Engineering Drawing from the Beginning

VOLUME 2

by

M. F. COUSINS

UNTIL RECENTLY CHIEF DESIGNER, CAMBRIDGE INSTRUMENT CO. LTD.
DESIGN CONSULTANT
PART-TIME LECTURER IN ENGINEERING DRAWING,
CAMBRIDGESHIRE COLLEGE OF ARTS AND TECHNOLOGY

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Editor's Preface

THIS book is the second of two volumes written by the author to teach the technique of communicating technical information by the use of engineering drawings. This technique is both an art and a science and it can only be developed by continual practice and constant reference to the accepted standards recommended in B.S. 308. Volume 1 was introductory in nature and commenced from the very beginning assuming that the reader had not previous experience in making engineering drawings. This Volume 2 continues the process of developing more advanced techniques and good drawing practice.

These two volumes have been written for students on the General Course in Engineering, G.C.E. O-level courses and technician courses of the City and Guilds of London Institute.

Cambridge

N. HILLER,
Editor

Author's Acknowledgements

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Great Shelford
Cambs.

M. F. COUSINS

1. *Revision and Introduction*

1.1. REVISION OF PREVIOUS WORK FROM VOLUME 1

It is most important to remember and to use the correct type of line when making a particular drawing. We have used from the beginning the lines recommended in B.S. 308. Starting with construction lines, the views are built up until there is sufficient detail to finish the drawing in good, firm outline.

1.2. TYPES OF PROJECTION

Earlier lessons illustrated various types of projection as follows (Fig. 1):

(i) Perspective, or an artist's impression of an object. The lines on the drawing fade away to a vanishing point and no measurements can be made.

(ii) Isometric projection is somewhat similar to perspective drawing except that measurements can be made along any of the lines.

(iii) First angle projection (English) (F.A.P.), consists of views on the drawing with the PLAN projected from the FRONT ELEVATION and placed directly *under* it. The END VIEWS and PLAN are placed at the opposite end to the viewed side.

(iv) *Third angle* projection (American) (T.A.P.), also consists of views on the drawing with the PLAN projected from the FRONT ELEVATION but placed directly *above* it. The END VIEWS and PLAN are placed adjacent to the viewed side of the FRONT ELEVATION.

1.3. DIMENSIONING

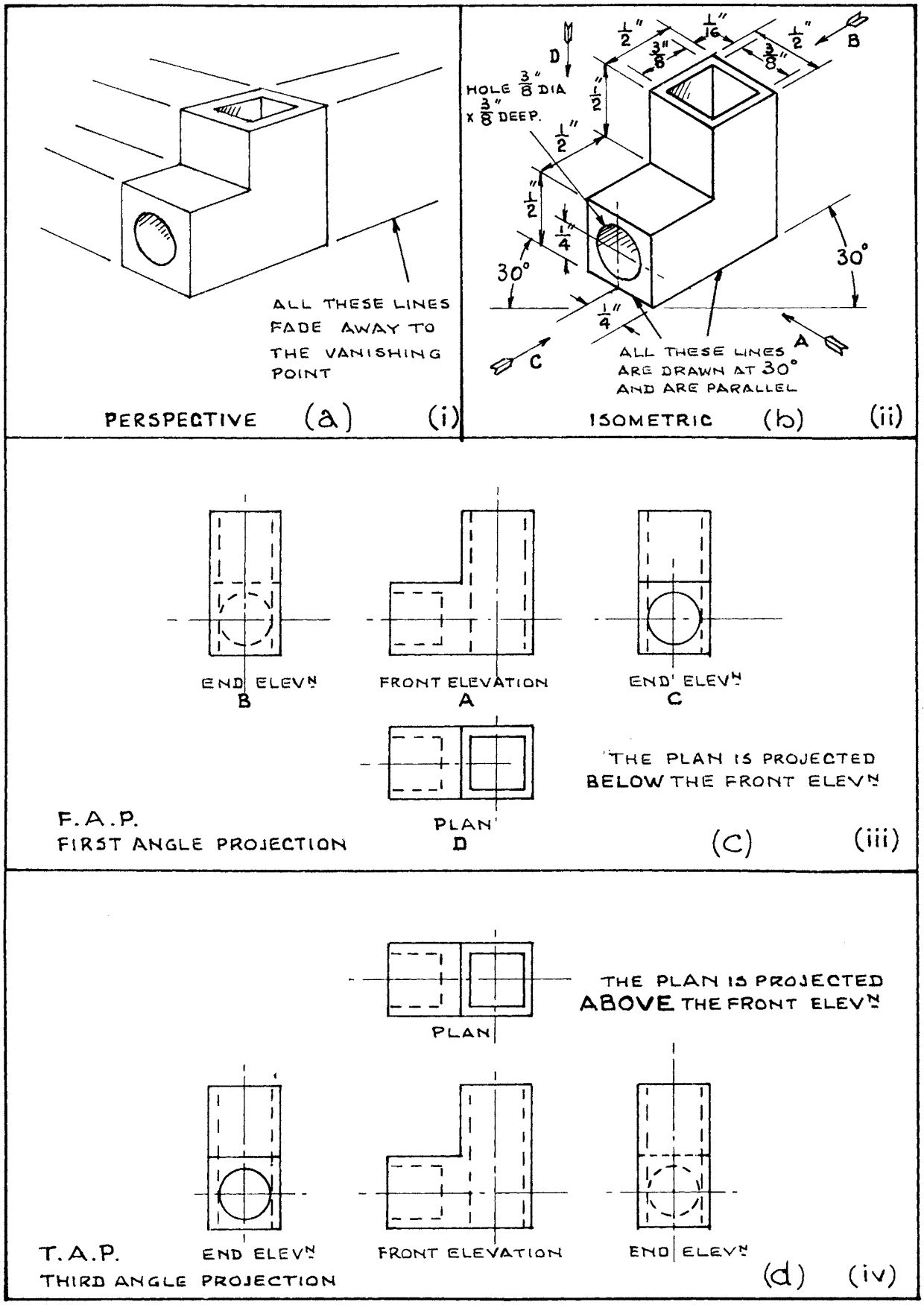
Dimensions are placed on a drawing with figures perpendicular to and just above the dimension line. The dimensions are read from the BASE of the drawing and from the RIGHT-hand side. (Fig. 2(*a*).)

1.4. SECTIONAL VIEWS

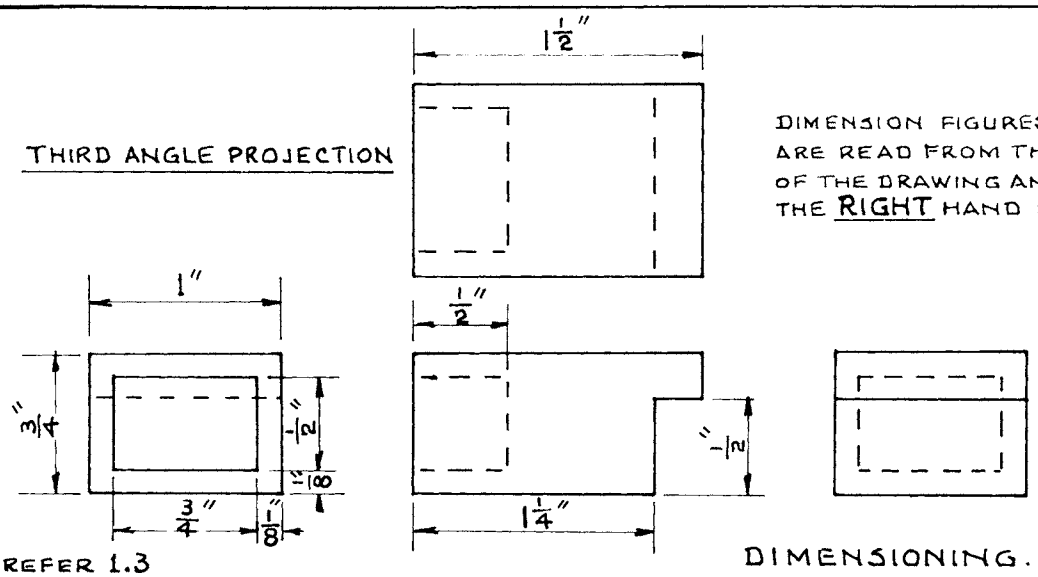
When a drawing of an object is to be made, the number of views should always be kept to a minimum. However, in order that sufficient information is given, it is sometimes necessary to make a sectional view. This is a view of an imaginary cut through any part and any plane of the object in order to explain what is happening under the external surface. See Fig. 2(*b*) and notice section lines are always at 45° and spaced as shown.

1.5. PART OR DETAIL DRAWING

When a drawing is made of a part of a mechanism it is called a part, or detail, drawing.



REFER 1.2 FIG. 1 TYPES OF PROJECTION



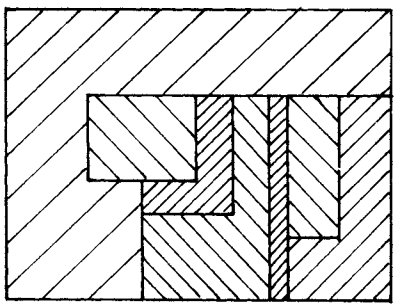
THIRD ANGLE PROJECTION

DIMENSION FIGURES ARE READ FROM THE BASE OF THE DRAWING AND FROM THE RIGHT HAND SIDE.

REFER 1.3

DIMENSIONING. (a)

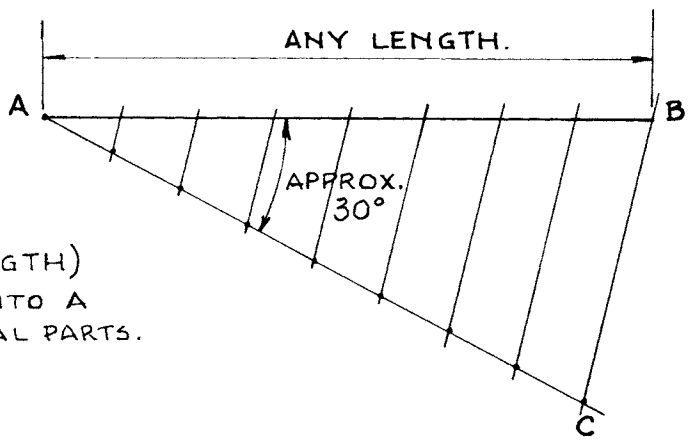
SECTION LINES ALWAYS AT 45° AND SPACED TO SUIT AREA TO BE COVERED.



THIS IS A SECTIONAL VIEW THROUGH A COMPLICATED STRUCTURE. EACH INDIVIDUAL PIECE SHOWS UP VERY CLEARLY.

REFER 1.4

SECTION LINING DETAIL (b)



AB (ANY LENGTH) TO BE DIVIDED INTO A NUMBER OF EQUAL PARTS.

REFER 1.8

DIVISION OF LINE (c)

GENERAL INFORMATION **FIG. 2**

1.6. ASSEMBLY DRAWING

If all the parts are fitted together and a drawing is made it is then known as an assembly drawing or general arrangement (G.A.).

1.7. SUB-ASSEMBLIES

The G.A. can be broken down into sub-assemblies each of which consists of a group of parts.

1.8. DIVISION OF A LINE INTO EQUAL PARTS

The method of dividing a line of any length into a number of equal parts will be used many times in this volume. See Fig. 2(*c*).

1.9. JOINING OF STRAIGHT LINES TO CURVES

Many students have difficulty in joining curves to straight lines. Remember the following rule: *Join straight lines to curves and not curves to straight lines.*

1.10. PENCIL POINT

Remember that a good conical point on your pencil will give consistently good lines and the best result on all drawings.

1.11. DIVISION OF CIRCUMFERENCE OF A CIRCLE

In many of the problems we shall be attempting, the circumference of a circle has to be divided into twelve equal parts. There are two methods of doing this.

(i) *With set squares*

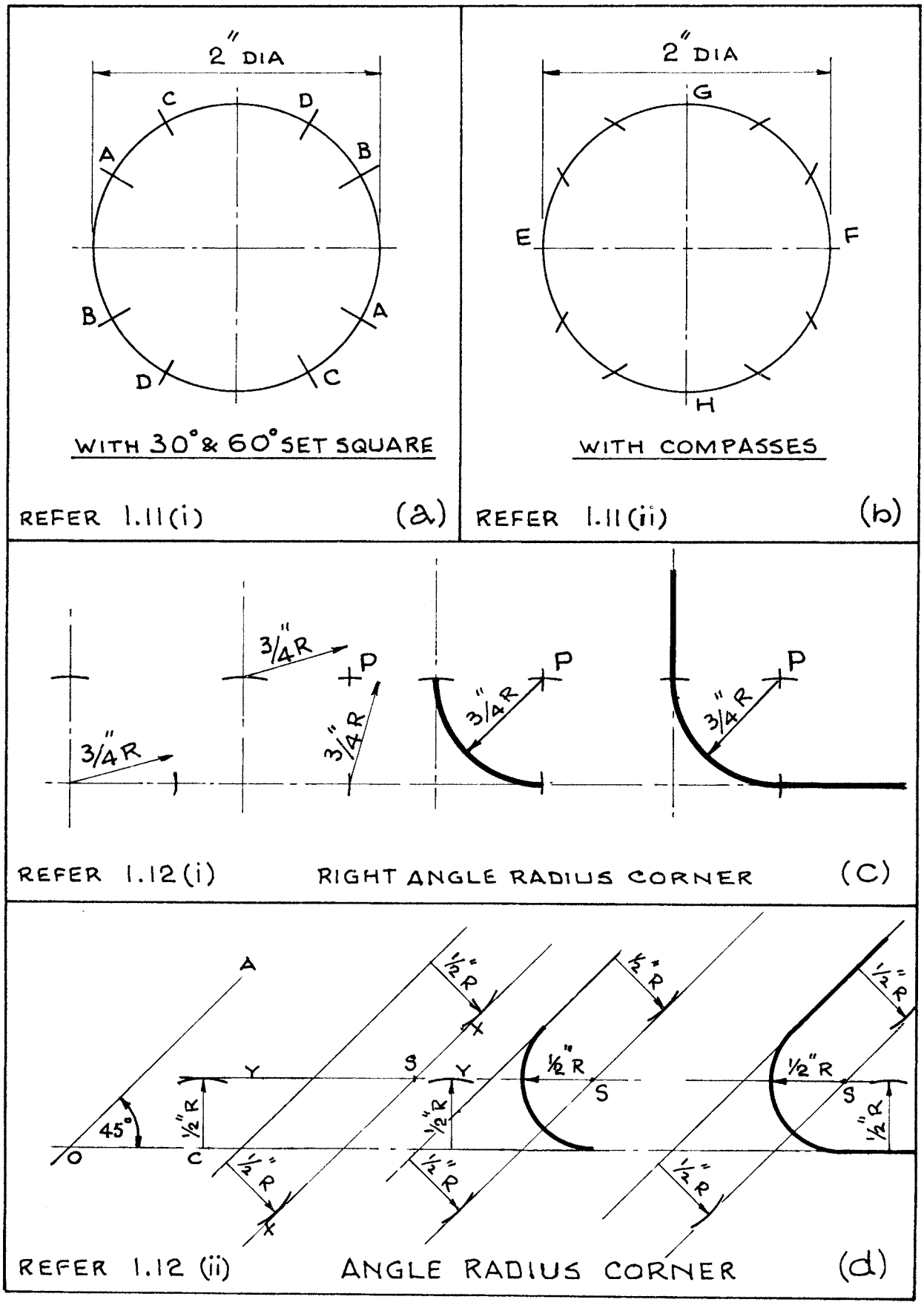
Draw a circle 2 in dia., as in Fig. 3(*a*). Mark off at AA and BB with the 30° and at CC and DD with the 60° set square as shown. However, it is much simpler to divide off as in (ii) below.

(ii) *With compasses*

Draw another circle 2 in dia., as in Fig. 3(*b*). With the compasses remaining set at 1 in radius, mark off two small arcs from each of the centres E, F, G, H. At the points where these arcs intersect, the circle is divided into twelve equal parts. This method is much quicker than (i), and if reasonable care is taken it is equally accurate.

1.12. RADIUS CORNERS

There are two radius corners which we shall be drawing, the "right-angle" type and the "angle" type. A line-by-line construction for both types is shown in Fig. 3.



GENERAL INFORMATION

FIG. 3

(i) *Right-angle Radius Corner. Fig. 3(c)*

In construction draw two lines at right angles and mark off two arcs of radius $\frac{3}{4}$ in. Now draw from these arcs two more arcs of radius $\frac{3}{4}$ in to intersect at *P*. From *P* draw in outline the corner curve. Finally, in outline, join the straight lines to the curve.

(ii) *Angle Radius Corner. Fig. 3(d)*

The following construction will apply to a corner of any angle *AOC*. In construction draw two lines at any angle (in this case 45°). At two points draw two arcs, of $\frac{1}{2}$ in radius, perpendicular to the horizontal base line and join them with a line parallel with the base line at *YY*. Now draw two more arcs, of $\frac{1}{2}$ in radius, perpendicular to the sloping line and join them with a line parallel with the sloping line at *XX*. The two lines will intersect at point *S*. From point *S* draw, in outline, a curve of $\frac{1}{2}$ in radius. Finally, in outline, join the straight lines to the curve.

2. *The Helix*

2.1. DEFINITION OF THE HELIX

The helix is the path traced by a point moving uniformly around the surface of a right cylinder which is moving axially. The ratio of the speeds of the point and the cylinder is constant. The helix forms the basic construction of screwthreads, helical grooves (single-start or multi-start), and helical springs.

2.2. THE CONSTRUCTION OF A HELIX

All lines must be construction or projection lines until the curve is drawn in outline.

To draw a helix $2\frac{1}{2}$ in dia. and 3 in pitch:

(i) Draw two views, i.e. front elevation and end elevation of a cylinder $2\frac{1}{2}$ in dia. and approximately 4 in long, as Fig. 4(*a*).

(ii) Divide the end view into twelve equal parts by the compasses method. This divides the curved surface of the cylinder, i.e. the circumference, into twelve equal parts. Number the parts counter-clockwise. (Fig. 4(*b*).)

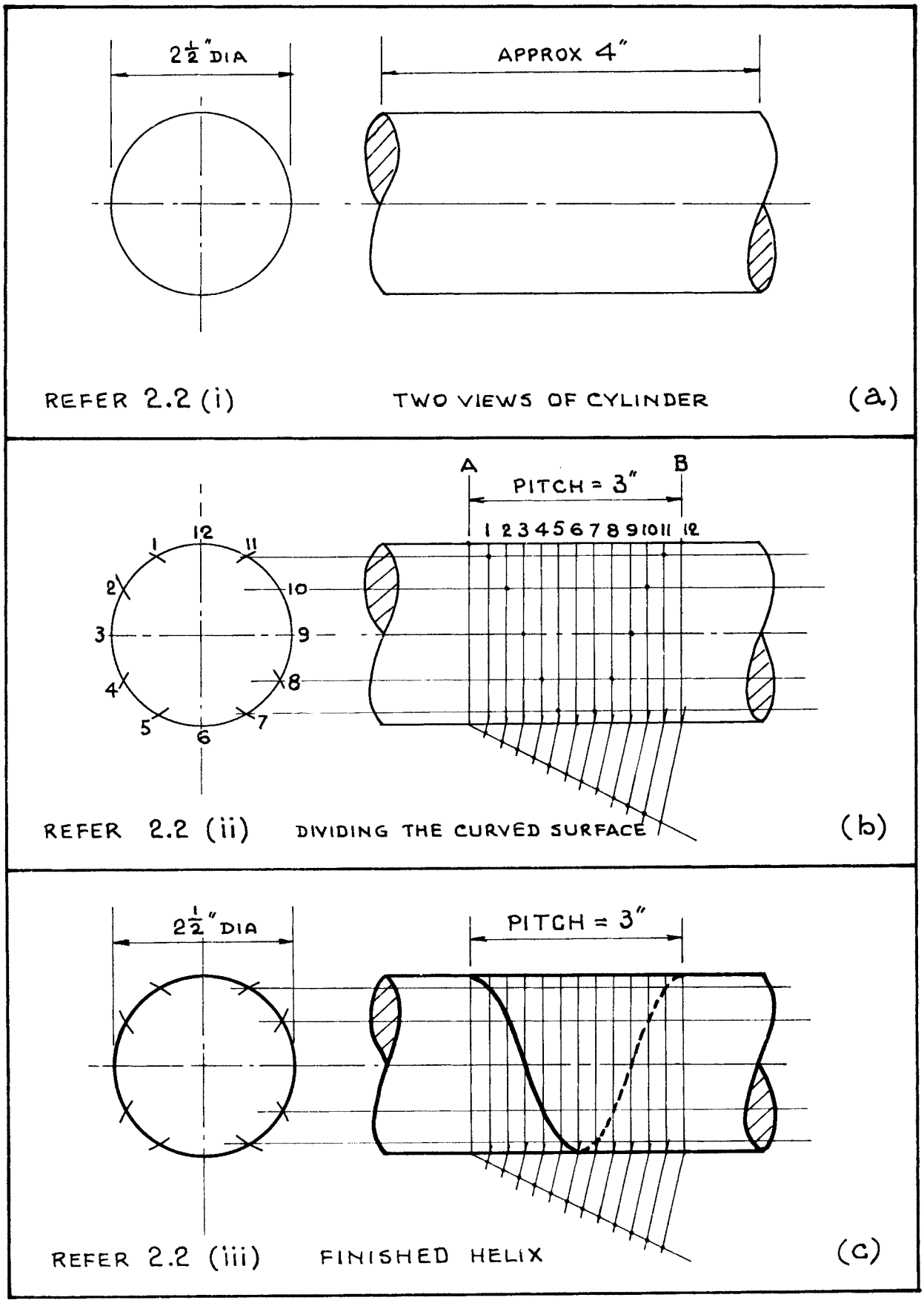
Mark off points *A* and *B*, 3 in apart. This distance is known as the PITCH and is the distance from a point on one turn of the helix to the corresponding point on the next. Divide the pitch into twelve equal parts and number the parts 0–12 from left to right.

Notice that the end view and front elevation are divided into the *same number* of parts so that if (ii) were divided into twenty parts then the pitch would also be divided into twenty parts.

Project the lines from points 11, 10, 9, 8, 7 horizontally as far as *B*. You will notice that points 1, 2, 3, 4, 5 are in line with points 11, 10, 9, 8, 7 respectively.

The point moves from *A* along the cylinder one-twelfth of the pitch and at the same time moves one-twelfth of a turn from 0 to 1. If this is repeated six times, progressively, then the point moves from *A* six-twelfths along the pitch and six-twelfths around the cylinder until point 6 is reached. It will be noticed that the point has passed through intersections of the vertical and horizontal coordinates. Repeat the process from the sixth point to the twelfth point, which is *B*.

(iii) Draw a fair curve passing through all the points. The first half (points 0–6) should be in full outline and the other half (points 7–12) should be hidden detail. (Fig. 4(*c*).) Your construction lines should be very thin, but still visible, and will not be as seen in Fig. 4(*c*) where lines have been accentuated for instructional purposes only.



REFER 2.2 CONSTRUCTING A HELIX FIG. 4

2.3. THE CONSTRUCTION OF A DOUBLE HELIX

After constructing the helix as in Fig. 4, we will now construct a double helix 2 in dia. by 4 in pitch by $\frac{3}{4}$ in apart in a linear direction. The following order should be observed.

(i) Construct two views of a cylinder as in Fig. 5(*a*) 2 in dia. and $5\frac{1}{2}$ in long.

(ii) Construct a helix as in Fig. 5(*b*) to dimension 2 in dia., pitch 4 in and $\frac{1}{2}$ in from the left-hand end of the cylinder which leaves us with a clear 1 in in which to position the second helix.

(iii) Now plot the second helix $\frac{3}{4}$ in horizontally to the right of the first helix. A simple method of doing this is to set your compasses at $\frac{3}{4}$ in radius and mark along horizontally from each point 1, 2, 3, etc. After carefully marking all the points, draw fair curves through them as shown in Fig. 5(*c*), firmly outlining the first half and showing the second half in dotted hidden detail.

2.4. THE CONSTRUCTION OF A HELICAL GROOVE IN A CYLINDER

The groove which we shall draw is $\frac{1}{2}$ in wide by $\frac{1}{2}$ in deep of 3 in pitch on a 3 in dia. cylinder. This should be drawn in the following order:

(i) Draw two views of a cylinder 3 in dia. and 5 in long. Mark off the pitch *A* to *B* of 3 in starting about $\frac{1}{2}$ in from the left-hand side. Divide the pitch into twelve equal parts and also the end view into the *same number* of parts. Produce the horizontal lines from the end view and, at the intersections, draw the first major curve.

Note: When drawing curves freehand, keep the hand inside the curve so that the pencil has a natural radial movement.

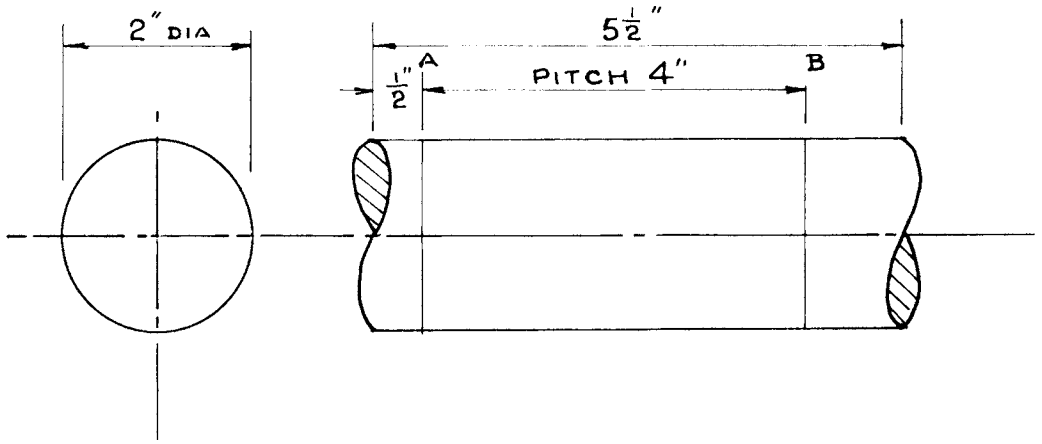
Now draw the second major curve $\frac{1}{2}$ in from the first curve. You will notice that it will start at the second division from *A* (two-twelfths of 3 in pitch = $\frac{1}{2}$ in). The curve can be completed by marking off with the compasses the points 13 and 14 beyond *B*, as explained in Section 2.3 (iii). All work should be drawn in thin lines, slightly emphasizing the two half-curves, as shown in Fig. 6(*a*).

(ii) We now turn to the construction of the minor curves which are in fact the bottom of the groove. The groove is $\frac{1}{2}$ in deep and so a construction circle 2 in dia. (the bottom of groove) should be drawn and divided into twelve equal parts. You can use the same twelve divisions of the pitch. Project the lines across to the right-hand view. At the intersections draw two curves in construction, as shown in Fig. 6(*b*).

(iii) To complete the drawing of the groove all that is necessary is to draw the curves in *firm* outline. Two things should be noticed. The *D* lines show continuous curves symmetrical with the major curve. The *E* lines illustrate the bottom groove and are therefore straight. A little shading (not too much) clearly shows up the shape of the groove, as Fig. 6(*c*).

2.5. A HELICAL SPRING (ROUND WIRE)

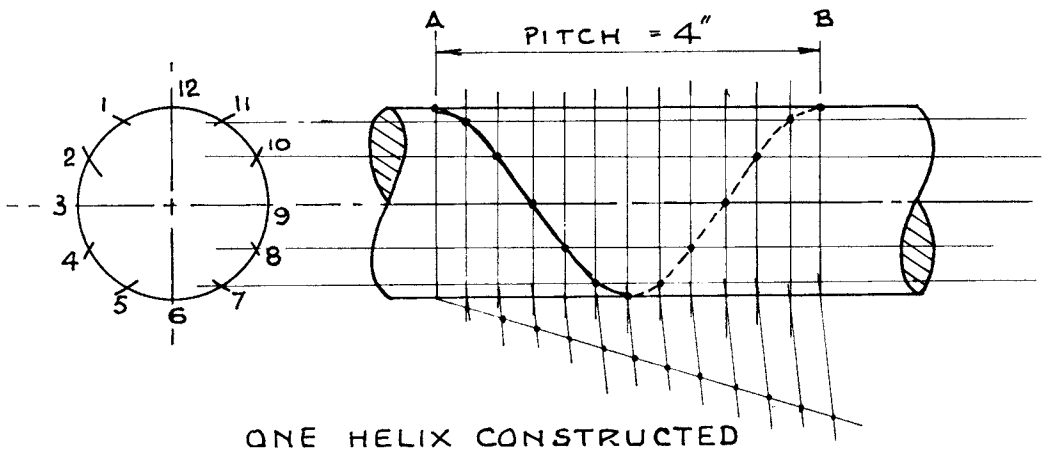
The spring we shall draw is made from round wire $\frac{1}{2}$ in dia. and wound right-hand into a helical spring $3\frac{1}{2}$ in O/D and 3 in pitch. We shall show two turns only.



TWO VIEWS OF CYLINDER

REFER 2.3 (i)

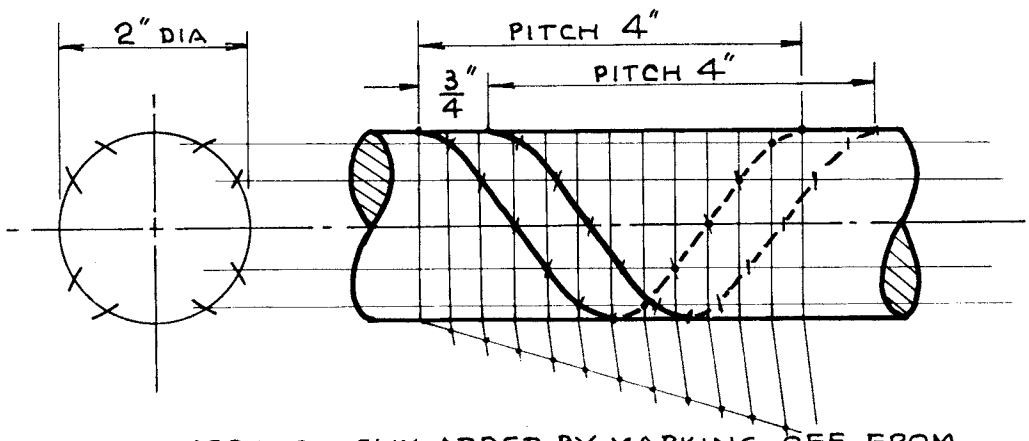
(a)



ONE HELIX CONSTRUCTED

REFER 2.3 (ii)

(b)



SECOND HELIX ADDED BY MARKING OFF FROM POINTS 1.2.3. ETC $\frac{3}{4}$" ALONG THE HORIZONTAL LINES.

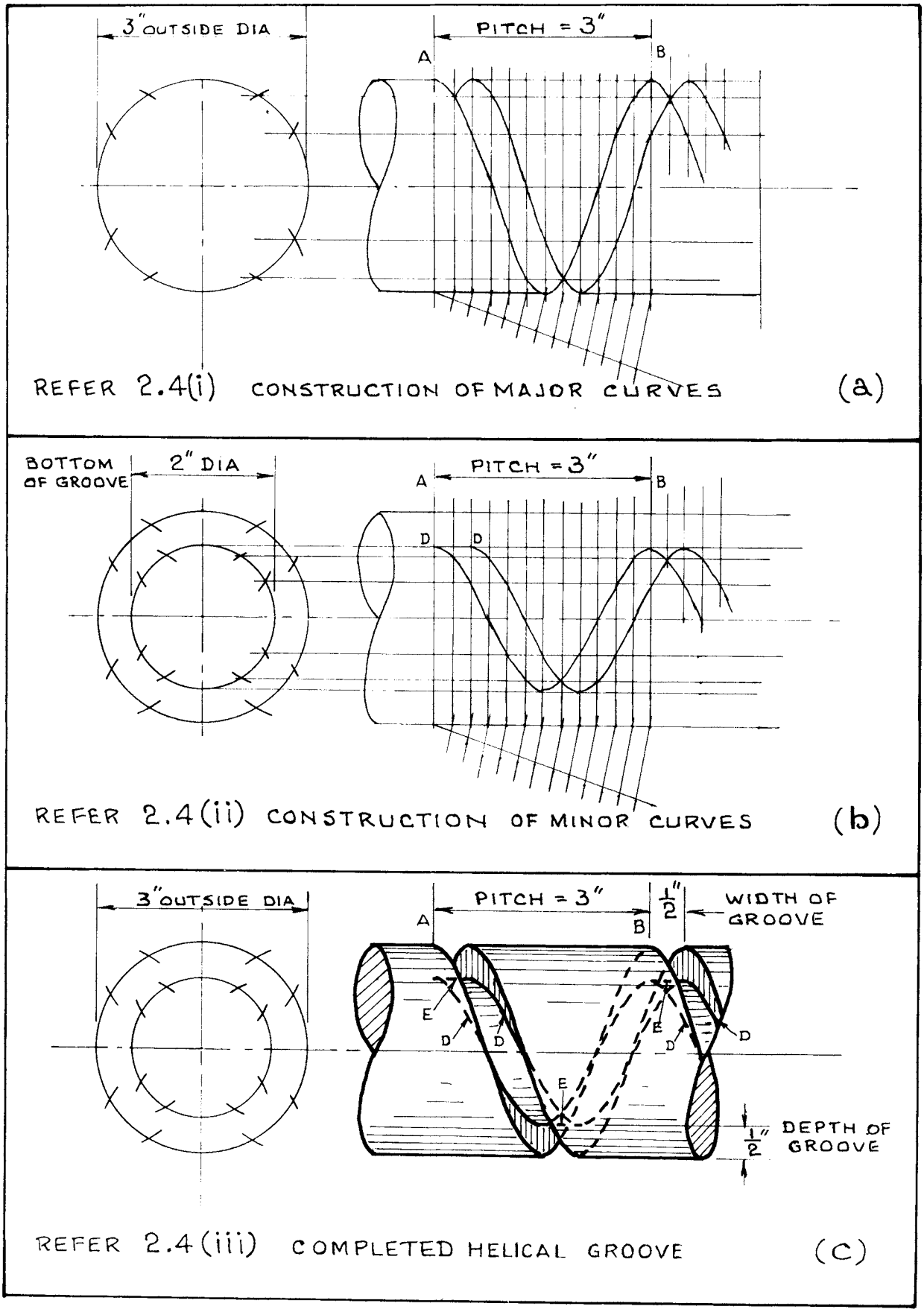
REFER 2.3(iii)

SECOND HELIX CONSTRUCTED

(c)

DOUBLE HELIX

FIG. 5



HELICAL GROOVE FIG 6

The construction is as follows:

(i) As the wire is $\frac{1}{2}$ in dia. the drawing of the spring is constructed on a mean dia. of 3 in. Draw a view showing the circle of mean dia. 3 in and a projected view from it showing twice the pitch (which means showing two turns). Divide the circle into twelve equal parts and the first 3 in pitch into the same number of parts. Project lines across and at the intersections mark off the points of the helix in the first 3 in pitch. With the compasses set at 3 in pitch mark off the second helix so that you now have two helices exactly alike. Do NOT draw any curves. (Fig. 7(*a*).)

(ii) Carefully draw on each of the marked centres a circle of $\frac{1}{2}$ in dia. (the dia. of wire) in thin construction. For two turns of the spring there will be twenty-five circles. (Fig. 7(*b*).)

(iii) Now draw lines touching the circles. For a right-hand turn you will show the $\frac{1}{2}$ in dia. section at the right-hand end of the coil (Fig. 7(*c*)). A little shading (not too much) will help to show the overlap on each coil.

2.6. A SQUARE THREAD

The square thread to be drawn is 3 in dia. and $\frac{1}{2}$ in square section. We shall draw only two full turns of a $\frac{1}{2}$ in square thread with a pitch of 1 in and a thread section of $\frac{1}{2}$ in by $\frac{1}{2}$ in.

To draw the thread, proceed as follows:

(i) Draw the end view of 3 in O/D and a circle of 2 in dia. which is the bottom of the thread. Mark off two and one-half complete pitches, i.e. five half-pitches or five times $\frac{1}{2}$ in to give at least two complete turns. Divide the circles into twelve and project the outer intersections across horizontally. Divide the first pitch only (1 in) into twelve equal parts by the easy division method. Draw the major curves in light outline through the intersections, as in Fig. 8(*a*), marking off the curves in the second pitch with compasses set at 1 in pitch.

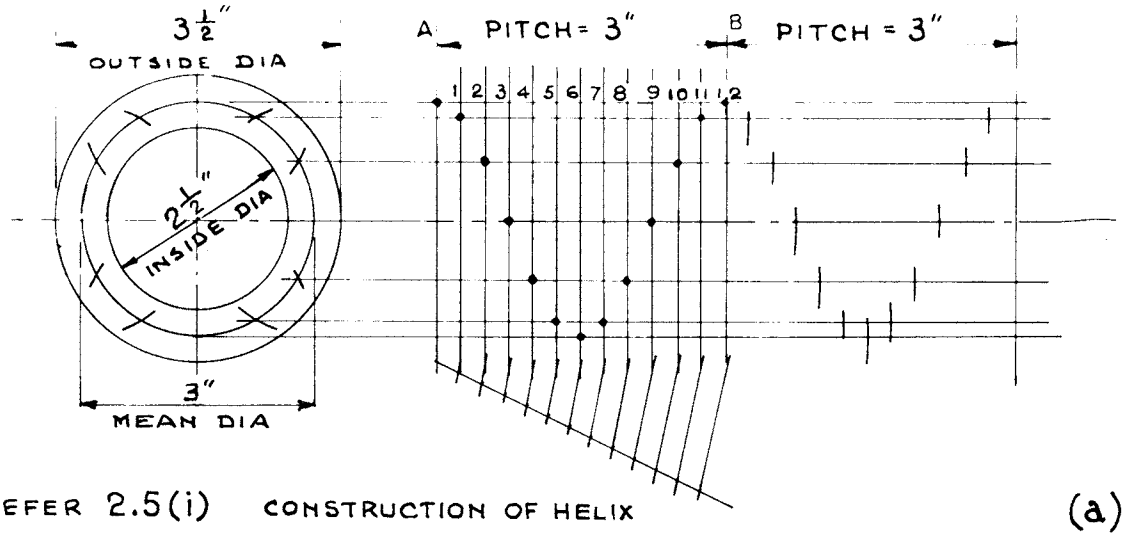
(ii) From the smaller circle project the inner intersections across horizontally. At the points where these lines intersect with the twelve vertical pitch lines, draw the minor curves in light outline, as in Fig. 8(*b*).

(iii) Now very carefully draw in firm outline the major and minor curves, omitting any hidden detail. A little shading, but not too much, will help to show up the shape of the thread (Fig. 8(*c*)). This thread should be repeated from the beginning at least twice. As an exercise draw a square thread 4 in O/D and $\frac{3}{4}$ in square section.

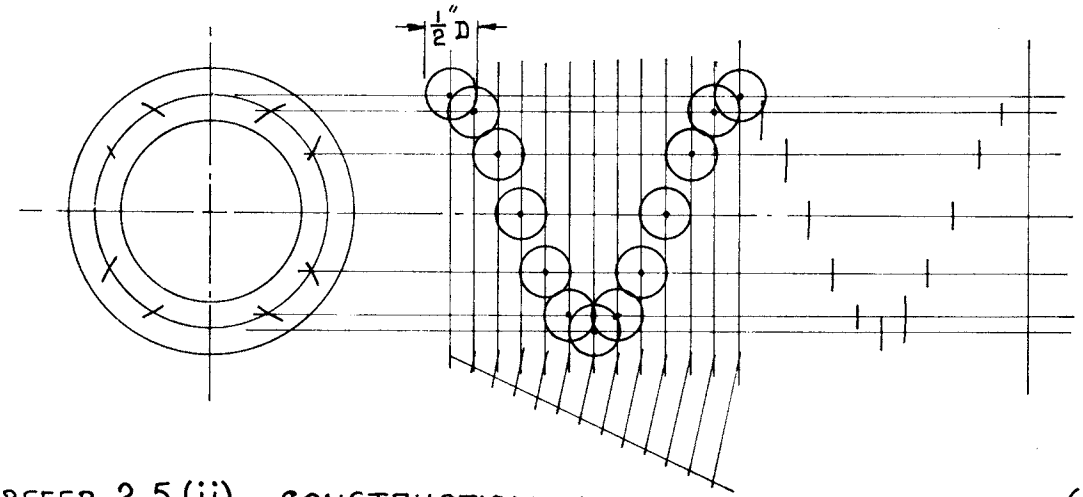
2.7. A HELICAL SPRING (SQUARE WIRE)

We will now draw two complete turns of a right-hand wound helical spring $3\frac{1}{2}$ in O/D, 3 in pitch, and $\frac{5}{8}$ in square section in the following order:

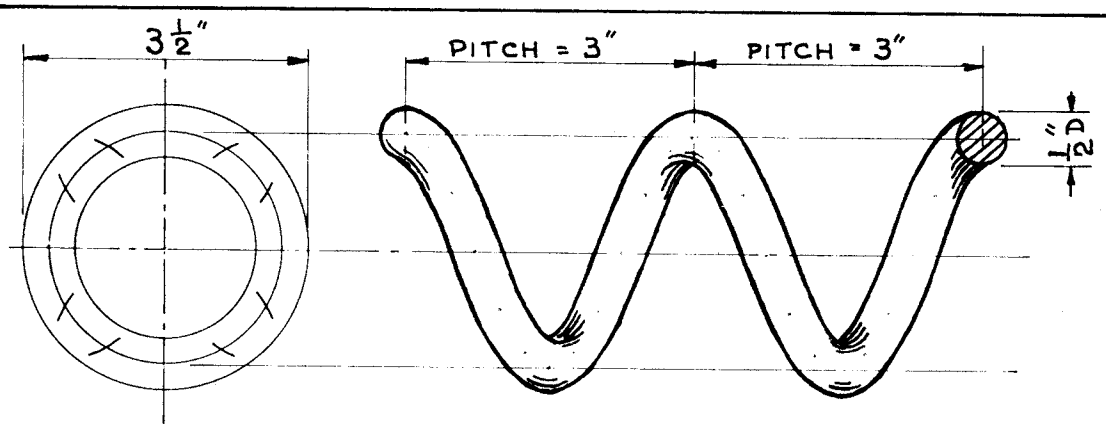
(i) Draw the end view, i.e. one circle $3\frac{1}{2}$ in O/D and one circle $2\frac{1}{4}$ in I/D ($3\frac{1}{2}$ in less twice the thickness of the spring). Divide the two circles into twelve equal parts and project only the larger circle intersections across horizontally (seven lines). Mark off two complete pitches of 3 in each. Divide the first 3 in pitch into



REFER 2.5(i) CONSTRUCTION OF HELIX (a)

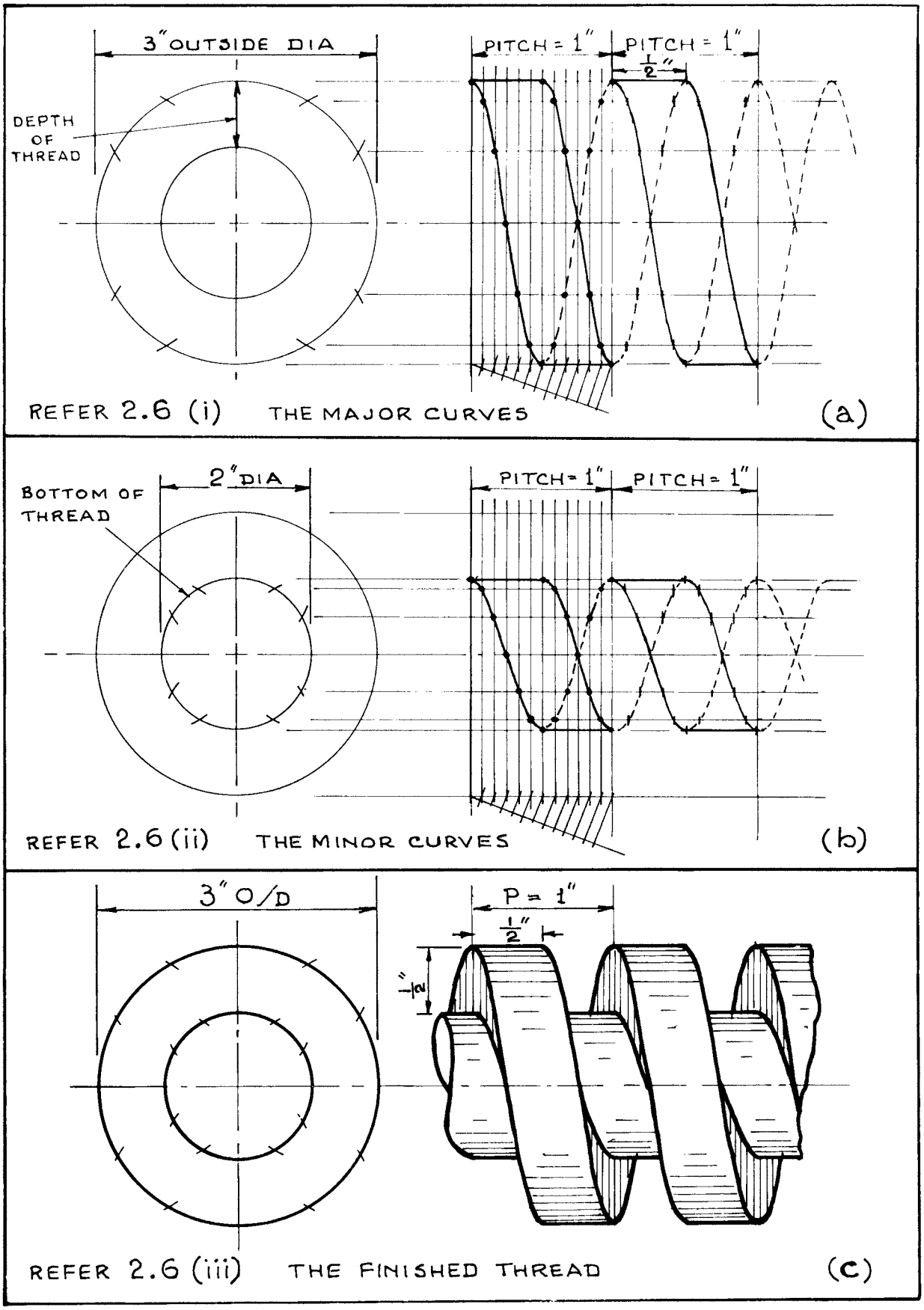


REFER 2.5(ii) CONSTRUCTION WITH CIRCLES (b)



REFER 2.5(iii) FINISHED SPRING (c)

HELICAL SPRING (ROUND WIRE) FIG. 7



1/2" SQUARE THREAD FIG. 8

twelve parts. Draw the major curves in *light outline* through the intersections, as in Fig. 9(*a*).

(ii) From the smaller circle project the inner intersections across horizontally (seven lines). At the points where these lines intersect with the twelve vertical pitch lines, draw the minor curves in *light outline*, as in Fig. 9(*b*).

(iii) Now very carefully draw in *firm outline* the major and minor curves and show the hidden detail. A little shading, but not too much, will help to show up the shape of the spring. (Fig. 9(*c*).)

2.8. THE ELLIPSE

The ellipse is the front elevation of a circle at any position between the vertical and horizontal planes when rotated about its horizontal axis. For convenience we will deal with ellipses whose major axes are approximately twice the minor axes. There are several ways of drawing an ellipse, and when drawn with compasses it is only approximate.

(i) *The Trammel Method. Fig. 10*

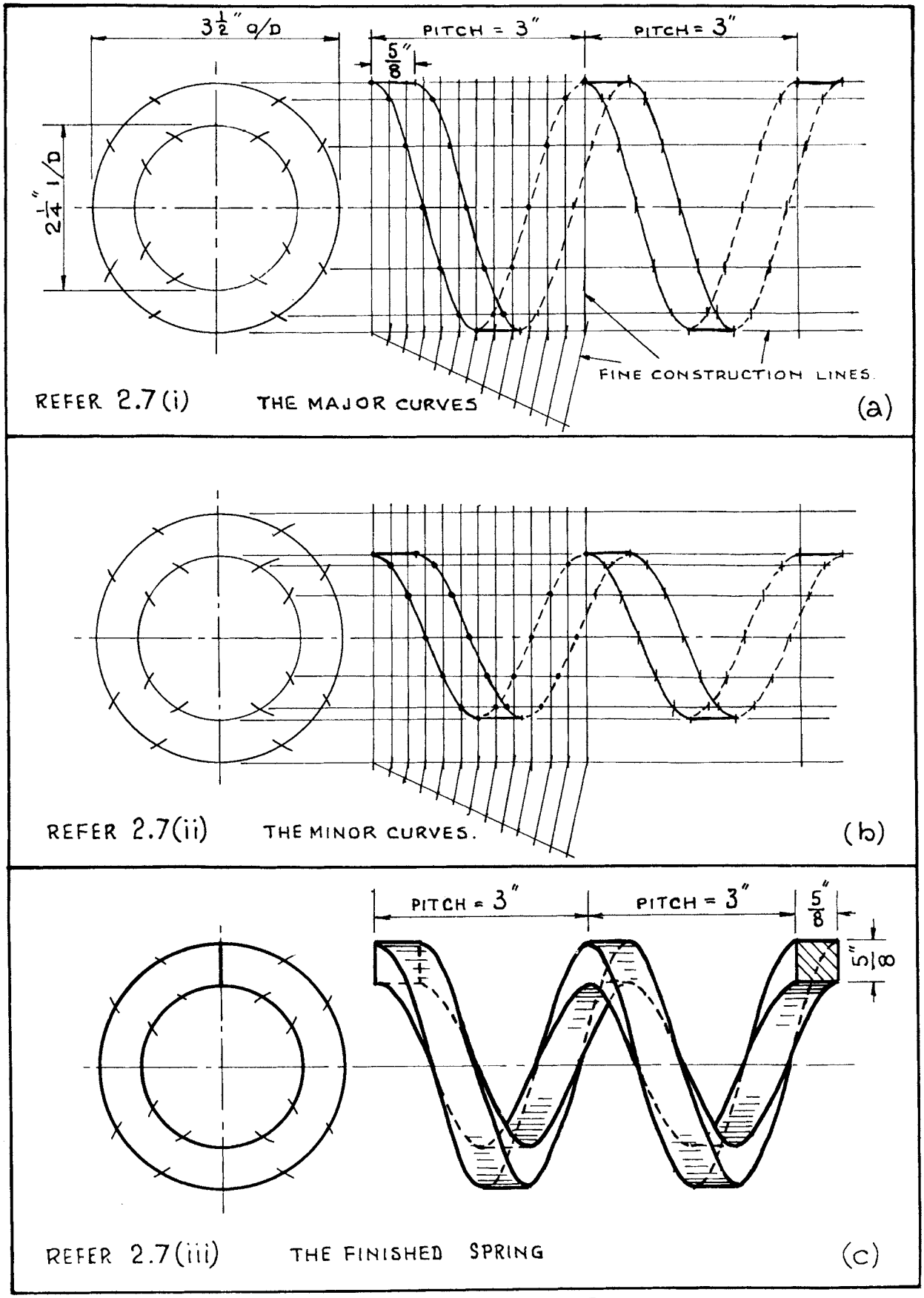
This is a reasonably accurate freehand method of drawing an ellipse. Mark off the minor axis *AB* (2 in) and the major axis *DC* ($3\frac{1}{2}$ in), as in Fig. 10(*a*). Cut a strip of paper or thin card 3 in by $\frac{1}{2}$ in. Mark on it half minor axis (*EF*) and half major axis (*EG*), as in Fig. 10(*b*). Place the trammel on the paper so that *E* is against *A*, and *F* against *O*. Rotate the trammel carefully to the left so that *F* and *G* are always touching the lines *OD* and *OB* respectively. Continue to make marks at *E* until *D* is reached. Repeat the marking for the other three-quarters. Draw a fair curve in firm outline, passing through each of the markings. (Fig. 10(*c*).)

(ii) *The String Method. Fig. 11(a)*

The method shown in Fig. 11(*a*) gives an orthodox shape, but it is difficult to produce an ellipse of definite size. Take a piece of string, or thread, and attach each end to a pin which is fixed into the paper. With a pencil held vertical to and also looped into the string, move the pencil carefully keeping the string taut. This will produce an ellipse of good shape but not necessarily the required exact size.

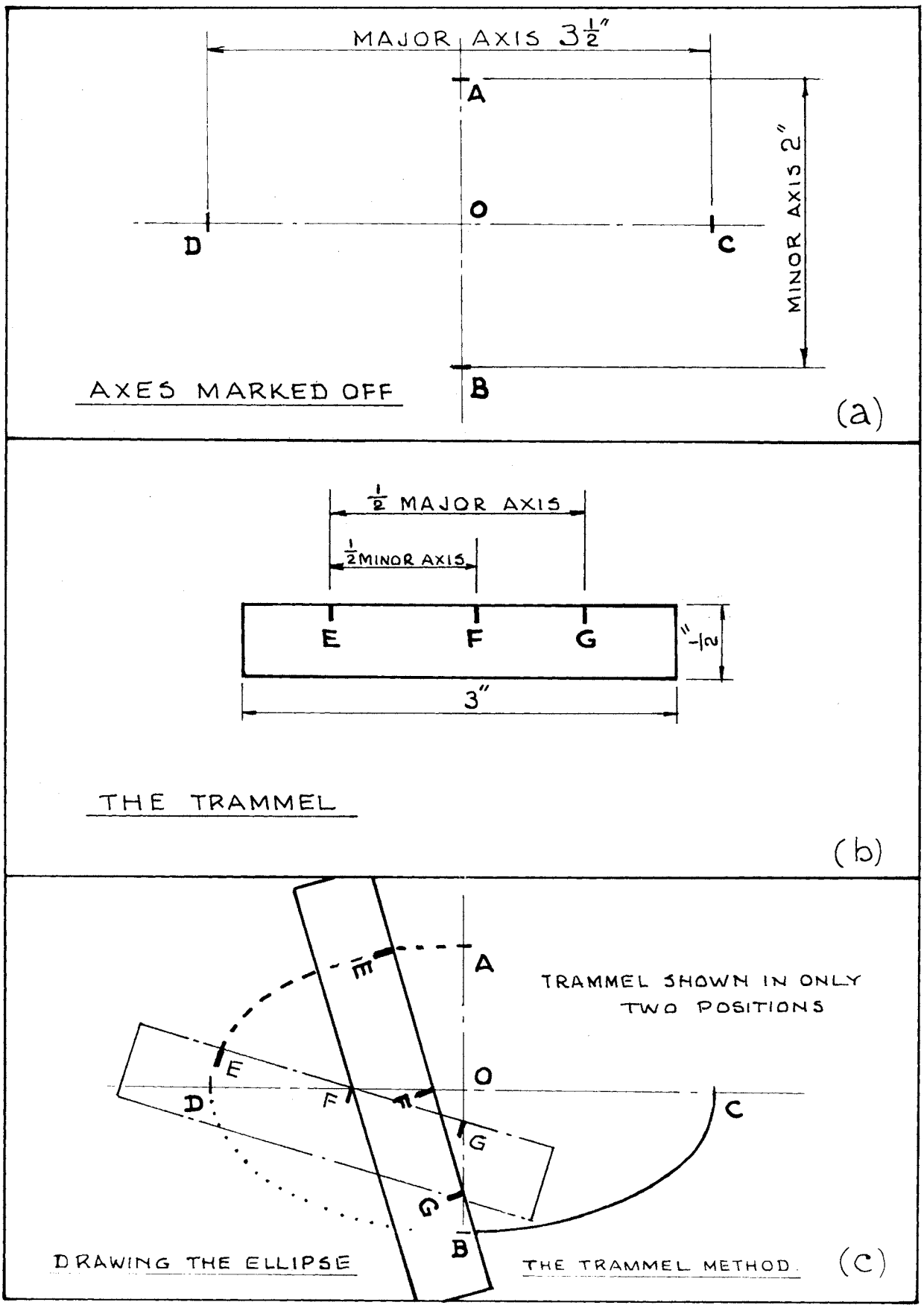
(iii) *The Circle Method. Fig. 11(b)*

The following method produces quite a good ellipse, but the result is again a freehand drawing. Draw two circles whose diameters are equal to the major and minor axes $3\frac{1}{2}$ in and 2 in, *DOB* and *AOC* respectively. Draw any number of radial lines at any angle. At the point where these lines touch the outer circle, draw a vertical line. Then draw a horizontal line from the point where the line crosses the smaller circle. Through all the points where verticals and horizontals intersect, draw a fair curve in firm outline (freehand). For clearness only one quarter *AOD* of the ellipse has been shown. The other three-quarters have been marked off in readiness for the curve to be drawn.

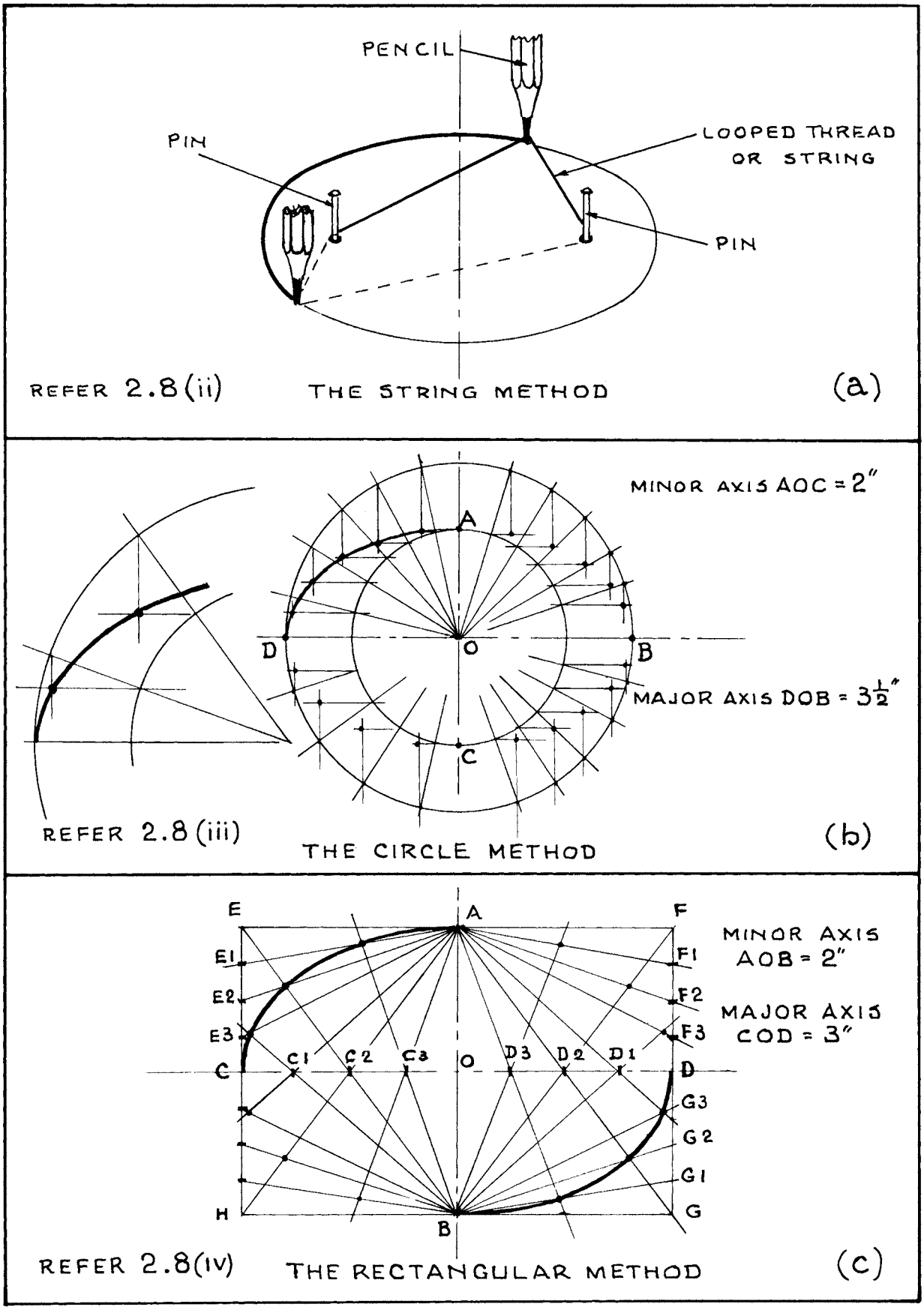


HELICAL SPRING. SQUARE WIRE

FIG. 9



REFER 2.8 (i) FIG. 10 THE ELLIPSE



THE ELLIPSE FIG. 11

(iv) *The Rectangular Method. Fig. 11(c)*

This is an easy way of drawing an ellipse, but again it is freehand. Draw the minor axis *AOB* and the major axis *COD* 2 in and 3 in respectively. Complete the rectangle *EFGH*. Divide the centre lines *OC* and *OD* each into a number of equal parts (say four). Divide the sides *EC*, *CH*, *FD*, *DG* into the same number of equal parts (say four). Draw lines from *B* through C^1, C^2, C^3, and from *A* through E^1, E^2, E^3. Draw lines from *A* through D^1, D^2, D^3, and from *B* through G^1, G^2, G^3. Through the intersections draw a fair curve in firm outline. Continue with the other two rectangles and finish the ellipse.

The rectangles *AFDO* and *BHCO* have been marked off ready for the ellipse outline.

(v) *Four Arc Method. Fig. 12(a)*

This drawing of an ellipse is only approximate but it can be drawn with compasses. Mark off *GOH* and *EOF*, the major and minor axes, 3 in and $1\frac{3}{4}$ in respectively. Draw the arc *GJ* with centre *O* and radius *GO*. Draw the arc *JP* with centre *E* and radius *JE*. Join *GE* through *P*. Bisect *GP* (notice that it is *GP* and NOT *GE*) and drop a perpendicular to pass through the vertical centre line *JF* at *K* and the horizontal centre line at *L*. Mark off *ON* equal to *OL* and *OM* equal to *OK*. With centre *L* and radius *GL* draw an arc through *G*. Repeat the same arc through *H* with radius *NH*. With centre *K* and radius *EK* draw an arc through *E*. Repeat the same arc through *F* with radius *MF*. Join the arcs freehand to form an approximate ellipse.

(vi) *The Isometric Ellipse. Compasses Method. Fig. 12(b)*

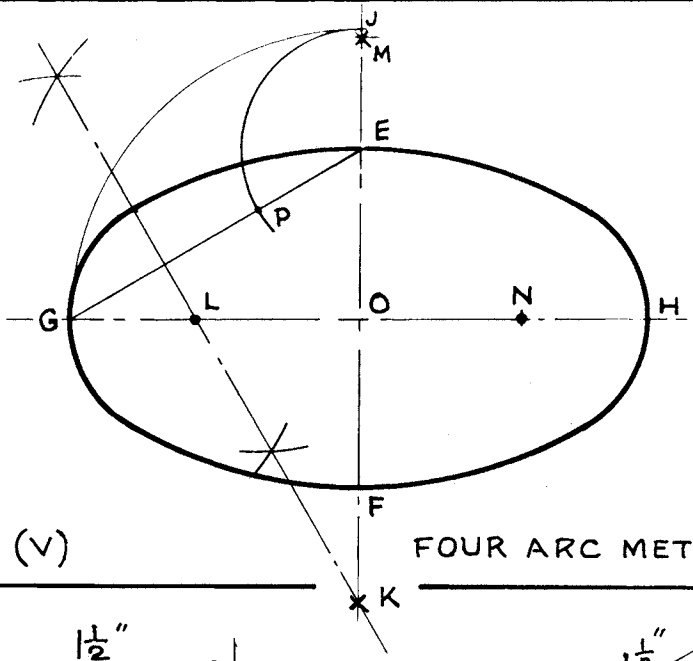
When making an isometric drawing of an object it is often necessary to include a projection of a complete circle or part of a circle. When this occurs it will be necessary to draw an ellipse or part of it. One method of drawing this is with compasses in the following way:

First, draw a circle $1\frac{1}{2}$ in dia. inside a $1\frac{1}{2}$ in square. Then isometrically project the square *ABCD* with sides $1\frac{1}{2}$ in long. Remember that measurements are made along the lines and that the base lines are at 30° to the normal horizontal. Draw all the lines *CA*, *BD*, *EF*, and *HG*. Now join *EB* and *DF*. The line *EB* crosses *CA* at *J*. With centre *J* and radius *EJ* draw an arc. The line *DF* crosses *CA* at *K*. With centre *K* and radius *KF* draw an arc. With centre at *B* draw an arc with radius *EB*. With centre at *D* draw an arc with radius *FD*. All four arcs should meet continuously with a firm outline.

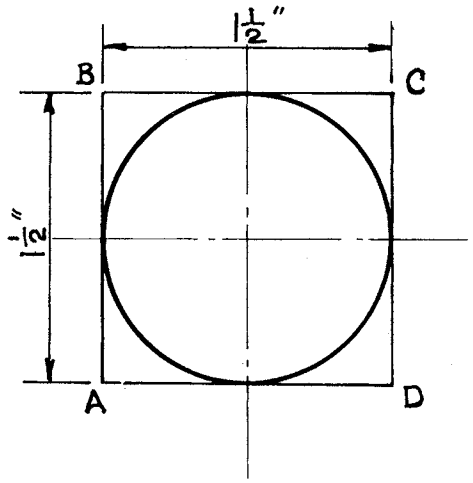
This method is only approximate, but is very useful in isometric projection because compasses can be used for the outline.

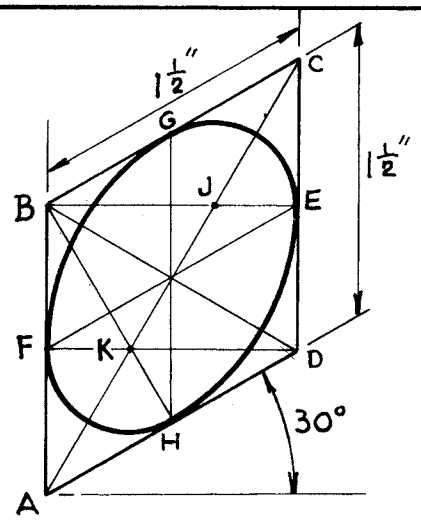
(vii) *The Isometric Ellipse. Freehand Method. Fig. 12(c)*

The following method gives a good shape with the outline drawn freehand. First draw a circle $1\frac{1}{2}$ in dia. and show the horizontal and vertical centre lines

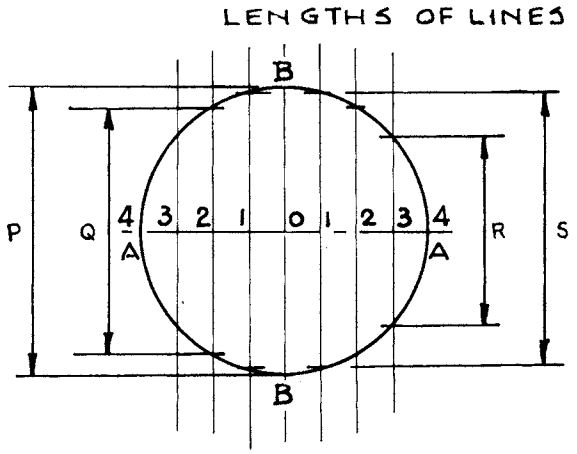


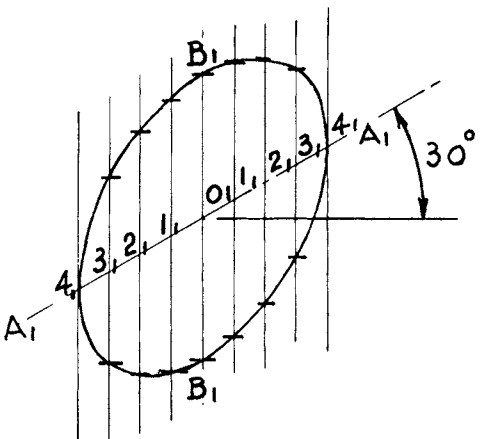
REFER 2.8 (V) FOUR ARC METHOD (a)





REFER 2.8 (vi) ISOMETRIC ELLIPSE - COMPASS METHOD (b)





REFER 2.8 (vii) ISOMETRIC ELLIPSE - FREEHAND METHOD (c)

THE ELLIPSE FIG. 12

AA and BB respectively. Now divide each half into four equal parts and mark them 1, 2, 3, 4. Letter the length of each line P, Q, R, S. For the right-hand view draw a line A_1A_1 at 30° to the horizontal. In the centre of this line draw a vertical centre line B_1B_1, $1\frac{1}{2}$ in long. Divide A_1A_1 into four equal parts each side of the line B_1B_1 and number them 1_1, 2_1, 3_1, 4_1. Draw vertical lines through each of the divisions and mark them off at lengths corresponding with P, Q, R, S in the left-hand view. Each length will be bisected by the line A_1A_1. These lengths should be transferred with compasses. Draw a fair curve through the marked points. This curve should be drawn carefully in firm outline.

Note: You can divide both views into a larger number of equal parts if you require an outline which is easier to draw.

3. *Interpenetration of Solids*

THIS chapter will deal with drawings of solid objects such as prisms, pyramids, cylinders, and cones. We shall deal also with curves of intersection of these solid objects with planes at various angles.

3.1. SIMPLE RECTANGULAR OBJECTS

The first drawing we shall make is of a rectangular object shown in Fig. 13(*a*). Draw this in first angle projection and in thin construction lines. In Fig. 13(*b*) we have removed the upper portion so that the object now has a height of $1\frac{1}{2}$ in slanting to 1 in. Draw the three views in outline. You will notice that the plan remains unchanged and the view in direction of arrow shows the sloping surface. In Fig. 13(*c*) we have a different shape in the elevation. Draw the three views in outline. This time the view in the direction of the arrow is exactly the same as in Fig. 13(*b*) but the plan has now changed because we show a line where the two planes meet. The last elevation, Fig. 13(*d*), shows two sloping faces in the elevation joined by a vertical face. Although there are three faces the plan remains the same as in Fig. 13(*c*). Draw the three views in outline. You will notice that whereas the plan remains unaltered the end elevation is considerably altered.

3.2. HEXAGONAL PRISMS

When drawings are made of hexagonal shapes it is easy if one knows the "distance across flats", as in Fig. 14(*a*).

(i) *How to Draw a Hexagon. Fig. 14(a)*

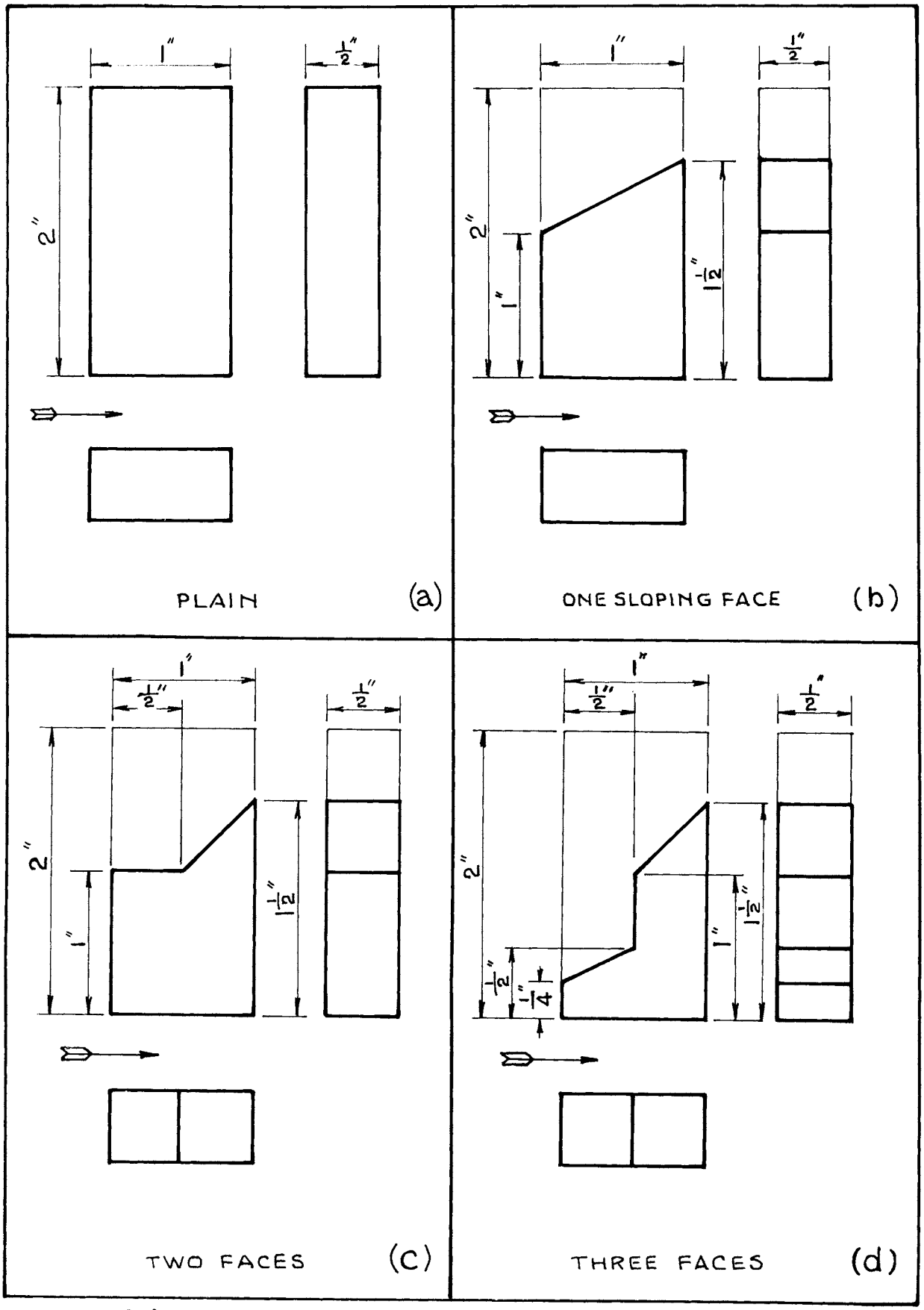
There are two ways of illustrating a hexagon: (1) with corners horizontal, and (2) with corners vertical. In both cases start by drawing a circle with a diameter equal to the distance across the flats of the hexagon. In this case we will draw the circle 2 in dia.

In (1) we will draw six lines at a tangent to the circle using the 60° set square. This will produce a hexagon with corners horizontal.

In (2) we will draw six lines at a tangent to the circle using the 30° set square. This will produce a hexagon with corners vertical.

(ii) *Hexagonal Prism. Corners Horizontal. Fig. 14(b)*

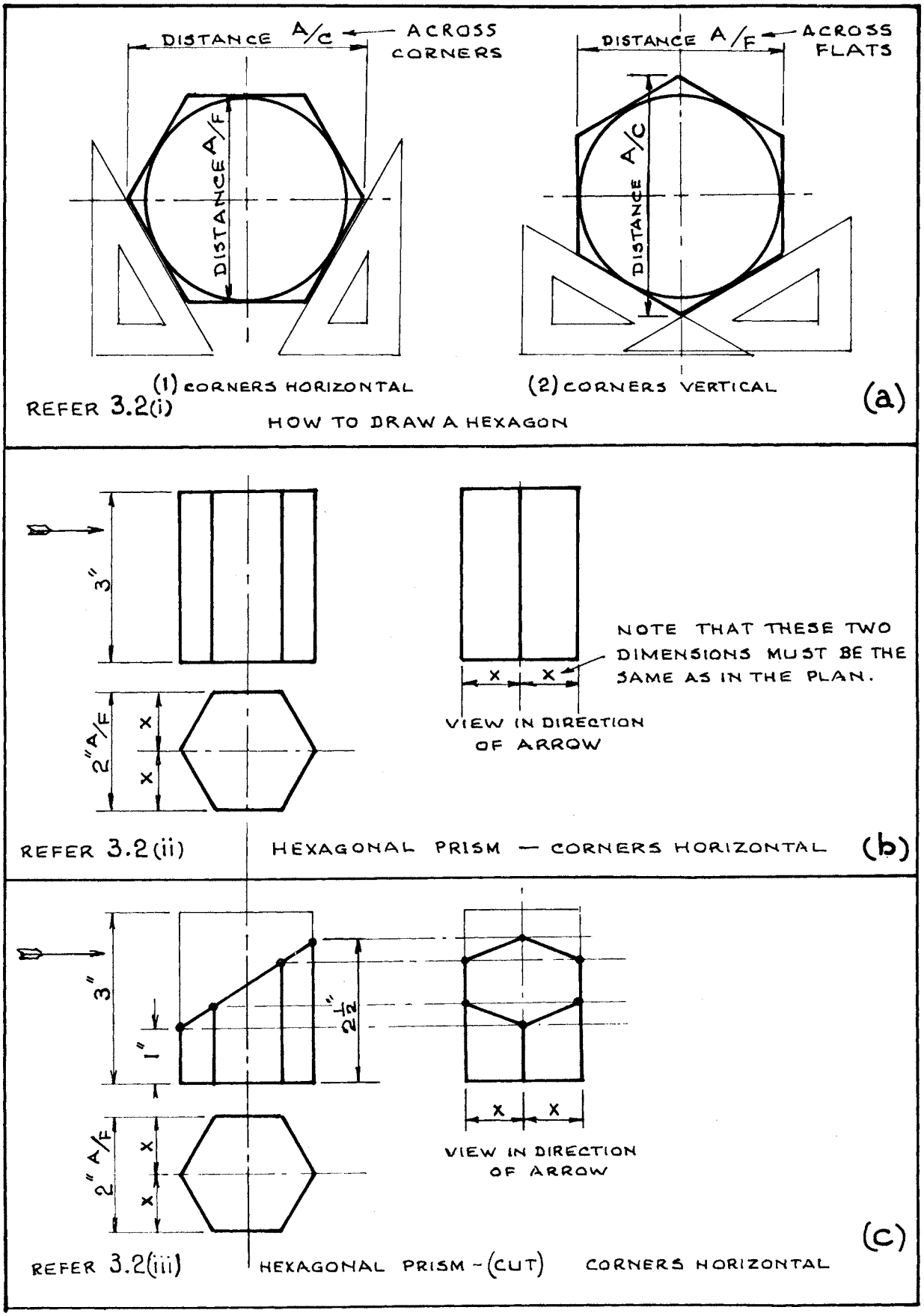
Consider a hexagonal bar standing on one end and we are to draw three



REFER 3.1

FIG. 13

RECTANGULAR OBJECTS
INTERPENETRATION



HEXAGONAL PRISMS FIG. 14 INTERPENETRATION

views: front elevation, side elevation, and plan (corners horizontal). The hexagon is 2 in across flats (A/F) and the height of prism is to be 3 in. The plan must be drawn first, allowing space of 3 in plus a space between views. After drawing the plan project the four corners vertically and draw the front elevation. Project the side elevation making sure that only two faces *XX* are seen in this view.

(iii) *Hexagonal Prism (Cut). Corners Horizontal. Fig. 14(c).*

In fine construction lines, re-draw the prism shown in Fig. 14(*b*). At points 1 in and $2\frac{1}{2}$ in a line is drawn. At the four intersections project lines horizontally to the side elevation. Notice the shape of the sloping face in this view.

(iv) *Hexagonal Prism (Cut). Corners Horizontal. Fig. 15(a)*

Draw three views of the prism shown in Fig. 15(*a*). You must draw the plan first and project the front elevation to show three faces and the side elevation to show only two faces which are measured across the flats in the plan. Draw this in thin construction lines. Notice the shape of the cut surface in the plan and the two lines showing where the three planes meet.

(v) *Hexagonal Prism (Cut). Corners Vertical. Fig. 15(b)*

In this example, the plan has been turned through 90° and is drawn as in Fig. 14(*a*)(2). You must again draw the plan first and project the front elevation to show only two faces. Do this in thin construction lines. Letter the six faces in the plan *A*, *B*, *C*, *D*, *E*, *F*. Now project the side elevation and show the three faces *A*, *B*, *C* which are measured across corners from the plan. Draw the sloping line and complete the front elevation in outline. Project the three points of intersection to the side elevation and complete the outline as shown.

(vi) *Hexagonal Prism (Cut). Corners Vertical. Fig. 15(c)*

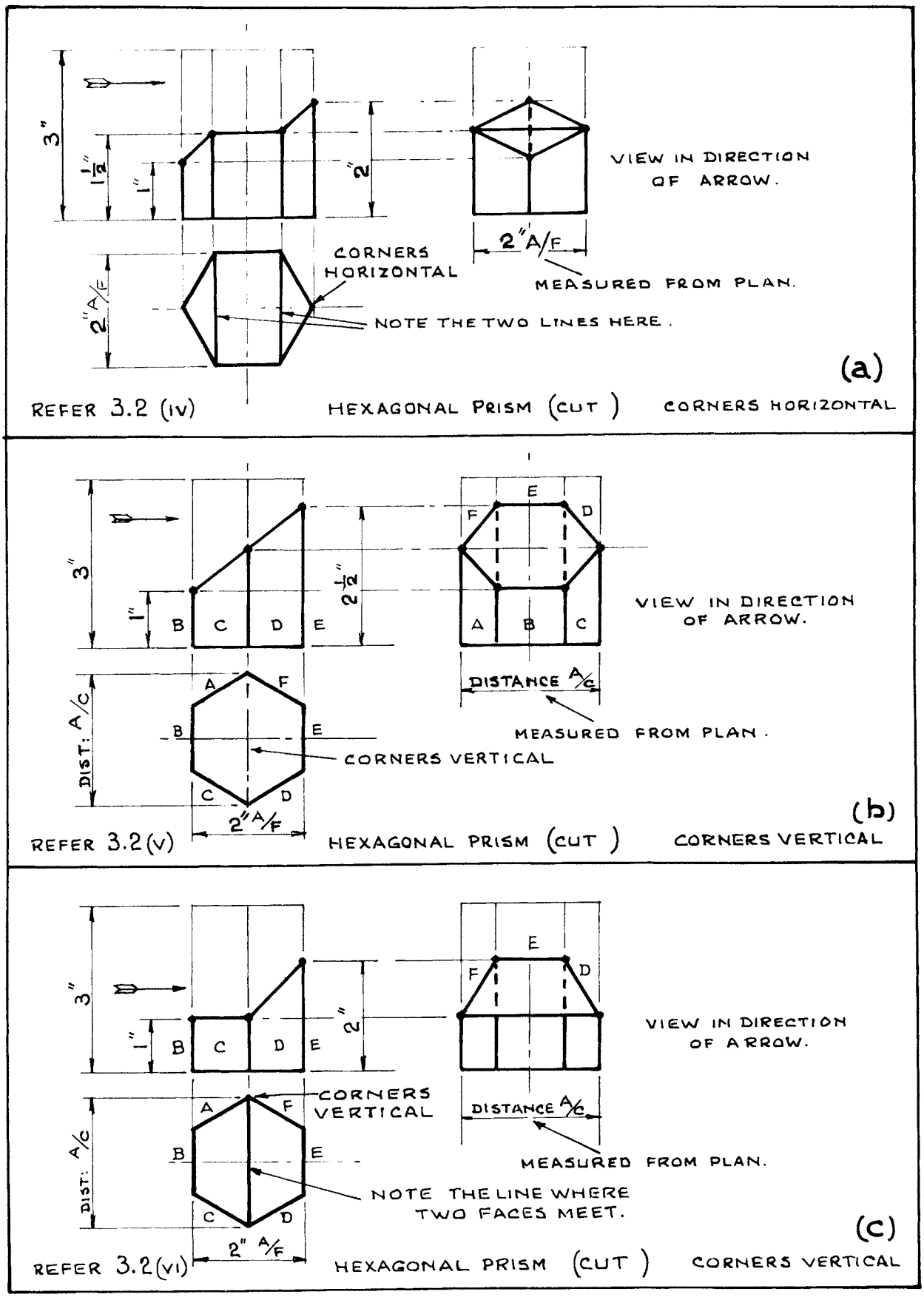
Draw the plan and front elevation in outline. Notice that as there are two planes in the elevation they produce a line in the plan. Letter the six faces in the plan *A*, *B*, *C*, *D*, *E*, *F*. Project the side elevation and complete this in outline as shown in Fig. 15(*c*). Notice the line in the plan which divides the two faces.

3.3. SQUARE PYRAMIDS

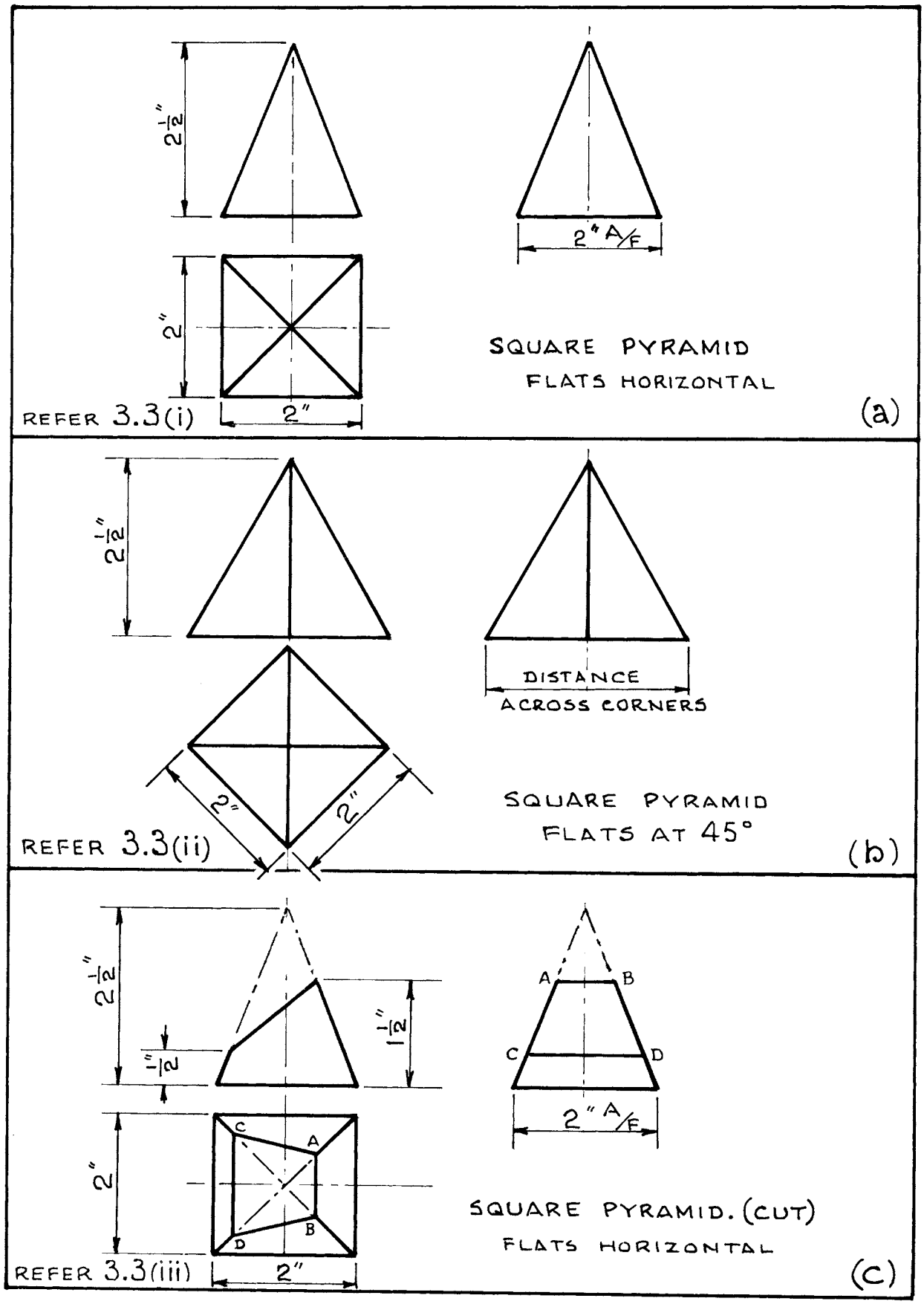
A square pyramid is an object with a square base and joined by four triangular faces each of the same area.

(i) *Square Pyramid. Flats Horizontal. Fig. 16(a)*

When drawing a square pyramid the plan is a square with diagonal lines illustrating the four sloping faces. Projected from the plan is the front elevation. The end view is projected from the front elevation and is exactly the same shape.



HEXAGONAL PRISMS — FIG. 15 — INTERPENETRATION



SQUARE PYRAMID FIG. 16 INTERPENETRATION

(ii) *Square Pyramid. Flats at 45°. Fig. 16(b)*

When the same square pyramid is drawn with the front elevation "across the corners", the plan becomes a square, drawn with the flats at 45° to horizontal. The end view is projected from the front elevation, and is exactly the same shape.

(iii) *Square Pyramid (Cut). Flats horizontal. Fig. 16(c)*

The pyramid in this figure is drawn to the same dimensions as Fig. 16(*a*) but the upper portion has been removed at an angle. Projecting the side elevation, the sloping face becomes two straight lines *AB* and *CD*. Continuing with the plan, the ends of the sloping face become two lines, *AB* and *CD*, joining the diagonal lines. To complete the plan we only have to draw *AC* and *BD*. The completed drawing should look like Fig. 16(*c*).

(iv) *Square Pyramid (Cut). Flats at 45°. Fig. 17(a)*

Draw the pyramid in construction as Fig. 16(*b*) and remove the upper part as shown in the elevation at *DC*. When projecting the side elevation notice that the edges of the upper two faces slope up to the centre line at *C* and the edges of the other two faces slope down to the centre line at *D*. To show the sloping face in the plan you can project point *D* and point *C* directly from the front elevation. The distance *AB* must be measured from the side elevation and marked off on the plan. Now in outline draw the square, the lines joining *ABCD* and the four short diagonal lines. Show the sloping face by thin section lines at 45° in one direction. Your completed drawing should look like Fig. 17(*a*).

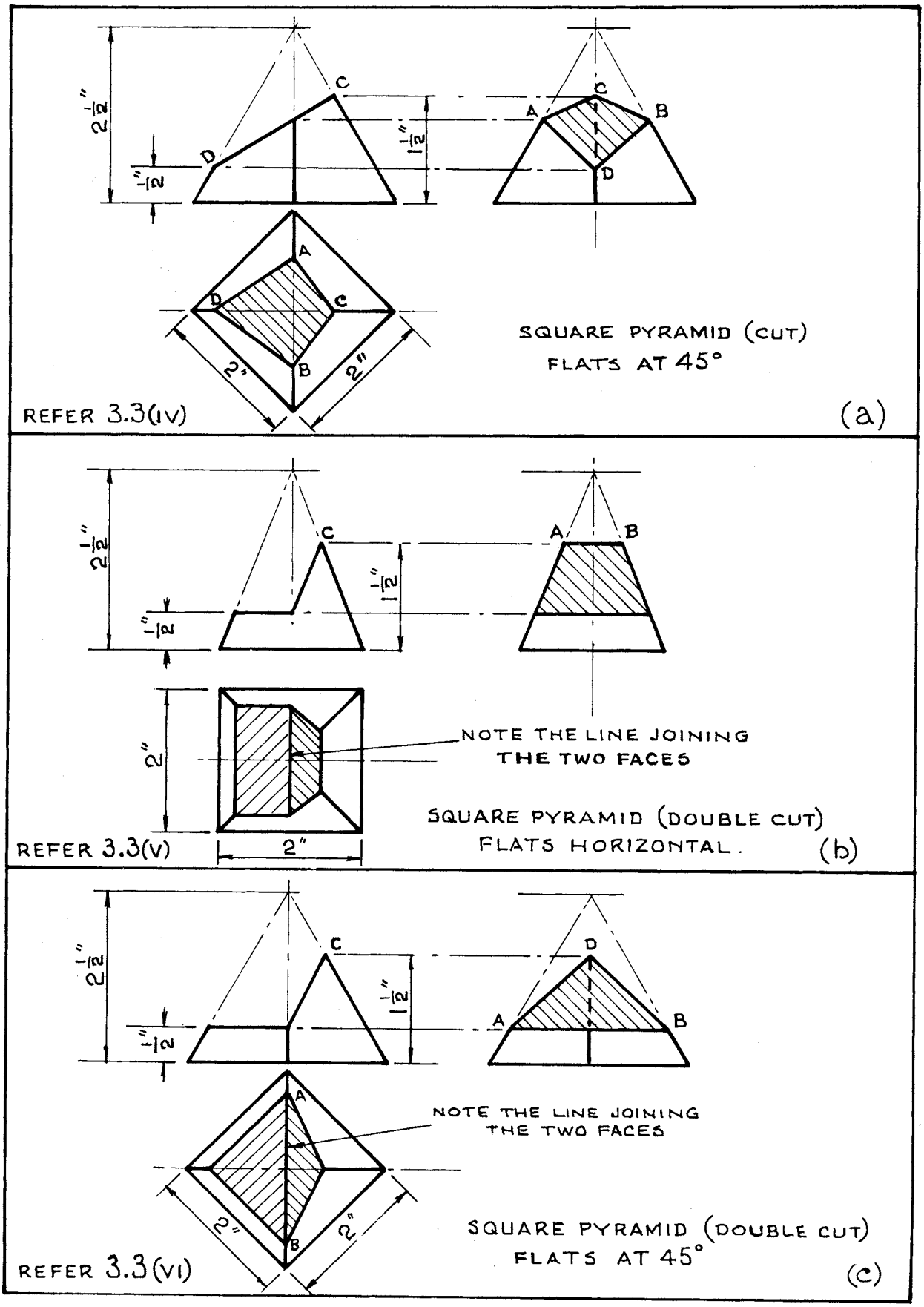
It must be remembered when drawing cut pyramids that: when the "flats are horizontal" then the highest point on the sloping surface becomes a straight line in the side elevation; when the "flats are at 45°" then the highest point on the sloping surface becomes a point on the centre line of the side elevation.

(v) *Square Pyramid (Double Cut). Flats horizontal. Fig. 17(b)*

The pyramid drawn here in construction is to the same dimensions as Fig. 16(*a*) but the upper portion has been removed to leave one-half horizontal face and one-half sloping face, as in the front elevation. This will be very straightforward if you remember that the highest point *C* becomes a straight line *AB* in the side elevation, and also that the horizontal face in the elevation produces, in the plan, a rectangle, with three sides equidistant from the outline of the square base. Note that in the plan the two cut faces are joined by a straight line and section-lined at 45° in two directions. The completed drawing should look like Fig. 17(*b*).

(vi) *Square Pyramid (Double Cut). Flats at 45°. Fig. 17(c)*

The pyramid drawn here in construction is to the same dimensions as Fig. 16(*a*) but the upper portion has been removed to leave one-half horizontal face and one-half sloping face as in the front elevation. The highest point *C* in the



SQUARE PYRAMID FIG. 17 INTERPENETRATION

front elevation becomes a point D on the centre line of the side elevation. The distance AB should be measured on the side elevation and marked off on the plan. The horizontal face in the elevation produces, in the plan, a triangle with two sides equidistant from the outline of the square base.

Note that in the plan the two cut faces are joined by a straight line and section-lined at 45° in two directions.

3.4. AUXILIARY VIEWS AND TRUE SHAPES

An auxiliary view is one projected from the front elevation (not in the positions occupied by the side elevation or the plan) to illustrate more clearly some important feature not seen in the other views. It so happens that the important feature is usually a face whose true shape is required.

(i) *Auxiliary Views and Projected True Shapes. Fig. 18(a)*

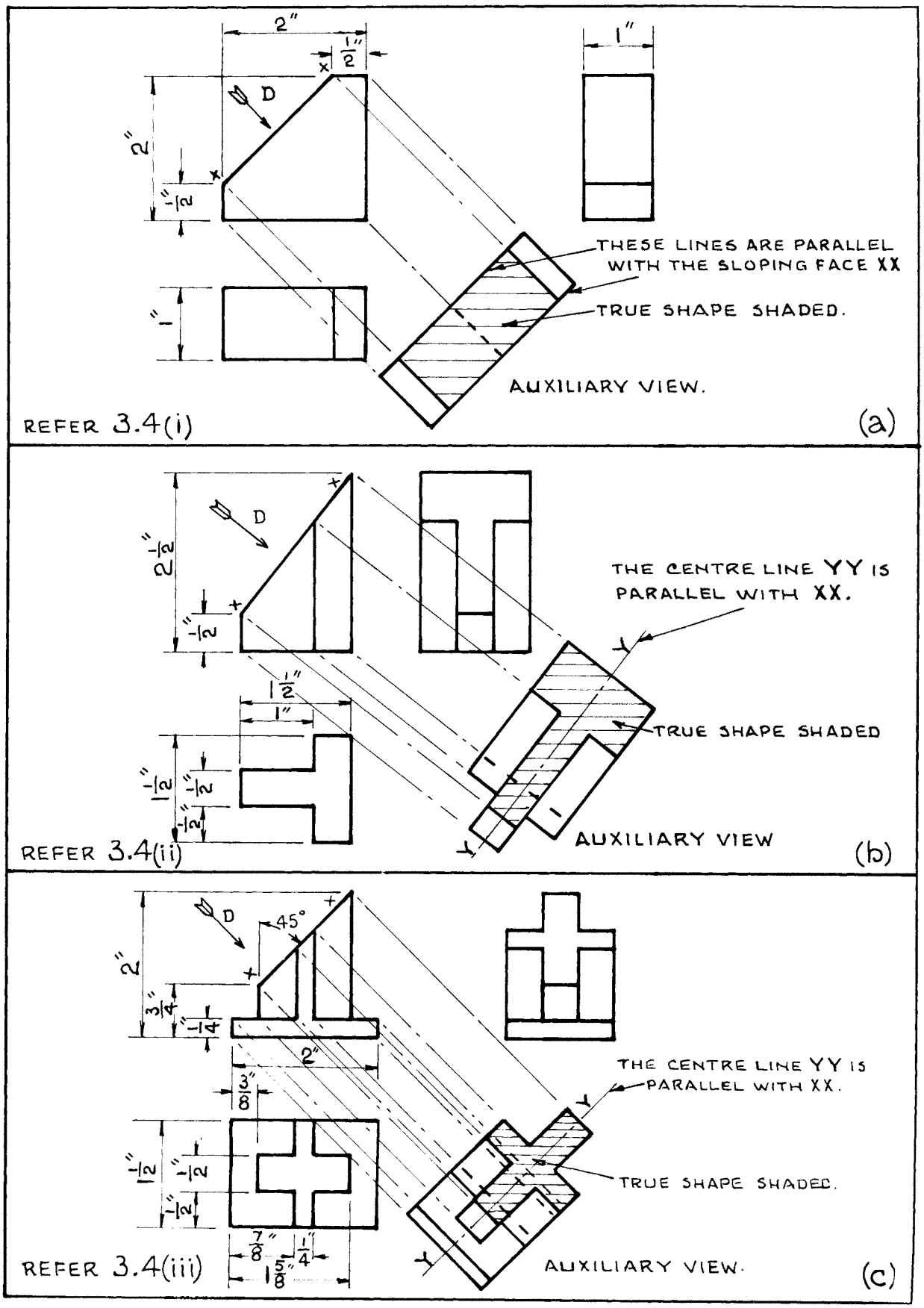
To explain this point more fully let us first draw the front elevation, plan and side elevation to dimensions shown in Fig. 18(*a*). An auxiliary view can be projected from any viewpoint. However, the "true shape" of the sloping face can only be shown when projected perpendicularly, as shown by the shaded portion in the auxiliary view in Fig. 18(*a*). This is projected in the direction of the arrow D in first angle projection. The point to remember here is that the projected view is drawn parallel to the sloping surface.

(ii) *Auxiliary View and True Shape. Fig. 18(b)*

The object in Fig. 18(*b*) is a T-shaped section with a sloping face. We are to draw a true shape of the sloping face and at the same time an auxiliary view. First, draw the three views, front elevation, plan, and side elevation, as in Fig. 18(*b*). Now project from arrow D each corner and intersection and build up the view on a centre line YY which is parallel with the sloping surface XX. As the view is built up you will naturally see the difference between the true shape (the shaded portion) and the complete auxiliary view.

(iii) *More difficult Auxiliary View and True Shape. Fig. 18(c)*

The object in Fig. 18(*c*) is more difficult and great care must be taken in projecting from arrow D the true shape and auxiliary view on to a centre line parallel with the sloping face. The three views, front elevation, plan, and side elevation, must be drawn first. After drawing a centre line YY parallel with the sloping surface XX, project lines from all the corners and intersections and build up the auxiliary view making the width $1\frac{1}{2}$ in, the same as the plan. When the outline is complete, the true shape of the sloping surface should be lightly shaded. The finished view should look like Fig. 18(*c*).



AUXILIARY VIEW FIG. 18 INTERPENETRATION

3.5. HEXAGONAL PRISMS

(i) *Hexagonal Prism. Corners Horizontal and True Shape. Fig. 19(a)*

We return once again to the hexagonal prism, but in this case we draw an extra view, the true shape (not the auxiliary view). Draw the three views, front elevation, plan and side elevation, as Fig. 19(*a*), constructing them as shown in Fig. 14(*c*) (i.e. with corners horizontal and distance A/F equal to $1\frac{1}{2}$ in). Continuing the drawing, only the true shape will be added and this is constructed on the centre line *YY* which is parallel with the sloping face *XX*. Project the corners and intersections from arrow *D* (first angle projection).

(ii) *Hexagonal Prism. Corners Vertical and True Shape. Fig. 19(b)*

In this drawing the dimensions are similar to section 3.5(i) but the front elevation is projected after constructing the plan with corners vertical. This construction should be drawn as instructed and as in Fig. 15(*b*). As in section 3.5(i), we shall only add the drawing of the true shape of the sloping surface on the centre line *YY*. The view should be shaded and the result should look like Fig. 19(*b*).

(iii) *Hexagonal Prism. Corners Vertical. True Shape and Auxiliary View. Fig. 19(c)*

The prism shown in Fig. 19(*c*) is slightly different from Fig. 19(*b*) but the plan still has the corners vertical.

Construct the three views as shown, and project from arrow *D* the true shape of the sloping surface on to the centre line *YY*, which should be parallel with *XX*.

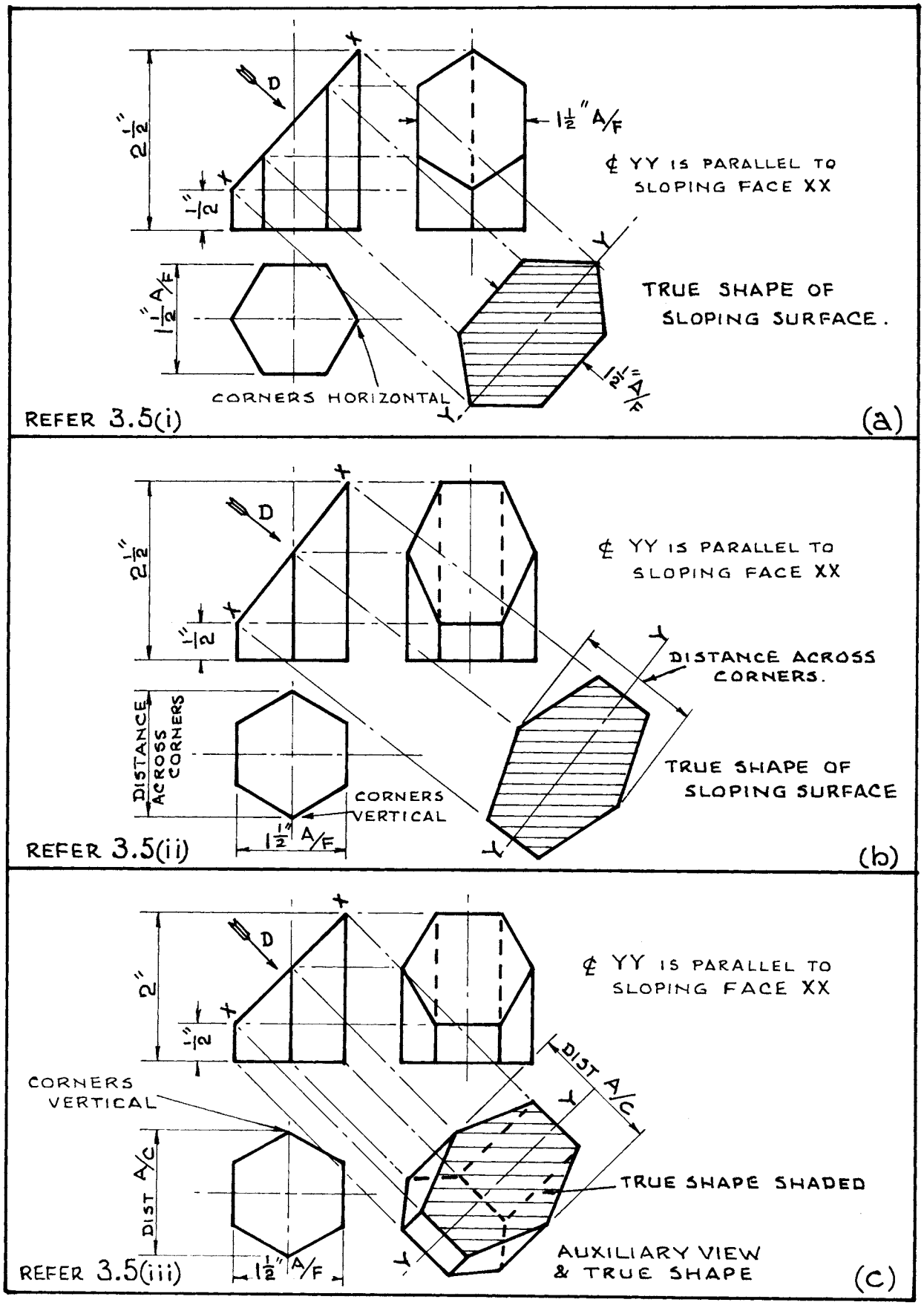
Now project the remainder of the corners and intersections and construct the lower part of the view. Notice particularly the hidden detail behind the true shape. The view should be shaded and the result should look like Fig. 19(*c*).

3.6. HEXAGONAL PYRAMIDS

(i) *Hexagonal Pyramid. Corners Horizontal. Fig. 20(a)*

Construction of the three views of the hexagonal pyramid needs a brief explanation. Figure 20(*a*) shows the plan with corners horizontal. First, draw the plan, leaving sufficient space to project the elevation above it, by drawing a circle 2 in dia. and around this a hexagon with corners horizontal, as shown in Fig. 14(*a*)(1). Add the six radial lines showing where the six sloping faces meet.

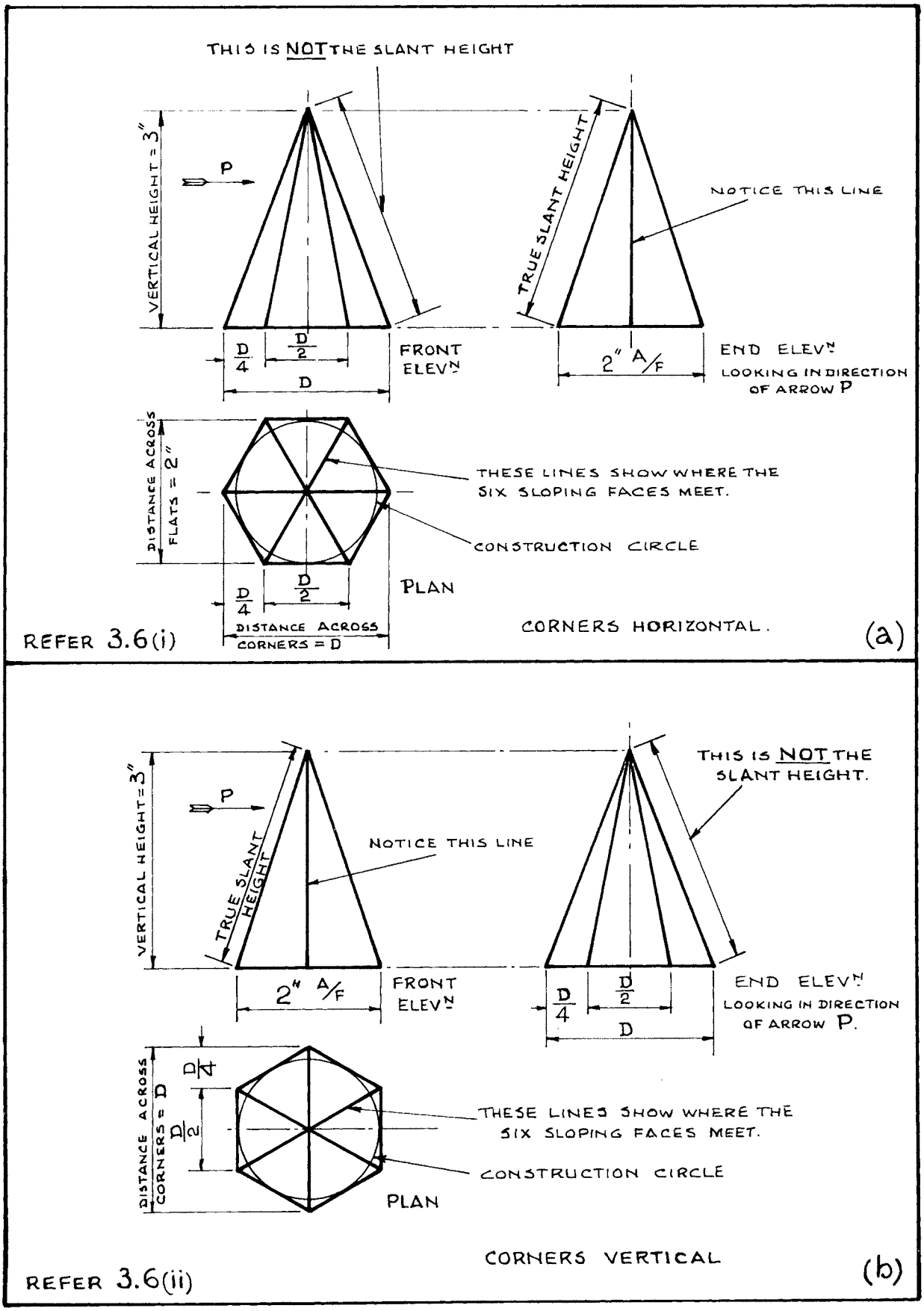
For the front elevation, using fine construction lines, project from the plan a view showing three faces to the proportions given in Fig. 20(*a*). Notice that the height 3 in is measured on the vertical centre line. From the front elevation, project in fine construction lines a view looking in the direction of arrow *P*. This view will show only TWO faces joined by a line. The width of this view is taken from the plan and is the distance across the flats, 2 in. In this view you will see that the slant height is the distance along a FLAT face and not along a corner edge in the front elevation.



HEXAGONAL PRISM AND TRUE SHAPE

FIG. 19

INTERPENETRATION



HEXAGONAL PYRAMID INTERPENETRATION

FIG. 20

After fully constructing all the views, fill in the outline and add all the notes and dimensions so that the finished drawing looks like Fig. 20(*a*).

(ii) *Hexagonal Pyramid. Corners Vertical. Fig. 20(b)*

The second method of drawing an hexagonal pyramid is shown in Fig. 20(*b*) and is with corners vertical.

Draw the plan first, leaving sufficient space to project the elevation above it. In fine construction lines draw a circle 2 in dia. and around this construct a hexagon with corners vertical, as shown in Fig. 14(*a*)(2). Add the six radial lines showing where the six sloping faces meet.

For the front elevation, using fine construction lines, project from the plan a view showing two faces joined by a line. The width of the view is the distance across the flats, 2 in. Notice that the height 3 in is measured on the vertical centre line. The slant height is the perpendicular distance along one flat face. To obtain the end elevation from the front elevation, project in fine construction lines a view looking in the direction of arrow *P*. This view will show three faces to the proportions given in Fig. 20(*b*). Notice that the distance along the corner edge is NOT the slant height, since this is found in the front elevation and is the distance along one FLAT face.

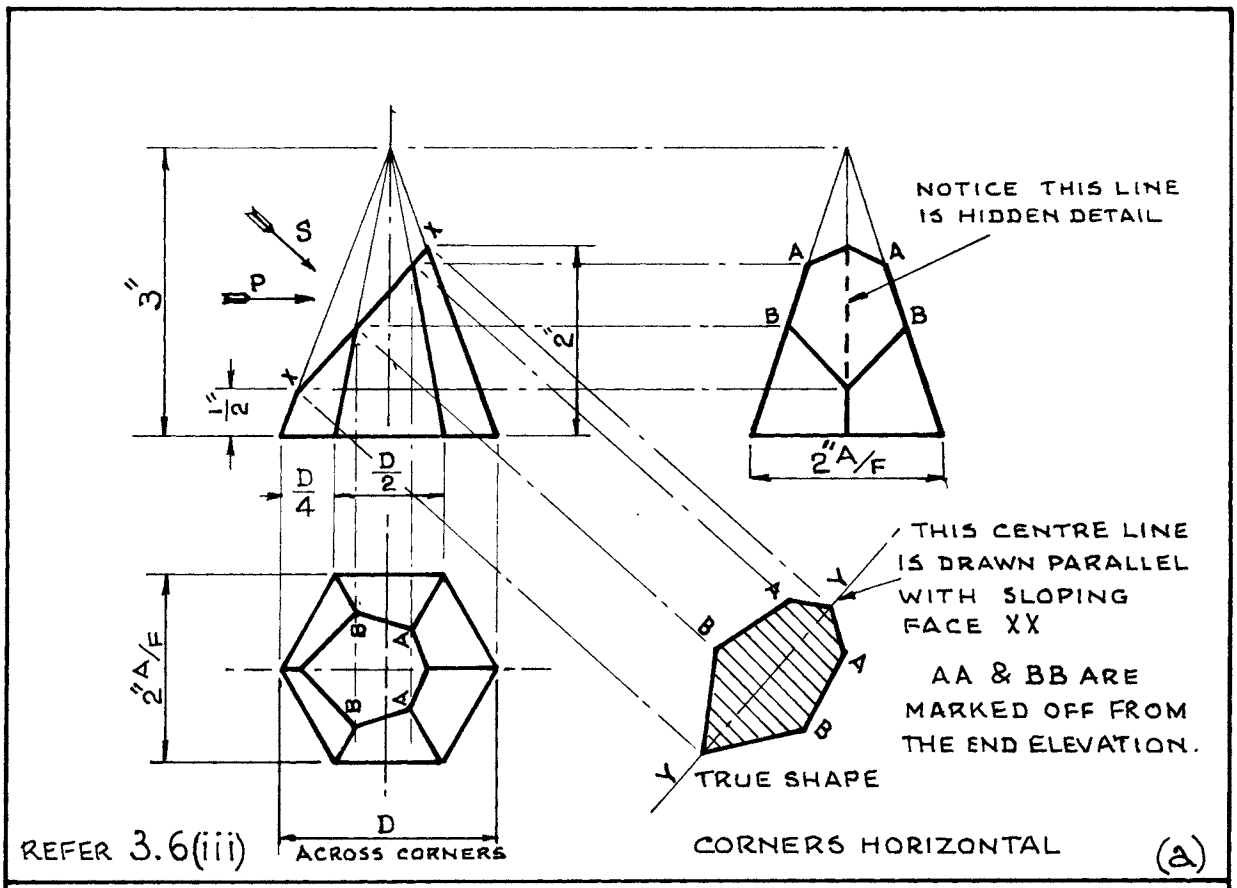
After fully constructing all the views, fill in the outline and add all the notes and dimensions so that the finished drawing looks like Fig. 20(*b*).

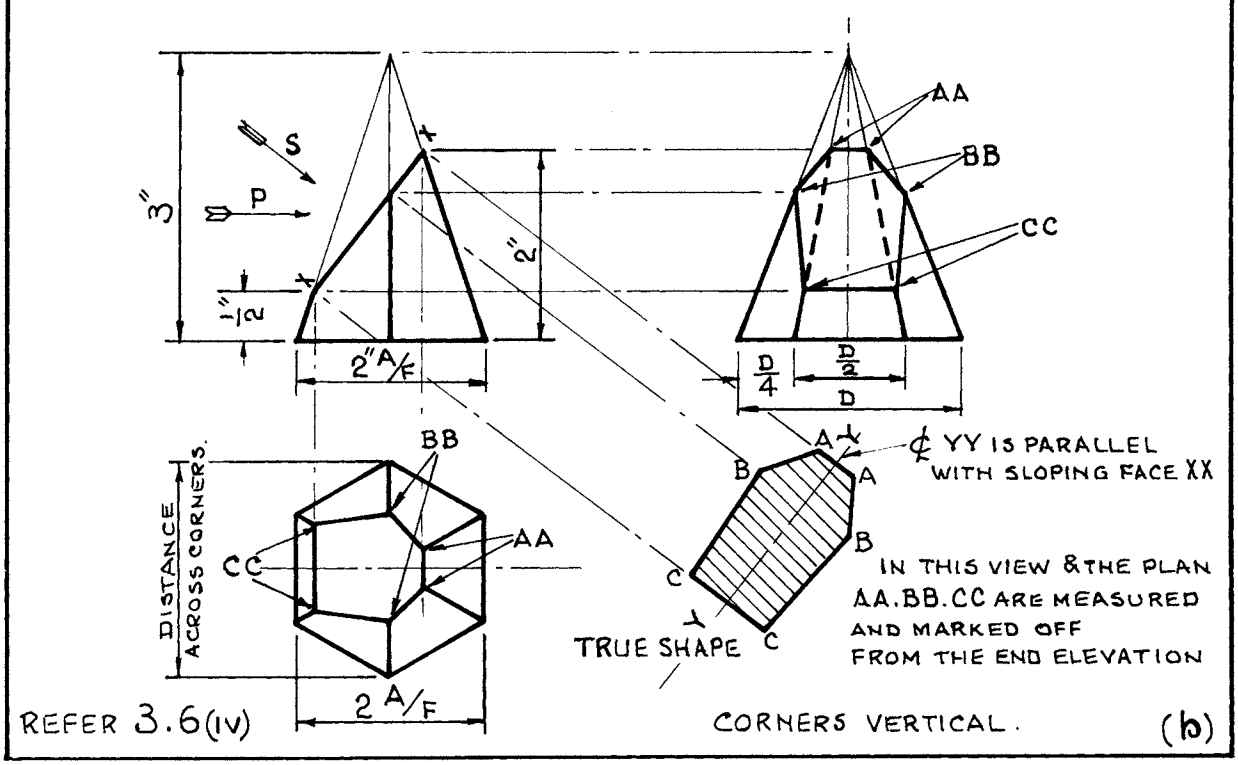
(iii) *Hexagonal Pyramid (Cut). True Slope. Corners Horizontal. Fig. 21(a)*

We now come to draw the true shape of the sloping face of an hexagonal pyramid. To do this we first draw the three views to dimensions given in Fig. 21(*a*). Draw the plan first, using fine construction lines. Draw a circle 2 in dia. and construct a hexagon with corners horizontal, as in Fig. 14(*a*)(1). Add the six radial lines showing where the six sloping faces meet.

Draw the front elevation in fine construction lines by projecting from the plan a view showing three faces to the proportions given in Fig. 21(*a*). Mark off the sloping face *XX* $\frac{1}{2}$–2 in high.

For the end elevation, project from the front elevation in fine construction lines a view looking in the direction of arrow *P*. This view will show only two faces joined by a central line and the width is 2 in A/F taken from the plan. For the sloping face projection, first project the corners and intersections of the sloping face *XX* both to the plan and to the end elevation. The two intersections projected horizontally give points *AA* and *BB*. Mark off in construction the six sloping lines showing the area of the sloping face *XX* as shown in the end elevation. In addition, project vertically down to the plan and mark off in construction the six sloping lines shown in the plan. To find the true shape of the sloping surface project the intersections in the direction of arrow *S* on to a centre line *YY* which is drawn parallel to the sloping face *XX*. The lengths *AA* and *BB* respectively are measured from the end elevation. The length of the true shape at *YY* is the same as *XX* in the front elevation.





HEXAGONAL PYRAMID (CUT) TRUE SHAPE

FIG. 21 INTERPENETRATION

After fully constructing all the views fill in the outline and add all the notes and dimensions so that the finished drawing looks like Fig. 21(*a*).

(iv) *Hexagonal Pyramid (Cut). True Shape. Corners Vertical. Fig. 21(b)*

Draw the three views, in fine construction lines, to dimensions given in Fig. 21(*b*) and Fig. 14(*a*)(2). Notice the sloping face in the front elevation and the projected shapes in the plan and end elevation. For the true shape, drawn in fine construction lines, project the sloping face *XX* on to the centre line *YY*, which is drawn parallel with *XX*. Notice *AA*, *BB*, and *CC* are measured from the end elevation (right-hand view).

After constructing all the views, fill in the outline and add the notes and dimensions so that the finished drawing looks like Fig. 21(*b*).

(v) *Hexagonal Pyramid (Cut). Auxiliary View and True Shape. Corners Horizontal. Fig. 22(a)*

The auxiliary view of an hexagonal prism has been explained in section 3.5 (iii). We are now to draw an hexagonal pyramid (cut) in normal first angle projection and then project a true shape of the sloping face and an auxiliary view.

Draw the three views in Fig. 22(*a*) in fine construction lines. Draw the plan first and complete the three views by projection. Now project the auxiliary view, including the true shape, in the direction of arrow *S* on to a centre line *YY*, which is parallel with *XX*.

The dimensions across the true shape are measured from the end elevation at *AA*, *BB*. The length is as *XX* in the front elevation. After fully constructing all the views, fill in the outline and add all the notes and dimensions so that the finished drawing looks like Fig. 22(*a*).

(vi) *Hexagonal Pyramid (Cut). Corners Vertical. Fig. 22(b)*

To obtain the auxiliary view and the true shape, draw the three views in Fig. 22(*b*) in fine construction lines. Draw the plan first and construct these views as previously explained. Notice that the dimension *BB* in the plan is measured from *BB* in the end elevation. When projecting the auxiliary view notice that the widest part is the distance *A*/*C* and that the three widths of the sloping face are measured from the end elevation at *AA*, *BB*, *CC*.

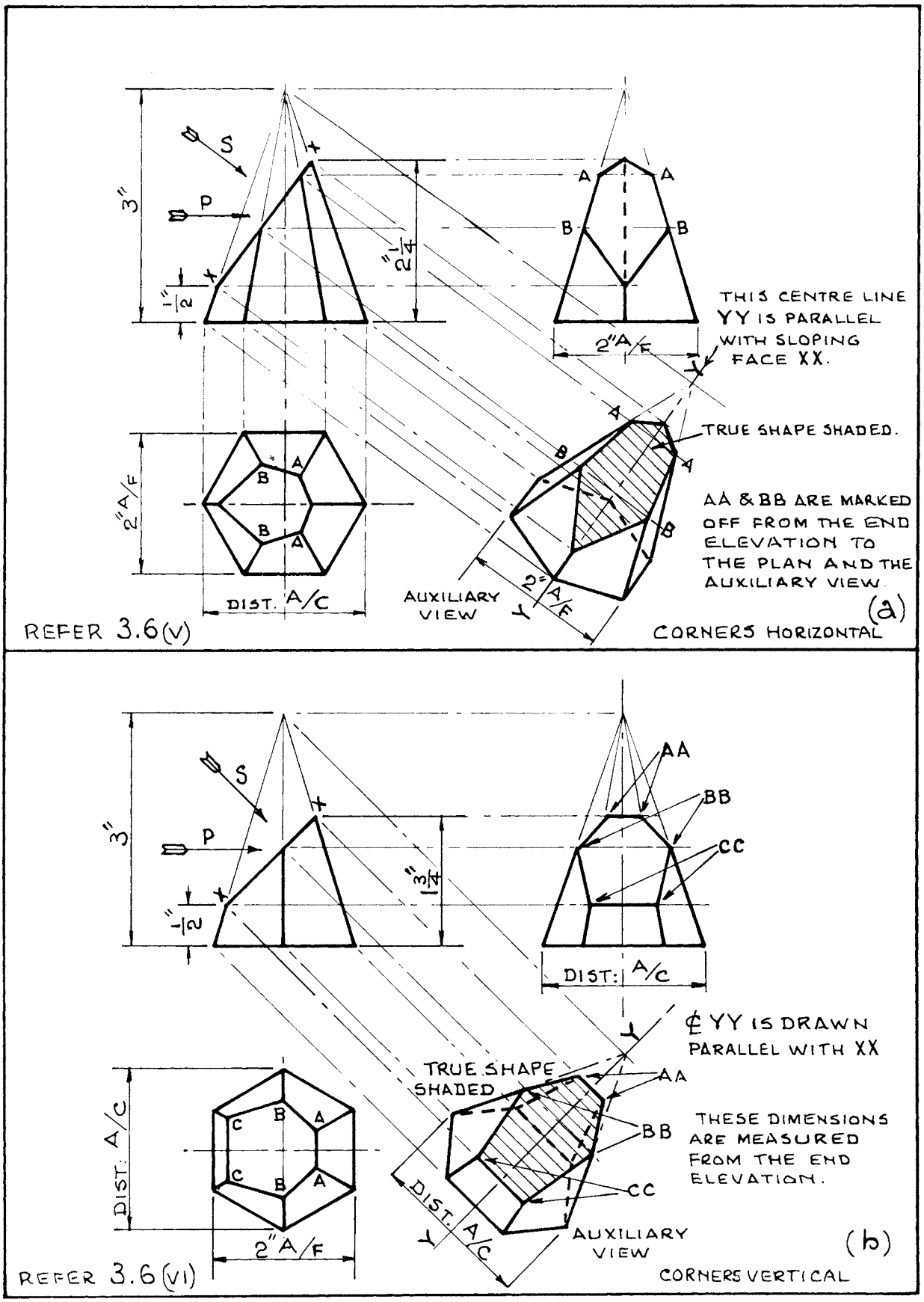
After full construction, fill in the outline and add notes and dimensions so that your finished drawing looks like Fig. 22(*b*).

3.7. CYLINDERS

(i) *Cylinder. Method of Dividing the Circumference into Twelve Equal Parts. Fig. 23(a)*

We now come to the construction of three views of a cylinder. In Fig. 23(*a*) a cylinder $1\frac{1}{2}$ in dia. by 2 in high is shown in plan, front elevation, and end elevation.

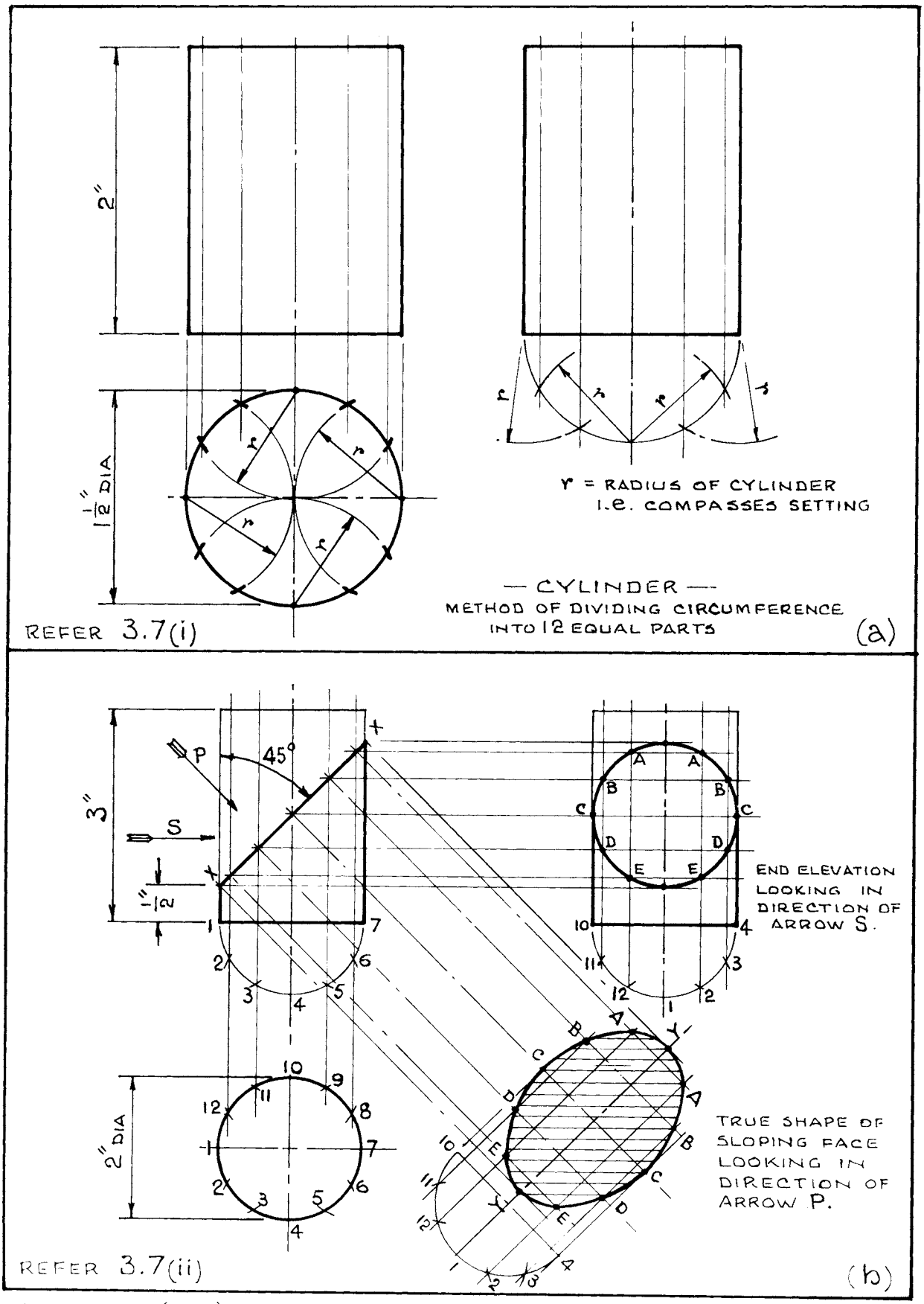
For the next series of exercises it is necessary to divide the circumference into



HEXAGONAL PYRAMID (CUT) AUXILIARY VIEW AND TRUE SHAPE

FIG. 22

INTERPENETRATION



CYLINDER (CUT)
TRUE SHAPE

FIG 23

INTERPENETRATION

an equal number of parts. The most convenient and useful number is twelve. This is explained in sections 1.11(i) with set squares and 1.11(ii) with compasses. Either method can be used, but the compasses method is quicker. After drawing the plan leave the compasses set and mark off in eight places so that with the four centre points the circle is divided into twelve parts.

To divide the front elevation into six parts the divided points in the plan must be projected vertically.

To divide the end elevation into six parts draw a semicircle on the bottom line. Divide this semicircle into six by the compasses method and project the divided points vertically.

The front elevation and the end elevation are now divided into exactly the same divisions.

A cylinder, cone, or any other object with a circular base can be divided by the above method.

(ii) *Cylinder (Cut). To Draw the True Shape of Sloping Face. Fig. 23(b)*

We now take a cylinder 2 in dia. by 3 in high and remove the upper portion, leaving a sloping face at 45°. Draw this as shown in the plan, front elevation, and end elevation. Divide all these views into equal lengths, as shown in Fig. 23(*a*).

After projecting the intersections of the sloping face *XX* the view (F.A.P.) looking in direction of arrow *S* is as seen in the end elevation. Notice that this is a circle only when the slope is at 45°, otherwise it is an ellipse.

To make a drawing of the true shape of the sloping face projected in the direction of arrow *P*, first draw a line *YY* parallel with sloping face *XX*. This line *YY* is the centre for the view of the true shape. The length of the shape is *XX* projected perpendicularly from *P*. Now divide the width of the auxiliary view (2 in in this case) into six parts as in Fig. 23(*a*), and project the lines 1, 2, 3, 4, 10, 11, 12 through the area and where they intersect draw an ellipse. The length of lines *AA*, *BB*, *CC*, *DD*, *EE* are the same in the end elevation and the true shape view.

Fill in the outline, leaving all the construction lines. The result should look like Fig. 23(*b*).

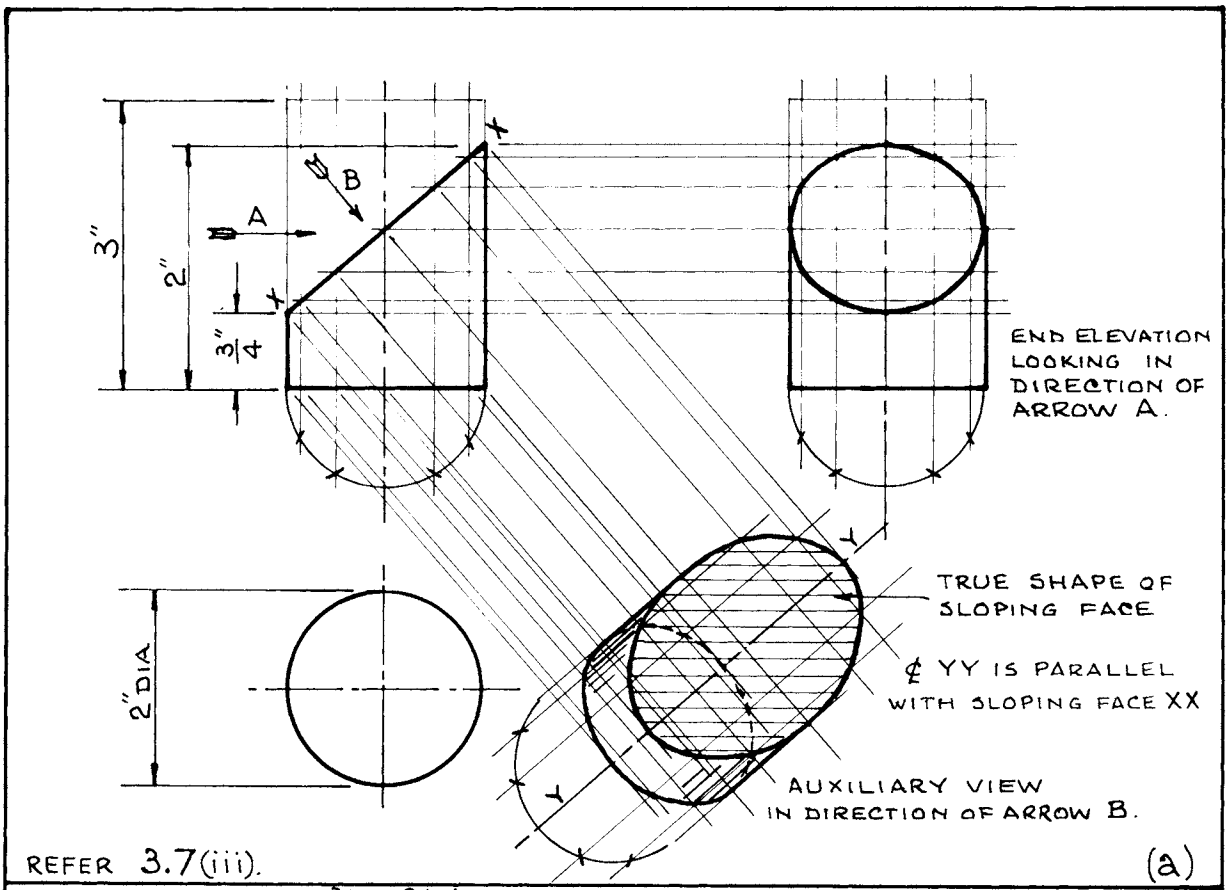
(iii) *Cylinder (Cut). To Draw the Auxiliary View and True Shape. Fig. 24(a)*

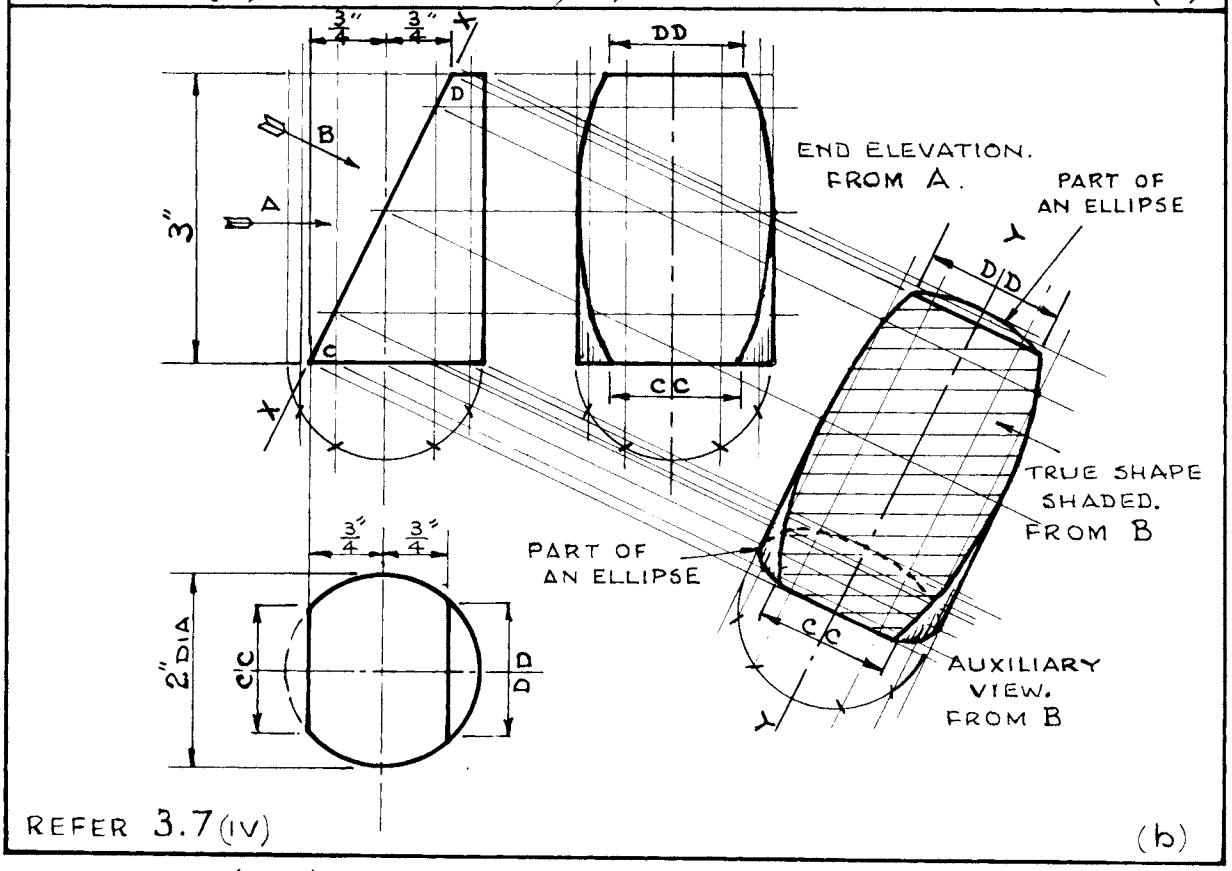
In this exercise we have a cylinder 2 in dia. by 3 in high and we remove the upper portion, leaving a sloping face from $\frac{3}{4}$ in to $2\frac{1}{2}$ in, as in Fig. 24(*a*).

Following the instruction given in section 3.7(ii) and Fig. 23(*a*), proceed as far as the projection of the true sloping face, which is the shaded portion constructed on the centre line *YY* parallel with sloping face *XX* and looking in the direction of arrow *B*.

To complete the auxiliary view project all intersections in the front elevation perpendicularly in the direction of arrow *B*. At the intersections with the dividing lines in the auxiliary view draw curves, one full outline and one with hidden detail.

After filling in the outlines and leaving the construction details the result should look like Fig. 24(*a*).





CYLINDER (CUT)
AUXILIARY VIEW & TRUE SHAPE

FIG. 24

INTERPENETRATION

c

(iv) *Cylinder (Cut). To Draw the Auxiliary View and True Shape. Fig. 24(b)*

This exercise is slightly more difficult and you should proceed as follows:

Draw in fine construction lines the plan, front elevation, and end elevation of the cylinder only (no cut-away). Construct the cut-away sloping face in front elevation to dimensions given. Project points *C* and *D* to the plan and draw two straight lines *CC* and *DD* in length. Mark off these lengths by measurement in the end elevation at *CC* and *DD*. Project intersections of sloping face to the end elevation. Fill in the outline of three views, not forgetting the bottom corners of the end elevation. To obtain the true shape of sloping face project all the intersections on *CD* perpendicularly in the direction of arrow *B* to the centre line *YY*. The upper end of the auxiliary view is part of an ellipse and is a direct projection from the front elevation and finishes at the straight line *DD*. The lower end of the auxiliary view is part of another ellipse, including hidden detail, and is a direct projection from the front elevation and finishes at the straight line *CC*.

When all the outlines are filled in the result should look like Fig. 24(*b*).

3.8. CONES

(i) *Cone. Method of Dividing Curved Surface into Twelve Equal Parts. Fig. 25(a)*

The next series of exercises deal with the cone, and for these we have to divide the curved surface into an equal number of parts. As in the case of the cylinder (Fig. 23(*a*)), we divide the circular base into twelve by the method first explained in section 1.11(ii).

The cone for these exercises is 3 in dia. and 4 in vertical height. This should be drawn plan first, leaving space above for the front elevation. Divide the plan into twelve. Now project all points to touch the base line of the front elevation. All the lines must then be joined to the apex.

The end elevation should now be projected from the front elevation. The base can be divided by the semicircular method shown and all the lines joined to the apex.

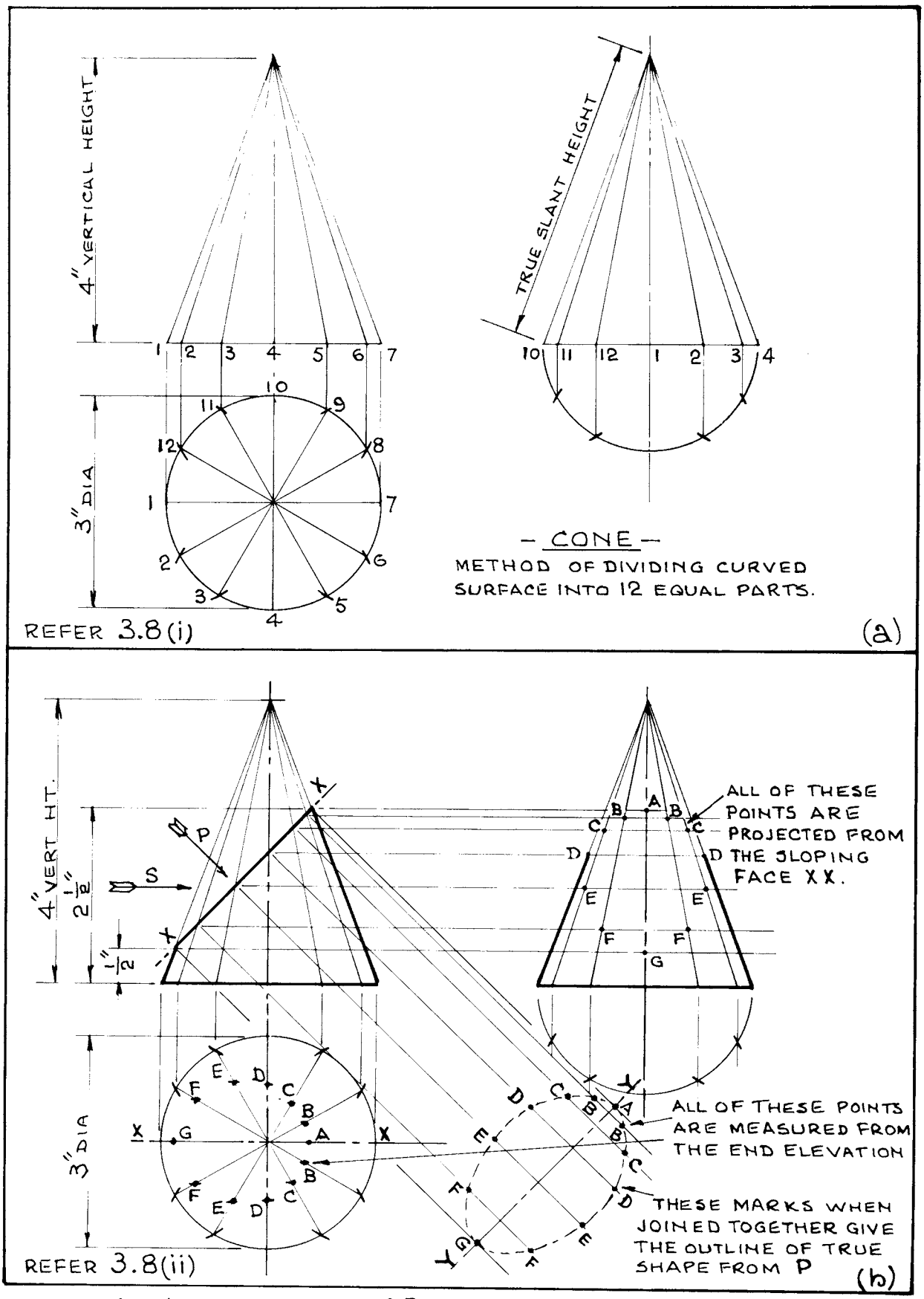
It will be seen that in all three views the curved surface has been divided into twelve.

Note: Do NOT join the points on the circle or semicircle directly to the apex; first project to the base, then join to the apex.

(ii) *Cone (Cut). True Shape of Sloping Face. Fig. 25(b)*

For this exercise draw the three views of the cone to the same dimensions and divide each view as in Fig. 25(*a*). Now construct the sloping face *XX* in the following way.

Project all the intersections of the sloping face horizontally to the end elevation. Mark off and letter where these lines intersect the slant lines. Mark off a centre line *YY* parallel with *XX* and project lines perpendicularly from the sloping face intersections in the direction of arrow *P*. Along the lines just drawn, and also on each side of the plan, mark off *A*, *BB*, *CC*, *DD*, *EE*, *FF*, *G* measured



CONE (CUT) TRUE SHAPE

FIG. 25

INTERPENETRATION

from each side of *AG* in the end elevation. The marks (right-hand bottom corner) when joined by a fair curve give the outline of the true shape of the sloping face. If the marks in the plan were joined by a fair curve you would obtain the plan of the sloping face (but *not* the true shape). If the marks in the end elevation were joined by a fair curve you would obtain a view of the sloping face looking in the direction of arrow *S* (but *not* the true shape).

(iii) *Cone (Cut). To Draw the True Shape of the Sloping Face. Fig. 26(a)*

The cone is 3 in dia. by 4 in vertical height and is cut through by plane *XX* $2\frac{1}{2}$ in on the right-hand slope to 1 in from the vertical centre line. After dividing the curved surface in each view into twelve equal parts, project the bottom end of *XX* down to the plan. It is a straight line and the length *BB* in the plan should be transferred to the end elevation and to the true shape view to be constructed on the centre line *YY*, which is drawn parallel with *XX*. The intersections along the sloping face are projected to the end elevation. Where these lines intersect the slanting lines at *EE*, *FF*, etc., the lengths should be transferred by compasses to both the plan and the true shape. When filling in the outline notice how the corners of the cone appear in the end elevation.

The finished drawing should look like Fig. 26(*a*).

(iv) *Cone (Cut). To Draw the Auxiliary View and True Shape. Fig. 26(b)*

This cone 3 in dia. by 4 in vertical height is cut from $2\frac{1}{2}$ in to $\frac{1}{2}$ in as shown in Fig. 26(*b*). Project all the intersections of the sloping face across to the end elevation. Transfer the various lengths on this view to the plan and to the true shape. The views are not lettered but you should follow the same procedure as in Fig. 26(*a*). Project the base in the front elevation to the auxiliary view to form the ellipse, half of which is hidden detail. Notice that to construct this view the semicircle method is necessary to divide the base into twelve.

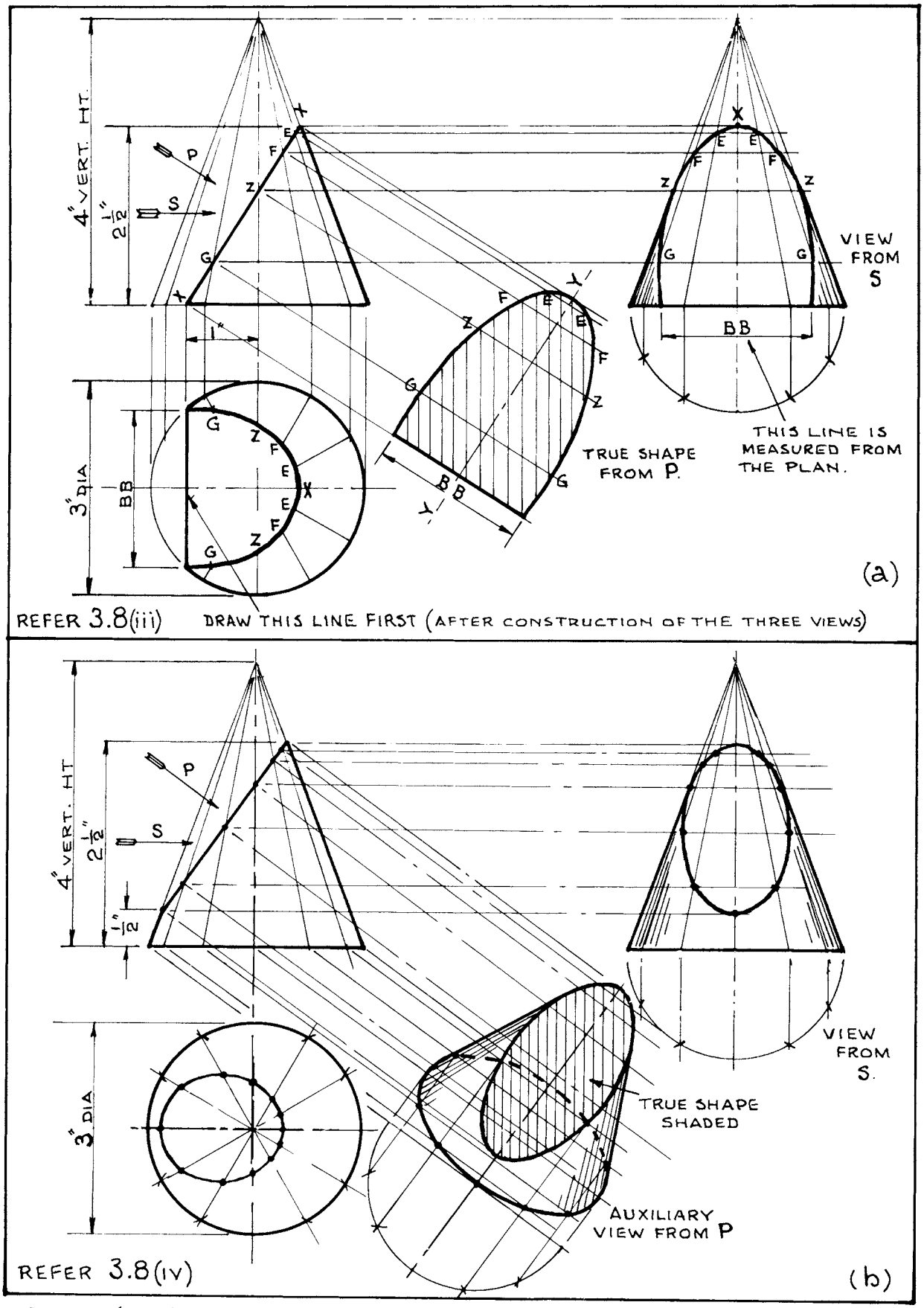
The finished drawing should look like Fig. 26(*b*).

We are approaching the end of the series of interpenetrations, and the problems have become progressively more difficult. If the student has followed through all the problems he will have noticed that although he has had improved results the explanations of the drawings have become much less.

There are now only two further problems in the series and these are concerned with cones having a double cut-away.

(v) *Cone (Double Cut). To Draw the Auxiliary View and True Shape. Fig. 27(a)*

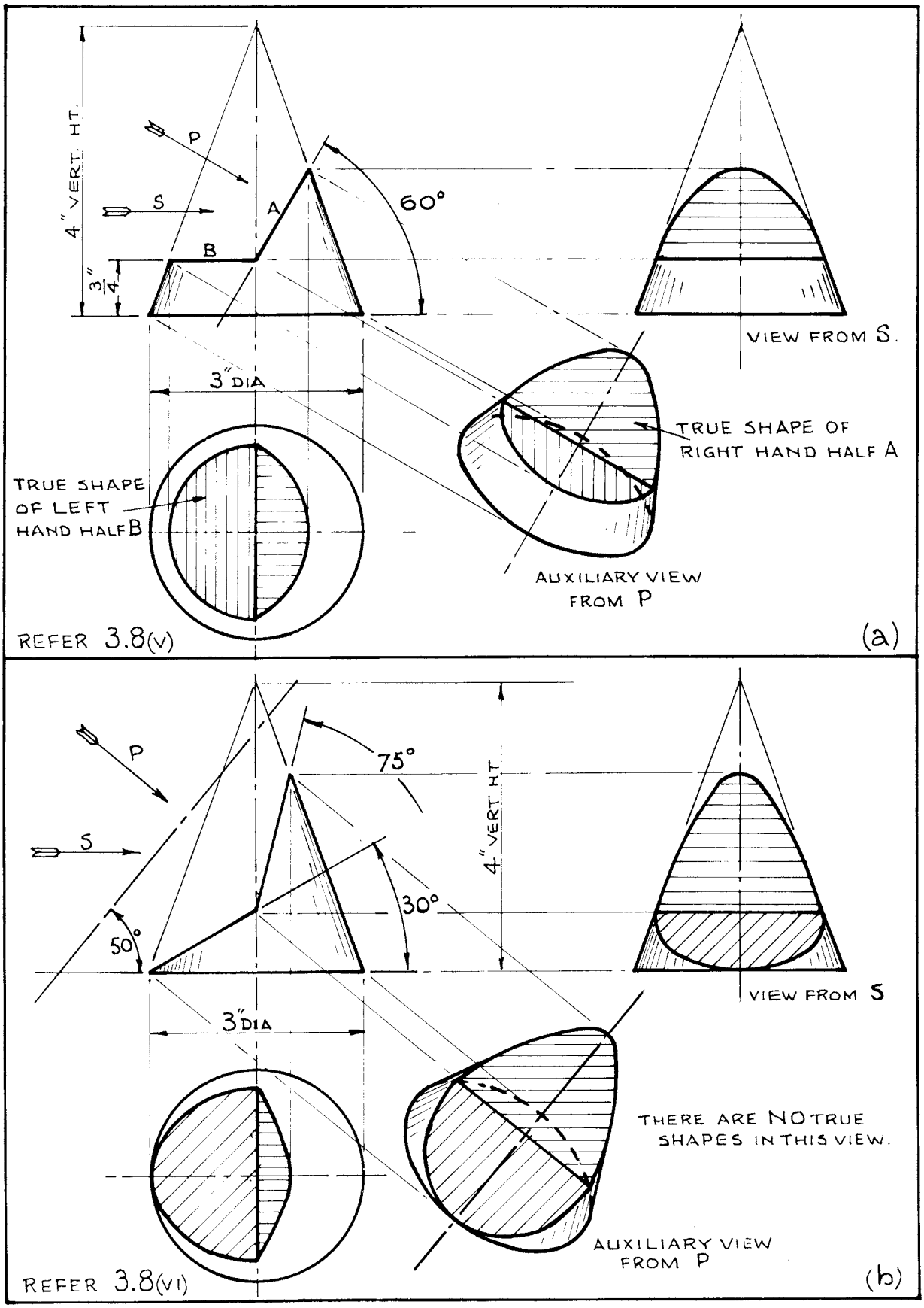
For this problem draw in construction lines the outline of the cone in the plan, front elevation, and end elevation. Continue in the following order, using the methods of construction as previously explained. In the constructions which follow it is important to remember to divide each view into twelve, as explained earlier.



CONE (CUT) TRUE SHAPE AND AUXILIARY VIEW

FIG. 26

INTERPENETRATION



CONE (DOUBLE CUT) AUXILIARY VIEW

FIG. 27

INTERPENETRATION

In construction lines draw the front elevation to the dimensions given in Fig. 27(*a*). Project to the right the end elevation. Notice that the flat surface $\frac{3}{4}$ in high in the front elevation produces a straight horizontal line in the end elevation. Project down to the plan and transfer the measurements from the end elevation to construct the shape of the right-hand portion. The left-hand portion of the plan is drawn with compasses because the flat surface in the front elevation is parallel with the base. This will give a true shape for the left-hand half only. Project the auxiliary view from the front elevation in the direction of the arrow *P*. This is perpendicular to the sloping face and when projected will give a true shape of the right-hand portion.

Complete all the views in outline and fill in the cut portions with fine cross-hatching in two directions. A little shading, but not too much, helps to illustrate the finished drawing. When completed the drawing should look like Fig. 27(*a*).

(vi) *Cone (Double Cut). To Draw an Auxiliary View. Fig. 27(b)*

The final, but slightly more difficult problem, is that in which the two cut portions are at angles of 30° and 75° respectively, but the auxiliary view is projected at 50°. From previous instructions you should now be able to draw the three views front elevation, plan, and end elevation. Do not forget to divide each view into twelve, as explained earlier. Project the auxiliary view in the direction of the arrow *P* at the angle given, 50°. In the construction of this view it is essential that measurements are transferred from the end elevation to the auxiliary view and plan. Because the angle of projection is 50° and is not perpendicular to any sloping face, no true shapes can be seen in the auxiliary view.

Complete all the views in outline and fill in the cut portions with fine cross-hatching in two directions. A little shading, but not too much, helps to illustrate the finished drawing.

The completed drawing should look like Fig. 27(*b*).

4. *Development*

IN THE previous chapter we have dealt with solid objects. This present chapter will be devoted entirely to hollow objects made from sheet material. As an example, we know that a certain object is to be made from thin sheet metal and it has been drawn either in first angle, third angle, or isometric projection. From one of these projections we can draw a developed shape or a development. If the material is cut out to the developed shape and bent, we should obtain an object exactly similar to our original drawing.

In the first place we shall deal with very simple objects and then work up to more difficult examples later.

For the following examples it must be emphasized that we only make a development drawing of the exact area of the material required for the object and do not include the material for any joints.

4.1. CYLINDER. Fig. 28

(i) *Isometric.* The first object is a cylinder 1 in dia. by $1\frac{1}{2}$ in long. This is shown in Fig. 28(*a*) drawn in isometric projection. Draw the cylinder as shown, using the isometric ellipse at each end (refer Fig. 12(*b*)).

(ii) *Development.* The developed shape shown in Fig. 28(*b*) of a cylinder is a rectangle whose *width* is equal to the length of the cylinder and whose *length* is equal to the circumference of the cylinder. This gives us the body area of $1\frac{1}{2}$ in wide by 3·142 in long.

The cylinder has two ends which can be drawn as two circles 1 in dia.

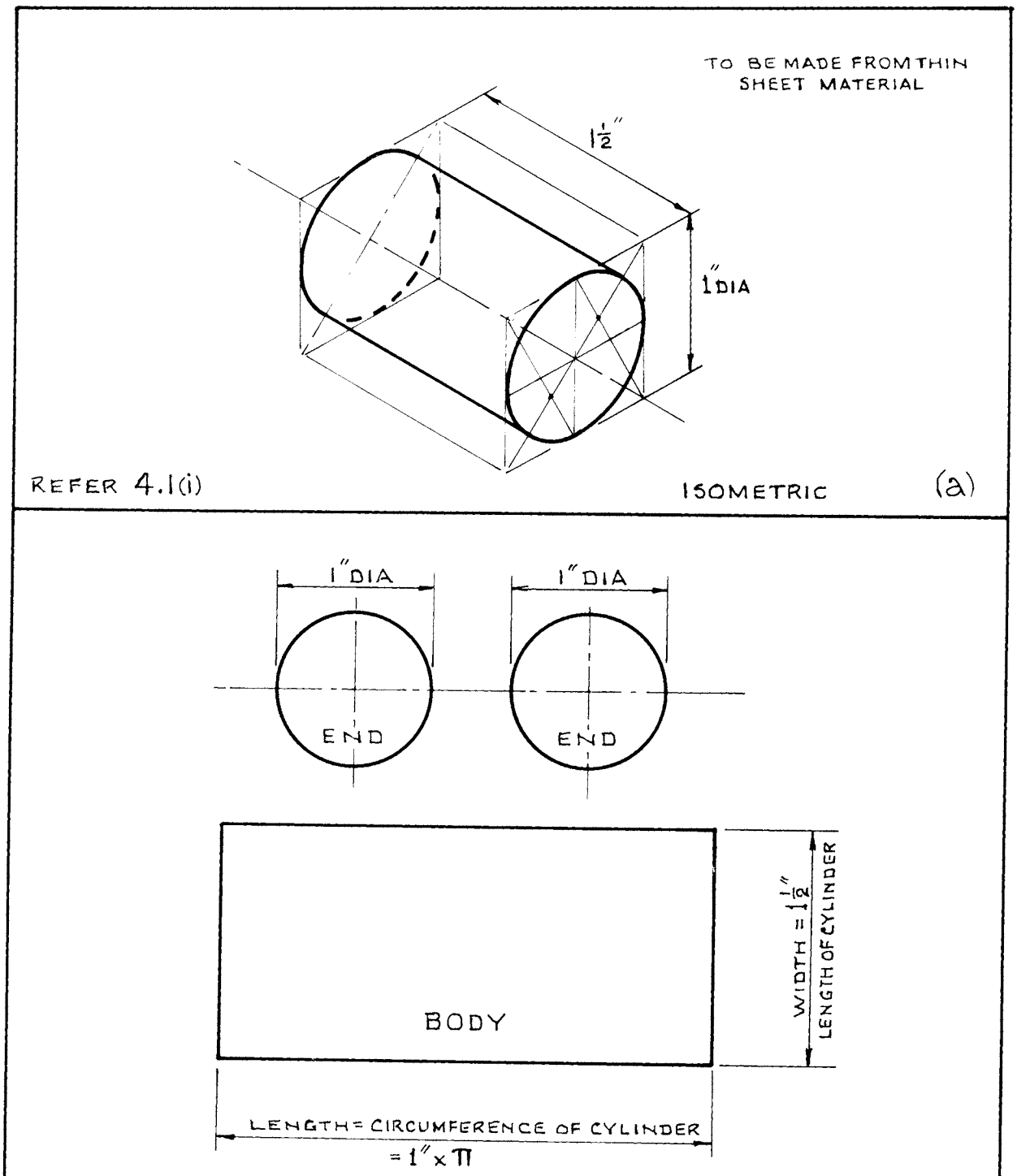
Remember that we are showing the required area only and no allowance is made for lap or seam joints.

Draw the developed shapes as shown in Fig. 28(*b*). Cut out these shapes in stiff drawing paper and fold to the shape as in Fig. 28(*a*).

4.2. CUBE. Fig. 29

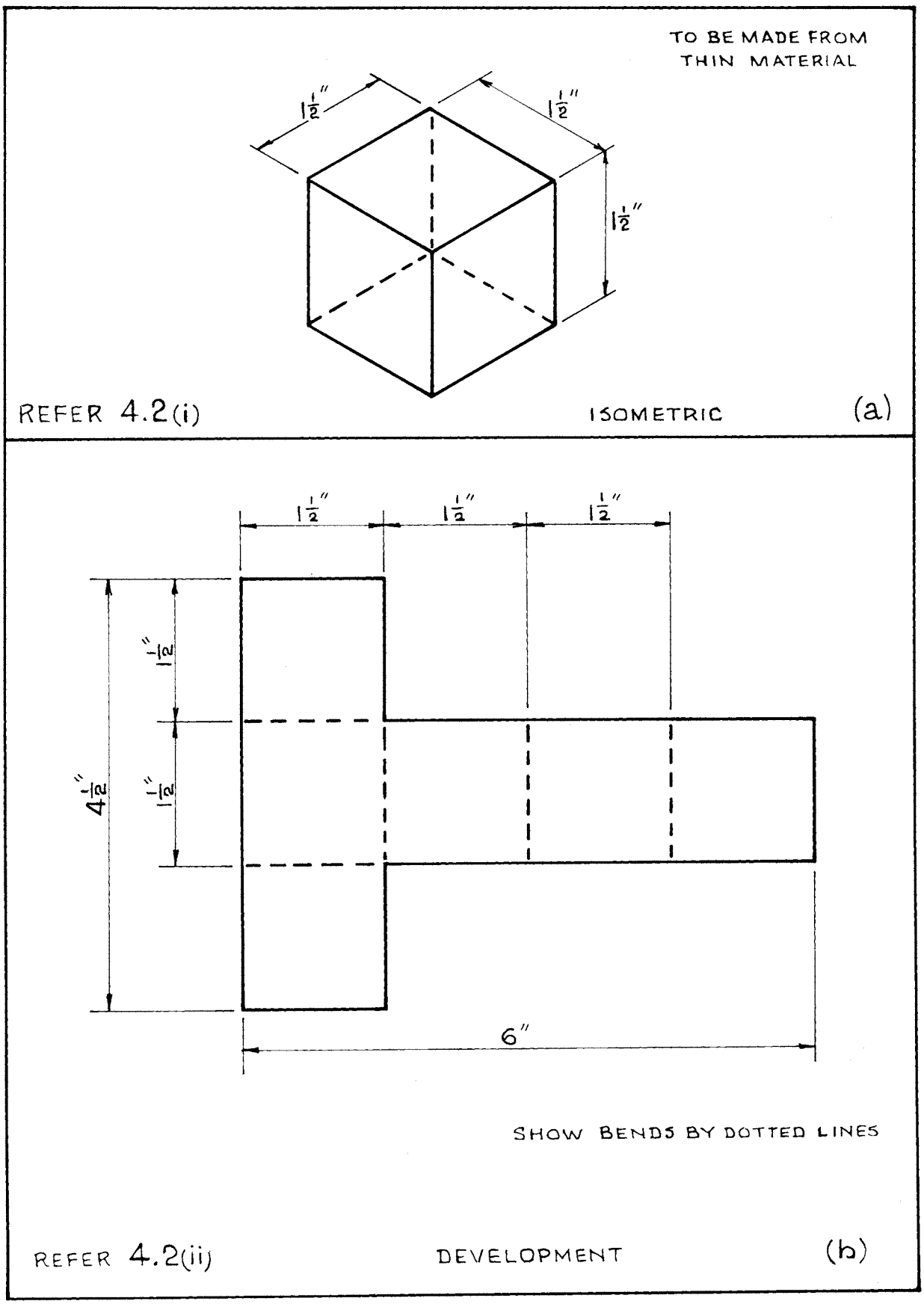
(i) *Isometric.* We now go from a circular object to a cube, which is an object with six identical square sides shown in isometric projection in Fig. 29(*a*). Draw the cube as shown in the figure with sides of $1\frac{1}{2}$ in.

(ii) *Development.* Now look at the above drawing and imagine the sides being unwound. This should lead you to the shape shown in Fig. 29(*b*), which shows six squares $1\frac{1}{2}$ in by $1\frac{1}{2}$ in laid flat in one piece. The bend between each piece is shown by a dotted line. The best layout (not necessarily the only one) is shown in Fig. 29(*b*). Draw this developed shape on stiff drawing paper and cut it out.



CYLINDER DEVELOPMENT

FIG. 28



CUBE DEVELOPMENT FIG 29

Bend carefully along the dotted lines and the result should be a shape as seen in Fig. 29(*a*).

4.3. RECTANGULAR OBJECT. Fig. 30

(i) *Isometric.* The object seen in Fig. 30(*a*) follows the same pattern as the cube and has six rectangular sides. Draw this object in isometric projection.

(ii) *Development.* The best layout, but not necessarily the only one, is shown in Fig. 30(*b*). The bends are shown by dotted lines. Draw this development as shown, on stiff drawing paper, and cut it out. Bend carefully along the dotted lines and the result should be as seen in Fig. 30(*a*).

4.4. HEXAGONAL OBJECT. Fig. 31

(i) This object has six equal sides and two hexagonal ends and is seen in Fig. 31(*a*). Draw this object as shown.

(ii) *Development.* Fig. 31(*b*). To avoid a series of difficult calculations it is better to draw only one hexagon first. From previous instructions and Fig. 14(*a*) (1) draw the upper hexagon based on $1\frac{1}{2}$ in dia. circle. Measure one side of the hexagon and mark off six equal faces on a horizontal line. Now draw seven vertical lines 2 in long from these faces (five being dotted for bending). Complete the bottom line and draw the lower hexagon. Where the hexagon shapes join the main rectangle there should be dotted lines for bending.

When completed the drawing should look like Fig. 31(*b*). Draw the development on stiff drawing paper and cut it out. Bend carefully along the dotted lines and the result should be as seen in Fig. 31(*a*).

4.5. CUBE (Cut). Fig. 32

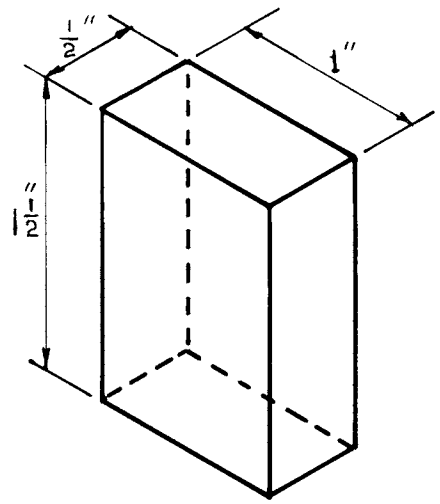
(i) *Isometric.* This object is a cube with part removed, as seen in Fig. 32(*a*). Draw the view and letter the faces as shown.

(ii) *Development.* To enable us to understand the development more easily, it is better to letter the horizontal faces *A*, *B*, *C*, *D*, *E* and the two vertical faces *F* and *G*. First, the faces *A*, *B*, *C*, *D*, *E* must be plotted inside two parallel lines 1 in apart. Then draw the vertical faces *G* and *F*. The length of the sloping face *D* can be measured from the length of the sloping line on the vertical face *G* and is found to be 0·707 in. This dimension can also be found by the solution of the small triangle shown in inset in Fig. 32(*b*).

The developed shape is shown in Fig. 32(*b*) suitably dimensioned. Draw this shape on stiff drawing paper and cut it out. Bend carefully along the dotted lines and the result should be as seen in Fig. 32(*a*).

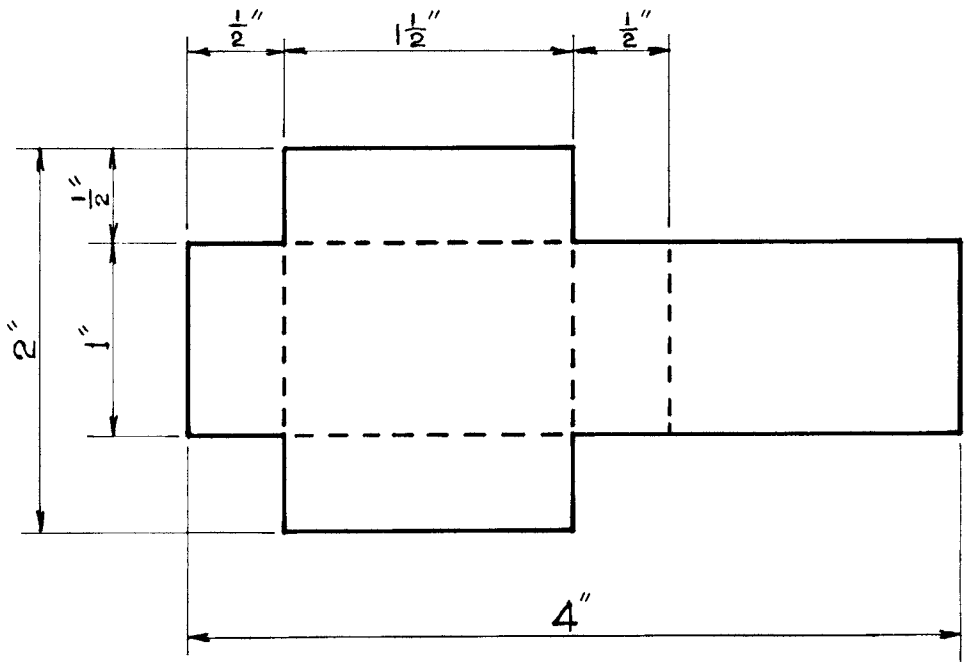
4.6. SQUARE PYRAMID. Fig. 33

(i) *First angle projection.* We first dealt with a square pyramid in Fig. 16(*a*) as a solid object. We will now deal with it as a hollow object, seen in Fig. 33(*a*),



TO BE MADE FROM THIN MATERIAL

REFER 4.3(i) ISOMETRIC (a)



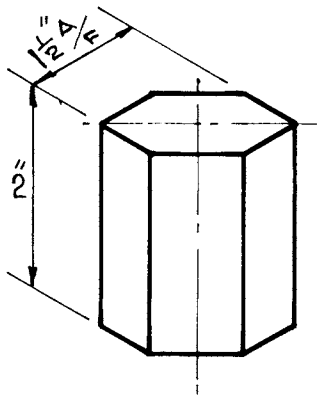
SHOW BENDS BY DOTTED LINES

REFER 4.3(ii) DEVELOPMENT. (b)

RECTANGULAR OBJECT DEVELOPMENT

FIG. 30

TO BE MADE FROM
THIN MATERIAL



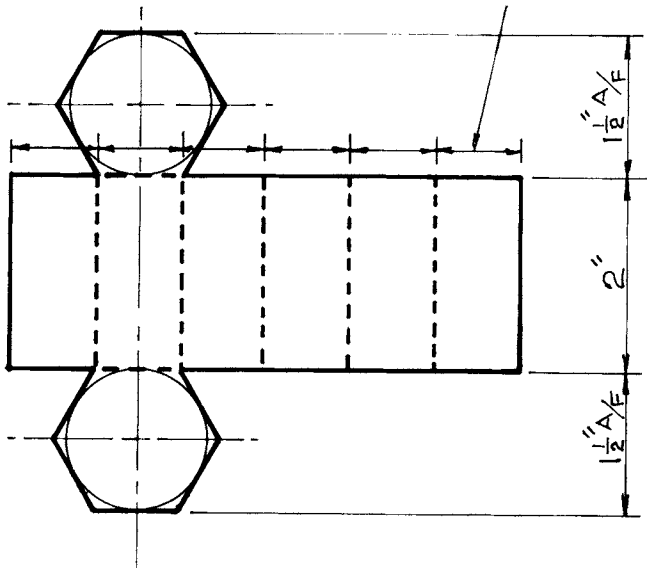
VIEW OF HEXAGONAL OBJECT

REFER 4.4 (i)

(a)

UPPER HEXAGON END

SIX EQUAL FACES CAREFULLY
MARKED OFF FROM ONE SIDE
OF THE HEXAGON



LOWER HEXAGON END

SHOW BENDS BY DOTTED LINES

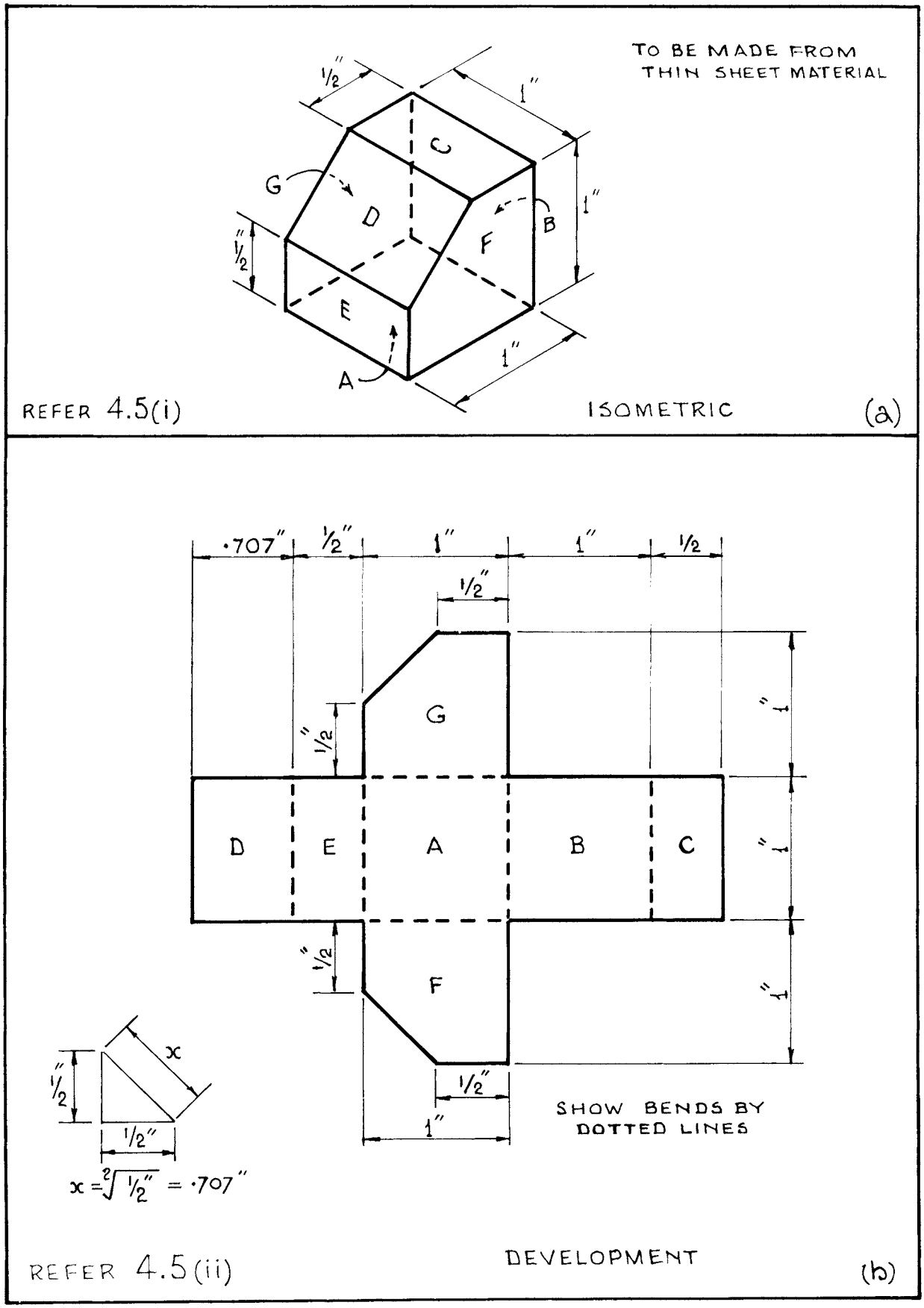
REFER 4.4(ii)

DEVELOPMENT

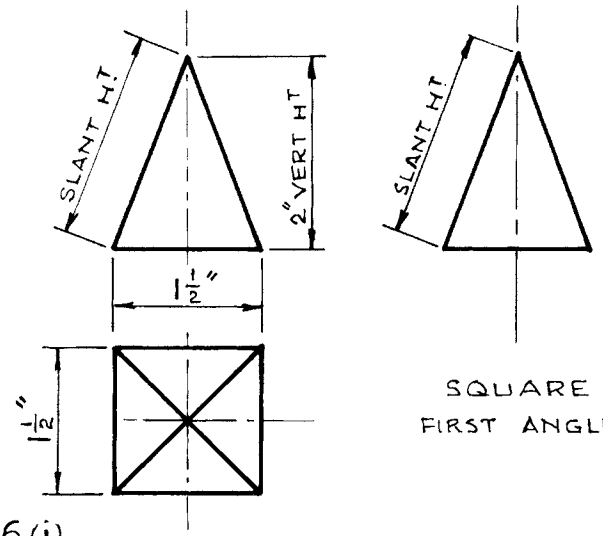
(b)

HEXAGONAL OBJECT
DEVELOPMENT

FIG. 31



CUBE (CUT) FIG 32 DEVELOPMENT

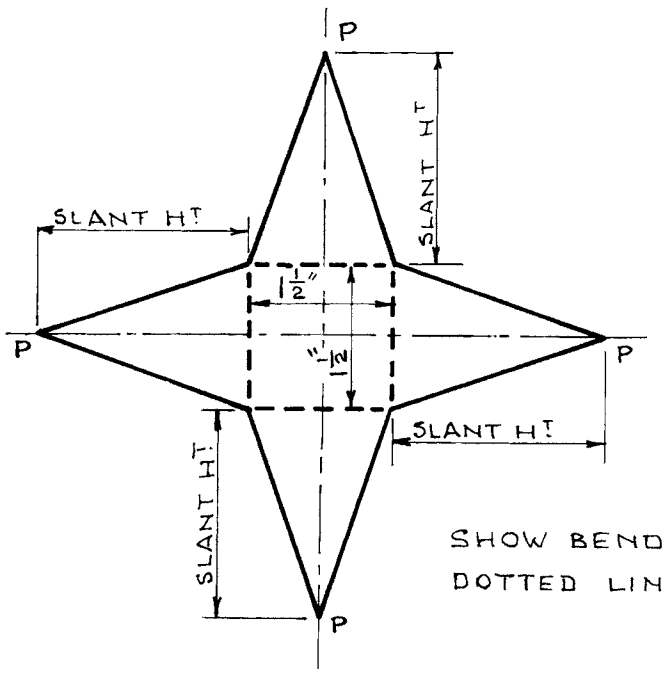


TO BEMADE FROM
THIN SHEET MATERIAL

SQUARE PYRAMID
FIRST ANGLE PROJECTION

REFER 4.6 (i)

(a)



SHOW BENDS BY
DOTTED LINES.

REFER 4.6 (ii)

DEVELOPMENT

(b)

SQUARE PYRAMID
DEVELOPMENT

FIG. 33

and drawn in first angle projection. Notice that the front and end elevations are exactly the same. Notice also the slant height in both views because this is an important dimension when making the development drawing.

(ii) *Development.* First, lay out the square base $1\frac{1}{2}$ in by $1\frac{1}{2}$ in, on two long crossed centre lines. Now measure the slant height from the elevations and mark off four points on the centre lines at P. Join these points to each corner of the square base, as shown in Fig. 33(*b*). This layout should be drawn on stiff drawing paper and cut out. Bend carefully on the dotted lines and the result should be as shown in Fig. 33(*a*).

As mentioned previously, no allowance is made for jointing.

4.7. SQUARE PYRAMID (CUT). Fig. 34

(i) *First angle projection.* Figure 34(*a*) shows a hollow square pyramid with upper portion removed, leaving a sloping face. Before making a drawing of the development we must draw carefully the three views shown in first angle projection. There are six faces in this shape.

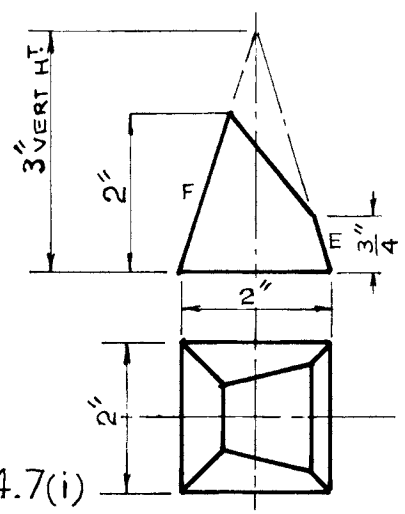
(ii) *Development.* To draw a development from the above views we must draw in fine construction lines the outline of the complete pyramid as shown in Fig. 33(*b*) to the dimensions 2 in square base and 3 in vertical height. We must not forget the slant height when marking out X_1, X_2 and Y_1, Y_2, which is measured from the end elevation in Fig. 34(*a*).

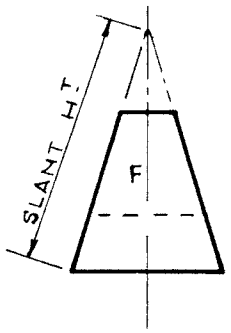
Along the centre line X_1X_2 transfer the measurement E in inset to E_1. Also transfer the measurement F in inset to F_1. Draw dotted lines from B_1 to C_1 and from A_1 to D_1. Rotate B_1 to B_2 with centre B and C_1 to C_2 with centre C. Rotate A_1 to A_2 with centre A and D_1 to D_2 with centre D. Join A_2 to B_2 and C_2 to D_2. The length of the sloping face A_2B_2 should now be marked off along the centre line X_1X_2 as a continuation of E_1. Notice that this measurement is made along the horizontal centre line and not along any other line. At the end of this line draw GH, which is the same length as A_1D_1 and joins to it when the model is finally folded into shape. Draw B_1G and C_1H. Draw this outline on stiff drawing paper. Cut out carefully along the outline and fold along the dotted lines. It is very interesting to watch the shape develop as each bend is made. If the paper is stiff enough it will remain in position after bending so that the finished shape will look like Fig. 34(*a*).

4.8. SQUARE PYRAMID (DOUBLE CUT). Fig. 35

(i) *First angle projection.* The next object we shall deal with is a hollow square pyramid 2 in base and $2\frac{1}{2}$ in vertical height which has the upper part removed, leaving one sloping and one flat face joined on the centre line, as in Fig. 35(*a*). There are seven faces in this shape. Draw carefully the three views, making sure that the projection used is first angle.

(ii) *Development.* Construct the 2 in square base and the outline of the complete pyramid as previously instructed in Fig. 33(*b*) on cross-lines X_1X_2 and Y_1Y_2.



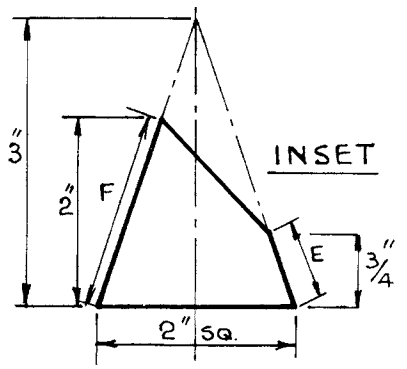


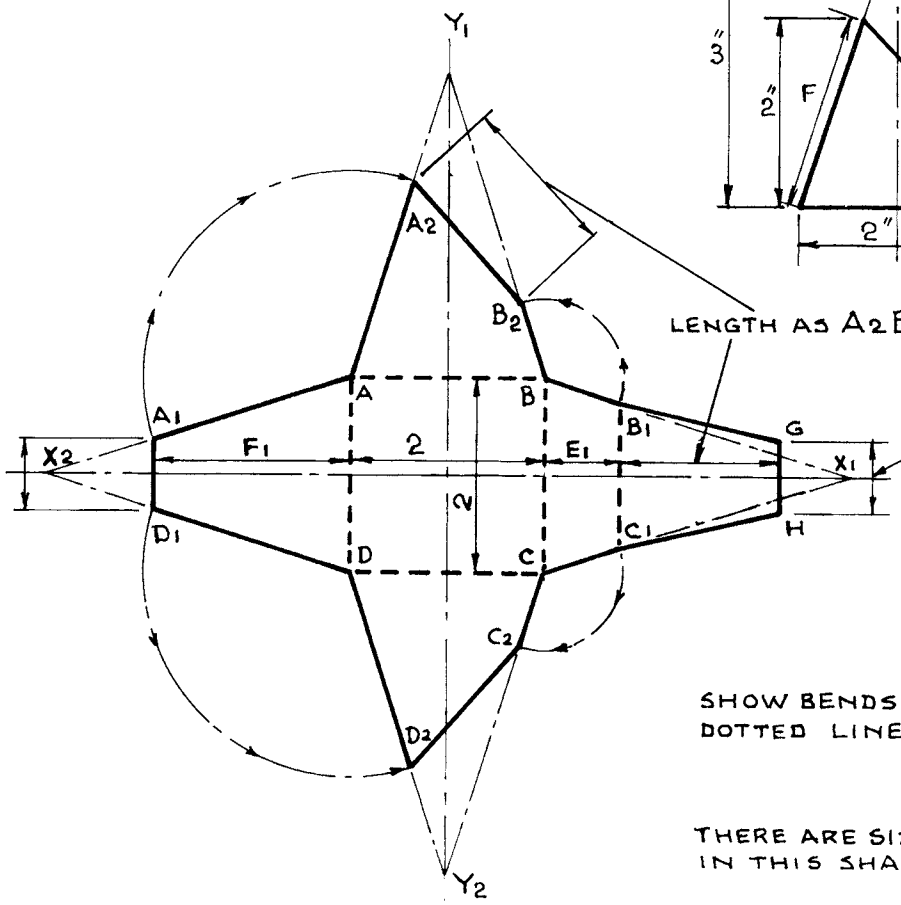
TO BE MADE FROM THIN SHEET MATERIAL

SQUARE PYRAMID (CUT)
FIRST ANGLE PROJECTION.

(a)

REFER 4.7(i)





SHOW BENDS BY DOTTED LINES.

THERE ARE SIX FACES IN THIS SHAPE.

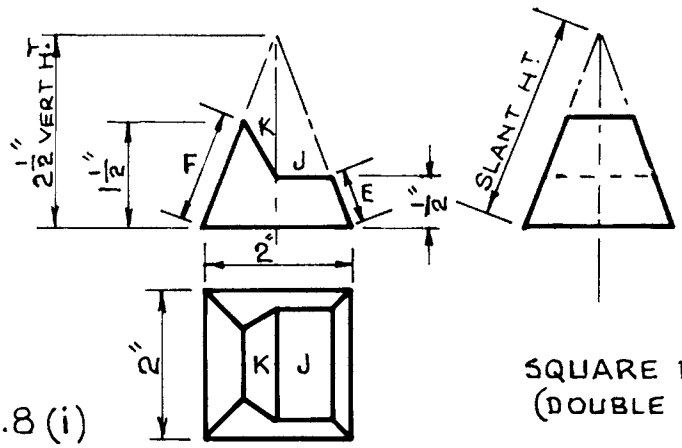
REFER 4.7(ii)

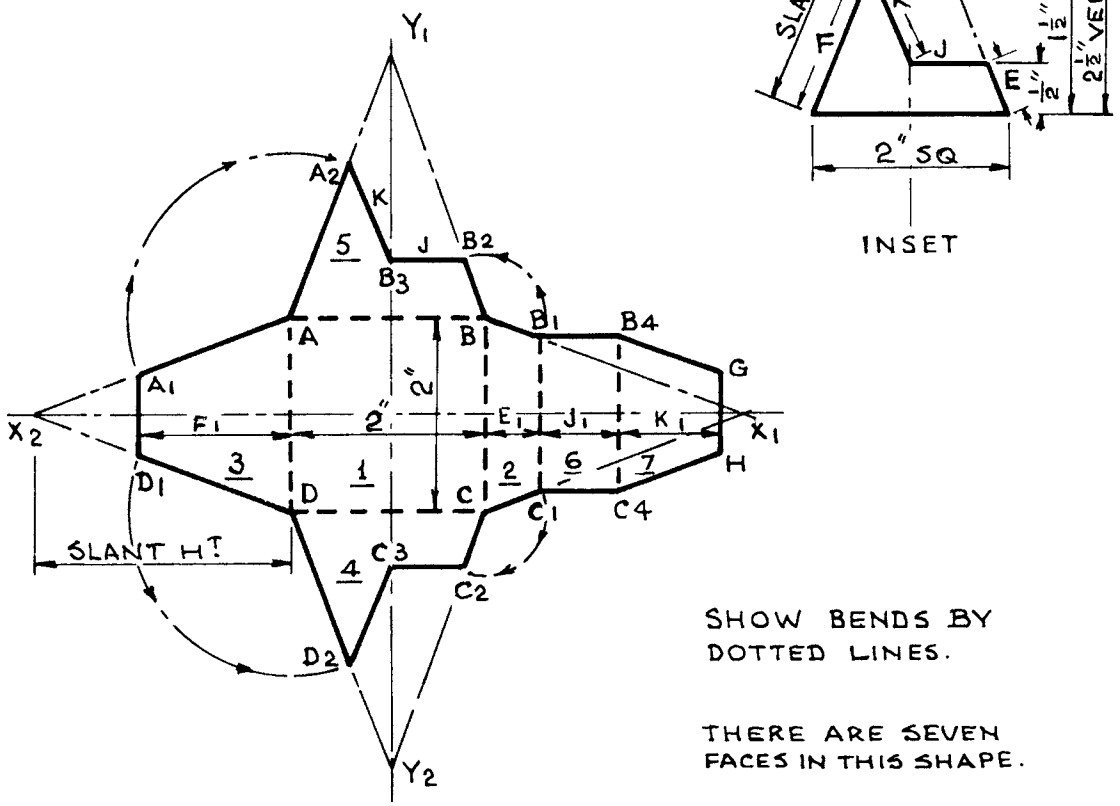
DEVELOPMENT

(b)

SQUARE PYRAMID (CUT)
DEVELOPMENT

FIG 34





SQUARE PYRAMID (DOUBLE CUT) FIG. 35
DEVELOPMENT

Again we must not forget that the slant height is the measurement we require for the height of the triangles up to X_1, X_2, Y_1 and Y_2 (see Fig. 35(*b*)). Transfer measurement E from inset to E_1. Transfer measurement F from inset to F_1. Continue construction as in Fig. 35(*b*) including the rotation of points B_1 to B_2, C_1 to C_2, A_1 to A_2, D_1 to D_2. J is a flat surface and its length should be transferred to J_1 as far as B_4C_4, which should be drawn as a dotted line. K is a sloping surface and its length should be transferred to K_1 as far as GH. The length of GH is the same as A_1D_1 and these two lines should be drawn in outline. Draw B_4G and C_4H.

Draw this outline on stiff drawing paper, cut out carefully along the outline, and bend along the dotted lines. It is very interesting to watch the shape develop as each bend is made, and to see the way in which faces 6 and 7 fit all the sloping sides to look like Fig. 35(*a*).

4.9. CYLINDER (CUT). Fig. 36

(i) *First angle projection.* Fig. 36(*a*). We have dealt with cylinders twice before, once as a solid object (Fig. 23(*a*) and (*b*)), and once as a development (Fig. 28(*a*) and (*b*)). We shall refer to both of these during the working of this example.

Draw the cylinder shown in Fig. 36(*a*) which has its upper part removed leaving one sloping face. Although it is hollow draw it as solid (see Fig. 28(*a*) and (*b*) for method). Also project the true shape of the sloping face.

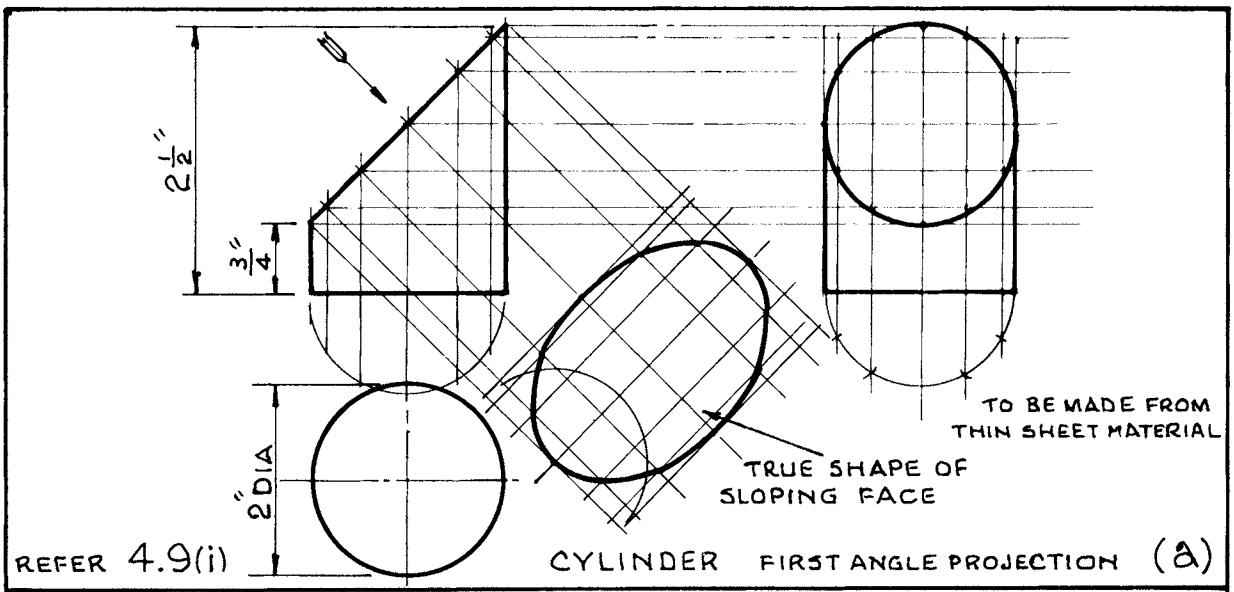
(ii) *Development.* Fig. 36(*b*). In order to lay out the developed shape we must draw the front elevation, divide the curved surface into twelve equal parts, and to the right leave sufficient space for the circumference and to insert dimensions.

Draw the front elevation to the dimensions given. Divide the base semicircle into six parts, number them 0–6, and project these vertically upwards to intersect the sloping surface. This is the same thing as dividing the diameter into twelve parts.

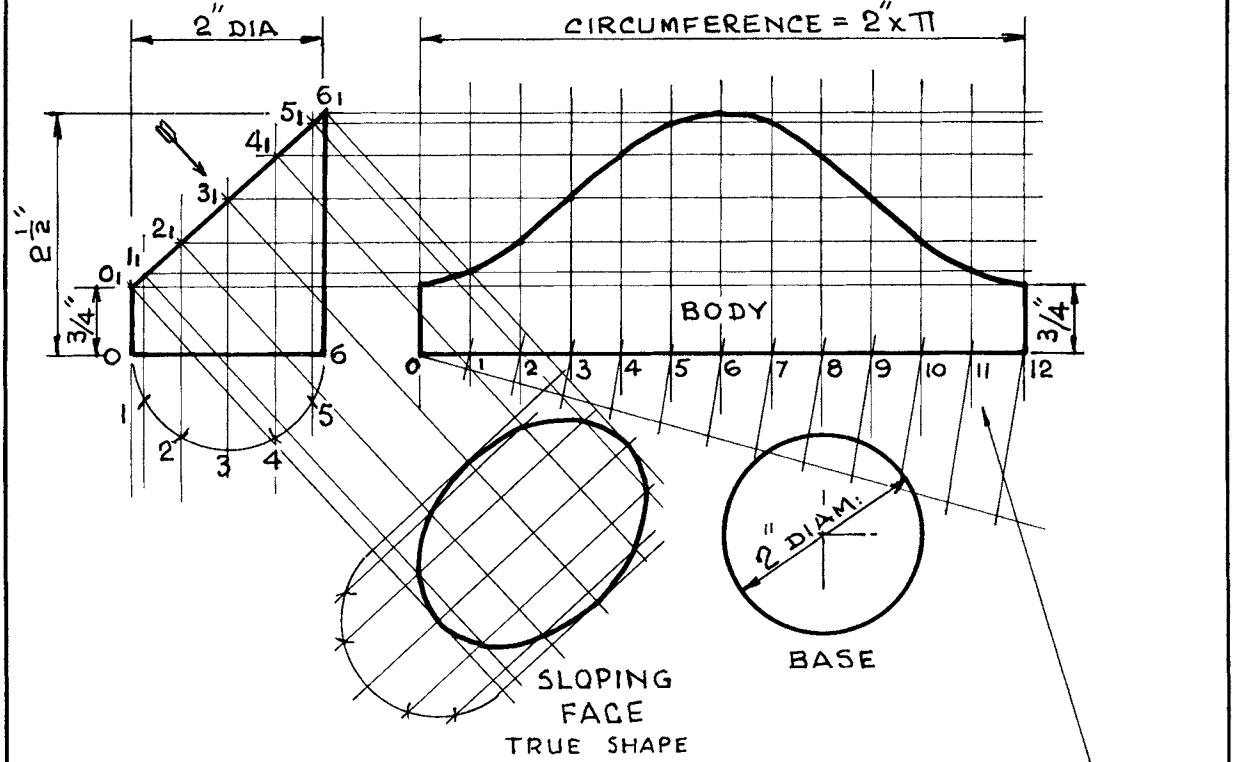
From the front elevation project a rectangle $2\frac{1}{2}$ in high and the length equal to the circumference of the cylinder. Divide the length of the rectangle into twelve equal parts by the method shown in Fig. 2(*c*). Project these points vertically and number them 0–12. Now project all the intersections, 0_1–6_1 of the sloping face horizontally to the rectangle. At each place where the horizontal and vertical lines intersect make a mark. Join these marks with a carefully drawn curve outline and complete with a vertical line at each end and a base line. This is then the developed shape of the body. To complete the development we must show the base and the true shape of the sloping face. The base is just a simple circle 2 in dia. and should be placed near the other outline. The true shape of the sloping face is transferred from Fig. 36(*a*) and also placed near the other outline.

The development includes the shape inside the rectangle, the base, and the sloping face. These should be shown in outline. The front elevation is for construction only and need not be outlined.

The result should be like Fig. 36(*b*) and should be drawn on stiff drawing



REFER 4.9(i) CYLINDER FIRST ANGLE PROJECTION (a)



NO ALLOWANCE FOR JOINTING.

REFER 4.9(ii) DEVELOPMENT (b)

CYLINDER (CUT) DEVELOPMENT

FIG. 36

paper. Cut out carefully along the outline and leave the construction lines on each piece. Roll the body into a cylindrical shape with the construction lines showing outside and butt the ends together with sellotape. Secure the base in position. Fix the sloping face into a position so that the centre line corresponds with the centre line of the body. You will notice that the intersections on the sloping surface correspond with the vertical lines on the body.

The method just described is made clearer and much easier to understand if the model is carefully drawn and made.

4.10. CYLINDER (CUT). Fig. 37

(i) *Third angle projection.* This method of projection will not affect the developed shape of the cylinder. Draw the cylinder to the dimensions given in Fig. 37(*a*) in third angle projection and remember that the plan is above the front elevation and the true shape of the sloping face is projected away from the front elevation and perpendicular to the sloping face. Remember also that the projections and intersections are exactly the same as for first angle projection.

(ii) *Development.* Fig. 37(*b*). As we are not using first or third angle projection in the development we can adopt the same method as that used in previous examples, remembering that the developed shape of a cylinder is a simple unrolling to a flat rectangle. Proceed with the development as follows.

In fine construction lines draw the front elevation, leaving sufficient room on the paper for the length of the circumference. By the semicircle method divide the curved surface into six equal parts, projecting the lines vertically to pass through the sloping surface. Also, in fine construction lines, lay out the circumference and divide it into twelve equal parts. Project the seven intersections from the sloping surface horizontally to the right. At each place where the horizontal and vertical lines intersect make a mark. Join these marks with a carefully drawn outline and complete with a vertical line at each end and a baseline. This gives the development of the body.

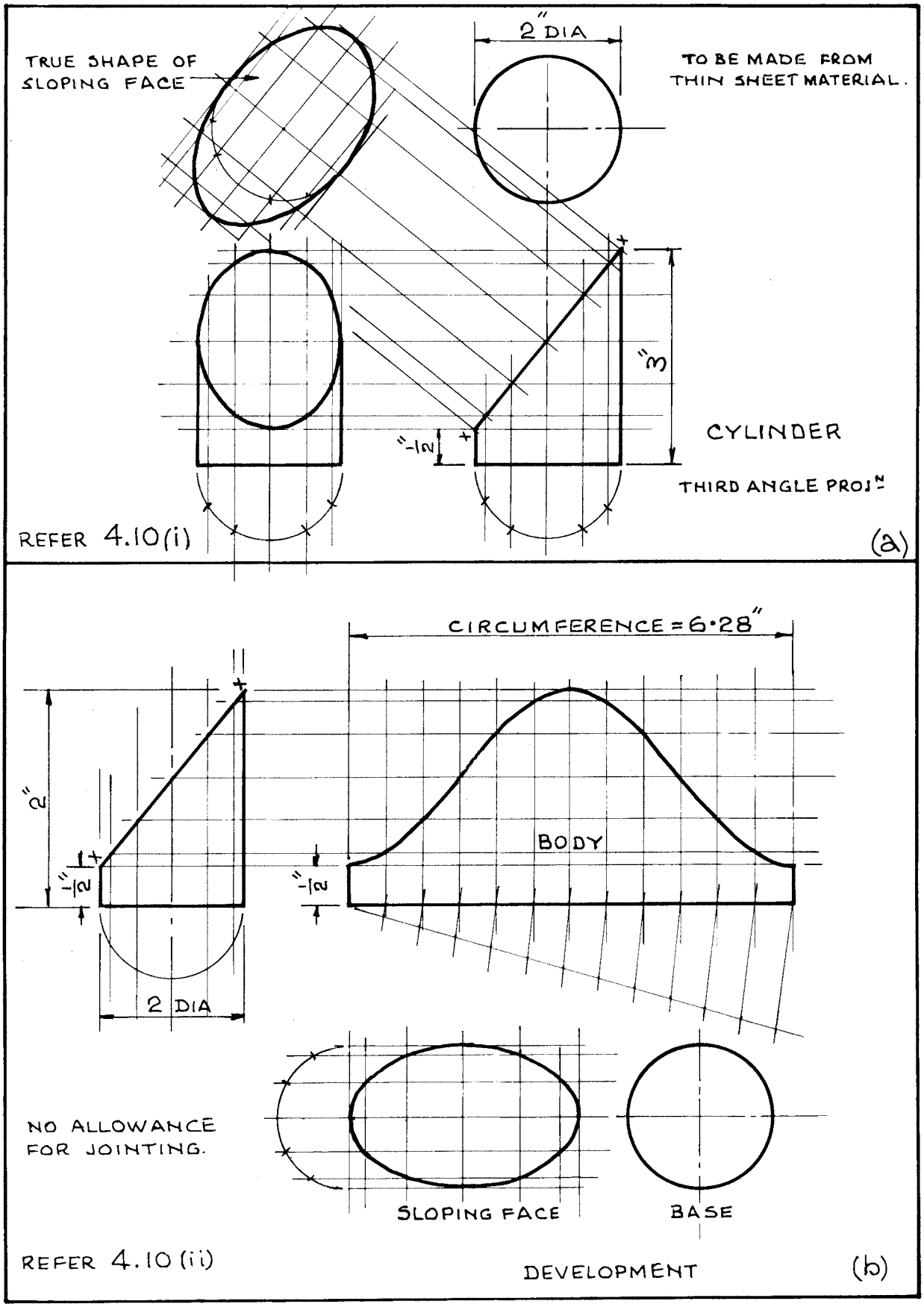
To complete the development we must show the base, which is a circle, and the true shape of the sloping face which is transferred from Fig. 37(*a*). These two parts must be drawn in outline and placed near the developed outline of the body.

The result, drawn on stiff drawing paper, should be like Fig. 37(*b*). Cut out and make a model similar to the one you have made in Fig. 36(*b*). Roll the body and fix the parts in the same way. The intersections on the sloping surface should correspond with the vertical lines on the body.

4.11. ELBOW, 90°. Fig. 38

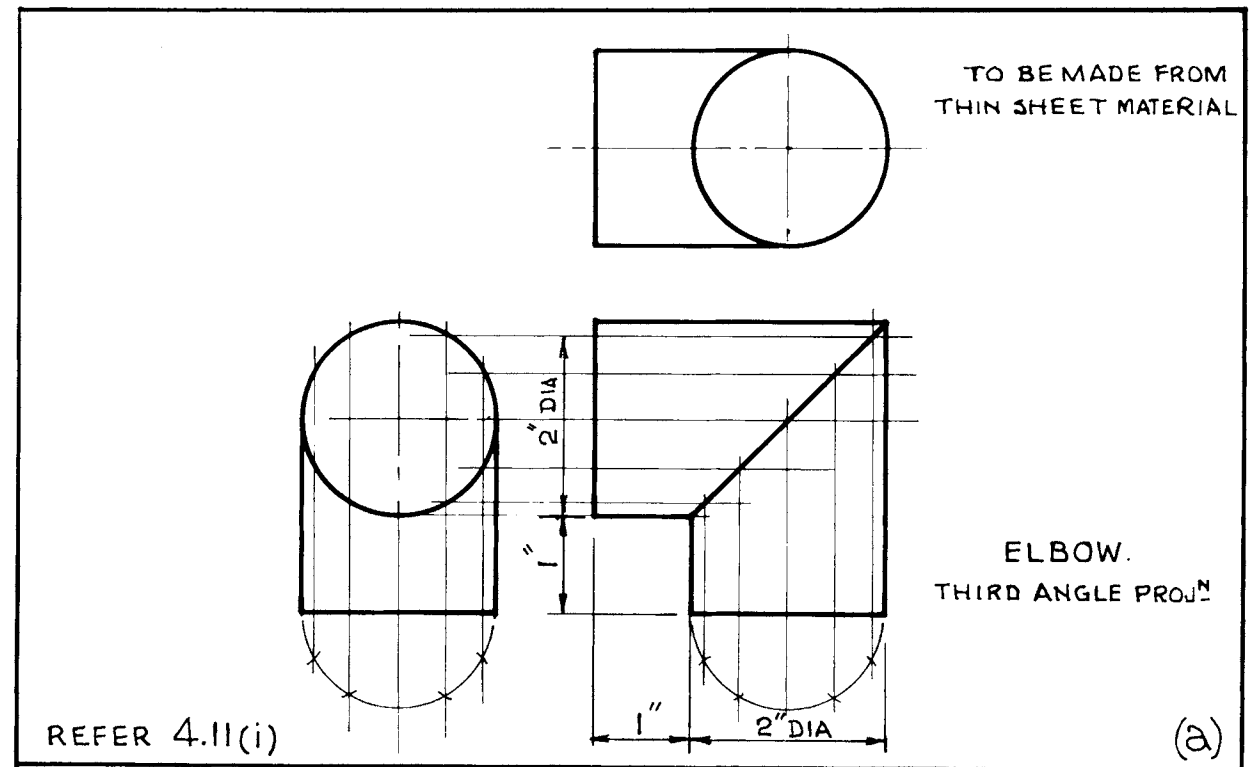
(i) *Third angle projection.* If the elbow is the same length in both pipes two identical developments will be required. If the elbow has different length pipes then there will be two developments with the curves exactly similar but with the pipe lengths different.

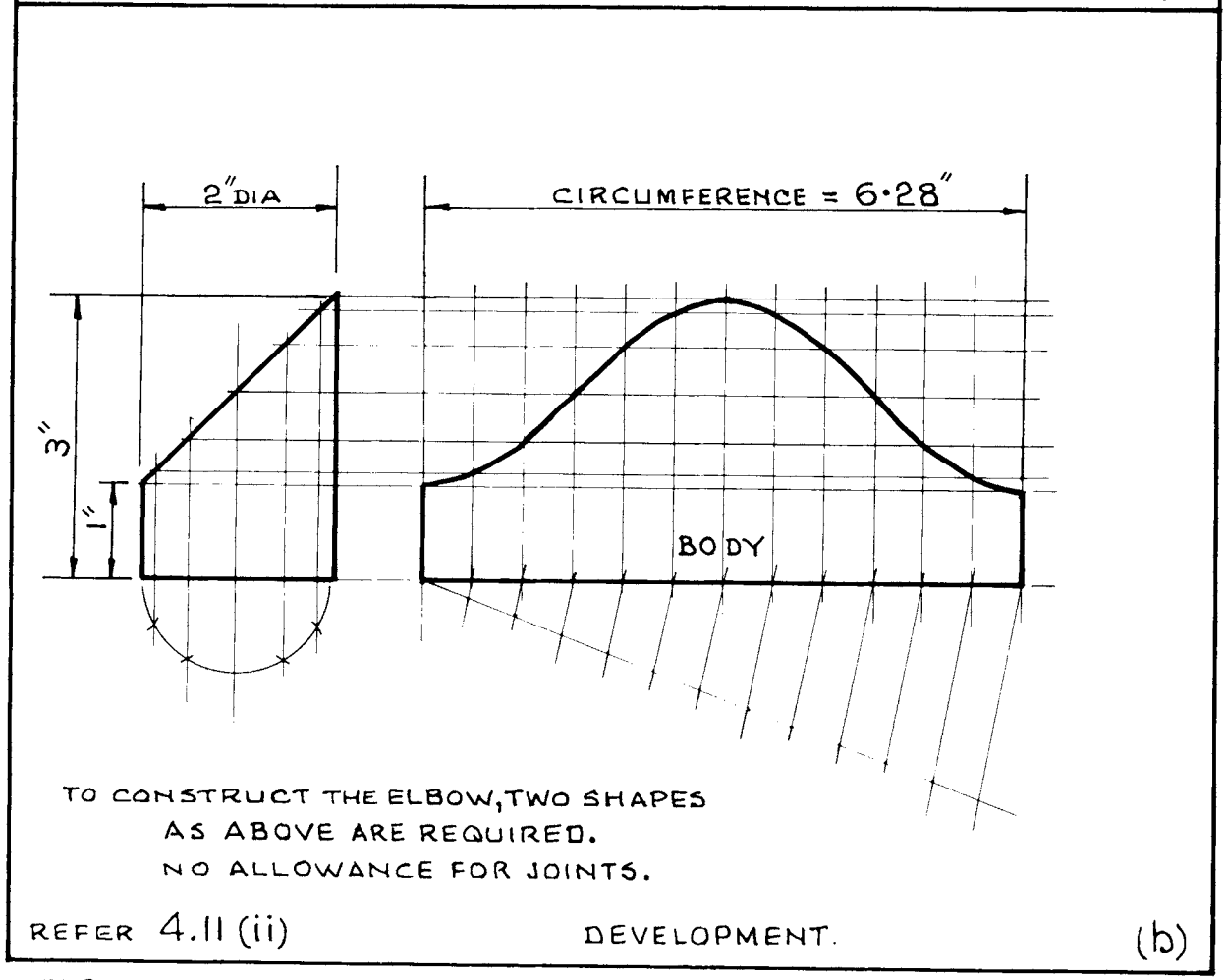
Draw the three views in third angle projection complete with all construction as shown in Fig. 38(*a*).



CYLINDER (CUT) DEVELOPMENT

FIG. 37





ELBOW DEVELOPMENT

FIG. 38

(ii) *Development.* In fine construction lines draw the front elevation showing the sloping edge and the dividing lines. Project the circumference and divide into twelve equal parts. Project intersections on the sloping edge horizontally to the right. Complete in outline the curve, the two upright lines, and the base line, as in Fig. 38(*b*).

If two of these shapes are cut out, rolled, and the sloping edges stuck together you will have a model like the one shown in Fig. 38(*a*).

There is no allowance for jointing, and you do not require a shape for the sloping surface or the base because in an elbow there is a free passage.

4.12. T WITH EQUAL DIAMETER PIPES. Figs. 39 and 40

(i) *90° T with Both Pipes the Same Diameter*

Figure 39(*a*) shows the outline, with dimensions, of a 90° T with the short pipe the same diameter as the long pipe, and you are asked to find the curve of intersection. Draw the outside shapes only of the plan, front elevation, and end elevation as shown in Fig. 39(*b*). Divide the short pipe shown in both the lower views into six equal parts and project the lines vertically as far as the horizontal centre line.

In the end elevation, where the vertical lines cut through the long pipe, the intersecting points should be projected to the front elevation to intersect the other vertical lines. It will be found that the intersections shown in the elevations form two straight lines in this view and they are the "curves of intersection". It must be pointed out that the two lines are straight and at 90° but that this occurs only when the pipes are of equal diameter.

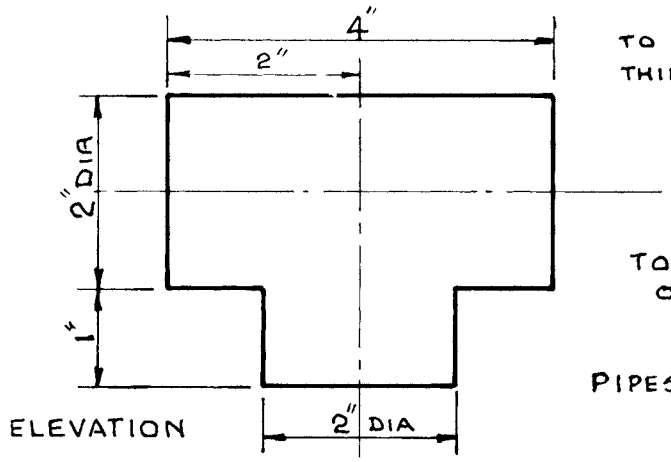
(ii) *90°T. Complete development*

In Fig. 40 we can follow the complete development of a 90° T with pipes of equal diameter. You can see the developed shape of both the lower pipe and the upper pipe, including the matching hole.

To construct a complete development of the T proceed as follows.

Construct the front elevation (*a*), outside shape only. Project the end elevation (*b*), outside shape only. Divide the short pipe in both views into six, and project the intersections in (*b*) horizontally to (*a*). At the intersections of the lines produce a curve of intersection, as in Fig. 39(*b*), which is two straight lines at right angles when the pipes are of equal diameter. Construct a rectangle (*c*) whose length is the circumference of the lower pipe and divide into twelve. At each intersection in (*a*) construct lines to continue through (*c*). Join up these points with a fair curve. Construct a rectangle (*d*) whose length is the circumference of the upper pipe, and divide into twelve. Produce the lines at (*e*) through the rectangle (*d*). At the intersections join with a fair curve. Fill in the outline and the drawing should look like that in Fig. 40.

The drawing should be made on stiff drawing paper. The developments (*c*) and (*d*) should be cut out and rolled into a cylindrical shape. Fix with a small piece of sellotape. Fit the cut edges of (*c*) to (*d*) and you should find that they fit perfectly.

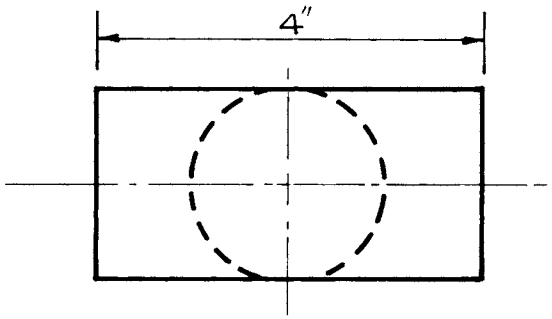


TO BE MADE FROM THIN SHEET MATERIAL.

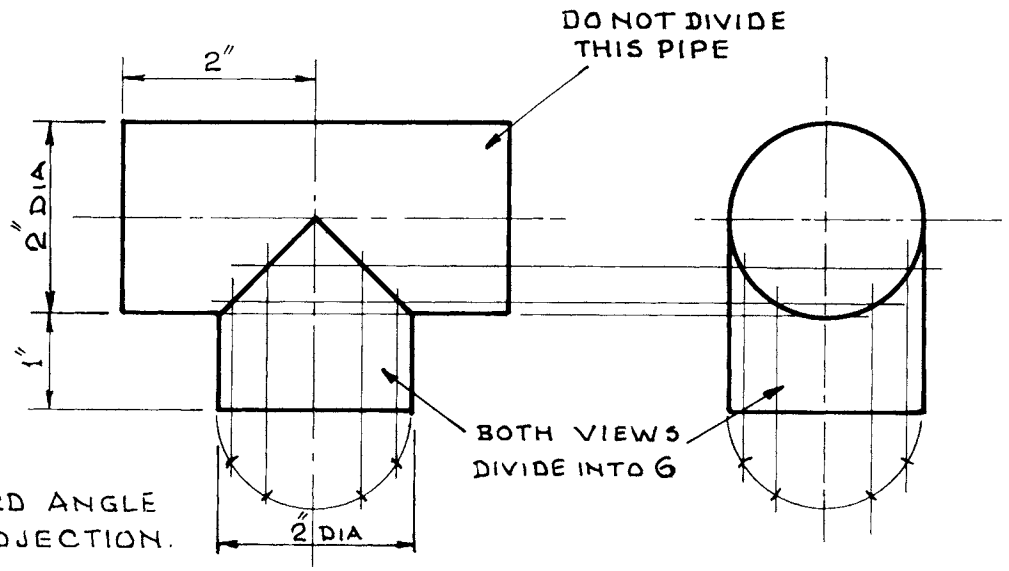
TO FIND THE CURVES OF INTERSECTION.

PIPES OF EQUAL DIAMETER

(a)



TO BE MADE FROM THIN SHEET MATERIAL



THIRD ANGLE PROJECTION.

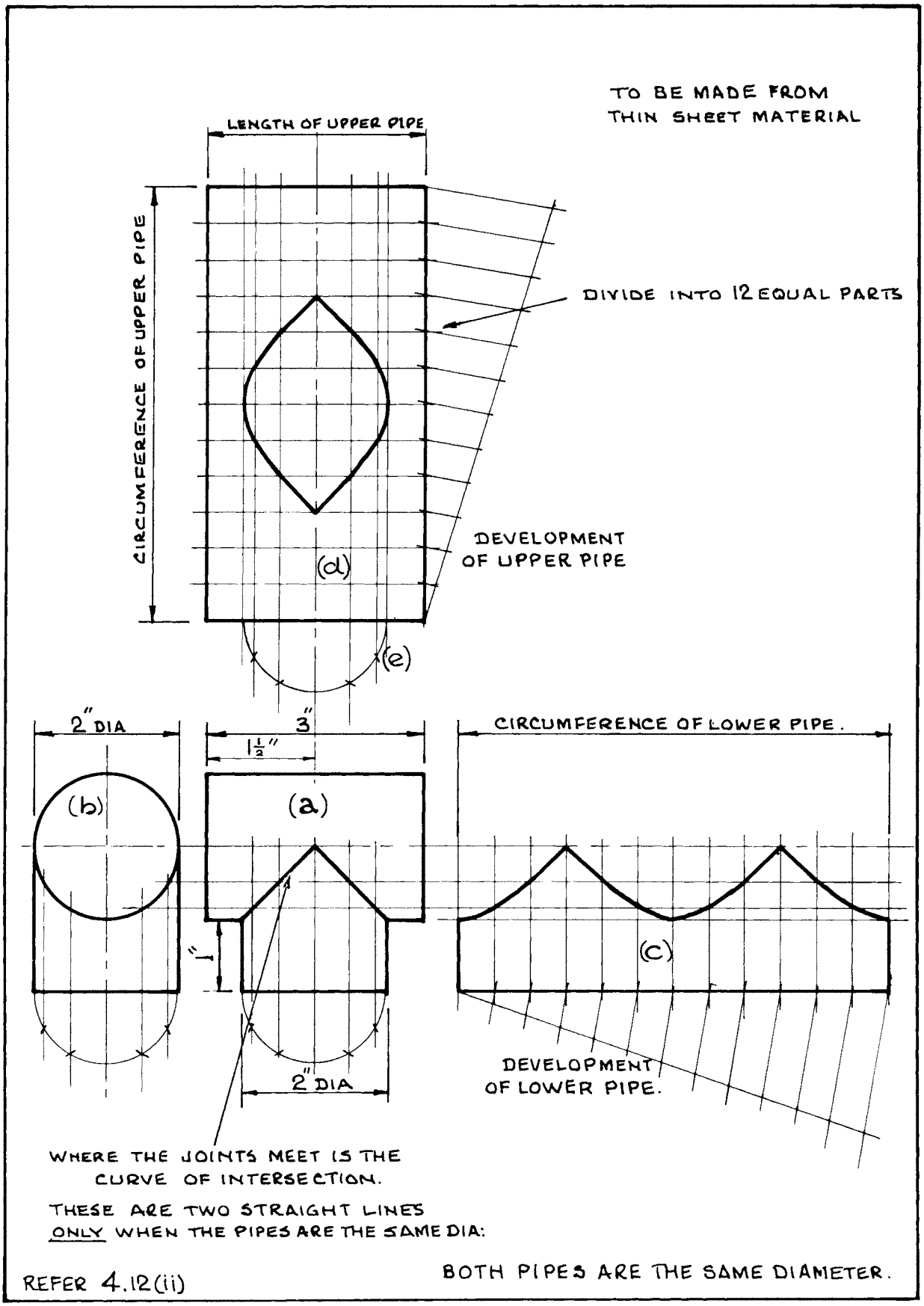
BOTH PIPES ARE THE SAME DIAMETER.

(b)

REFER 4.12(i) METHOD OF CONSTRUCTING CURVES OF INTERSECTION

90° TEE

FIG. 39 DEVELOPMENT



90° TEE (DEVELOPMENT) FIG. 40

4.13. T WITH UNEQUAL DIAMETER PIPES. Figs. 41 and 42

(i) *90° T with Pipes of Unequal Diameter*

In Fig. 41(*a*) you are given the outline with dimensions of a 90° T with the short pipe of smaller size than the long pipe, and you are asked to find the curve of intersection.

Draw the outside shapes only of the plan, front elevation, and end elevation as shown in Fig. 41(*b*). Divide the short pipe in both the lower views into six equal parts and project the lines vertically as far as the horizontal centre line. In the end elevation, where the vertical lines cut through the long pipe, the intersecting points should be projected to the front elevation to intersect the other vertical lines. Join these intersections with a fair curve. Fill in the outline and the drawing should look like that in Fig. 41. It will be seen that the curve of intersection is a "curve" and not a straight line, as is the case when the pipes are of equal diameter.

(ii) *90° T. Complete Development with Pipes of Unequal Diameter*

In Fig. 42 we see a complete development of a 90° T with pipes of unequal diameter.

To construct a complete development of the T proceed as follows.

Construct the front elevation (*a*), outside shape only. Project the end elevation (*b*), outside shape only. Divide the short pipe in both views into six. At the intersections of the lines produce the curve of intersection, shown in (*a*) of Fig. 42. Construct a rectangle (*c*) whose length is the circumference of the lower pipe and divide into twelve. At each intersection produce lines to continue through (*c*). Join up these points with a fair curve. Construct a rectangle (*d*) whose length is the circumference of the upper pipe. Do NOT divide this into twelve but mark off the centre line only. Produce the lines at (*e*) through the rectangle (*d*). From the end elevation (*b*) measure *ab*, *bc*, *cd* and mark these in the rectangle (*d*) each side of the centre line at *a*, *b*, *c*, *d*. Notice that you take the measurements *ab*, *bc*, *cd*, and NOT *ab*, *ac*, *ad*. At the intersections join with a fair curve. Fill in the outline and the drawing should look like that in Fig. 42.

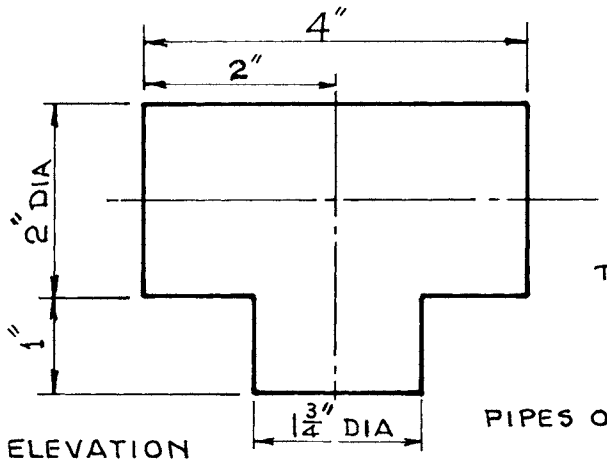
Make the drawing on stiff drawing paper and cut out the developments (*c*) and (*d*). Roll into a cylindrical shape and fix with sellotape. Fit the cut edges of (*c*) and (*d*) together and they should fit perfectly.

4.14. 45° ANGLE T. Figs. 43 and 44

(i) *45° angle T. Complete Development for Pipes of Equal Diameters*

In Fig. 43 we see a complete development of a 45° angle T and to construct it proceed as follows.

Construct the front elevation (*a*), outside shape only. Project the end elevation (*b*), outside shape only. Divide the short pipe in both views into six. Do this by drawing a semicircle and dividing it into six with compasses. Produce the lines as far as the horizontal centre line. From (*b*) project the intersections horizontally to (*a*). At the intersections of the lines produce a curve of intersection, which consists of two straight lines at right angles when the pipes are of equal diameter.

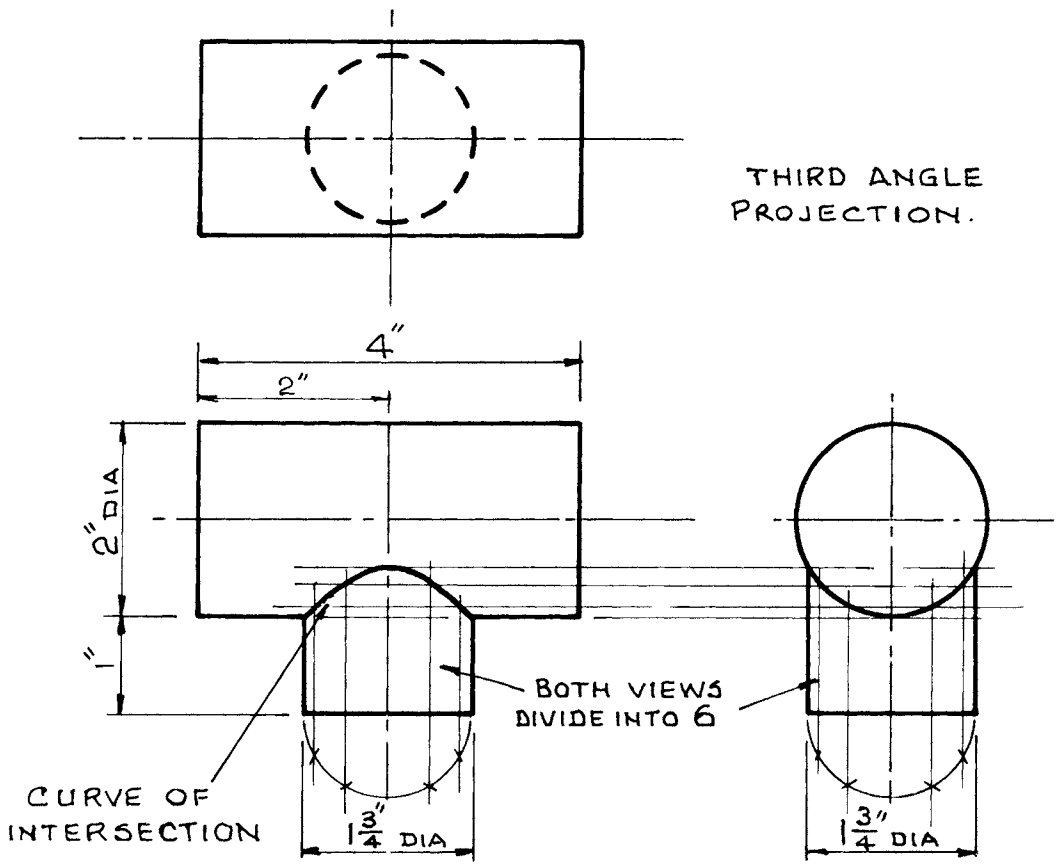


TO BE MADE FROM THIN SHEET MATERIAL.

TO FIND THE CURVE OF INTERSECTION.

PIPES OF UNEQUAL DIAMETER

(a)



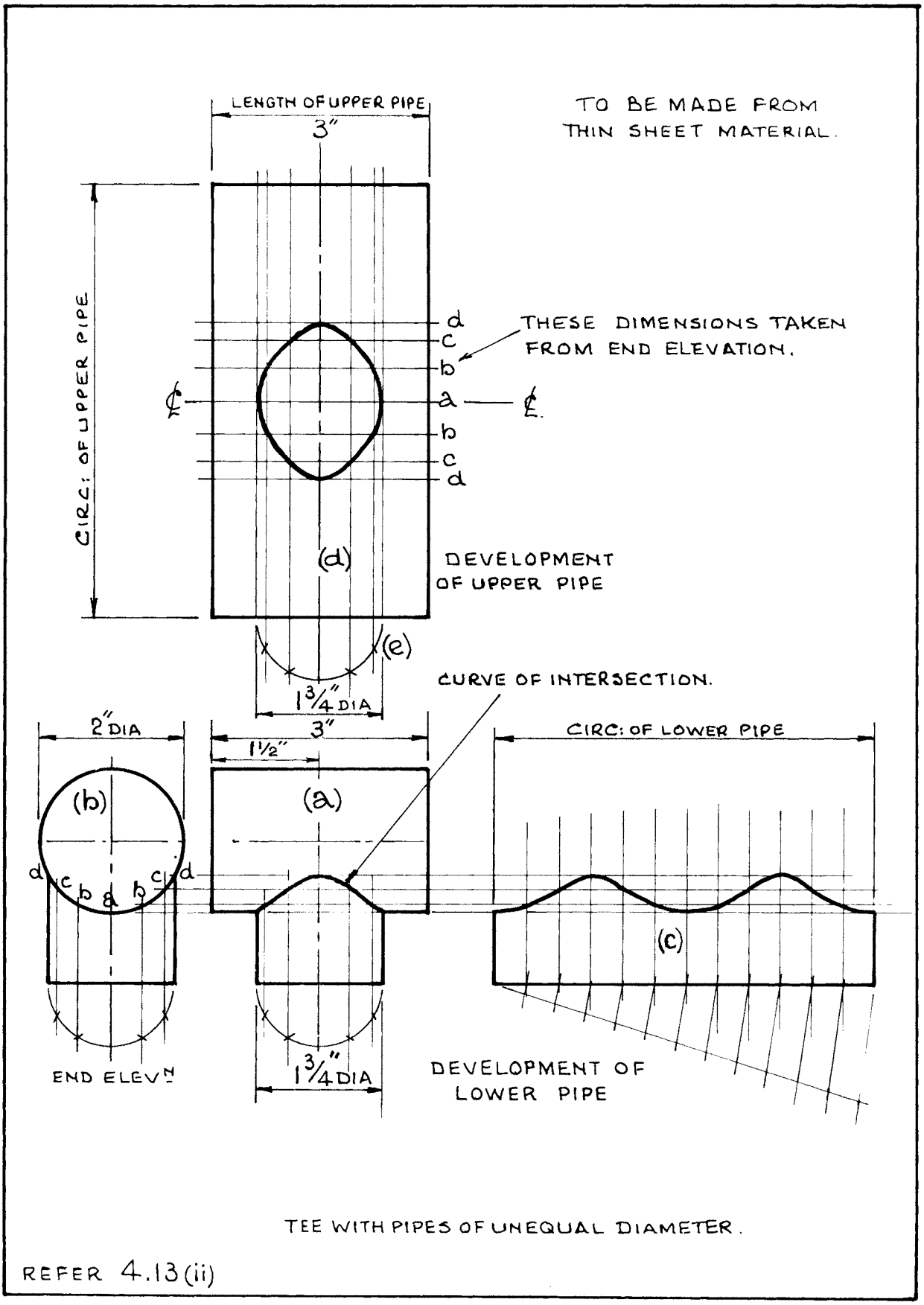
THIRD ANGLE PROJECTION.

90° TEE WITH PIPES OF UNEQUAL DIAMETER

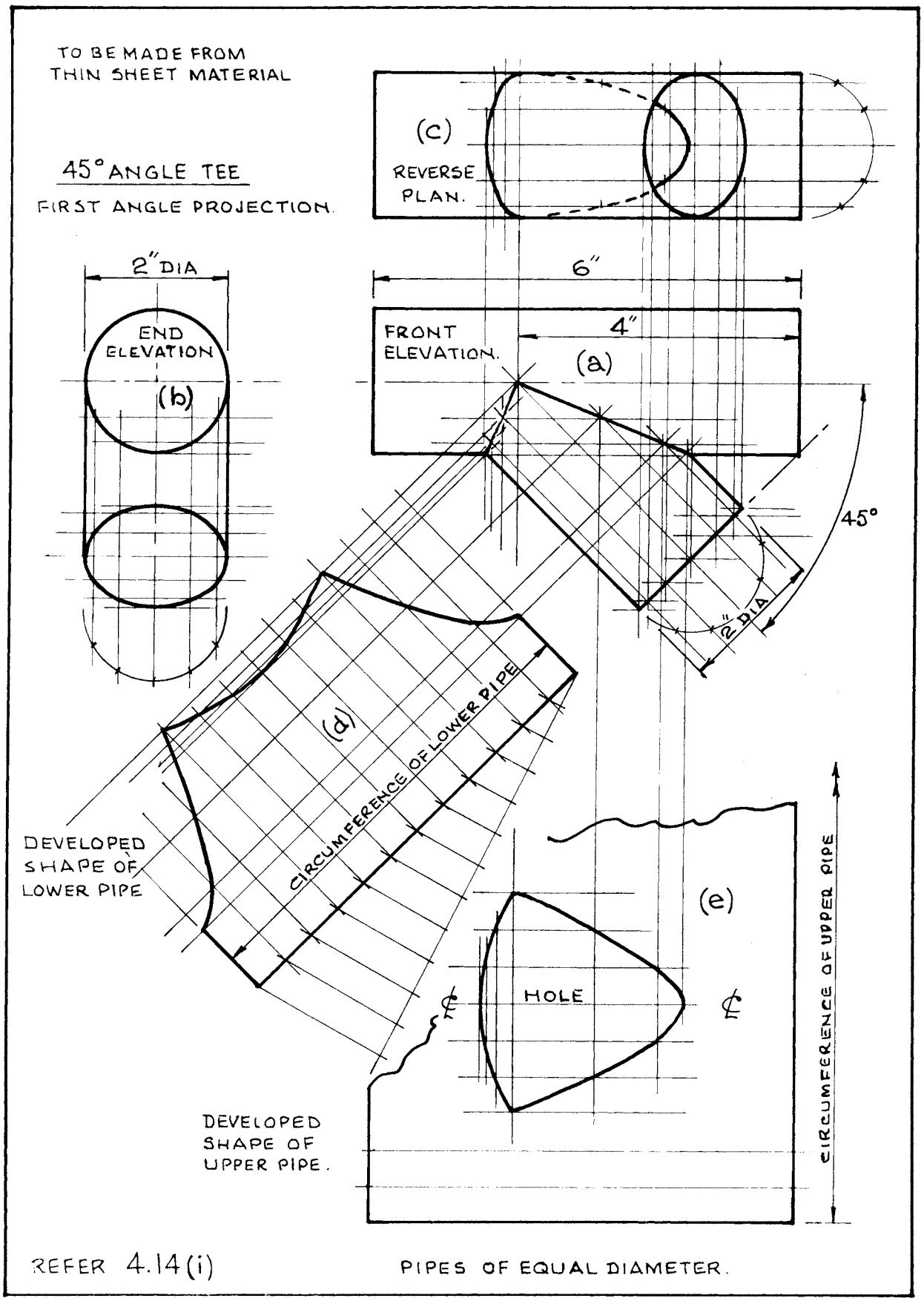
(b)

REFER 4.13(i)

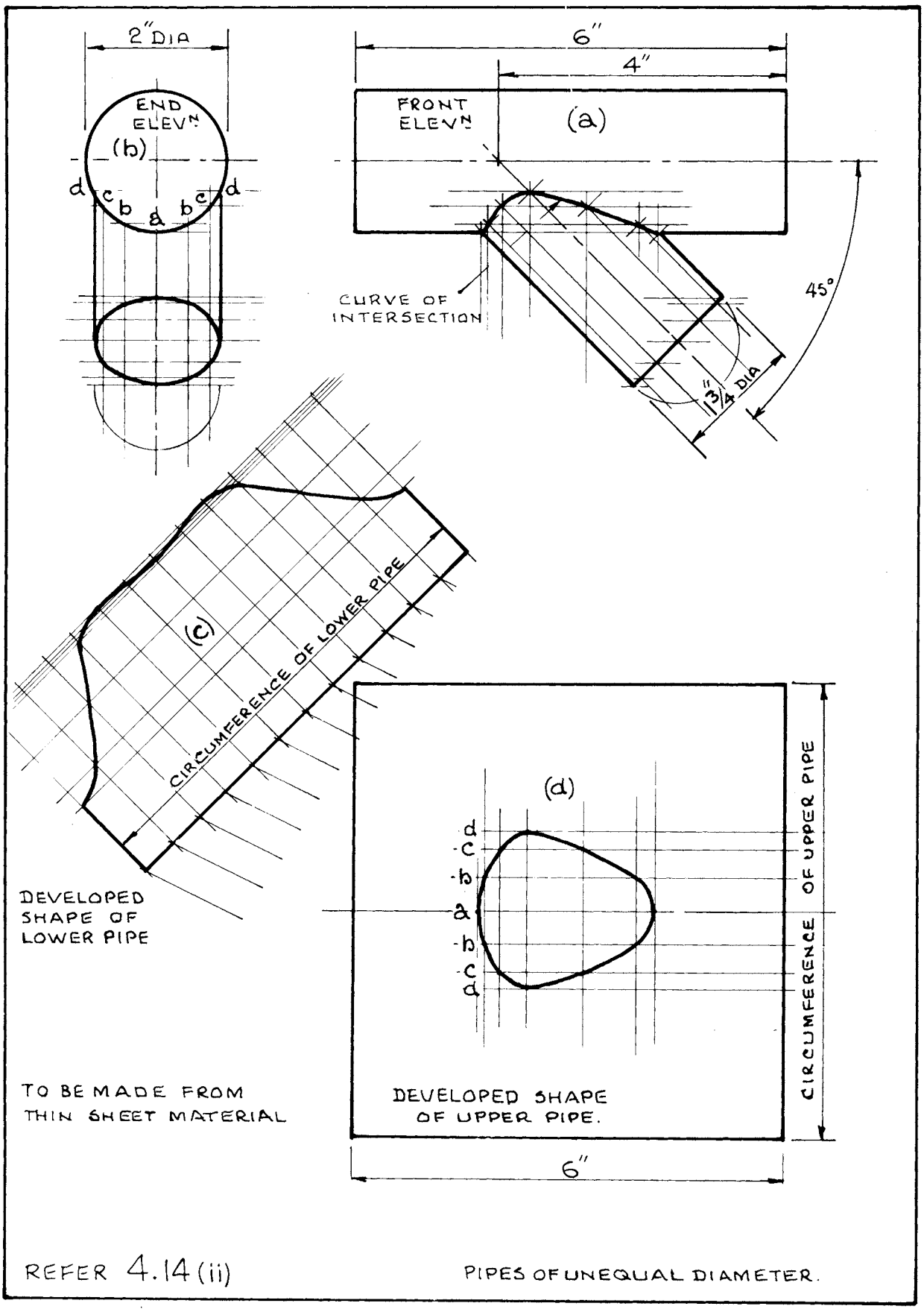
90° TEE FIG. 41 CURVE OF INTERSECTION



90° TEE FIG. 42 COMPLETE DEVELOPMENT



45° ANGLE TEE (DEVELOPMENT) FIG. 43 COMPLETE DEVELOPMENT



45° ANGLE TEE FIG. 44 COMPLETE DEVELOPMENT

Divide the reverse plan (*c*) into six, and by projection construct an ellipse both in the reverse plan and the end elevation. Now at an angle of 45° project a rectangle (*d*) whose length is the circumference of the lower pipe. Divide this into twelve. All the intersections at (*a*) should now be projected to pass through the rectangle (*d*). At the intersections construct a fair curve and notice how this dips in the centre. Now consider the long pipe and construct under the elevation (*a*) a rectangle (*e*) with the length equal to the circumference of the upper pipe. Divide into twelve. Project vertically downwards all the intersections in the front elevation (*a*) and where these intersect in the rectangle (*e*) draw a fair curve which is the developed shape of the hole.

Make the drawing on stiff paper, cut out the developments (*d*) and (*e*), and roll into a cylindrical shape. Fit the edges of (*d*) and (*e*) together.

(ii) *45° angle T. Development of Pipes of Unequal Diameters*

Figure 44 shows the full development of a 45° angle T with pipes of unequal diameters.

The construction is as follows.

Construct the front elevation (*a*), the end elevation (*b*), and by methods previously explained draw the curve of intersection. At 45° project the rectangle and inside it construct the developed shape (*c*). Project the rectangle (*d*) from the front elevation (*a*). Project the intersections from (*a*) to (*d*). Mark off *ab*, *bc*, *cd* from (*b*) to (*d*). Construct a fair curve which is the developed shape of the hole.

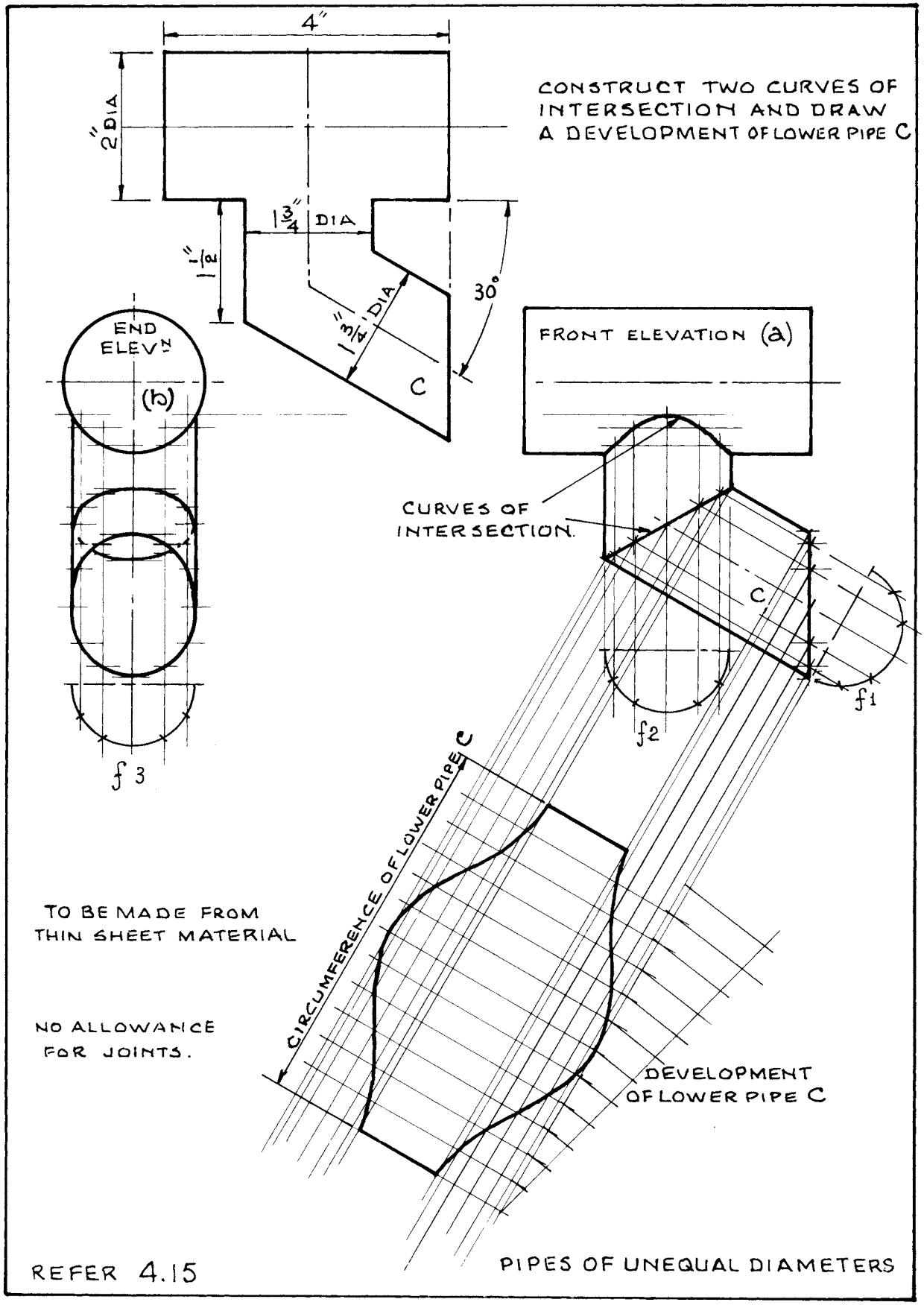
Again make your drawing on stiff paper, cut out the developments (*c*) and (*d*) and roll into a cylindrical shape. Fit the edges of (*c*) and (*d*) together.

4.15 BRANCH T. DEVELOPMENT OF PIPES OF UNEQUAL DIAMETERS. Fig. 45

In the figure we are given the outline elevation of a 90° T with a 30° branch. The two short pipes are of the same diameter but the long pipe is of larger diameter. You are required to construct two curves of intersection and a development of the lower pipe *C*. Proceed as follows.

Construct the front elevation (*a*), outside shape only. Project the end elevation (*b*), outside shape only. Divide, in three places, f_1, f_2, f_3, the short pipes in both views into six and project the intersections in (*b*) horizontally to (*a*). Construct the upper curve in (*a*). The lower curve is a straight line in the elevation because the two pipes are of the same diameter. Project at 60° a rectangle whose length is equal to the circumference of the branch pipe and divide into twelve. Project all the intersections from *C*. Construct two curves starting at a short side. This forms the developed shape of the pipe *C*. Fill in the outline and the finished drawing should look like that in Fig. 45.

In this particular instance you have not been asked to construct the developed shape of any other parts.



BRANCH TEE FIG. 45 DEVELOPMENT

D

4.16. BRANCH T. DEVELOPMENT OF PIPES OF UNEQUAL DIAMETERS. Fig. 46

In the figure we are given the outline shape of a 45° branch T with a second branch at 45°. The two branch pipes are of equal diameters but are smaller than the main pipe diameter.

You are asked to construct two curves of intersection and to draw a development of the first branch pipe *B*. Proceed as follows.

Construct the front elevation (*a*), outside shape only. Project the end elevation (*b*), outside shape only. Divide all the short pipes in both elevations into six and project all the intersections in (*b*) horizontally to (*a*). Construct the upper curve of intersection in the front elevation. The lower curve in the front elevation is a straight line because the pipes are of equal diameter. The curve constructed in the end elevation (*b*) is part of an ellipse to illustrate the joint of the two lower pipes. Project at 45° a rectangle whose length is equal to the circumference of the first branch pipe *B* and divide into twelve. Project all the intersections from both ends of *B*. Construct two curves starting at the short side. This forms the developed shape of the pipe *B*. Fill in the outline and the drawing should look like Fig. 46.

In this problem you have not been asked to construct the developed shape of the main pipe.

4.17. OFFSET T. COMPLETE DEVELOPMENT. Fig. 47

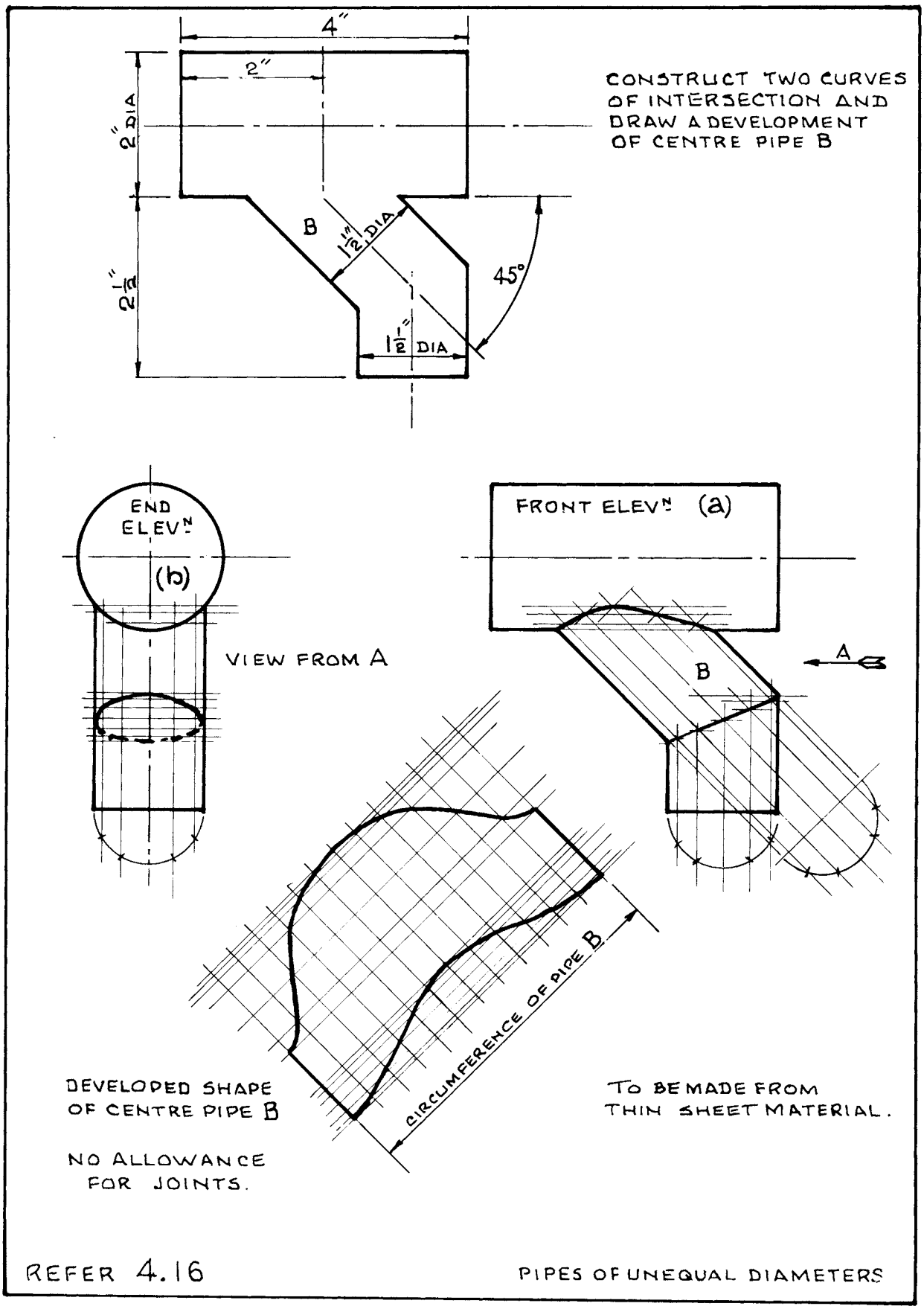
In Fig. 47 we are given the outline shape of an offset T. This is a small pipe entering a larger pipe at right angles but the centre lines are offset. You are required to construct the curves of intersection and a complete development. Proceed as follows.

Construct the plan (*a*), end elevation (*b*), and front elevation (*c*) in third angle projection. Divide the small pipes into six and construct the curves of intersection. Notice that the one in the foreground is full and the one in the background is dotted hidden detail, and reaches as far as the centre line because the edges of the pipes are in line at this point. Construct a development (*d*) of the lower pipe. Project a rectangle (*e*) for the upper pipe. Project the seven lines from (*c*). Measure *ab*, *bc*, *cd*, *de*, *ef*, *fg*, from (*b*) and transfer to (*e*), carefully positioning about the centre line. Join up the intersections and construct the shape of the hole. Draw the outline in all views, which should look like Fig. 47.

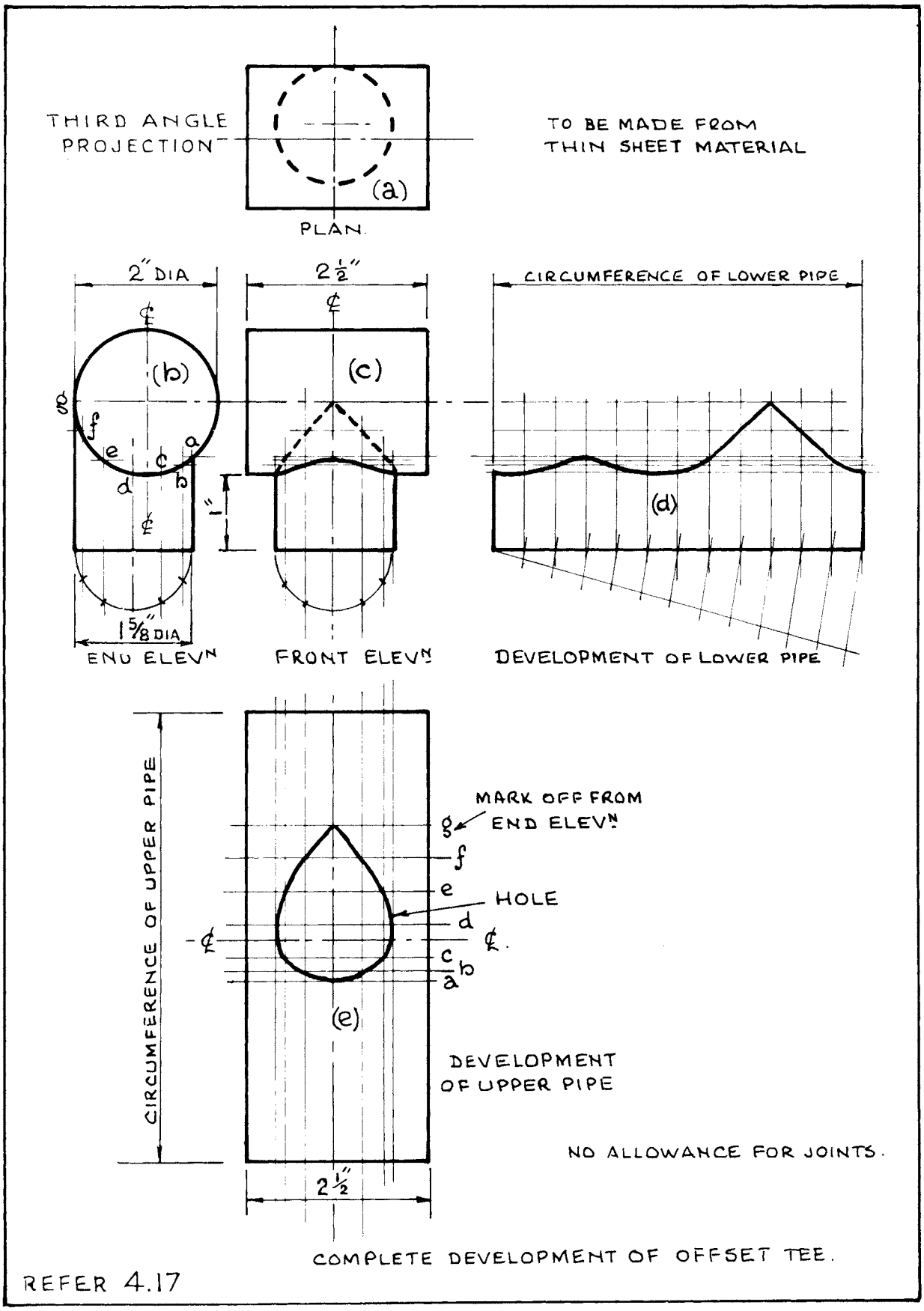
4.18. CONE DEVELOPMENT. Fig. 48

The inset at the top of the figure shows the outline of a hollow cone. The vertical height is measured on the vertical centre line which is perpendicular to the circular base. The important dimension is the slant height which is measured normally along the sloping face from the edge of the base to the apex.

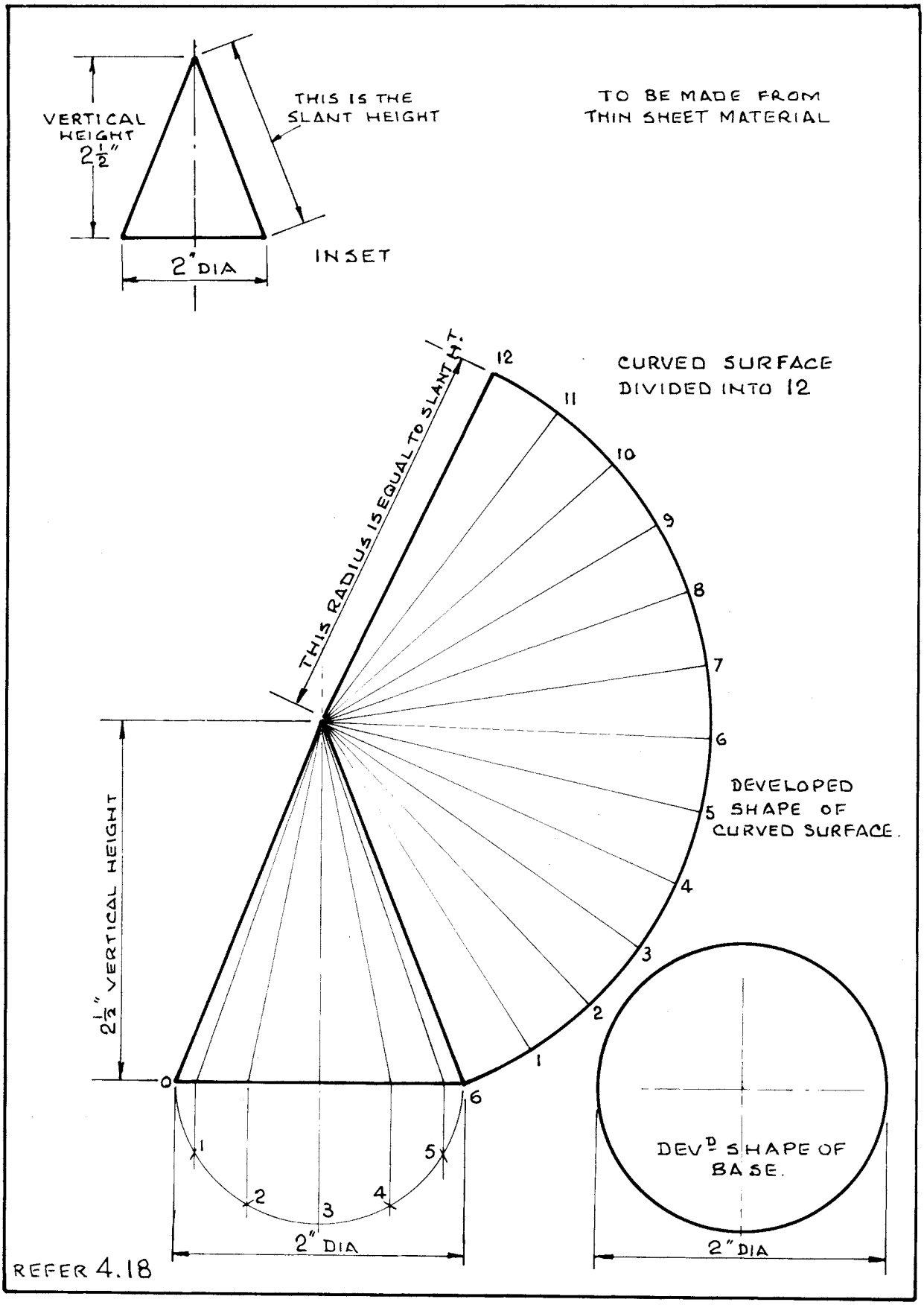
To draw a development, first construct the outside shape of the front elevation. Then divide half the base into six. Now produce the lines to the base line and then away to the apex. Do NOT draw the lines direct from the semicircle to the apex. Construct an arc of approximately half a circle, taking as a radius the slant height of the cone. Measure any one of the six equal parts and mark off twelve of these



BRANCH TEE FIG. 46 DEVELOPMENT



OFFSET 90° TEE FIG. 47 COMPLETE DEVELOPMENT



CONE DEVELOPMENT FIG 48

around the radial line. Draw in outline the elevation of the cone and the developed shape of the curved surface. Add the developed shape of the base which is a true circle.

Together with the front elevation, you have drawn a development of the curved surface of the cone and divided it into twelve equal parts. The drawing should look like Fig. 48.

This development will be used many times in the next few figures.

4.19. CONE (CUT). DEVELOPMENT. Fig. 49

The inset at the top of the figure shows the front elevation of a hollow cone with the upper portion removed. To construct a development of the curved surface, the sloping face, and the circular base proceed as follows.

Construct the front elevation, outline shape only, of the cone cut away and including the sloping face. On the centre line of the front elevation construct a view of the sloping face from the arrow *P*. The reason for this construction is to find the true width of the sloping face. Use thin lines. Construct the complete curved surface with radius 0*h* and divide into twelve equal parts, as explained for Fig. 48. Find the true slant height of each intersection on the sloping face by transferring each point horizontally to the right-hand sloping side, in this case *a*, *b*, *c*, *d*, *e*, *f*, *g*. From each of the points *a*–*g*, construct an arc. Starting from the shortest line, No. 6, construct a curve passing through all the intersections on lines 1–12. To develop the sloping face mark off a centre line *XX* parallel with it. Project all the intersections of the sloping face through the perpendicular to the development area of the sloping face. Each side of the centre line, mark off b_1, b_2 to f_1, f_2, and a_1 and g_1. The measurements for these must be taken from the superimposed side elevation. In addition to the sloping surface there should also be drawn a developed shape of the circular base, i.e. a circle.

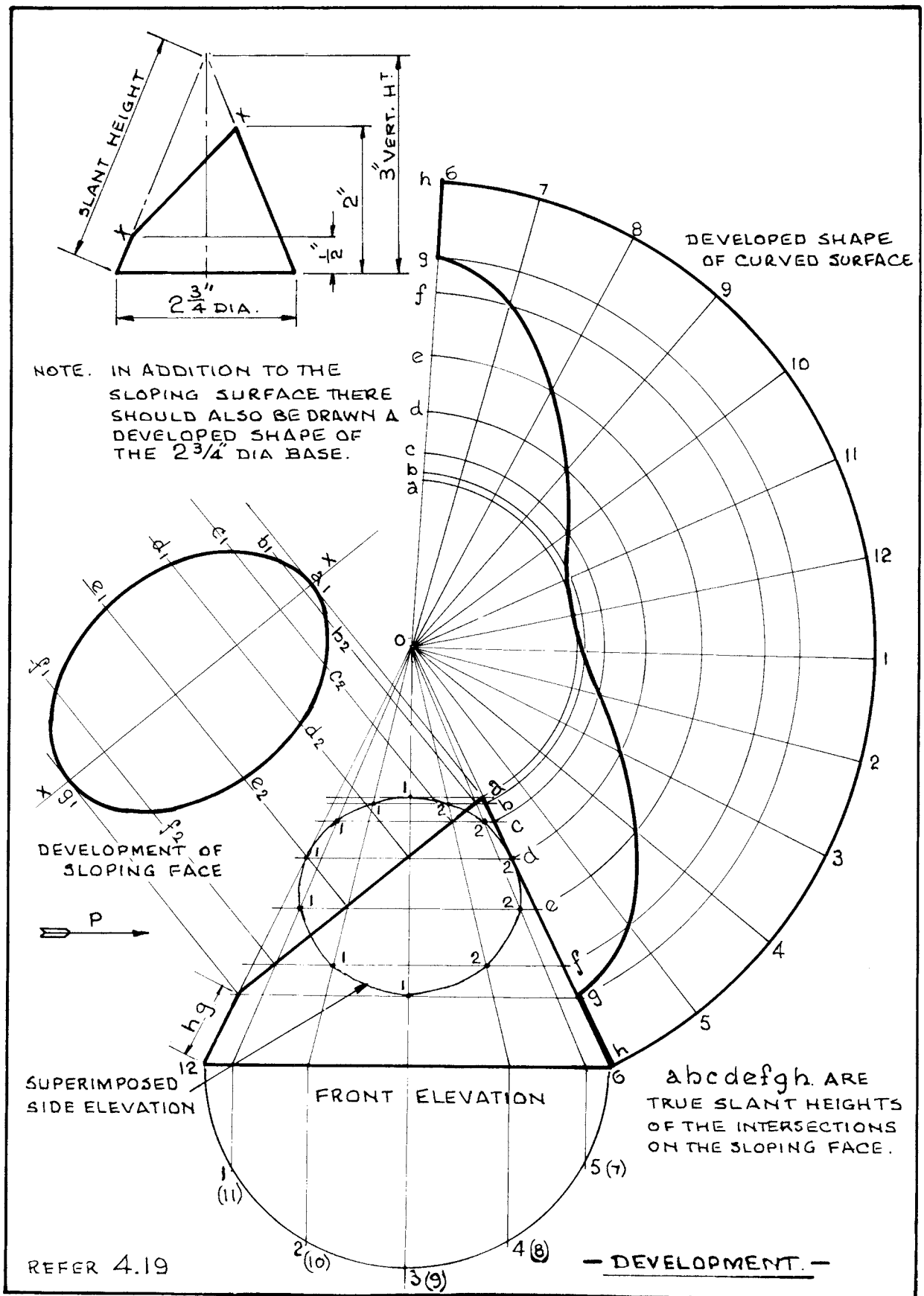
Fill in the outline and the drawing should look like Fig. 49 (except for the $2\frac{3}{4}$ in dia. base not shown).

4.20. CONE (DOUBLE CUT). COMPLETE DEVELOPMENT. Fig. 50

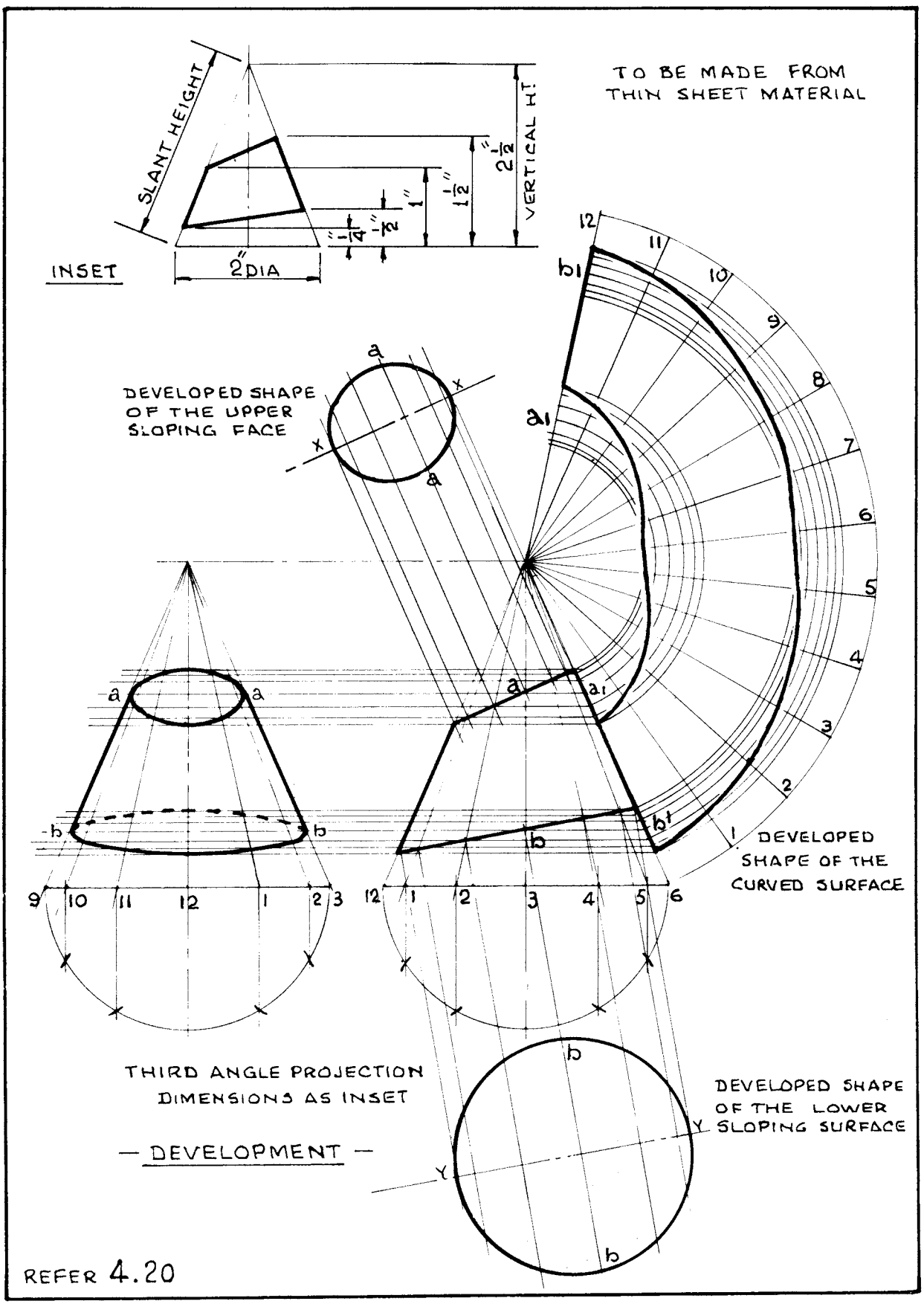
The inset shows a hollow cone with the upper and lower portions removed and covered with the sloping surfaces. To construct a development of the curved surface and the two sloping faces proceed as follows.

Construct the front and side elevations, outside shape only. Construct the complete curved surface and divide into twelve, as explained for Fig. 48. Construct a curve from each of the true slant height points on the right-hand sloping side. Through all intersections construct the two curves starting from the lowest point in each case as at *B*. Construct the developed shape of the upper face as at *A* and as explained in section 4.19. Project on to the centre line *XX*. Construct the developed shape of the lower face by projecting perpendicularly from each intersection to the centre line *YY*. Mark the width of each from the side elevation. Refer to *bb* in each view for the width of the middle line in the developed shape *C*.

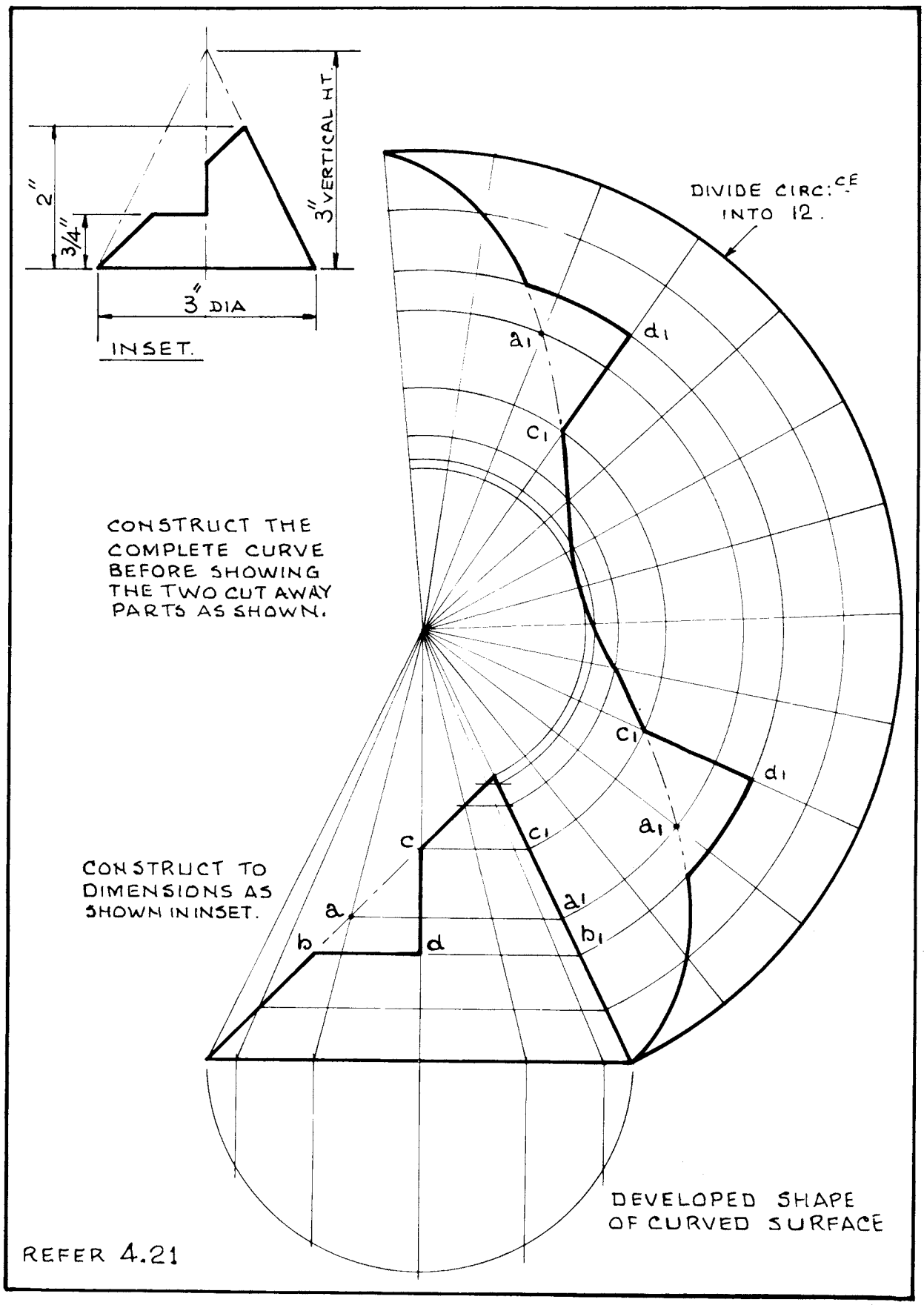
Fill in the outline and the drawing should look like that in Fig. 50.



CONE (CUT) FIG 49 COMPLETE DEVELOPMENT



CONE (DOUBLE CUT) FIG. 50 COMPLETE DEVELOPMENT



CONE. (CUT) FIG. 51 DEVELOPMENT

4.21. CONE (CUT). DEVELOPMENT OF CURVED SURFACE ONLY. Fig. 51

The inset shows a hollow cone with the upper part cut away to a special shape. As only the shape of the curved surface is required it is not necessary to construct any other surfaces. To obtain the curved surface proceed as follows.

Construct the front elevation and divide the base and the curved surface into six. Construct the complete curved surface of the cone and divide into twelve, as explained for Fig. 48. Take no notice, at the moment, of the cut-away notch but construct the cut curve complete, making use of the follow-through points at a and a_1. Produce the line b at the bottom of the notch at d to the right-hand side at b_1 and draw an extra radius line to d_1. Notice that bd is parallel with the base in the elevation and when produced is drawn parallel with the curved base-line at d_1. The side of the notch is a vertical line at c and is drawn on the third division at c_1. Repeat the notch on the ninth division at $c_1 d_1$.

Fill in the outline and the drawing should look like that in Fig. 51.

5. *Conventional Representations of Common Features. Extracts from B.S. 308*

5.1. SCREW THREADS. Fig. 52(*a*)

Some conventional methods of illustrating screw threads are shown in this figure. Both external and internal threads are shown. External threads of bolts are on the left-hand side and internal threads of nuts or screwed holes are on the right-hand side.

All three sets of threads should be drawn to a scale of diameter $d = 1$ in.

As mentioned previously, only one type, i.e. (i), (ii), or (iii) should be used on one drawing.

5.2. SPRINGS, COMPRESSION. Fig. 52(*b*)

Compression springs are open-wound and resist compressive forces from each end. The actual outline of the spring is seen on the left and the quick method of drawing shown on the right can be used for illustration.

5.3. SPRINGS, TENSION. Fig. 52(*c*)

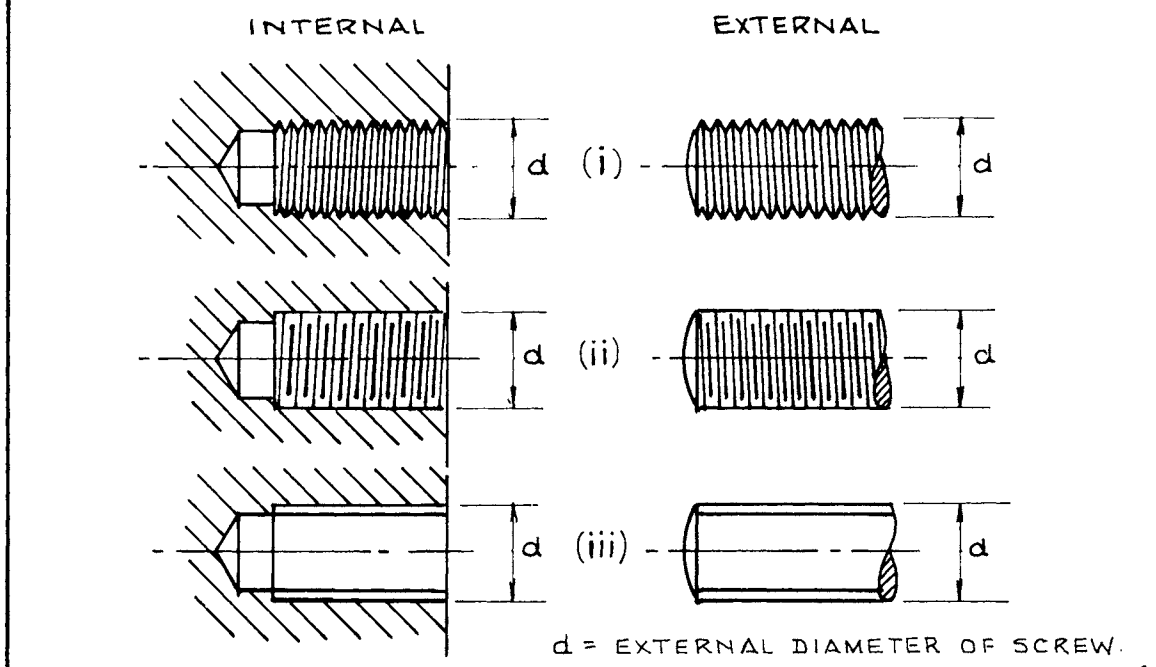
Tension springs are usually close wound and resist extension forces from each end. The actual outline is seen on the left, and the quick method of drawing shown on the right can be used for illustration.

5.4. KNURLING. Fig. 53(*a*) and (*b*)

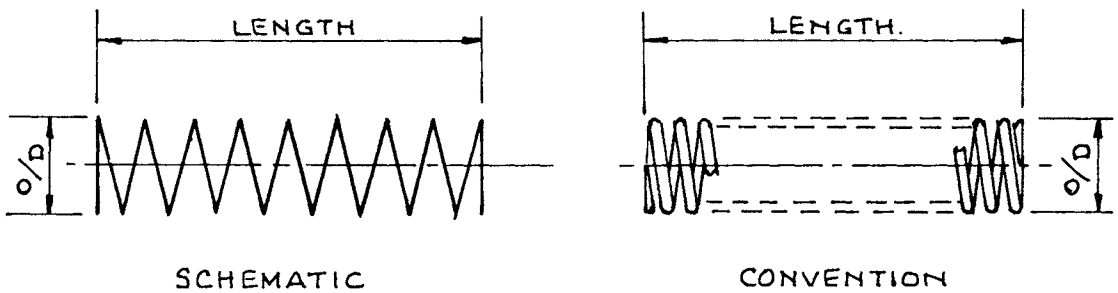
Knurling is the action of marking knobs, etc., when these have to be rotated by hand. There are two forms: straight knurling, where the edge of the rounded part has straight (parallel with the axis) ridges, and diamond knurling, where the edge of the rounded part has crossed diagonal ridges.

5.5. HEXAGON NUT. Fig. 53(*c*)

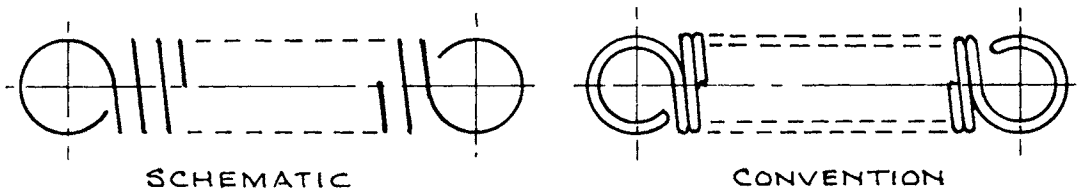
This item is included here because a great deal of time can be saved by using the "2 D across corners" method instead of having to accurately calculate the dimensions.



REFER 5.1 SCREW THREADS (a)

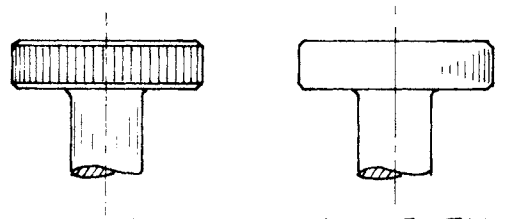


REFER 5.2 COMPRESSION SPRING (b)



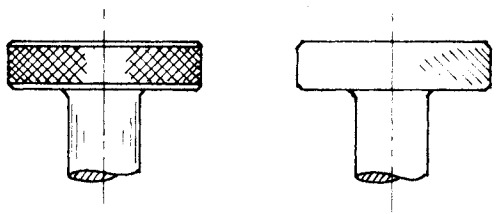
REFER 5.3 TENSION SPRING (c)

CONVENTIONS FIG. 52



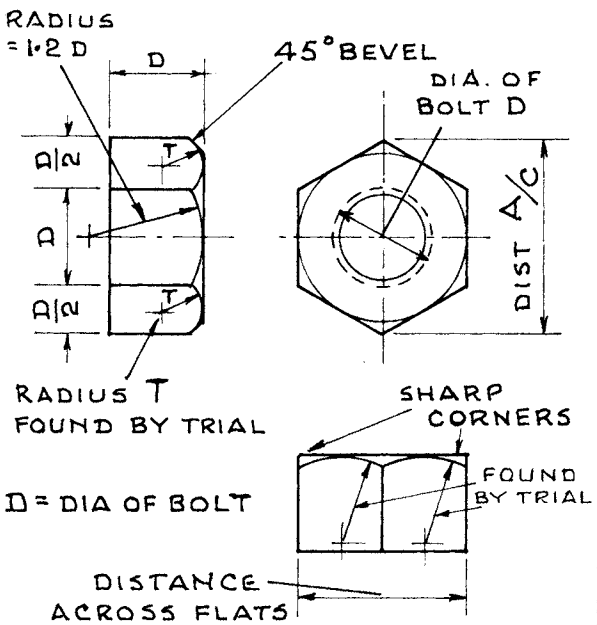
STRAIGHT KNURL

REFER 5.4 (a)



DIAMOND KNURL

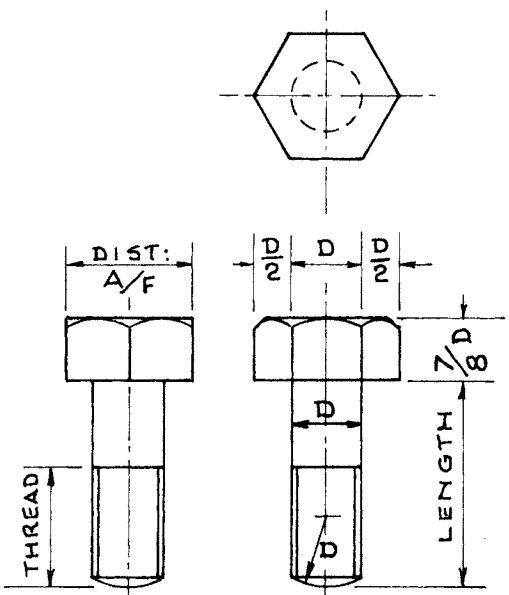
REFER 5.4 (b)



HEXAGON NUT

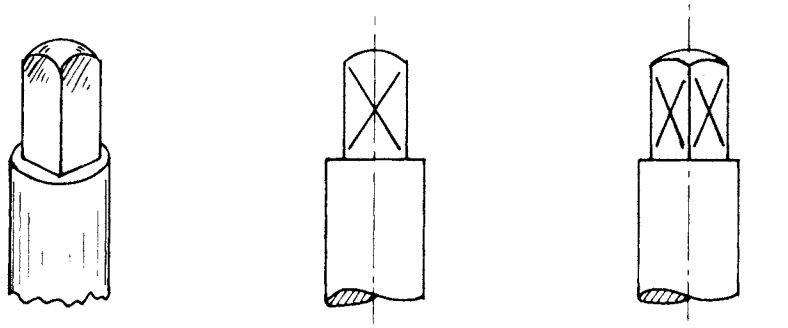
BASIC CONSTRUCTION BY
QUICK DRAWING OFFICE METHOD

REFER 5.5 THIRD ANGLE PROJ. (c)



HEXAGON BOLT

REFER 5.6 THIRD ANGLE PROJ. (d)



REFER 5.7 SQUARE ON SHAFT (e)

CONVENTIONS FIG. 53

5.6. HEXAGON BOLT. Fig. 53(*d*)

Time can also be saved here by using the "2 D across corners" method.

Reference can also be made for sections 5.5 and 5.6 to Fig. 47(*a*), Volume 1, section 10.3 and to Fig. 47(*b*), Volume 1, section 10.4.

5.7. SQUARE END ON SHAFT. Fig. 53(*e*)

The actual shape is shown on the left. On the right are two conventional methods of showing a square on the end of a shaft. The method on the extreme right is the better one to use where clearance has to be considered.

5.8. HOLES ON A CIRCULAR PITCH. Fig. 54(*a*)

When a number of similar holes are to be drilled on a specified radius and equally spaced, the drawing need only show the hole centres, two holes, and the number of holes required.

5.9. HOLES ON A LINEAR PITCH. Fig. 54(*b*)

As was the case with the circular pitch, the same applies to holes on a linear pitch and the drawing need only show the hole centres, two holes, and the number of holes required.

5.10. BEARINGS. Fig. 54(*c*)

To draw the complete section views of ball or roller bearings is very time-consuming and often unnecessary. The conventional and quick method of showing a ball or roller bearing is a rectangle having the same overall dimensions.

5.11. ROUND ROD. Fig. 55(*a*)

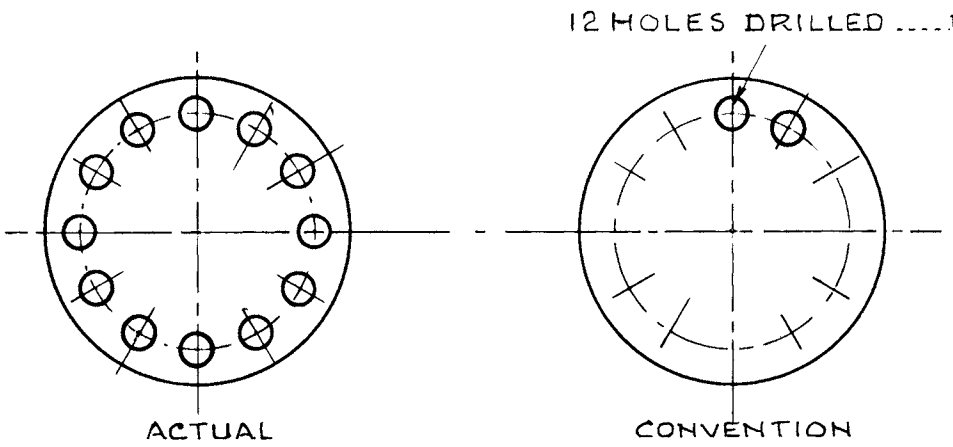
Spindles, shafts, and other long, round objects can be shown on a standard size drawing by the double break seen in Fig. 55(*a*) and its size controlled by the dimensions.

5.12. ROUND TUBE. Fig. 55(*b*)

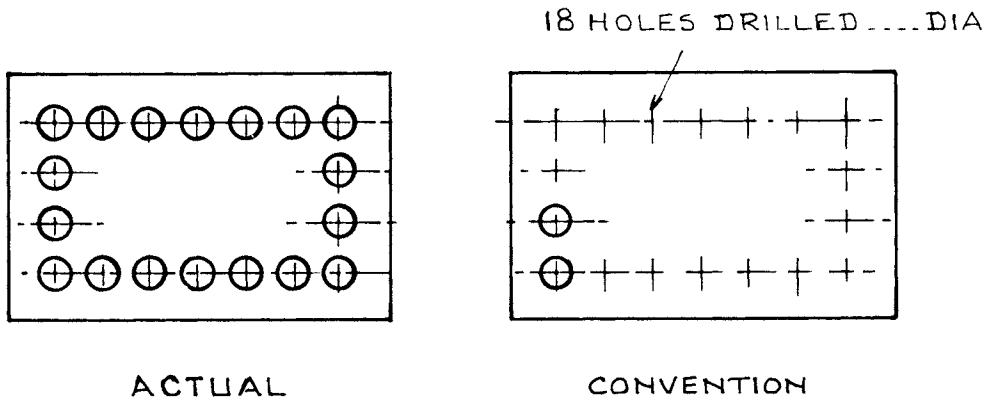
Tubes can be shown in the same way as rods, etc., but the double break illustrated in Fig. 55(*b*) shows clearly that it is tubular.

5.13. RECTANGULAR BAR (METAL). Fig. 55(*c*)

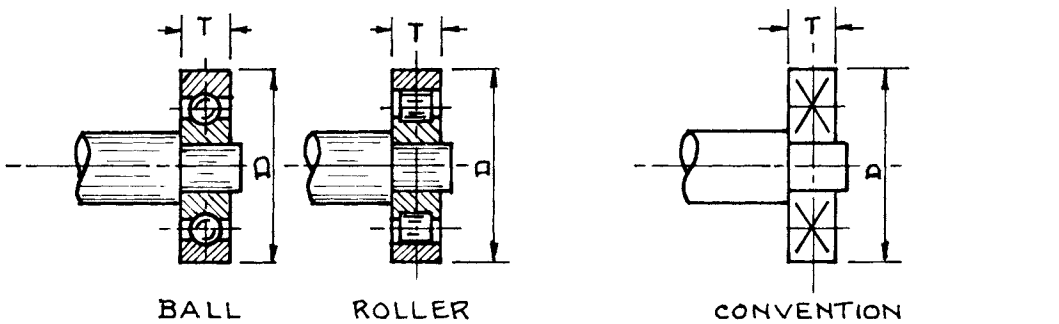
Bars, strips, or any long rectangular section objects can be shown on a standard size drawing by the double break seen in Fig. 55(*c*) and controlled by the dimensions L = length, T = thickness, W = width.



REFER 5.8 — HOLES ON CIRCULAR PITCH — (a)



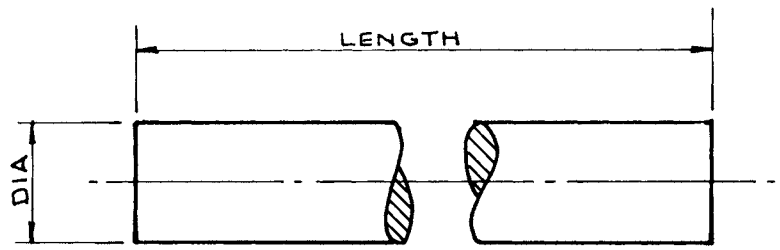
REFER 5.9 — HOLES ON LINEAR PITCH — (b)



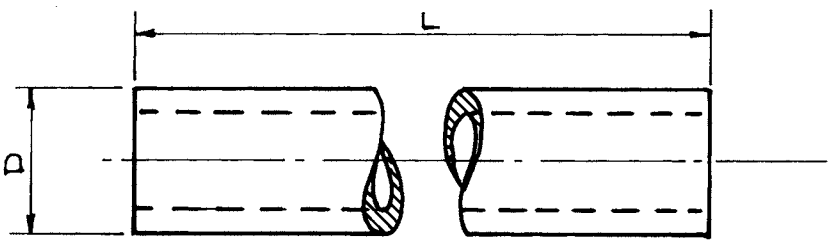
REFER 5.10 — BEARINGS — (c)

CONVENTIONS

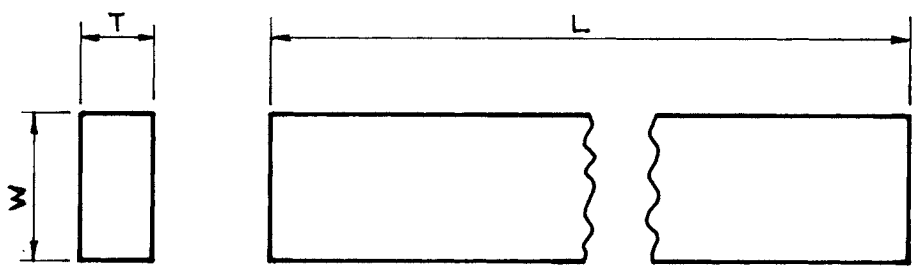
FIG. 54



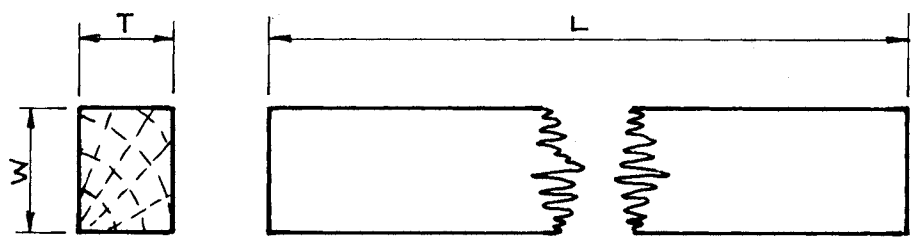
REFER 5.11 — ROUND (SOLID) — (a)



REFER 5.12 — ROUND (TUBULAR) — (b)



REFER 5.13 — RECTANGULAR BAR — METAL — (c)



REFER 5.14 — RECTANGULAR BAR — WOOD — (d)

CONVENTIONS FIG. 55

5.14. RECTANGULAR BAR (WOOD). Fig. 55(*d*)

A wooden bar is shown by the double break, as seen in Fig. 55(*d*). The section on the left should be used in any end view of a wooden bar, etc.

All the illustrations in this chapter should be practised as many times as possible and used on drawings where appropriate.

The foregoing are sufficient for introductory engineering drawing, but a complete list of conventions can be found in B.S. 308A for more advanced students.

6. *Fastenings*

IN THIS chapter we shall be dealing with all forms of fastenings, and the figures will explain each type.

Fastenings are mechanical items used to hold together pieces of material. To illustrate any fastenings on a drawing certain conventions are used. These conventions are important and should be practised as much as possible. Draw each of the figures at least once and understand the reason for each convention.

Fastenings can be placed into two categories: (a) permanent, and (b) temporary.

(a) Permanent fastenings:
riveting, welding, brazing, soldering.

(b) Temporary fastenings:
screws, nuts, studs, pins, keys and cotters.

We shall take all these items in sequence.

6.1. RIVETING. Fig. 56

Rivets are used when two or more pieces of metal are to be connected together permanently.

Rivets are generally made of the same metal as the parts to be joined, and are commonly made from mild steel, wrought iron, brass, copper, or aluminium. They are made with heads of various shapes and these are shown in Fig. 56(*a*).

Snap or Cup Head. Fig. 56(a)(i)

This is the most common form used. Very often the rivets are inserted hot and the tail end closed over to a cup head by a special tool.

Pan Head. Fig. 56(a)(ii)

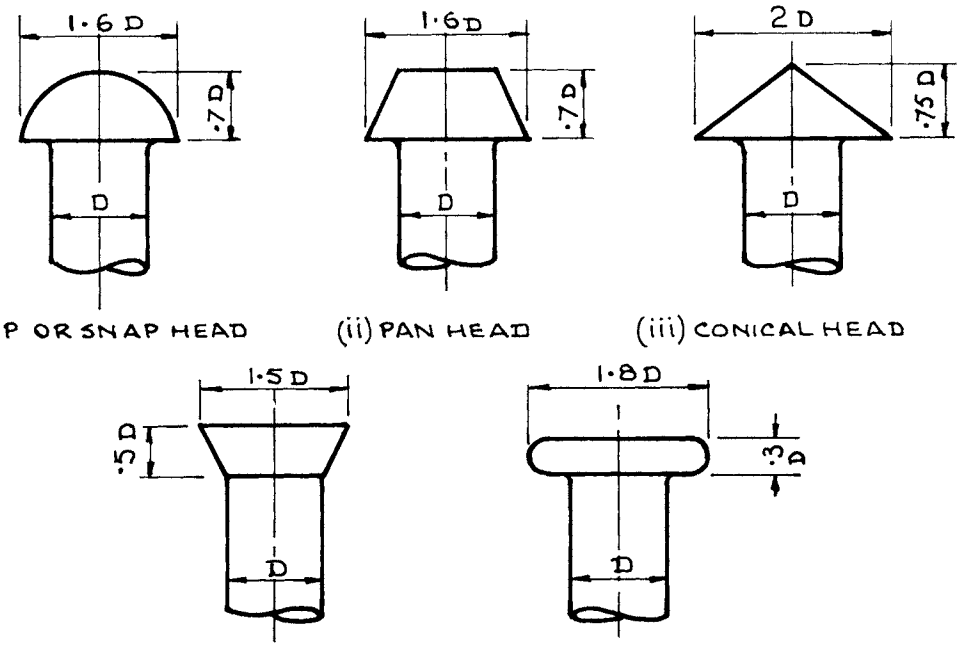
This type is also commonly used where the joint must be as strong as possible.

Conical Head. Fig. 56(a)(iii)

This type is used extensively for small articles and can also be used to produce a decorative effect.

Countersunk Head. Fig. 56(a)(iv)

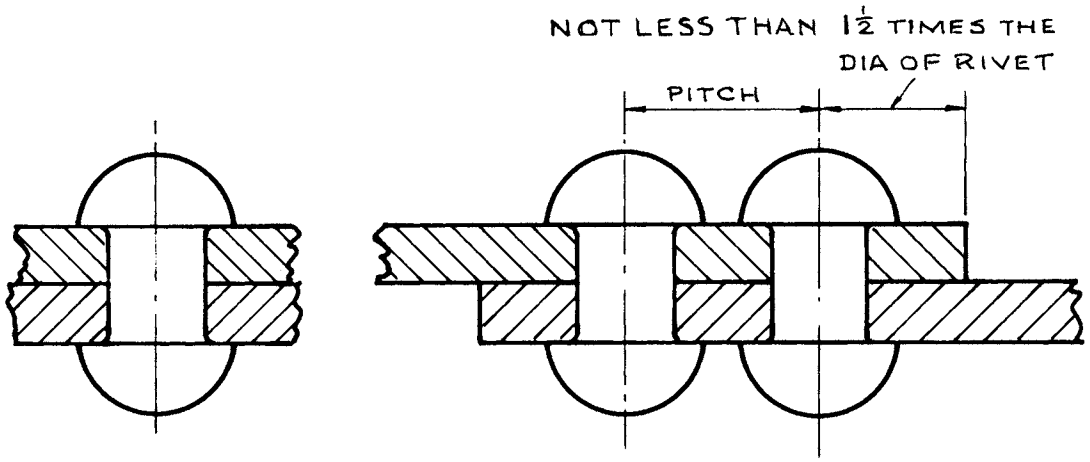
These heads have the advantage that they do not project from the surface of the work.



TYPES OF RIVET HEAD

REFER 6.1.

(a)



RIVETED LAP JOINTS

REFER 6.2

(b)

RIVETING

FIG. 56

Flat Head. Fig. 56(a)(v)

These rivets are usually made of copper, brass or aluminium and are used chiefly for light work in ironmongery, and small tank construction, where the metal is very thin and great strength is not necessary.

6.2. LAP JOINTS. Fig. 56(*b*)

In the figure we see two lap joints in which the tail of each rivet has been formed to a cup head. It is essential that the diameter of the rivet should not be too small and that the distance from the centre of the hole to the edge of the plate should not be less than $1\frac{1}{2}$ times the diameter of the rivet.

6.3. BUTT JOINT. SINGLE COVER PLATE. Fig. 57(*a*)

Notice in Fig. 57(*a*) that the cover plate is $1\frac{1}{8}$ times the thickness of the main plates.

6.4. BUTT JOINT. DOUBLE COVER PLATES. Fig. 57(*b*)

In Fig. 57(*b*) the two cover plates are each five-eighths the thickness of the main plate.

6.5. ANGLE-RIVETED JOINT. Fig. 57(*c*)

Strong angle joints are made in constructional work by using angle iron riveted to two plates, as seen in Fig. 57(*c*).

6.6. ANGLE-RIVETED JOINT. Fig. 57(*d*)

Another arrangement similar to section 6.5 is to join the two plates to a strong angle plate by riveting, as seen in Fig. 57(*d*).

6.7. BUILT-UP GIRDER. Fig. 58(*a*)

Figure 58(*a*) shows the possibility of building a very strong girder section by suitably riveting angles and plates together.

6.8. BUILT-UP BOX GIRDER. Fig. 58(*b*)

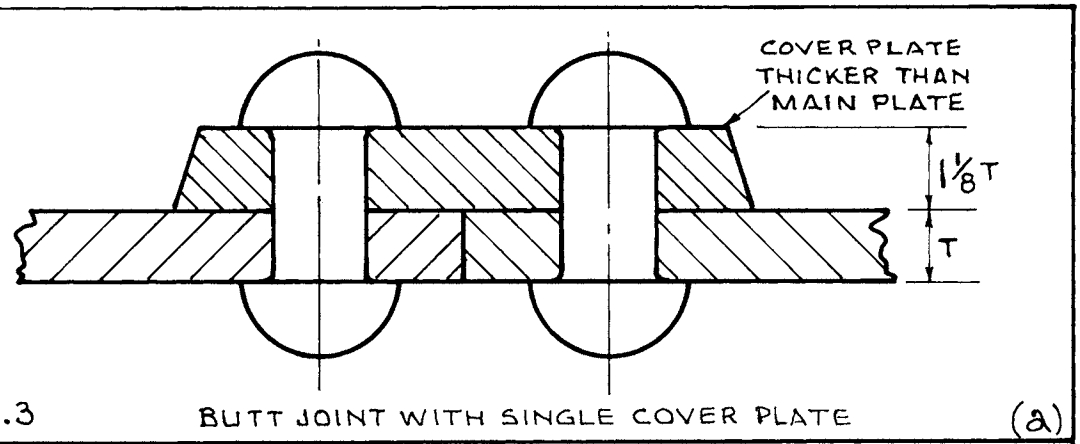
Figure 58(*b*) shows how a stronger structure can be built by riveting together plates and angles.

Keys and Cotters. Fig. 59

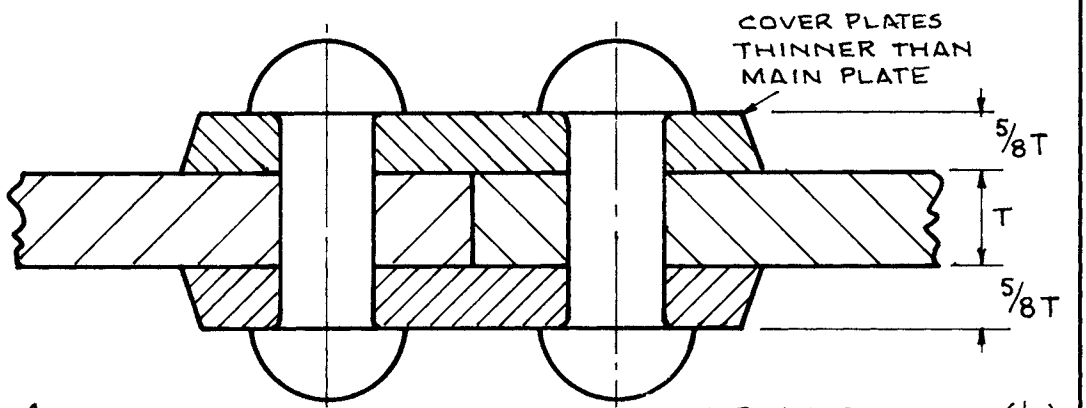
A *key* is a piece inserted in an axial direction between a shaft and hub to prevent relative rotary movement.

A *keyway* is a recess in a shaft or hub to accommodate a key.

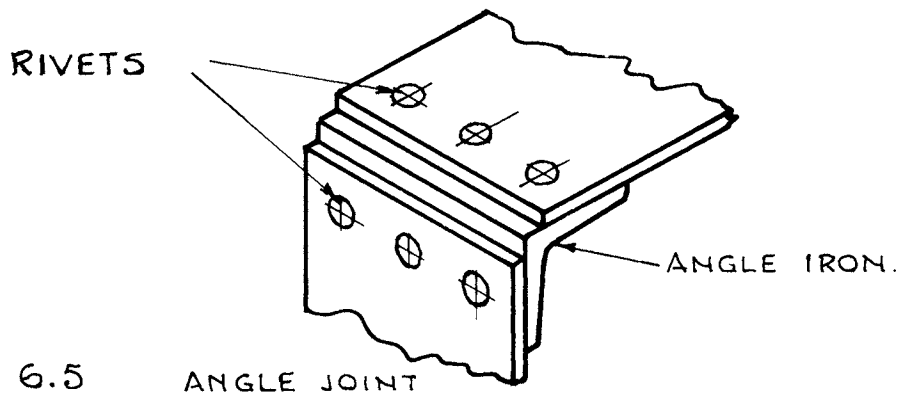
The following are the various types of keys:



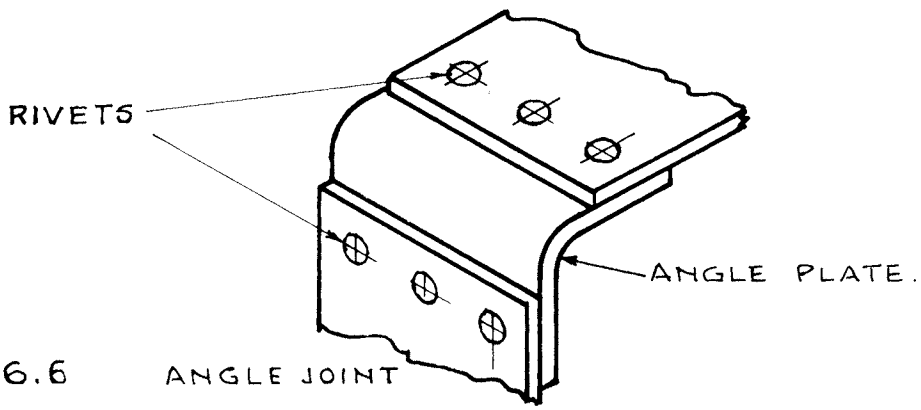
REFER 6.3 BUTT JOINT WITH SINGLE COVER PLATE (a)



REFER 6.4 BUTT JOINT WITH DOUBLE COVER PLATES (b)

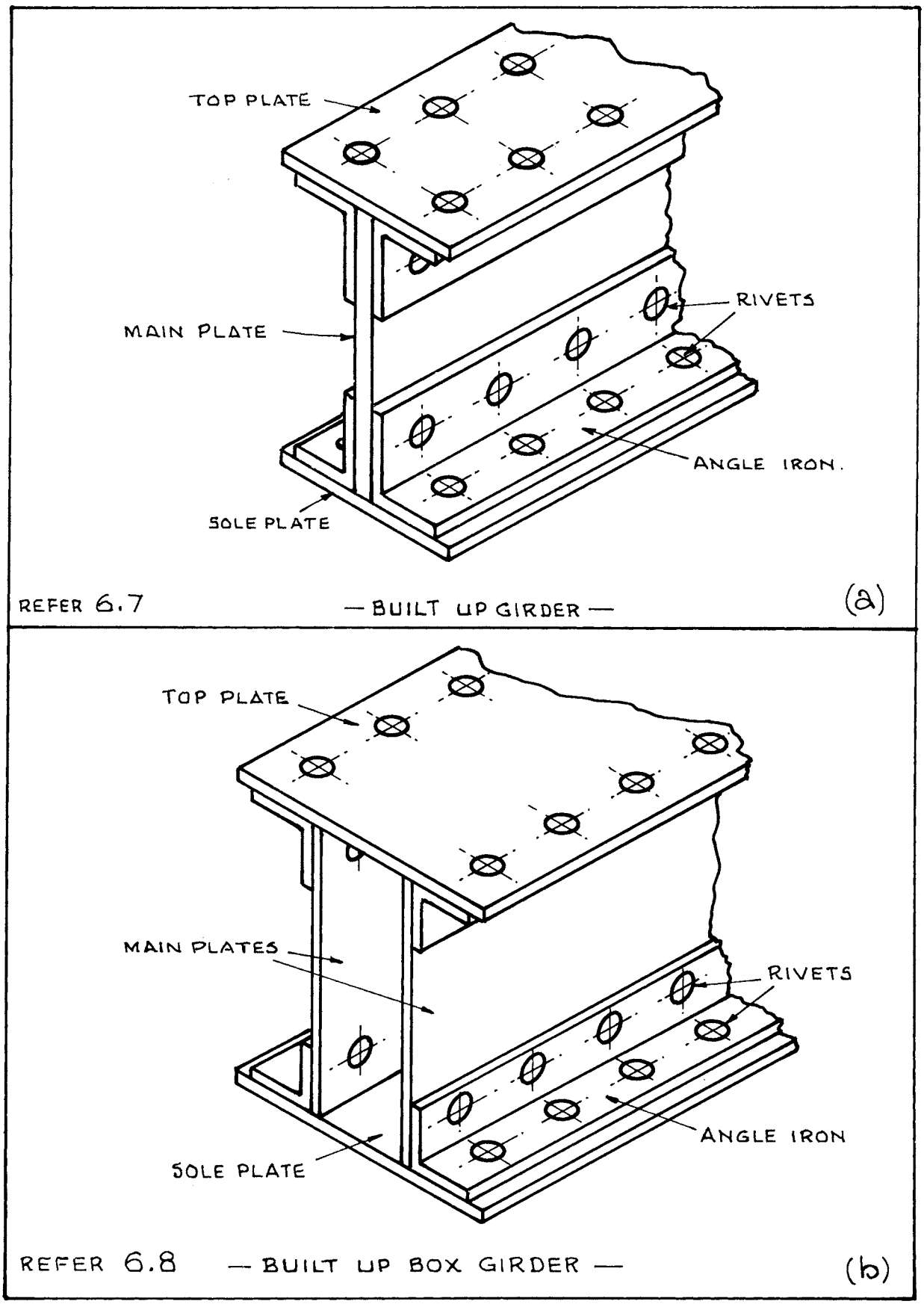


REFER 6.5 ANGLE JOINT (c)



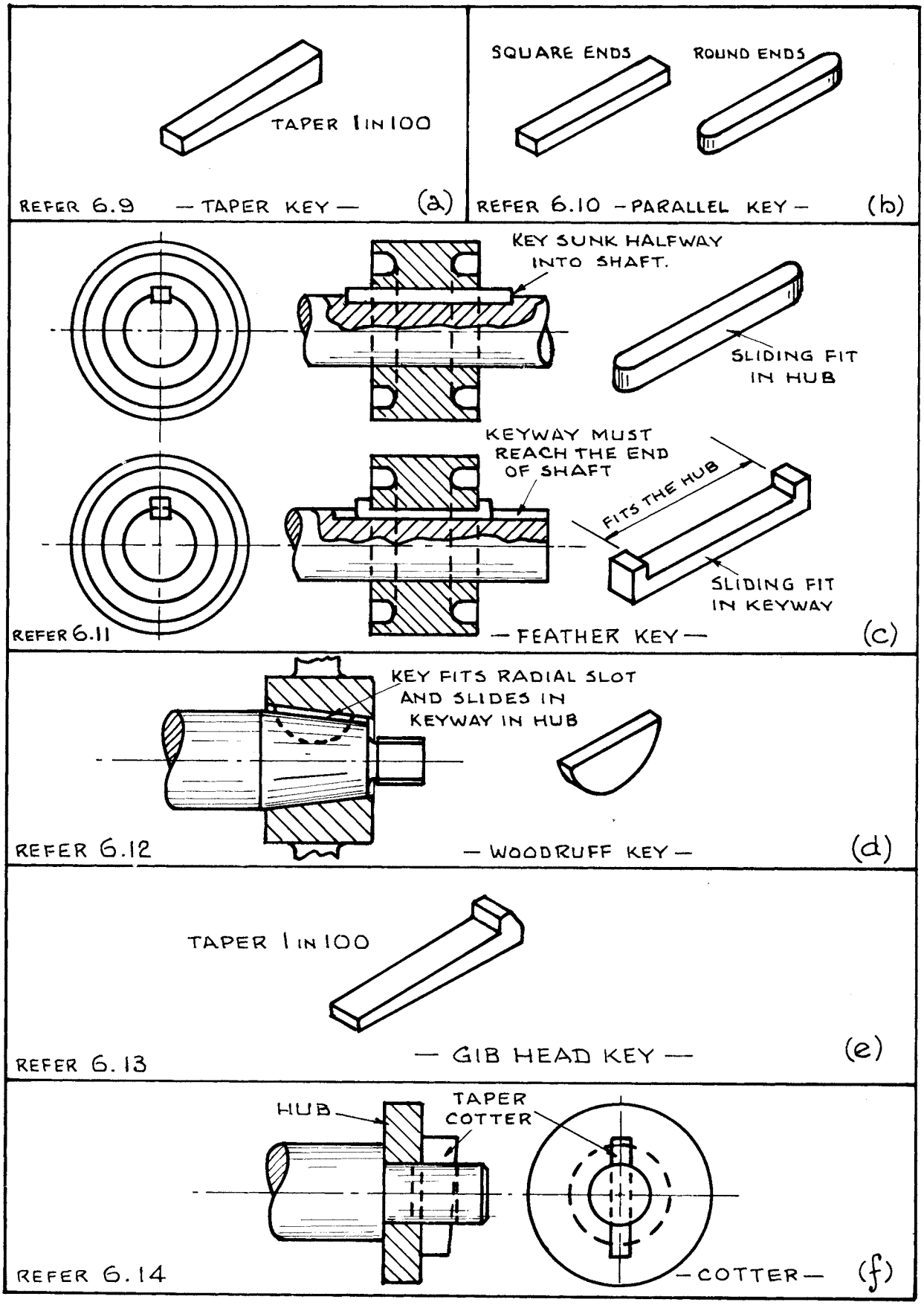
REFER 6.6 ANGLE JOINT (d)

RIVETING FIG. 57



FABRICATION

FIG. 58



KEYS AND COTTER FIG. 59

6.9. TAPER KEYS. Fig. 59(*a*)

These are rectangular or square in section, uniform in width, and tapered in thickness.

6.10. PARALLEL KEYS. Fig. 59(*b*)

These are rectangular or square in section, uniform in width and thickness, and can have round or square ends.

6.11. FEATHER KEY. Fig. 59(*c*)

The B.S.I. defines this as a key attached to one member of a pair and permitting relative axial movement. It is fastened either to the shaft or to the hub, the key being a sliding fit in the keyway of the moving piece.

6.12. WOODRUFF KEY. Fig. 59(*d*)

This is an easily adjustable sunk key. It is segmental in front view, being part of a cylindrical disc capable of tilting in a recess milled in the shaft.

6.13. GIB HEAD KEY. Fig. 59(*e*)

Keys with gib heads are used to facilitate withdrawal.

As we have seen, keys are wedges, generally used parallel with the axes of shafts, and transmit torsional stress.

6.14. COTTER. Fig. 59(*f*)

These are used at right angles to the axis of the connected piece and are subject to tensile and compressive stresses.

Welding. Fig. 60

In this section we shall deal with the broad outline of welding because, being a very highly skilled trade, only a brief knowledge is required for introductory engineering drawing.

The basic principle of welding is the fusing together of two metal edges so that when the molten metal flows and is cooled the joint is permanently made.

Joints similar to those shown in Fig. 56(*b*), i.e. a lap joint, are made more easily by welding than by riveting. The following are some welded joints that can be made.

6.15. BUTT WELD. Fig. 60(*a*)

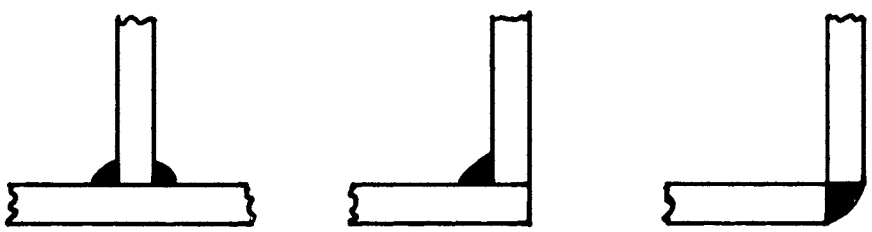
This type is employed when joining two edges together.

6.16. LAP WELD. Fig. 60(*b*)

Two pieces lapping one another are shown joined by welding.

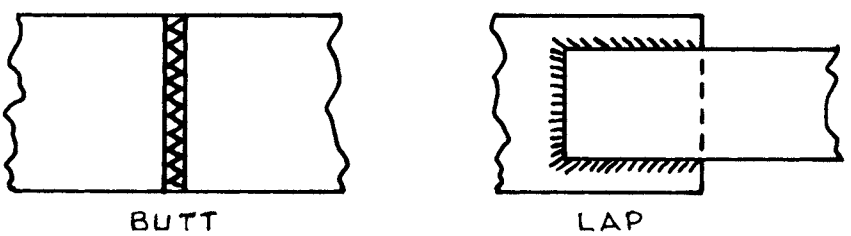
REFER 6.15 BUTT WELDS (a)

REFER 6.16 LAP WELD (b)



REFER 6.17 TEE AND CORNER FILLET WELDS (c)

REFER 6.18 SEAM WELDS (d)



REFER 6.19 TWO METHODS OF ILLUSTRATING A WELDED JOINT ON A DRAWING (e)

WELDING FIG. 60

6.17. FILLET WELD. Fig. 60(*c*)

Generally used when two pieces are welded at right angles.

6.18. SEAM WELD. Fig. 60(*d*)

When two circular rims are to be made pressure tight or vacuum tight a seam weld is made. In Fig. 60(*d*) the right-hand view shows a method of reducing the cross-section to make both pieces of equal thickness for easy welding.

6.19. DRAWING WELDED JOINTS. Fig. 60(*e*)

Two methods of illustrating a welded joint on a drawing are shown.

Other Methods of Fastening

Apart from welding, there are several other methods of fixing metal parts together, i.e. (1) soft solder, (2) hard solder, (3) brazing, (4) metals can now be effectively glued together.

Locking Devices. Fig. 61

When machinery is subjected to vibration, bolts and nuts tend to slacken. Many locking, or jamming, devices have been produced to prevent the nut from unscrewing accidentally. A number of these devices are detailed, as follows.

6.20. LOCK NUT. Fig. 61(*a*)

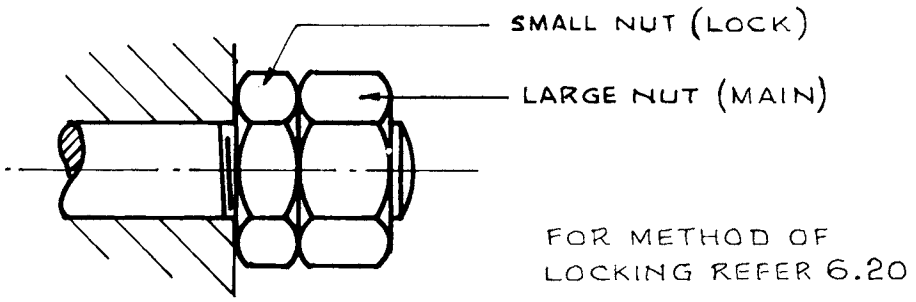
The illustration shows a standard lock nut, double chamfered and approximately two-thirds thickness of a standard nut. The lock nut is first tightened down with ordinary force. Then the main nut is tightened down on the lock nut. The main nut is then held firmly whilst the lock nut is slackened back on to it using two spanners.

6.21. NUTS PINNED. Fig. 61(*b*)

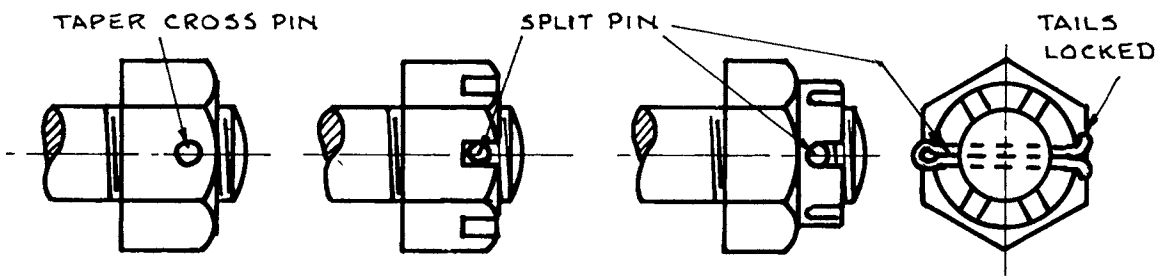
(i) In this example the nut is screwed hard home, cross drilled and fitted with a taper pin.

(ii) The hexagonal nut has six slots each equal in width to the diameter of the pin. After drilling the bolt for the pin, the nut can be tightened through multiples of 60°. Finally, the split pin is inserted.

(iii) The well-known castle nut has six slots in a cylindrical upper portion around which the split pin tails are wrapped. Two views are shown of the castle nut which has six slots cut through a cylindrical upper portion. After a cross hole is drilled in the bolt, the nut can be locked by a split pin in six positions per nut revolution. The tails of the pin can be wrapped round the cylindrical portion.



REFER 6.20 — LOCKNUT FITTING — (a)



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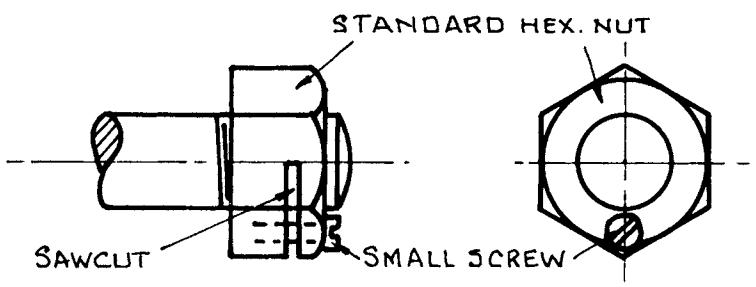
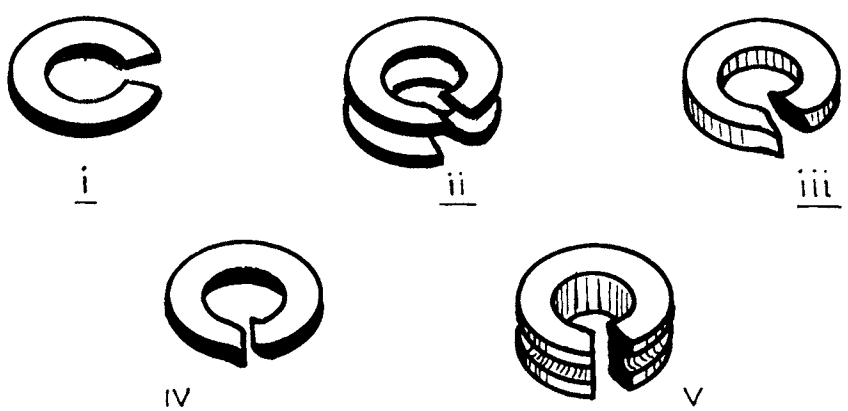


REFER 6.22 — SAWN NUT — (c)



REFER 6.23 — SPRING WASHERS — (d)

LOCKING DEVICES FIG. 61

6.22. SAWN NUT. Fig. 61(*c*)

In this example the hexagon nut has a saw-cut approximately one-third from the end face and a small screw fitted to pull the parts together and lock the nut.

6.23. SPRING WASHERS. Fig. 61(*d*)

The following illustrate various types of spring washers used to lock, by friction, a nut on a screw thread:

(i) single coil, light pattern;
(ii) double coil, light pattern;
(iii) single coil, heavy pattern;
(iv) single coil, grip pattern;
(v) single coil, girder pattern, very heavy section.

It will be noticed that when the nut is tightened the end turns of the spring tend to prevent the nut unscrewing.

Screwed Constructions. Fig. 62

In the following section the student will learn various methods of fastening items together with screws or screwed fittings.

6.24. TWO PLATES CLAMPED. Fig. 62(*a*)

The first type to be drawn is a simple fitting, i.e. two plates held together by two screws and nuts. This fastening is one which is used very extensively. Lock washers can be used to prevent loosening.

6.25. CABLE CLAMP. Fig. 62(*b*)

A very small variation of the above is a simple pipe or cable clamp but with tapped holes and no nuts.

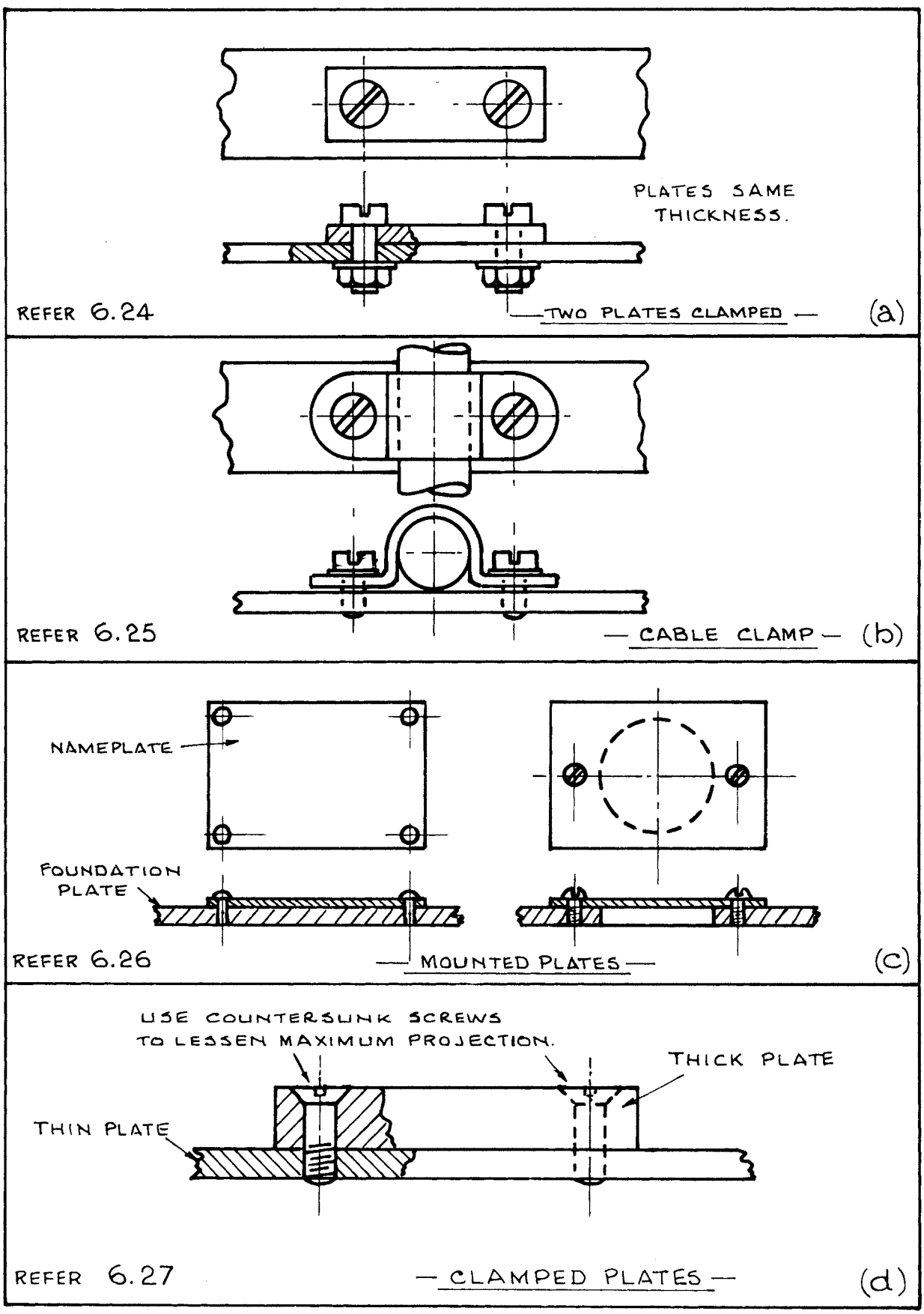
6.26. MOUNTED PLATES. Fig. 62(*c*)

Name plates and cover plates are held by two or four screws screwed into the foundation plate. Self-tapping screws are used very extensively at the present time.

6.27. CLAMPED PLATES. Fig. 62(*d*)

When a thick mounting plate is to be fitted to a thinner plate it is preferable to use screws with counter-sunk heads, or instrument heads, to lessen the maximum projection.

It is most essential that the student should practise all the views shown in Fig. 62 and note each method of clamping.



SCREWED CONSTRUCTIONS FIG. 62

6.28. MULTIPLE PLATES. Fig. 63(*a*)

This is an example of more than two plates being clamped together by screws and nuts. There are two sets of clearance holes through the plates for the screws. On the left is shown a thin plate with a cheese-head screw clamping the plates. On the right is shown a plate slightly thicker so that a countersunk or Swiss head screw can be used.

6.29. MULTIPLE PLATES WITH SPACERS. Fig. 63(*b*)

Two or more parallel plates, or wafers, are to be clamped together with a standard gap between each. These can be held by two long screws with spacer collars between each plate and the nuts fitted with lock washers. Where the overall length is too long for standard screws, screwed studding with hexagon nuts and lock washers can be used.

6.30. SHAFT LOCATION. Fig. 63(*c*)

Illustrated here is a small pinion and shaft running in bearings which must, of course, be in line. A suitable construction is shown in Fig. 63(*c*) in which the bottom bearing plate has two shouldered pillars riveted in. The other end of these pillars is shouldered to make a spigot fit into the top bearing plate. This bearing plate can be removed and replaced accurately and held in position by cheese head or countersunk head screws.

6.31. GEAR REDUCTION UNIT ASSEMBLY. Fig. 63(*d*)

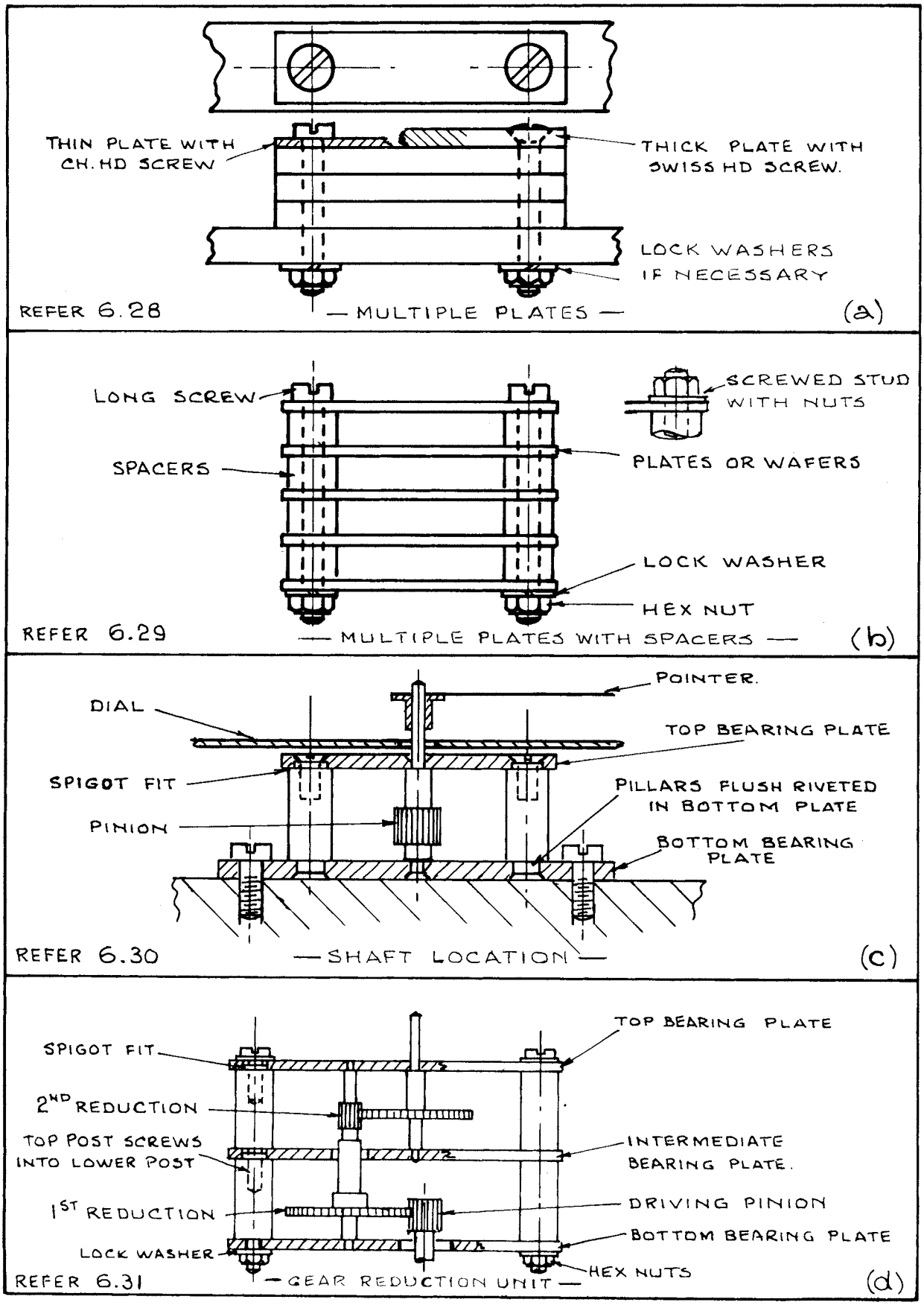
When more than two plates are to be screwed together, and also accurately positioned, the method shown in Fig. 63(*d*) can be adopted. You will find from the illustration that all the plates can be similarly "marked off" or jig drilled and hole positions selected. All the pillars can be machined alike and in some cases used as screws to clamp the plates together. The pillars have reduced diameters for spigot fitting and are threaded to act as screws for clamping the plates. Examine the figure and you will notice that it is the construction of a gear reduction unit.

6.32. SCREWED FITTING METAL LAMP HOLDER. Fig. 64(*a*)

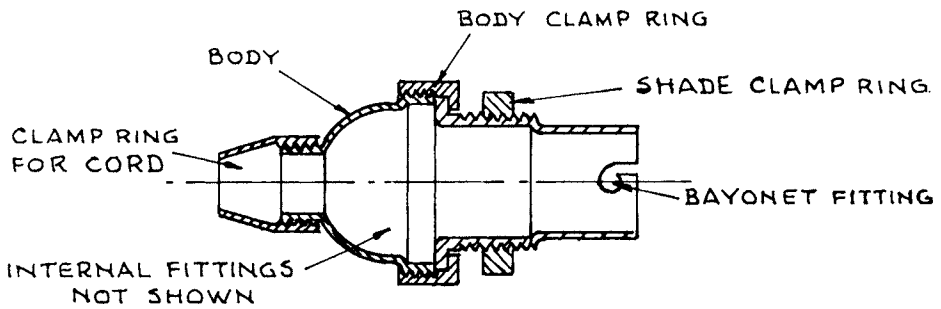
A good example of a screwed fitting is to be found in an ordinary domestic bayonet-cap lamp holder (metal). The cord clamp ring screws on the body, which also has a body clamp ring screwed on to it to hold the bayonet fitting. The shade clamp ring screws on the bayonet fitting.

6.33. SIMPLE SLIDING PLATFORM. Fig. 64(*b*)

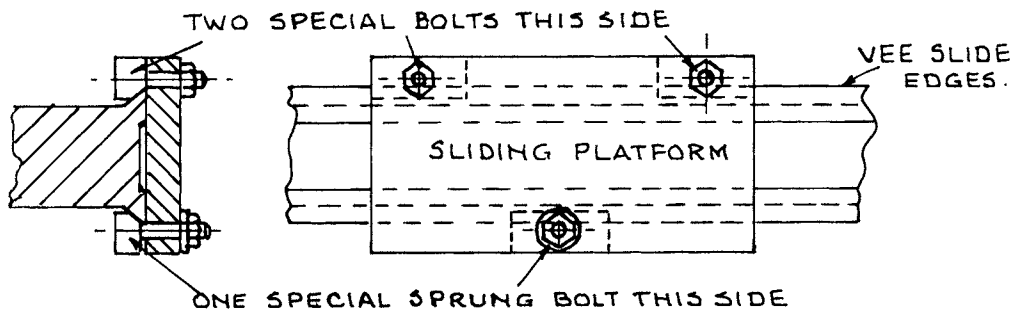
The stationary member has two machined faces along which the two well-spaced angle bolts will slide. There is only one clamp bolt, and when this is released a small amount the bracket can slide to a new position and be reclamped.



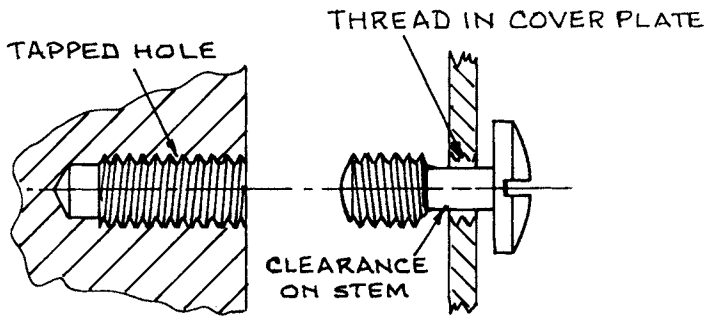
SCREWED CONSTRUCTIONS FIG. 63



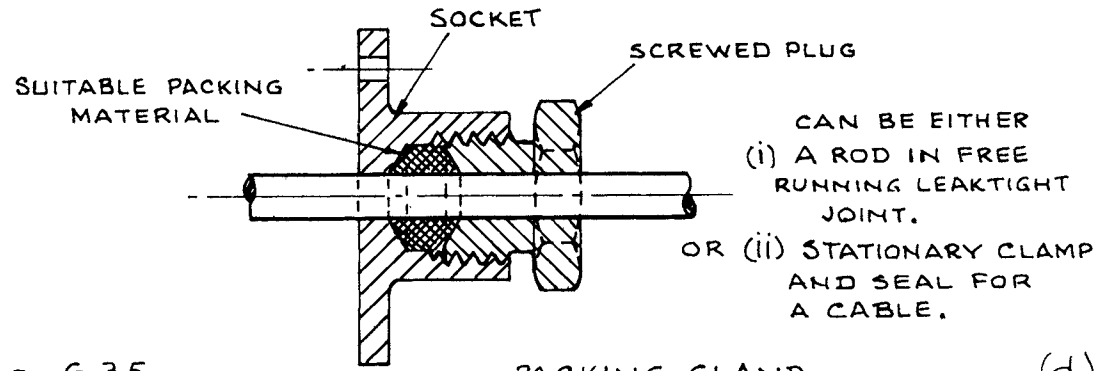
REFER 6.32 — METAL LAMP HOLDER — (a)



REFER 6.33 — SIMPLE SLIDING PLATFORM — (b)



REFER 6.34 — CAPTIVE SCREW — (c)



REFER 6.35 — PACKING GLAND — (d)

SCREWED CONSTRUCTIONS FIG. 64

6.34. CAPTIVE SCREW. Fig. 64(*c*)

Screws which have to be undone to remove a cover plate can be easily lost or mislaid. This leads to the useful idea of a captive screw. A captive screw is one which, when unscrewed from the fixed part, remains attached to the removable part.

6.35. PACKING GLAND. Fig. 64(*d*)

This screwed fitting is included to show how, by exerting screw pressure on suitable packing material, a free running leak-tight joint, or a sealed stationary clamp for a cable, etc., can be produced.

Screws, screw-threads, and heads are most important and should be thoroughly revised at this stage in readiness for later assembly work.

All the examples shown in Figs. 62, 63, and 64 should be carefully copied by measuring the outline and drawing each of them to a scale twice full-size.

7. *Metrication in the Drawing Office. Limits, Fits, and Tolerances*

7.1. METRICATION

The United Kingdom is to adopt metric units of weights and measures. The units used will be the International System of Units (S.I.), which is a rational and coherent form of the traditional metric system. A large and increasing number of countries in the world already use the metric system of units, and most of those countries agreed to adopt the S.I. system when its use was formally recommended in 1960 by the C.G.P.M. (General Conference of Weights and Measures) of which Britain is an active member.

Full definitions of the basic units, and of certain derived units in the S.I., are given in B.S. 3763, 1964, *International System Units*; and the B.S.I. publication P.D. 5686, 1969, *The Use of S.I. Units*, lists the commonly used units together with their multiples and sub-multiples as recommended for general use in industry.

The United Kingdom is adopting the metric system of S.I. units primarily for the purpose of improving British export trade. The lack of uniformity of engineering practice and engineering standards between different countries has in the past tended to create barriers to trade. There will clearly be advantages in greater ease of communication between engineers when uniformity of units and engineering textbooks in different countries has been achieved.

The operation of changing the units now in use in the United Kingdom will also provide an opportunity for rationalization of the ranges of materials and components commonly used in industry. Attempts are being made to bring British standards into conformity with international engineering practice in those areas where agreement on international standards has been reached.

During the years 1970–5 there will be a constant transition from the Imperial system of units to the Metric system, and it will be common to find both systems of dimensional units in use on drawings. By 1975 it is intended that the bulk of British industry will have been converted to the general use of metric units.

The conversion of dimensions and quantities from one system of units to the other is therefore only a passing phase in the process of metrication. The principal purpose of metrication is to bring British engineering practice into conformity with internationally agreed engineering practices. This will be achieved chiefly through adherence to British standards documents revised in metric terms.

It is not expected that the advent of metrication will occasion any change in the actual techniques of drawing office practice.

Attention should be drawn to B.S. 2856, 1957, *Precise Conversion of Inch and Metric Sizes on Engineering Drawings.*

7.2. MACHINED SURFACES

One of the purposes of machining metal parts is to make them fit other machined parts.

To manufacture parts to fit accurately always proves to be a long and tedious process. If a part is made individually it can be made to match a mating part by hand fitting. This means that the parts are not then interchangeable and, of course, they become more costly to make. With skilled workmen, handmade parts are usually good examples of precision workmanship.

To enable parts to be interchangeable, and therefore cheaper to make, a system of manufacturing was introduced into engineering which allowed all parts to be made to a specific size within certain limits. This system enabled the interchange of parts whatever the source of manufacture.

During the manufacturing of parts, inspection is a most important factor. The use of limits makes it possible to produce parts which, although they cannot be made to precise dimensions, vary very little from the nominal size.

Quantity, or mass production, is made possible by good design coupled with the use of special tools, fixtures, and automatic machines. A designer or draughtsman must therefore state exactly, on the drawing he makes, the size and type of fit he requires for a certain part or mating parts.

7.3. DEFINITION OF TERMS. Fig. 65(*a*)

(i) *Nominal size* is the designed size of the part or parts.

(ii) *High limit* is the larger of the two dimensions of each part.

(iii) *Low limit* is the smaller of the two dimensions of each part.

(iv) *Tolerance* is the difference between the high and low limit for each part.

(v) *Allowance* is not the same as tolerance. Minimum allowance is the difference between the largest shaft and the smallest hole. Maximum allowance is the difference between the smallest shaft and the largest hole.

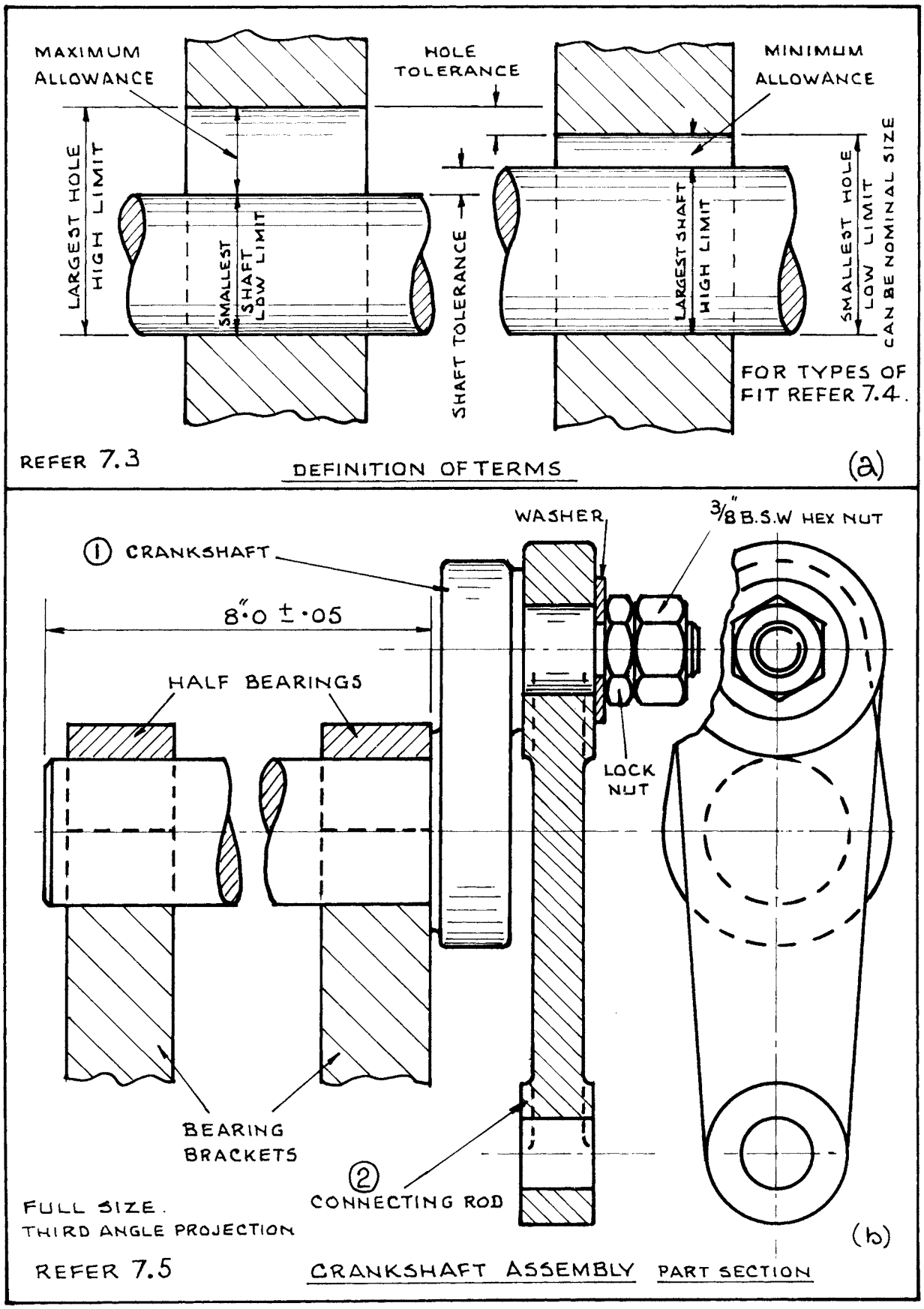
These terms are explained more fully by the practical examples shown in Fig. 66 and with reference to section 7.4.

The crankshaft assembly (Fig. 65(*b*)) illustrates the problem of interchangeable fits and will be explained later.

7.4. TYPES OF FITS. Fig. 66

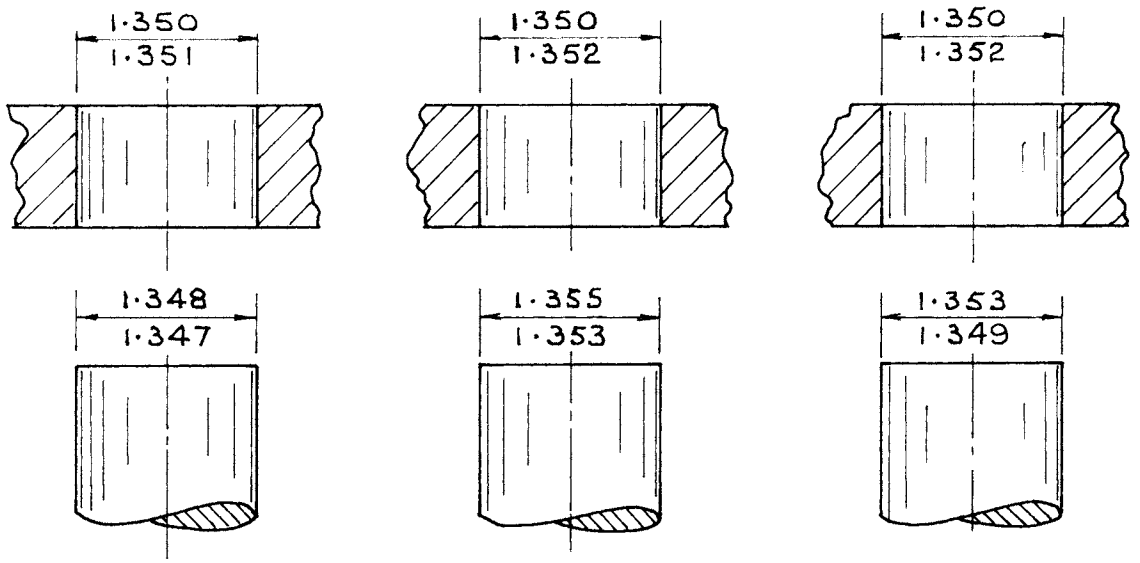
Following the Definition of Terms (7.3) section we come now to the different types of fits for shafts and holes. Since standard drills and reamers can produce holes to close dimensions, and shafting can be turned and ground to any size required, limits and fits are determined on the basic hole system.

The whole range of fits can be divided into three main classes: clearance, interference, and transition. Each of these classes can then be subdivided into finer or coarser fitting. As an example a clearance fit can range from a very fine running fit to a very coarse clearance with plenty of "play". These types of fits are shown in Fig. 66 in both English and metric dimensions. For reference two conversion tables are given in Fig. 77.

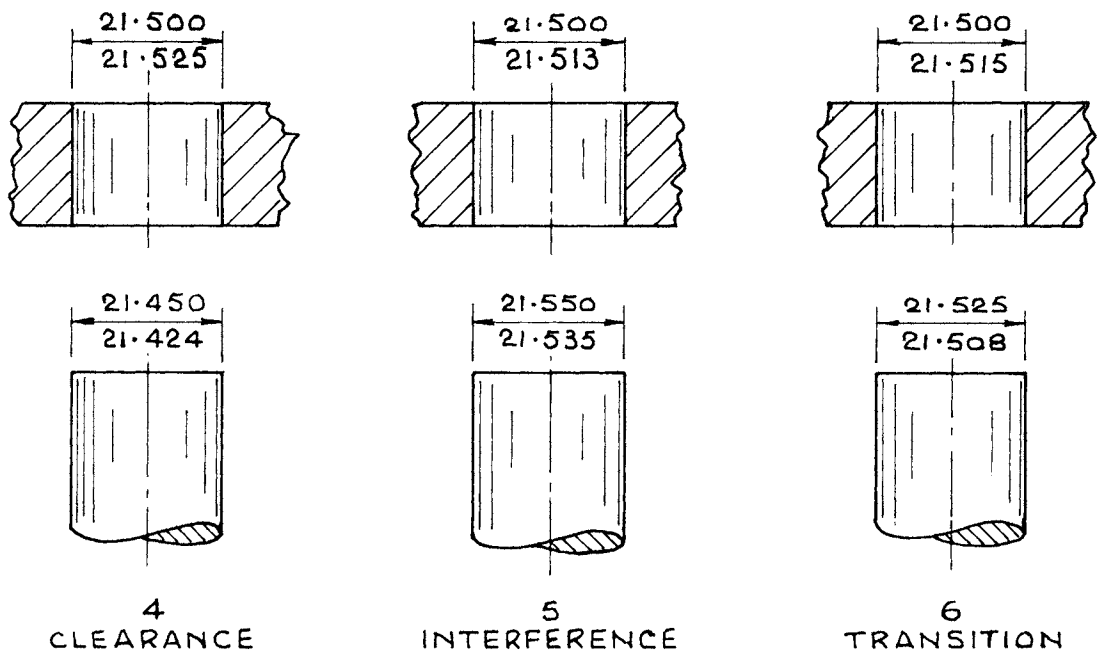


DEFINITION OF TERMS
CRANKSHAFT ASSEMBLY

FIG. 65



REFER 7.4 — ENGLISH — INCHES (a)



REFER 7.4 — METRIC — MILLIMETRES (b)

TYPES OF FITS

FIG.66

(1) *Clearance Fit. English. Fig. 66(a)*

The nominal size of hole is 1·350 in. Subtracting the diameter of the largest shaft 1·348 in from the diameter of the smallest hole 1·350 in we get 0·002 in as the minimum clearance.

Subtracting the diameter of the smallest shaft 1·347 in from the largest hole 1·351 in we get 0·004 in as the maximum clearance.

From the above it can be seen that the allowance can only vary from 0·002 in to 0·004 in and at no time, no matter which pieces are selected, will there be less than a clearance fit.

(2) *Interference Fit. English. Fig. 66(a)*

The nominal size of hole is 1·350 in. Repeating the calculations made in (1) it will be seen that the smallest shaft is always larger than (and has an interference of metal with) the largest hole. In this case the variation is between 0·005 in and 0·001 in interference when any interchangeable pieces are assembled. These figures can be varied so that much more force is required to mate the two parts.

(3) *Transition Fit. English. Fig. 66(a)*

The nominal size of hole is 1·350 in. Here we have a condition in which both clearance and interference fits are possible because of the limits which have been set. Assembly will therefore be selective and not interchangeable. The parts are grouped into sections so that the smaller shafts and holes are matched; also the larger shafts and holes. By making the parts to less critical dimensions, good fits can be obtained at less expense.

In this case four selective fits are available, i.e. 0·001 in to 0·003 in clearance and 0·001 in to 0·003 in interference.

(4) *Clearance Fit. Metric. Fig. 66(b)*

The nominal size of hole is 21·5 mm. Repeating the calculations made in (1), it will be seen that the largest shaft is always larger than the smallest hole varying from a clearance of 0·050 mm to 0·101 mm.

(5) *Interference Fit. Metric. Fig. 66(b)*

The nominal size of hole is 21·5 mm. In this case, repeating the calculations made in (1), the smallest shaft is always larger than (and has an interference of metal with) the largest hole. The interference varies from 0·050 mm to 0·022 mm.

(6) *Transition Fit. Metric. Fig. 66(b)*

The nominal size of hole is 21·5 mm. Four selective fits are available, viz. 0·008–0·025 mm interference; 0·010–0·027 mm clearance. By making the parts to less critical dimensions, good fits can be obtained at less expense.

7.5. CRANK SHAFT ASSEMBLY. Fig. 65(*b*)

The figure shows a part section of a crank shaft assembly. The dimensions of the main shaft, the crank pin and the centre distance, must be controlled. The parts are shown in detail in Fig. 67.

7.6. CRANKSHAFT. PART NO. 1. Fig. 67(*a*)

The shaft should be a good running fit in the bearing bracket, Part No. 3, and the crank pin a running fit in Part No. 2. The nominal hole size is 1 in dia. and so the shaft must never be larger than this. If two minus limits of 0·9992 in and 0·9984 in are given, the shaft tolerance is 0·0008 in.

The nominal size of the crank pin is 0·625 in dia. If two minus limits of 0·6237 in and 0·6244 in are given the pin tolerance is then 0·0007 in. The length of the pin to the shoulder must not be less than 0·5 in so two plus limits are given.

The overall length of the steel shaft is unimportant so it has a limit of ± 0·05 in.

The centre distance of pin and shaft is nominally 1·25 in and can have a limit of ± 0·005 in, and as it is a rotary movement will have a total throw of 2·5 in ± 0·01 in.

7.7. CONNECTING ROD. PART NO. 2. Fig. 67(*b*)

This is a gunmetal casting and the large hole is a running fit on Part No. 1. The small hole is a running fit on another pin, not shown. Each hole can be given a plus limit above the nominal size, i.e. 0·0007 in, making the sizes 0·6250–0·6257 in for the large hole and 0·500 –0·5007 in for the small hole.

7.8. BEARING BRACKET. PART NO. 3. Fig. 67(*c*)

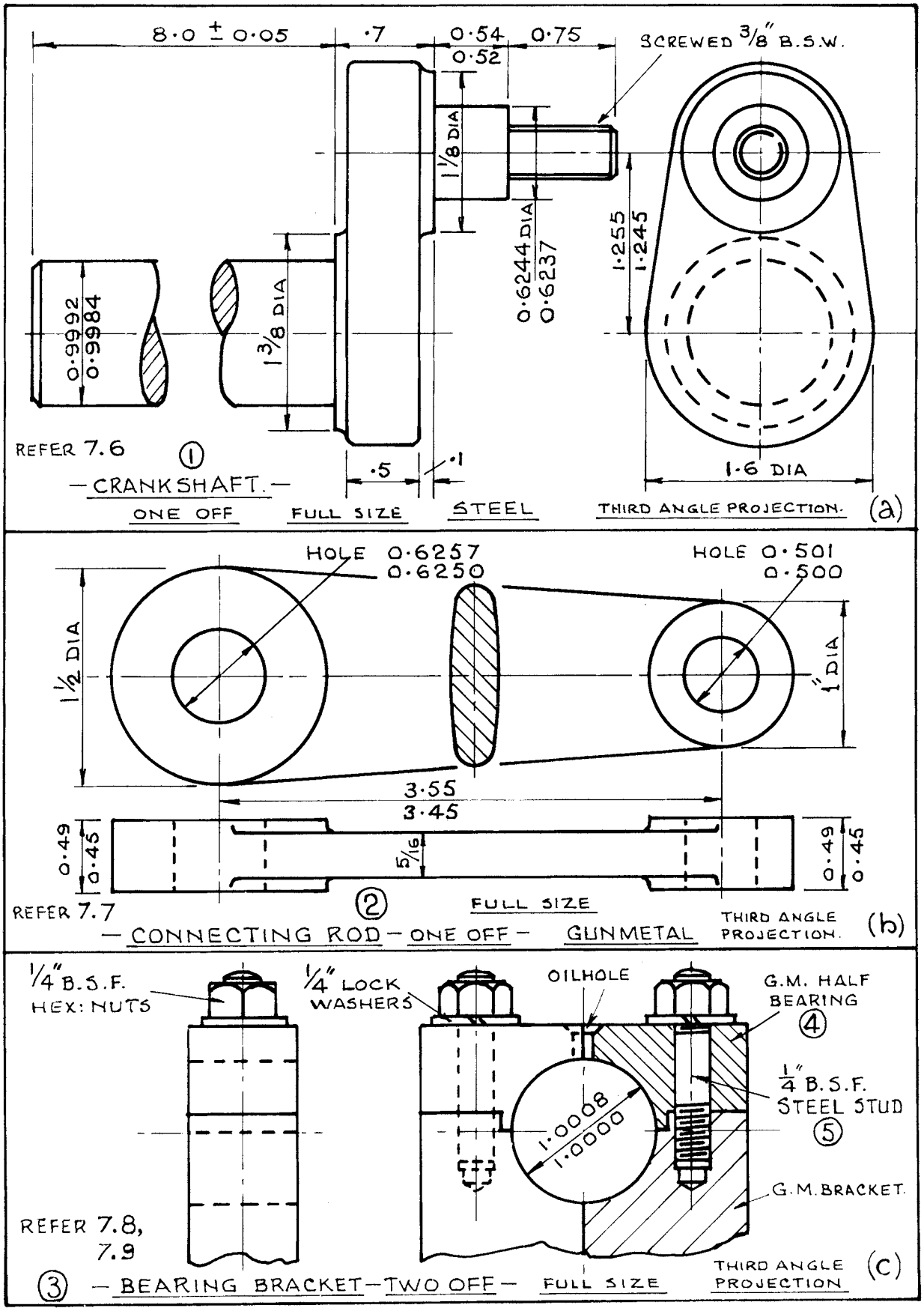
These are gunmetal castings and the holes are a running fit for Part No. 4. The bearing caps, Part No. 4, are halved for easy assembly. The parts in the sub-assembly are numbered but are not detailed separately because, in this exercise, we are dealing with limits and fits and not with design.

The nominal size of the hole is 1 in and must never be smaller than this, so we give plus limits to this dimension. We then have 1·0008 in and 1·0002 in. Comparing these with figures in section 7.6 we see that within the limits the shaft will clear the hole by 0·001–0·0024 in.

7.9. BEARING CAP. PART NO. 4. Fig. 67(*c*)

The bearing cap is gunmetal with a shoulder fit into the main bracket. The two parts are clamped together by two steel studs, Part No. 5, screwed into the main bracket, and two hexagon nuts screwed $\frac{1}{4}$ in B.S.F. (British Standard Fine Thread) and fitted with lock washers. After fitting the two parts together the hole is machined, as in section 7.8. The shoulder fitting prevents any side movement after the shaft and hole have been made a running fit.

All the views shown in Figs. 65, 66, and 67 should be copied and the dimensions shown.



CRANKSHAFT ASSEMBLY FIG 67 DIMENSIONS IN INCHES.
DETAIL PART DRGS

When drawing Fig. 65(*b*) the main shaft and the end view should be drawn full size without any breaks.

For the more advanced student a much more comprehensive coverage for holes, shafts, and fits is given in the booklet *Limits and Fits*, B.S. 1916, Part 1953.

A further example of fits is given in Fig. 97 (refer section 8.74), which shows a simple spindle running in bushed bearings.

8. *Working Drawings*

THIS chapter will be devoted to working drawings of assemblies and parts taken from those assemblies. The figures in the book are restricted by the size of page but each has been drawn to scale and is dimensioned. The exercises set are of various kinds.

(1) Certain views of some machine detail are given, generally drawn to a small scale. You are required to produce drawings to dimensions marked on these views.

(2) You are asked to produce views which can only be obtained from your knowledge of the assembly.

(3) To be able to draw all the views required for an assembly it may be necessary to refer to the drawings of detail parts found on another page.

(4) There are isometric drawings from which you will make third angle or first angle projection orthographic drawings of assemblies and parts.

(5) It is left to your discretion to draw any small radius or fillet in good proportion and also to include carefully any shape not fully dimensioned.

Some of the examples will be dimensioned in fractions and decimals of an inch, and other examples will be in metric, i.e. millimetres.

Conversion charts are shown in Fig. 77(*c*).

Most of the examples will require one view to contain a complete section, or a part section, and may be taken through a particular plane.

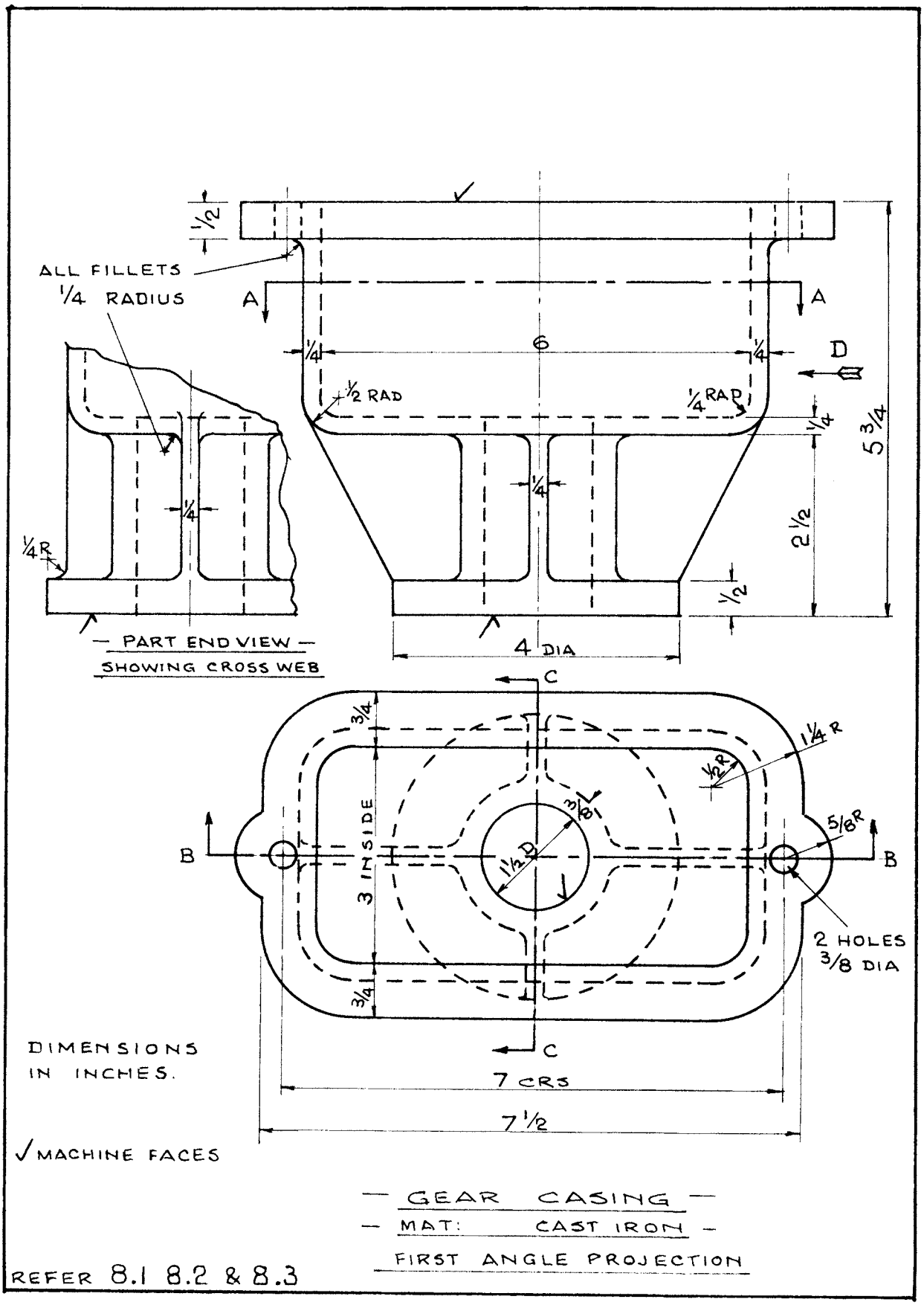
Every drawing should include the type of projection used, neatly printed, together with the title and scale, and a border line.

8.1. GEAR CASING. Fig. 68

The first example is a cast-iron box in which a gear runs in an oil bath. As you can see from the figure, it is rectangular and stands on a circular base stiffened by four webs. Through the centre hole runs a $1\frac{1}{2}$ in dia. shaft. Details of the shaft and any gearing are omitted. To make an oil seal the top and bottom faces must be effectively machined flat to accommodate some form of gasket (not illustrated).

8.2. ASSIGNMENT A. GEAR CASING. Fig. 68

Make a drawing of the gear casing showing the front elevation, the plan, and complete end view from arrow *D*. These should be drawn in first angle projection to full-size scale. Print the title, scale, and projection, and finish the drawing neatly with a border line. Remember to sharpen your pencil and draw fine lines to construct the outline of the three views. Main outlines should be firm and drawn



PART DRAWING
OF GEAR CASE

FIG. 68

with a conical pencil point, but do not make the line too thick. Notice that the end view should be a complete view and not part view as shown.

From the plan it will be seen that the upper flanges overhang the vertical sides by $\frac{3}{4}$ in less $\frac{1}{4}$ in, i.e. $\frac{1}{2}$ in. Note the machined faces and where the symbols are placed. The finished drawing should be similar to Fig. 68.

8.3. ASSIGNMENT B. GEAR CASING. Fig. 68

Make a full-size drawing of the gear casing with the following views in first angle projection:

(a) A half-sectional front elevation through *BB* with the left-hand half in section.
(b) A half-sectional side elevation through *CC* with the left-hand half in section.
(c) A half-sectional plan through *AA* with the left-hand half in section and the right-hand half in full.

Take care that the viewing direction from each of the arrows is in keeping with first angle projection. The three views should be lightly plotted to see that the drawing area is evenly covered. The outlines should be firm and drawn with a conical pencil point, not making the line too thick. Draw a border line $\frac{1}{2}$ in from the edges of the paper and add the title, scale, and the projection used. When drawing the various section details you must remember that the web, although cut through its centre, should not be section lined but left as a full outline. Remember also that all section lines should be drawn at 45°.

8.4. SOLE PLATE. Fig. 69(*a*)

The sole plate shown is a cast-iron casting designed to carry a bearing block fixed to it. Any number of these can be set up in line so that a very long horizontal shaft can rotate truly and freely without sagging.

8.5. ASSIGNMENT. SOLE PLATE. Fig. 69(*a*)

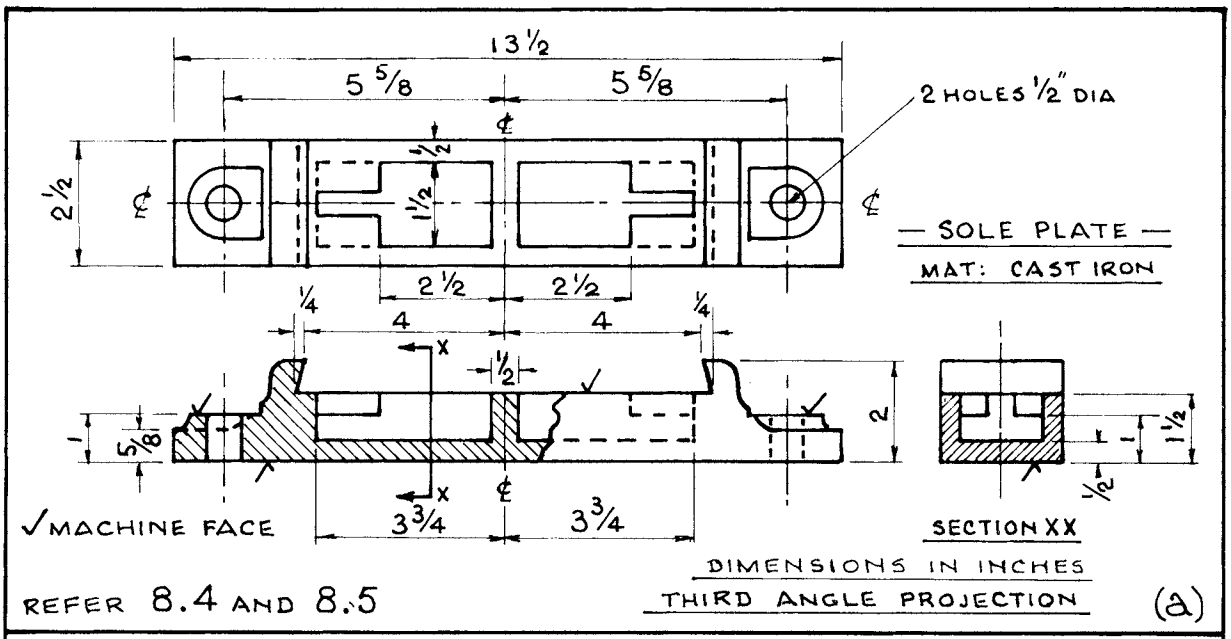
Copy the three views as shown to a full-size scale. Notice the undercut parts and the method of showing them in section *XX*.

Note the machined faces and the position of the symbols. Complete all the dimensions, draw a border line $\frac{1}{2}$ in from the edges of the paper, add the title, scale, and the projection used.

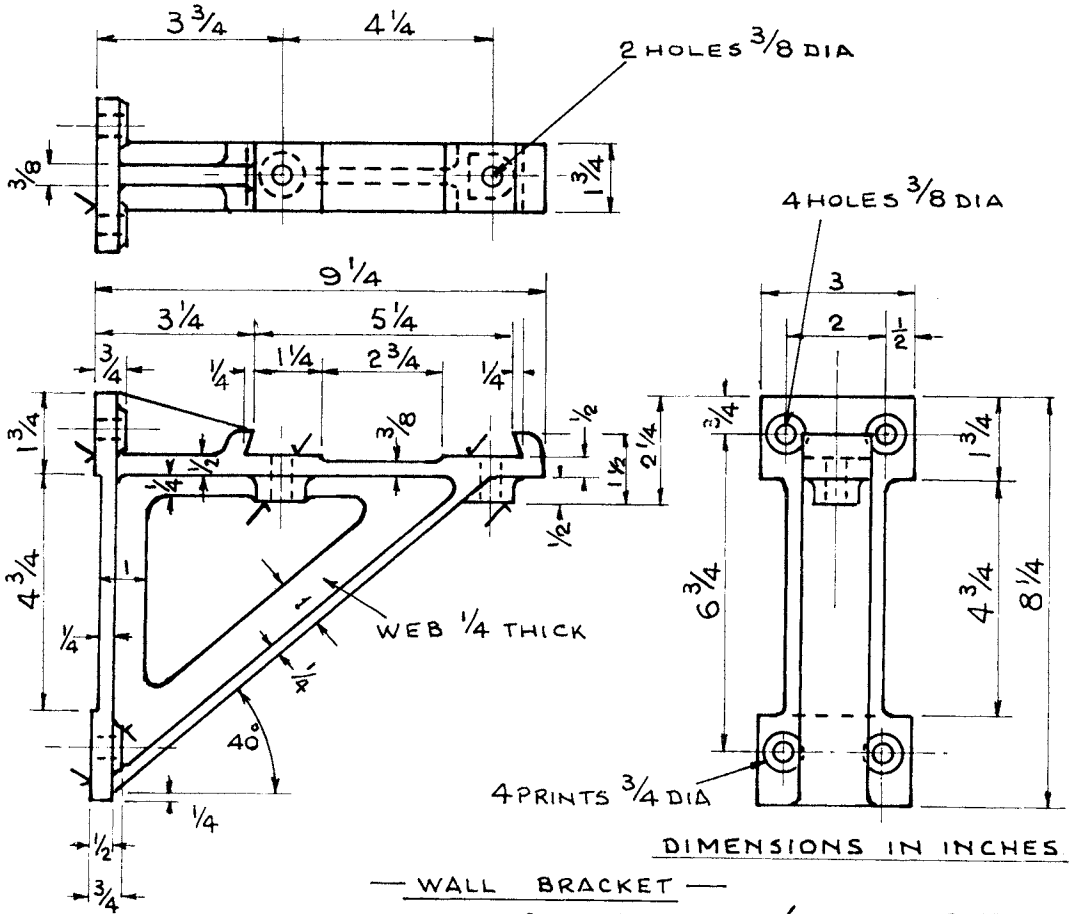
As an additional exercise, draw three views of the sole plate, i.e. a plan, a front elevation, and an end view. These should be drawn full-size and no sections should be shown.

8.6. WALL BRACKET. Fig. 69(*b*)

The wall bracket shown in Fig. 69(*b*) is designed for the same purpose as the sole plate but is used for carrying the shaft horizontally along a wall face at a specified distance from the floor.



REFER 8.4 AND 8.5



REFER 8.6 & 8.7

CAST BRACKETS FIG. 69

8.7. ASSIGNMENT. WALL BRACKET. Fig. 69(*b*)

Draw three views of the wall bracket as shown in Fig. 69(*b*). In this case the front elevation, side elevation, and plan should be drawn full size and the drawing finished in good quality lines with a border line. Add the title, scale, and the projection used.

8.8. DRILLHEAD BRACKET. Fig. 70(*a*)

In Fig. 70(*a*) we see a heavy cast-iron bracket consisting of two cylinders joined by an I-section web. The bracket is bolted on a 3 in dia. shaft, has a vertically guided running spindle, a screwed socket for a bush, and two screws to hold the bracket on to the large diameter shaft.

8.9. ASSIGNMENT. DRILLHEAD BRACKET. Fig. 70(*a*)

Draw the following views of the casting only to a full-size scale:

(1) Front elevation.
(2) End view, looking from the left.
(3) End view, looking from the right.
(4) Plan.
(5) Section cut through *XX*.

Do not show the hexagon bush or the 3 in dia. shaft and clamp screws.

Since there are five views you should spread out the dimensions and place them where you see the shape of a particular outline.

Draw the views in third angle projection and remember to build up and construct all five views simultaneously after plotting out carefully the positions of the views.

To finish the drawing add a border line, the title, scale, and the projection used.

Remember that only the section view needs a title which should read "SECTION THROUGH *XX*".

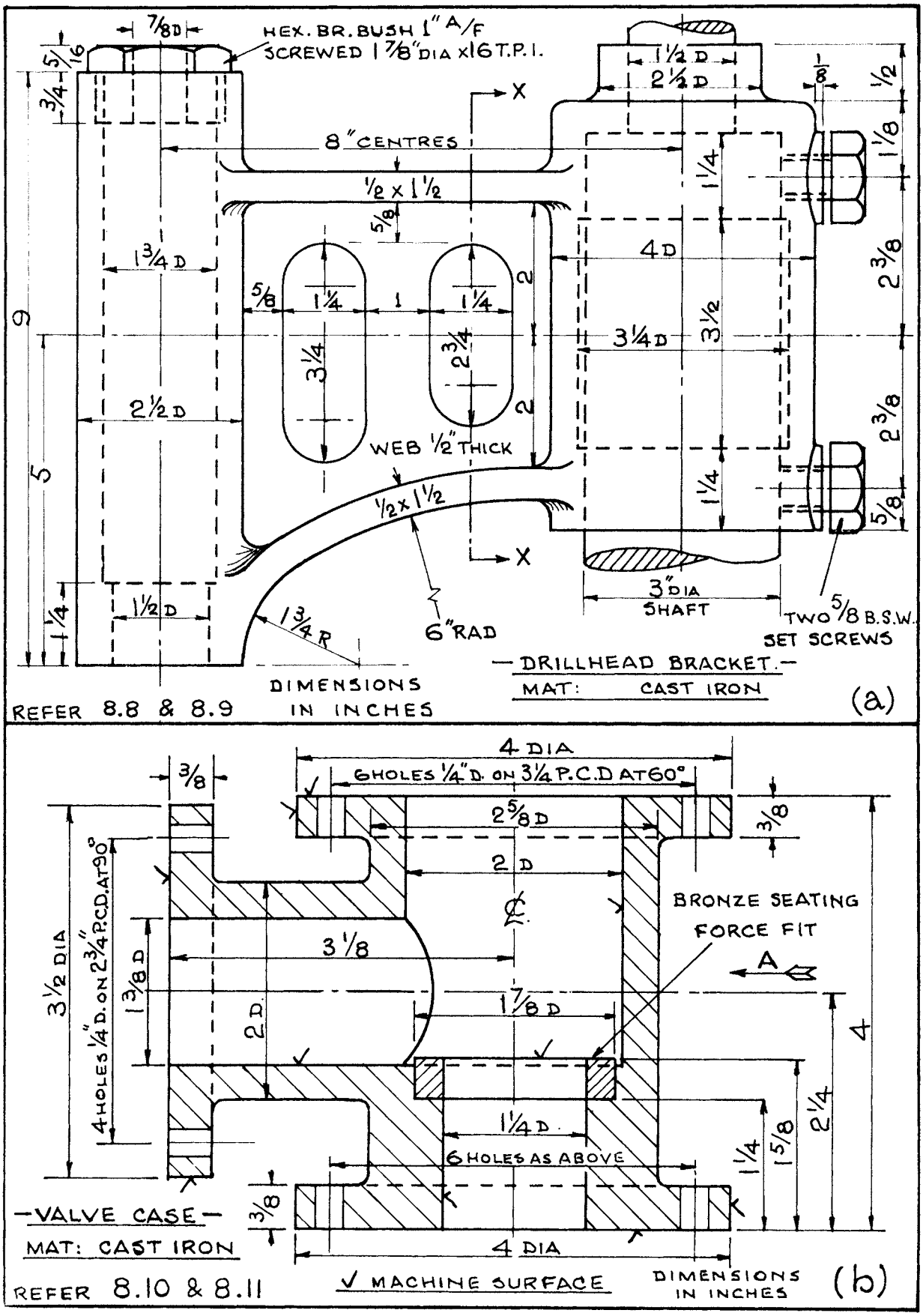
8.10. VALVE CASE. Fig. 70(*b*)

We now come to a drawing of a valve case which is, in effect, the sectional elevation of a flanged T with an inserted seating. Each flange is drilled with holes on a pitch circle diameter (P.C.D.). These holes must be spaced accurately to fit holes in any mating flanges.

8.11. ASSIGNMENT. VALVE CASE. Fig. 70(*b*)

Draw the following views to a full-size scale:

(1) The given sectional elevation.
(2) A cross-sectional elevation on a centre line looking in the direction of arrow *A*.
(3) A plan.
(4) An external front elevation.



DRILLHEAD BRACKET AND VALVE CASE

FIG. 70

In view (1) you must construct the curve of intersection and also show the bronze seating in position.

Notice that the flange on the left is smaller than the other two, and only has four holes drilled on a $2\frac{3}{4}$ in P.C.D. at 90°.

The upper and lower flanges each have six holes drilled on a $3\frac{1}{4}$ in P.C.D. at 60°. All holes in flanges should be as shown in the sectional elevation.

Do not place the dimensions where shown on the elevation but space them where you can see the shape of a particular outline, e.g. the diameter and P.C.D. of holes.

To finish the drawing add a border line, the title, scale, and the projection used.

8.12. STUFFING BOX ASSEMBLY. Fig. 71(*a*)

In Fig. 71(*a*) a section is shown of a stuffing box assembly. A shaft, sliding in two brass glands, can be made leakproof by closing the glands together to compress the greased packing. The flange containing the gland is moved by turning the hexagon nuts.

8.13. ASSIGNMENT. STUFFING BOX. Fig. 71(*a*)

Draw the two views given, i.e. sectional front elevation and end elevation. Then construct and draw a full front elevation and a plan view. Make all the views full-size, obtaining as much information as necessary from the given views. If you are in difficulty with the construction further information can be obtained from the parts detailed in Fig. 90.

8.14. ASSIGNMENT. SCREWED FLANGE. Fig. 71(*b*)

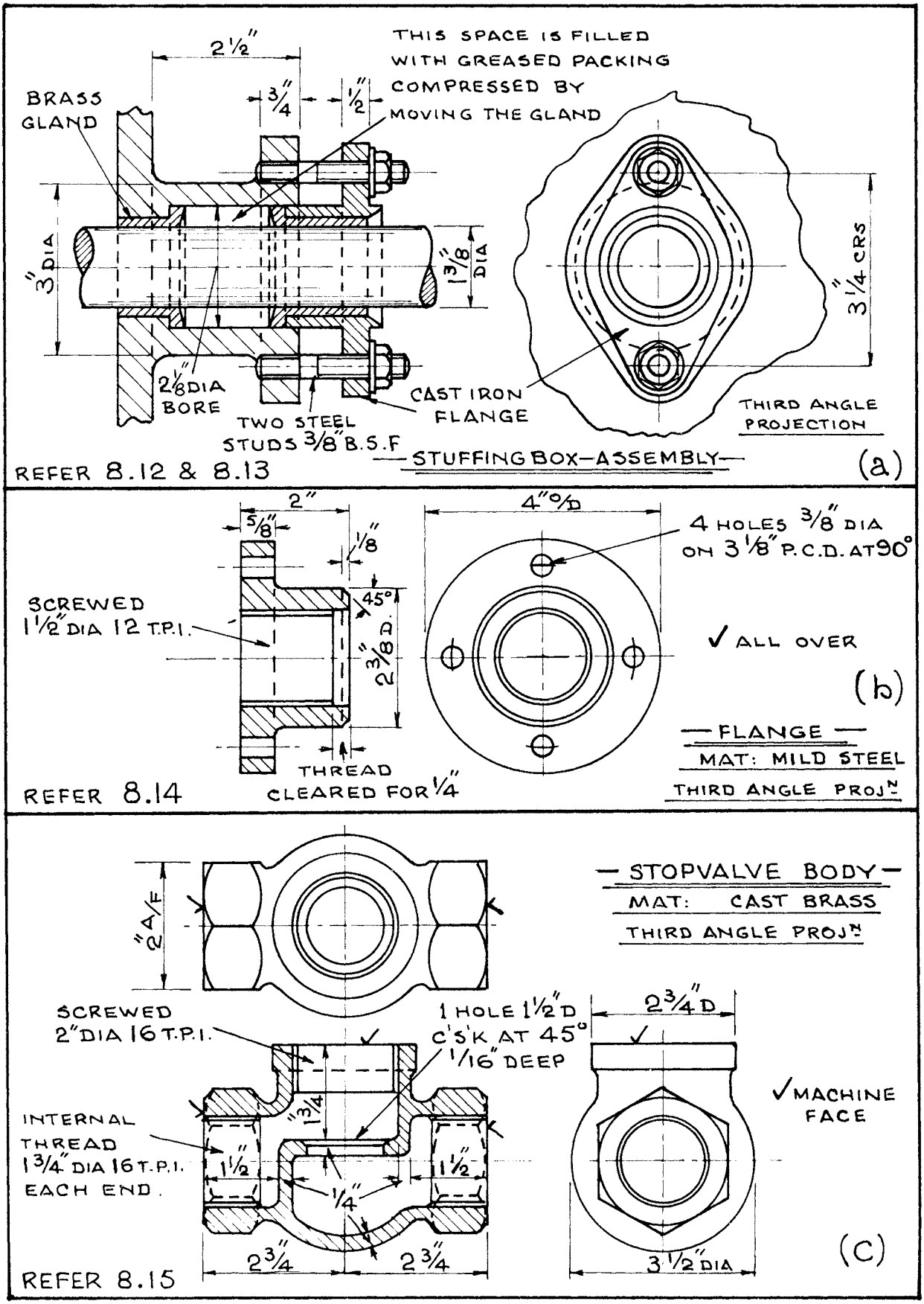
This figure shows details of the drawing of a heavy mild steel screwed flange. Copy the two views. Notice how the holes are positioned on the P.C.D. and how the thread is shown cleared for an "easy start".

8.15. ASSIGNMENT. STOP-VALVE BODY. Fig. 71(*c*)

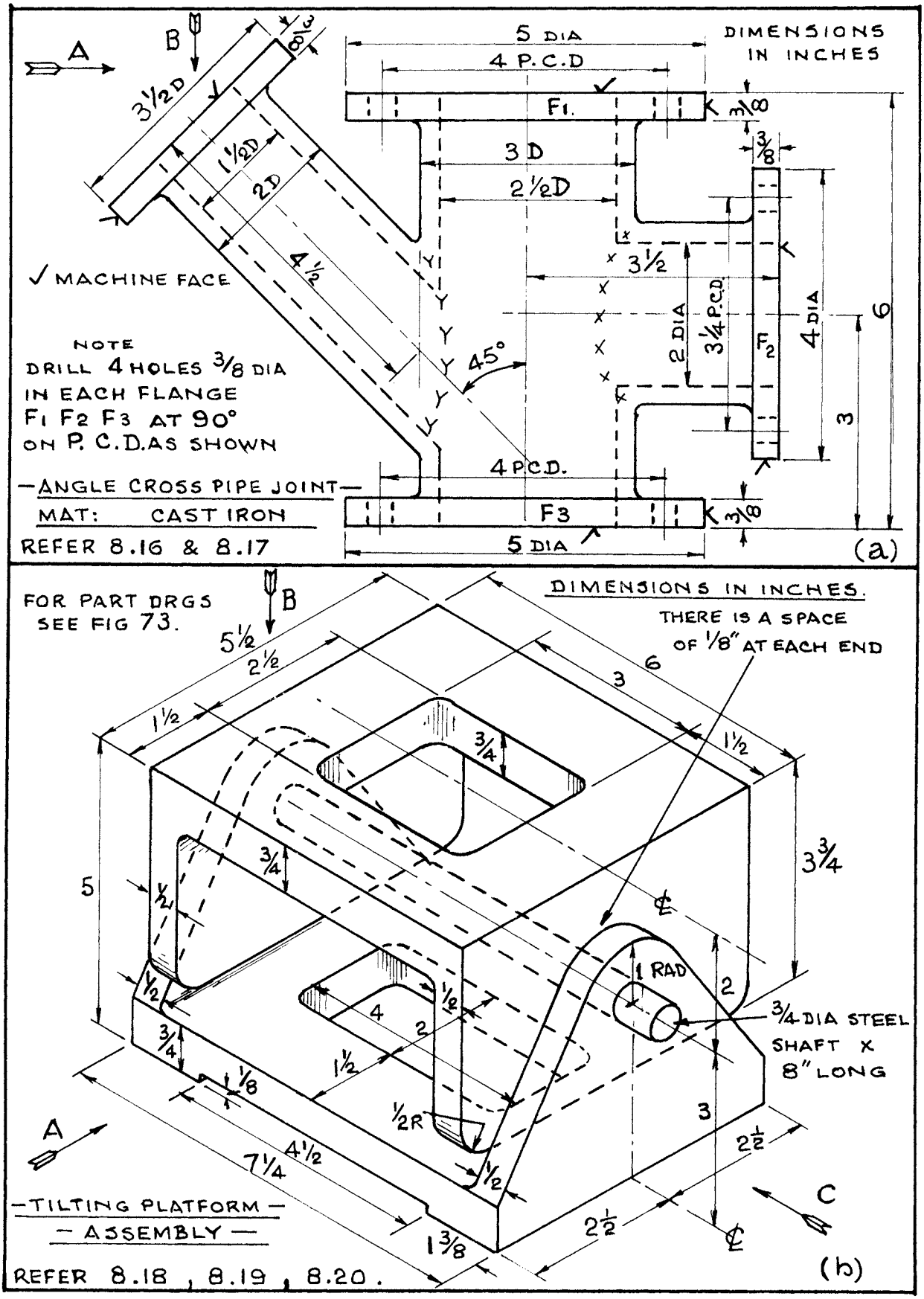
In this figure three views of a stop-valve body are shown, one being a section through the vertical centre line. This view shows the dividing partition and the hole and seating for the valve. The casting is cored out or undercut at the inner end of the threads. In this way it is possible to machine a thread without stopping at the inner end of the thread. Drilling the hole and machining the seating becomes an easy operation through the main top hole. Machined faces are shown by the symbol $\surd$. The hexagon faces are machined to an exact spanner size and are measured across the flats.

8.16. ANGLE CROSS-PIPE JOINT. Fig. 72(*a*)

In Fig. 72(*a*) we can see a cast-iron pipe joint with four outlets, each flanged but only three of the flanges have holes for jointing other flanged pipes. The holes,



PART DRGS FIG. 71



WORKING DRAWINGS FIG. 72

although shown drilled on a vertical plane centre line, should actually be drilled on the diagonal centre lines. The flange faces should be machined perpendicularly to their centres.

8.17. ASSIGNMENT. PIPE JOINT. Fig. 72(*a*)

In this exercise you are required to draw full size the following views:

(1) A front elevation.
(2) A plan from arrow *B*.
(3) A side elevation from arrow *A*.
(4) A sectional front elevation.

You should draw the above views in first angle projection and, before any outlines are made, the four views should be laid out and neatly spaced in the correct places, as follows:

(1) The front elevation should be drawn in fine construction lines built up on the main centre line and just positioning the edges of the flanges.
(2) The plan from arrow *B* should be projected under the front elevation, showing only the construction of the upper flanges and edges of right-hand flange.
(3) The side elevation from arrow *A* should be projected to the right of the front elevation and marked out at the same time as (2).
(4) Now lay out the sectional front elevation in construction lines.

If all the views are well spaced and in good positions, then further construction should be made, e.g. the curves of intersection at *X* and *Y*. These should be shown as single curved outlines (not shaded as for fillets). The curves of intersection should now be shown in the sectional front elevation. When produced, the flange at 45° will be a series of ellipses in the plan and side elevation. Draw the ellipses by the four arc method shown in Fig. 12(*a*).

Finally, fill in all outlines, print a title, scale, and the projection used, and draw a border line. Only one or two notes are required but all the dimensions shown in Fig. 72(*a*) should be moved to their appropriate positions on the four views, remembering that for a particular piece a dimension should appear only once.

8.18. TILTING PLATFORM. Fig. 72(*b*)

A tilting platform is a piece of equipment used very much in an engineering workshop. It is used as a flat surface on which to clamp an object which may then be tilted and clamped at a desired angle. The tilting platform shown in Fig. 72(*b*) is a simple type and has no clamps for the objects or the tilted position. An inverted U-shaped casting is carried from a U-shaped base casting by a spindle passing through all four ends.

8.19. ASSIGNMENT A. TILTING PLATFORM. Fig. 72(*b*)

The first drawing you are to make is a copy of the isometric view shown in Fig. 72(*b*). If this is carefully drawn you can understand the general construction more easily.

8.20. ASSIGNMENT B. TILTING PLATFORM. Fig. 72(*b*)

The second drawing you are to make contains three views in third angle projection as follows:

(1) A front elevation from *A*.
(2) A plan from *B*.
(3) A side elevation from *C*.

All the views are very straightforward and are easily drawn. A little difficulty may be experienced in the plan with the two rectangular holes. It is better to draw the larger, upper hole first, and then the lower hole, which being a longer rectangle shows a small amount of hidden detail. It must be noticed that the shaft can be seen through the top hole.

If you are in difficulty with the construction of the views, further information can be obtained from the parts detailed in Fig. 73.

Complete the drawing with firm outlines and draw a border line. The dimensions should be placed in positions where the shape of the part is clearly seen, and remember that a dimension only appears once.

8.21. TILTING PLATFORM. PART DRAWINGS. Fig. 73

The tilting platform was explained in section 8.18; an isometric view was drawn in section 8.19; and three views were drawn in section 8.20.

You are now to draw the three parts required to construct the tilting platform.

8.22. UPPER PLATFORM. Fig. 73(*a*)

Draw the three views in third angle projection shown in Fig. 73(*a*). Notice how the dimensions are placed in each case where the shape is clearly shown. Machined faces are indicated by the symbol $\surd$.

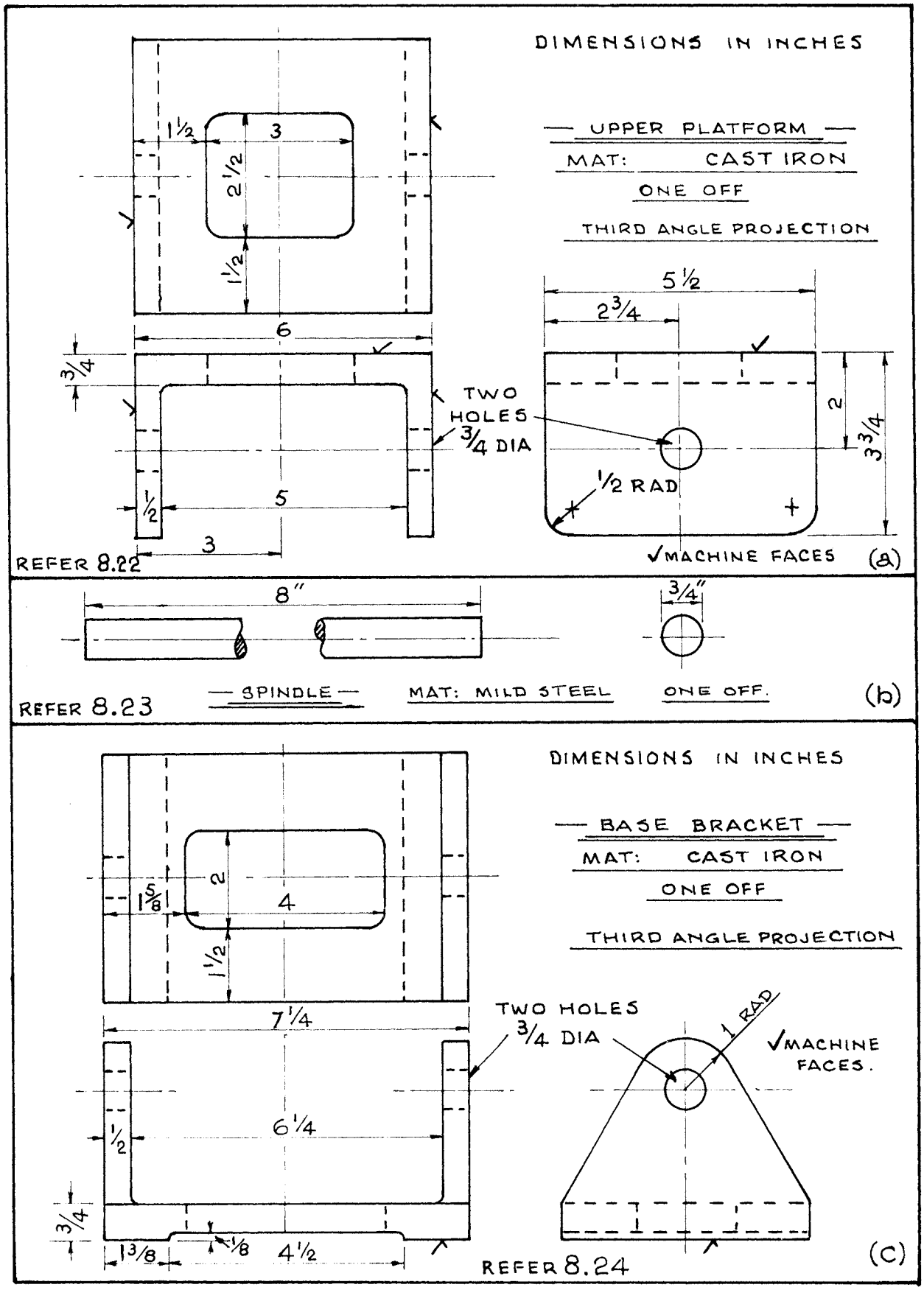
8.23. SPINDLE. Fig. 73(*b*)

The drawing of the spindle is very straightforward and needs only two views.

8.24. BASE BRACKET. Fig. 73(*c*)

The shape of this casting is similar to Fig. 73(*a*). Draw three views in third angle projection. Notice how the dimensions are placed and also where the machining symbols are shown.

Note. Normally, dimensions should not be placed inside the outline, but in Fig. 73(*a*) and (*c*) and in places where congestion can be avoided, some dimensions should be suitably placed to simplify the arrangement.



TILTING PLATFORM PART DRGS

FIG. 73

REFER 8.21

8.25. BRACKET BEARING. Fig. 74

It is generally accepted that bearings, of all sorts and sizes, form the largest individual parts to be found in general engineering. Figure 74 shows a medium size bearing which, being in two parts, can be fitted at any point on a long shaft. The lower part of the bracket can be bolted in position resting on the three projecting shoulders. The upper part, or cap, is held down by two of the square-headed bolts shown inset. When the two parts are clamped together the shaft must be a running fit in the bearing.

8.26. ASSIGNMENT A. BRACKET BEARING. Fig. 74

Make an isometric drawing of the bracket and screw as in Fig. 74. All the ellipses should be constructed by the isometric square method in Fig. 12(*b*). A little shading, but not too much, helps to show the shape. As some lubrication is required a simple hole is drilled $\frac{3}{16}$ in dia. with a $\frac{3}{8}$ in countersink at 45° as an oil receptacle. The top half is shown in part section on the centre line of the oil hole. You will notice that only one face is section lined. The reason for this is that the sectioned part (*a*) is an imaginary cut, whereas the other part (*b*) is an actual cut of separation.

8.27. ASSIGNMENT B. BRACKET BEARING. Fig. 74

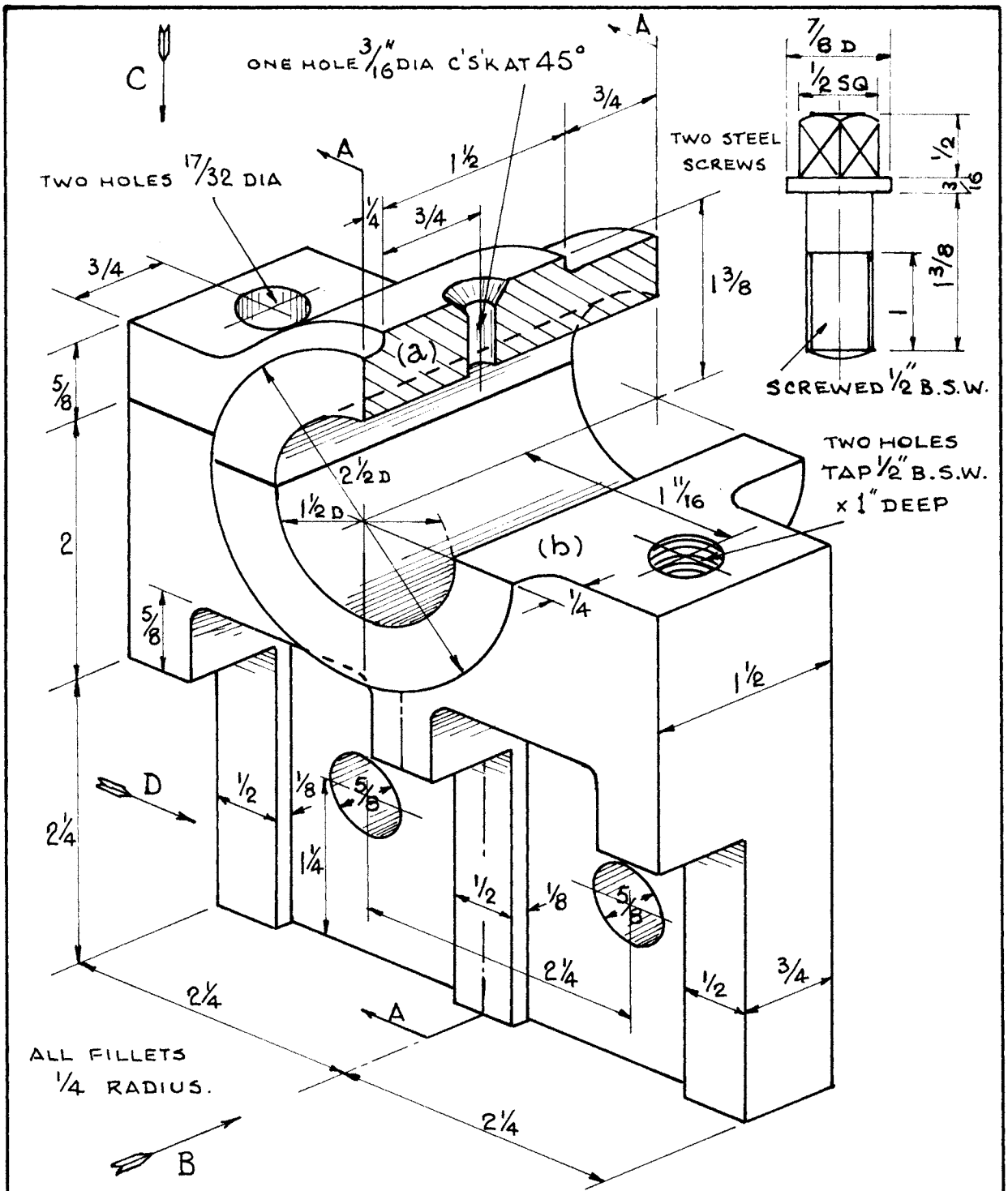
From the isometric drawing shown you are required to draw full size in third angle projection the following views of the assembled bracket:

(1) Front elevation from arrow *B*.
(2) Side elevation from arrow *D*.
(3) Plan from arrow *C*.
(4) Sectional elevation through *AA* looking in direction of arrow.

As this is third angle projection you should carefully lay out the views with plan *C* at the top centre of the paper, front elevation *B* projected under *C*, side elevation *D* to the left of *B*, and a sectional elevation through *AA* to the right of *B*. The section is the only view which needs a title. Draw all the views in firm outline and, where necessary, thin section lines at 45° but not too close together. Finish the drawing with a well-printed title, scale, the projection used, and add a neat border line. As these are assembly views, only a few major overall dimensions need be given. If any difficulty is experienced with the views, further information, together with detail dimensions, are given on the part drawings in Fig. 92.

8.28. ASSIGNMENT C. BRACKET BEARING. Fig. 74

As a further exercise the bracket bearing can be drawn with four views but in first angle projection. Remember that the front elevation *B* is at the top, the plan *C* is under *B*, the side elevation *D* is to the right, and section *AA* to the left. As in section 8.27, only a few major overall dimensions need be given.



BRACKET BEARING

MAT: CAST IRON

DIMENSIONS IN INCHES.

REFER 8.25 8.26 8.27 8.28

ISOMETRIC ASSEMBLY FIG. 74 FOR PART DRGS SEE FIG. 92

8.29. BELL CRANK LEVER. Fig. 75(*a*)

The assembly shown in Fig. 75(*a*) consists of a lever, one-to-one ratio, a keyed hole at the centre of the lever, and two driving pins. Driving rods are connected to the pins and a right-angle movement is obtained. Levers can also be made with different ratios giving a magnified movement or a reduced movement.

8.30. ASSIGNMENT A. BELL CRANK LEVER. Fig. 75(*a*)

Draw full size the three given views complete with notes, dimensions, and title. Notice that the driving pins are on alternate sides of the lever. This may lead to an undue amount of twisting moment, and to counter this the keyed hole must be of full length and fit, and the arms of the crank must be of good strong section.

An improved design would be for the two bosses of the driving pins to be on the same side of the lever as the centre boss. The driving forces would then be in the same plane and avoid the twisting moment.

8.31. ASSIGNMENT B. BELL CRANK LEVER. Fig. 75(*a*)

Draw full-size three views of the improved design as suggested in section 8.30. These views should be drawn in third angle projection. Finish the drawing with a printed title, scale, projection used, and border line.

8.32. OVERHUNG CRANK. Fig. 75(*b*)

The drawing in Fig. 75(*b*) shows two views of an overhung crank assembly. This is where a very strong steel shaft is keyed into a wrought iron crank, which has a steel driving pin shrunk fit into the crank to give a throw of 5 in radius.

A shrunk fit is often used where two metal parts are to be fitted together very tightly. In this case the wrought-iron crank is bored out to $2{\cdot}0 \pm 0{\cdot}05$ in dia. and the crank pin, or driving pin, is turned down to $2{\cdot}01$ in $\pm 0{\cdot}05$. The crank is then heated to go on to the pin. As the crank cools it shrinks and grips on to the pin firmly. It can then be riveted over.

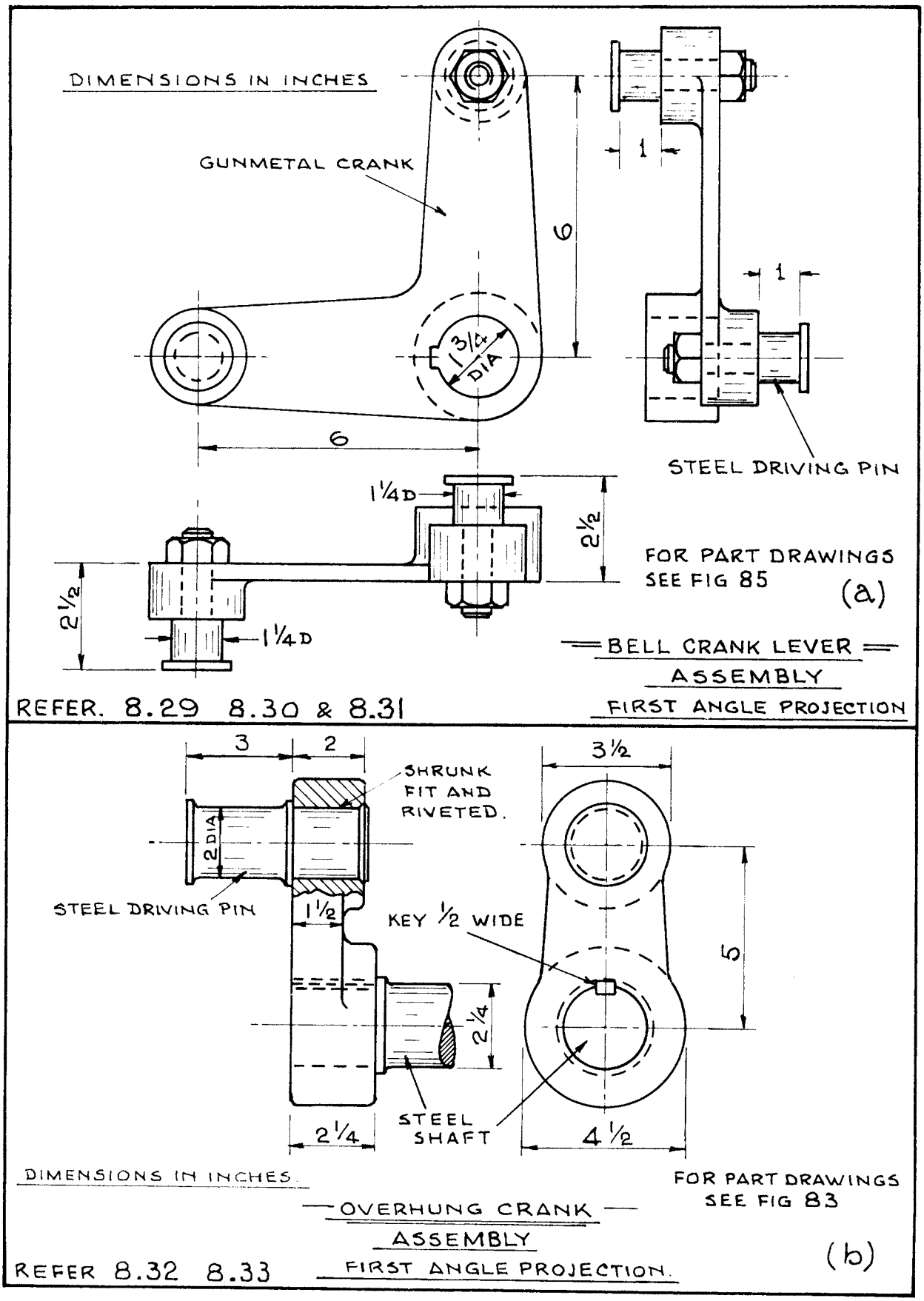
8.33. ASSIGNMENT. OVERHUNG CRANK. Fig. 75(*b*)

Draw the two views in Fig. 75(*b*). Add the notes and specification dimensions. Notice the method of fixing the crank by a long taper key forced in a keyway when the crank is against the shoulder on the main shaft. Part drawings for further information are to be seen in Fig. 83.

8.34. SPINDLE BEARING ASSEMBLY. Fig. 76

The assembly shown in Fig. 76 consists of a double-shouldered steel spindle running in two bronze half-bearings clamped together and held in position by a cast-iron cap bolted to a cast-iron base.

The assembly can be fitted with a pulley on each end and used as an intermediate unit to determine whether the final driven unit will be at a higher or lower speed than the driving unit.



ASSEMBLY DRAWINGS FIG. 75

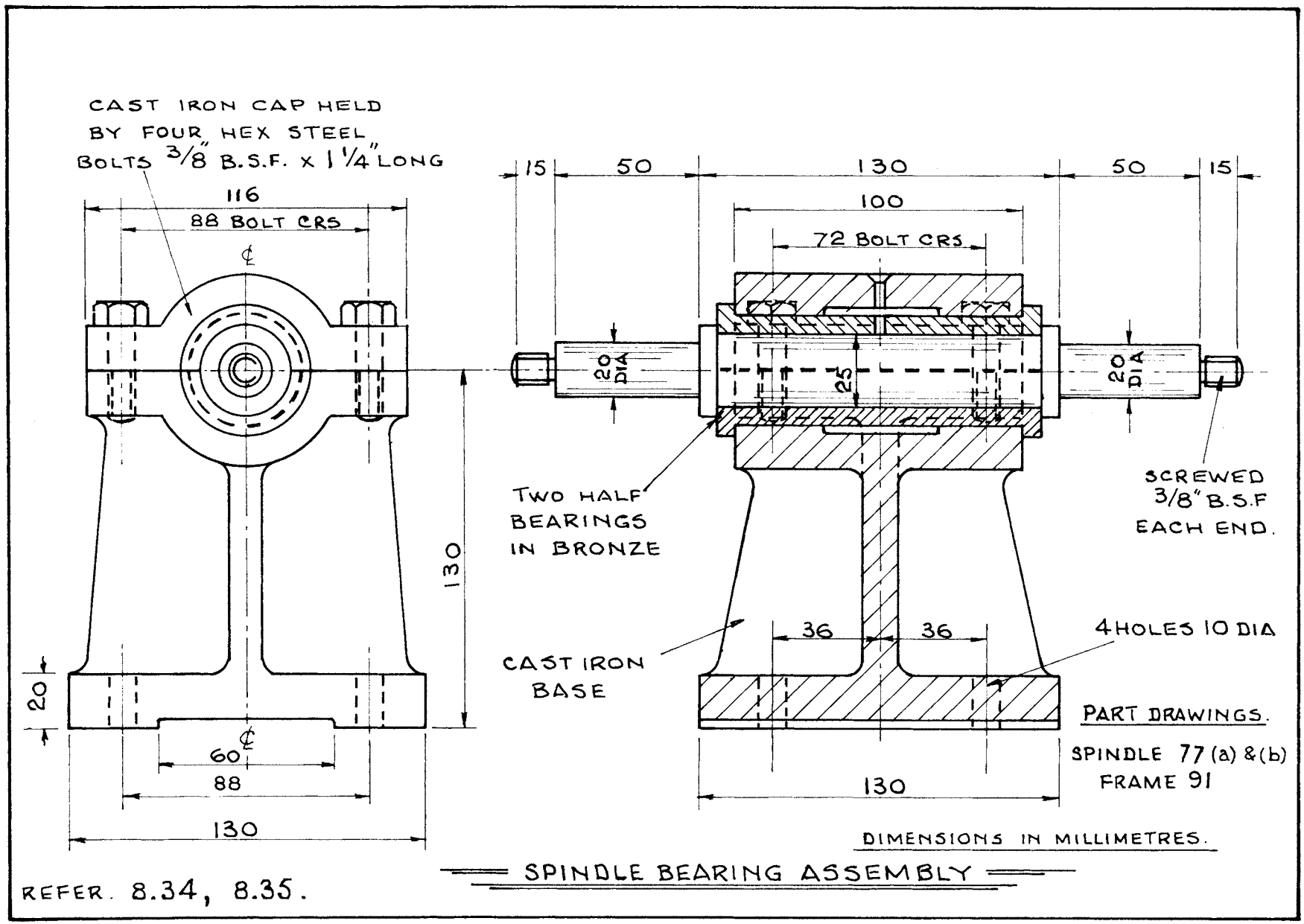

CAST IRON CAP HELD BY FOUR HEX STEEL BOLTS 3/8" B.S.F. x 1 1/4" LONG
116
88 BOLT CRS
130
20
60
88
130
15
50
130
50
15
100
72 BOLT CRS
20 DIA
25
20 DIA
TWO HALF BEARINGS IN BRONZE
SCREWED 3/8" B.S.F EACH END.
CAST IRON BASE
36
36
4 HOLES 10 DIA
130
PART DRAWINGS.
SPINDLE 77 (a) & (b)
FRAME 91
DIMENSIONS IN MILLIMETRES.
SPINDLE BEARING ASSEMBLY
REFER. 8.34, 8.35.

FIG. 76

Notice in the sectional elevation how the section of the web is shown. Although the section is cut through the vertical plane the two webs are left plain and only the centre part is cross-hatched. Look carefully at the drawing to understand fully how this is done.

This assembly is the first of the series to be dimensioned in millimetres. If you have used only fractions and decimals in Imperial units before, two conversion charts are given in Fig. 77(*c*). One chart converts inches into millimetres and the other millimetres into inches.

8.35. ASSIGNMENT. SPINDLE BEARING ASSEMBLY. Fig. 76

Draw the two given views and add a plan. Since no information is given to the contrary, you must assume that the plan of the cap and base will have square corners.

When you come to position the plan it will, of course, be projected from the sectional elevation. For third angle it will be above and for first angle it will be below the elevation. A point to notice here is that because the assembly is symmetrical the two views shown can be considered first angle or third angle projection.

Complete the drawing in good quality lines, print the title, projection used, scale, and add a border line.

For further details of parts, see Fig. 77 for spindle and bearings, and Fig. 91 for the cap and base.

8.36. SPINDLE BEARING. PART DRAWINGS. Fig. 77

The spindle bearing assembly was shown in Fig. 76. Figure 77 shows the spindle and half bearing detailed separately.

The spindle, Fig. 77(*a*), is machined from mild steel rod. The portion between the flanges has a parallel surface ground to a diameter which will be a running fit in two of the half bearings, shown in Fig. 77(*b*), which are cast in bearing bronze. Two of these are machined together to be a good running fit on the shaft shown in Fig. 77(*a*).

8.37. ASSIGNMENT. SPINDLE BEARING. Fig. 77

Both of these parts (*a*) and (*b*) should be drawn full-size and all relevant information should be neatly printed on the drawing.

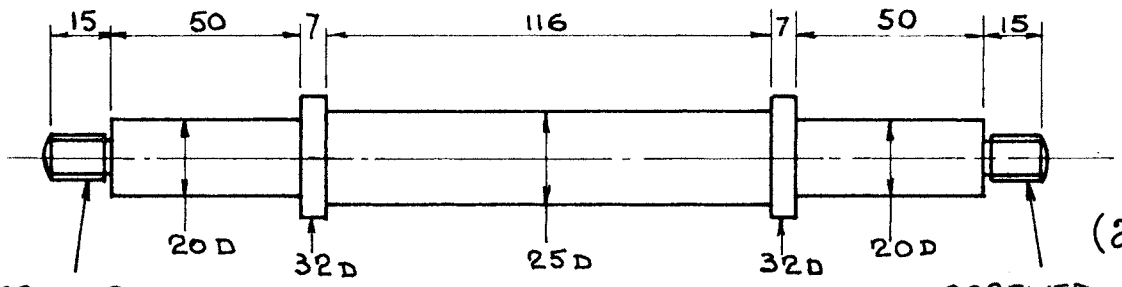
Finish the drawings with good quality lines and printing.

Reference should be made to the part drawings for the cap and base, Fig. 91.

8.38. RIGHT-ANGLE DRIVE ASSEMBLY. Fig. 78

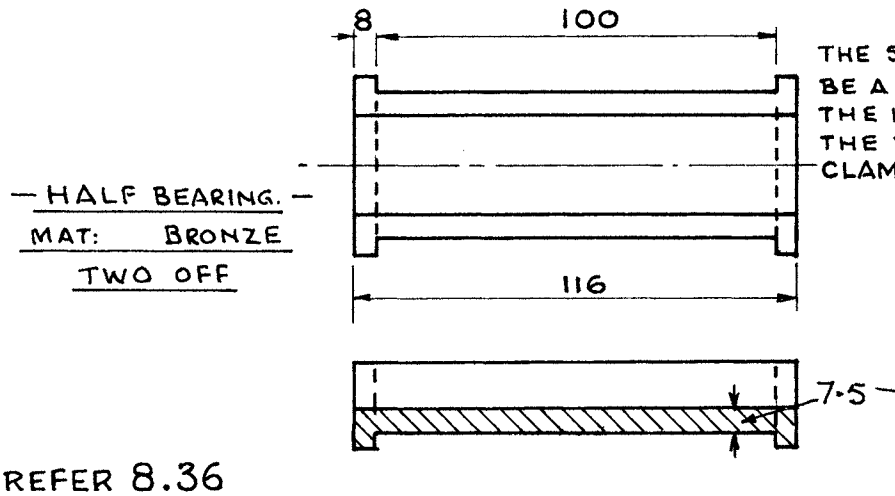
In Fig. 78 we see the assembly of a mechanical right-angle drive which has a pulley keyed to a shaft running in a bearing in a gearbox. Another shaft runs in a bearing at 90° to the first. At the centre of the right angle is fitted (not illustrated) two 45° bevel gears. The gearbox is made in cast iron and the shafts from mild steel.

REFER 8.36



(a)

ONE OFF — SPINDLE — MAT: MILD STEEL



— HALF BEARING. —
MAT: BRONZE
TWO OFF

THE SPINDLE (A) SHOULD BE A RUNNING FIT IN THE HOLE FORMED WHEN THE TWO HALVES ARE CLAMPED TOGETHER.

(b)

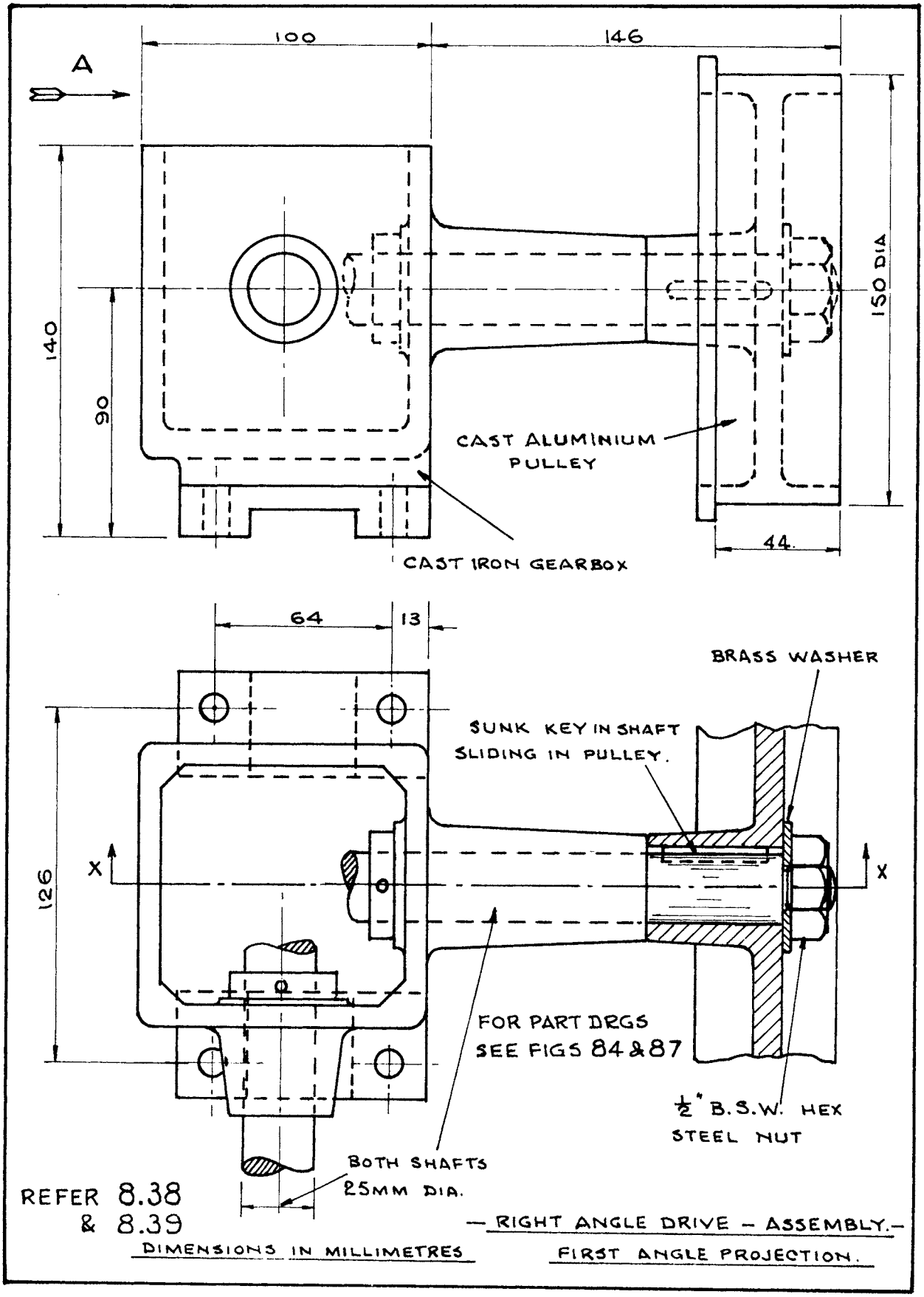
REFER 8.36

INCHES FRACTIONS	INCHES DECIMALS	mm
1/64	0·0156	0·3968
1/32	0·0312	0·7938
3/64	0·0468	1·1906
1/16	0·0625	1·5875
3/32	0·0937	2·3813
1/8	0·1250	3·1750
3/16	0·1875	4·7625
1/4	0·2500	6·3500
3/8	0·3750	9·5250
1/2	0·5000	12·7000
3/4	0·7500	19·0500
7/8	0·8750	22·2250
1	1·0000	25·4000
2	2·0000	50·8000
4	4·0000	101·6000
6	6·0000	152·4000

mm	INCHES	mm	INCHES
0·1	0·0039	125	4·9212
0·2	0·0078	150	5·9055
0·4	0·0157	200	7·8740
0·5	0·0197	250	9·8425
1·0	0·0394	300	11·8110
2·0	0·0787	350	13·7795
4·0	0·1575	400	15·7481
5·0	0·1968	450	17·7166
8·0	0·3149	500	19·6851
10·0	0·3937	550	21·6536
15·0	0·5905	600	23·6221
20·0	0·7874	650	25·5906
25·0	0·9842	700	27·5591
50·0	1·9685	800	31·4961
75·0	2·9527	900	35·4331
100·0	3·9370	1000	39·3701

(c)

FIG. 77



RIGHT ANGLE DRIVE — ASSEMBLY FIG. 78

8.39. ASSIGNMENT. RIGHT-ANGLE DRIVE ASSEMBLY. Fig. 78

You are required to draw the following views in first angle projection:

(1) A sectional front elevation through *XX*.
(2) A plan projected from (1).
(3) A side elevation looking in direction of arrow *A*.

When drawing (1) the section through the pulley should be shown at right angles, as in the plan. The spindle should be left full and not sectioned. For more details of the box, refer to Fig. 84.

The plan should be as in Fig. 78 except that the pulley will be shown full and at right angles as in the elevation.

When drawing (3), the side elevation from arrow *A*, you will see first the cast gearbox and behind it the pulley, etc. From the dotted lines in the elevation and plan (Fig. 78) you will notice that the box is undercut and the feet project each side for the mounting holes. Refer for further details to Fig. 84.

Finish the drawing with good quality lines and print the title, scale, projection used, and add a border line. As it is an assembly drawing, only specification dimensions are required.

8.40. LATHE FACE PLATE. Fig. 79(*a*)

This face plate is included in the present series of drawings to show how special sections can be taken through any plane so as to reduce the number of views and lessen the complication.

The face plate is circular and made of cast iron. Four slots are cast at 90° and the sides of each slot are stiffened between the centre hub and outer rim. The centre hub is screwed to suit the thread on the lathe mandrel.

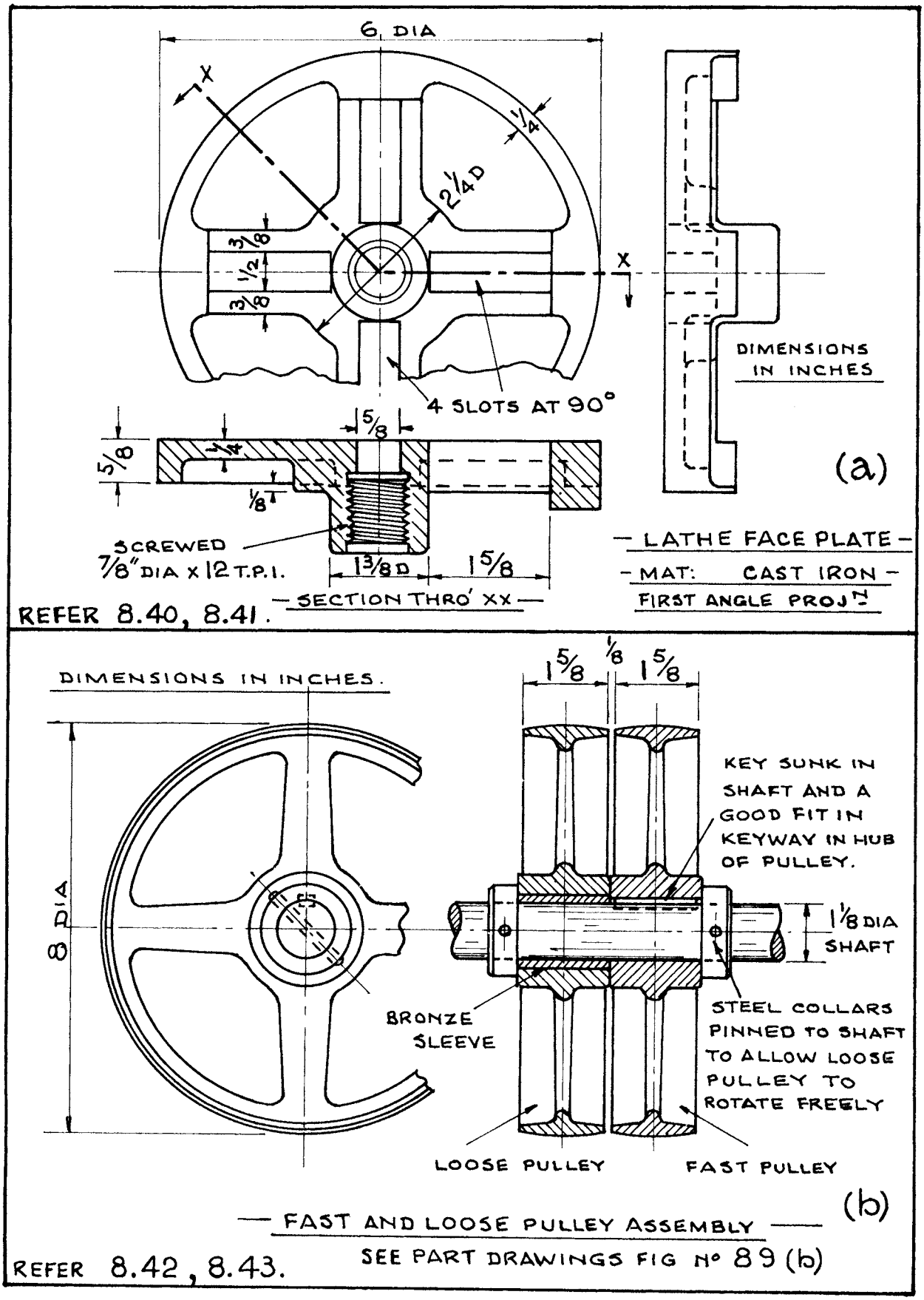
8.41. ASSIGNMENT. LATHE FACE PLATE. Fig. 79(*a*)

Draw full-size in first angle projection the three views given in Fig. 79(*a*). In the front elevation, by making a double break it is possible to save some space and drawing time providing that the side elevation is in full view.

The section (which is in the plan position) is taken through the plane *XX*, starting from the right, through the thick rim, the slot, and half the screwed boss to the centre. Now the plane turns at 45° and passes through the second half of the screwed boss, the thick part of the centre boss, and then through the thinner part of the flange to the thin rim.

Complete the drawing with good quality lines, print the title, scale, and projection, and add the border line. The views should be fully dimensioned, as shown.

In a section of this nature it is much clearer to show the conventional V-thread with the undercut and thread clearance for easy start.



LATHE FACE PLATE
FAST & LOOSE PULLEY

FIG. 79

8.42. FAST AND LOOSE PULLEY ASSEMBLY. Fig. 79(*b*)

When a series of machines are driven by continuously running shafting with belt drives to each machine, there must be a method of stopping any of the machines at will. This is done by moving the driving belt from the fast to the loose pulley.

It must be stressed here that this method of driving machines has been superseded by a self-contained electric motor for each machine, which is more efficient and cleaner. However, Fig. 79(*b*) is a good engineering example from which drawings can be made.

Examining the details of Fig. 79(*b*) you will see that there are two pulleys of the same diameter and shape. One of them is fitted with a bronze sleeve and is free to rotate, the other is keyed to the shaft. End play is prevented by collars pinned to the shaft.

More details of the pulley hubs can be seen in Fig. 89(*b*).

8.43. ASSIGNMENT. FAST AND LOOSE PULLEY ASSEMBLY. Fig. 79(*b*)

Draw the two views given and notice again that part of the pulley can be shown to save space and drawing time. As the pulley is symmetrical a third view is not necessary.

Finish the drawing with good quality lines, print the title, scale, and projection used, and add a border line. Being an assembly drawing, only specification dimensions are required.

8.44. UNIVERSAL COUPLING ASSEMBLY. Fig. 80(*a*)

When two shafts, coupled together, are required to run at an angle to one another, the coupling must be universal. If, however, both shafts are to be (1) parallel, (2) up to 90° angular displacement, or (3) centres offset but parallel, then two universal couplings must be fitted to an independent shaft between the driving and the driven shaft.

There are many types of universal couplings produced commercially. The one shown in Fig. 80(*a*) is known as a Hooke's joint.

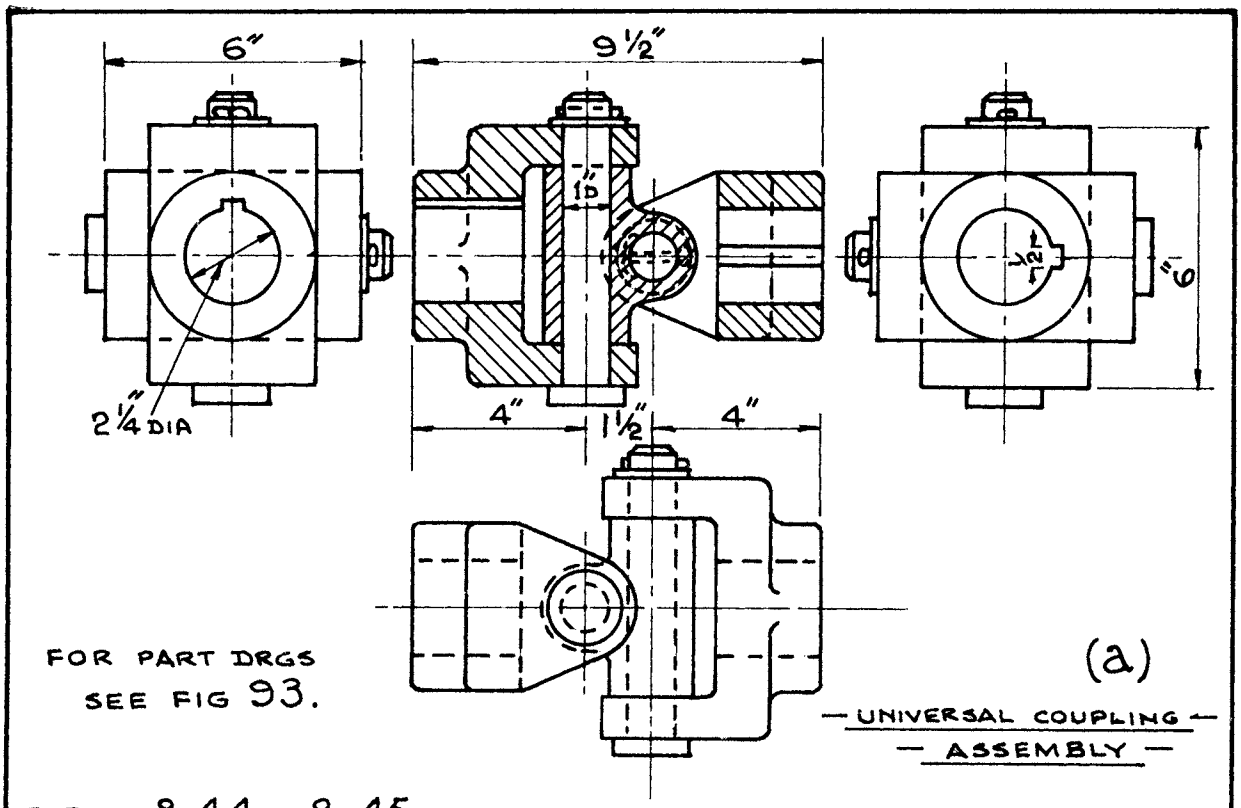
The construction is as follows. Two coupling forks are joined by a coupling link which has two link pins at right angles to each other. To understand this construction refer to the part drawings in Fig. 93.

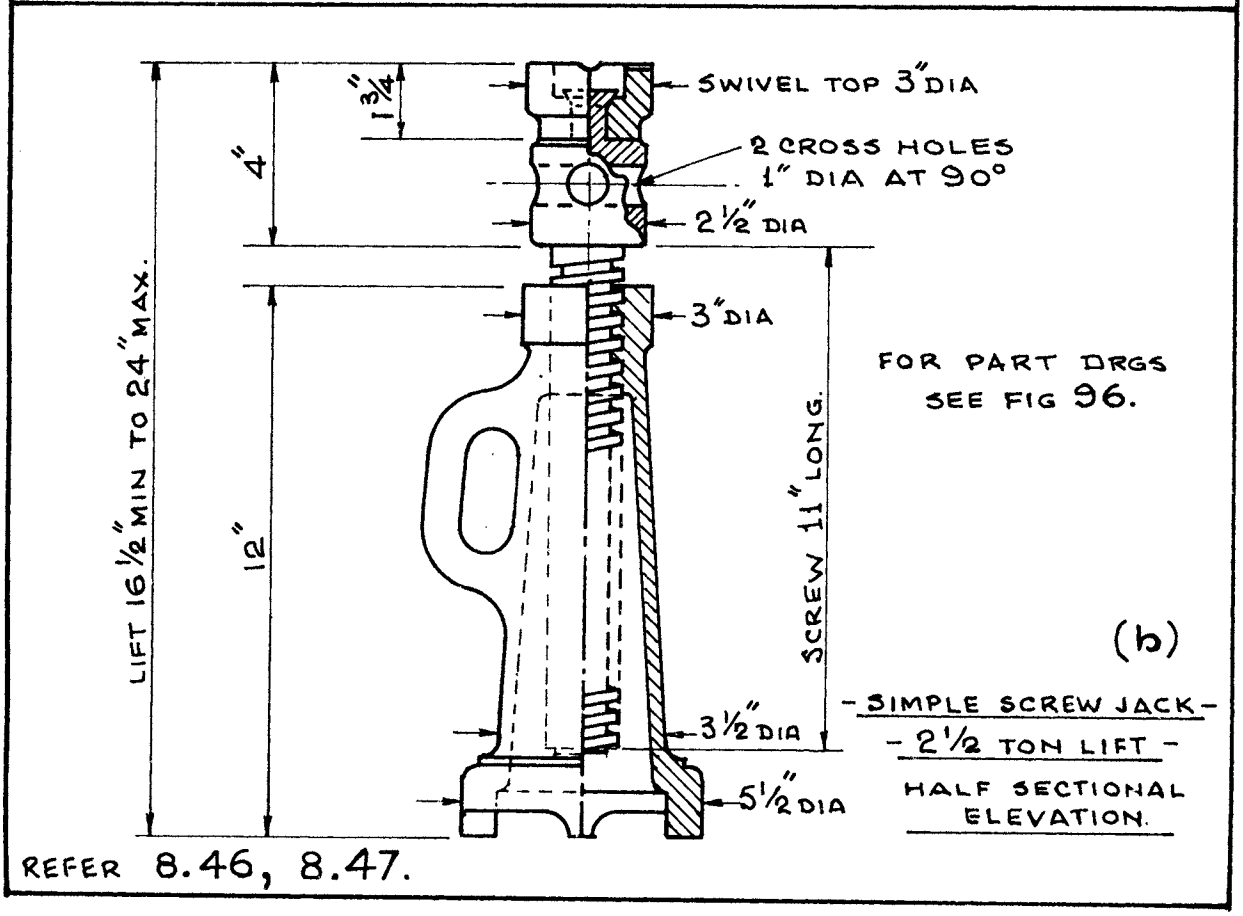
8.45. ASSIGNMENT. UNIVERSAL COUPLING ASSEMBLY. Fig. 80(*a*)

Draw the four views as shown in Fig. 80(*a*) full size and in third angle projection. Notice how the section includes both keyways and both link pins.

The drawing should be finished with good quality lines, a printed title, scale, and projection used.

Any further details can be obtained from the part drawings in Fig. 93.





UNIVERSAL COUPLING
SIMPLE SCREW JACK

FIG. 80

8.46. SIMPLE SCREW JACK. Fig. 80(*b*)

Figure 80(*b*) shows a half-sectional elevation of a simple screw jack capable of lifting $2\frac{1}{2}$ tons. The single view in half-section gives all the information necessary for an assembly. For detailed information refer to part drawings, Fig. 96. A very strong cast-iron stand acts as a nut for a long square-threaded screw which can be turned by a rod through the cross holes provided. At the upper end of the screw is a swivel cup which remains stationary when lifting takes place. Being circular and slightly conical gives the stand a particularly strong section. A square-section thread is also very strong.

8.47. ASSIGNMENT. SIMPLE SCREW JACK. Fig. 80(*b*)

Draw the half-sectional elevation in Fig. 80(*b*) getting all the necessary details from the part drawings in Fig. 96. Draw the elevation full size and place it horizontally on the paper.

Finish the drawing with good quality lines, a printed title, scale, and projection used.

8.48. FOOTSTEP BEARING. Fig. 81(*a*)

The bearing shown in Fig. 81(*a*) is designed for the lower end of a rotating vertical shaft. Examine the cross-section and observe its construction. A cast-iron base, which can be bolted to the floor, has an inserted bronze sleeve bearing. At the bottom of this is a bronze pressure pad which is shaped concave to suit the convex end of the shaft. Both the sleeve and pad are pinned to prevent rotation. A bevel or radial groove is machined to allow an amount of oil always to be present to lubricate the bearing.

8.49. ASSIGNMENT. FOOTSTEP BEARING. Fig. 81(*a*)

Draw the three views given in Fig. 81(*a*) in third angle projection and full size. Show all the hidden detail. For further internal details see the part drawings in Fig. 94. Notice that the base is recessed to allow the screws to hold the machined faces firmly to a flat foundation.

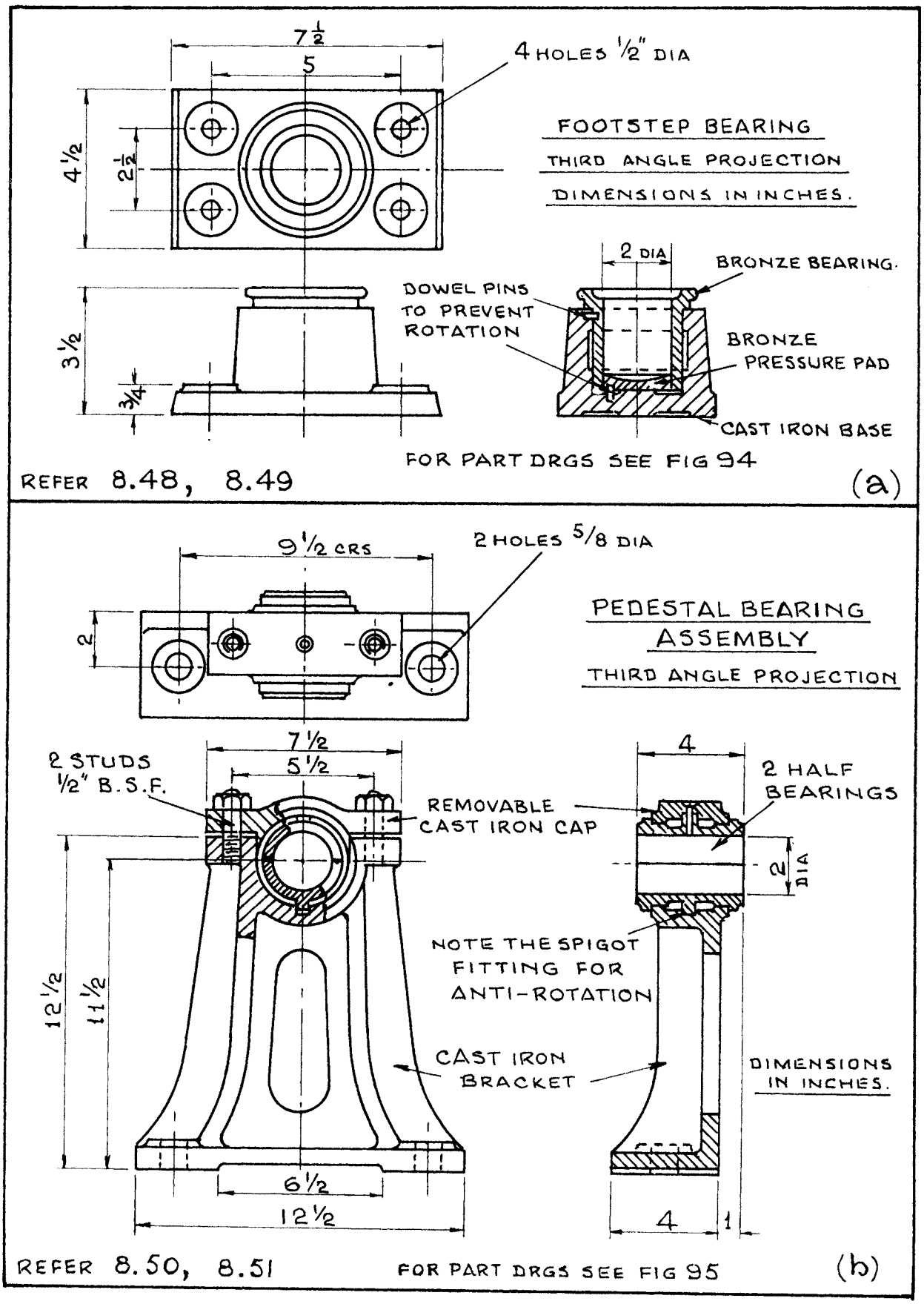
Finish the drawing with good quality lines, a printed title, scale and projection used.

8.50. PEDESTAL BEARING ASSEMBLY. Fig. 81(*b*)

This is another type of bearing, one which can be mounted on a foundation or hung from a horizontal beam. Numbers of these, being half-bearings, can be fitted at any position along a long rotating shaft.

8.51. ASSIGNMENT. PEDESTAL BEARING ASSEMBLY. Fig. 81(*b*)

Draw the three views to half full-size scale, getting details from the part drawings in Fig. 95. The curves of the main frame are symmetrical and need careful plotting before outlining. All other details are quite clear and straightforward.



FOOTSTEP BEARING
PEDESTAL BEARING

FIG. 81

Finish the drawing with good quality lines, a printed title, scale, and projection used.

8.52. PULLEY BEARING ASSEMBLY. Fig. 82

In this drawing we have an assembly of a pulley bearing which can be bolted down to a bench or other foundation. The spindle is belt driven through a pulley which is keyed and held by a nut. The pulley is crowned to retain the belt at fast speed and lubrication is provided for the spindle running in the bearing. To avoid a lot of machining a collar is pinned to the spindle which only leaves a small amount of turning for fitting the pulley. Being cast iron the pulley is machined all over and balanced to prevent out-of-balance vibration at the higher speeds.

8.53. ASSIGNMENT. PULLEY BEARING ASSEMBLY. Fig. 82

You are required to draw the sectional elevation and end elevation shown and then to add a complete plan. As the drawing is in third angle projection the added plan will be placed above the sectional elevation. The measurements are in millimetres and you are to make the drawing full size. Only specification dimensions are to be given.

Finish the drawing with good quality lines, a printed title, scale, and projection used. The notes must also be printed in good style.

See part drawings for further details in Figs. 86 and 88.

8.54. PART DRAWINGS FOR OVERHUNG CRANK. Fig. 83

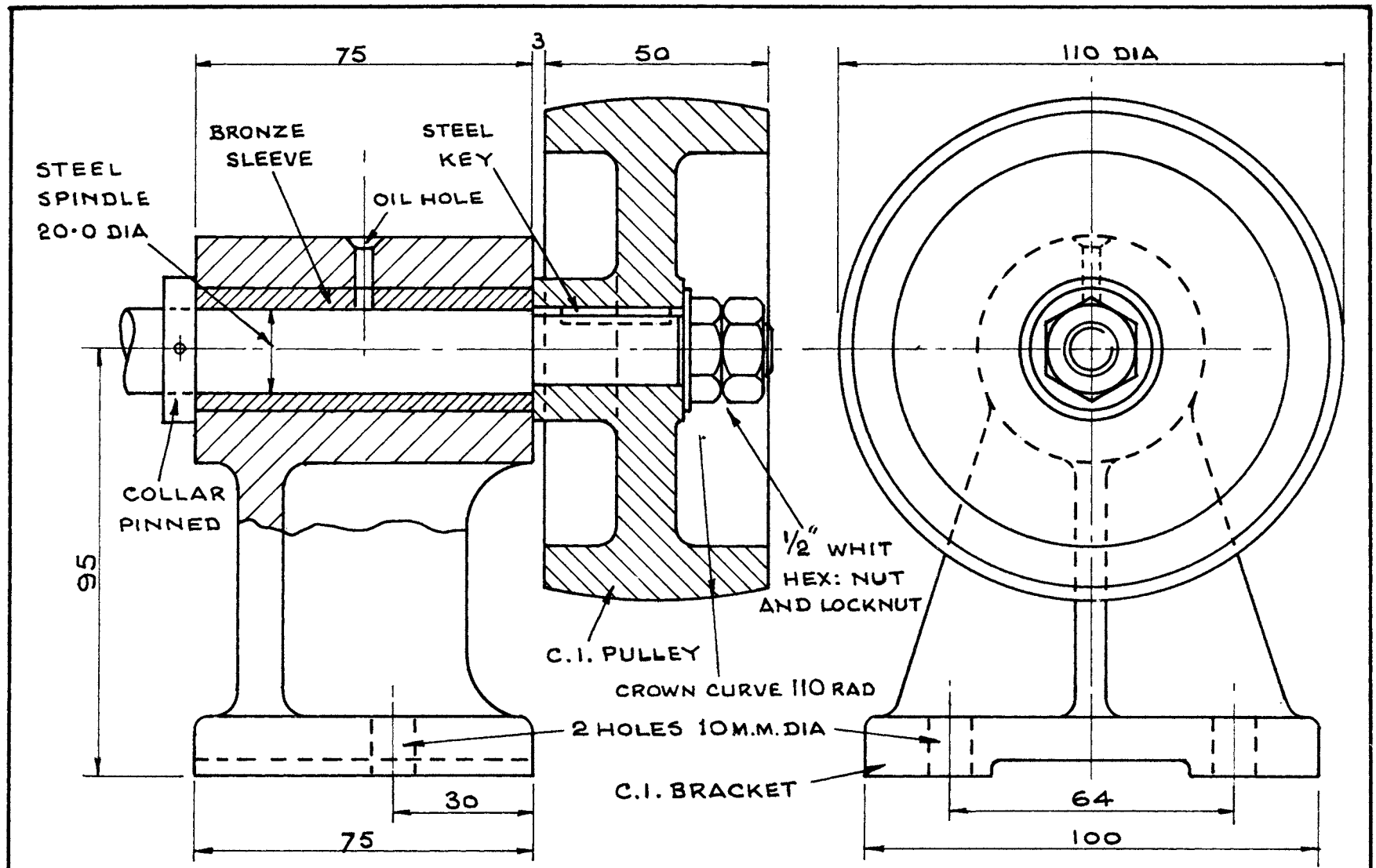
Here are the drawings of parts of the overhung crank which was earlier drawn in Fig. 75(*b*). In order to manufacture parts which will form the assembly, each part must be separately detailed and carefully dimensioned to mate with or match the corresponding part.

8.55. ASSIGNMENT. PART DRAWINGS FOR OVERHUNG CRANK. Fig. 83

(*a*) Copy the two views of the crank, Fig. 83(*a*), and add an end view from arrow *A*. Print a title, dimensions, projection used, and the number off. This refers to the number required for each assembly. The finished size of this drawing should be a border line of 10 in by 18 in.

(*b*) Copy the view shown in Fig. 83(*b*) on to paper with border line 8 in by 5 in. There is no need for an end view. Draw this view full size in good quality lines, and print a title, scale, etc.

(*c*) Copy the view shown in Fig. 83(*c*) in exactly the same way as in Fig. 83(*b*). Notice the scrap view of the keyway and also that it is only the end of the main shaft which is shown. Finish off the drawing as previously instructed, well spaced inside a border line 8 in by 5 in.



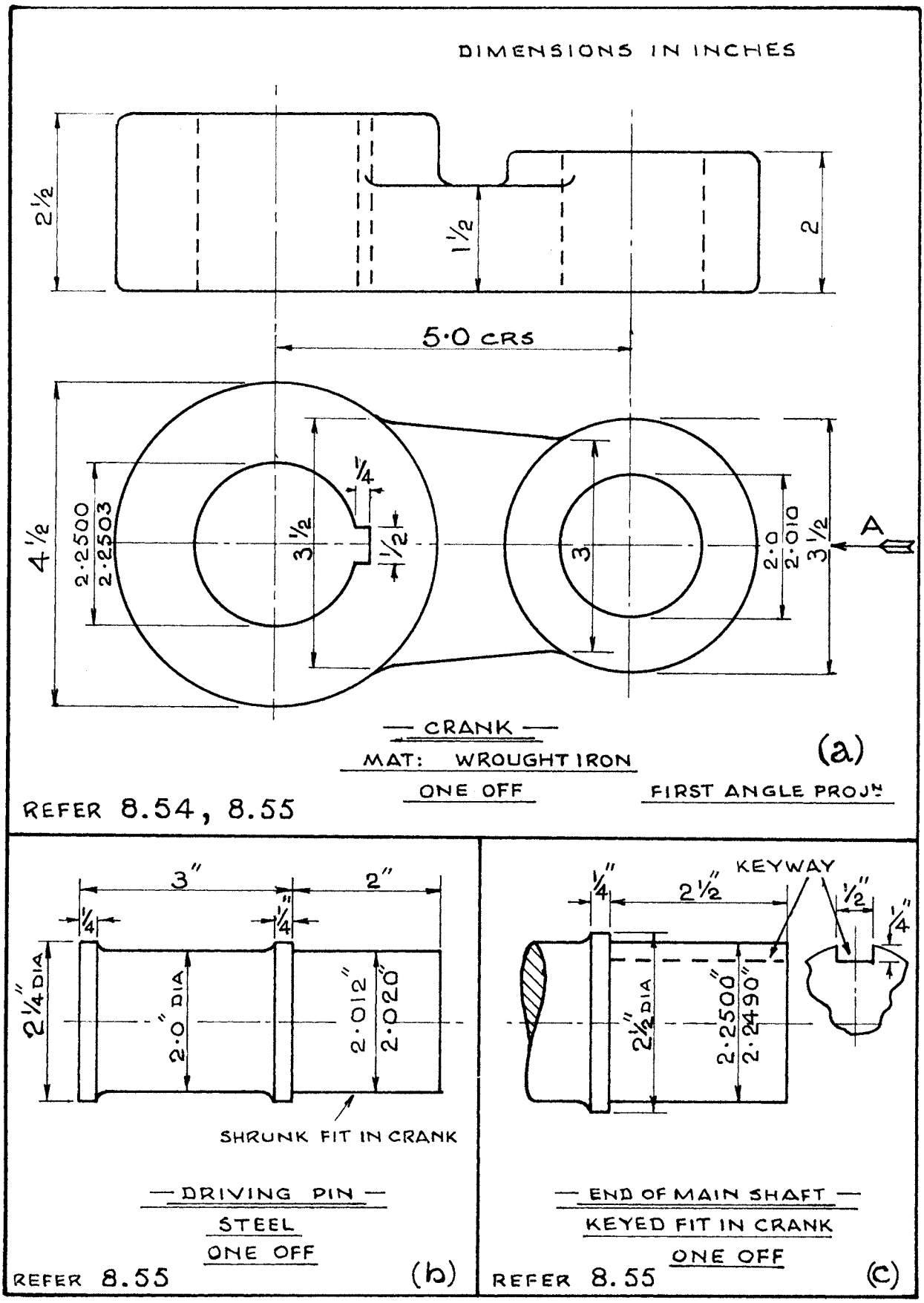
PULLEY BEARING

DIMENSIONS IN MILLIMETRES — ASSEMBLY — THIRD ANGLE PROJECTION

REFER 8.52, 8.53

FIG. 82

FOR PART DRGS SEE FIGS. 86 & 88



PART DRAWINGS FIG. 83 FOR ASSEMBLY SEE FIG. 75(b)

8.56. PART DRAWINGS OF GEAR BOX FOR RIGHT-ANGLE DRIVE. Fig. 84

Only two views were given in Fig. 78 and you were asked to construct and draw a side elevation. Figure 84 is a first angle projection of the gearbox only and gives the side elevation.

8.57. ASSIGNMENT. GEARBOX. Fig. 84

Draw the three views in Fig. 84 but show the bearings in the two elevations at their full length of 86 and 42 mm respectively from the inside machined faces. Make the drawing full size and fully dimension in millimetres.

Finish off the drawing with good quality lines, a printed title, scale, machine surfaces, and projection used.

8.58. ASSIGNMENT A. BELL CRANK LEVER. Fig. 85

(*a*) Draw the three views as shown in Fig. 85(*a*). The drawing should be full size and surrounded by a border line 18 in by 16 in.

The lines must be of good quality and you should print neatly the title, material, scale, number off, projection used, notes and dimensions. Remember that leaders to notes should not be vertical or horizontal.

(*b*) Draw the two views of the driving pin shown in Fig. 85(*b*). The drawing should be full size with a border line 8 in by 5 in.

Finish the drawing with good quality lines and observe all the instructions in (*a*).

8.59. ASSIGNMENT B. BELL CRANK LEVER. Fig. 85(*a*)

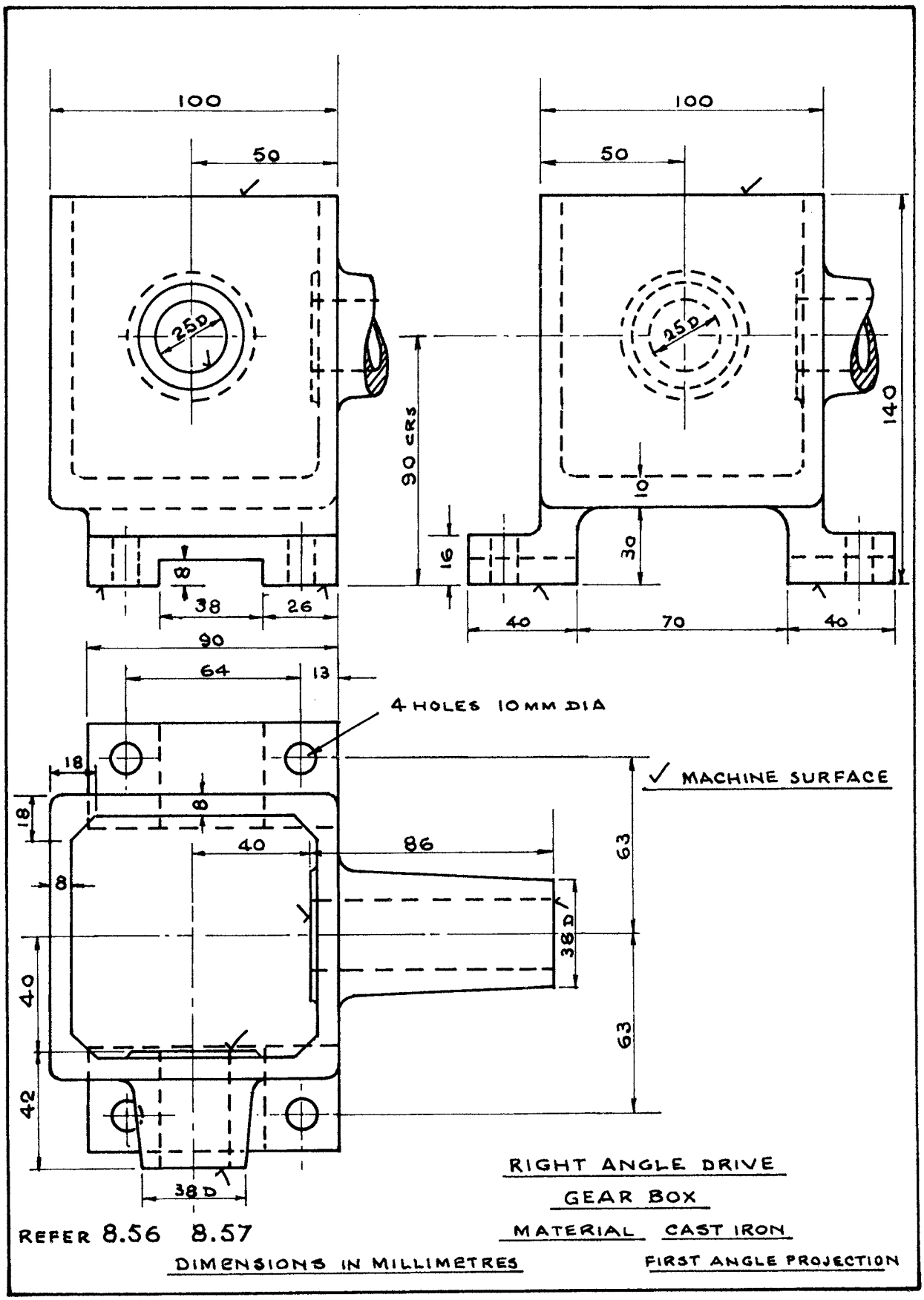
Referring to section 8.31 you were asked to draw the improved design.

You should now draw, full size, the lever only of the improved design. You will have three views similar to Fig. 85(*a*) but with the two driving pin bosses on the same side of the lever plate as the centre boss. Apart from this, there is no other change and the complete drawing will be surrounded by a border line 18 in by 16 in.

Lines must be of good quality and you should print the title, material, scale, number off, projection used, notes, and dimensions.

8.60. ASSIGNMENT. PART DRAWINGS FOR PULLEY BEARING ASSEMBLY. Fig. 86

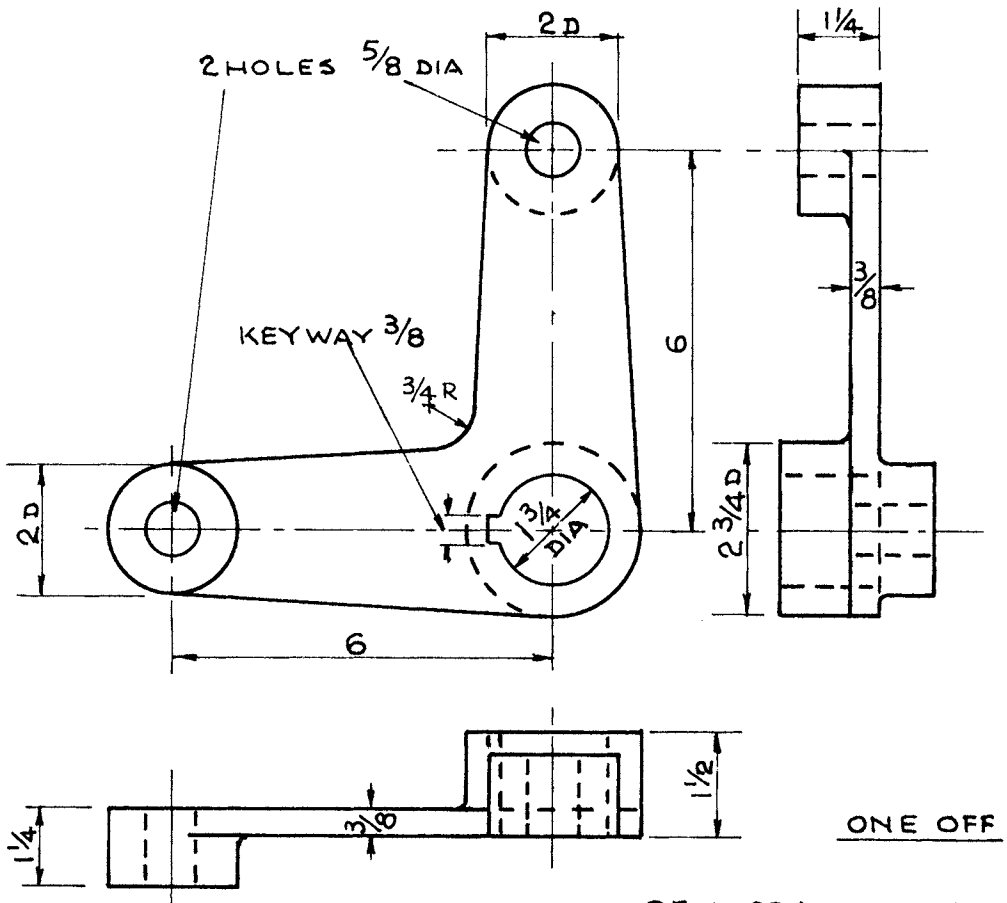
(*a*) The pulley is cast aluminium and is machined all over. The crown curve is 110 mm which happens in this case to coincide with the diameter. This is not always the case. Copy the two views in Fig. 86(*a*). One view is a true section on the centre line. The hole is machined a good fit and keyed on the spindle (*b*). Make this drawing 250 mm by 200 mm and finish with a border line. Print the title, material, scale, number off, projection used, notes, and dimensions in millimetres.



GEAR BOX FOR RIGHT ANGLE DRIVE

FIG. 84

FOR ASSEMBLY SEE FIG. 78



(a)

ONE OFF

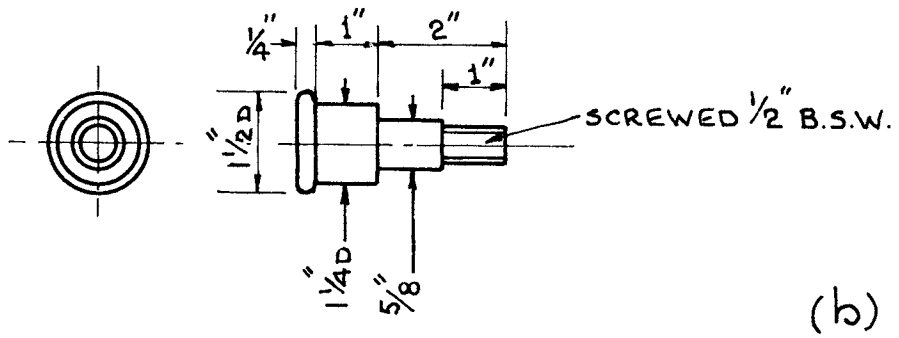
— BELL CRANK LEVER —

MAT: GUNMETAL

FIRST ANGLE PROJECTION

DIMENSIONS IN INCHES.

REFER 8.58, 8.59



(b)

TWO OFF

— DRIVING PIN —

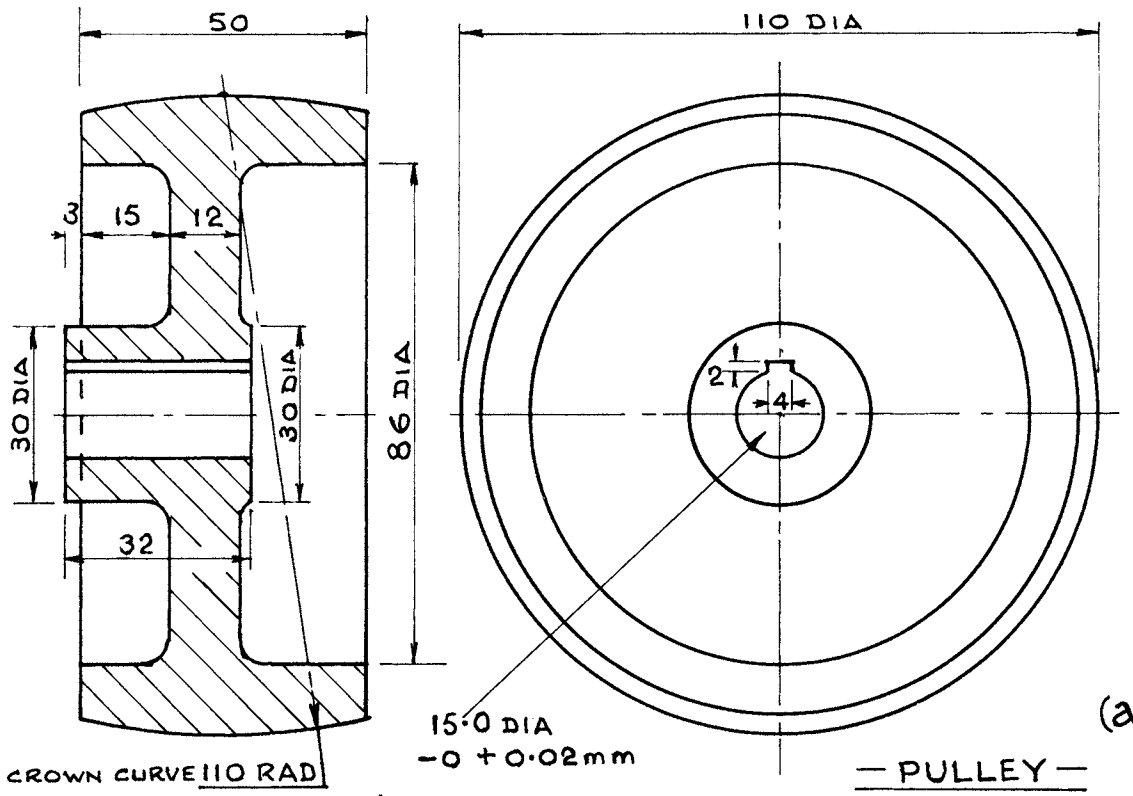
MAT: MILD STEEL

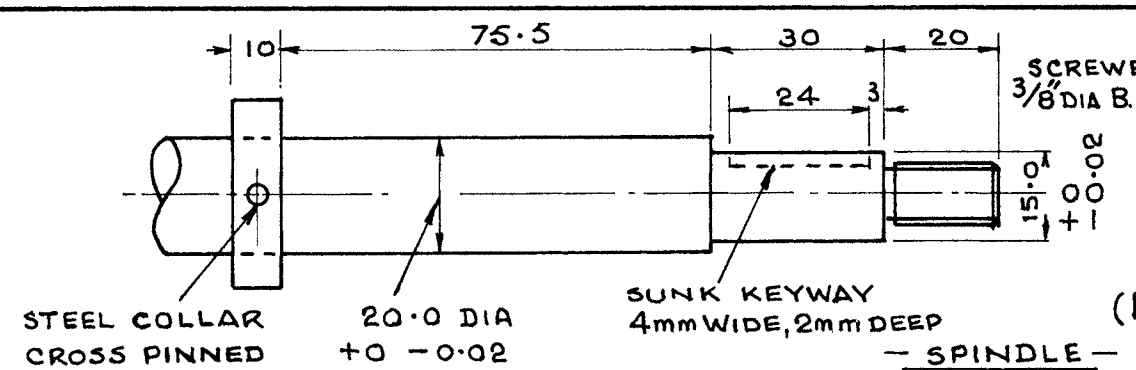
FIRST ANGLE PROJECTION.

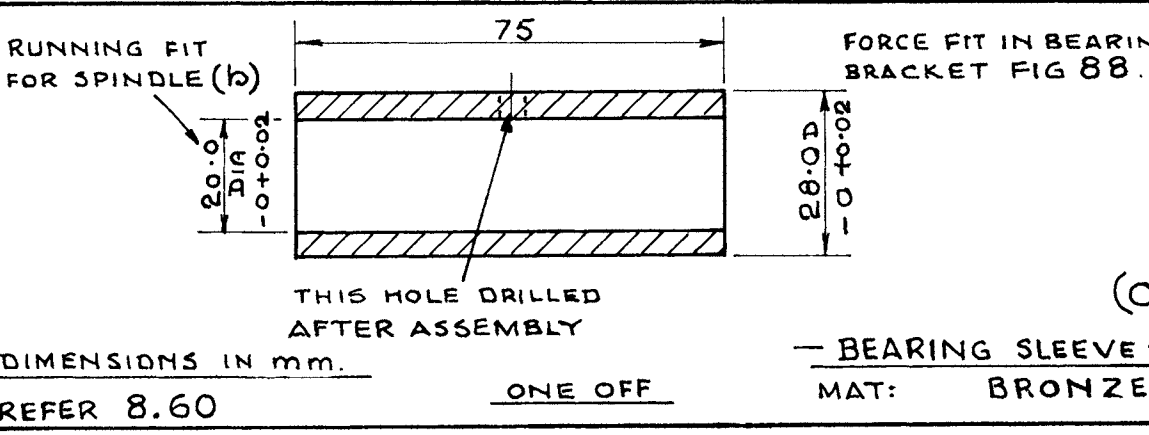
REFER 8.58

PART DRGS FOR BELL CRANK LEVER

FIG. 85







PART DRGS OF PULLEY BEARING

FIG. 86

FOR ASSEMBLY DRG SEE FIG. 82

(*b*) Only part of the spindle is shown here. Draw this view on 200 mm by 130 mm with border line. Notice the steel collar pinned on the spindle. This avoids extensive machining and leaves only the fitting for the pulley and the screw thread to be machined. The spindle is to be a running fit in (*c*). Finish the drawing to the same instructions as (*a*).

(*c*) The sleeve is made from bearing bronze, is a running fit on (*b*), and is a force fit in the bearing bracket Fig. 88. A means of lubrication (an oil hole) is provided. Draw this view on 200 mm by 130 mm with border line. Finish the drawing to the same instructions as (*a*).

8.61. ASSIGNMENT. PART DRAWINGS FOR RIGHT-ANGLE DRIVE. Fig. 87

(*a*) The pulley on this drive is made of cast aluminium. It has a flat belt drive, a flanged rim, is keyed on the shaft, and is machined all over.

Draw the two views, one of them being a section on the centre line. Dimensions are in millimetres. To position the views neatly on 250 mm by 200 mm draw them half full-size and in first angle projection. Finish the drawing with good quality lines, print the title, material, scale, number off, projection used, notes, and dimensions in millimetres.

(*b*) Draw the pulley shaft shown in four scrap views. Notice that all the views have a direct purpose—to supply information. The shaft is ground mild steel to be a running fit in gearbox Fig. 84. The pulley is keyed to the shaft and positioned, not up against a shoulder, but by the steel collar and the brass washer locked in position by the nut. Where space is limited the shaft can be drawn at any convenient length (say about 70 mm) and two conventional breaks included. Draw the shaft full size on 200 mm by 130 mm with border line. Although the shaft is drawn 70 mm long with two breaks it must be dimensioned correctly as 144 mm. Finish the drawing to the same instructions as (*a*).

(*c*) When a small item is to be drawn it is advisable to make it to a scale twice or three times full size, or even greater if the item is extremely small.

In this case make a drawing twice full size on 130 mm by 100 mm with border line. All part drawings, large or small, have to carry the same amount of information, so the drawing should be finished to the same instructions as (*a*).

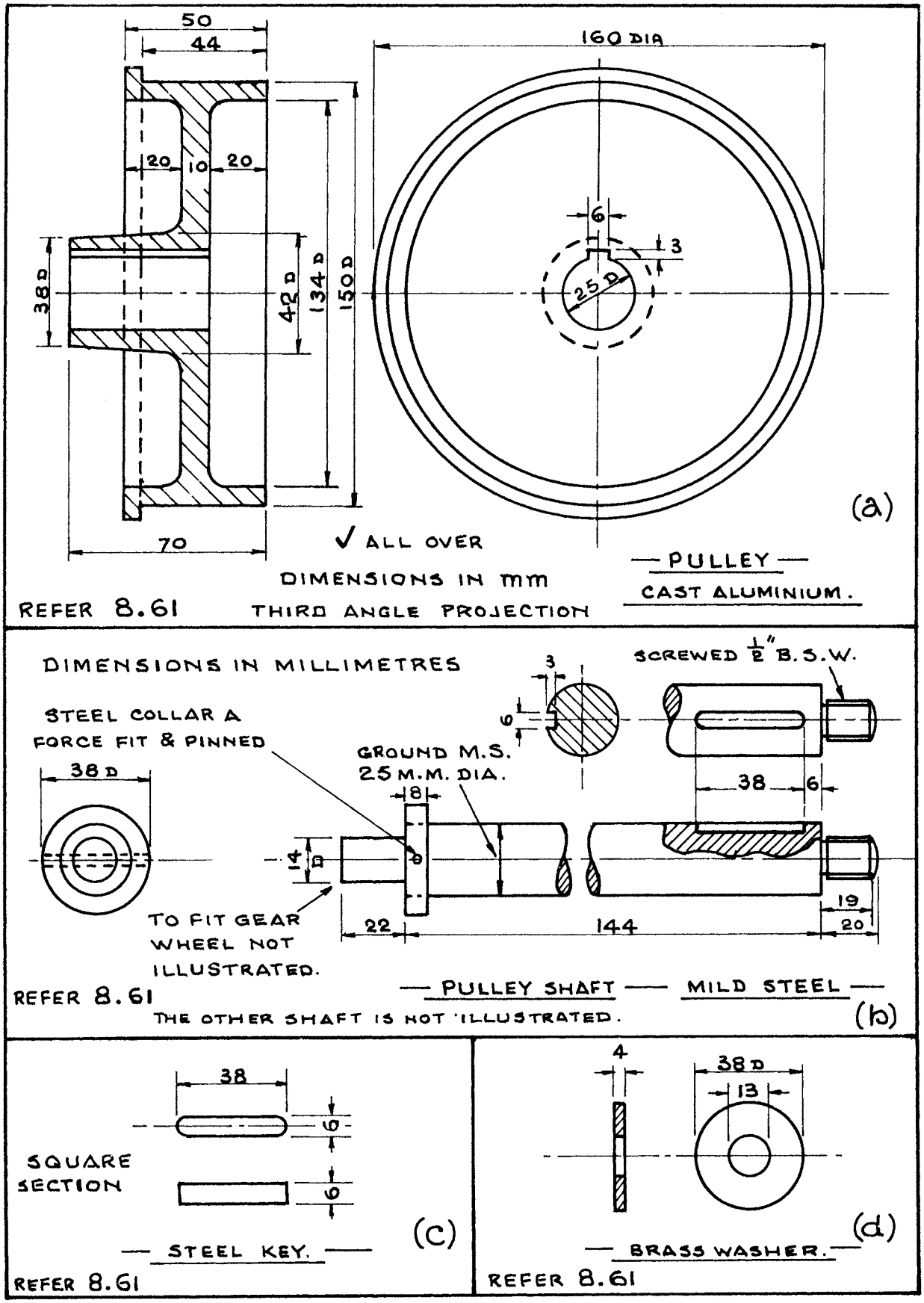
(*d*) This is a special washer and should be drawn twice full size and the drawing finished to the same instructions as (*a*).

8.62. ASSIGNMENT. BEARING BRACKET. Fig. 88

This is a cast-iron bracket and part of the pulley bearing assembly in Fig. 82.

Draw the three views in Fig. 88 on 250 mm by 450 mm with border line. Position the views neatly in third angle projection. In the sectional elevation notice how the main part of the web is not sectioned. Indicate the machined faces with the appropriate symbol. Notice also how the small holes are positioned from the large hole which is on the centre line.

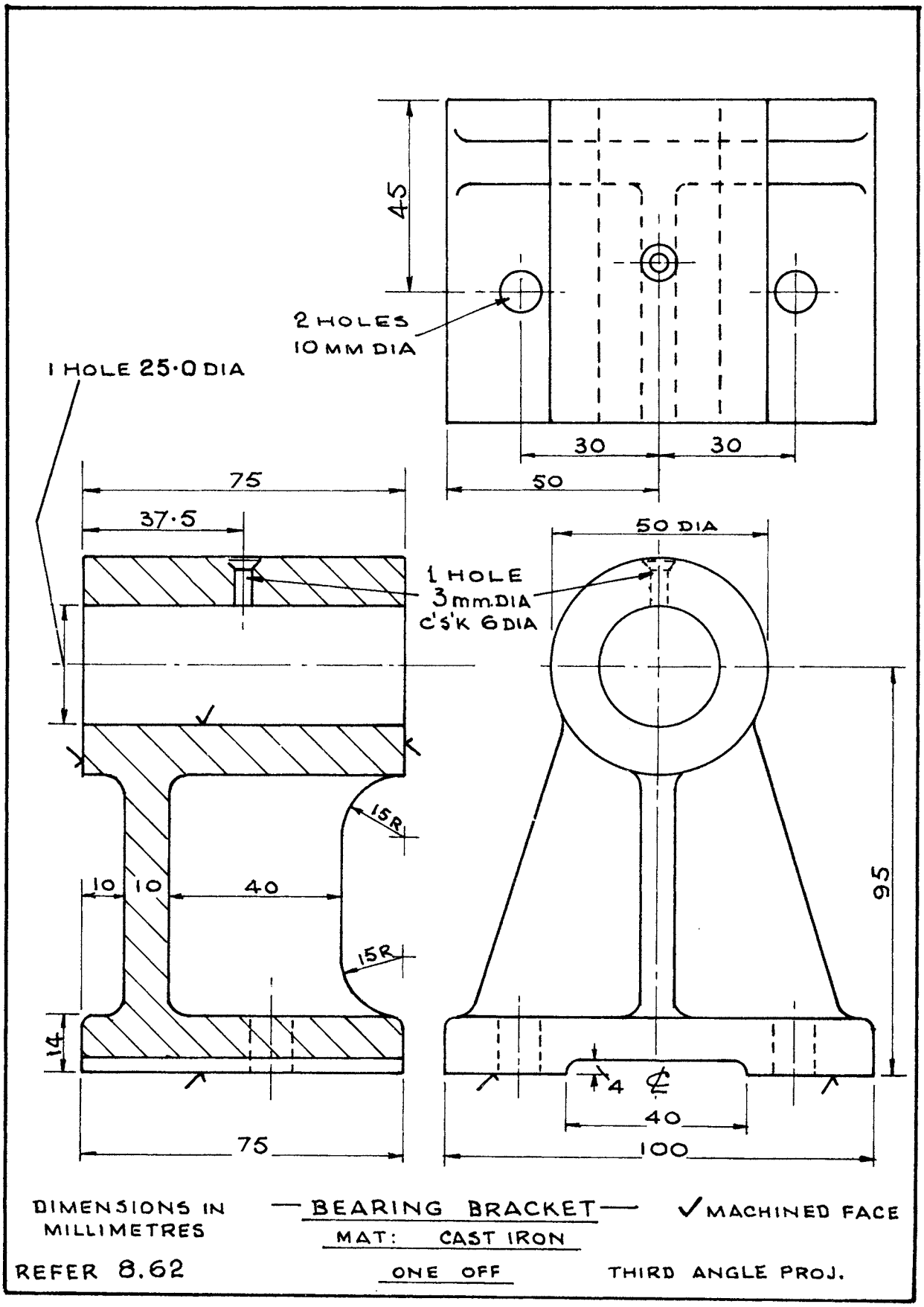
Finish the drawing with good quality lines, print the title, scale, material, number off, and projection used.



RIGHT ANGLE DRIVE
PART DRGS

FIG. 87

DIMENSIONS IN mm
FOR ASS: DRG SEE FIG. 78



DIMENSIONS IN MILLIMETRES

BEARING BRACKET

MAT: CAST IRON

ONE OFF

✓ MACHINED FACE

THIRD ANGLE PROJ.

REFER 8.62

PULLEY BEARING PART DRG

FIG. 88

FOR ASS: DRG SEE FIG. 82

8.63. WALL BOX. Fig. 89(*a*)

When a long length of rotating shaft projects from one department through a wall to another it is sometimes necessary to make the hole in the wall neat and tidy, and fitted with a bearing in which the shaft will run. This is achieved by the wall box shown in Fig. 89(*a*). This is an iron casting with a flat foundation, two 25° sloping projections to position a bearing block, and an archway over to keep the bearing free from wall dust and to give a neat appearance.

8.64. ASSIGNMENT. WALL BOX. Fig. 89(*a*)

Draw the three views full size in third angle projection. The right-hand view is a sectional side elevation or section through *XX*. The top view is a half-sectional plan. Make the drawing 12 in by 18 in with a border line. Print the title, material, scale, projection used, notes, and dimensions.

8.65. ASSIGNMENT. FAST AND LOOSE PULLEYS. Fig. 89(*b*)

Draw full size the views shown in Fig. 89(*b*). Notice the crown curvature of 4 in radius and also the sections through the loose pulley, showing the bearing sleeve, and through the fast pulley showing the keyway. Make the drawing 15 in by 12 in with a border line. Print the title, material, scale, projection used, notes, and dimensions.

8.66. PART DRAWINGS FOR STUFFING BOX ASSEMBLY. Fig. 90

(*a*) Draw the three views which show the machining required as a basis for the assembly shown in Fig. 71(*a*). This should be drawn on 15 in by 12 in with border line. Use a conventional method for the tapped holes. Notice how the oval shape is dimensioned. Finish the drawing with good quality lines, etc.

(*b*) Draw the stud full size on 8 in by 5 in and finish to instructions as (*a*).

(*c*) Draw the two views of the flange in Fig. 90(*c*) and fully dimension. The centre distances of the holes for the studs must be the same. A 45° bevel at one end is used for a lubrication well when mounted vertically. The outside diameter must slide into part (*a*). Finish the drawing on 8 in by 5 in with border line and to instructions as (*a*).

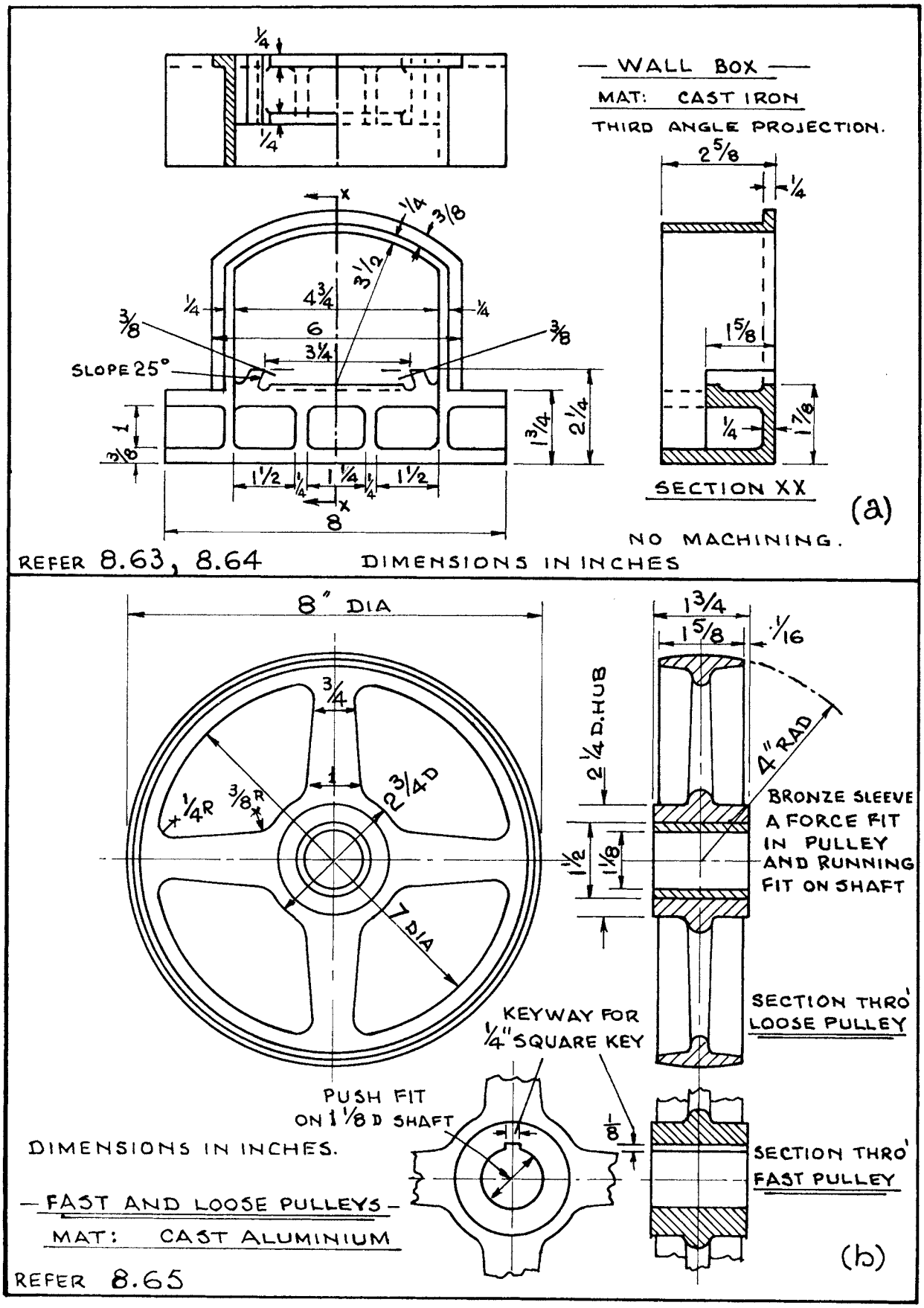
(*d*) Draw the fixed gland, one view only, full size on 8 in by 5 in. The outside diameter must fit into part (*a*). Finish the drawing with a border line and to instructions as (*a*).

(*e*) This part is similar to part (*d*) but longer and should be drawn full size on 8 in by 5 in. The outside diameter must be a sliding fit in part (*a*).

Finish the drawing with a border line and print the title, scale, number off, material, projection used, notes, and dimensions.

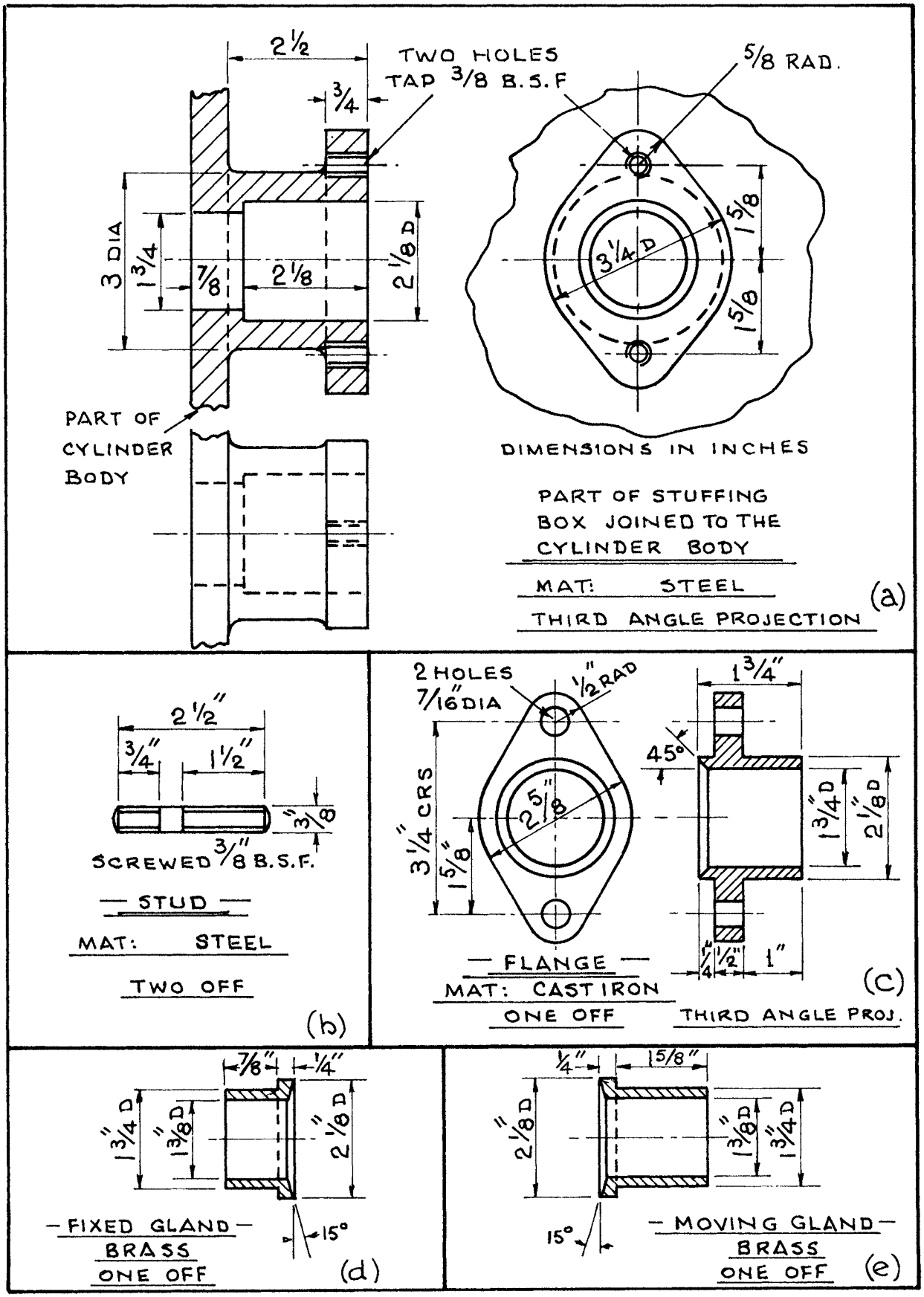
8.67. SPINDLE BEARING. FRAME. Fig. 91

The frame shown in Fig. 91 is the main part of the spindle bearing assembly, Fig. 76. The cap and base are cast in one piece. After drilling and tapping four



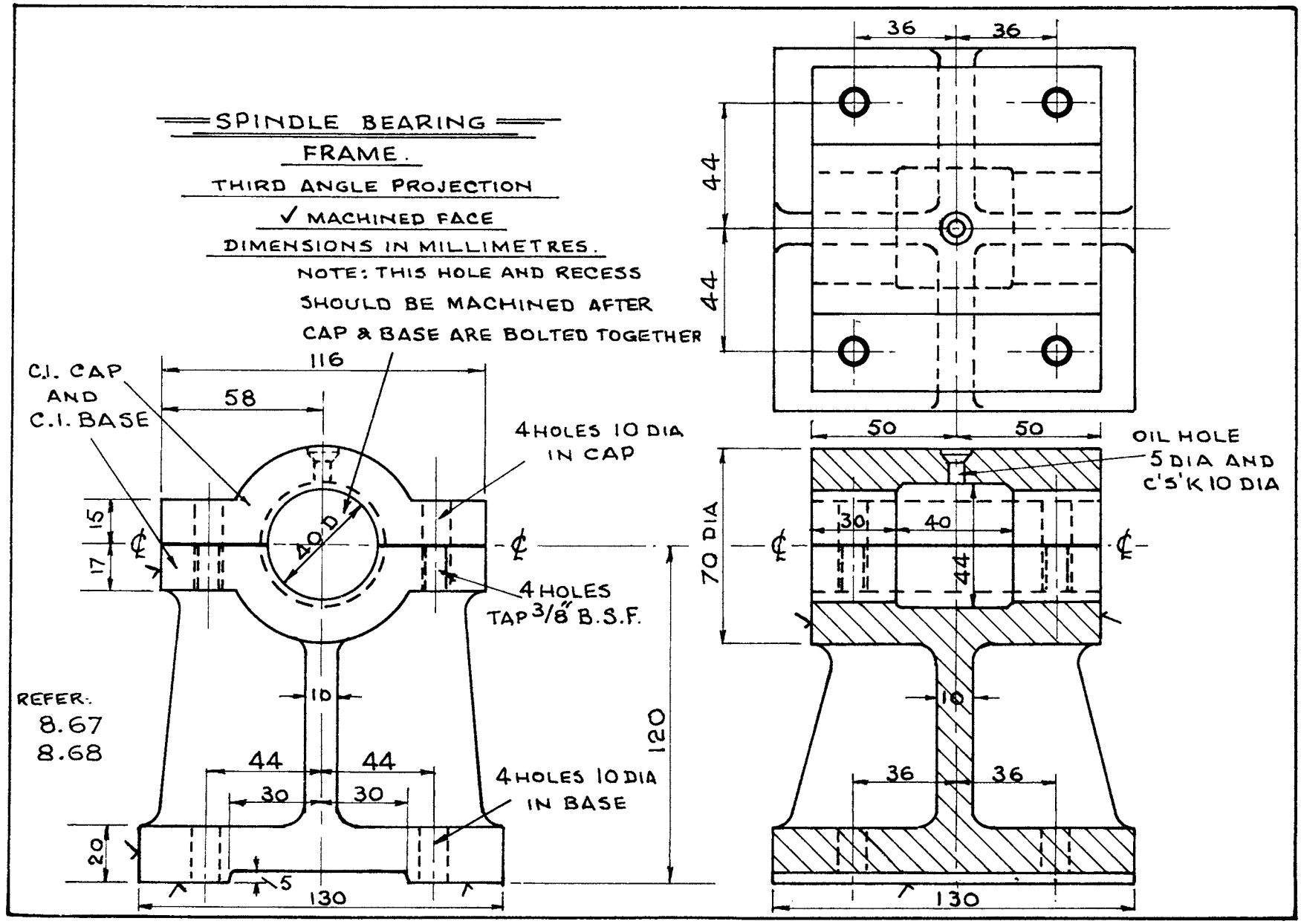
PART DRGS

FIG. 89



STUFFING BOX - PART DRGS
REFER 8.66

FIG. 90 FOR ASS: DRG SEE FIG. 71(a)



PART DRG.

FIG. 91

FOR ASSEMBLY DRG SEE FIG. 76

holes the cap is then separated from the base. The cap is bolted back into position, and the hole can be bored and recessed to fit the half-bearings. The mounting holes in the base are on the same centres as the four bolt holes in the cap.

8.68. ASSIGNMENT. PART DRAWING OF SPINDLE BEARING FRAME. Fig. 91

Draw the three views shown in Fig. 91, neatly spaced, on 380 mm by 500 mm, full size, and in third angle projection. Dimensions are in millimetres. Notice how the two webs are shown full in the sectional elevation. The large hole must be bored and recessed when the cap and base are bolted together. This hole must be machined to fit the two half bearings shown in Fig. 77(*b*). Indicate the machined faces by the appropriate symbol. The four holes in the plan are each shown by two circles because you are looking first at the clearance hole in the cap and through it you can see the tapped hole underneath.

Finish the drawing with a border line and print the title, scale, material, number off, projection used, notes, and dimensions.

8.69. ASSIGNMENT. MAIN BRACKET. Fig. 92

Draw the views in Fig. 92(*a*) and (*b*) full size and in third angle projection. These views show part drawings of the main bracket taken from the isometric drawing of a bearing bracket in Fig. 74.

These drawings will help with the four views asked for in section 8.27.

In this drawing the bearing cap and main bracket are shown separated but when the centre hole is machined they are bolted together.

The views should be drawn as above and neatly spaced on 15 in by 20 in with a border line. Finish the drawing with good quality lines, print the title, material, scale, machine surfaces, and state projection used.

8.70. ASSIGNMENT. PART DRAWINGS FOR UNIVERSAL COUPLING. Fig. 93

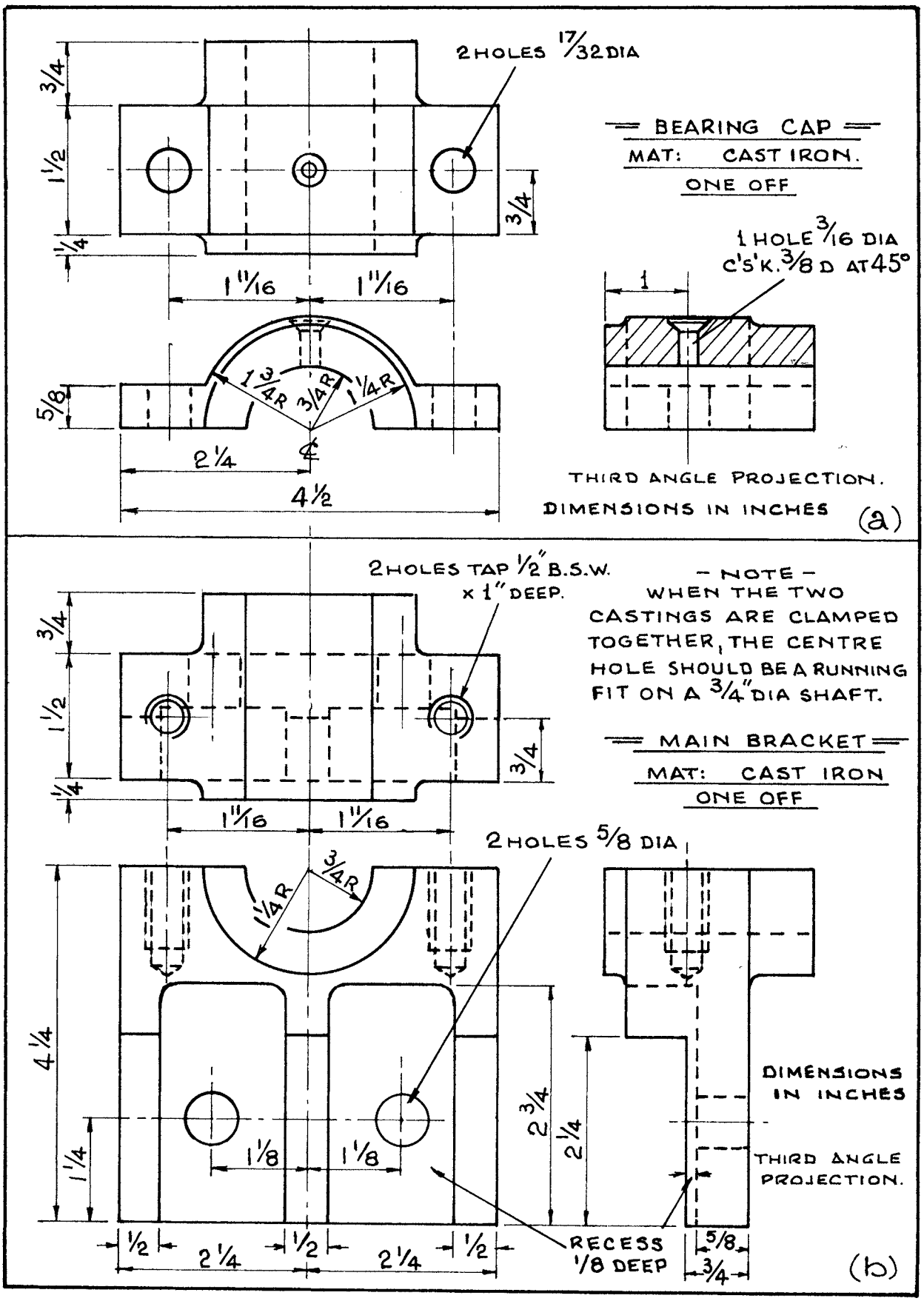
(*a*) The coupling fork is the main part of the universal coupling. Two of them are required in cast iron and of good robust design. Each is symmetrical on the shaft centre line. It is essential that they are balanced to prevent vibration.

Draw the three views shown, and notice how the part is dimensioned from the centre lines. The drawing should be made on 18 in by 15 in with a border line. Print the title, material, number off, projection used, notes and dimensions in inches.

(*b*) Only one coupling link is required to join the forks.

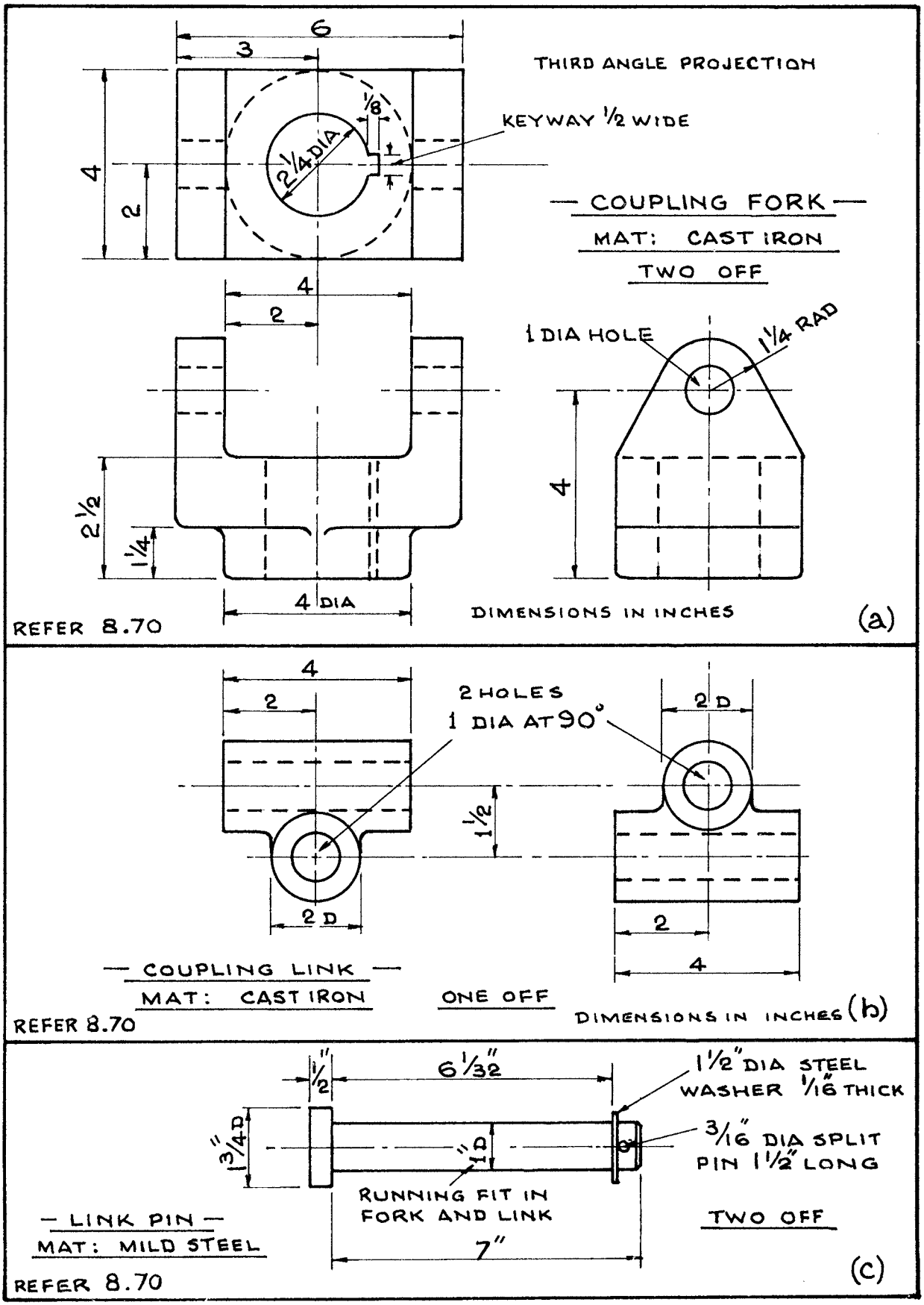
Draw the two views shown and notice the importance of the holes being at right angles to each other. The drawing should be made full size on 12 in by 10 in with a border line. Finish the drawing as instructed in (*a*).

(*c*) Two pins are required to complete the assembly. The drawing should be made full size on 12 in by 10 in with a border line. Finish the drawing as instructed in (*a*).



PART DRGS
REFER 8.69

FIG. 92 FOR ISOMETRIC ASS: SEE FIG. 74



UNIVERSAL COUPLING PART DRGS

FIG. 93

FOR ASS: DRG SEE FIG. 80(a)

8.71. ASSIGNMENT. PART DRAWINGS FOR FOOTSTEP BEARING. Fig. 94

(*a*) The base shown in Fig. 94(*a*) is in cast iron and should be drawn on 18 in by 12 in with a border line. Notice how the recess is shown on the underside. This recess allows a firm, flat contact under the centre of the pressure pad, and under the four bolt holes. Notice also the steady pin and slot for anti-rotation of the sleeve bearing and the pressure pad.

Draw the three views full size and in third-angle projection. Fully dimension the views in the correct positions, i.e. "where you can see the shape of a part".

Finish the drawing in good quality lines, print the title, number off, projection used, scale and border line.

(*b*) Draw the two views of the sleeve bearing. The outside diameter of the bearing must be a good fit in the base (*a*). Notice the steady pin fitted adjacent to the shoulder to prevent rotation.

Finish the drawing to the instructions in (*a*). Size of drawing 12 in by 8 in.

(*c*) The pressure pad is the last part required for the assembly. Draw the two views, one being in section to show the concave curvature and the clearance hole for the steady pin.

Finish the drawing to the instructions in (*a*). Size of drawing 8 in by 5 in.

8.72. ASSIGNMENT. PART DRAWINGS FOR PEDESTAL BEARING ASSEMBLY. Fig. 95

Note: Space out the views neatly and appropriately arrange the size of each of the drawings. They are to be drawn in third angle projection.

(*a*) The main frame is cast iron and is designed to be mounted vertically or inverted.

Draw the three views as shown in Fig. 95(*a*) and add a fourth view on the left-hand side of the front elevation. This is to be a sectional elevation through *XX* on the centre line which will show the bearing recess and steady pin hole. Notice the dimensioning of the curves, which is repeated for the opposite side. Exercise great care when constructing the curves. When filling in the outline remember "curves first, straight lines after".

Finish the drawing with good quality lines, a printed title, scale, number off, material, projection used.

(*b*) The bearing cap is also of cast iron and this is machined to fit and to be bolted to the top of the main frame (*a*). The recess is cast, leaving two faces to be machined at the same setting as the main frame (*a*) to receive the two half-bearings (*c*).

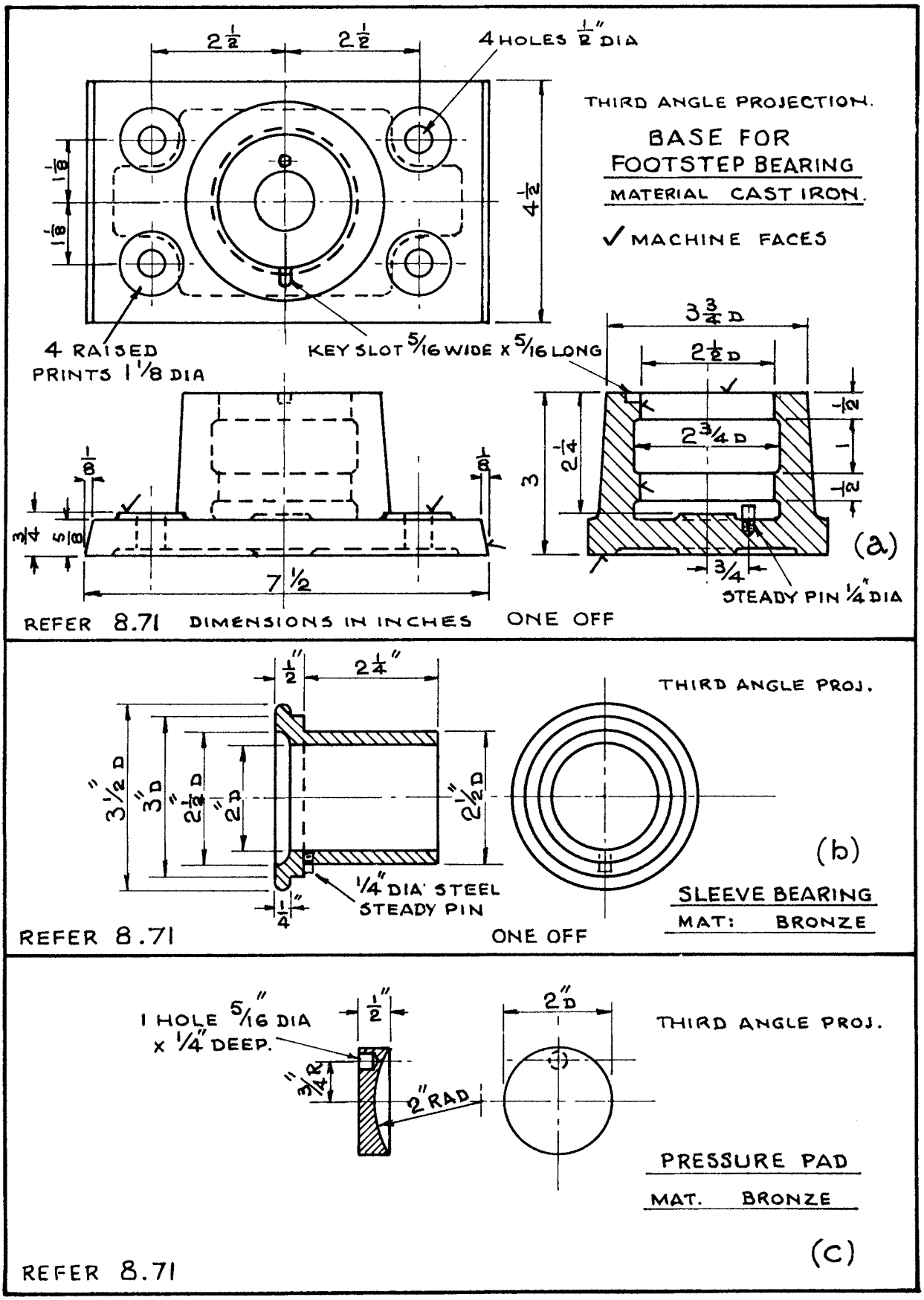
Finish the drawing as instructed in (*a*).

(*c*) The two half-bearings are cast in bronze and machined when clamped together. They should be an easy running fit on a clean 2 in dia. shaft.

Finish the drawing as instructed in (*a*).

(*d*) Two steel studs are the last parts required for the assembly. Draw one view and show one form of screw thread as per B.S. 308 and Fig. 52(*a*).

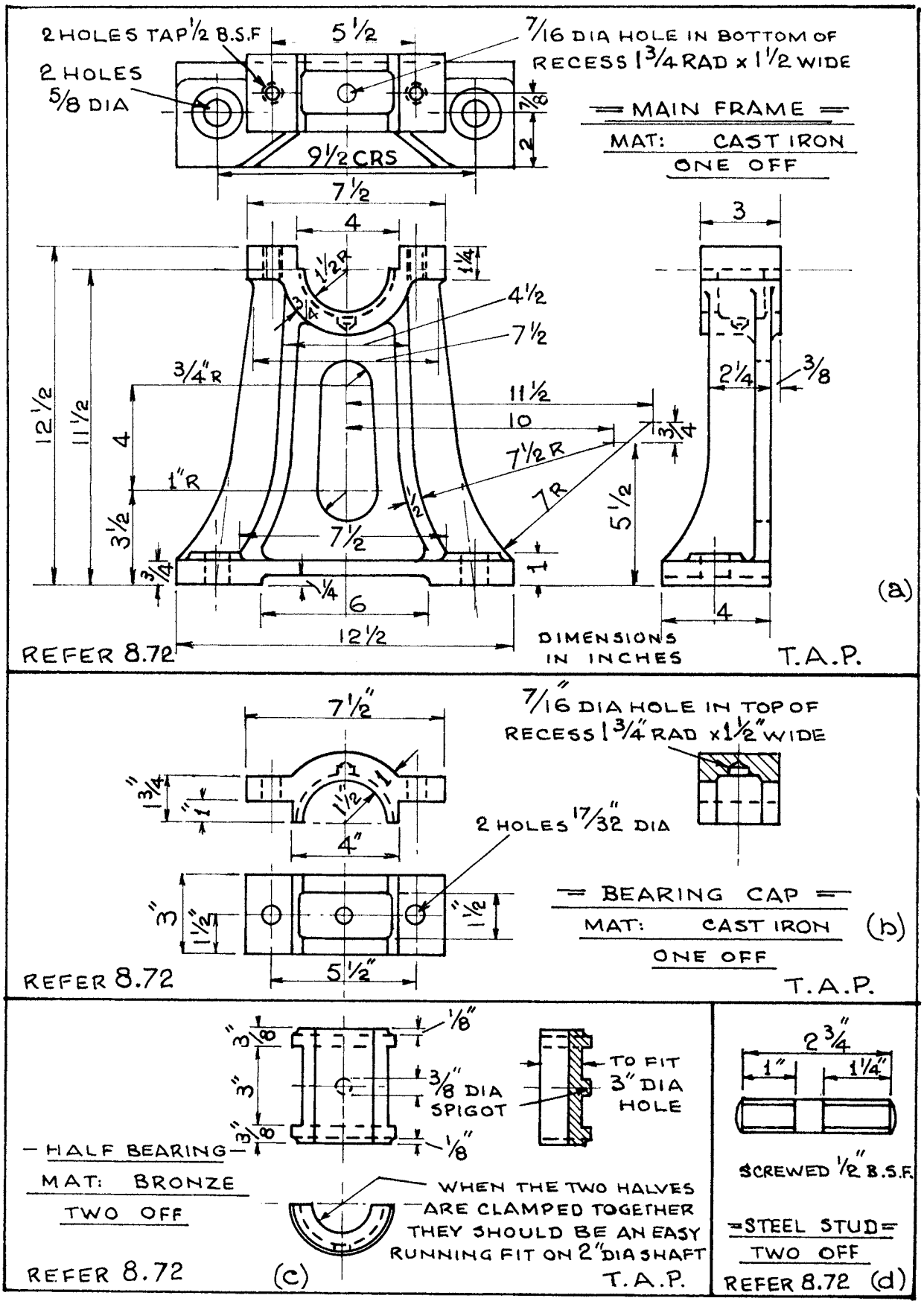
Finish the drawing as instructed in (*a*).



FOOTSTEP BEARING
PART DRGS

FIG. 94

FOR ASS: DRG SEE FIG. 81(a)



PEDESTAL BEARING PART DRGS

FIG. 95

FOR ASS: DRGS SEE FIG. 81 (b)

8.73. ASSIGNMENT. PART DRAWINGS FOR SIMPLE SCREW JACK. Fig. 96

(*a*) The body of a jack must be strong and stable when in use. A design, such as the one shown in Fig. 96(*a*), being tubular and also slightly conical, is probably the strongest and most reliable shape that can economically be produced. A handle is provided to enable the jack to be easily positioned. The handle is an integral part of the body which is cast iron. A good strong thread is machined at the top to allow a movement of approximately $7\frac{1}{2}$ in vertically.

Draw the two views of the body full-size as shown in (*a*) and finish the drawing with good quality lines, etc., on 24 in by 12 in with a border line.

(*b*) The screw is machined from solid with the square thread as long as possible. Two holes are cross drilled to act as a capstan head. A pin is left at the top end on which the swivel top (*c*) is loosely riveted.

Draw the screw full-size, as shown in (*b*), and finish the drawing with good quality lines, etc., on 24 in by 12 in with a border line.

(*c*) Draw the swivel top as shown in Fig. 96(*c*). It is machined from solid mild steel. The four grooves are intended to make a non-slip surface.

Finish the drawing with good quality lines, etc., on 12 in by 8 in with a border line.

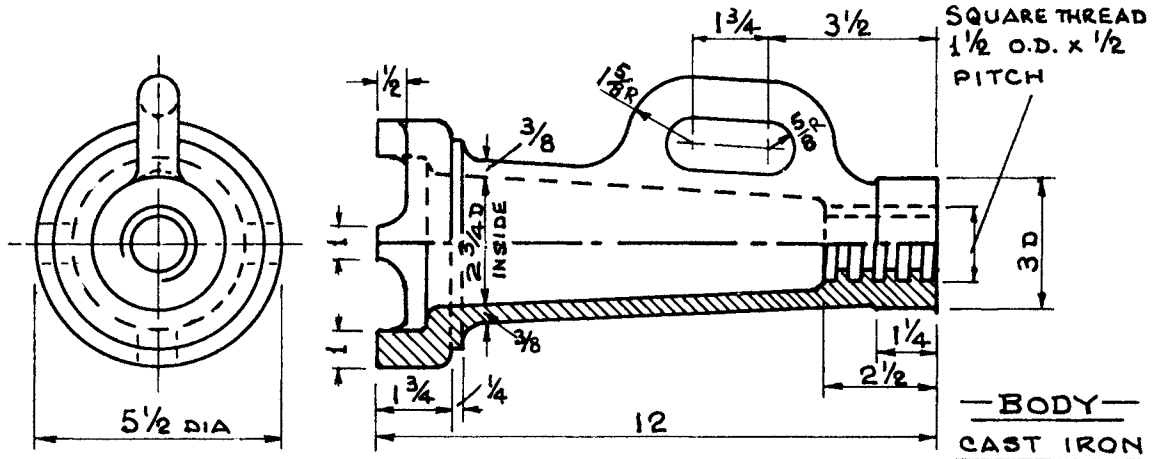
8.74. BEARING BRACKET ASSEMBLY. Fig. 97

Figure 97(*a*), (*b*), and (*c*) show the part drawings and Fig. 97(*d*) a complete assembly of a bearing bracket. It consists of a simple steel shaft, Part No. 1, which is a running fit in bronze bushes, Part No. 2, which are themselves held in two aluminium brackets, part No. 3. The brackets can be mounted, with the feet turned inwards or outwards, on to a firm base. The bushes are a good press fit in the brackets.

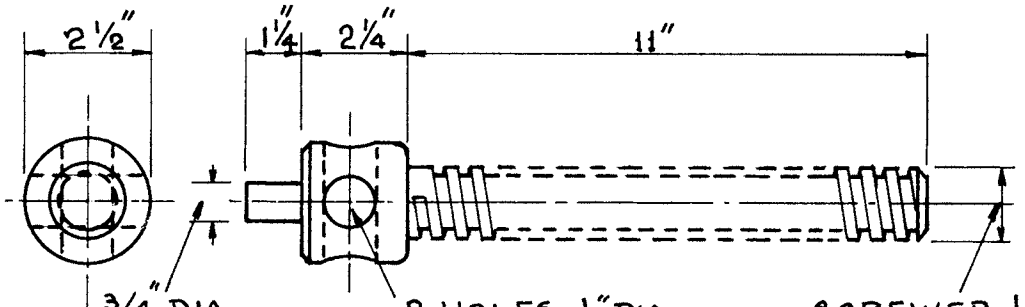
(i) In Fig. 97(*a*) we see the shaft which has a nominal diameter of 0·5 in. To make it a running fit in the bushes we give two negative limits of 0·4994 in and 0·4987 in and the shaft is a fine finish between these limits. The tolerance on the shaft is 0·0007 in.

(ii) Figure 97(*b*) shows a bush and this has nominal diameters of 0·75 in O/D and 0·5 in I/D, so that limits are required on the outside and the inside diameters. In this instance we give limits of 0·7515 in and 0·7512 in to the O/D, and 0·5007 in and 0·5000 in to the I/D. It will be noticed that the limit on the O/D is larger than the nominal diameter because it is an interference fit, while the limit on the I/D is smaller than the nominal diameter because here we have a running fit.

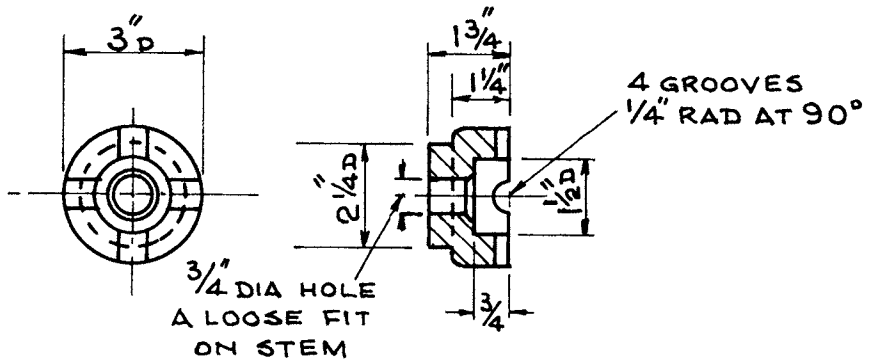
(iii) Figure 97(*c*) shows the bracket, which is made from aluminium. It can be machined from solid bar or casting. The nominal size of the hole is 0·75 in dia. which has to be an interference fit for Part No. 2. We therefore give limits of 0·7508 in and 0·7500 in. The centre distance has a nominal dimension of 1·5 in and has limits of 1·501 in and 1·499 in.



REFER 8.73 DIMENSIONS IN INCHES. (a) FIRST ANGLE PROJ.

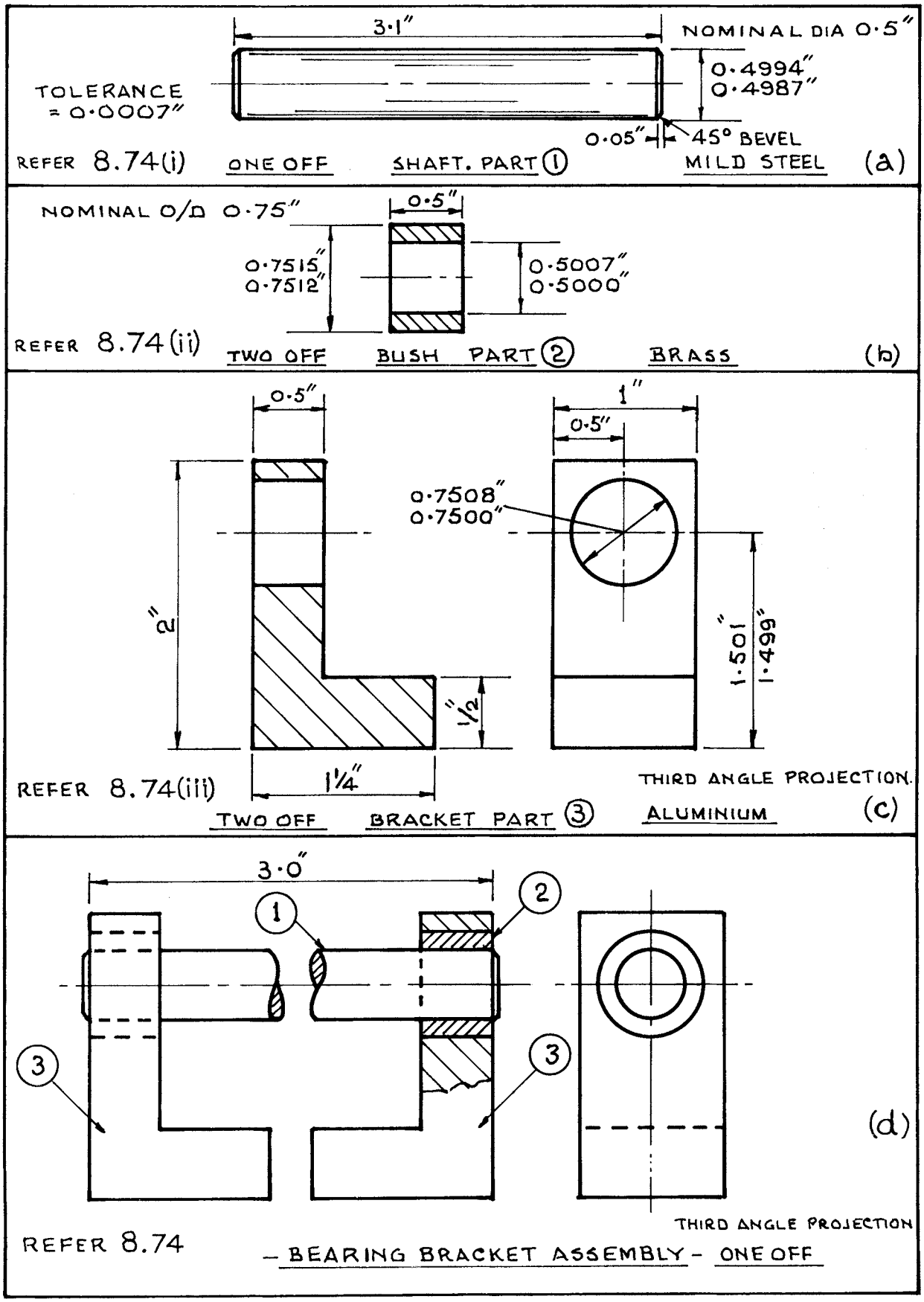


REFER 8.73 FIRST ANGLE PROJ. —MAIN SCREW— —MILD STEEL— (b)



REFER 8.73 FIRST ANGLE PROJ. — SWIVEL TOP — — MILD STEEL — (c)

SIMPLE SCREW JACK PART DRGS FIG. 96 FOR ASS: DRG SEE FIG. 80(b)



BEARING BRACKET ASSEMBLY

FIG. 97

DETAIL DRGS

8.75. OFFSET LENS MOUNT ASSEMBLY. Fig. 98

The figure shows an isometric section, in the plane of the vertical centre line, of an aluminium casting with an aluminium end plate. The top face is machined to carry a brass cell in which would be mounted a lens (not shown). This cell is offset exactly 5·0 mm in the vertical plane. Three views are shown half full size in third-angle projection and the dimensions are in millimetres.

8.76. ASSIGNMENT A. ASSEMBLY DRAWINGS FOR OFFSET LENS MOUNT

Draw the following assembled views to a full-size scale in third angle projection:

(a) front elevation (outside);
(b) complete plan;
(c) end view (right hand);
(d) end view (left hand);
(e) sectional elevation through the plane of the vertical centre line.

Only specification dimensions are required on an assembly drawing.

8.77. ASSIGNMENT B. DETAIL DRAWINGS FOR OFFSET LENS MOUNT

Make separate detailed drawings of the casting, end plate, and recessed brass cell. Dimension the drawings fully for complete machining details and include all relevant production data.

8.78. ASSIGNMENT C. ISOMETRIC VIEW OF OFFSET LENS MOUNT

As a further exercise copy the isometric view in Fig. 98.

8.79. BEARING BRACKET ASSEMBLY. Fig. 99

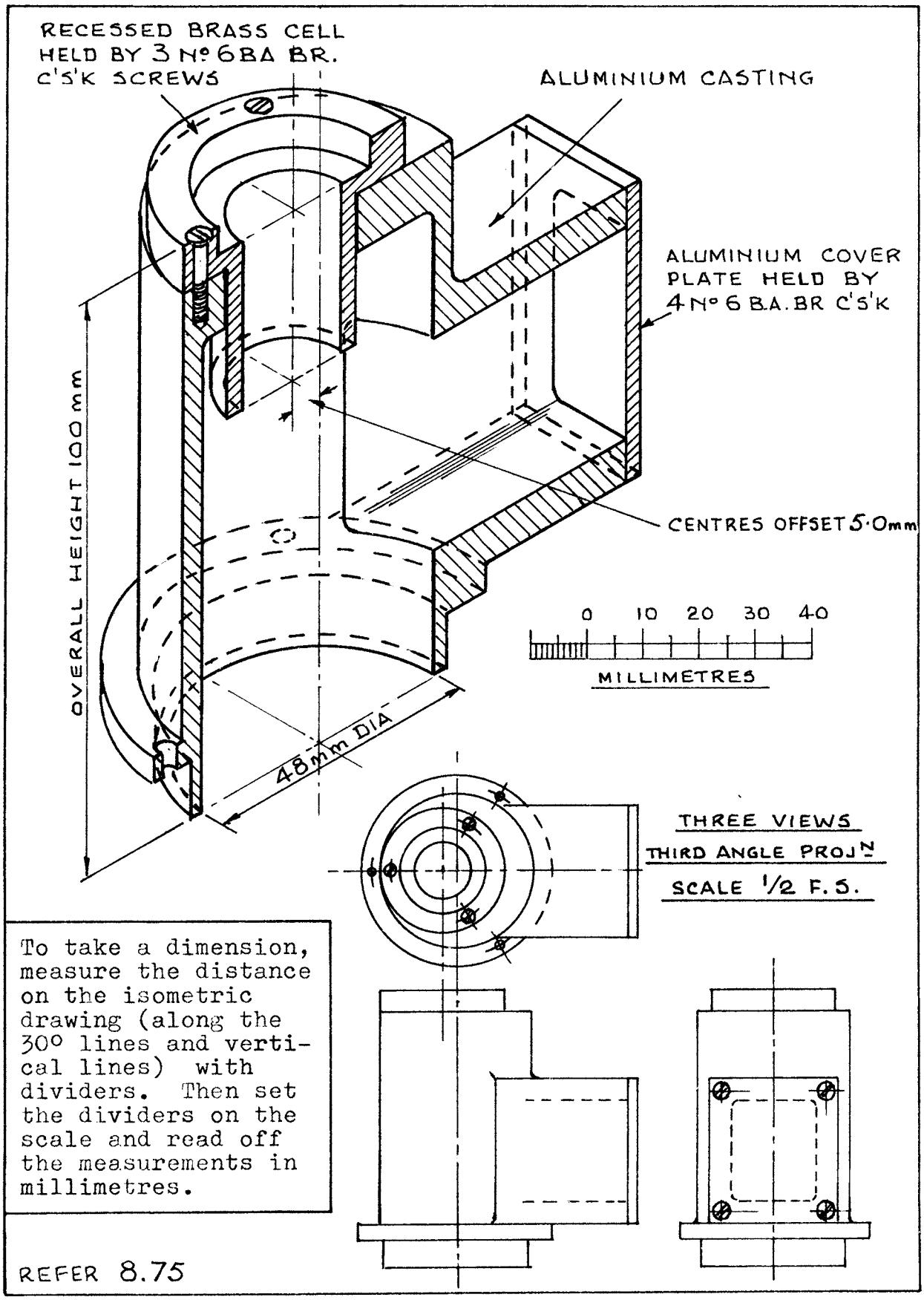
The assembly shown in the figure consists of a strong aluminium casting with an aluminium bridge secured in position by two $\frac{3}{8}$ in B.S.F. bolts. Notice the shoulder fitting for alignment of the bearing bushes. These bushes, made in bearing bronze, are a good push fit in both castings and are flush fitting. Each casting is machined all over to a suitable machine finish.

8.80. ASSIGNMENT A. ASSEMBLY DRAWINGS FOR BEARING BRACKET

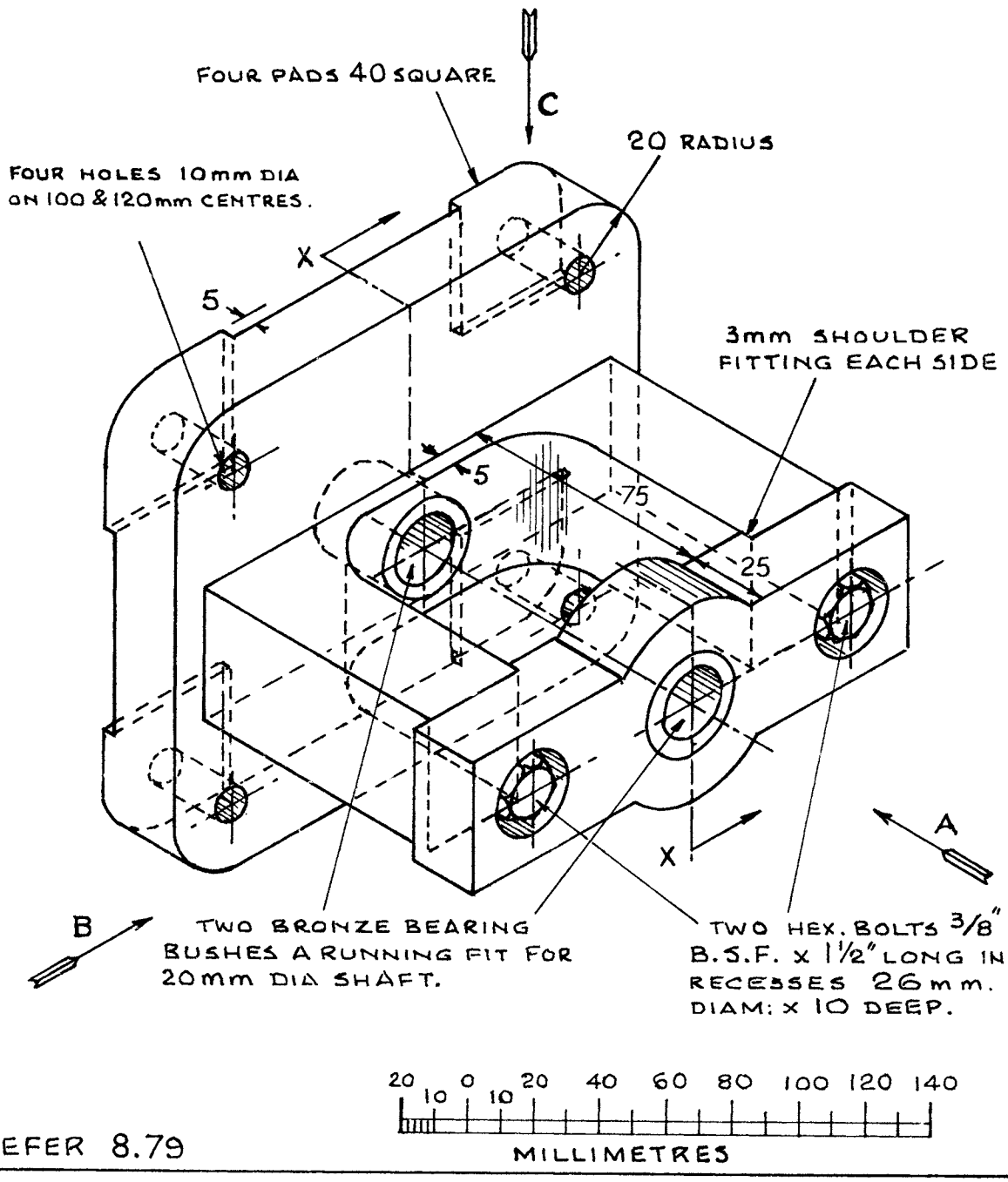
Draw the following assembled views to a full size scale in first angle projection:

(a) front elevation in direction of arrow *A*;
(b) end elevation in direction of arrow *B*;
(c) plan in direction of arrow *C*;
(d) cross-sectional elevation through plane *XX*.

Only specification dimensions are required on an assembly drawing.

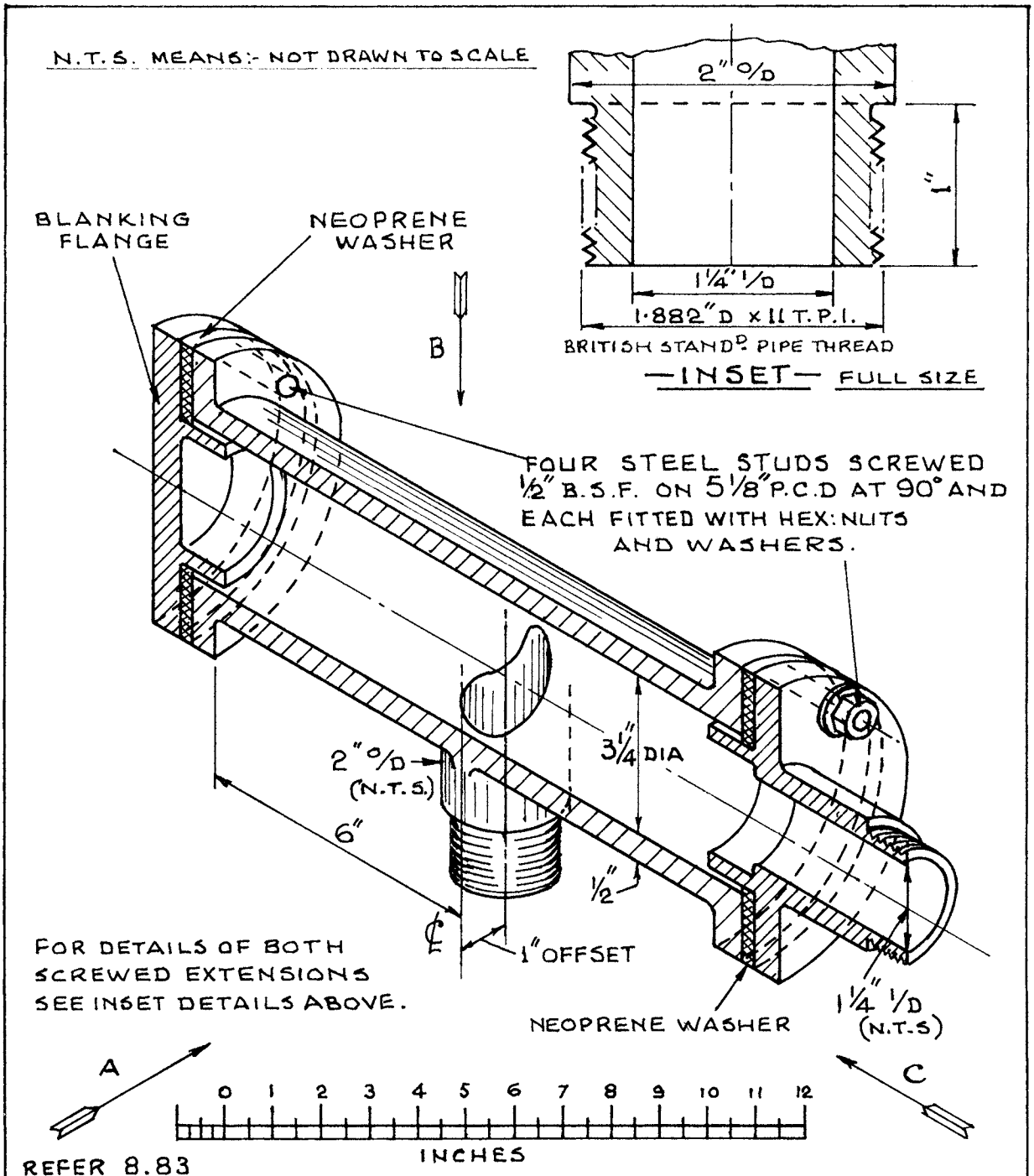


OFFSET LENS MOUNT ASSEMBLY FIG. 98



To take a dimension, measure the distance on the isometric drawing (along the 30° lines and vertical lines) with dividers. Then set the dividers on the scale and read off the measurements in millimetres.

BEARING BRACKET ASS: FIG. 99 ISOMETRIC



To take a dimension, measure the distance on the isometric drawing (along the 30° lines and vertical lines) with dividers. Then set the dividers on the scale and read off the measurements in inches.

FLANGED OFFSET TEE FIG. 100 SECTIONAL ASSEMBLY

8.81. ASSIGNMENT B. DETAIL DRAWINGS FOR BEARING BRACKET

Make separate detailed drawings of the two castings and the bronze bushes fully dimensioned for complete machining.

8.82. ASSIGNMENT C. ISOMETRIC VIEW OF BEARING BRACKET

As a further exercise copy the isometric view shown in Fig. 99.

8.83. FLANGED OFFSET T ASSEMBLY. Fig. 100

This figure shows an offset T with flanges each end. One of these flanges has a blanking off flange with packing washer while the other end has a flange with concentric screwed tube. Each of the end flanges has a short tubular extension to position the packing washers which are made from neoprene rubber sheet. At each end are fitted four steel studs $\frac{1}{2}$ in dia. screwed $\frac{1}{2}$ in B.S.F. The flanges are each held by four hexagon nuts and washers. Both projecting tubes are $1\frac{1}{4}$ in I/D by 2 in O/D and are reduced to 1·882 in dia. and screwed 11 threads per inch (T.P.I.). This thread is taken from the list of British Standard Pipe Threads. For details of both screwed extensions see the inset.

8.84. ASSIGNMENT A. ASSEMBLY DRAWINGS FOR FLANGED OFFSET T

Draw the following views in third angle projection:

(a) sectional front elevation through the vertical plane in direction of arrow *A*;
(b) plan projected from (a) showing hidden detail in direction of arrow *B*;
(c) complete end elevation in direction of arrow *C*;
(d) section cut across the vertical plane on the centre line.

8.85. ASSIGNMENT B. DETAIL DRAWINGS FOR FLANGED OFFSET T

Make detail drawings of all parts, viz. body, blanking flange, flange with screwed extension, packing washers, and the screwed studs.

8.86. ASSIGNMENT C. ISOMETRIC VIEW OF FLANGED OFFSET T

As a further exercise, copy the isometric view shown in Fig. 100.