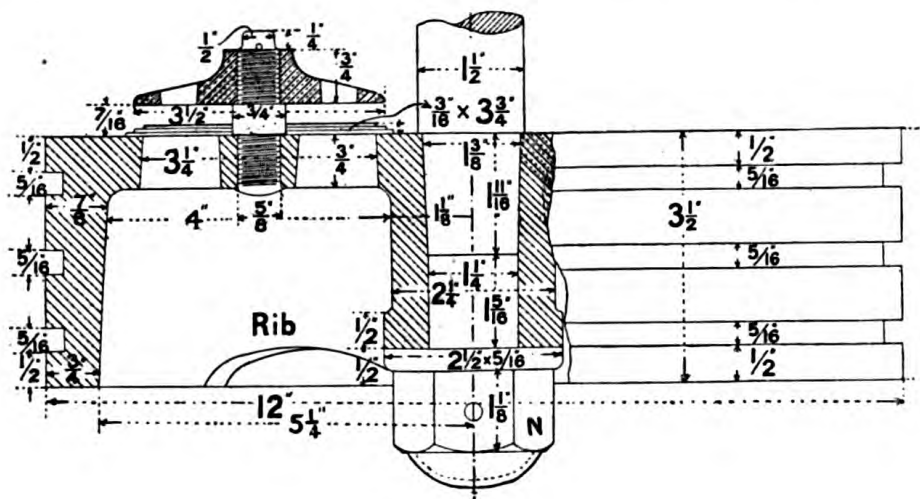
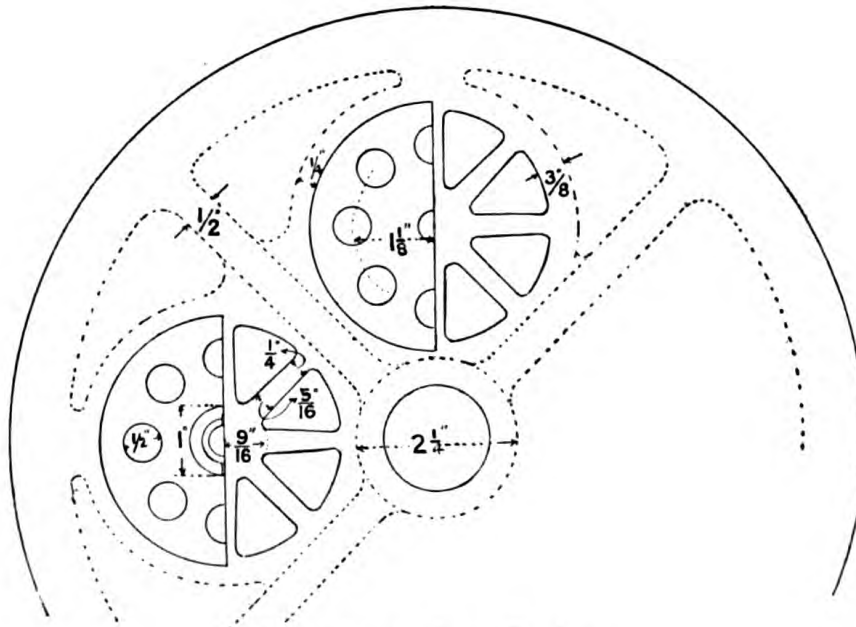


FIG. 236.—Metal Flap Valve.



Air pump bucket—a sectional elevation of a bucket used in Edw. four Kinghorn's valve metal. Those nearest usually to allow air between the surface also is perforated for pump rod is fastened of a *box nut*, **N**, in is closed to preserve

Example
two views shown
(Fig. 237).



Standard plug are used to open passage of water or made of a taper for—and fits accurate casing. The passage is formed through. When the holes in with the metal surface is closed. Four view Adjustment is provided bolts and the screw

Example
views of a p

FIG. 237.—Air Pump Bracket.

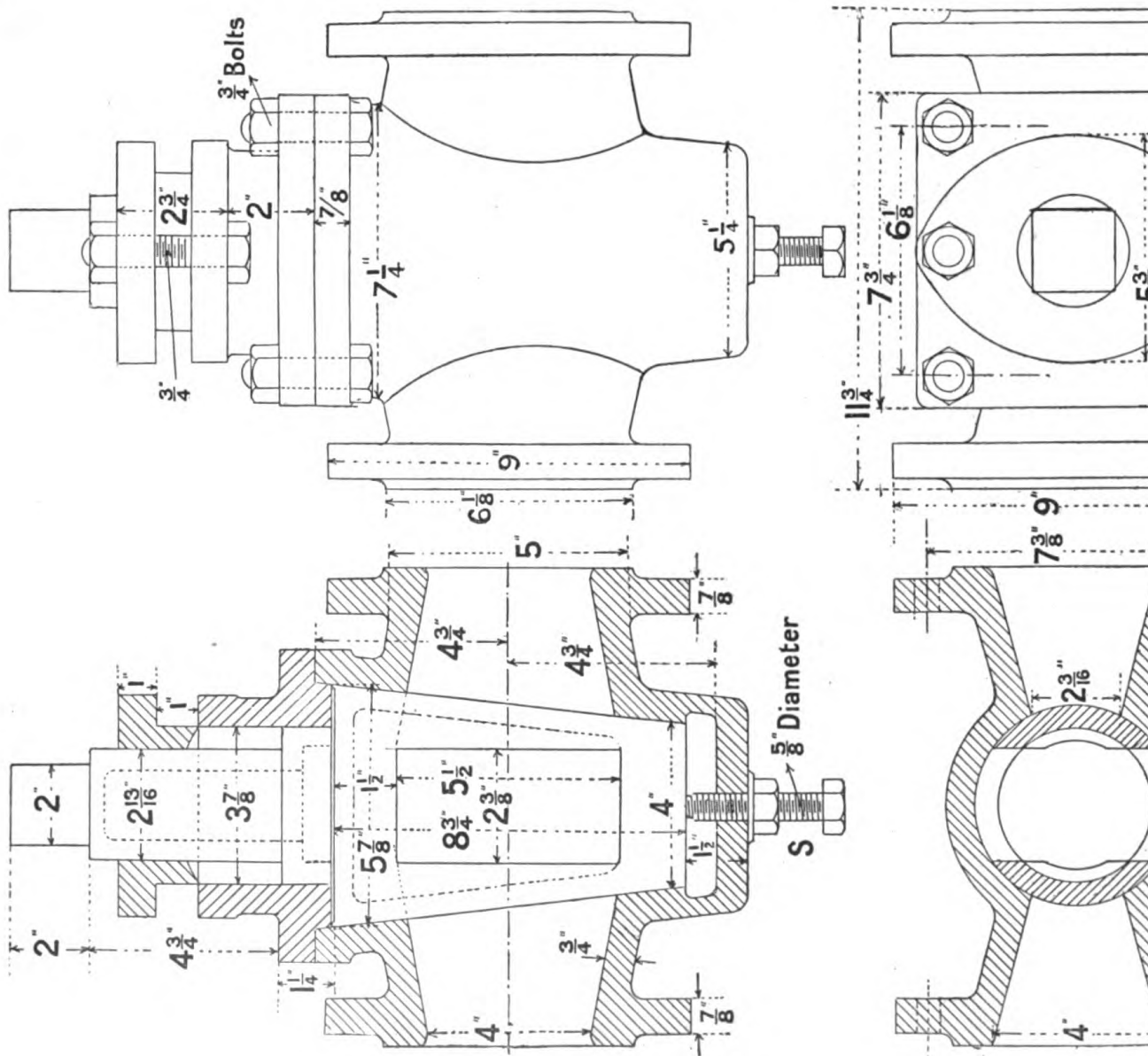
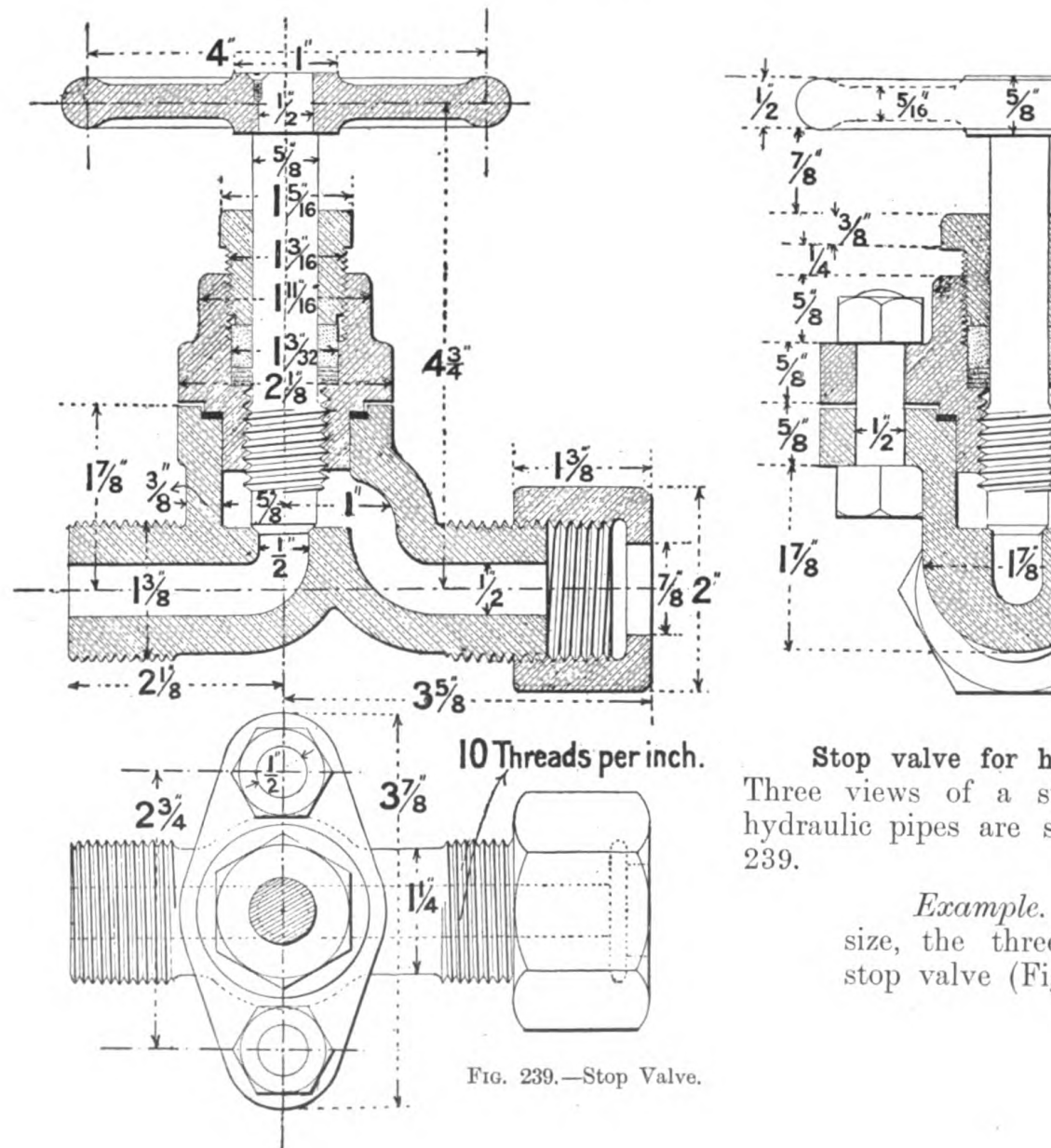


FIG. 238.—Plug Cock.
O

C.M.C.



Ramsbottom double safety valve. Fig. 240 shows a sectional elevation and plan of a safety valve; the two disc valves are each 2" diameter and are placed $5\frac{1}{2}$ " apart. The valve faces are made flat instead of conical—the width of each face being about $\frac{1}{8}$ ". The valves are held down by a helical spring made of $\frac{3}{16}$ " square steel. The pressure on the valves is regulated by the nut N. By means of the lever L either one or the other of the valves can be relieved to ensure that no jamming occurs.

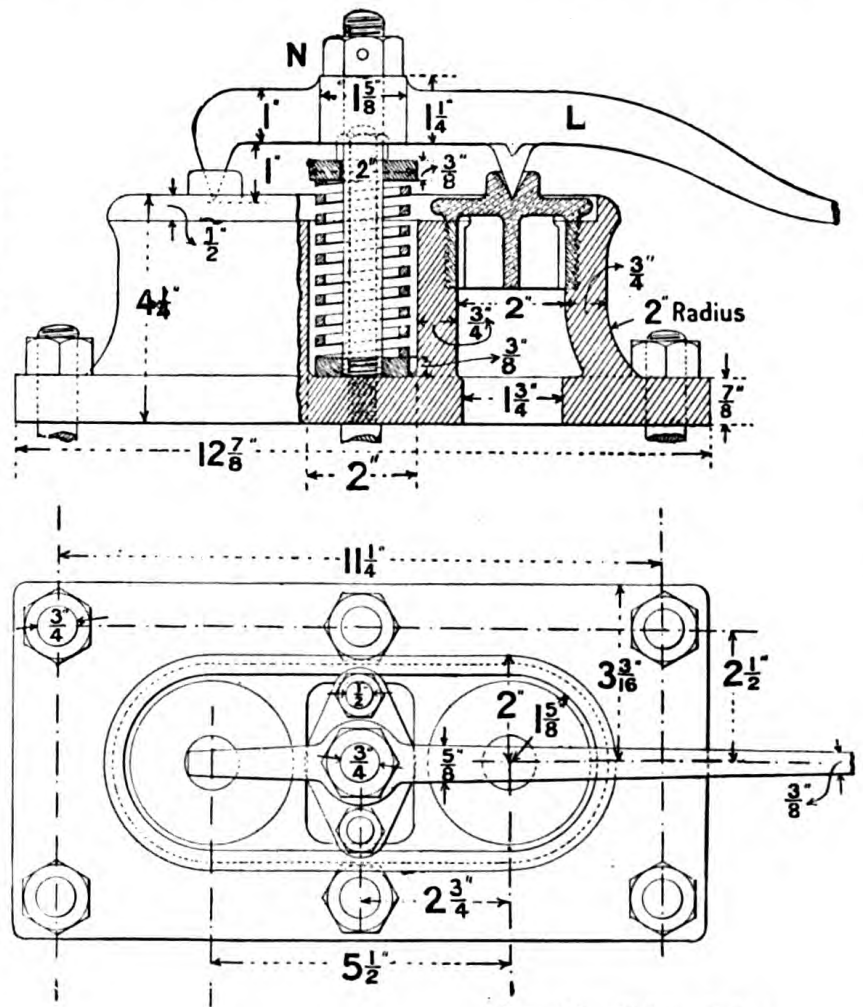


FIG. 240.—Safety Valve.

Example. Draw sectional elevation, plan, and end view of safety valve (Fig. outside diameter; made of $\frac{3}{16}$ " square steel, pitch of coils $\frac{3}{8}$ ". Scale half size.

EXERCISES. XIV

1. Give sketches showing the construction of a conical metal lift or puppet valve, how the valve is guided in its movement and how the height of the lift is limited.
2. Sketch a slide valve in mid-position to the following dimensions: Exhaust 1" wide; steam ports, 2" wide; outside lap, $1\frac{1}{2}$ ". Sketch also the same valve at the stroke with $\frac{1}{8}$ " lead.
3. Show, by sketches, the construction of a slide valve for a steam engine. Show how it is secured to the valve, mentioning the conditions to be observed in this part of the construction.
4. What should be the lift of each of the valves of the pump (Fig. 246) so that the water passages may not be obstructed?
5. With the aid of sketches, describe the construction of some kind of screw-down valve, the seating is made of soft metal which is arranged to be readily renewable.
6. With the aid of sketches, describe how the valves of the air pump of a condensing engine are fitted (1) when made of india-rubber, (2) when made of thin flexible metal. Compare the merits of the two.
7. Give sketches showing the construction of any form of turn-cock for shutting off steam. When, after use, it leaks, point out where the ill fit generally occurs, and describe how to remedy it.

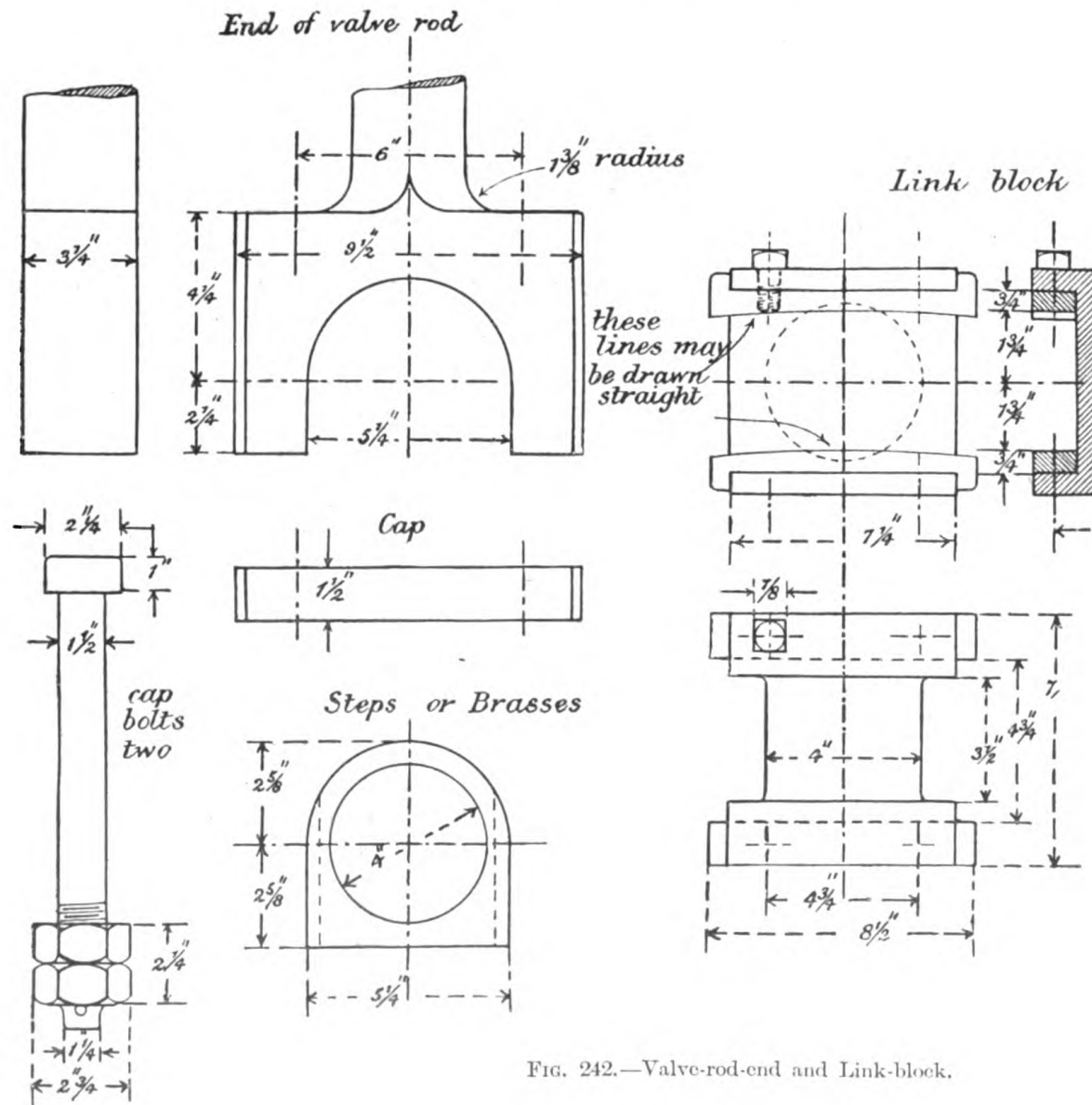


FIG. 242.—Valve-rod-end and Link-block.

10. Draw, half size, the two views of the slide valve for a steam engine (F

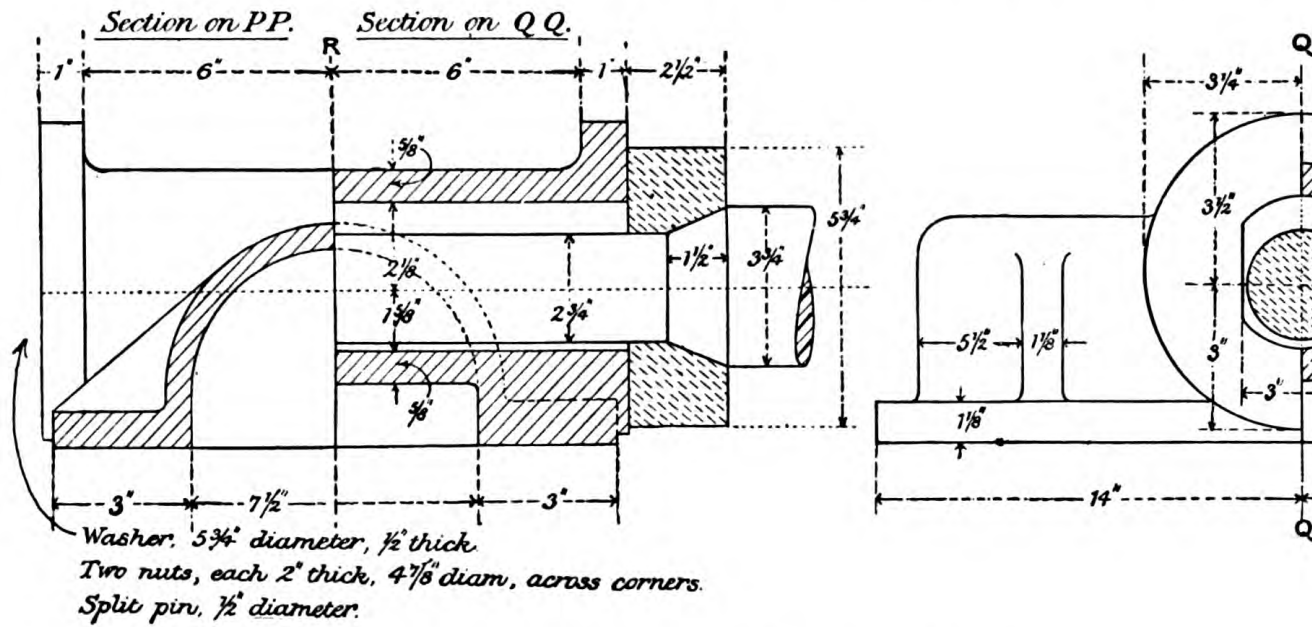


FIG. 244.—Slide Valve.

Section on A.B.

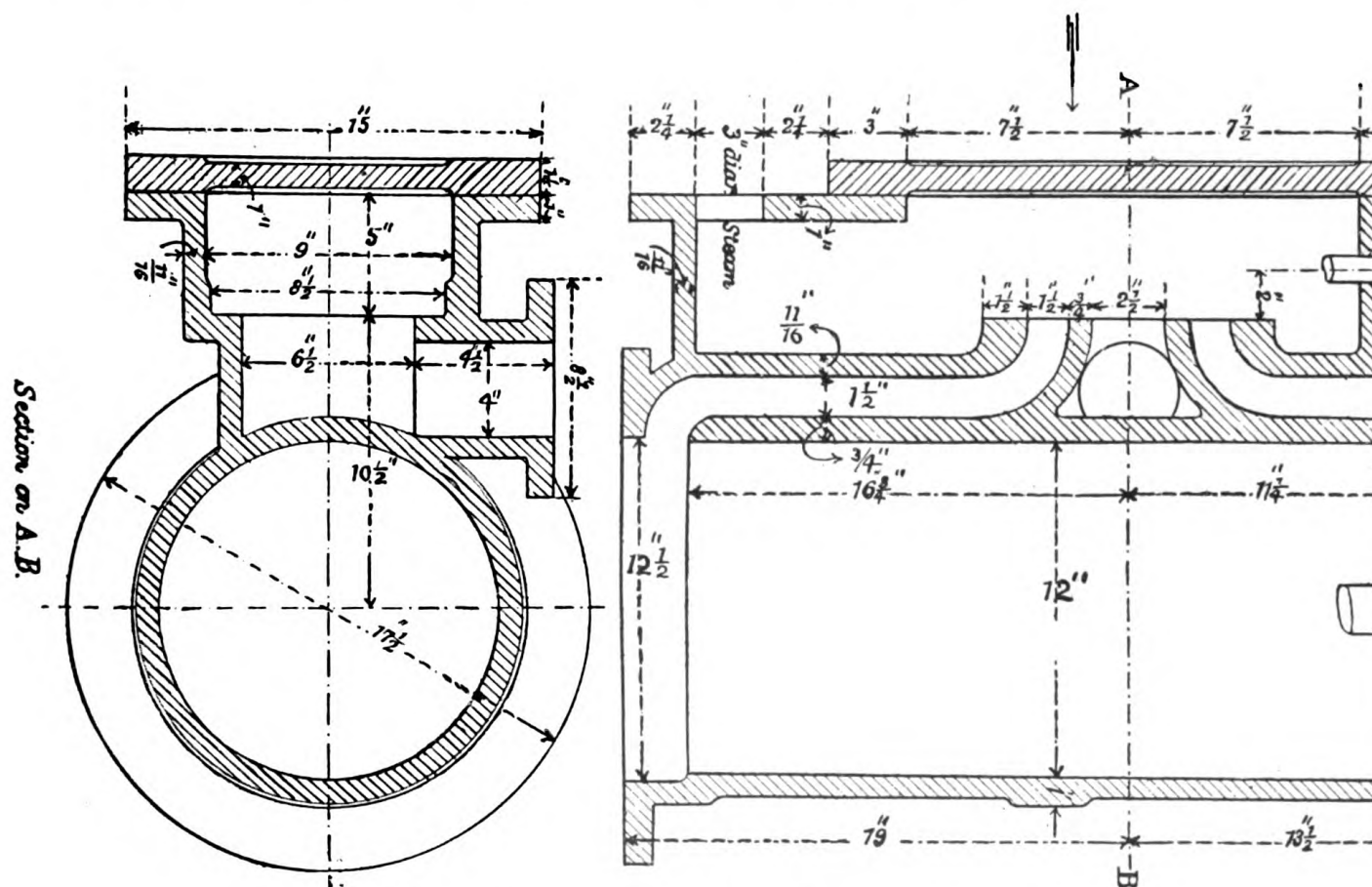
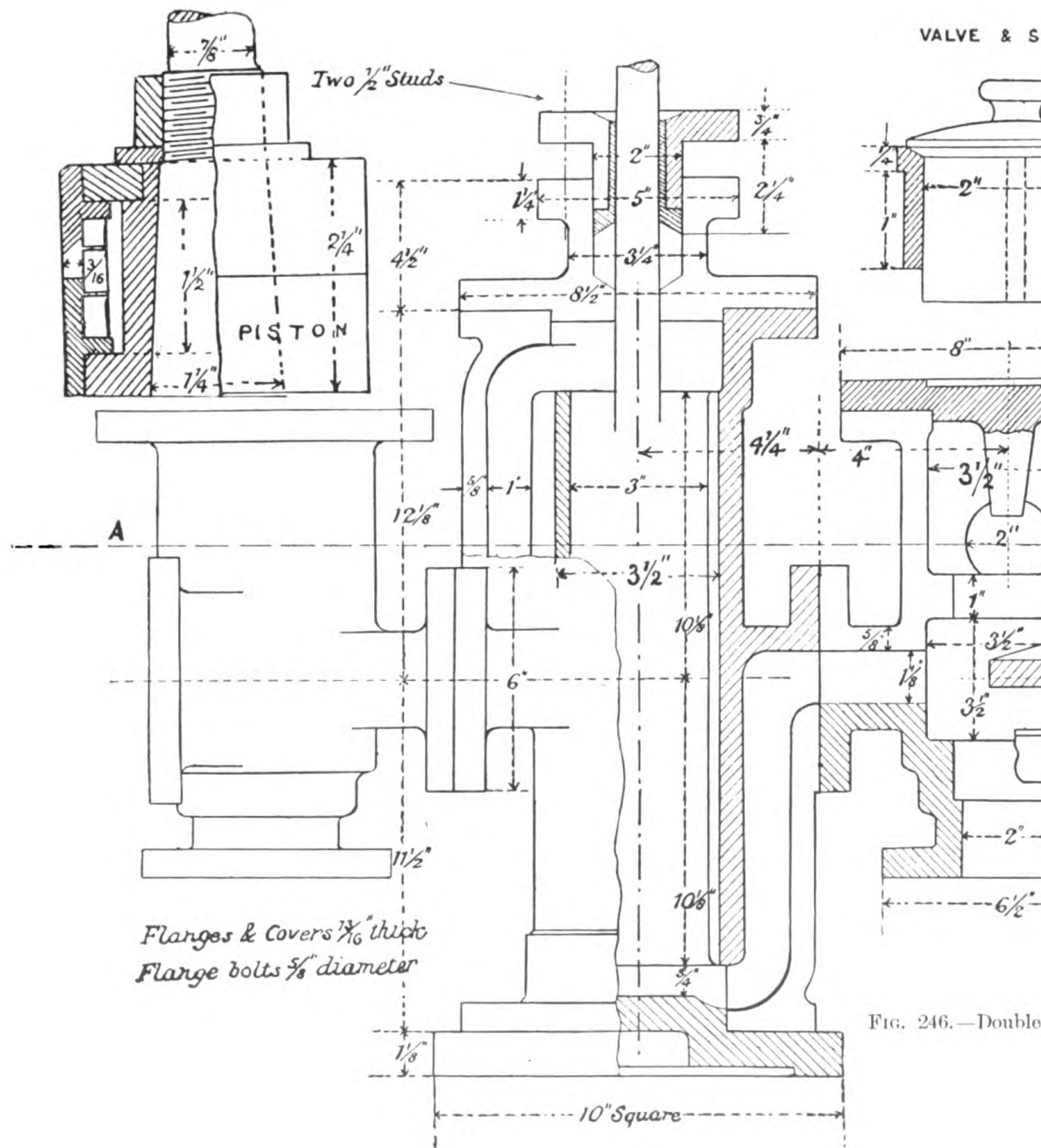


FIG. 245.—Steam Engine Cylinder.



12. Draw and complete the sectional elevation and plan of a double-acting pump the valves and piston placed in position. Scale $\frac{1}{4}$. [B.E.]

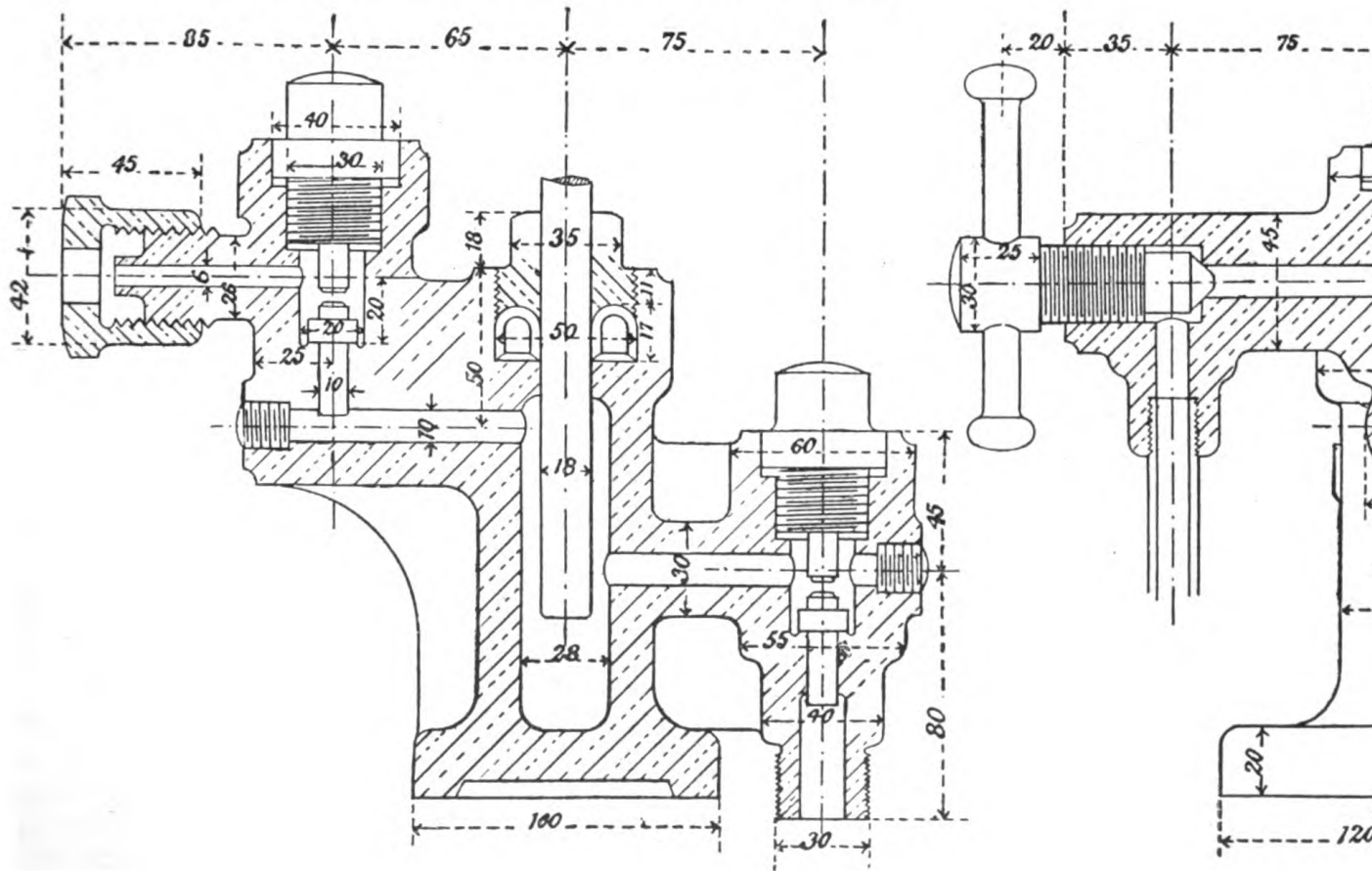


FIG. 247.—Force Pump.

*The dimensions
given in millimetres*

13. Draw the two views shown (Fig. 247) of a pump for forcing water. Scale full

14. Draw and complete the two views shown (Fig. 248) of a Ramsbottom's safety valve.

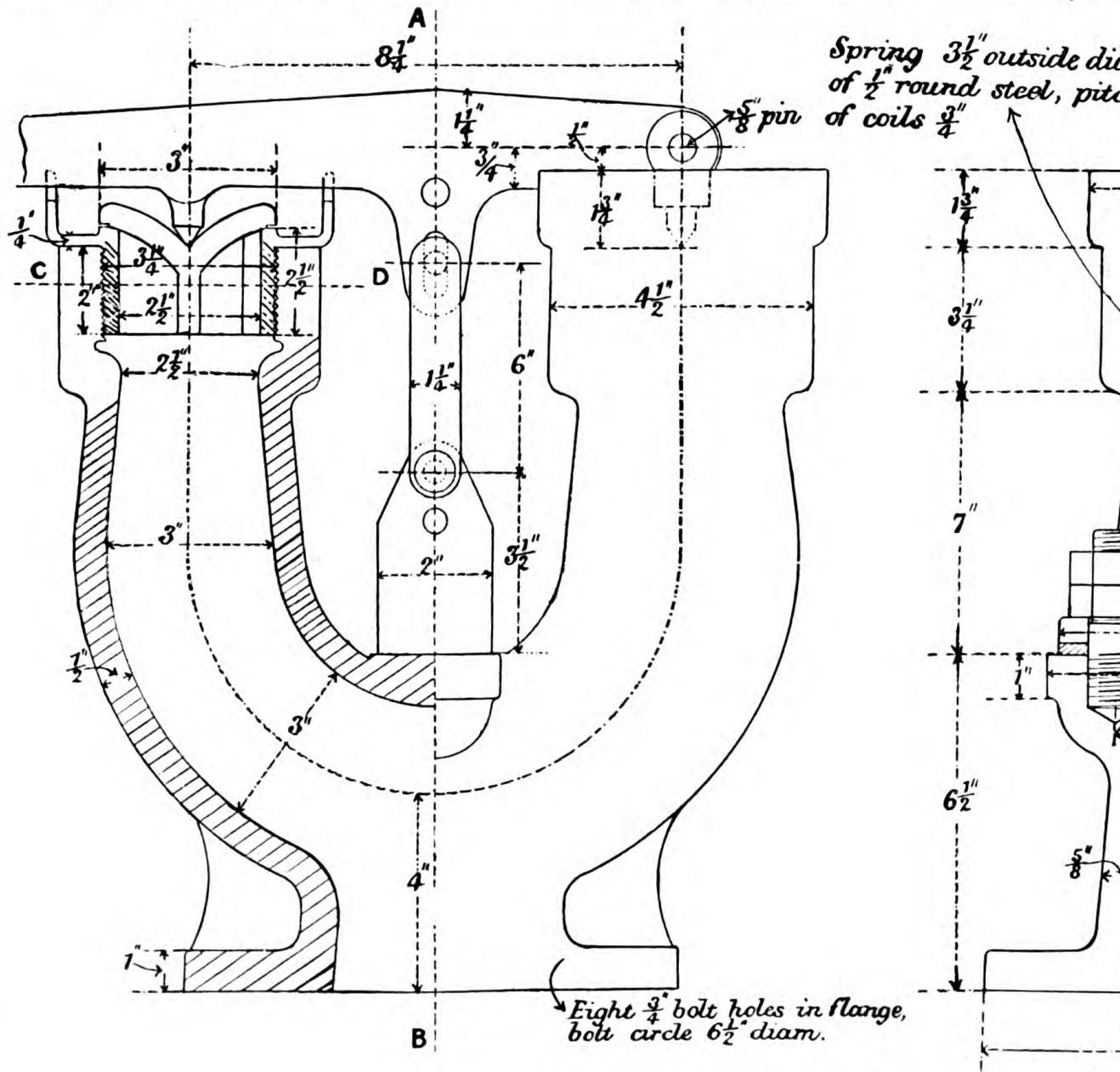


FIG. 248.—Ramsbottom's Safety Valve.

CHAPTER XV.

MATERIALS.

It is only possible in these pages to give brief notes of a few of the more important by engineers. For more detailed information the reader is referred to larger books with the subject.

Iron. Using the term in its general sense to include cast iron, wrought iron, and steel obtained from *iron ore*. This ore consists of iron in combination with oxygen and carbon, the compound being mixed with earthy matters, such as clay, etc.

The chief characteristics of the three varieties of iron may be said roughly to depend on the amount of carbon present. Thus *cast iron*, a compound of iron and 2 to 5 per cent. carbon, can be run into suitable moulds. The material is brittle; and the surfaces formed are of a crystalline texture. *Wrought iron* is either pure iron or iron containing a small amount of carbon; it is *fibrous* and ductile and can be welded; it is used for shafts, bolts, and is magnetised rapidly and very quickly loses its magnetism; it is therefore used for making

Steel. The materials included under the general term steel vary from *mild steel*, containing iron and about $\frac{1}{2}$ per cent. carbon and closely resembling wrought-iron, to *tool steel*, containing 1 to 1.5 per cent. carbon. Tool steel, when made hot and suddenly cooled, becomes very hard; hardness may be removed partially by reheating and by the process known as *tempering*. p. 227. When made hot and allowed to cool slowly steel remains soft.

Steel of this kind can not only be tempered but can also be permanently magnetised. Steel containing less than 0.5 per cent. of carbon, cannot be tempered.

Between the extremes referred to there are a large number of varieties of steel.

The three metals described are of great importance to an engineer, and it is necessary to give more detailed explanation.

Cast iron. The materials included under this general term vary to a great extent in strength. Cast iron is obtained from iron ore *by smelting*. During this process a flux of lime—is added. This flux serves the purpose not only of promoting the fusion but also combines with some of the earthy matters to form a fusible glassy substance called *slag*. In its molten state it is run into a series of shallow grooves and is afterwards broken into lumps known as *pig iron*. The material thus obtained contains from 2 to 5 per cent. carbon, as well as silicon, phosphorus, sulphur, and manganese, which may to a great extent be eliminated by the process of remelting, the quality of the iron improving with each remelting up to roughly about the third time.

Moulds and patterns. Patterns made of wood or metal of the exact shapes of the objects to be used to obtain cast-iron objects. These patterns are embedded in foundry sand. When the pattern is removed an exact shape is left in the sand. This is called *the sand*. Molten iron is poured into such a mould and allowed to cool—a process known as *founding*. When sufficiently cooled the castings are removed from the sand and cleaned. This process is called *finishing*.

The great and uncertain stresses in the material, which may be induced during the process of cooling, constitute one of the great objections to its use, and its place is being taken more and more by iron, mild, or cast steel. The contraction during the process of cooling varies in different kinds of iron. The material is also liable to have what are called *blow holes*, formed by *gas bubbles*, which obviously reduce the soundness and strength of an object.

The soundness of an object may be in many cases ensured by casting the object in a vertical position. This is effected usually by placing the mould in a vertical position with some additional sand above it. The lighter impurities, dross, etc., together with air or gas bubbles, ascend to the top and are afterwards cut off.

The different varieties of cast iron are designated by iron merchants usually by numbers, the higher numbers denoting the whiter and harder kinds, and the lower numbers the softer. The whiter kinds are hard and brittle, and are, therefore, not often used for heavy machinery. A considerable amount of stress is likely to occur, or which have to be subjected to great strains in workshop tools. These whiter kinds of cast iron are called *forge irons*, or *forge quality*, and are used for conversion into wrought iron. In these whiter kinds the carbon is in chemical combination with the iron, but in the greyer varieties, known as *foundry irons*, or *foundry pigs*, only a small amount of carbon is in chemical combination, while the remainder exists in the free state, similar to that in pig iron.

Machine details and the frames of machines are made of cast iron frequently on account of the facility with which an object even of complicated form can be cast. For a similar reason, together with its comparatively great strength in compression of the material, columns and pillars are in many cases made of cast iron.

Malleable iron. The brittleness of small cast-iron objects may be removed partially by heating them to a bright red heat and keeping it for some time in contact with powdered red hematite, which is chiefly of peroxide of iron. In this process the carbon is partially burnt out; the material becomes malleable and converted into what is called *malleable iron*, resembling to some extent wrought iron.

Chilled castings. When molten metal is cooled rapidly in a mould, it is found that the surface carbon disappears and white hard cast iron is formed. This property is utilised in many cases where a particular portion of a casting is required to be made harder than the remainder, as in the case of the points of conical iron shells. In such cases the mould at the part requiring to be made harder is usually rest usually consists of a thick block of cast iron. In this manner the casting in contact with the iron block is cooled very rapidly and becomes extremely hard to a depth varying from one-fourth to half an inch. The surface in contact with the molten metal is protected by a wash of oil.

Ultimate strength and safe stress. The ultimate or breaking strength of cast iron is from 40 to 45 tons per square inch in compression, and from $7\frac{1}{2}$ to 10 tons per square inch in tension. The average shearing strength is about 12 tons per sq. in.

The material may be made to take complicated shapes by casting in suitable moulds. It is of the utmost importance that the cross-section shall be as uniform as possible; when this is not the case, the thinner parts cool first, and, in consequence, initial and unknown stresses due to unequal contraction exist in the metal. The magnitude of these is sometimes so great that fracture may occur before the casting is removed from the mould or during the subsequent workshop processes. In order to prevent this tendency to fracture that all sudden variations in thickness and shape be avoided, and that the cross-section shall throughout be as uniform as possible.

In cast-iron girders this uniformity of thickness is to some extent ensured by taking the ratio of the area in compression and tension to be as 4 to 1 instead of 6 to 1. This gives as the safe working stress 4 tons per sq. in. in compression and $1\frac{1}{2}$ tons in tension. The cross-section of a cast-iron girder should be of the same thickness throughout. When, as in Fig. 249, the upper flange is made thinner than the web **W** is made taper as shown, the areas of the two flanges are as 4 to 1.

What are known as *stiffeners* are inserted sometimes at distances of about to ensure lateral strength. One of these is shown at **S** (Fig. 249).

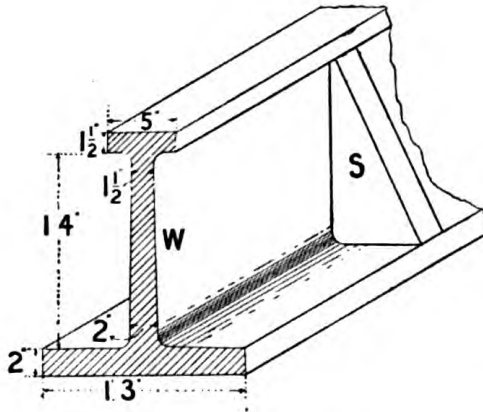


FIG. 249.—Cast-iron Girder.

Example. Draw cross-section and elevation of a cast-iron girder, 18 feet long. Scale $\frac{1}{4}$ (Fig. 250).

Wrought iron. Wrought iron is used for including the making of shafts, bolts, nuts, etc. machine parts requiring strength and toughness. It is made from cast iron by the processes of *refining*, *puddling*, in which the greater part, or the whole, of the carbon and other constituents, such as phosphorus, etc., are eliminated.

When the metal is heated to a sufficiently high temperature in the presence of air, the oxygen of the air combines with the carbon to form an oxide of carbon, and when this is driven off by the blast or by the hammer or nearly pure, iron. The mass of white hot metal is then passed through the hammer—an operation known as *shingling*—and then through suitable rolls.

The fibrous character of the material and its tensile strength are found to depend upon the rolling that the material receives during the process of formation into bar iron, and the number of times it is rolled. The letters *P*, *B*, and *R* are used to designate various qualities of iron and indicate primarily the amount of rolling received. Thus, *Puddle bar* denotes iron which has only been rolled once; *Best bar* is made from puddle bar by reheating and rolling. In both these cases the bars produced are brittle and cannot be welded easily. By continuing the process, *Best bar* is prepared from puddle bar.

Ductility. One of the most important properties of wrought iron is its ductility, or the stretching that occurs before fracture of the material takes place. Thus, the best quality of wrought iron will stretch from 20% to 25% in a length of 8" before breaking with a contraction of area not less than 40 per cent.

Welding. Unlike cast iron, in which two separate pieces cannot be welded together, wrought iron can be hammered or pressed together when the metal is at a white heat, and as to form one piece of material. Also, it cannot be cast; at high temperature it is too brittle to be poured.

Ultimate strength and safe stress. The ultimate or greatest tensile strength of the iron; but ordinary good material will bear from 20 to 25 tons per sq. in. The greatest compressive strength varies from 16 to 20 tons per sq. in. The *safe working stress* is obtained by dividing these values by a number or factor called the *factor of safety*. Thus, if the factor of safety is 4, then the safe working stress is about 5 tons per sq. in. in tension and 4 tons in compression. In most cases, for convenience in calculation, 10,000 lbs. per sq. in. is used instead of the proper value for tension and compression, and 9,000 lbs. per sq. in. for shearing.

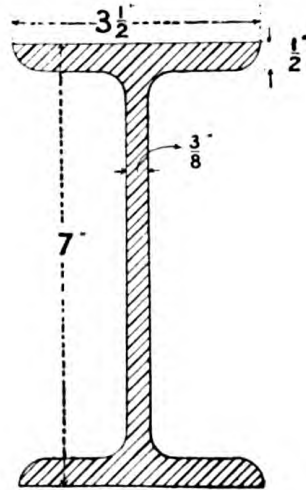


FIG. 250.—Rolled Iron Girder

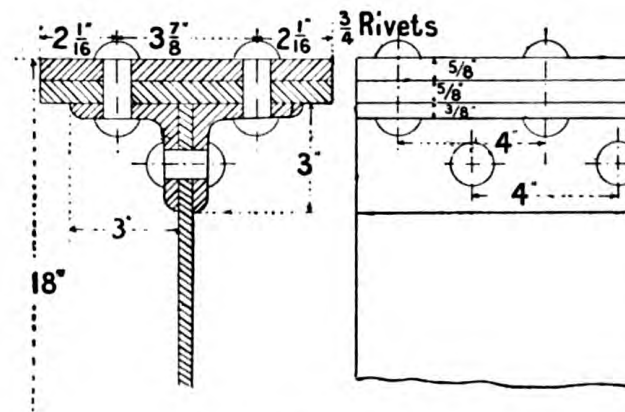


FIG. 251.—Plate Girder.

In the case of a wrought-iron girder the two flanges are usually equal in size (Fig. 250). They are known as rolled iron girders in this form.

Example. Draw, half size, the cross-section of a rolled iron girder (Fig. 250) showing about 3 feet of the length.

In *plate girders* each flange consists of one, two, or more plates joined together by rivets (Fig. 251).

Example. Complete the two views shown in Fig. 251 making the elevation and plan.

Scale $\frac{1}{4}$.

C.M.C.

P

Effects produced by vibration. It is found that continual vibration tends to change wrought iron to a more or less crystalline material resembling cast iron. Intermittent stresses are liable to fracture. The effects referred to, and known as *shot*, are particularly noticeable in the fractured surfaces of crane and other chains after they have been in use for some considerable time. The fibrous nature of the material may be restored by *annealing*, in which the material is heated to a red heat and allowed to cool slowly.

Case hardening. The surfaces of wrought-iron and cast-iron objects, after the tools, may be hardened by heating the object to a red heat, then coating the surface with powdered yellow prussiate of potash and quickly cooling in water. A similar process is used when the surfaces are heated, they are kept for some time in contact with carbonaceous materials such as bone dust and cuttings of horn and leather. In this manner the outer surface of the object is converted into steel. The depth to which the surface is converted into steel depends on the time during which the process takes place.

Steel. Steel may be obtained either from cast iron by eliminating some of the carbon, or from wrought iron by adding carbon to it. The term steel includes materials which differ very materially in many respects. These differences are produced chiefly by the amount of carbon. The softer kinds containing 0.15 to 0.2 per cent. of carbon are used for boiler plates. Plates containing 0.25 to 0.3 per cent. are used largely for boiler plates, etc. Wrought iron in many respects, having the same facility of welding, equal toughness, etc. Such steel cannot be *hardened*.

The harder qualities of steel contain more carbon, *i.e.* from 0.3 to 1.5 per cent. They possess more toughness than the softer kinds, but much greater strength. The harder the steel the more carbon it should contain. Thus, *razor steel*, which becomes very hard and is used for cutting a very keen edge, contains 1.5 per cent. carbon. *Tool steel*, which does not become too hard and can with care be welded, contains 1.2 per cent. carbon. When the carbon content is less than 1.2 per cent. it is called *chisel steel*. This steel admits of a good cutting edge, and is also tough. Steels containing less than 0.7 per cent. carbon are not used for tools.

Manufacture of steel. Steel is made by what are known as the *Siemen's* and *Open-hearth* processes. The cementation process is used for high carbon steel.

In the *Siemen's-Martin* process, the pig-iron is melted in a Siemen's gas furnace carbon necessary is obtained by adding clean iron ore, scrap iron, etc., containing the re

In the *Bessemer* process, the molten metal is poured into a *converter* and a blast of it. In this manner the oxygen of the air combines with and carries away the carbon in dioxide, and also results in the removal of many of the impurities, such as silicon, mang sufficient cast iron of the whiter kind, called *spiegeleisen*, is added to give the exact amount

In the *Cementation* process, bars of pure wrought iron and broken charcoal are heated and kept at that temperature for several days. The steel produced in this manner, after hammering process, is known as *shear steel* and is used largely for tool making.

Mild steel is from 20 to 25 per cent. stronger than wrought iron, and, on account of facility with which it can be made, it is now used very largely for the various parts of tools, etc. The steel used for boiler work has usually a tensile strength of from 27 to 30 with an elongation of about 20% in a length of 8".

Nickel steel. Contains 7 to 30 per cent. of nickel. Tensile strength 40 to 45 tons per square inch

Hardening. One of the most important properties of steel is that known as *hardening*. A piece of the material is heated to a red heat and cooled by immersion in water, it becomes hard and brittle. The degree of hardness depends upon the composition of the steel and the rapidity

Tempering. Closely associated with the hardening properties of steel is that known as *tempering*. A cutting tool of any kind—such as a chisel—would, if made red hot and slowly cooled, be cut easily by a file. If made red hot and cooled quickly it becomes very hard. The hardness is reduced to any extent by the process of reheating. This process is called *tempering*.

A common practical method adopted for hardening tools is to make as much as may be red hot and suddenly to cool the cutting edge by immersing it in water, afterwards allowing it to cool by the conduction of heat from the other and thicker portions of the cutting tool to the necessary "temper" required. When this occurs the whole is cooled, to *fix*, or to *set* the temper.

One process of tempering may be illustrated by the method adopted to temper a chisel. The chisel is heated to a red heat, to a distance of say three or four inches from the cutting edge. The cutting edge is partially cooled by immersing the cutting edge to a depth of about an inch in water.

next rubbed on a piece of stone so that the colour of the film can be clearly seen. by the metal, the change in the colour of the film indicates roughly the degree of the colour changes from a pale yellow to a straw colour it is immersed in water to respond to that used for razors and instruments of a similar kind. If the cooling the colour of the oxide would alter from straw to (a) brown, (b) purple, (c) blue suitable say for a chisel; the next (b) for wood turning and many other tools; and (c) for springs. Where elasticity is required the blue colour is also suitable for various tools which require to be sharpened from time to time by files. Such tools are, however, given a suitable degree of hardness by heating and immersion in an oil bath. As already mentioned, be allowed to proceed slowly, then, when cold, the material can be operated upon as wrought iron, a material which it closely resembles.

Cast steel. Steel is fusible and objects of it can be cast. But, unless treated under pressure, the object is porous and contains numerous cavities.

Whitworth fluid compressed steel. Sir J. Whitworth has overcome this difficulty by subjecting the steel to great pressure whilst cooling in the mould. The steel produced by this process is capable of withstanding from 30 to 40 tons per sq. in.

Lapping. When two surfaces of unequal hardness are pressed together, and one is moved over the other, friction between the two may result in the cutting or abrasion of the harder surface only suffers slightly, unless particles from other sources are embedded in the softer surface and act as cutting tools. In the operation of lapping, emery, or other very hard material is used on a softer one such as lead, the lead merely acting as a holder for the cutting material.

In a similar manner, in polishing and in cutting hard rock sections, diamond is used on a softer surface of an iron disc or wheel.

Friction. Friction may be used as a means of transmitting motion. Examples are found in belt and rope gearing, and in friction clutches of various kinds, etc. In all such cases the object is to make the frictional resistance as great as possible. These cases are considered in detail in the chapters on friction.

The object of a machine may be defined to be to control or to utilise energy for the purpose of doing useful work. As all machines are more or less imperfect, a part only and in some cases a large part of the available energy is wasted in various ways, *i.e.* in friction between the rubbing surfaces, in the resistance of the moving parts, and in the resistance of the

the air, etc. It is of course of primary importance to diminish as far as possible the friction on the surfaces and in this manner to reduce the loss of energy to its smallest possible amount.

It is a matter of common experience that when two surfaces which may be appressed together they cannot be moved without the application of force. This is necessarily due to the roughness or unevenness of the surfaces in contact. The surfaces, although apparently smooth, are assumed to consist of a large number of minute projections which exist on the surface. The friction experienced is probably due to the interlocking which occurs when the surfaces are moved. Friction between two surfaces is therefore a force acting in the opposite direction to the motion, and may be either *sliding* or *rolling friction*. It is easy to verify that much less friction is offered to rolling than to sliding friction. Thus, a heavy block of stone which may offer great resistance to a push or pull may probably be moved quite easily when placed upon rollers. It is for this reason that *friction wheels* are provided, that vehicles are furnished with wheels, and that ball bearings are used on cycles, etc.

Measurement of friction. When two surfaces are placed horizontally, the ratio between the force necessary to move one surface over the other and the weight of the surfaces in contact is called the *coefficient of friction* for the two surfaces in contact; it is usually denoted by the letter μ . In many cases the friction referred to is simply that due to the weight of the moving body, and if F denote the force of friction, W the weight of the moving body, and μ the coefficient of friction, then the relation is

$$F = \mu W.$$

It will be obvious that much will depend on the nature of the surfaces in contact, which are termed smooth, rough, or any intermediate stage between these extremes. The laws of friction can only be expected to give, in any actual case, a fair approximation. The laws of friction which are approximately true within certain limits are:

- (1) friction is directly proportional to the pressure between the surfaces;
- (2) is independent of the extent or area of the surfaces in contact;
- (3) is independent of the velocity.

Friction may be reduced by making the surfaces in contact exceedingly hard and as smooth as possible. There are many reasons why such a process is not always practical, such as the great cost, etc. Hence, other and simpler methods are used. Thus, the surfaces in contact are made as smooth as possible and of ample size to diminish the intensity of the pressure. Another method is to use lubricants.

different metals for the two surfaces which work together, and by the use of various lubricants to prevent the surfaces actually coming into contact.

For example, the journal in a rotating shaft may be of steel or of wrought iron in which it rotates consists of some kind of alloy. This plan serves the double purpose of reducing friction, and that the wear chiefly occurs in the small steps. Bushes are of comparatively small size and when worn can be replaced easily. They introduce a thin film between two smooth surfaces, and in this manner to prevent them. If, however, the pressure between two surfaces is too great, the lubricant is forced out and the two metals come into contact. When this occurs, what is called *seizing* occurs, and the metals adhere so closely that usually considerable force is necessary to effect a separation.

Copper. This material, easily recognised by its characteristic reddish colour, is well known to the engineer. It is malleable and ductile, not only at ordinary temperatures but also at high temperatures, and therefore can be worked either hot or cold. It is largely used for pipes which retain their shape when cold, also in firebox plates, etc., where its power of resisting heat is of great value. It is a good conductor of heat and electricity. The ultimate tensile strength of cast copper is about 20 tons per square inch.

Alloys. What are known as *alloys* are used for a great variety of purposes. They are used for wearing parts of *bushes*, *steps*, etc., of rotating pieces, for the sheathing plates for locomotives, for boilers, for water cocks, for valves, and for hydraulic purposes. In casting in sand moulds must, when molten, be sufficiently liquid to be capable of flowing into every part of the mould, and registering faithfully the most minute details of the mould. In addition, brass must be strong enough to be subjected to hydraulic tests, and the castings must therefore be free from what are called *defects*.

Alloys consist of varying proportions of copper, tin, zinc, etc. It is possible to give a list of the more important and to state fairly average values of the constituents. For more information works dealing with this subject alone must be consulted.

Brass. The term *brass* is usually taken to apply to those alloys of which copper is the chief and essential constituents. The range is a wide one; *i.e.* copper 90 to 35 per cent. and zinc 10 to 65 per cent. Many of these alloys, as will be seen from the following list, receive special names.

The composition of brass for ornamental work varies from 90 per cent. copper to 80 per cent. copper, 20 per cent. zinc.

Brass containing 65 to 70 per cent. copper and 35 to 30 per cent. zinc is largely used for sheets, drawing into wire, and is also used for steps, valves, cocks, etc.

Zinc is of a bluish colour. It is a malleable and ductile material and forms a variety of forms of alloys. It is used in the process of galvanizing iron and also for a variety of other purposes.

Aluminium is a whitish metal which is malleable and ductile. It is extremely light compared with other metals. Its specific gravity is 2.6, or about $\frac{1}{3}$ that of iron and steel. Its tensile strength is varying from 6 to 14 tons per sq. in.

Muntz metal contains about 60 per cent. copper and 40 per cent. zinc; in some cases lead is added. It is used for the tubes of locomotives, the sheathing plates of ships. Plates of this kind do not corrode readily. The thin coating of zinc which forms on the surface, too, to some extent, the attachment of barnacles. Tensile strength about 20 tons per sq. in.

Naval brass has usually a composition of copper 70 per cent., zinc 29 per cent., tin 1 per cent. The name implies, it is extensively used in marine work for bolts, spindles, nuts, etc.

Gun metal or bronze. Alloys in which copper and tin are the chief constituents are called *gun metal* or *bronze*. The hardness of the metal depends upon and increases with the amount of tin. Thus, a composition of 90 per cent. copper and 10 per cent. tin would correspond to a soft bronze, 82 per cent. to 18 per cent. forms a hard bronze. In some cases a little zinc is added. The specification for gun metal is 88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc.

Phosphor bronze is an alloy consisting of copper and tin together with a small proportion of phosphorus. Unlike ordinary bronze, it can be remelted without deterioration of quality. Tensile strength about 20 tons per sq. in.

Babbitt's metal. This anti-friction metal is largely used for lining the bearing surfaces of steel, or brass bushes. The composition varies from 5 per cent. copper, 86 per cent. tin, 9 per cent. antimony to 9 per cent. copper, 82 per cent. tin, and 9 per cent. antimony. The friction is greatly reduced by its use, and it is therefore used for bearings, connecting rod ends, etc. It is comparatively soft, and must be supported in shallow trough-shaped recesses (Fig. 210).

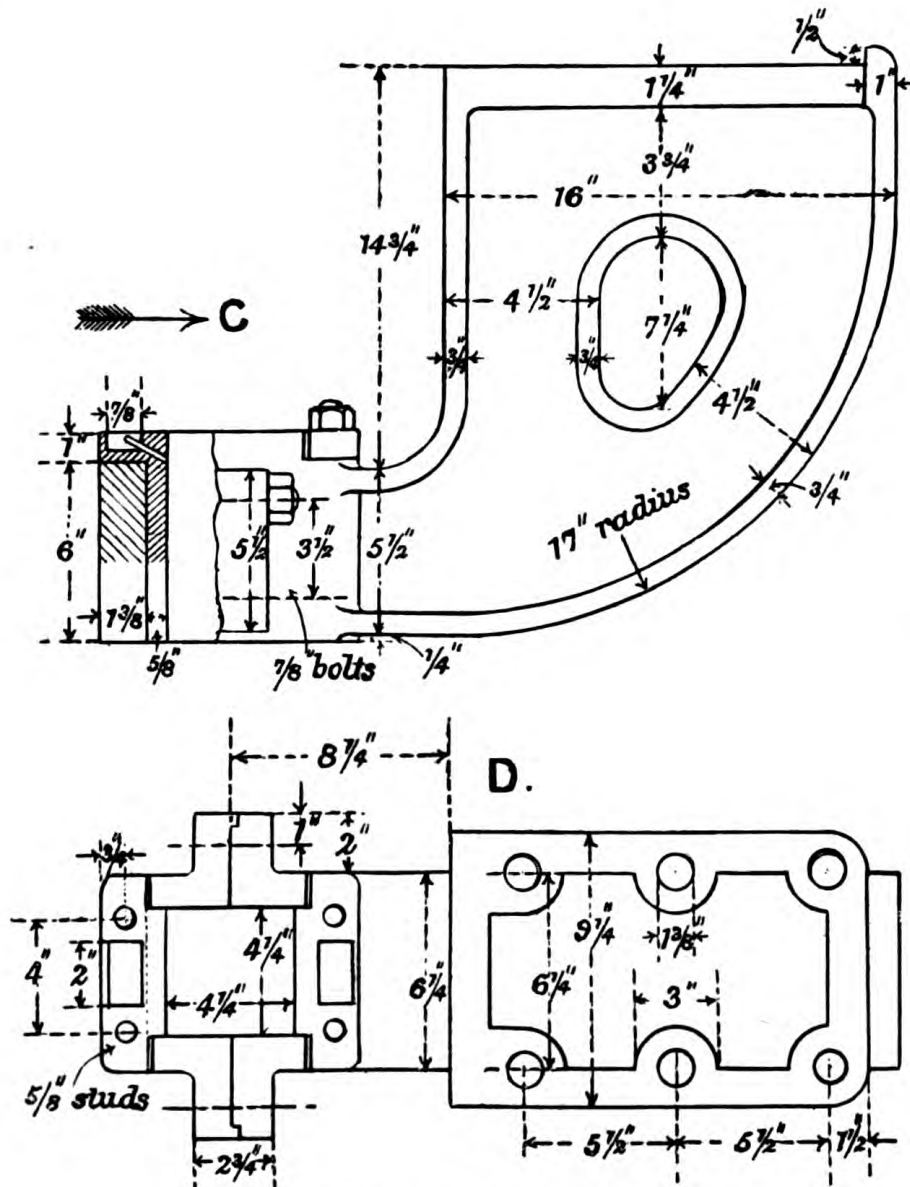
Delta metal. Is a brass alloy containing a proportion of iron, tensile strength 22 to 25 tons per sq. in. It can be worked hot or cold.

EXERCISES. XV.

1. State the characteristic properties of brass, cast iron, and wrought iron. of machine details in which the metal used is selected on account of the possession of [B.E.]
2. What is the composition of the soft alloy used for bearings known as advantages due to its use, and show by sketches how it is attached to the bearing. [B.E.]
3. Name the material you would use in the construction of (a) a lathe b water pump; (c) a steam boiler. In each case give reasons for your answers.
4. Give an instance in which some portion of a machine is case-hardened. I case-hardening is performed, and how the hardened surface is made accurate and s
5. Describe the manufacture of malleable iron.
6. As an example of hardening and tempering, explain the process of making a
7. Why are wrought-iron girders preferable to those made of cast iron? Sket iron and also a cast-iron girder.
8. Give sketches showing two instances, differing as much as possible from o where rollers are used in machines for the purpose of diminishing friction.
9. The flanges of a plate girder are $7'' \times \frac{1}{2}''$, the web $16'' \times \frac{3}{8}''$, angles $3'' \times 3''$ 4" pitch.
Draw a cross-section and a portion of the elevation of the girder. Scale $\frac{1}{4}$.

MISCELLANEOUS EXERCISES XVI.

1. Elevation and plan of a bracket for supporting a pair of shafts at rig connected by mitre wheels (Fig. 252). Draw the elevation and plan, the wheels place. Scale full size. [B.E.]



2. Guide bracket
and complete the view.
Draw also a front elevation
as seen when looking along
arrow. Scale $\frac{3}{8}$ ths. 1 in.
views. [B.E.]

FIG. 253.—Guide Bracket for Valve-rod.

MISCELLANEOUS EXERCISES

3. Hydraulic press. The diagram (Fig. 254) shows three views **D**, **E**, **F** of detached views of the cross-head plunger gland, etc. You are required to fit the instead of drawing view **D** in outside elevation as shown, to draw a section taken through the cylinder; also, in place of view **E**, draw an outside view when looking in the same direction.

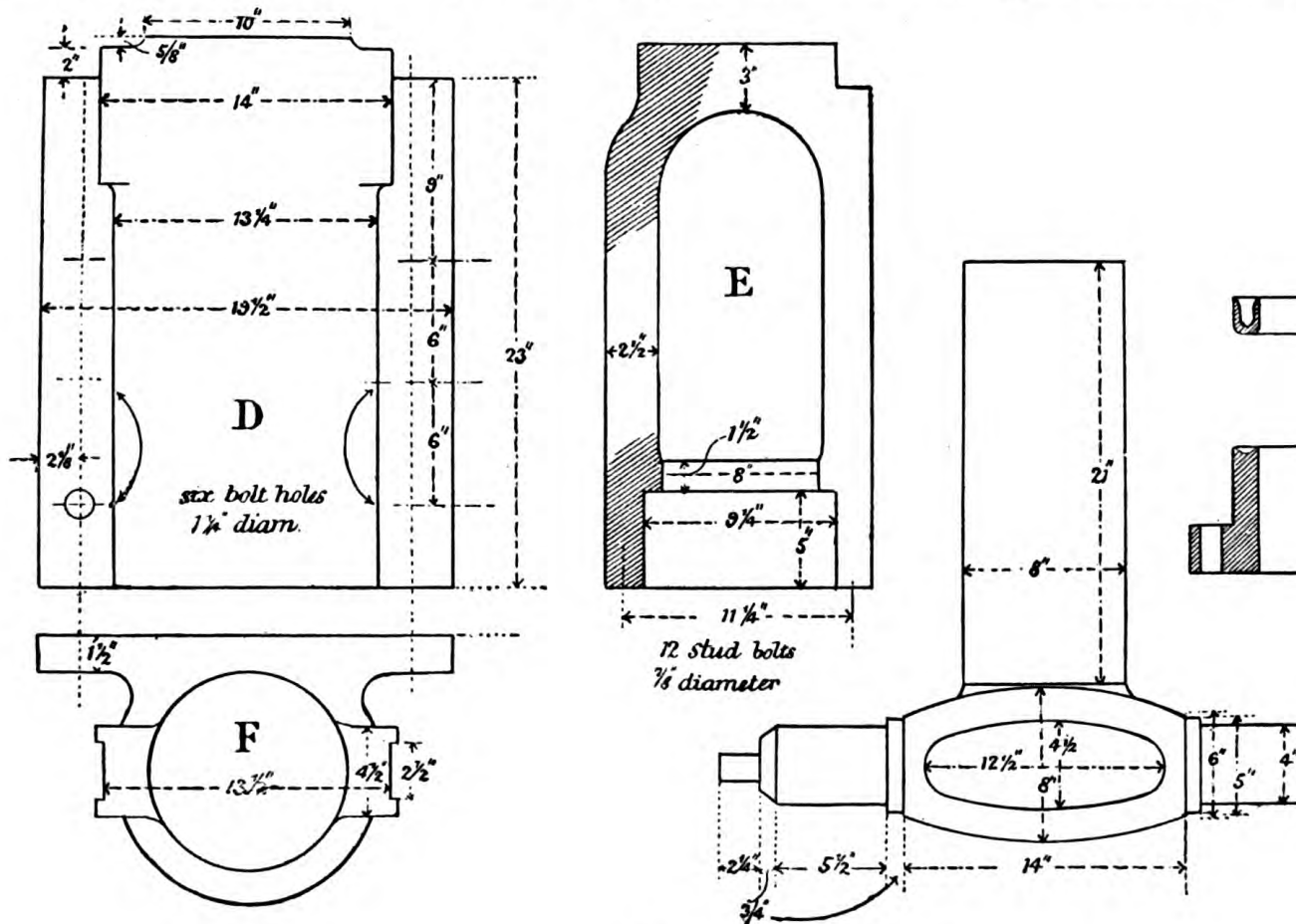


FIG. 254.—Hydraulic Press.

CHAPTER XVI.

ENGINEERING DRAWINGS.

It may be advisable to give a brief summary of the various points—many of which are referred to in the preceding pages—that must be attended to in order to produce a drawing of good style and finish.

(a) In commencing a working drawing the centre lines should be drawn first, so that the lines forming the drawing are equidistant from these lines.

(b) Although pencil lines may be set out of an indefinite length until the final line is obtained, these must be made finally to terminate exactly at the points intended. Drawings either in pencil or ink.

(c) All the lines of a drawing should be firm and of uniform thickness. The straight lines, and the curves, should be drawn by the aid of instruments. In inking in, all lines should be of uniform thickness.

(d) Circles and curves touching lines should do so accurately; the point of contact should be noticeable by the curve failing to touch the line.

(e) It is easier to draw a line to touch a curve than conversely. Hence, in inking in, the curves should be inserted first, then the straight lines, and finally any curves requiring the use of the straight lines.

(f) Section lines should be equally spaced. If a flat wash of colour is used, it should be placed at a slight slope and the colour put on quite evenly beginning at the upper part and ending at the lower parts of the drawing. Small pools of colour must not be left on any part of the drawing.

(g) The letters and figures must be clear, well formed, and so arranged that they do not alter the position of the drawing. The arrowheads at the ends of dimension lines should be placed on the lines to which they refer.

It should be noticed that no written instructions can replace practice and experience. The preceding hints will tend to lessen some of the many failures which are seen in the work of those beginning the subject. Some of the more important points to be attended to in comparing the two drawings of a piston (Fig. 255).

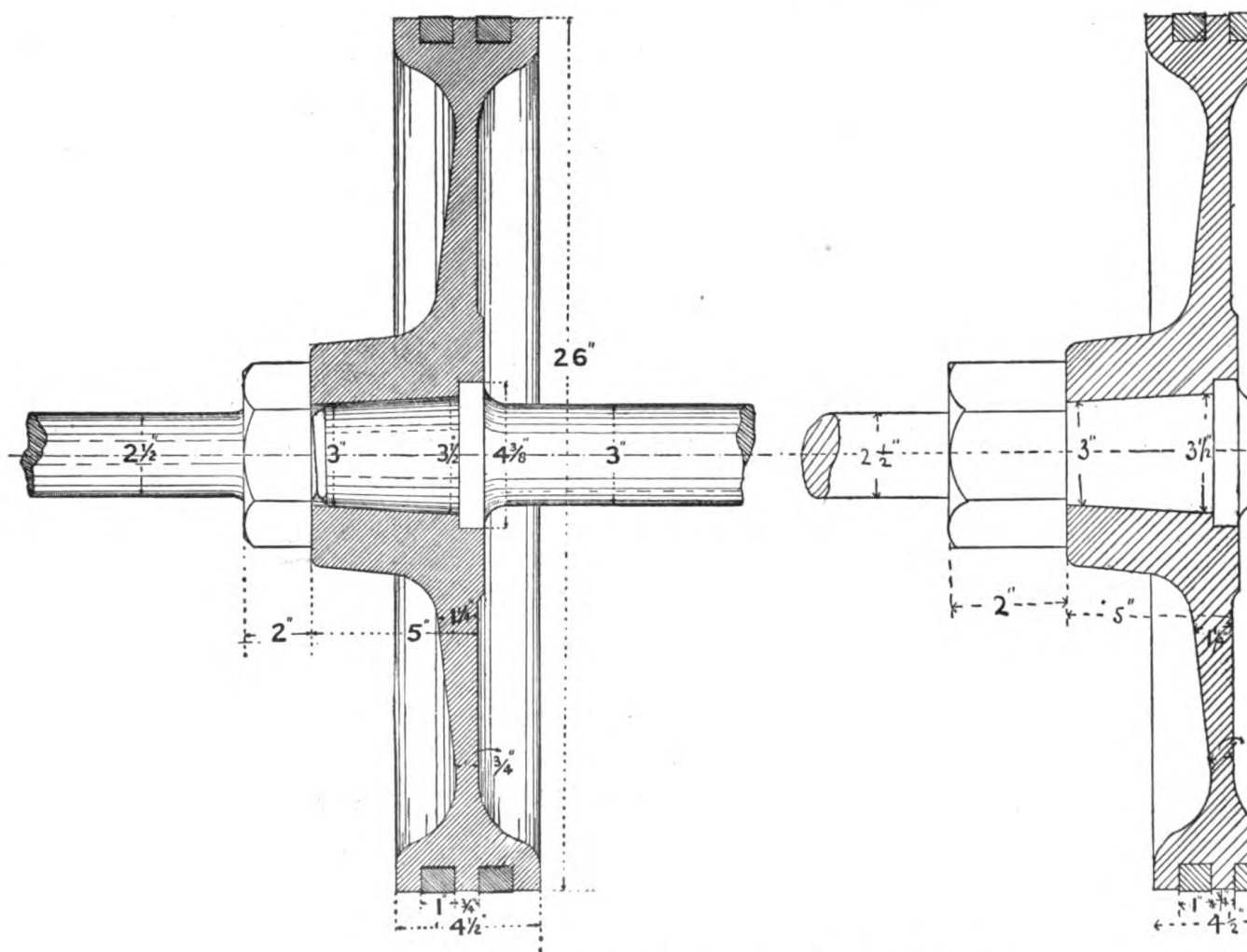


FIG. 255.—Contrast between a good and bad Drawing.

Use of squared paper.

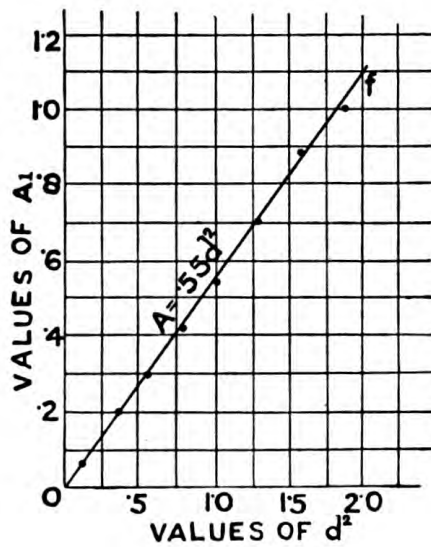


FIG. 256.

It will be noticed that when the area of cross-section A_1 has been found by calculation, that its diameter d_1 and the dimensions of the bolt-head and nut can be obtained from those in Table V.

A simple relation between the diameter d and the bottom of the thread, for bolts in common use (f), can be obtained as follows:

Plot on squared paper numerical values of d^2 and A_1 and a straight line passes evenly through the plotted points (Fig. 256) and the origin O . The equation of the line may be written

$$A_1 = cd^2 \dots (1).$$

The value of the constant c is simply the slope of the line and can be obtained by substituting in (1) the values of A_1 and d^2 at any point on the line.

Thus, at f , the values of A_1 and d^2 are 1.1 and 2 respectively. Substituting these values in (1) we obtain

$$1.1 = c \times 2;$$

$$\therefore c = \frac{1.1}{2} = 0.55.$$

Hence,

$$A_1 = 0.55d^2.$$

The sectional area of the bolt is $0.7854d^2$, and as $0.55 = \frac{7}{10} \times 0.7854$ the relation is

$$A_1 = \frac{7}{10}A,$$

or the sectional area at the bottom of the thread = $\frac{7}{10}$ area of bolt.

$$d_1 = \sqrt{\frac{7}{10}}d;$$

$$\therefore d = 1\frac{1}{5}d_1,$$

or the diameter of the bolt = $1\frac{1}{5}$ diam. at the bottom of the thread.

Thus, when d_1 the diameter at the bottom of the thread is known, it is only necessary to obtain the diameter of the bolt.

The relation between d_1 and d could also be found by plotting values of d_1 and d from

The relations given on p. 51, connecting the diameter d with the width across the flats across the corners for nuts and bolt-heads, may be obtained by plotting the values given

The relation between d , the diameter of a rivet, and t , the thickness of the plate, may be found by plotting numerical values of d and $\sqrt{t}$. The numerical value of c in the relation $d = c\sqrt{t}$ is then found as on p. 31 to be 1.2, and the relation is $d = 1.2\sqrt{t}$.

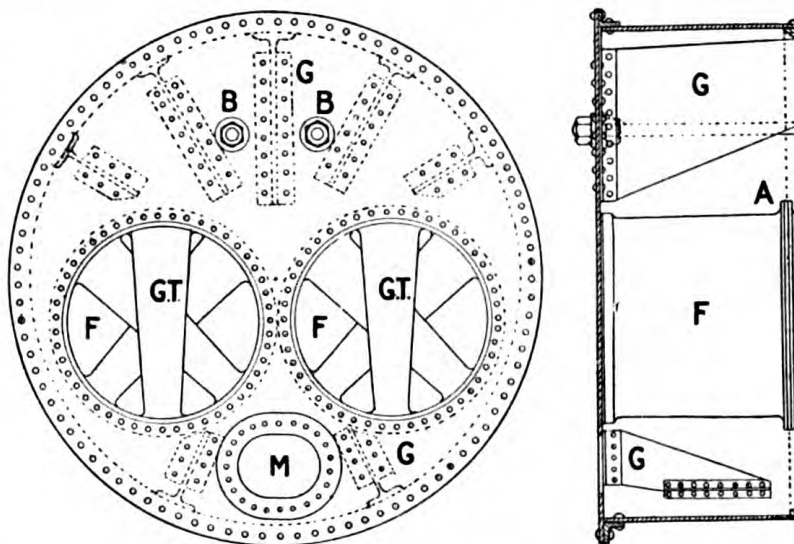
The various linear relations connecting the size of the key and the diameter of the shaft, the proportions adopted for couplings, pipes, etc., may be obtained also by using squared paper.

Lancashire boiler. If the diameter is 7 ft. 6 in., pressure of steam 90 lb. per sq. in., safe stress 5 tons per sq. in., the thickness of the shell plates may be obtained by the formula on p. 38, and the size and pitch of the rivets as

The pressure on the end plates is very great. Thus, if each flue (F) is 3 ft. diameter

$$\text{Pressure on end plate} = \frac{\pi}{4}(7.5^2 - 2 \times 3^2) \times 90 \times 144 \div 2240 = 173.8 \text{ tons.}$$

The method of staying by gusset stays (G) and bar stays (B) is shown in Figs. 257, 258.



FIGS. 257, 258.—Lancashire Boiler.

A. Adamson ring; G.T. Galloway tubes; M. Manhole.

Water tubes. The effective heating surface is increased, a better circulation of the water and the strength of the furnace tubes is increased, by **tapered** or parallel water tubes. The tubes, may be flanged at each end as is shown in Fig. 259, the upper end being made large enough to allow of easy access for cleaning. The advantage that there is less fear of leakage at the riveted joints.

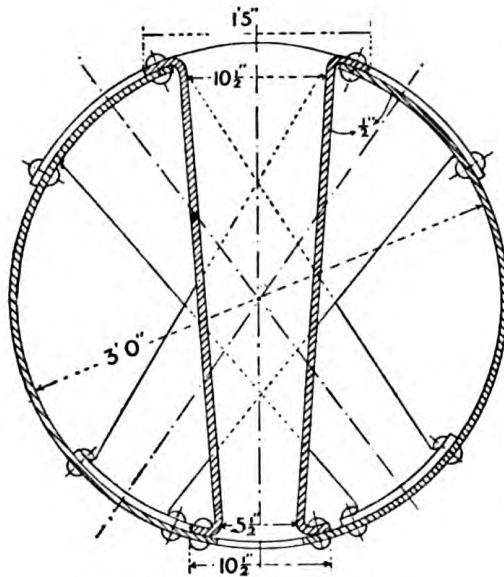


FIG. 259.—Galloway's Tubes.

The dimensions adopted are as follows :—

Up to 2 ft. long,	diameters
Over 2 ft. up to 2 ft. 3 in.	„
Above 2 ft. 3 in.	„

Furnace tubes. These are invariably of either plain or corrugated tubes of comparative thickness, by one of the joints, or strengthening rings should be used. The object of these rings is to strengthen the tubes against contraction and prevent collapse under external pressure.

The formula $PD = 2 \text{ ft.}$ (p. 38) for a thin tube can be used only for a tube subjected to external pressure. The formula remains *always* of a circular form in cross-section. The formulae are used as follows :—

(a) Fairbairn's Rule.

$$P = \frac{806300t^{2.19}}{L \times D},$$

P = collapsing pressure lb. per sq. in. ; L = length in feet ; t = thickness in inches ; D = diameter in inches.

This rule is based on the assumption that the strength of a tube varies inversely with the length, which is not strictly correct. The collapsing pressure given by it is found to be too small for long. Hence, other rules are used, such as :—

$$(b) p = \frac{46550t^{2.19}}{D \times \sqrt{L}}.$$

$$(c) p = \frac{90000t^2}{(L+1)D} \text{ (Board of Trade).}$$

In any case, the safe or working pressure p found from (b) and (c) must not exceed that given by (a).

Ex. 1. Find the collapsing and safe pressure for a furnace tube 3 ft. diameter, thickness $\frac{3}{8}$ in. (between the rings). Let P denote the collapsing and p the safe pressure.

$$P = \frac{806300 \times (0.375)^{2.19}}{3.5 \times 36} = 746.7 \text{ lb.}$$

From (b)
$$p = \frac{46550(0.375)^{2.19}}{36 \times \sqrt{3.5}} = 80.69 \text{ lb. per sq. in.}$$

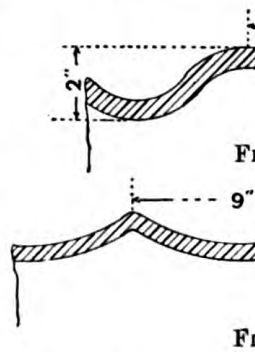
„ (c)
$$p = \frac{90000(0.375)^2}{4.5 \times 36} = 78.1 \text{ lb. per sq. in.}$$

„ (d)
$$p = \frac{9000(0.375)}{36} = 93.74 \text{ lb. per sq. in.}$$

Corrugated Furnace Tubes. The furnace tubes of many boilers are made in one piece, and the corrugations, which are placed in a circumferential direction round the tubes, make the tubes much stronger to resist collapse; they also give considerable elasticity in a longitudinal direction and greater heating surface.

In **Fox's** corrugated furnace, with tubes above 2 ft. diameter, the corrugations have a depth of 2 in. and a pitch of 6 in. (Fig. 260). The Board of Trade rule is $p = 14000t/D$. Where p and t have the same meaning as before, D = outside diameter at bottom of corrugation in inches.

Morison's Suspension Furnaces. In this form (Fig. 261) the corrugations consist of a series of ribs, or comparatively sharp ridges, pitch 9 in., depth 2 in., connected by *catenary* curves. The Board of Trade Rule is $p = 13500t/D$. p and t have the same meaning as before. D is the least outside diameter



Ex. 2. If the thickness of a corrugated tube is $\frac{3}{8}$ in., diameter 3 ft., find the safe working pressure for (a) Fox's Corrugated Furnace Tube (b) Morison's Suspension Tube.

(a)
$$p = \frac{14000 \times 0.375}{36} = 145.8 \text{ lb. per sq. in.}$$

C.M.C.

(b)
$$p = \frac{13500 \times 0.375}{36} = 140.6 \text{ lb. per sq. in.}$$

Q

Connection of Parallel Plates. The lower parts of the fire boxes of locomotives, are connected in various ways to the external shell of the boiler. Four such meth

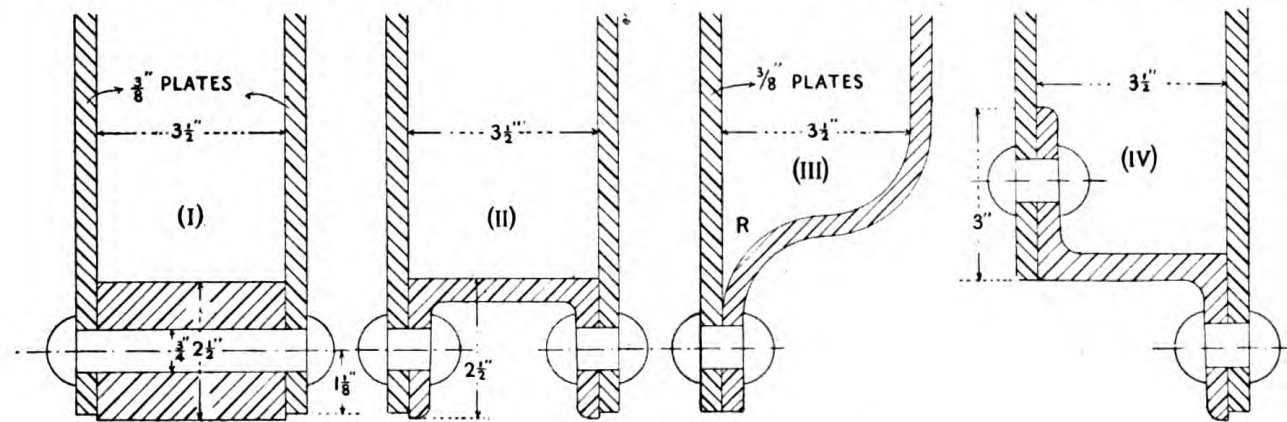


FIG. 262.—Connection of Parallel Plates.

and cause corrosion of the plates. The form shown in (IV) is rarely used if the pressure

Intersection of two cylinders. The intersection (or interpenetration) of two cylinders, boiler, a main and a branch pipe, etc., is of frequent occurrence. In Fig. 263 (I) the intersection of two cylinders is shown. Section planes (which may be either horizontal or vertical), cutting through the cylinders, are drawn in the required curve. These planes are most easily obtained by using two semicircles, divided into a number of equal parts and numbering as indicated. The intersection of lines drawn through these points determine points in the required curve. Thus, projectors from the points 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

Draw a straight line **EG** equal to the circumference of the smaller pipe (p. 83) and divide it into 16 equal parts, as at Fig. 263 (III); number these as shown, and draw lines perpendicular

G3 equal to **C3'**. Points in the required curve are found by making the distances **2**, to the perpendicular distances of **2'**, **1'** and **0'** from the line **AB**. Drawing a fair curve through the points so obtained is the development required, and is the shape to which the sheet metal must be cut.

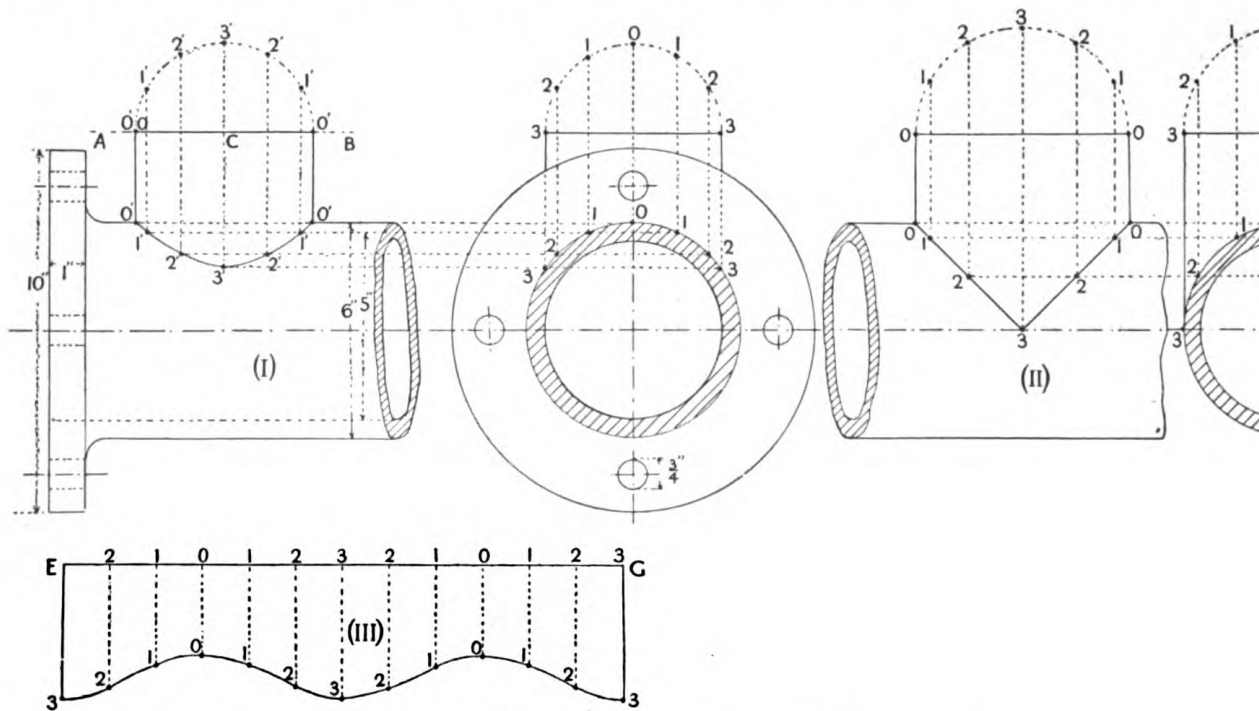


FIG. 263.—Intersection of Main and Branch Pipes.

If the larger cylinder be made by bending a sheet of stiff paper to the cylindrical form, development on a similar sheet of paper and bending to a cylindrical form, so that the lines **E3** be found that the shape thus obtained will fit the larger cylinder.

Marine Connecting Rod End. In Fig. 264 the elevation, end view, and plan of a portion of is given, consisting of a round rod and a rectangular block. The diameter of the rod increases

block and the junction of the rod and block produces a curve as shown at **C**. To determine the curve, a series of vertical sections indicated by the numbers 1, 2, 3 may be taken, from which points **p**, **q**, **r** may be obtained. Thus, the end view of a vertical section **ef** will consist of two circular arcs **sp**, **qx** and the points **p**, **q** are obviously points on the surface of the block, and a projection line from **p** to **s** is a point in the required curve. To obtain the vertex of the curve, a section **mn** is taken

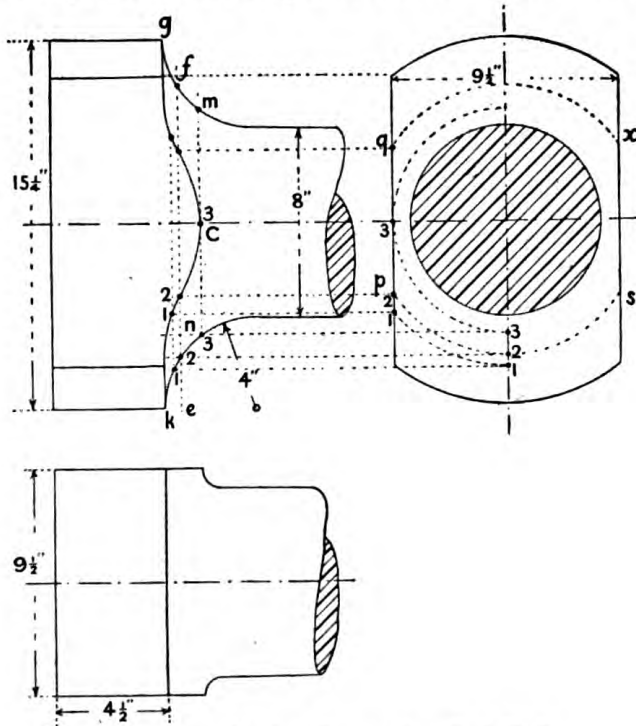


FIG. 264.—Marine Connecting Rod End.

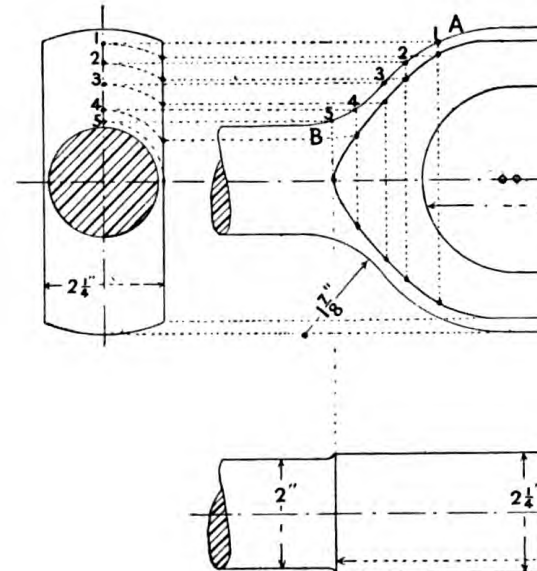


FIG. 265.—Forked End of a Crank.

width of the block. The limiting points in the curve are obtained by means of a section taken through the rod (the diameter of the rod). Other points can be found by taking sections indicated in Fig. 264. The curve can be drawn through the points so obtained. The vertex of the curve will be found to be at a distance from the block equal to the least diameter of the rod.

WROUGHT-IRON CRANK

Forked End of a Connecting Rod. Another example of a machine part which is turned and (as a section of a surface of revolution) is shown in Fig. 265 as in the preceding case, a series of vertical lines **AB** are taken; then points in the required curve are obtained by projection. Finally, a smooth curve is drawn through these points.

Ex. 6. Draw the three views of a connecting rod end to the given dimensions (Fig. 264) and the crank pin at **C** when the width of the block is equal to the rod or 8 in. Scale 6" = 1 ft.

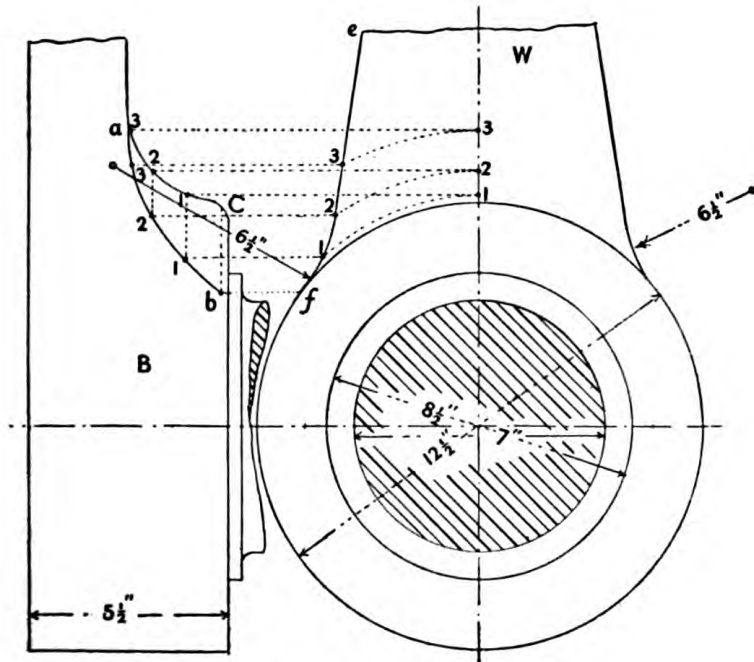


FIG. 266.—Wrought-iron Crank.

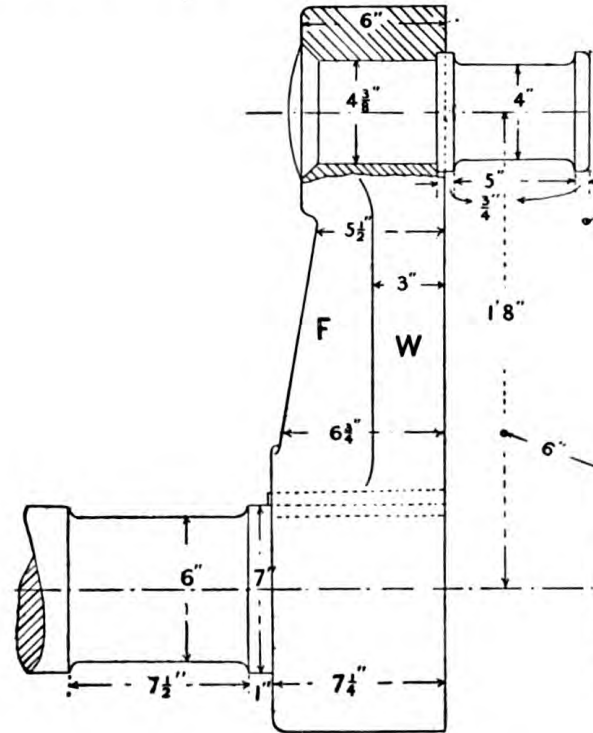


FIG. 267.—Cast-iron Crank.

Wrought-iron Crank. In the elevations of a crank, as in Figs. 216, 217, p. 187, a curve is formed by the intersection of the surface of the rectangular web and the cylindrical boss. The form and extent of this curve may be obtained by the following method.

number of sections (as in the preceding cases), and determining points in the curve. The end view of the larger end of a wrought iron or mild steel crank is shown. The curve and ends at *b*. The latter is obtained by a projective from *f* where the curve *ef* touches

The remaining points in the curve are found by means of sections, the construction in Fig. 266.

Cast-iron Crank. The form of this crank is similar to that of the wrought iron crank web is stiffened by means of one or two feathers *F*. When one feather is used it is placed in Fig. 267; when two are used they are placed on the edges of the web instead of at the centre.

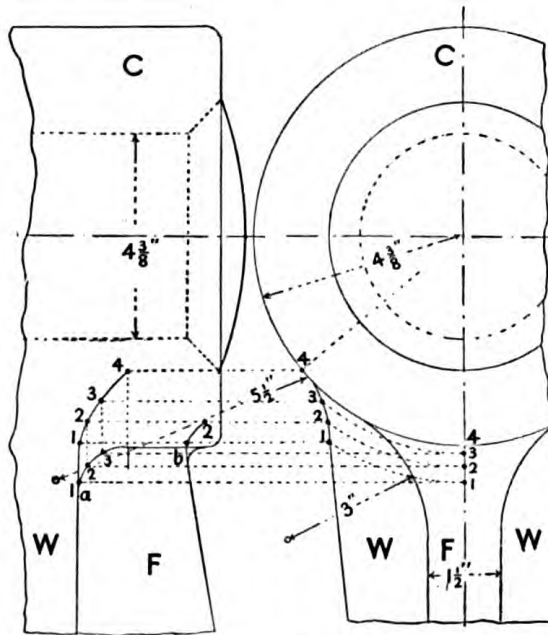


FIG. 268.

The crank is fixed to the crank shaft, crank, either by forcing or shrinking (see pp. at the junction of the web and the boss obtained as in the preceding example, and in crank pin end the junction of the web, *W*, the curve *a*, 4. Fig. 268. The junction of gives the curve *b*, 2. The construction is Fig. 268.

Wheel Teeth. The condition for smooth are in gear is that the ratio of their speed same as two non-slipping rollers, or cylinders, the pitch circles of the wheels; hence, from $v = \omega_1 R$ (p. 95), the velocity ratio V/v must be

In Fig. 269 the points *C* and *D* are the wheel; *r* and *R* the radii of the pitch circles point *P*. Two teeth are in contact at *m*, *n* on the wheel is in contact with *n* a point on the

From geometry it is known that when (269) are in contact they have a common perpendicular

The points, *m* on the tooth of one wheel, in contact with the point *n* on the other velocities, the point *m* moving in the direction of the tangent to the circle, centre *D*

the direction of the tangent to the circle centre **C**, velocity **V**; but the components of these velocities along **TT** must be the same or the two points **m** and **n** would have relative motion along the line **TT**. Let **V₁** denote the component velocity of **m** and **n** in the direction of **TT**, draw **DM**, **CN**, from the centres **D** and **C** perpendicular to the line **TT**, then the ratio of the angular velocities is given by

$$\frac{V_1}{DM} \div \frac{V_1}{CN} = \frac{CN}{DM} = \frac{CP}{DP} = \frac{r}{R}$$

The required condition is, therefore, that the common perpendicular to the profiles of the teeth at any point where they are in contact must pass through the pitch point. This condition is satisfied either by **Cycloidal** or by **Involute** curves, and portions of one of these curves are used for the profiles of the teeth of wheels. (Neglecting friction, the pressure between the teeth is in the direction of the common perpendicular at the point of contact.)

Cycloid. One method of describing a cycloid is given on p. 101. Another is as follows:—Draw the rolling circle, the

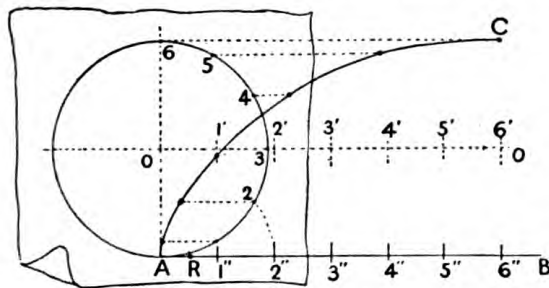


FIG. 270.—Cycloid.

tangent at **A** and make **A6''**, equal to the arc **A.6** (p. 83). Divide the arc and the straight line each into the same number of equal parts. Fig. 270. Draw lines parallel to **AB** through 1, 2 ... 6. As the circle rolls along **AB** the points 1, 2 ... 6 coincide in turn with

the points 1'', 2'' ... 6''. Using each point 1', 2' ... 6' on the path of the centre in turn, radius equal to that of the rolling circle, points on the required curve

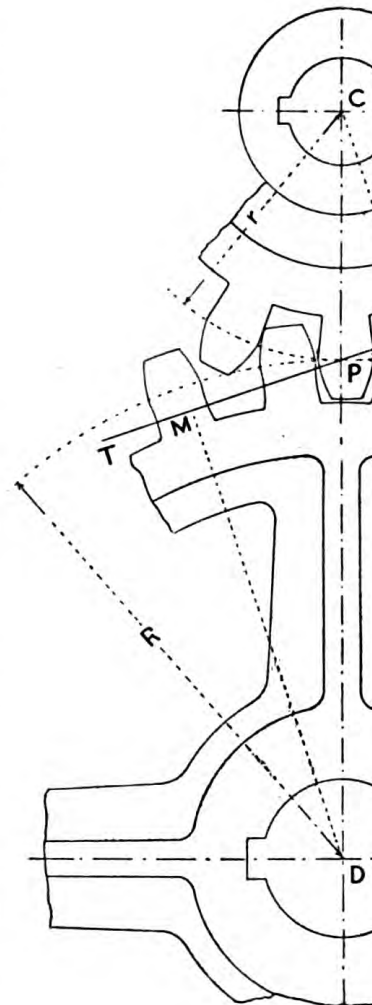


FIG. 268

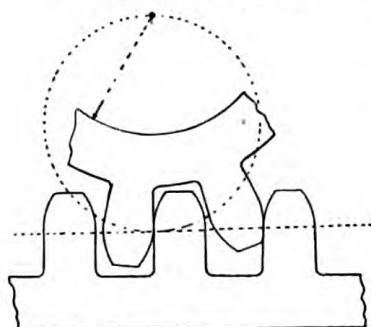
Rack and Pinion.

FIG. 271.—Rack and Pinion.

A cycloidal curve may be used for the teeth of a rack, Fig. 271. To be fixed, a point on the teeth of a wheel in contact with the rack will describe a cycloid, and hence the wheel will leave the rack's tooth of a rack is made of a cycloidal form. The flank of the wheel is made radial.

Epicycloid and Hypocycloid.

The curve traced out by a point on the circumference of a circle rolling on the outside of another (fixed circle) is called an *epicycloid*. The curve traced out by a point on the inside of a circle rolling on the outside of another (fixed circle) is called a *hypocycloid*. Let **C**, Fig. 272, be the centre of the fixed circle. A portion **AB** is shown. **D** and **E** are the centres of the rolling circles. The constructions necessary to obtain the same as these used in drawing a cycloid. Fig. 270.

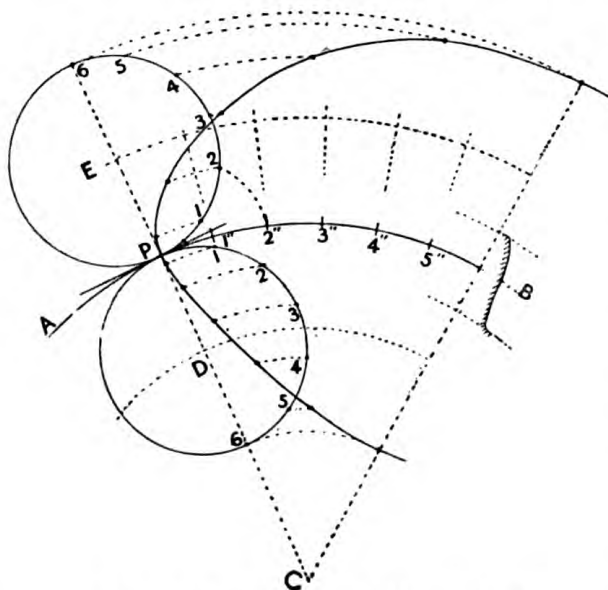


FIG. 272.—Epicycloid and Hypocycloid.

Involute of a Circle.

If a straight line is drawn tangent to a circle at any point, any point on the line is called an *involute* of the circle. The involute of the circle **OABD**, Fig. 273, may be drawn by dividing the circumference **OAB** (p. 83). Divide each into equal parts and draw tangents to the circle at these points. The points 0, 1" ... 6" is the involute required.

Involute Teeth. Involute teeth for wheels are usually better adapted for general purposes than those of cycloidal form. The *path of contact* (locus of the points of contact of a pair of teeth) is a straight line inclined at 75° to the line of centres, or 15° to the tangent at the pitch point. With involute teeth the

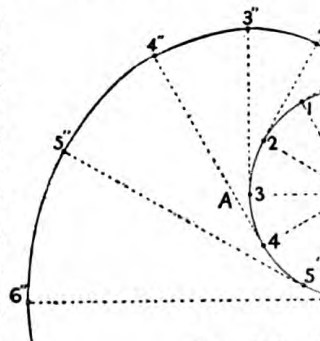


FIG. 273.—

line of centres, or 15° to the tangent at the pitch point. With involute teeth the

between the teeth is constant, instead of being variable as in cycloidal teeth. All involute pitch will gear together; also the distance between the axes of the wheels may be slightly change in the smooth working of the wheels.

The curves for the teeth may be obtained by drawing an involute as in Fig. 273 or by line on a piece of tracing paper, placing the line in contact with the curve, and by means of rotating the line about the base circle. Mark the ends of the line, and finally obtain a circular arc to pass through the points; in this manner the required curve can be obtained. An approximate method given by Prof. Unwin may be stated thus:—

Draw (Fig. 274), the pitch circle **AB**, the tangent **TT** at **P**, and the line **CP** at 15° to **TT**; the base circles are drawn touching the line **CP**. Make **Pn** equal to the height of a tooth, and $mg = \frac{2}{3}mn$; draw the line **fg** touching the base circle at **f**; then **c** the required centre is found by making $fc = \frac{1}{4}fg$, and a circular arc radius **cP** determines the required curve **PO**.

The flanks of the teeth within the base circle are made radial. Contact of the teeth does not take place within the base circle.

Helical and Screw Gearing. When two wheels are in gear the motion becomes smoother as the pitch of the teeth is reduced, but this reduces the strength by diminishing the thickness of the teeth. The difficulty is obviated as follows:—if the teeth of a spur wheel instead of being parallel to the axis of the wheel are twisted through a definite angle, then what is called a single helical wheel is obtained. Fig. 275 (I). Two such wheels will gear together when the angles of the teeth are the same and they are suitable obliquity produces side pressure. This difficulty is overcome by using double helical wheels angle is usually about 30° . Helical wheels with machine-cut teeth transmit motion uniformly for high and low speeds; they are largely used for milling machines, cranes, etc., also in reducing turbine to propeller shaft. Thus, in a Parsons double reduction geared turbine, 3510 rev.

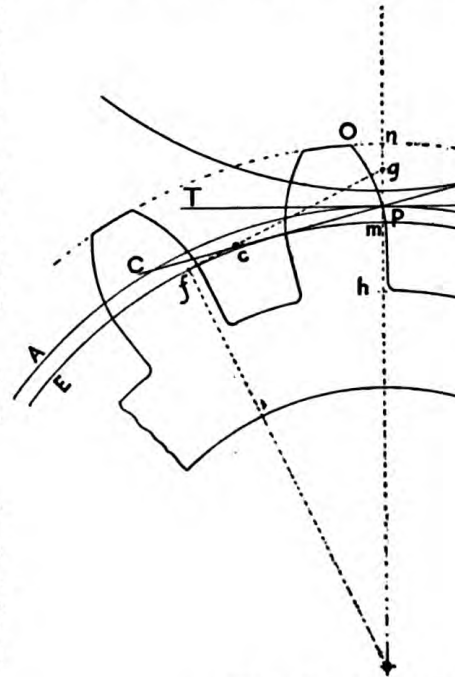


FIG. 274.—Involute

propeller shaft at 78 rev. per min., the reduction gearing of 1:45 in two steps is effected by pinions of double helical type; the wheels are of cast iron with steel tyres shrunk on, axial pitch $\frac{7}{12}$ in. and 1 in. respectively, angle of teeth 30° .

Worm Gearing. A worm wheel **W** consists of a wheel with the teeth set obliquely on the thread of a screw **SS**. Fig. 276. The wheel will advance one, two or three teeth of the worm **SS** according as the screw thread consists of a single, double or triple thread.

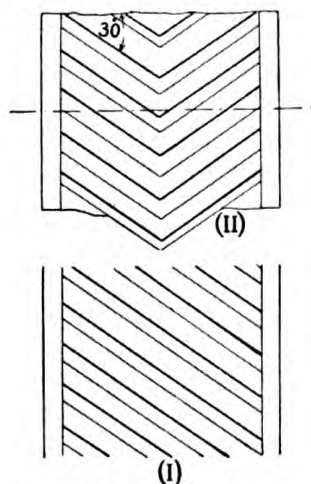


FIG. 275.—Helical Wheels.

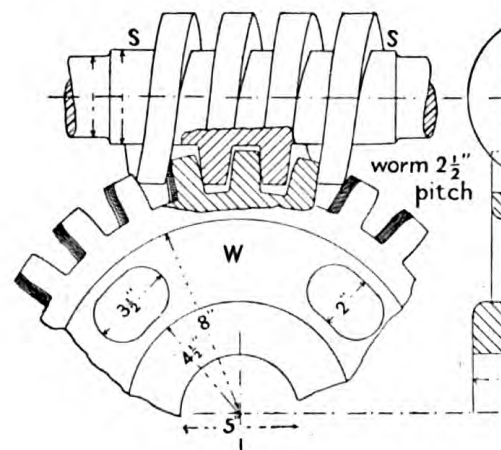


FIG. 276.—Worm and Worm Wheel.

Worm gearing may be used for reducing speed, as in some electric motors, for tighter coupling, etc. Fig. 186, etc.

The worm and wheel are usually made so that the worm drives the wheel; in light cases the wheel may be used to drive the worm by increasing sufficiently the obliquity of the teeth. The sections of the worm and wheel are the same as those of a rack and pinion in gear.

Built-up Wheels and Pulleys. The rim and arms of a pulley may be made of wrought iron or steel, and the nave of cast iron as in Fig. 112 (p. 84). Pulleys of this kind are lighter than those of solid cast iron and are more worthy at high speed. For convenience in handling and manufacture, spur and fly-wheel

BUILT-UP WHEELS AND PULLEYS

usually *built-up*. One method of fastening the segments of the rim to each other and to the arms in Fig. 134 ; another method is shown in Fig. 277. The arms and nave of the wheel may be cast in one piece as in Fig. 278. To lessen the strains due to unequal contraction in cooling the nave is frequently

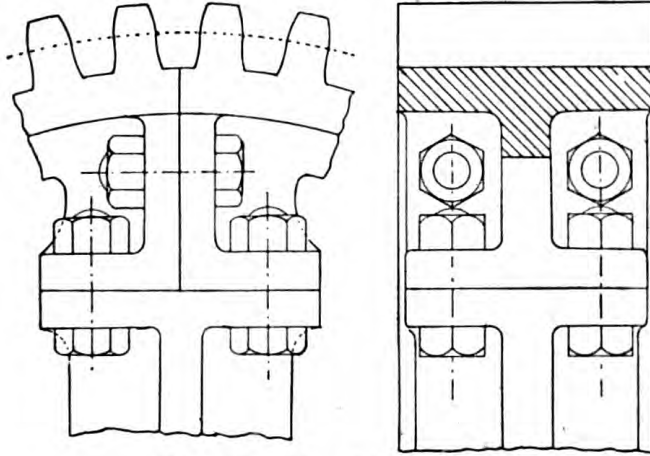


FIG. 277.—Rim of built-up Wheel.

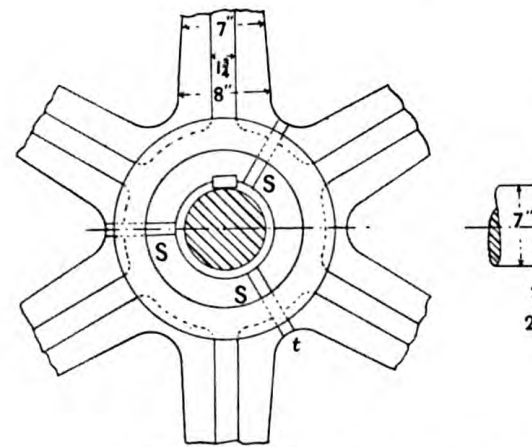


FIG. 278.—Boss and Arms of Spur Wheel.

arms, as at **SS**. These are fitted with metal plates, and finally wrought iron or steel rings, **V**, hold the parts of the nave firmly together.

MACHINE CONSTRUCTION

TYPICAL EXAMINATION QUESTIONS.

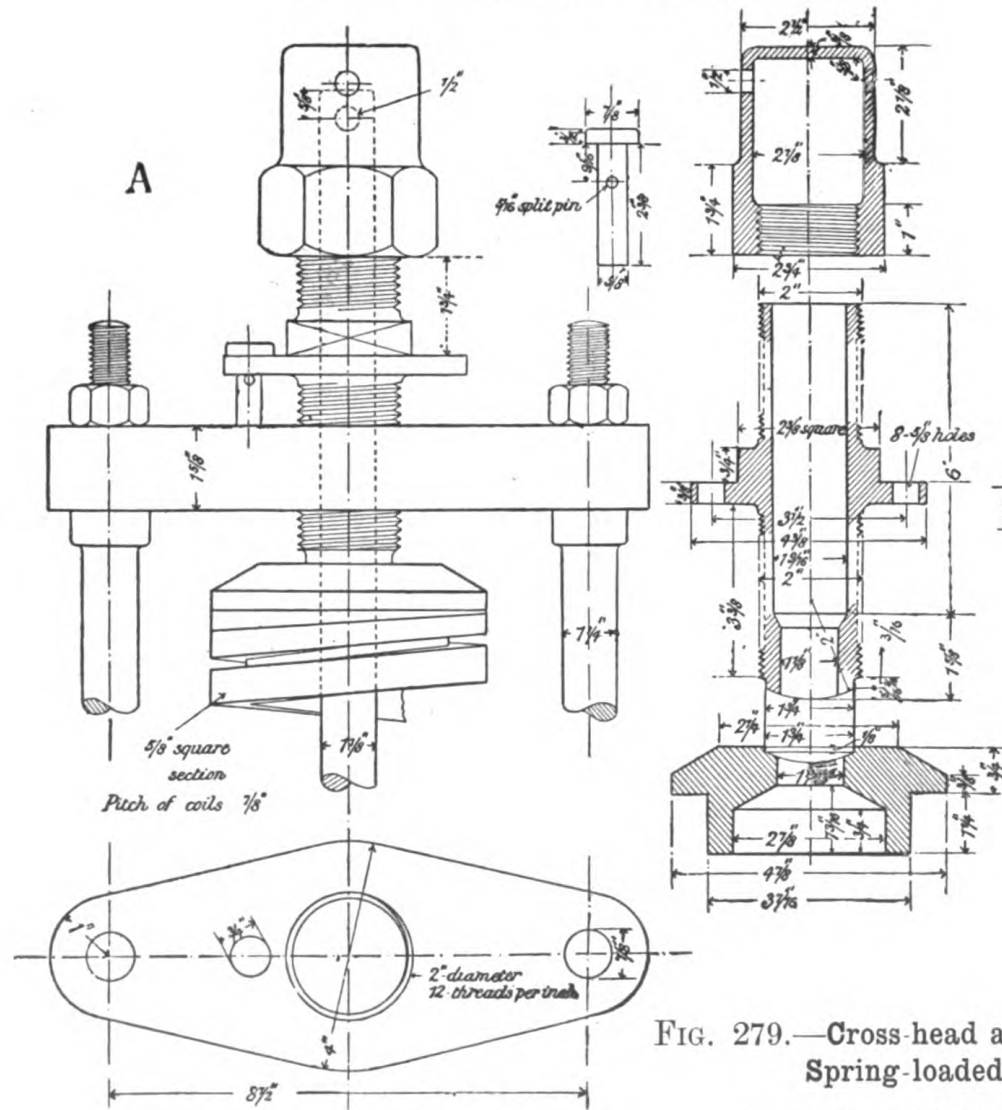
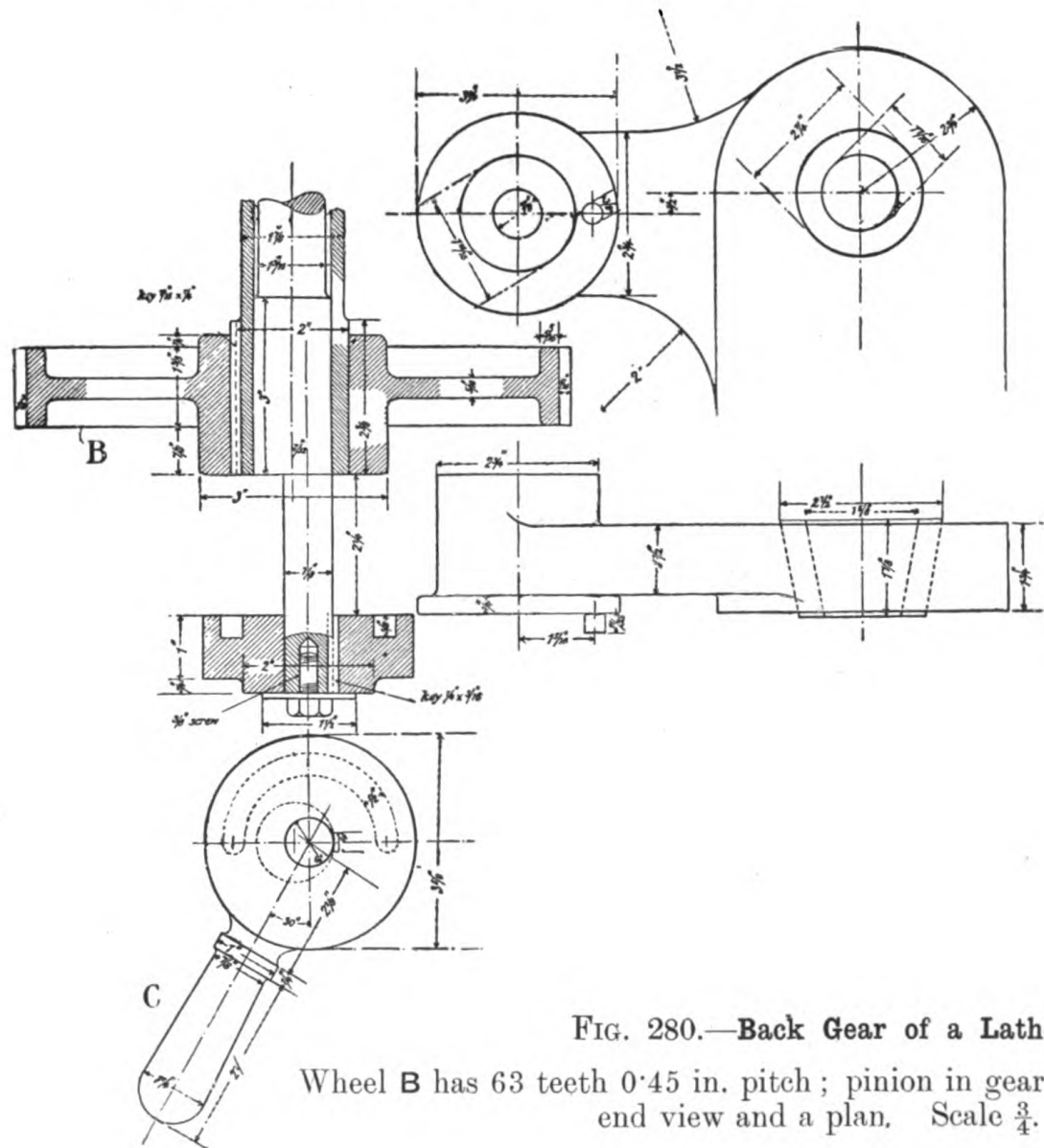


FIG. 279.—Cross-head and
Spring-loaded

Draw to scale $\frac{3}{4}$;

TYPICAL EXAMINATION QUESTIONS



TYPICAL EXAMINATION QUESTIONS

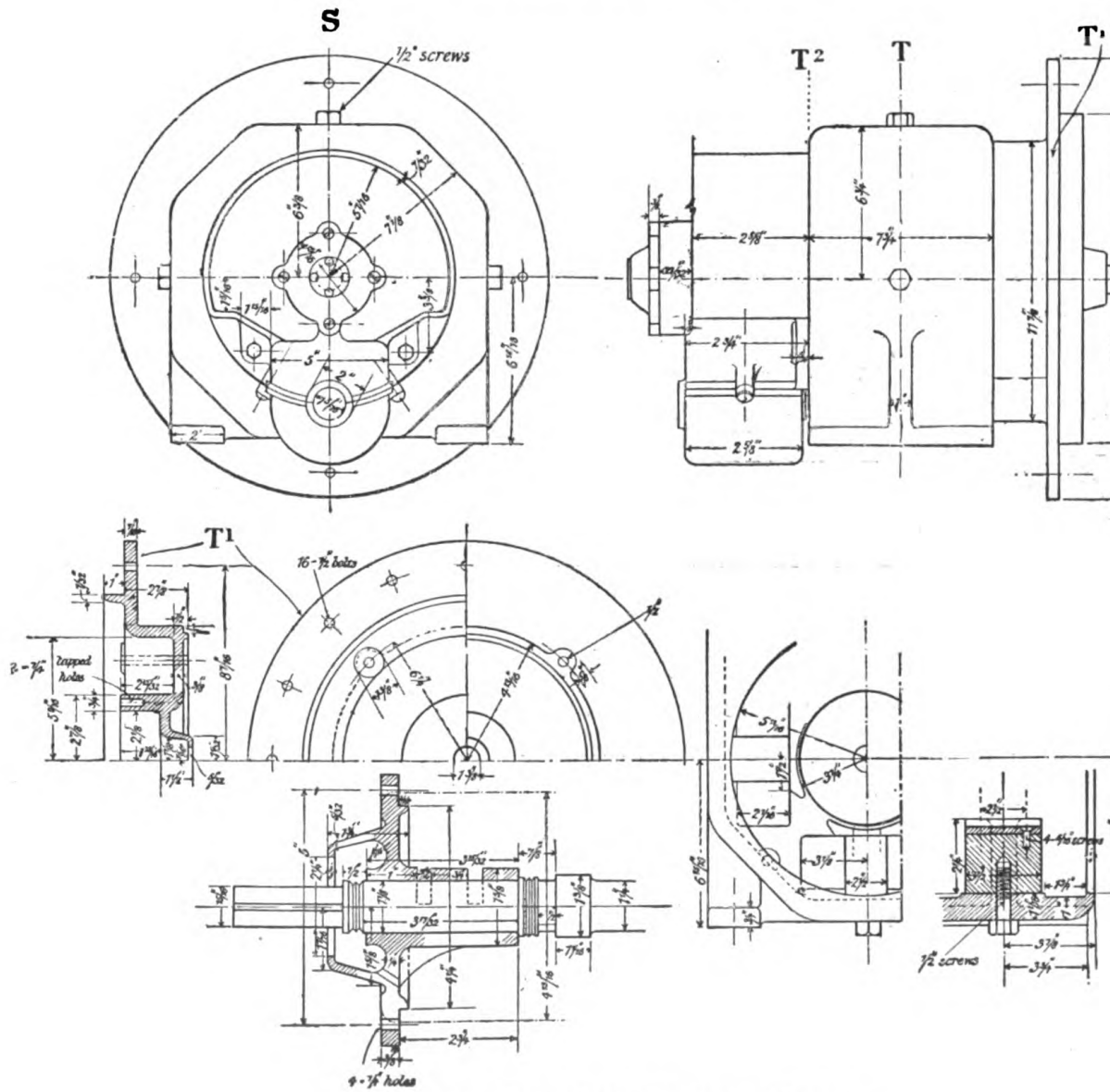


FIG. 282.—Four-Pole Electric Motor.

Draw to scale $\frac{3}{4}$.

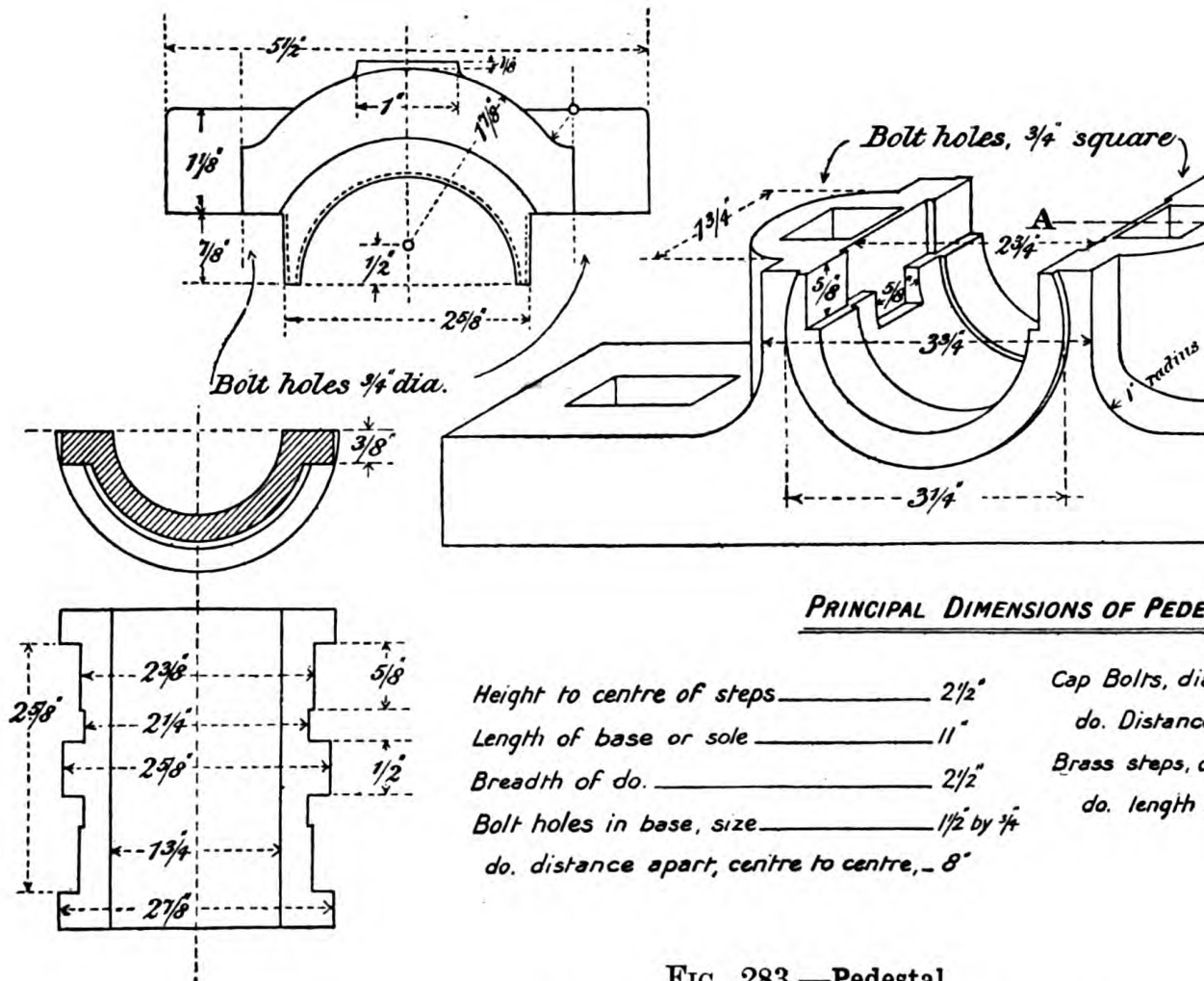


FIG. 283.—Pedestal.

Draw elevation, end view and plan, scale, full size.

TYPICAL EXAMINATION QUESTIONS

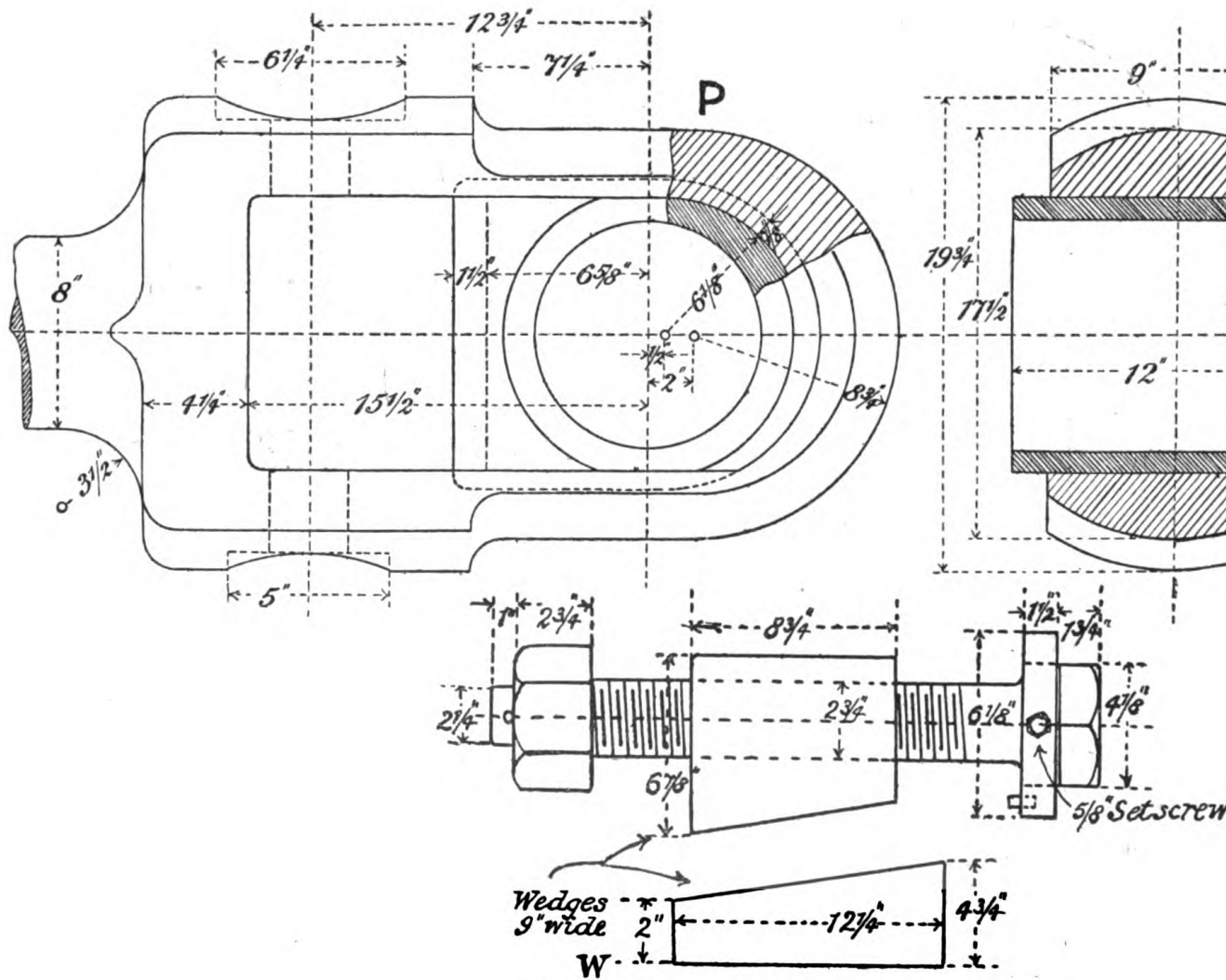


FIG. 284.—End of Connecting-rod.

Draw elevation, end view and plan. Scale $\frac{1}{4}$.

R

C.M.C.

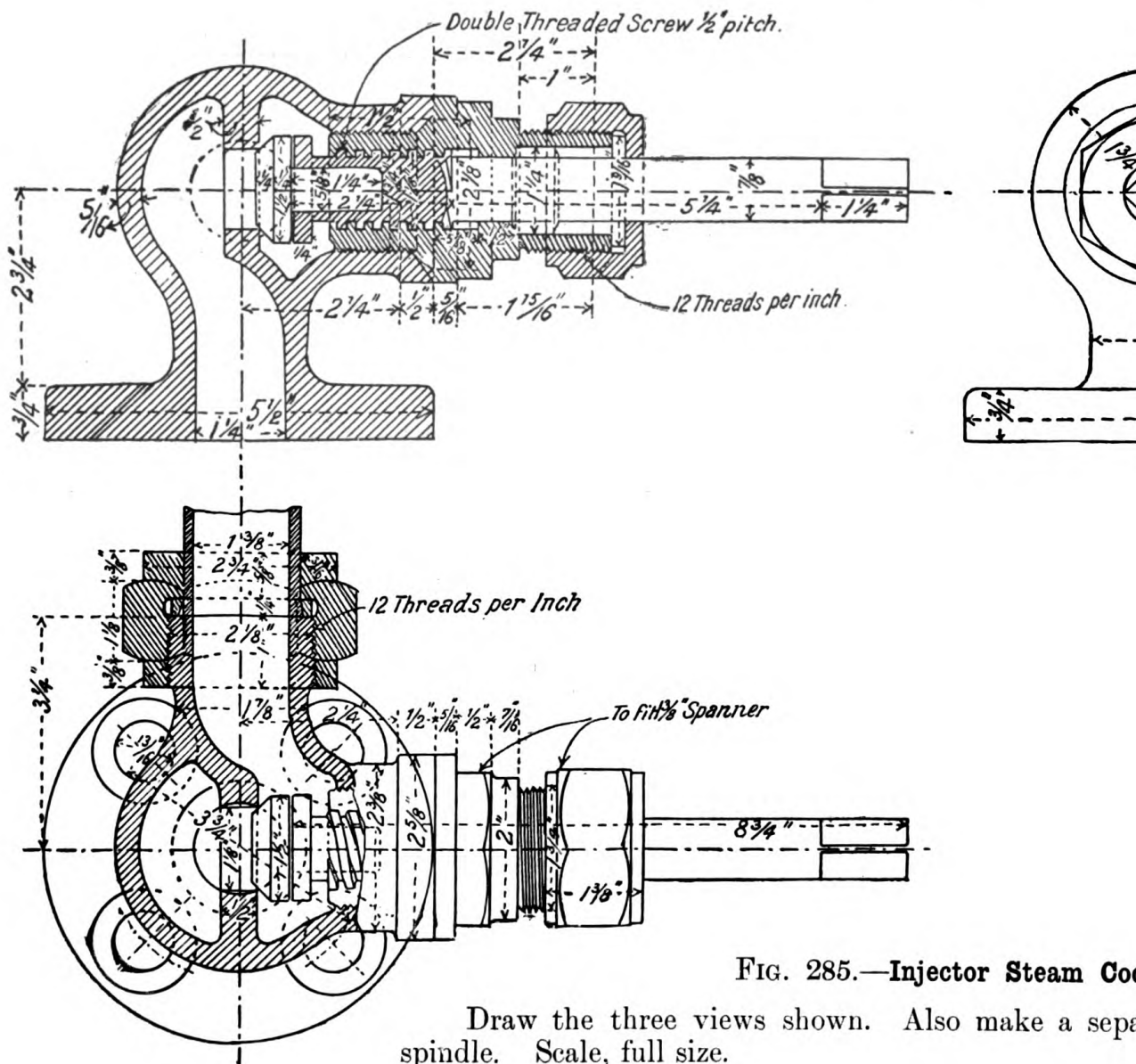


FIG. 285.—Injector Steam Co

Draw the three views shown. Also make a separate spindle. Scale, full size.

TYPICAL EXAMINATION QUESTIONS

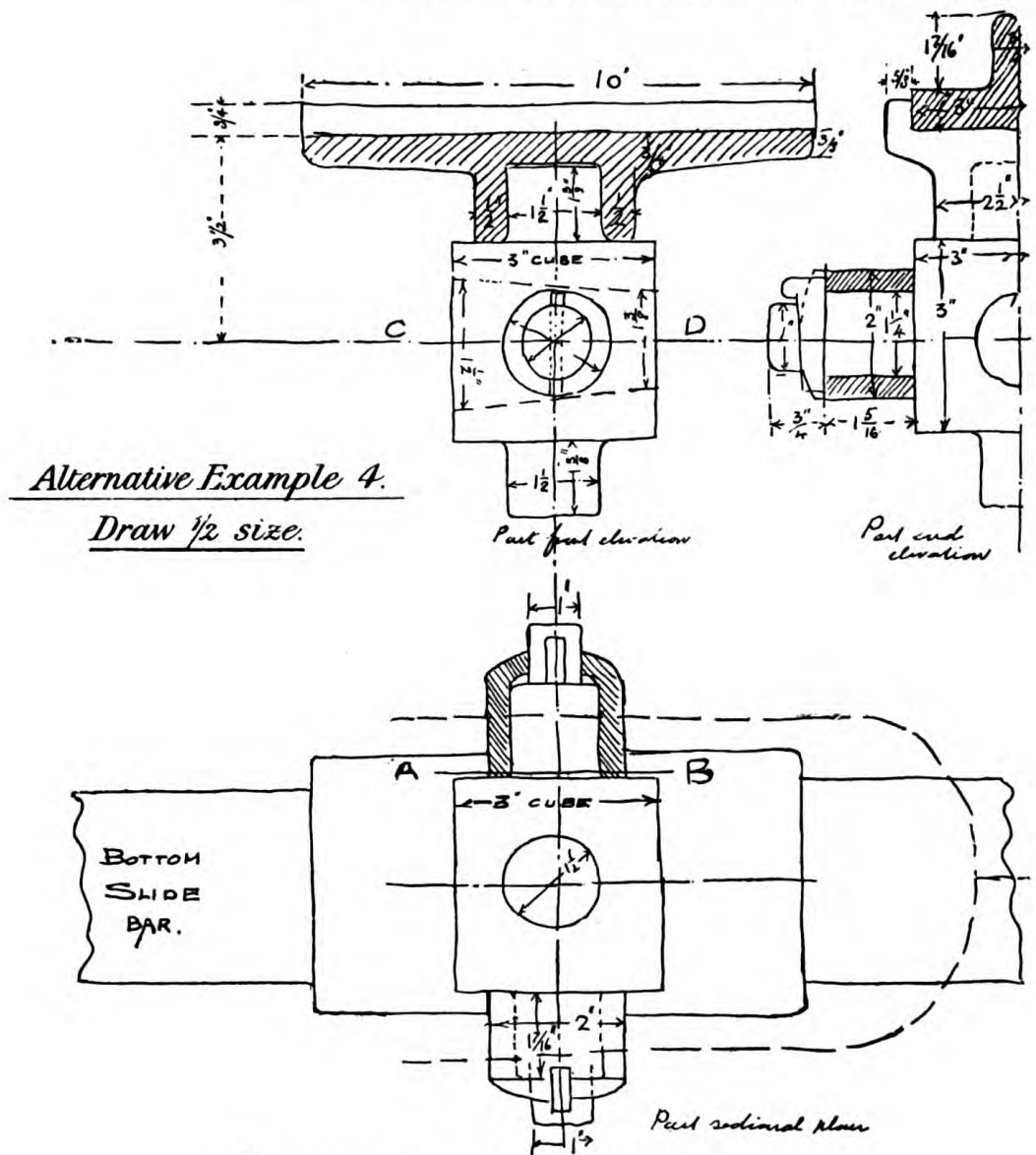


FIG. 286.—Crosshead for a Steam Engine.

Sketches from a draughtsman's note-book. Complete the three views shown. Scale $\frac{1}{2}$.

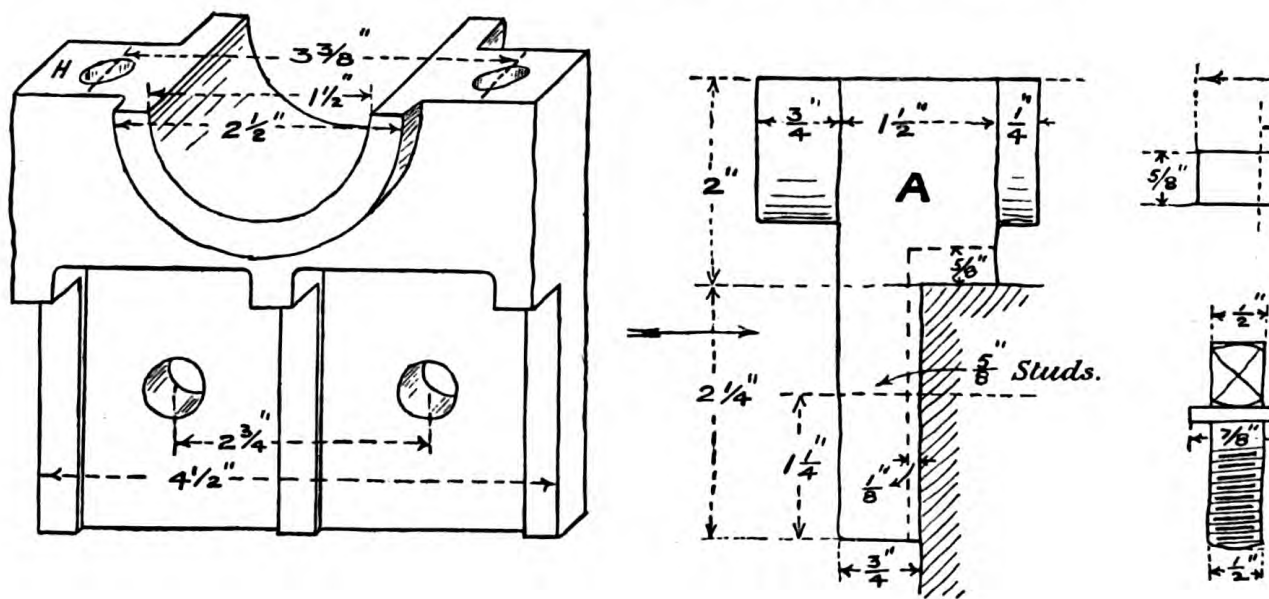


FIG. 287.—1½-inch bearing.

The diagram gives dimensioned hand-sketches of details of a simple bearing dimensions :

- (a) An elevation corresponding with **A**, but in section, adding the cap and cap screws.
- (b) An elevation, projected from (a), looking on the face indicated by the cap, cap screws, and the $\frac{5}{8}$ " studs should be shown.
- (c) A plan.

N.B.—Do not draw the pictorial view, nor the parts separated as in the plan. The parts representing hidden parts, are not required.

TYPICAL EXAMINATION QUESTIONS

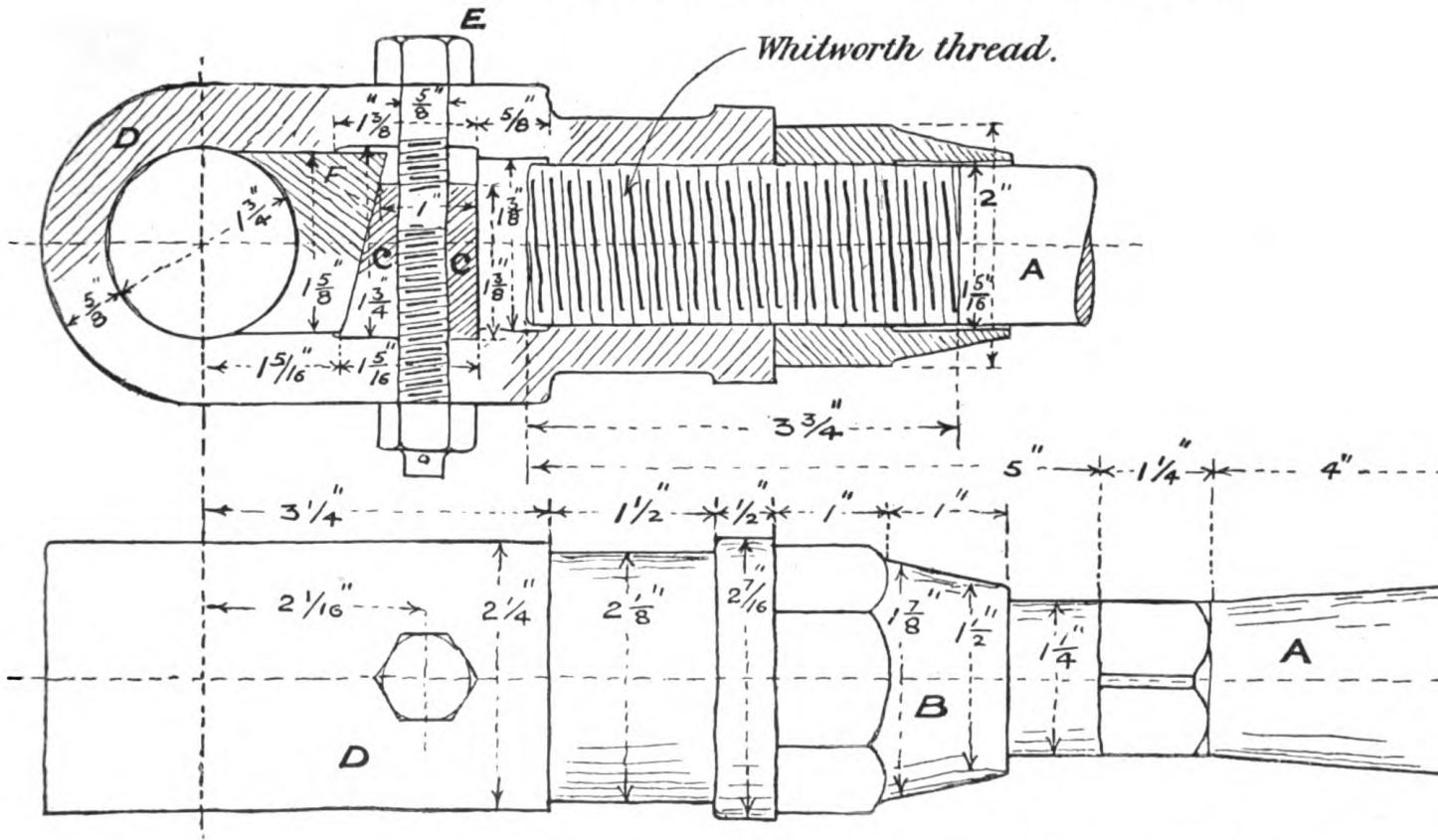


FIG. 288.—End of a Connecting-Link of an Air Compressor.

Make full size separate scale drawings of details, with dimensions, as follows :

- (a) A longitudinal and an end view of the rod end **A**. The screw thread may be drawn in the manner shown.
- (b) Three views of the nut **B**.
- (c) Three views of the washer **C**.
- (d) Three views of the bolt **D**.

N.B.—No credit will be given for drawing the parts assembled, as in the diagram representing hidden parts, are not required.



Questions.

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

1. Sketch full size, inserting dimensions, two views of a wheel boss, fixed to a shaft by a key, as follows :

Diameter of shaft,	-	-	-	-	-	-	2
Diameter of boss,	-	-	-	-	-	-	4
Length of boss, -	-	-	-	-	-	-	3
Width of key, -	-	-	-	-	-	-	
Depth of key, -	-	-	-	-	-	-	
Taper of key, $\frac{1}{8}$ " per foot.							

2. Name the materials of which the parts of the $1\frac{1}{2}$ inch Bearing, Fig. 287, and the parts **E** and **F** of the end of connecting link of an Air Compressor, Fig. 288, would be constructed.
3. Sketch full size, inserting dimensions, a 1" rag bolt *or* Lewis bolt, suitable for securing a machine to a stone foundation. Explain how the bolt is fixed in the stone.
4. Explain briefly, with sketches, how you would set out, drill, and tap the hole for the Bearing on the diagram, Fig. 287.
5. Sketch in section the armature of a small drum wound motor, showing clearly how the coils are secured.

TYPICAL EXAMINATION QUESTIONS

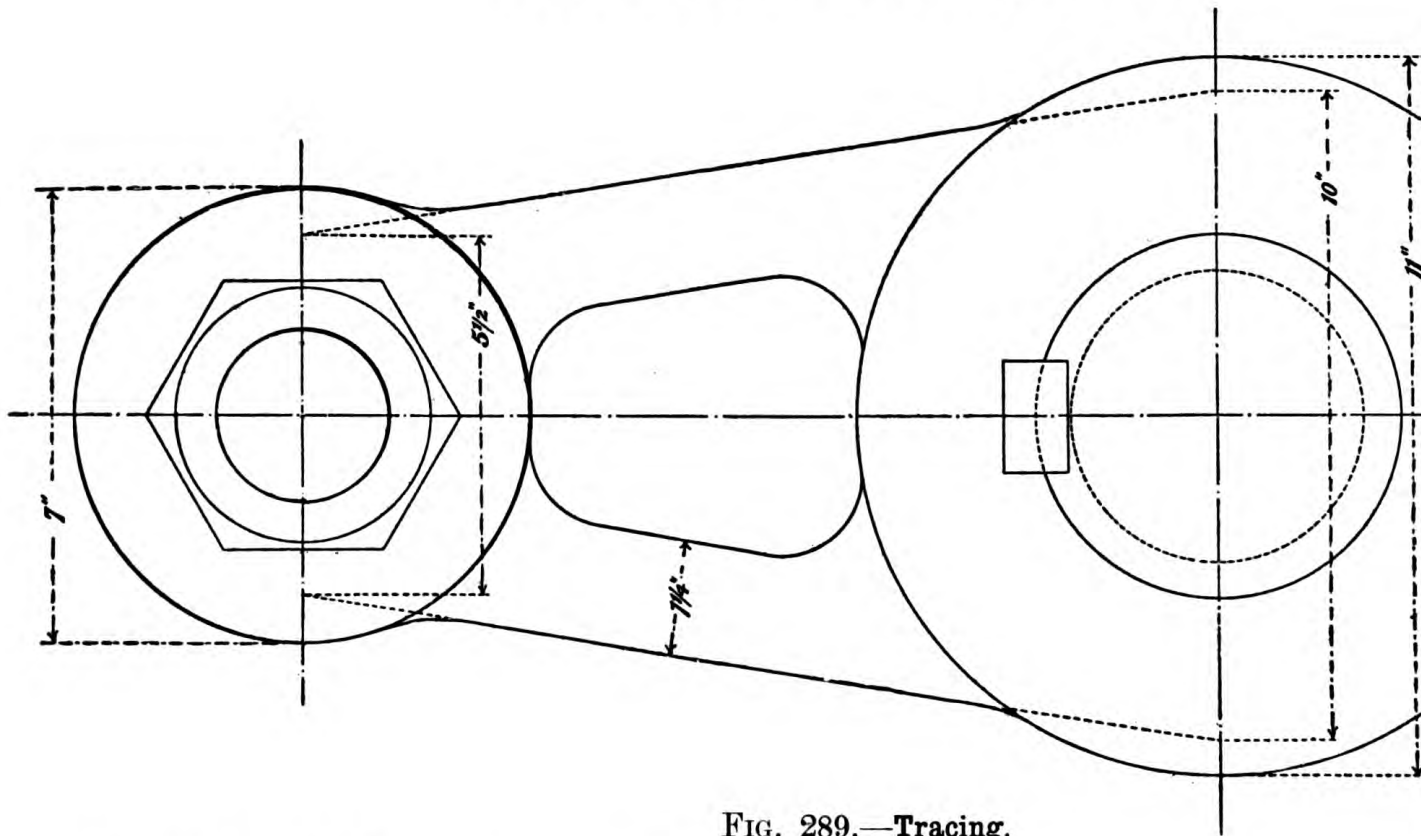


FIG. 289.—Tracing.

Trace in ink the drawing of a crank shown.

The lines should be very black, of uniform and moderate width, and as continuous as possible.

TYPICAL EXAMINATION QUESTIONS

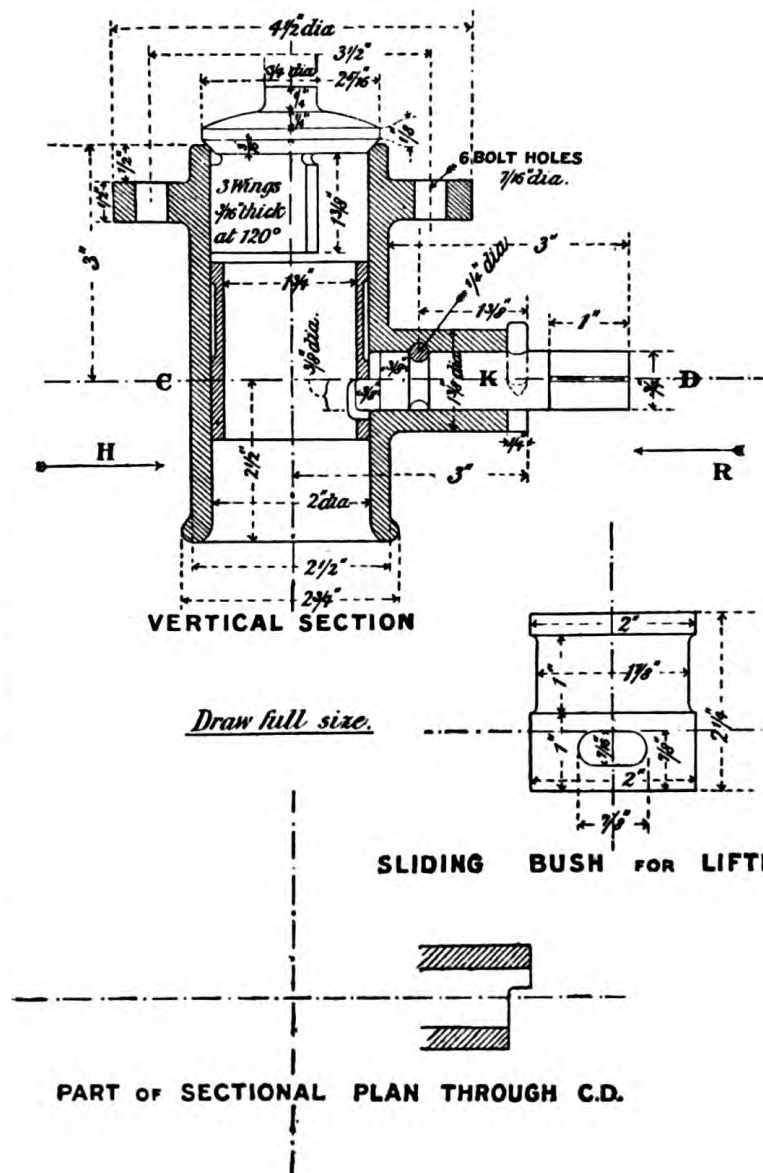
FIG. 291.—Lift Valve.

Draw, full size, an outside view corresponding to the vertical section shown. Draw also a sectional plan through line **CD**, with the spindle **K** removed. Finally draw a sectional elevation taken through the centre line, looking in the direction of the arrow marked **H**.

Also make a plan and the two end elevations of the spindle marked **K**, all the necessary dimensions being shown on it.

Scale, full size.

No dotted lines need be shown and figured dimensions need not be inserted in the three first views.



Questions.

The Sketches in answer to these questions should be drawn freehand on squared paper.

1. State of what materials you would make the parts marked **M**, **N**, **O**, **P**, Fig. 290. Also sketch an arrangement to prevent the rotation of the footstep bearing.
2. A wrought iron crank shaft is formed by bending a 2" round bar as shown



How would you proceed to turn the part marked **A**?

3. A plate girder is made up of a vertical web 2' deep connected to top and bottom flange plates by two angle irons $3'' \times 3'' \times \frac{1}{2}''$. The web and flange plates are $\frac{1}{2}''$ thick. Sketch the girder, putting in the necessary dimensions. Show also a suitable stiffener.
4. Sketch to scale, half size, inserting dimensions, a double-riveted butt joint used in the longitudinal joint of a boiler. Rivets, $\frac{7}{8}''$ diameter, pitch, 3", and thickness of plates, $\frac{1}{2}''$. What would be the efficiency of this joint?
5. Show, by sketches, the method of holding and insulating the bars of a commutator current dynamo. The shaft is 3" diameter, and the outside of the bars 8" diameter.

TYPICAL EXAMINATION QUESTIONS

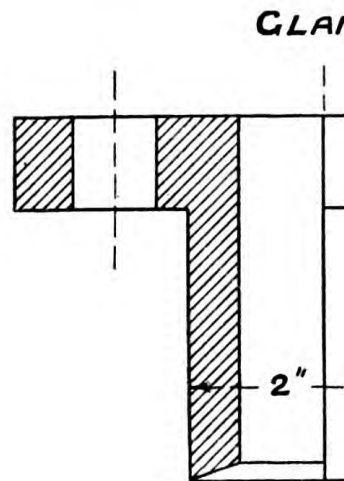
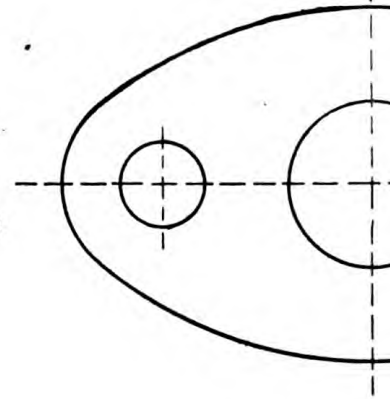


FIG. 292.—Tracing.

Trace in ink the two views of the gland shown on Diagram. Insert the dimensions and print the title as shown.

The lines should be very black, of uniform and moderate width, and as continuous as possible.



Copy to be

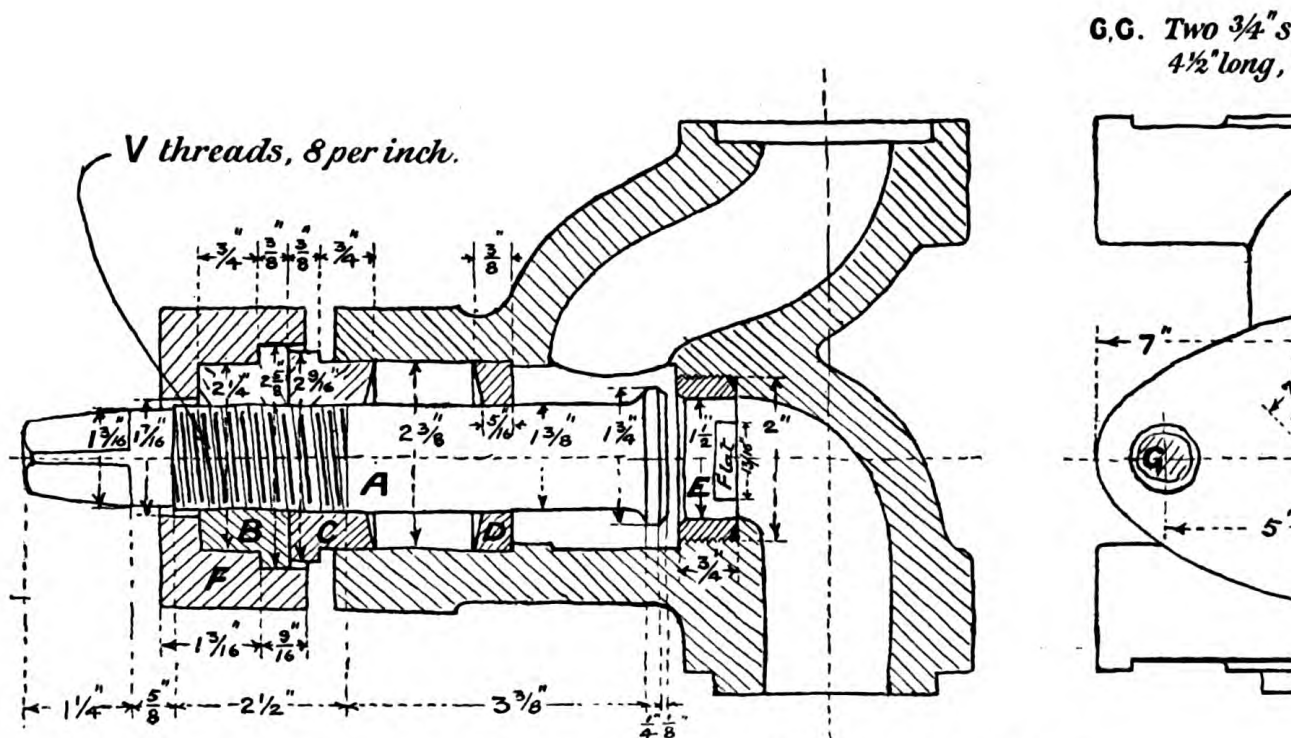


FIG. 293.—Hydraulic Stop Valve.

Make full size separate scale drawings of details, fully dimensioned, as follows:

- (a) Two views of the valve spindle **A**. The screw thread may be shown conventionally, as in the diagram.
- (b) Two views of the nut **B**.
- (c) Two views of the gland **C**.
- (d) Two views of the body **D**.
- (e) Two views of the seat **E**.
- (f) Three views of the cone **F**.
- (g) Three views of one of the glands **G**.

N.B.—No credit will be given for drawing the parts assembled, as in the main view. Hidden parts, where they are not required.

TYPICAL EXAMINATION QUESTIONS

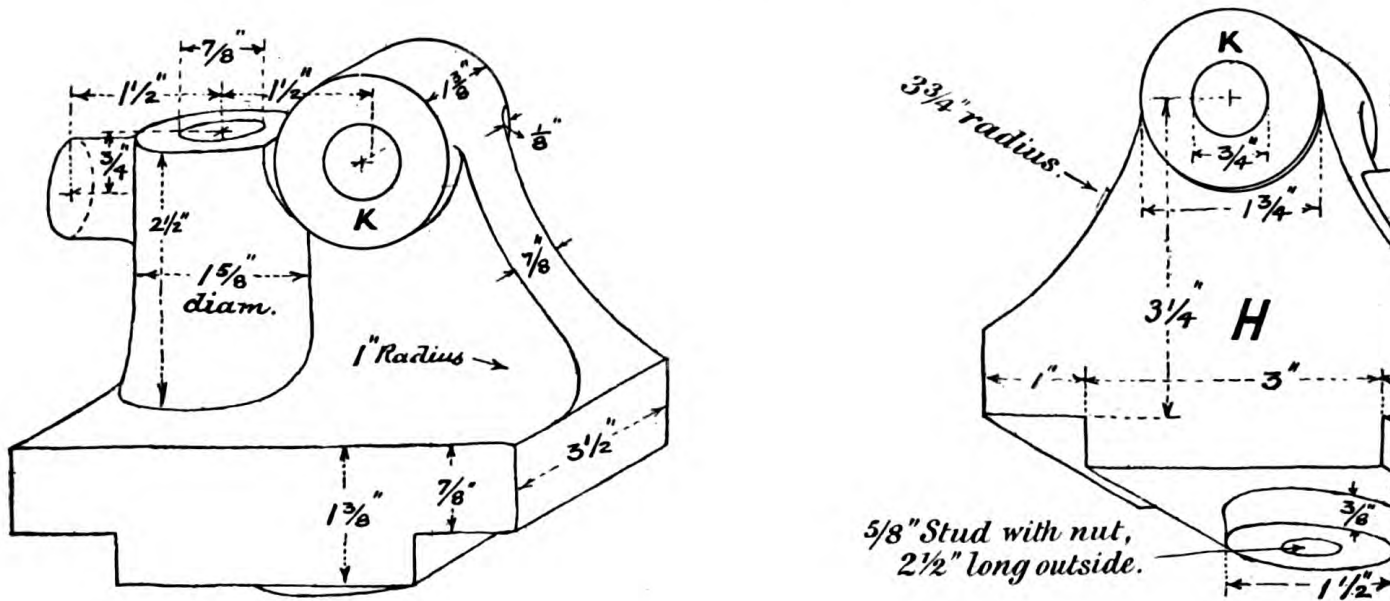


FIG. 294.—Bracket.

The form and dimensions of a bracket (for a lathe bed) are exhibited by two pictures, full size, inserting dimensions:—

(a) An elevation, as seen when looking in the direction of the arrow **R**. Put in $\frac{5}{8}$ " stud.

(b) A sectional elevation on a plane parallel to the face **H**, and 1" distant therefrom. The section plane is taken through the axis of the $\frac{1}{2}$ " setscrew and $\frac{7}{8}$ " hole.

(c) A plan.

N.B.—Do not draw the pictorial views. Dotted lines, representing hidden parts, are

Questions.

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

1. Indicate the parts of the stop valve, Fig. 293, which you would make respectively cast and wrought iron. Sketch a method of preventing the nut **B** from turning in the hole marked **K**, **K**, in the bracket Fig. 294.
2. Explain briefly, with sketches, how you would drill or bore the $\frac{3}{4}$ " hole marked **K**, **K**, in the bracket Fig. 294.
3. You are given the dimensions of a shaft coupling of the ordinary muff or box type. Draw sketches, half size, consisting of an end view and a longitudinal section, with the shaft in place.

Diameter of coupling outside	-	-	-	-	-
Diameter of bore of coupling	-	-	-	-	-
Length of coupling	-	-	-	-	-
Width of keys	-	-	-	-	-
4. Sketch in section, full size, inserting dimensions, a steam engine piston 6' long with three Ramsbottom rings of section $\frac{1}{4}$ " square. The conical hole for the piston rod is at the larger end, and the taper is 1" per foot.
5. Describe briefly, with sketches, any method you would consider suitable for joining the ends of a stranded cable made up of seven copper wires, each of No. 20 gauge, for cable.

TYPICAL EXAMINATION QUESTIONS

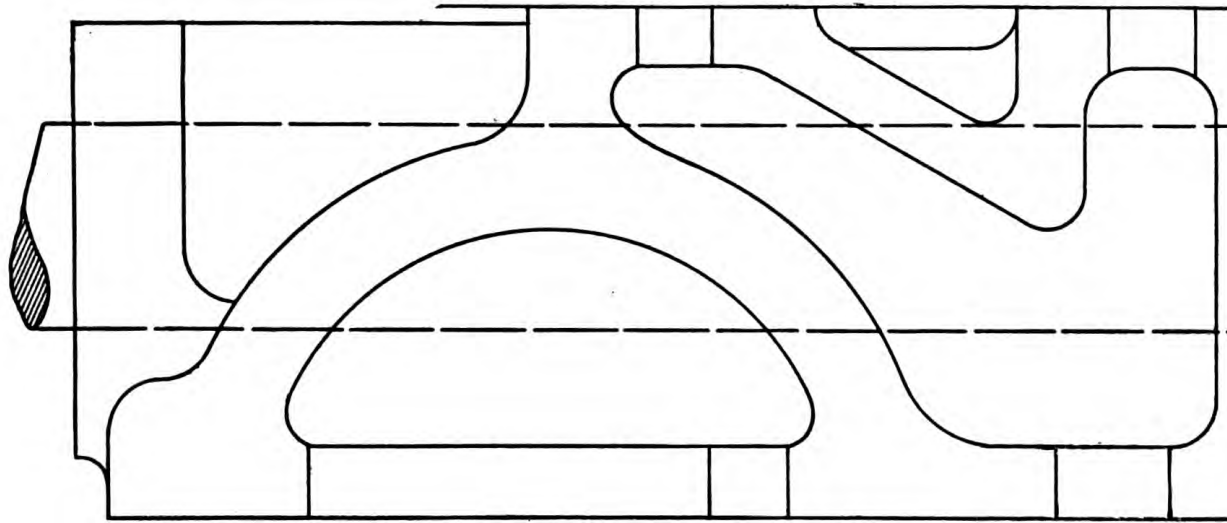
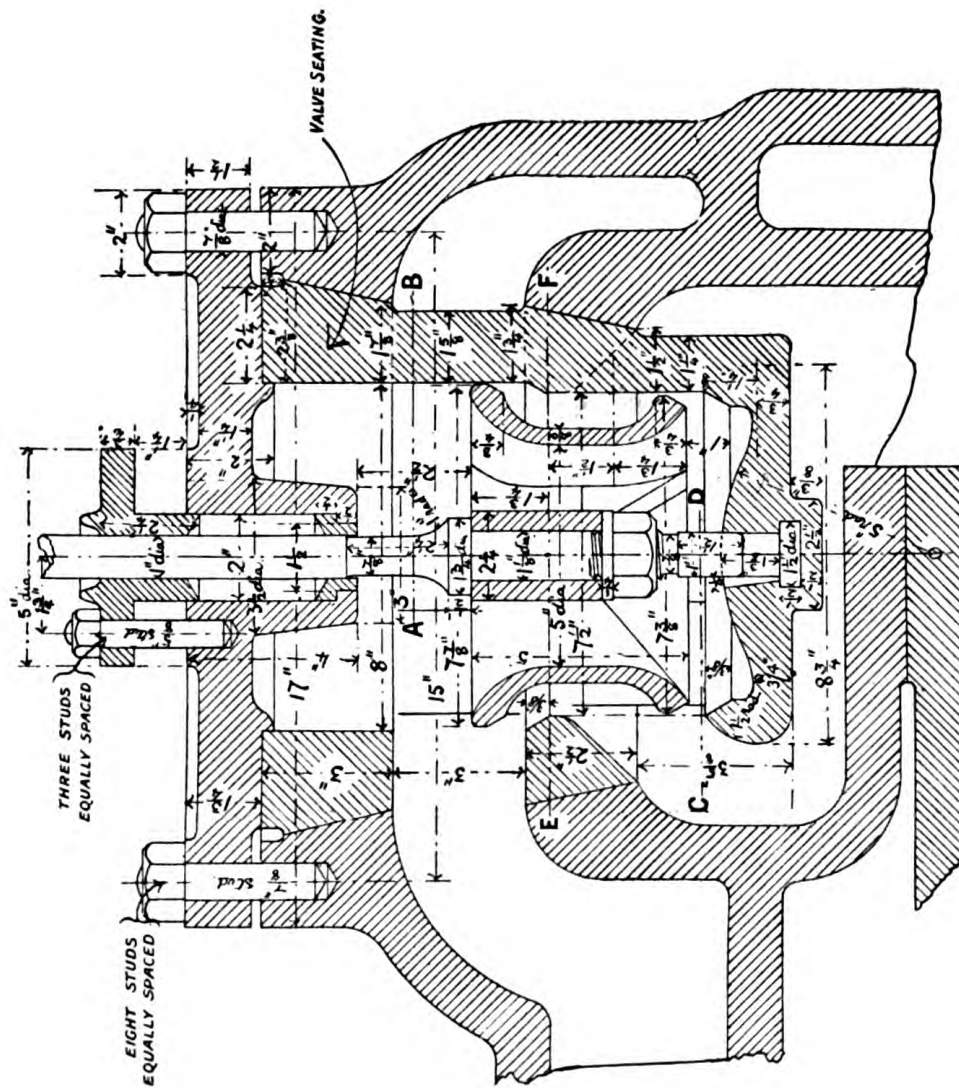


FIG. 295.—Expansion Valve.

Tracing.

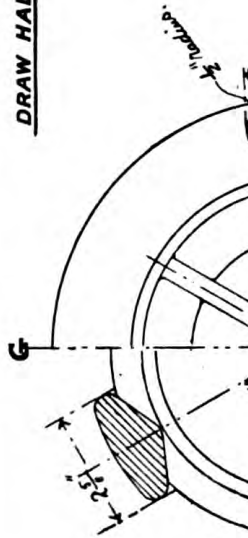
Trace in ink the expansion valve shown.

The lines of the tracing should be black, uniform in width, and of moderate thickness.



SECTION THROUGH CENTRE.

DRAW HALF SIZE.



TYPICAL EXAMINATION QUESTIONS

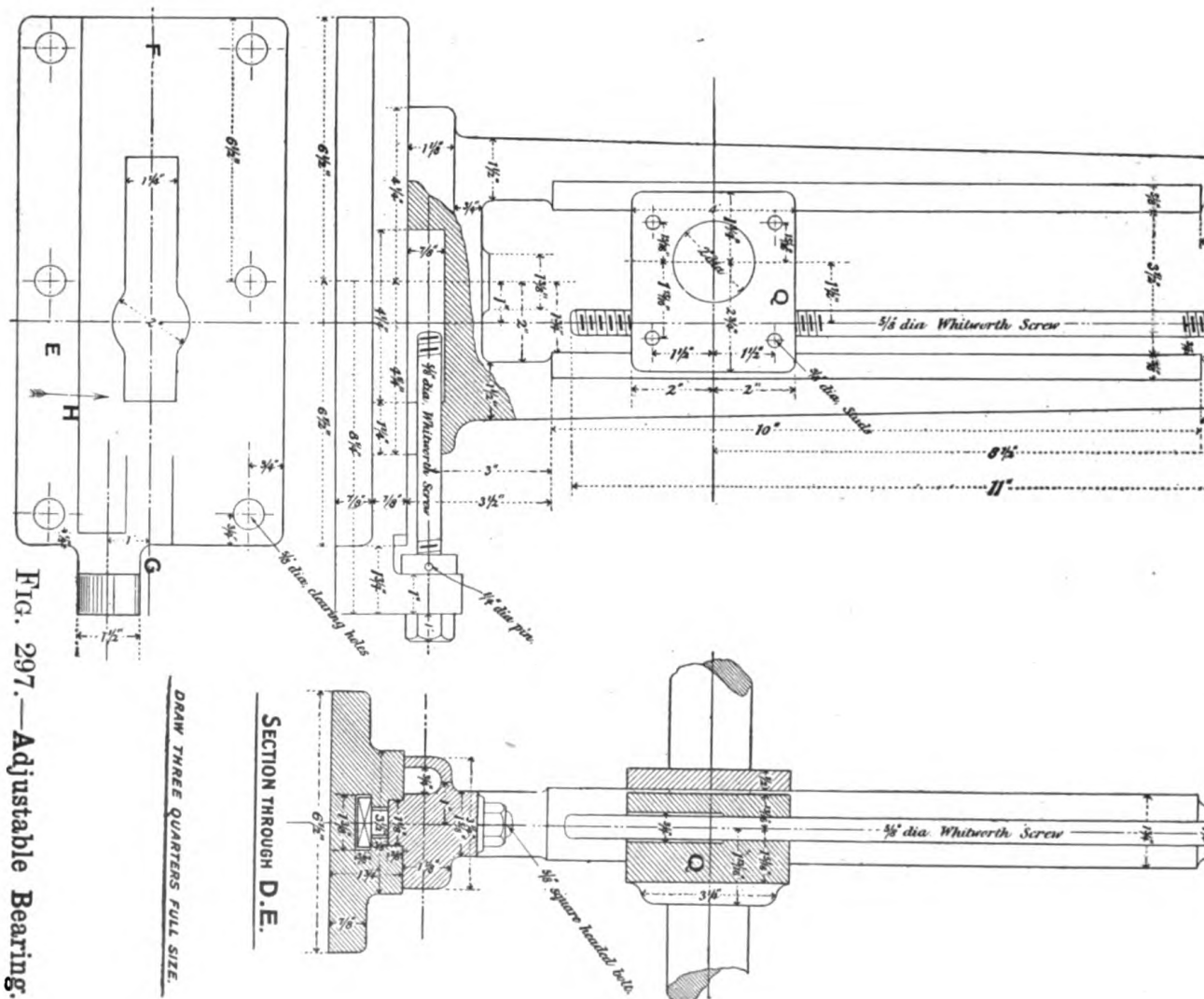


FIG. 297.—Adjustable Bearing.

C.M.C.

Questions.

The Sketches in answer to these questions should be drawn freehand, and are to be drawn

1. Sketch, in good proportion, giving a few leading dimensions, a muff or connection of two lengths of a machine shop main shaft 3 inches diameter.
2. How would you proceed to mark off and machine the block Q, Fig. 297, in which the centre line of the hole for the boring bar is exactly parallel to the sliding surfaces and the direction of vertical sliding?
3. The leading screw of a lathe is right-handed and has 4 threads per inch. Sketch a suitable train of wheels, and show how the wheels are supported. Assume that the wheel on the mandril has 20 teeth.
4. Make a sketch of a switch for carrying a continuous current of 100 amperes on a switchboard. The circuit voltage is about 200.
5. Sketch a gib and cotter connecting rod end, and show clearly how the gib is slacking back.

TYPICAL EXAMINATION PAPER

Draw either Example 1 or *Alternative Example 2*, but not both.

Also answer any *two*, but not more than *two* of the questions numbered 1 to 5.

Trace in Indian ink on the tracing paper supplied the drawing shown.

Example 1.

Tumbling Bearing.

The details of a tumbling bearing for a lathe are given on p. 276. The bearing supports the long shaft at the back of a lathe in such a way that a boss projecting from the shaft and encircling the shaft may pass the bearing freely in either direction. The boss moves along the lathe bed, and eventually comes in contact with the tumbling bearing, displacing it. The bearing falls sufficiently far below the shaft to allow of the passage of the boss. The tumbling bearing is restored to its vertical position after lateral displacement, and is held in its vertical position by the action of the bell-crank balance-weight levers gearing with the vertical levers attached to the bearing supporting the long shaft.

You are required to draw to a scale of one-half full size:

(a) The left half of the outside elevation seen when looking in the direction of the arrow, and all the parts assembled together, so that the bearing stands in its normal position.

Note.—The dotted lines required to show the outlines of the hidden parts of the levers are to be shown in this view.

(b) Project from the half outside elevation (a) the outside end elevation.

Note.—Dotted lines need not be shown in this view.

Dimension lines are not required in either view.

TYPICAL EXAMINATION PAPER

Alternative Example 2.

Engine Cylinder.

The drawings of this example show one of a pair of cylinders for a vertical steam engine. The cylinder cover nor the steam-chest cover are shown.

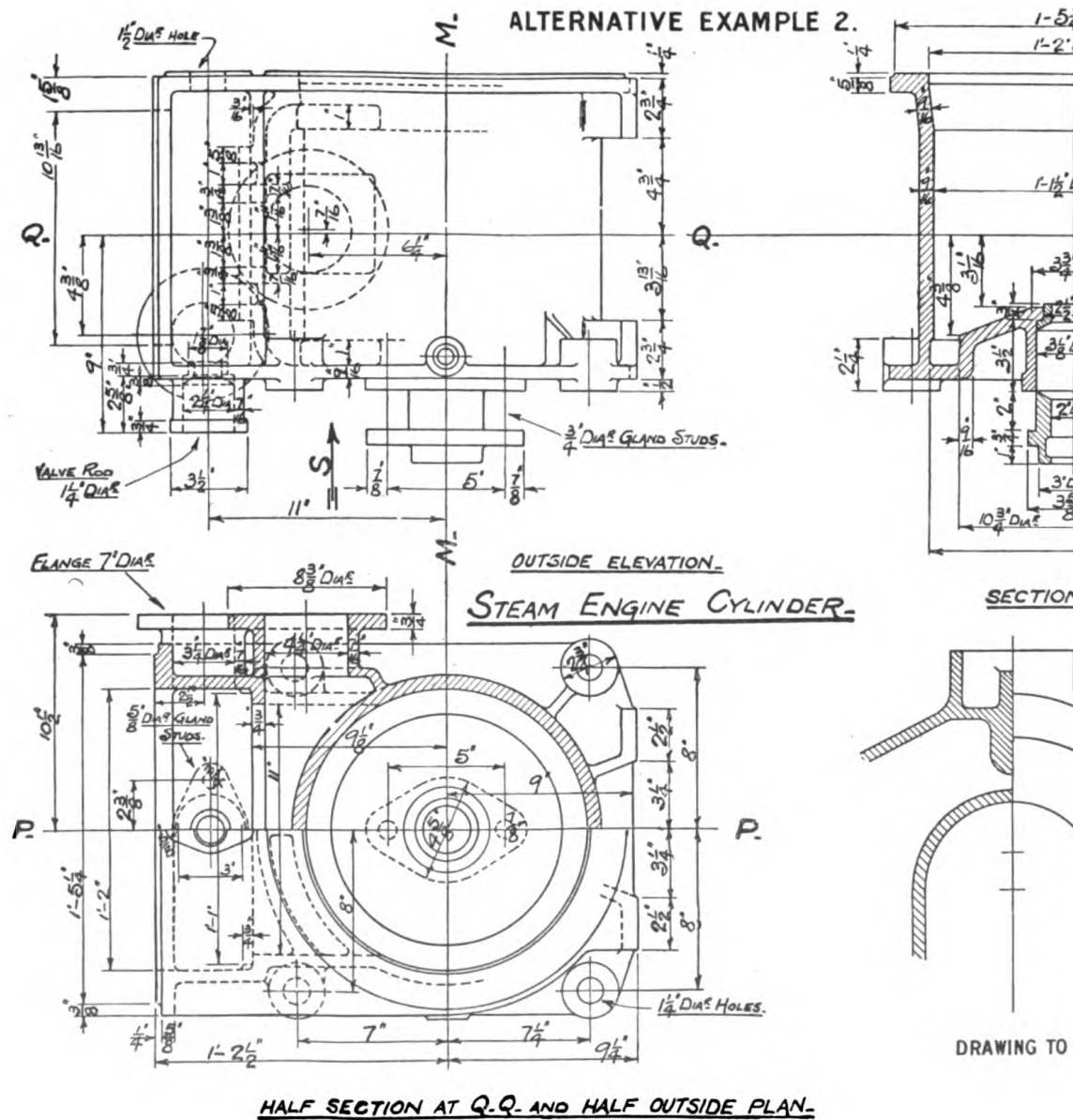
Arranging the vertical centre line of the cylinder lengthways of the paper, in order to place the required views in their proper relative positions, draw to a scale of one-half inch to one foot.

(c) In the place of the outside elevation shown, a sectional elevation of the part shown, taking the section through **PP**.

(d) An outside view, looking in the direction of the arrow **S**, of the portion you have shown in answer to (c).

Note.—In neither of these views are you required to show the piston rod, gland, gland bush, the cylinder cover, and the steam-chest cover.

Neither dotted lines nor dimension lines need be shown.



TYPICAL EXAMINATION PAPER

Questions—only two to be answered.

The sketches and answers to these questions are to be drawn freehand, either in pencil or with Indian ink, on the squared foolscap paper attached to the drawing paper. The sketches must not be made on the drawing paper.

1. Make a careful freehand sketch of a lubricator of the kind used on the crank end of a connecting rod. Show how the oil is brought to the bearing, and very briefly explain the action of the lubricator. You may select a type of crank end suitable for either a locomotive or a marine engine or a stationary engine.
2. Calculate the thickness of plate for a cylindrical boiler shell, 5 feet diameter and 200 pounds pressure. Assume a factor of safety of 6 when the boiler pressure is 200 pounds per square inch. The tensile strength of the longitudinal riveted joint is 70 per cent. of the strength of the plate and the shear strength of the plate is 30 tons per square inch.
3. Make a bold freehand sketch of a 1-inch stud screwed to the Whitworth standard form of thread. The stud is 2 inches from one end and long enough to allow a distance of $2\frac{1}{2}$ inches from the face of the nut to which it is screwed to the other end. Explain, with the aid of sketches, how you would secure it in place.
4. Make a sketch showing how a condenser tube is packed in a tube plate. Assume a tube outside diameter and a tube plate 1 inch thick.
5. The crank shaft of a petrol engine is coupled to the armature shaft of a dynamo. Sketch a form of coupling which will allow for a deviation of exact alignment in the two shafts.

Table I.

USEFUL NUMBERS AND FORMULÆ.

$$\sqrt{2}=1.414, \sqrt{3}=1.732, \sqrt{5}=2.236, \sqrt{6}=2.449.$$

$$\pi=3.1416 \text{ or } 3.142 \text{ or } \frac{22}{7}, \frac{1}{\pi}=0.3183.$$

$$\pi^2=9.872. \quad 1 \text{ inch}=2.54 \text{ cm.}$$

$$1 \text{ lb.}=453.6 \text{ grams, } 2\frac{1}{2} \text{ lbs.}=1 \text{ kilogram.}$$

$$1 \text{ gallon of water}=10 \text{ lbs.}=0.1604 \text{ cub. ft.}$$

$$1 \text{ cubic foot of water}=62.3 \text{ lbs.}$$

$$\text{Volts} \times \text{ampères} = \text{watts.}$$

$$1 \text{ horse-power}=33000 \text{ ft.-lbs. per min.} \\ =746 \text{ watts.}$$

$$1 \text{ radian}=57.3 \text{ degrees.}$$

$$\log \pi = 0.4972$$

$$\log 2.718 = 0.4343$$

$$\log .7854 = \bar{1}.8951$$

$$\log 62.3 = 1.7945$$

$$\log 1728 = 3.2375$$

$$\log .5236 = \bar{1}.7190$$

$$\log .1605 = \bar{1}.2054$$

To convert common into Napierian logarithms, multiply by 2.3026 ($e=2.718$).

Mensuration Formulae. In the following formulae: A denotes area; S , surface; V , volume; a , b , c , the sides; l , the slant height; R and r , radii of circles.

Rectangle or Parallelogram. $A=ah$.

Triangle. $A=\frac{1}{2}ah$, or $\sqrt{s(s-a)(s-b)(s-c)}$, where $s=\frac{1}{2}(a+b+c)$.

Trapezium. Parallel sides a and b . $A=\frac{1}{2}(a+b)h$.

Circle. Circumference $=2\pi r$, $A=\pi r^2$ or $\pi(R^2-r^2)$.

Ellipse. Semi-axes a and b . $A=\pi ab$.

Simpson's Rule. $A=\frac{s}{3}(A_1+4B+2C)$ where s is the space or distance between two consecutive ordinates, B is sum of even, and C is sum of the odd ordinates.

Prism. $S=2(ab+bc+ac)$, $V=abc$, diagonal $=\sqrt{a^2+b^2+c^2}$.

Cylinder. $S=2\pi rh+2\pi r^2$, $V=\pi r^2 h$.

Cone. $S=\pi rl+\pi r^2$, $V=\frac{1}{3}\pi r^2 h$.

Sphere. $S=4\pi r^2$, $V=\frac{4}{3}\pi r^3=0.5236d^3$.

Ring. $S=4\pi^2 Rr$, $V=2\pi^2 r^2 R$.

Weight in lbs. per cub. in.:—Cast iron, 0.26; Wrought iron, 0.28; Steel, 0.29; Brass, 0.298; Copper, 0.32.

APPENDIX

Table II.
LOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170						4	9	13	17	21	26	30	34	38
11	0414	0453	0492	0531	0569	0212	0253	0294	0334	0374	4	8	12	16	20	24	28	32	36
12	0792	0828	0864	0899	0934	0607	0645	0682	0719	0755	4	8	12	15	19	23	27	31	35
13	1139	1173	1206	1239	1271	0969	1004	1038	1072	1106	4	7	11	15	19	22	26	30	33
14	1461	1492	1523	1553	1584	1303	1335	1367	1399	1430	3	7	11	14	18	21	25	28	32
						1614	1644	1673	1703	1732	3	7	10	14	17	20	24	27	31
15	1761	1790	1818	1847	1875						3	6	9	11	14	17	20	23	26
16	2041	2068	2095	2122	2148	1903	1931	1959	1987	2014	3	6	8	11	14	17	19	22	25
17	2304	2330	2355	2380	2405	2175	2201	2227	2253	2279	3	5	8	11	14	16	19	22	24
18	2553	2577	2601	2625	2648	2430	2455	2480	2504	2529	3	5	8	10	13	15	18	20	23
19	2788	2810	2833	2856	2878	2672	2695	2718	2742	2765	2	5	7	9	11	14	16	18	21
						2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6600	6610	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8

Table II.
LOGARITHMS.

	0	1	2	3	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059
51	7076	7084	7093	7101	7119	7118	7126	7135	7143
52	7160	7168	7177	7185	7193	7202	7210	7218	7226
53	7243	7251	7259	7267	7275	7284	7292	7300	7308
54	7324	7332	7340	7348	7356	7364	7372	7380	7388
55	7404	7412	7419	7427	7435	7443	7451	7459	7466
56	7482	7490	7497	7505	7513	7520	7528	7536	7543
57	7559	7566	7574	7582	7589	7597	7604	7612	7619
58	7634	7642	7649	7657	7664	7672	7679	7686	7694
59	7709	7716	7723	7731	7738	7745	7752	7760	7767
60	7782	7789	7796	7803	7810	7818	7825	7832	7839
61	7853	7860	7868	7875	7882	7889	7896	7903	7910
62	7924	7931	7938	7945	7952	7959	7966	7973	7980
63	7993	8000	8007	8014	8021	8028	8035	8041	8048
64	8062	8069	8075	8082	8089	8096	8102	8109	8116
65	8129	8136	8142	8149	8156	8162	8169	8176	8182
66	8195	8202	8209	8215	8222	8228	8235	8241	8248
67	8261	8267	8274	8280	8287	8293	8299	8306	8312
68	8325	8331	8338	8344	8351	8357	8363	8370	8376
69	8388	8395	8401	8407	8414	8420	8426	8432	8439
70	8451	8457	8463	8470	8476	8482	8488	8494	8500
71	8518	8519	8525	8531	8537	8543	8549	8555	8561
72	8573	8579	8585	8591	8597	8603	8609	8615	8621
73	8633	8639	8645	8651	8657	8663	8669	8675	8681
74	8692	8698	8704	8710	8716	8722	8727	8733	8739
75	8751	8756	8762	8768	8774	8779	8785	8791	8797
76	8808	8814	8820	8825	8831	8837	8842	8848	8854
77	8865	8871	8876	8882	8887	8893	8899	8904	8910
78	8921	8927	8932	8938	8943	8949	8954	8960	8965
79	8976	8982	8987	8993	8998	9004	9009	9015	9020
80	9031	9036	9042	9047	9053	9058	9063	9069	9074
81	9085	9090	9096	9101	9106	9112	9117	9122	9128
82	9138	9143	9149	9154	9159	9165	9170	9175	9180
83	9191	9196	9201	9206	9212	9217	9222	9227	9232
84	9243	9248	9253	9258	9263	9269	9274	9279	9284
85	9294	9299	9304	9309	9315	9320	9325	9330	9335
86	9345	9350	9355	9360	9365	9370	9375	9380	9385
87	9395	9400	9405	9410	9415	9420	9425	9430	9435
88	9445	9450	9455	9460	9465	9469	9474	9479	9484
89	9494	9499	9504	9509	9513	9518	9523	9528	9533
90	9542	9547	9552	9557	9562	9566	9571	9576	9581
91	9590	9595	9600	9605	9609	9614	9619	9624	9628
92	9638	9643	9647	9652	9657	9661	9666	9671	9675
93	9685	9689	9694	9699	9703	9708	9713	9717	9722
94	9731	9736	9741	9745	9750	9754	9759	9763	9768
95	9777	9782	9786	9791	9795	9800	9805	9809	9814
96	9823	9827	9832	9836	9841	9845	9850	9854	9859
97	9868	9872	9877	9881	9886	9890	9894	9899	9903
98	9912	9917	9921	9926	9930	9934	9939	9943	9948
99	9956	9961	9965	9969	9974	9978	9983	9987	9991

Table III.
ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	2	3
14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	2	3
15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	2	3
16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	2	3
17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	2	3
18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	2	3
19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	2	2	3
20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	2	2	3
21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	1	2	2	2	2	3
22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	1	2	2	2	2	3
23	1698	1702	1703	1710	1714	1718	1722	1726	1730	1734	0	1	1	1	2	2	2	2	3
24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	1	2	2	2	2	3
25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	1	2	2	2	2	3
26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	1	2	2	2	2	3
27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	1	2	2	2	2	3
28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	1	2	2	2	2	3
29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	1	2	2	2	2	3
30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	1	2	2	2	2	3
31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	1	2	2	2	2	3
32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	1	2	2	2	2	3
33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	1	2	2	2	2	3
34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	2	2	2	2	3
35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	2	2	2	2	3
36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	2	2	2	2	3
37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	2	2	2	2	3
38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	2	2	2	2	3
39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	2	2	2	2	3
40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	2	2	2	2	3
41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	2	2	2	2	3
42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	2	2	2	2	3
43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	2	2	2	2	2	3
44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	2	2	2	2	2	3
45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	2	2	2	2	2	3
46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	2	2	2	2	2	3
47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	2	2	2	2	2	3
48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	2	2	2	2	2	3
49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	2	2	2	2	2	3

Table III.
ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9
50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228
51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304
52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381
53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459
54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540
55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622
56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707
57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793
58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882
59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972
60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064
61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159
62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256
63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355
64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457
65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560
66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667
67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775
68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887
69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000
70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117
71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236
72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358
73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483
74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610
75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741
76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875
77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012
78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152
79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295
80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442
81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592
82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745
83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902
84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063
85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228
86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396
87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568
88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745
89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925
90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110
91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299
92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492
93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690
94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892
95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099
96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311
97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528
98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750
99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977

APPENDIX

Table IV.
CHORDS OF ANGLES.

Deg.	0'	10'	20'	30'	40'	50'	Deg.	0'	10'	20'	30'	40'	50'
0	000	003	006	009	012	014	45	765	768	771	773	776	779
1	017	020	023	026	029	032	46	781	784	787	789	792	795
2	035	038	041	044	046	049	47	797	800	803	805	808	811
3	052	055	058	061	064	067	48	813	816	819	821	824	827
4	070	073	076	078	081	084	49	829	832	835	837	840	843
5	087	090	093	096	099	102	50	845	848	850	853	856	858
6	105	108	110	113	116	119	51	861	864	866	869	871	874
7	122	125	128	131	134	137	52	877	879	882	885	887	890
8	139	142	145	148	151	154	53	892	895	898	900	903	905
9	157	160	163	166	168	171	54	908	911	913	916	918	921
10	174	177	180	183	186	189	55	923	926	929	931	934	936
11	192	195	197	200	203	206	56	939	941	944	947	949	952
12	209	212	215	218	221	223	57	954	957	959	962	964	967
13	226	229	232	235	238	241	58	970	972	975	977	980	982
14	244	247	249	252	255	258	59	985	987	990	992	995	997
15	261	264	267	270	273	275	60	1000	1002	1005	1007	1010	1013
16	278	281	284	287	290	293	61	1015	1018	1020	1023	1025	1028
17	296	298	301	304	307	310	62	1030	1033	1035	1037	1040	1042
18	313	316	319	321	324	327	63	1045	1047	1050	1052	1055	1057
19	330	333	336	339	342	344	64	1060	1062	1065	1067	1070	1072
20	347	350	353	356	359	362	65	1075	1077	1079	1082	1084	1087
21	364	367	370	373	376	379	66	1089	1092	1094	1097	1099	1101
22	382	384	387	390	393	396	67	1104	1106	1109	1111	1113	1116
23	399	402	404	407	410	413	68	1118	1121	1123	1126	1128	1130
24	416	419	421	424	427	430	69	1133	1135	1138	1140	1142	1145
25	433	436	438	441	444	447	70	1147	1149	1152	1154	1157	1159
26	450	453	456	458	461	464	71	1161	1164	1166	1168	1171	1173
27	467	470	472	475	478	481	72	1176	1178	1180	1183	1185	1187
28	484	487	489	492	495	498	73	1190	1192	1194	1197	1199	1201
29	501	504	506	509	512	515	74	1204	1206	1208	1211	1213	1215
30	518	520	523	526	529	532	75	1217	1220	1222	1224	1227	1229
31	534	537	540	543	546	548	76	1231	1234	1236	1238	1240	1243
32	551	554	557	560	562	565	77	1245	1247	1250	1252	1254	1256
33	568	571	574	576	579	582	78	1259	1261	1263	1265	1268	1270
34	585	587	590	593	596	599	79	1272	1274	1277	1279	1281	1283
35	601	604	607	610	612	615	80	1286	1288	1290	1292	1294	1297
36	618	621	624	626	629	632	81	1299	1301	1303	1305	1308	1310
37	635	637	640	643	646	648	82	1312	1314	1316	1319	1321	1323
38	651	654	657	659	662	665	83	1325	1327	1330	1332	1334	1336
39	668	670	673	676	679	681	84	1338	1340	1343	1345	1347	1349
40	684	687	689	692	695	698	85	1351	1353	1355	1358	1360	1362
41	700	703	706	709	711	714	86	1364	1366	1368	1370	1372	1375
42	717	719	722	725	728	730	87	1377	1379	1381	1383	1385	1387
43	733	736	738	741	744	746	88	1389	1391	1393	1396	1398	1400
44	749	752	755	757	760	763	89	1402	1404	1406	1408	1410	1412
							90	1414					

Table V.
WHITWORTH STANDARD SCREWS.

d	Diameter of bolt in inches.	Number of threads per inch.	d ₁ Diameter at bottom of thread.	Area of Cross-section at bottom of thread in square inches.
$\frac{3}{8}$	375	16	0.295	0.068
$\frac{1}{2}$	5	12	.393	.1214
$\frac{5}{8}$	625	11	.508	.2027
$\frac{3}{4}$	75	10	.622	.3039
$\frac{7}{8}$	875	9	.733	.4220
1	1	8	.840	.5543
$1\frac{1}{8}$	1.125	7	.942	.6971
$1\frac{1}{4}$	1.25	7	1.067	.8935
$1\frac{3}{8}$	1.375	6	1.162	1.061
$1\frac{1}{2}$	1.5	6	1.287	1.301
$1\frac{3}{4}$	1.625	5	1.369	1.472
$1\frac{7}{8}$	1.75	5	1.494	1.754
$1\frac{1}{2}$	1.875	4.5	1.590	1.986
2	2	4.5	1.720	2.324
$2\frac{1}{8}$	2.125	4.5	1.840	2.659
$2\frac{1}{4}$	2.25	4.0	1.930	2.926
$2\frac{3}{8}$	2.375	4.0	2.055	3.318
$2\frac{1}{2}$	2.5	4.0	2.180	3.734
$2\frac{7}{8}$	2.625	4.0	2.305	4.172
$2\frac{3}{4}$	2.75	3.5	2.384	4.464
$2\frac{1}{2}$	2.875	3.5	2.509	4.942
3	3	3.5	2.634	5.451
$3\frac{1}{8}$	3.25	3.25	2.855	6.401
$3\frac{1}{4}$	3.5	3.25	3.105	7.573
$3\frac{3}{8}$	3.75	3.0	3.323	8.673
4	4	3.0	3.573	10.027
$4\frac{1}{8}$	4.25	2.875	3.804	11.37
$4\frac{1}{4}$	4.5	2.875	4.054	12.91
$4\frac{3}{8}$	4.75	2.75	4.284	14.41
5	5	2.75	4.534	16.14
$5\frac{1}{8}$	5.25	2.625	4.762	17.81
$5\frac{1}{4}$	5.5	2.625	5.012	19.72
$5\frac{3}{8}$	5.75	2.5	5.238	21.55
6	6	2.5	5.488	23.65

ANSWERS TO EXERCISES.

EXERCISES II. p. 44.

14. By shearing. 15. $1.78''$. 16. By shearing. 17. $2.078''$, $1.813''$.

EXERCISES III. p. 65.

18. $\frac{3}{4}''$ ($d_1 = 0.598''$). 19. $2\frac{5}{8}''$ ($d_1 = 2.309$).

24.

d	$1''$	$1\frac{1}{2}''$	$2\frac{1}{2}''$	$3''$
p	$0.125''$	$0.165''$	$0.245''$	$0.285''$
n	8	6	4	3.5
d_1	$0.84''$	$1.27''$	$2.11''$	$2.54''$

EXERCISES V. p. 92.

7. $12' 6''$. 8. 60 rev. per min.; $34\frac{2}{7}''$, $13\frac{5}{7}''$.
 13. 47.13 ft.; 352.8 rev. per min. 14. 24 in.; 42 in.

EXERCISES VIII. p. 138.

9. $\frac{1.9}{3.2}''$, ($0.5978''$).

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