# N3 Plating and Structural Steel Drawing


Gateways to Engineering Studies - Chris Brink

HYBRID LEARNING SOLUTIONS

# Gateways to Engineering Studies

## Plating and Structural Steel Drawing

## N3

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# Icons used in this book

We use different icons to help you work with this book; these are shown in the table below.

| Icon | Description | Icon | Description |
|---|---|---|---|
| | Assessment / Activity | | Multimedia |
| | Checklist | | Practical |
| | Demonstration/ observation | | Presentation/ Lecture |
| | Did you know? | | Read |
| | Example | | Safety |
| | Experiment | | Site visit |
| | Group work/ discussions, role-play, etc. | | Take note of |
| | In the workplace | | Theoretical – questions, reports, case studies, etc. |
| | Keywords | | Think about it |

# Module 1

# Fundamentals

**Learning Outcomes**
On the completion of this module the student must be able to:

- Identify the drawing requirements necessary for a building drawing
- Describe the following:
  - Drawing as a medium
  - Dimensioning
  - Projection of a circle
  - Ellipse
  - Basic developments
  - True lengths
  - Orthographic projections
  - Printing

## 1.1 Introduction

In this module we will consider the fundamental drawing requirements and principals involved in drawing and printing. Most of this module isn't new material, but good revision.

## 1.2 Drawing requirements

### 1.2.1 Drawing board and paper

The drawing board must be big enough to accommodate an A2 drawing sheet (i.e. 594 mm x 420 mm).

You must use a high quality A2 drawing cartridge paper. Both sides of the paper must be used.

Adhesive tape or drawing clamps may be used for fixing the drawing paper onto the drawing board.

### 1.2.2 T-square

A true and good quality T-square must be used so that accurate drawings can be drawn.

### 1.2.3 Two set squares

The set square must be made from a good material such as celluloid/plastic and must be fairly big, ± 200 mm in length. Various sizes are available. There are also adjustable set squares available.

The aforementioned drawing instruments are illustrated in **Figure 1.1**.

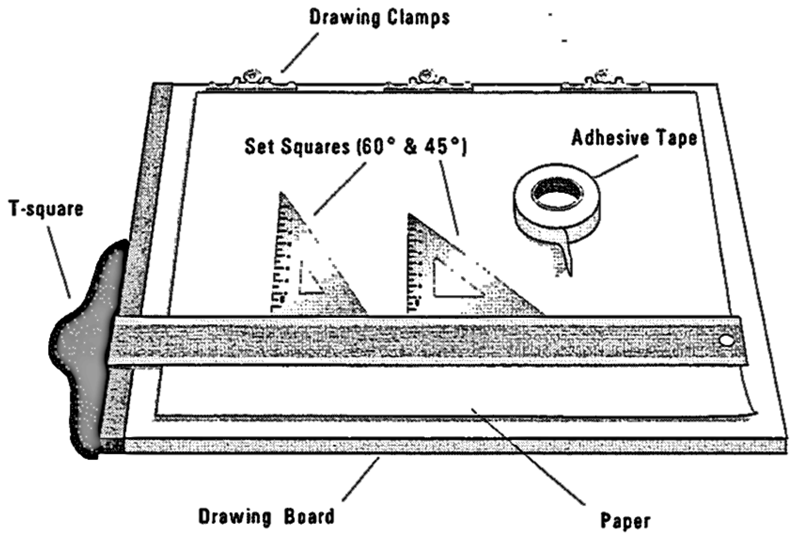



Figure 1.1 Drawing board and paper

### 1.2.4 Set square exercise

A standard set of set squares are available, namely the 30°, 60° and the 45°, each of which has a 900 angle.

**Figure l.2** illustrates a set square exercise. By manipulation of the set squares additional angles can be obtained.

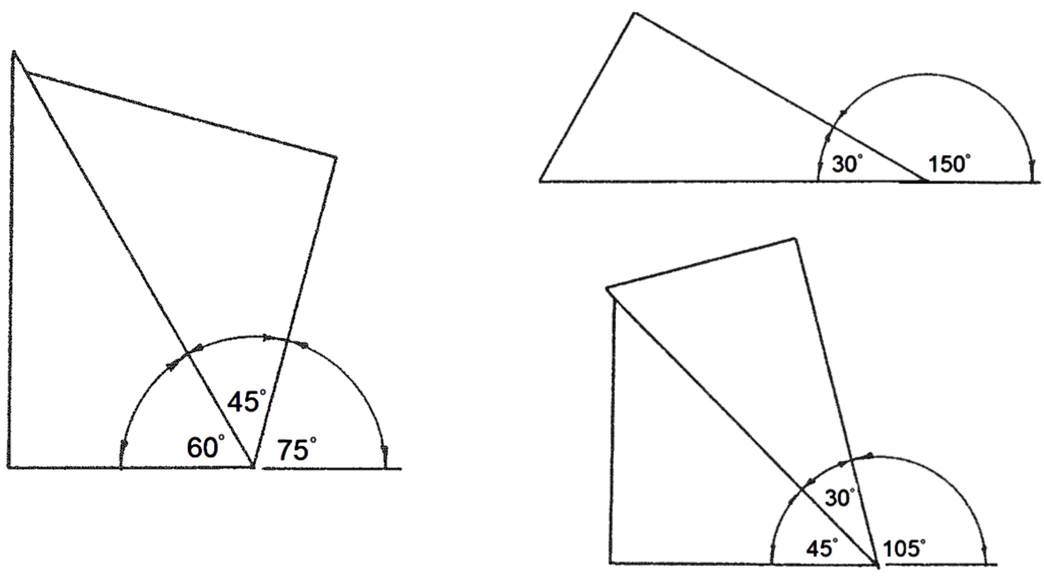



Figure 1.2 Exercise with set squares

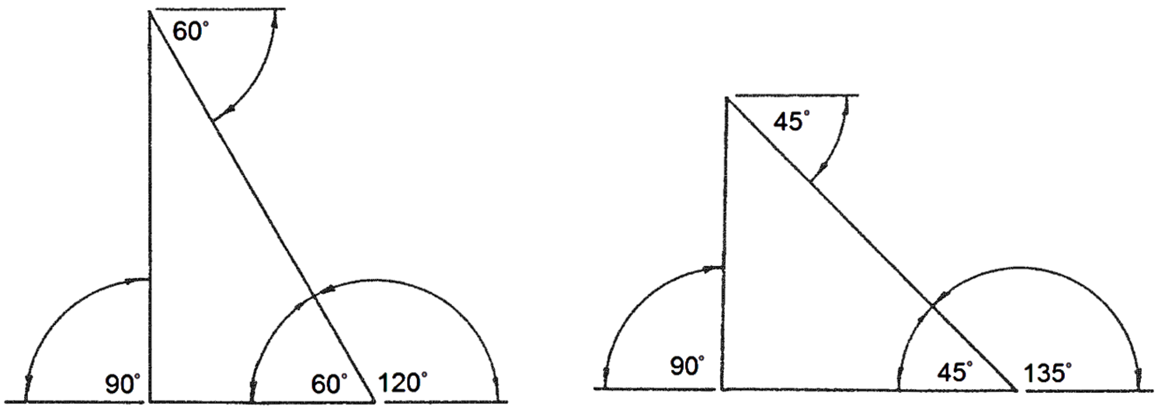



Figure 1.2 Exercise with set squares (continued)

**1.2.5 Drawing instruments**
It is not necessary to buy expensive drawing sets which may include drawing instruments which you might never need to use.

The instruments required for this building drawing course are:

- A good compass (with extension bar). The leg must be approximately 152 mm long.
- A divider of more or less the same size as the compass.
- A small spring bow compass.

These required building drawing instruments are illustrated in **Figure 1.3** below.

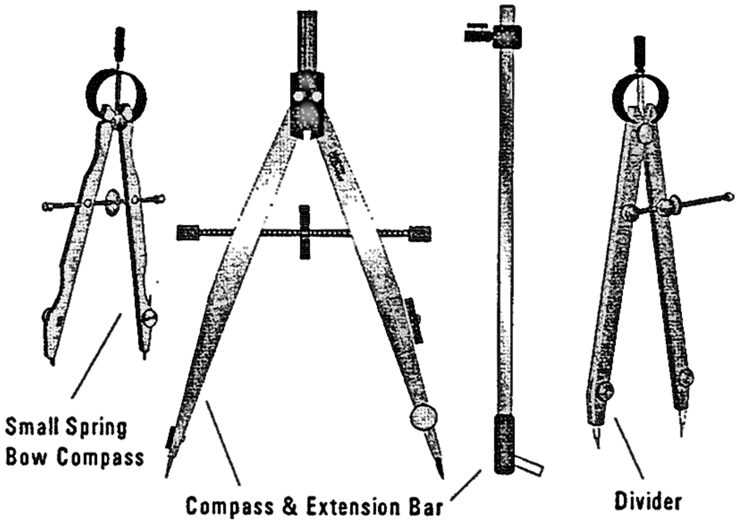



Figure 1.3 Drawing instruments

A yellow duster is necessary to clean all the instruments and the drawing board before they are used. This helps to keep the drawing paper clean.

**1.2.6 Pencils and eraser**

A draughtsman must have a supply of good drawing pencils or clutch pencils of different degrees of hardness, and thicknesses.

The degrees of hardness we recommend are H or F; 2H and HB. The sizes of leads for a clutch pencil should be 0,3 mm, 0,5 mm and 0,7 mm.

A good quality soft eraser is recommended. An erasing shield, as seen in **Figure 1.4**, is very convenient for erasing in small areas.

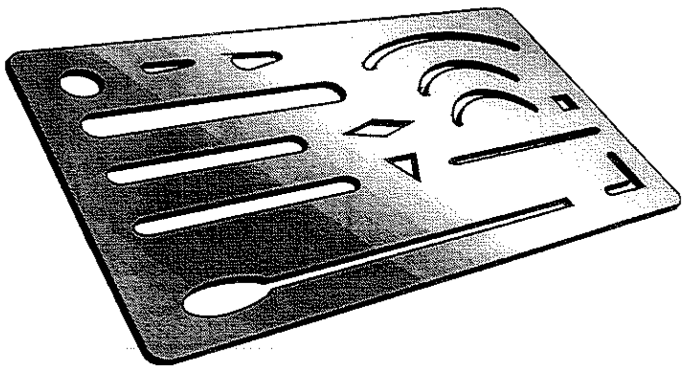


Figure 1.4 Erasing shield

**1.2.7 Scale Ruler**

A triangular plastic scale ruler with the following metric scales is essential: 1:1, 1:2, 1:5 and 1:10.

**1.2.8 Dividing lines and scales**

In many instances it is necessary to divide a line into equal parts. This can be done accurately by using a method shown in **Figure I.5**.

Other methods to obtain accurate scales are illustrated in **Figures 1.6** and **1.7**.

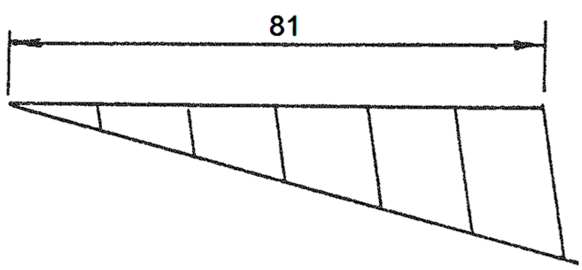



Figure 1.5 Divided into 6 parts

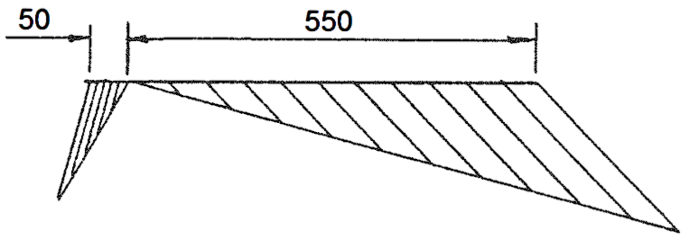



Figure 1.6 Scale 1:50 to measure 550 mm to the nearest 10 mm

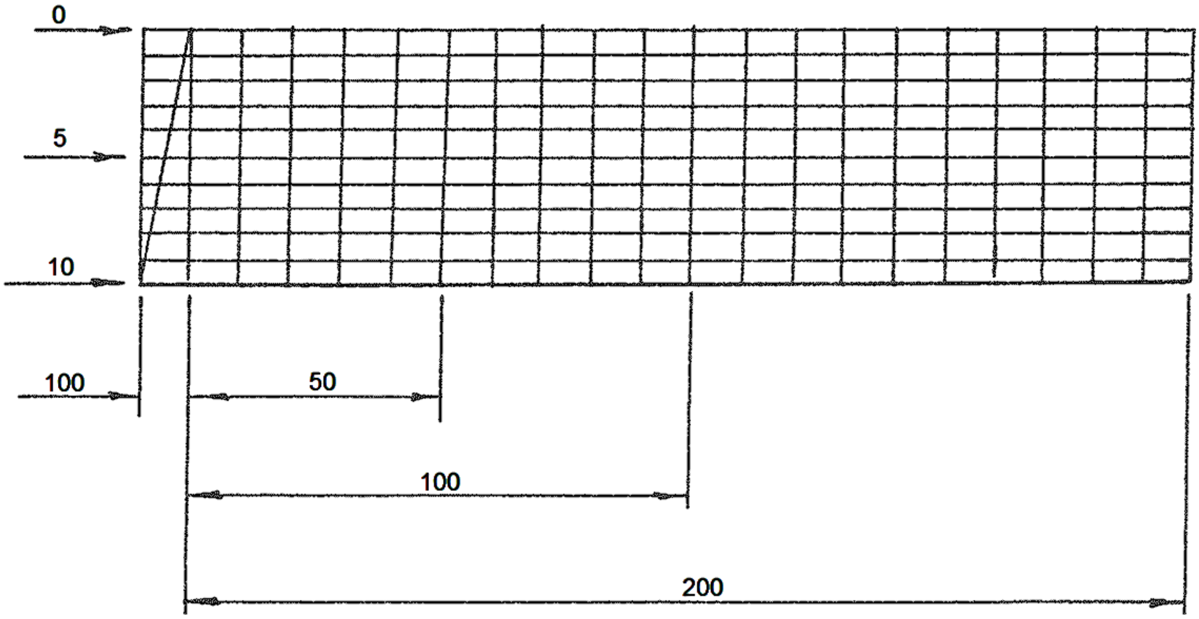



Figure 1.7 Scale 1:2 to measure up to 200 mm to the nearest mm

**1.2.9 Radius/flexi curve**
It will be worth your while to buy these instruments as it will save you time when drawing radii.

**1.2.10 Printing Stencil**
A printing stencil can also be used. Remember the stencil used must allow you to print 3,5 mm and 7 mm high letters and figures.

| | |
|---|---|
| ⚠ | "Practice makes perfect". This saying is very applicable to the use of drawing instruments. Nobody other than yourself can develop your drawing skill. |

These last three drawing instruments are well illustrated in **Figure 1.8** on the following page.

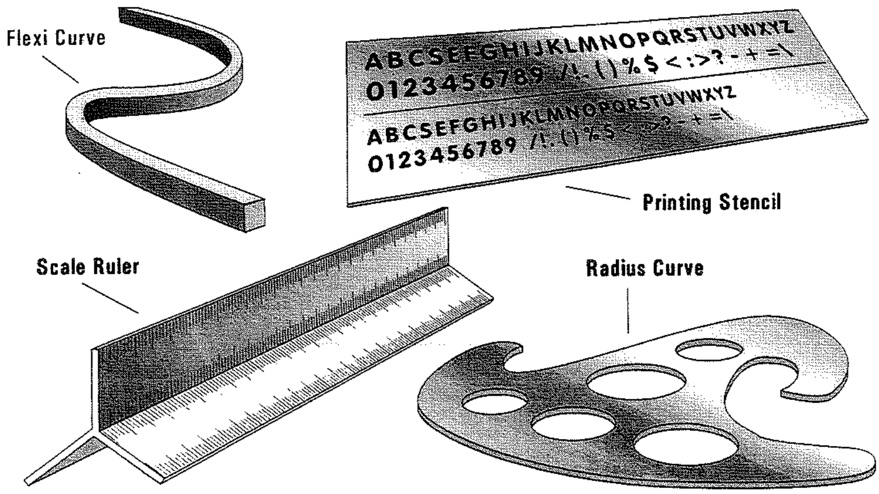



Figure 1.8 Various drawing instruments

## 1.3 Drawing as medium

Drawing, in a broad sense, is the art of producing on a flat surface the likeness of objects or of scenes.

In the restricted and more common use of the word, drawing usually includes only such representations as are produced in outline with some shading to show depth and perspective.

There are few studies which train so many faculties as does drawing.

Hand and eye are taught to cooperate with the powers of observation and memory, while the development of muscle control is no small part of the educational value of a thorough training in drawing.

That these facts are recognised generally is evidenced by the school curricula of nearly all nations, in which drawing features prominently from the primary grades upward.

In developing the art of producing good legible drawings, certain facts must be kept in mind.

There must be a definite difference in line work by the draughtsman to give distinct indications of what is needed. A set of lines is illustrated in **Figure 1.9.**

### 1.3.1 The drawing

- **General rules for drawing**
  The following is the procedure for setting out drawings:

- Consider the views required and the scale to be used.
- Estimate the space required for each drawing. First draw the centre line for each view to avoid overlapping of the drawings and therefore leaving insufficient space for the printing of measurements. The outside measurements of every view must be borne in mind. (The normal position of the different views will be given later in this course).
- The actual outline of the drawing is now built up lightly (2H pencil) around the centre lines.
- When all the lines have been drawn with a light pencil, the unnecessary lines are erased and outlines redrawn neatly. It is important that your measurements are accurate. Test your work while you are drawing to make sure it is exact.
- After the actual drawing has been completed, you can start printing in the measurements, cross hatching and printing the names and any other required information.

- **Types of lines**

The following types of lines follow the pattern laid down by the South African Bureau of Standards in the Code of Practice for Building Drawing.

We strongly recommend that if you intend to proceed to the more advanced grades of Building Drawing, purchase this book from the Bureau of Standards (No. SABS 0111-1990).

Lines must have the same thickness throughout. A thick line is twice or three times as thick as a thin line. The outline of a drawing must be its most outstanding feature.

**Table 1.1** Shows different types of lines used in building drawing.

| Line | Description | General Application |
|---|---|---|
| A | Continuous thick 0,5mm | Visible outlines<br>Visible edges |
| B<br>\ <br>BB | Continuous thin 0,3mm (straight or curved)<br><br>Continuous thin feint | Imaginary lines of intersection<br>Dimension lines<br>Projection lines<br>Leader lines<br>Hatching<br><br>Construction and guide lines |

| | | |
|---|---|---|
| C | Continuous thin freehand 0,3mm | Limits of partial or interrupted views and sections, if the limit is not a chain thin |
| F | Dashed thin 0,3mm | Hidden outlines<br>Hidden edges |
| G | Chain thin 0,3mm | Centre lines<br>Lines of symmetry<br>Trajectories |
| H | Chain thin, thick at ends and changes of direction 0,3mm and 0,5mm | Cutting Top Viewes |

Table 1.1 Types of lines used in building drawing

## 1.4 Dimensioning

In **Figure 1.9** the methods of dimensioning most widely used are shown. Dimensions should be written next to the drawings in order to keep the drawings clear.

Horizontal dimensioning should be above the line and vertical dimensions on the left. Dimensioning on the drawing itself should be kept to a minimum.

Remember that a drawing-is incomplete without the necessary annotations and dimensions. In this course dimensions on developments will be omitted for the sake of clarity.

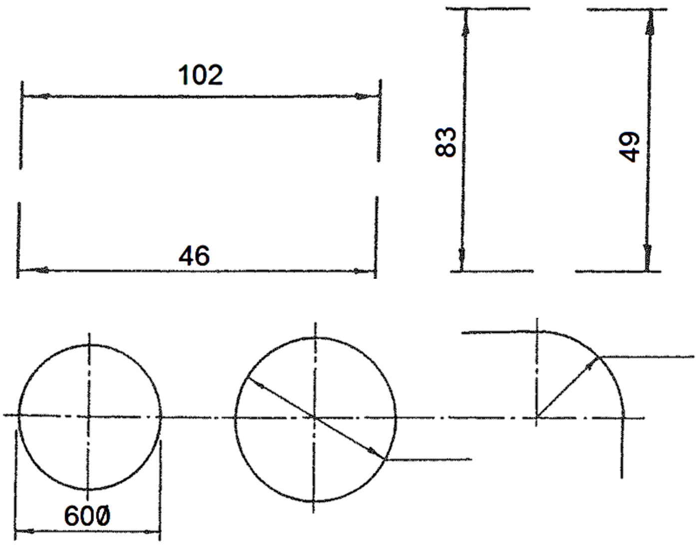



Figure 1.9 Dimensioning

## 1.5 Projection of a circle

The construction of the projection of a circle, which is very often used in this subject, is shown in **Figure 1.10**.

A circular plate is placed at an angle. An auxiliary view is drawn at an angle perpendicular to the plate.

The auxiliary view is divided into twelve equal parts and the points are numbered from I to 7 to I, which are projected horizontally and vertically from a centre line.

The distances a2; b3; c5; d6 are marked off, forming an ellipse when linked.

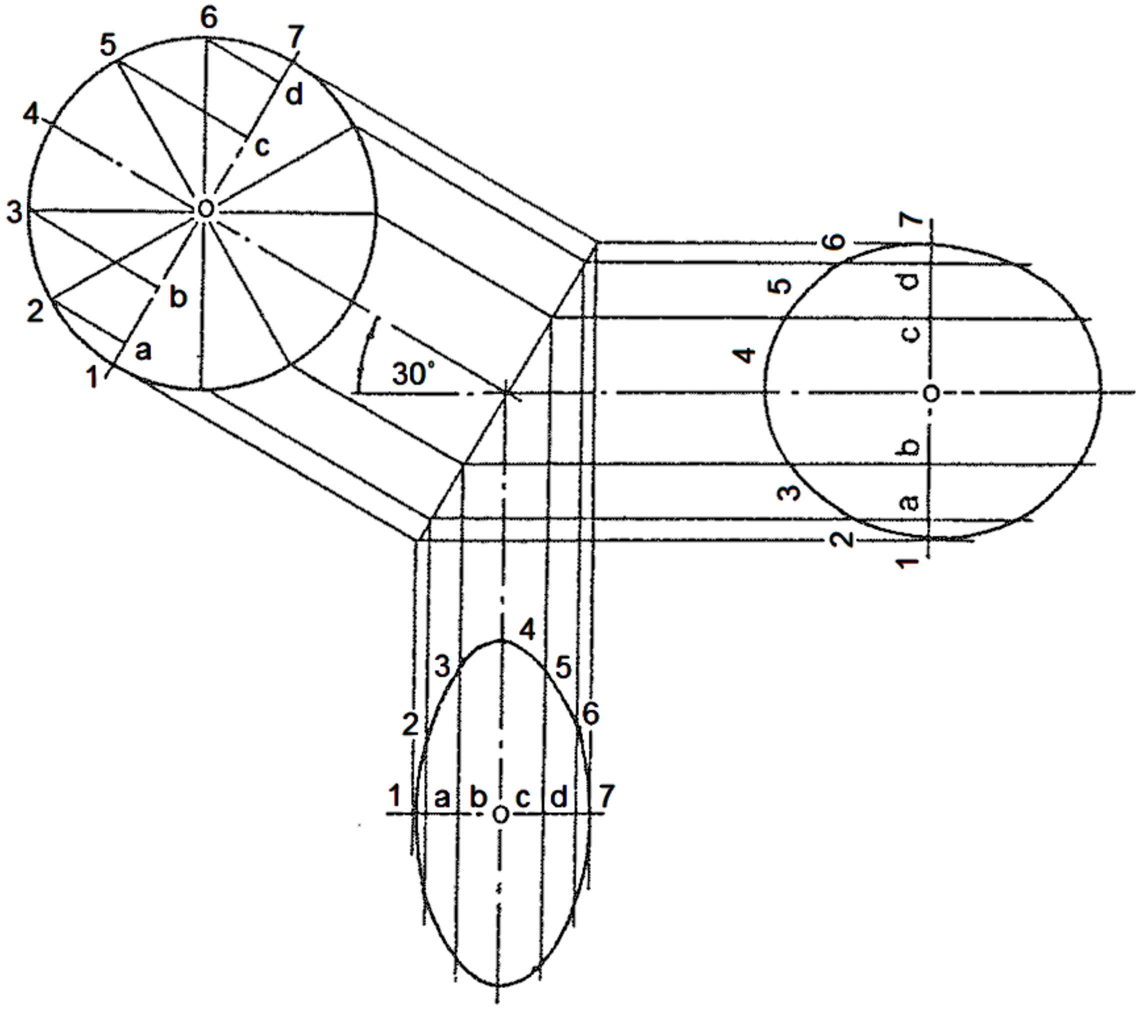



Figure 1.10 Projection of a circle

## 1.6 Ellipse

An ellipse is a figure bordered by an even curve. In **Figure 1.11,** on the following page, the construction of an ellipse is shown.

### 1.6.1 To construct the ellipse

The following steps should be taken to construct the ellipse:

- Draw the major and minor axes.
- With the radius OA scribe the arc AE.
- With the radius DE scribe the arc EF.
- Join BD but only bisect BF.
- Determine points G and H.
- Convert points G and H to the opposite side of the axes.
- Scribe the long arcs through CG and GD.
- Close the ends with the radius HB.

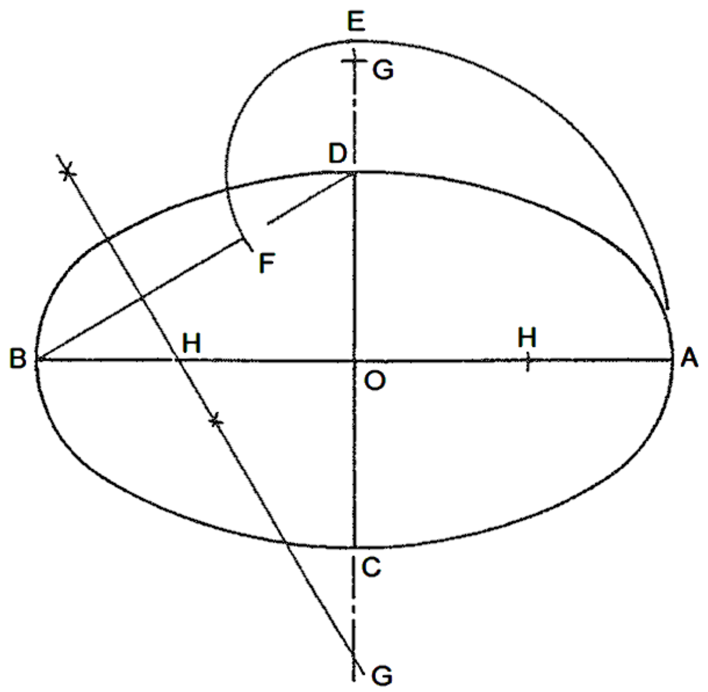



Figure 1.11 Ellipse

## 1.7 Basic developments

### 1.7.1 The Cylinder

**Figure 1.12** shows the basic developments of a cylinder. The method adopted to develop the cylinder is known as the *parallel line* method.

The length of the plate is obtained by dividing the cylinder into twelve equal parts, which is marked on the plate, from which point parallel lines are drawn.

A more accurate method is to calculate the circumference of the cylinder, then draw the girth line on the plate, and divide the line by construction into twelve equal parts.

Note that the circumference is calculated on the main diameter.

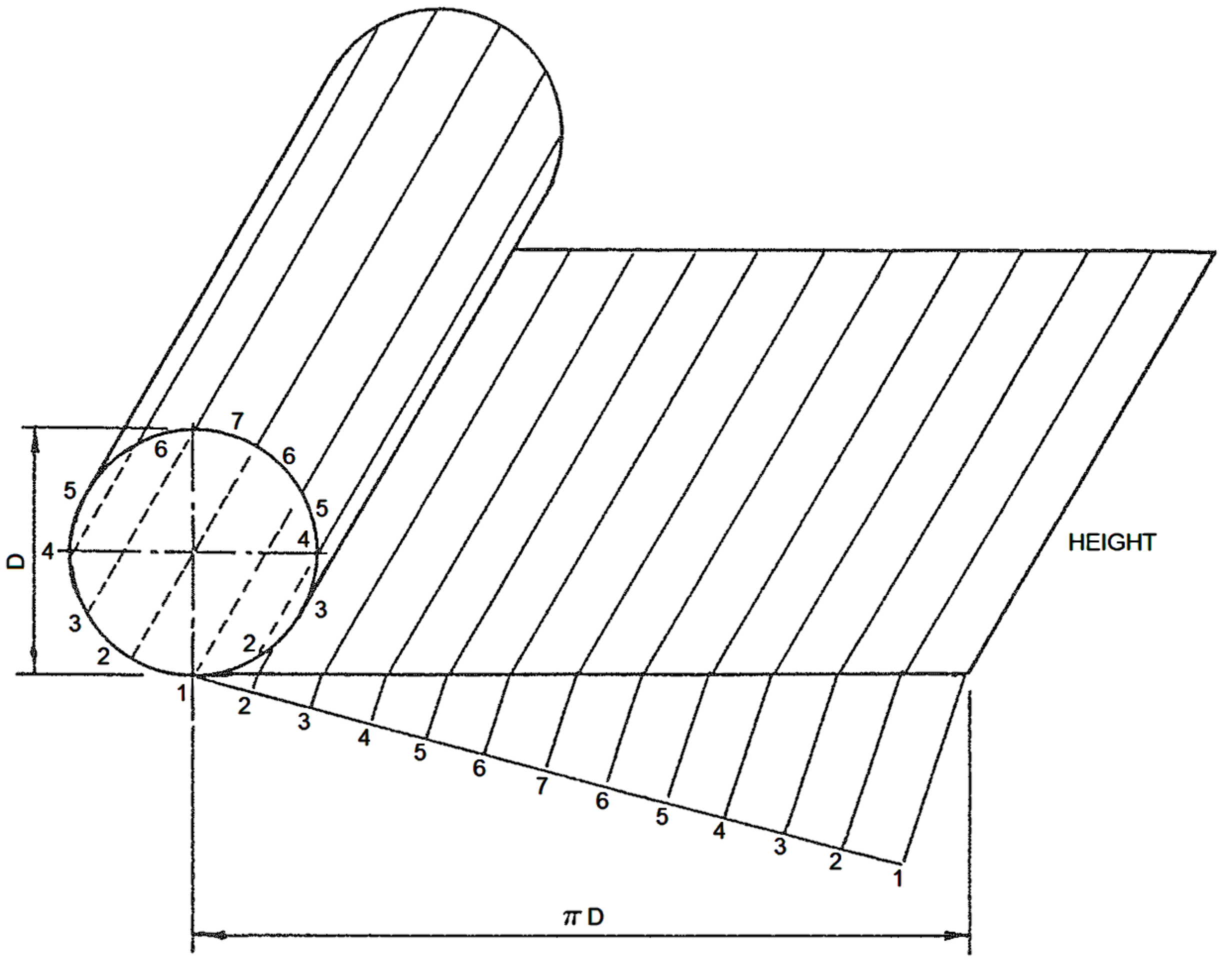



Figure 1.12 Development of a Cylinder

### 1.7.2 The cone

On the following page, **Figure 1.13** shows the basic development of a cone. The method applied to develop the cone is known as the *radial line* method.

Draw an arc, with the slant height as radius, on which twelve equal parts are marked off equal to the base of the cone

Or calculate the circumference of the base of the cone, and divide the figure into twelve equal parts.

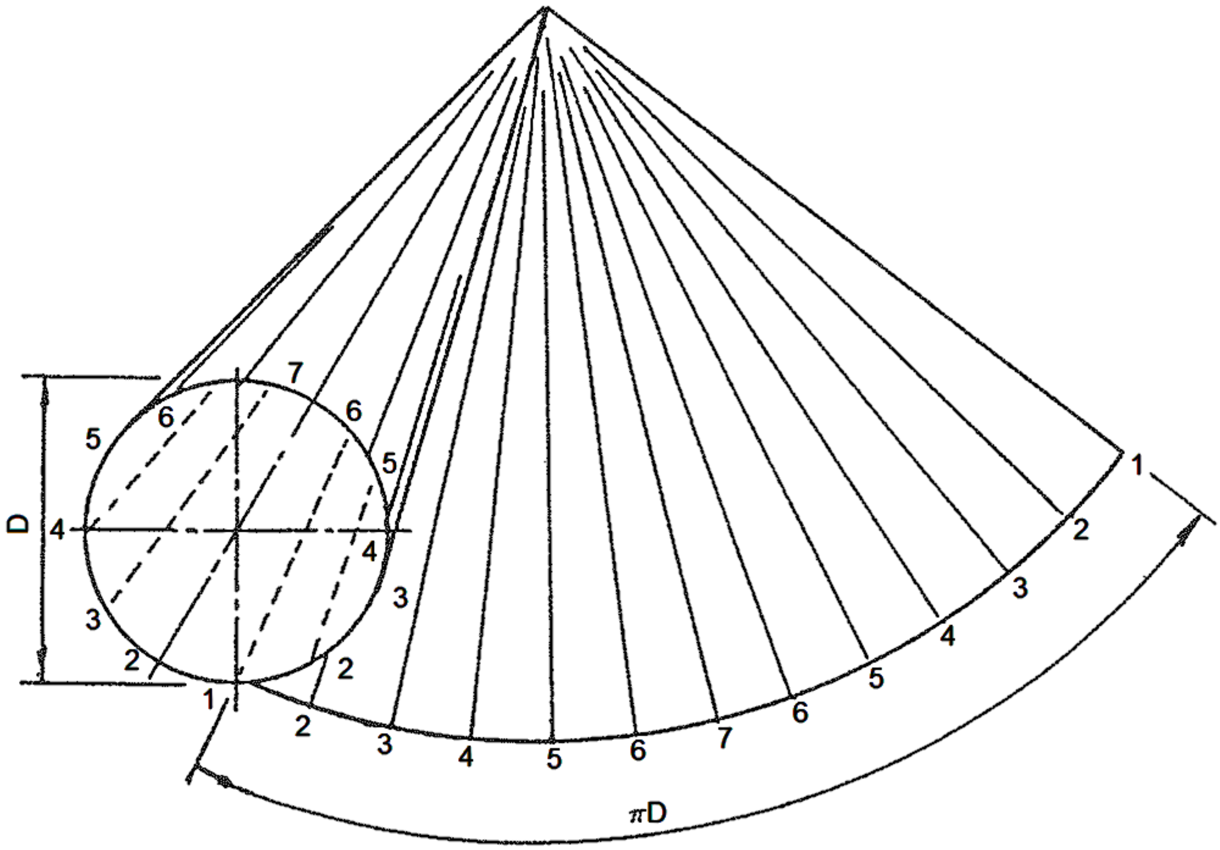



Figure 1.13 Development of a cone

## 1.8 True lengths

A third popular method of development is known as *triangulation*. This method is used to determine the true lengths of corner lines and diagonals in hoppers.

On the following page, **Figure 1.14** shows three views of a pole.

The true length of the pole can be determined as follows:

- Draw the vertical line CD according to the vertical height of the pole.
- Mark DE horizontal to the base of the pole.
- CE will be the true length of the pole.

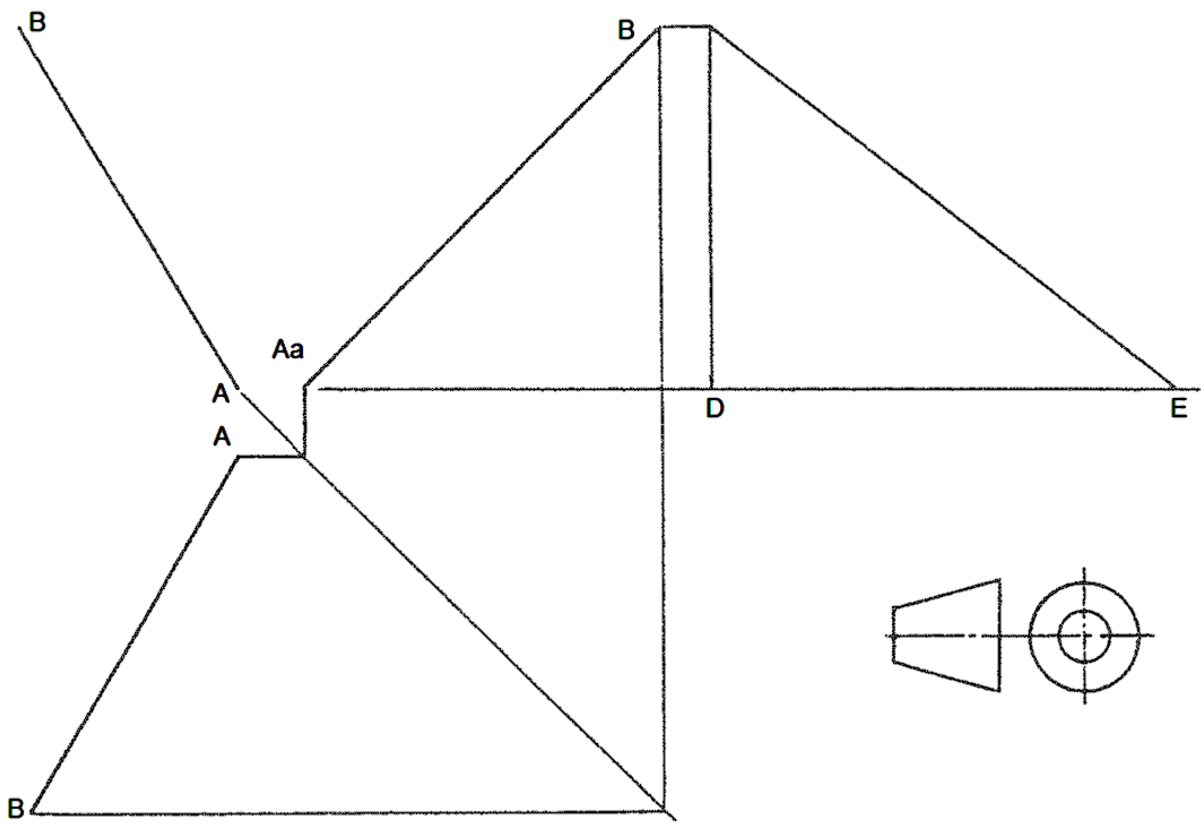



Figure 1.14 True length by triangulation

## 1.9 Orthographic projections

To distinguish the correct shape and proportion, views must be drawn as seen from different angles.

Three directions will be introduced. The two main projections are known as *first angle orthographic projection* and *third angle orthographic projection*.

In **Figure 1.15**, on the following page, an isometric view is shown. From the front, as seen in the direction of the arrow A, the length and height are shown; this is the front view.

From the side as seen in the direction of the arrow B - or from the left - the breadth and height are shown; this is the left view.

From the top as seen in the direction of the arrow C, the length and the breadth are shown; this is the top view.

In **Figure 1.16**, on the following page, an isometric view in third angle orthographic projection is shown.

The front view is seen from direction A; the right view from direction B; and the top view from direction C, but it is drawn above the front view.

To indicate the projections, specific symbols are used; note the position of the double circle in each projection.

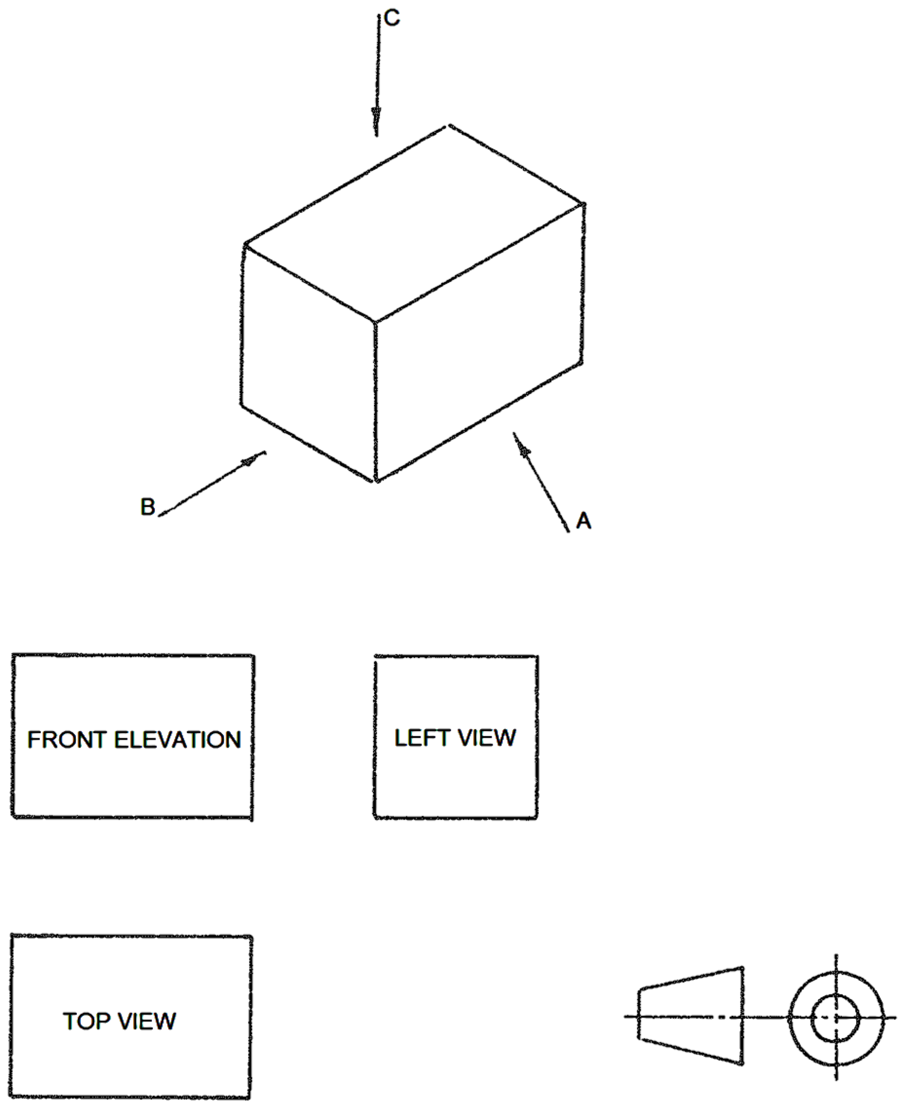



Figure 1.15 First angle orthographic projection

On the following page, **Figure 1.16** shows third angle orthographic projection. Take note of the three different views.

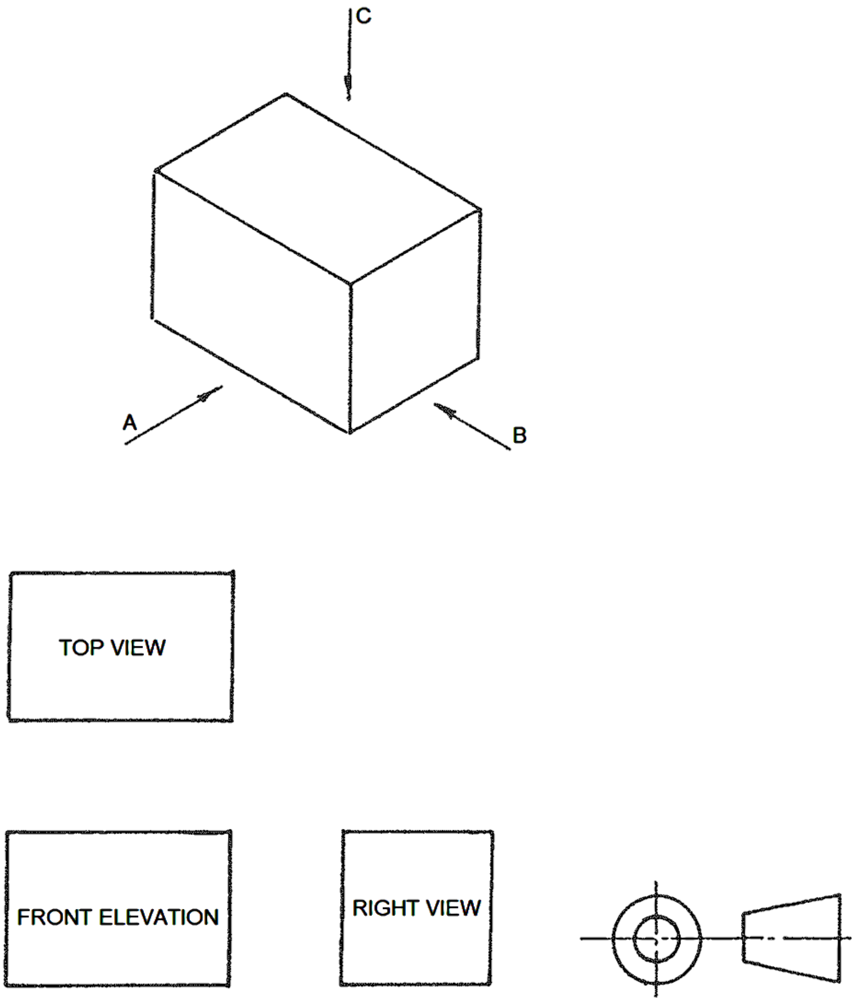



Figure 1.16 Third angle orthographic projection

## Activity 1.1

Draw the two views and a top view to third angle orthographic projection using scale 1:1

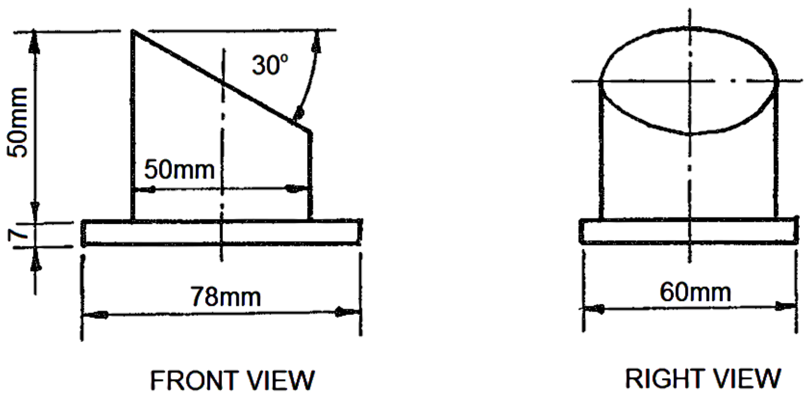



Figure 1.17 Front and right view

## Activity 1.2

**Figure 1.18** shows the front view of a welded steel connection that consists of the following parts:

Item 1 - 200 x 200 rolled steel joist (RSJ) - 1 off required
Item 2 - 200 x 85 rolled steel channel (RSC) - 1 off required
Item 3 - 20 mm thick shaped gusset plates - 2 off required

Draw the given front view and project according to first-angle orthographic projection the following views:

- The left view
- The top view

Print the title 'STEEL CONNECTION' and then 'SCALE' centrally beneath the views and insert the projection symbol.

SCALE 1:5

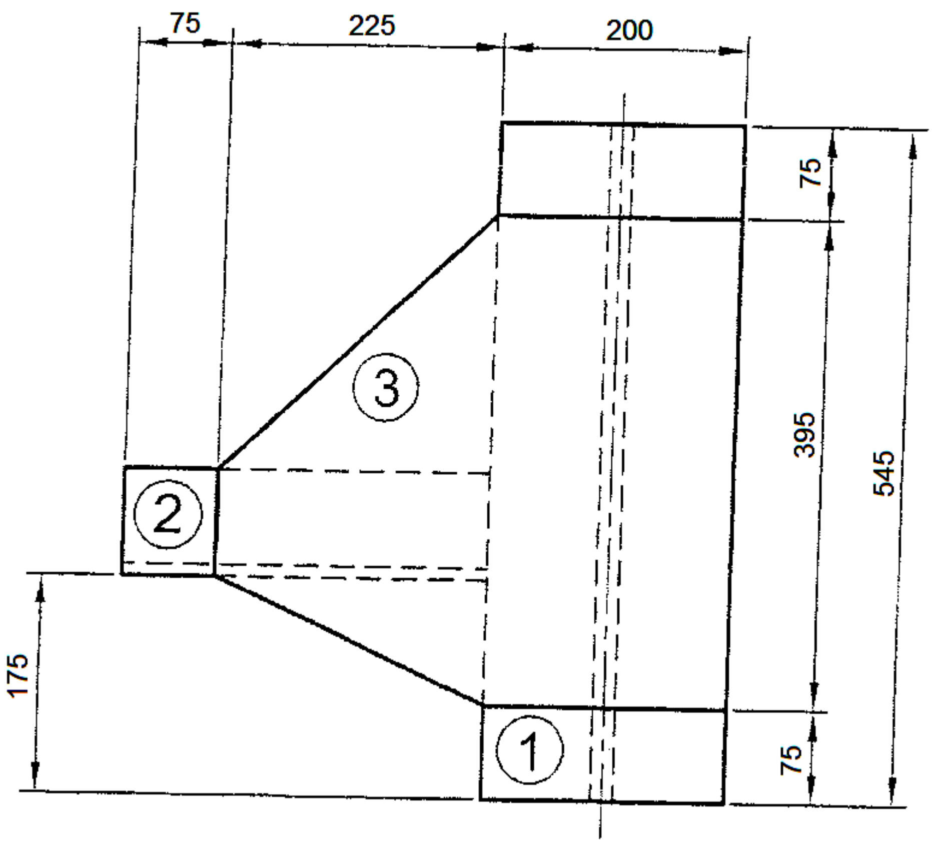



Figure 1.18 The front view of a welded steel

## 1.10 Printing

All printing must be printed neatly on the drawing paper. Please use guide lines for this purpose. A printing stencil can also be used.

> Remember the stencil used must allow you to print 3,5 mm and 7 mm high letters and figures.

### 1.10.1 Printing of measurements

All measurements will in future be given in metric units. Measurements may be written in metres or millimetres.

In this building drawing course all measurements are given in millimetres.

It is not necessary to add the abbreviation (mm) after each measurement. The abbreviation or symbol for diameter is dia, For example; 25 dia or scp 25 and for radius R, for example R12.

Often, a good architectural drawing is spoiled by poor printing of the measurements.

Note the following when printing measurements:

- Extension lines should start about 1 to 1,5 mm from the drawing and extend slightly beyond the arrow, as seen in **Table 1.1**.
- Measurements must be printed normal to the dimension lines and must be legible from the bottom or right hand side of the drawing, as seen in **Figure 1.5**.
- Measurement arrow heads must be clear with sharp points and must merely touch the lines they refer to, as seen in **Table 1.1**.
- A centre line must never be used as a dimension line. Nor should a dimension line be drawn where it can be mistaken for an outline.
- Measurements must be printed above the dimension line without touching it. Wherever possible, dimension lines should be drawn outside the actual drawing.
- Use extension lines. Try to insert all the measurements of your drawing equally amongst the views drawn as this will give your drawing a neat appearance.

Unless it is absolutely necessary, measurements should not be printed in a hatched portion of a drawing.

If this cannot be avoided, the hatching must be interrupted. For these reasons the hatching is always done last – after the measurements have been written in.

### 1.10.2 Printing of letters and figures

All letters and figures must be printed simply and clearly. The printed letters may be upright or slanting, but they must be the same throughout the drawing.

As it is difficult to print on the slant, we recommend the upright method for printing of letters and figures.

### 1.10.3 Types of lettering

**Table 1.2** below shows types of lettering. In particular, the difference between vertical and oblique letting and figuring is shown.

| Vertical lettering and Figuring | Oblique lettering and Figuring |
|---|---|
| ABCDEFGHI<br>JKLMNOPQR<br>STUVWXYZ | *ABCDEFGHI<br>JKLMNOPQR<br>STUVWXYZ* |
| ABCDEFGHIJKLM<br>NOPQRSTUVWXYZ | *ABCDEFGHIJKLM<br>NOPQRSTUVWXYZ* |
| ABCDEFGHIJKLM<br>NOPQRSTUVWXYZ | *ABCDEFGHIJKLM<br>NOPQRSTUVWXYZ* |
| abcdefghijklm<br>nopqrstuvwxyz | *abcdefghijklm<br>nopqrstuvwxyz* |
| 1234567890 | *1234567890* |
| 1234567890 | *1234567890* |
| 1234567890 | *1234567890* |

Table 1.2 Types of lettering

### Activity 1.3

Print:

1. The alphabet (letters 7 mm high) using either the slant or upright method, whichever you prefer; and
2. The figures 1-10 (7mm high) using either the slant or upright method.

## Activity 1.4

Draw five lines of each of the following lines, 150 mm long and 10 mm apart: (Print the name of the line above each set of lines)
a) Outlines
b)Dimension lines
c) Dotted or chain lines
d) Centre lines
e) Construction lines

**Self-Check**

| I am able to: | Yes | No |
|---|---|---|
| • Identify the drawing requirements necessary for a building drawing | | |
| • Describe the following: | | |
| o Drawing as a medium | | |
| o Dimensioning | | |
| o Projection of a circle | | |
| o Ellipse | | |
| o Basic developments | | |
| o True lengths | | |
| o Orthographic projections | | |
| o Printing | | |

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

# Module 2

# Definitions and Terminology

**Learning Outcomes**
On the completion of this module the student must be able to:

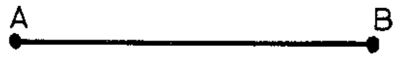
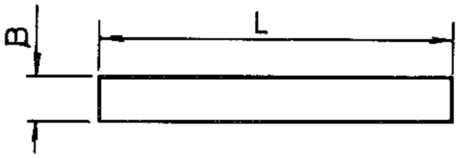
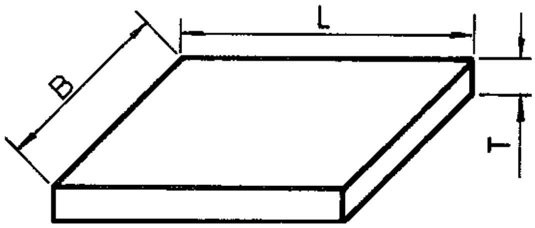
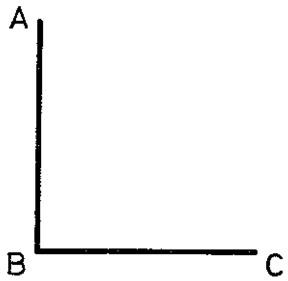
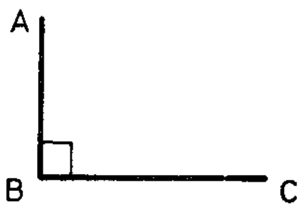
- Define and describe the following terms:
  - A straight line
  - A plane surface
  - A solid
  - A plane rectilineal angle
  - The Right angle
  - The Acute angle
  - The Obtuse angle
  - A triangle
  - An equilateral triangle
  - An isoceles triangle
  - A scalene triangle
  - A square
  - A rectangle
  - An arc
  - The chord
  - A segment of a circle
  - The mid-ordinate
  - The tangent

## 2.1 Introduction

The understanding and correct usage of a number of elementary geometrical problems are absolutely essential in the art of plate developing.

## 2.2 Definitions and Terminology

This module discusses a number of elementary definitions as seen in **Table 2.1** on the following page.

| Definitions | |
|---|---|
| 1. A straight line, shown in **Figure 2.1** is the shortest distance between two points. It has length but no breadth. | <br><br>Figure 2.1 A straight line |
| 2. **Figure 2.2** shows a plane Superficies or Surface has length and breadth only. | <br><br>Figure 2.2 A plane surface |
| 3. A solid has length, breadth and thickness, see **Figure 2.3**. | <br><br>Figure 2.3 A solid |
| 4. A plane rectilineal angle is the inclination of two straight lines to one another in a plane, which meet together but are not in the same straight line and is either Right, Acute or Obtuse (**Figure 2.4**).<br><br>To express an angle the letters which denote the two lines forming the angle are employed such as ABC. | <br><br>Figure 2.4 A plane rectilineal angle |
| 5. The Right angle (see **Figure 2.5**) is 90° and is usually said to be normal to the base line or perpendicular to the base line. | <br><br>Figure 2.5 A right angle |

6. The Acute angle is less than 90° as seen in **Figure 2.6**

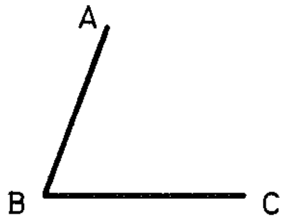



Figure 2.6 An acute angle

7. The Obtuse angle is greater than 90° (see **Figure 2.7**).


Figure 2.7 An obtuse angle

8. A triangle, see **Figure 2.8**, is a plane figure bounded by three straight lines and is either an Equilateral, Isoceles or Scalene triangle.

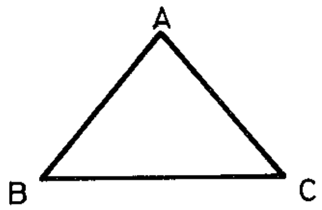



Figure 2.8 A triangle

9. Equilateral triangle (**Figure 2.9**) has three sides equal and therefore the three angles are equal. AB = BC = CA

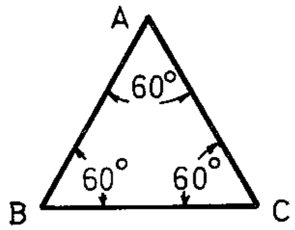



Figure 2.9 An equilateral triangle

10. The Isoceles triangle (**Figure 2.10**) has two of its sides equal and two of its angles equal. AB = AC

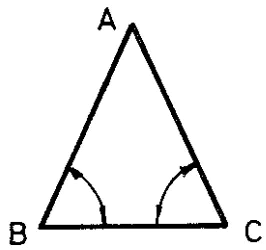



Figure 2.10 An isoceles triangle

11. The Scalene triangle (**Figure 2.11**) has all its sides and angles different.

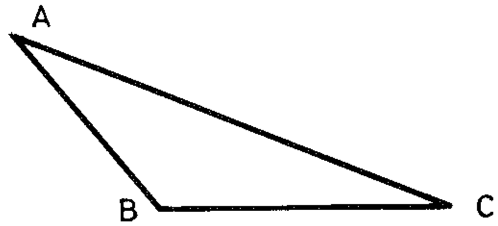



Figure 2.11 A scalene triangle

12. A Square, as seen in **Figure 2.12**, is a rectilineal figure with four sides equal and the angles are Right angles (90°).

    AB = BC = CD = DA

> The sides are parallel to each other.

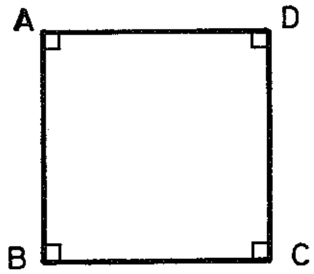



Figure 2.12 A square

13. A Rectangle (see **Figure 2.13**) is a four sided figure having Right angles (90°) and of which the length exceeds the breadth.

> The sides are parallel to each other; AB = BC and AB =CD.

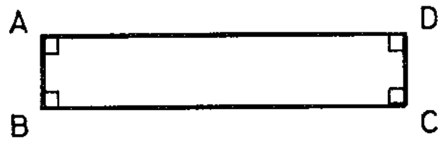



Figure 2.13 A rectangle

14. The Arc is any part of the circumference of a circle, see **Figure 2.14**, EDF.

15. The Chord is any straight line joining two points on the extreme of an Arc see **Figure 2.14**, EGF. ABC is the diameter but is also a chord.

16. The Segment of a circle is any part bounded by its Arc and Chord see **Figure 2.14**, ABCDA.

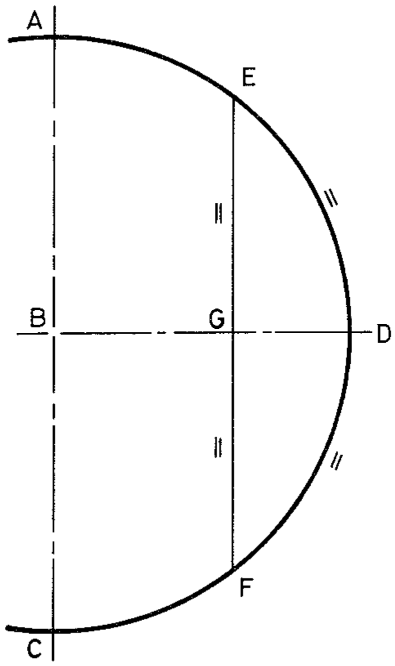
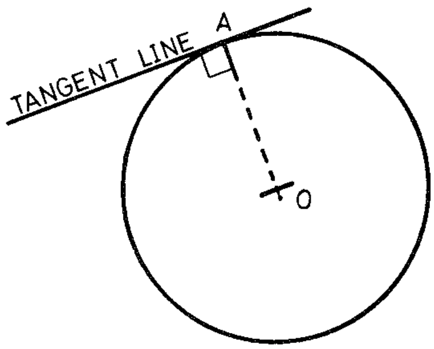
| | |
|---|---|
| 17. The mid-Ordinate is the distance between the Arc and Chord measured along a line drawn from the middle of the Arc through the middle of the Chord forming a right angle to the Chord see **figure 2.14**, GD and BD. | <br>Figure 2.14 A semi-circle showing an arc, a chord, a segment of a circle and the mid-ordinate |
| 18. The Tangent, see **Figure 2.15**, is a straight line touching the curvature of any arc (without cutting it) so that a line taken from the point of contact A to the centre point 0 of the arc forms a right angle (90°) to the tangent line. | <br>Figure 2.15 The tangent |

Table 2.1 Definitions and Terminology

**Self-Check**

| **I am able to:** | **Yes** | **No** |
|---|---|---|
| • Define and describe the following terms; | | |
| o A straight line | | |
| o A plane surface | | |
| o A solid | | |
| o A plane rectilineal angle | | |
| o The Right angle | | |
| o The Acute angle | | |
| o The Obtuse angle | | |
| o A triangle | | |
| o An equilateral triangle | | |
| o An isoceles triangle | | |
| o A scalene triangle | | |
| o A square | | |
| o A rectangle | | |
| o An arc | | |
| o The chord | | |
| o A segment of a circle | | |
| o The mid-ordinate | | |
| o The tangent | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 3

## Geometry

**Learning Outcomes**
On the completion of this module the student must be able to:

- Describe the following;
  - A right angle
  - Bisecting
  - Line division
  - How to draw a circle to touch 3 points:
  - Constructing a hexagon
  - Constructing a pentagon
  - Dividing a circle into 12 equal parts
  - How to draw the curve of a segment if the chord and mid-ordinate are given
  - The ellipse
  - Cutting planes:
  - Right pipe (round)
  - Oblique pipe (elliptical)
  - Right cone
  - Oblique cone
  - Parabola (direct construction)
  - Hyperbola (direct construction)
  - Cutting plane on cone (projection method)

## 3.1 Introduction

This module will only deal with a few basic principles which could be encountered in developing. These shall be presented in a precise and clear manner, with particular emphasis on preciseness.

## 3.2 Perpendicular to a straight line (right angle)

### 3.2.1 To a point in a line

On a line AB construct a line perpendicular through point O. Take O as centre and any radius scribe an arc to cut AB in C and D, as seen in **Figure 3.1**.

Then with centres C and D and any radius, scribe arcs to intersect at E. Now draw a line from O through E. The line OE is now the perpendicular.

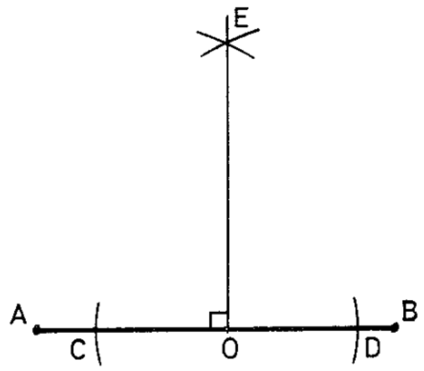



Figure 3.1 Perpendicular to a straight line, to a point in a line

**3.2.2 To a point on the end of a line**
On a line AB construct a line perpendicular through point A.

Take A as centre and any radius, scribe an arc CX touching AB at C, with same radius using centre C scribe arc to intersect arc CX at D, then with D as centre and same radius scribe arc to intersect arc CX at E.

Then with centres E and D and any radius scribe arcs to intersect at F. Now draw a line from A through F, the line AF is now the perpendicular, as seen in **Figure 3.2**.

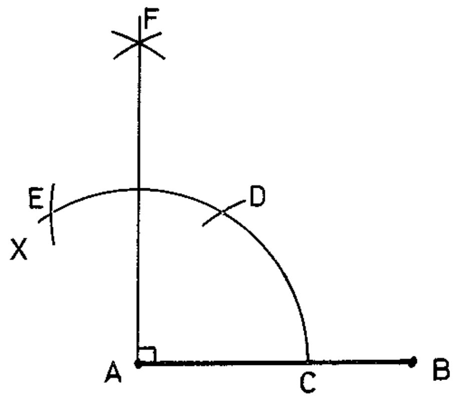



Figure 3.2 Perpendicular to a straight line, to a point on the end of a line

**3.2.3 No point specified**
On a line AB with centre C and any radius, such as in **Figure 3.3** on the following page**,** scribe an arc DE cutting AB in F, then with F as centre and any radius, scribe arcs cutting arc DFE at G and H.

Draw a line through G and H forming the perpendicular.

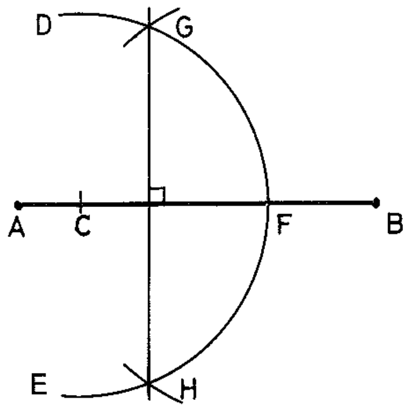



Figure 3.3 Perpendicular to a straight line, no point specified

## 3.3 Bisecting

### 3.3.1 Bisecting a line

To bisect line AB take radius AB and with centres A and B scribe arcs to intersect at C and D.

Then draw a line from C to D to cut line AB at E making AE = EB, as seen in **Figure 3.4**.

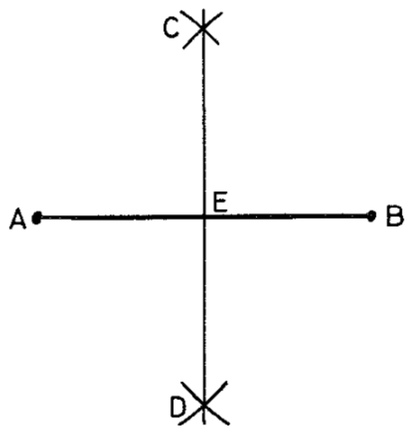



Figure 3.4 Bisecting a line

### 3.3.2 Bisecting an angle

To bisect angle ABC use B as centre and any radius, as seen in **Figure 3.5** on the following page.

Then scribe an arc cutting AB and BC at D and E and with these as centres and any radius, scribe arcs intersecting at F.

Draw a line from B to F making ABF = FBC.

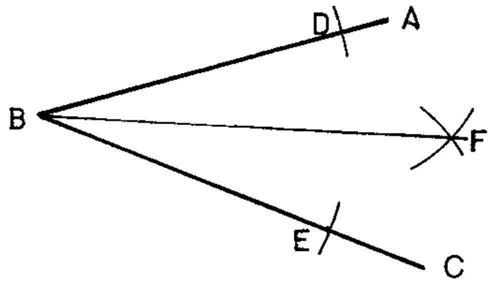



Figure 3.5 Bisecting an Angle

## 3.4 Line division:

To divide a given line AB into any number of equal parts, draw a line AC at any angle to AB, set dividers at approximate division and step of number required on AC.

Next, connect last point on AC to B.

Then draw up the other division points parallel to CB to cut AB, these points transferred thus to AB shall then be the correct divisions as seen in **Figure 3.6** below.

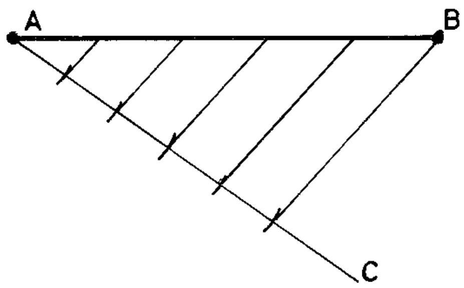



Figure 3.6 Line division

## 3.5 To draw a circle to touch 3 points:

To find the centre of a circle to touch the three points, A, B and C, join A to B and B to C then bisect lines AB and BC as seen in **Figure 3.7** on the following page.

**Figure 3.7** shows a circle touching three points.

Then extend bisecting lines to intersect at O, take O as centre and radius OA draw circle to touch A, B and C.

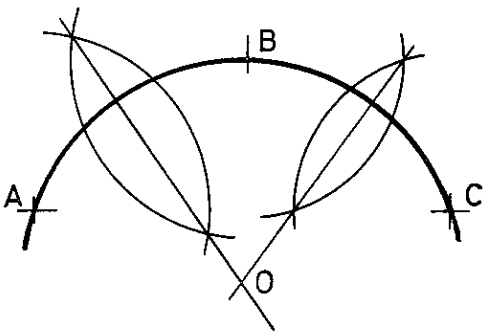



Figure 3.7 A circle touching three points

## 3.6 Constructing a hexagon

### 3.6.1 One side given

With side AB given draw a regular Hexagonal. Take A and B as centres and AB as radius, scribe arcs intersecting at O then with O as centre and OA as radius draw a circle through A and B.

Now with same radius and centres A and B step off along circle obtaining points CDE and F. Join points ABCDEF to form Hexagonal, as seen in **Figure 3.8**.

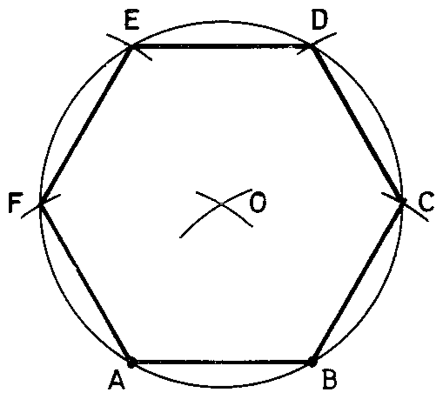



Figure 3.8 Constructing a hexagon, with one side given

> **Note:**
> From this construction we see that taking any circle and setting compass to radius, the radius can be stepped off around circle making six equal divisions.

## 3.7 Constructing a pentagon

### 3.7.1 Side given

Taking side AB, bisect to form point C and draw a perpendicular to point C, with C as centre and radius AB, scribe an arc to cut perpendicular at D, draw a line from B through D and extend, then with D as centre and radius CB, scribe an arc cutting extended line BD at E.

And with centre B and radius BE, scribe an arc to cut perpendicular at F; this point F will be one point of the pentagon, now bisect BF and extend bisecting line to cut perpendicular at O.

Using O as centre and radius OB draw a circle, as seen in **Figure 3.9**. Where the bisecting line cuts the circle at G is one of the other points of the pentagon.

Now with centre A and radius AB scribe an arc to cut circle at H, connect points ABGFH to complete pentagon.

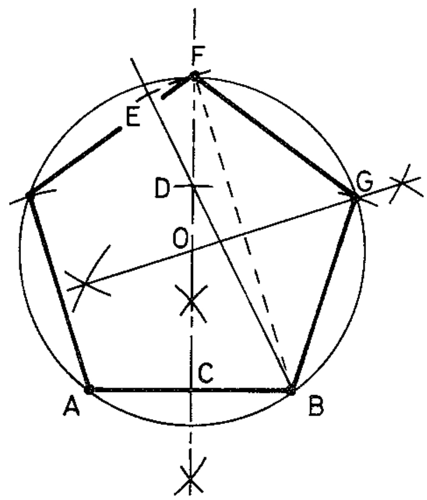



Figure 3.9 Constructing a pentagon with a side given

## 3.8 Dividing a circle into 12 equal parts

Set compass to radius of circle and using intersecting points ABC and D as centre points, scribe arcs to cut circle at A1, A2, B1, B2, C1, C2 and D1, D2, as seen in **Figure 3.10**.

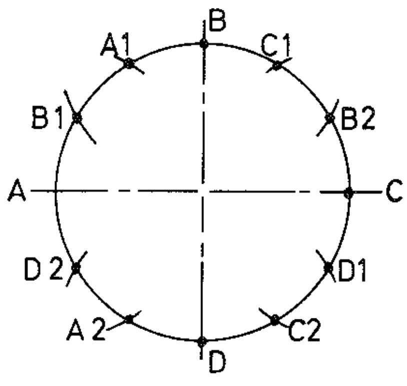



Figure 3.10 A circle, divided into 12 equal parts

## 3.9 To draw the curve of a segment if the chord and mid-ordinate are given

a) If possible to draw with trammel, use the bisecting method to draw a circle touching three points see *paragraph 3.5*.
b) Drawing the curve without having recourse to the centre:

Put down the chord B.O.B. and from a central point 0 place the mid-ordinate OA, perpendicular to B.O.B. Through A and parallel to B.O.B. draw a line. Connect points B to A, from B.

Perpendicular to AB, draw lines to cut the line parallel to B.O.B. at C. From point B draw a line perpendicular to line B.O.B. to cut lines AC at X, divide line BX into any number of equal parts, and number 1, 2, 3 etc. starting from point B (see **Figure 3.11**).

Also divide lines AC and lines OB into the same number of equal parts, numbering division points, 1, 2, 3, etc., starting from point B.

Connect points on lines AC to corresponding points on lines OB, now connect points 1, 2, 3, etc., on lines BX to A. Where corresponding numbered lines intersect is the point of the curvature.

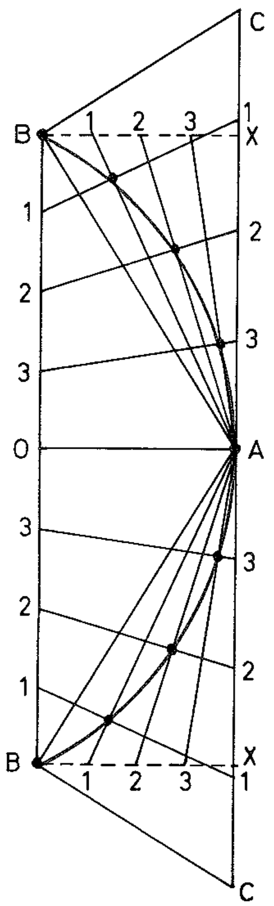



Figure 3.11 The curve of a segment

## 3.10 The ellipse

As the ellipse is of importance to us, we now consider the methods of drawing an ellipse.

### 3.10.1 The two circle method

Draw two circles with diameters equal to the major and the minor axis such as in **Figure 3.12**.

Divide the outer circle into any number of parts (not necessarily equal) and number 1, 2, 3, etc.

From these points draw lines to the circle centre to cut inner circle, and number correspondingly.

Then draw lines from the outer circle numbered points horizontally to cross lines drawn vertically from the corresponding points on the inner circle, these intersecting points from the ellipse.

Continue in the same manner until all points have been obtained, connect these points freehand, to complete the ellipse.

| | |
|---|---|
| ⚠ | **Note**: When the points on the outer circle are drawn horizontally, the minor axis will be horizontal and vice versa. |

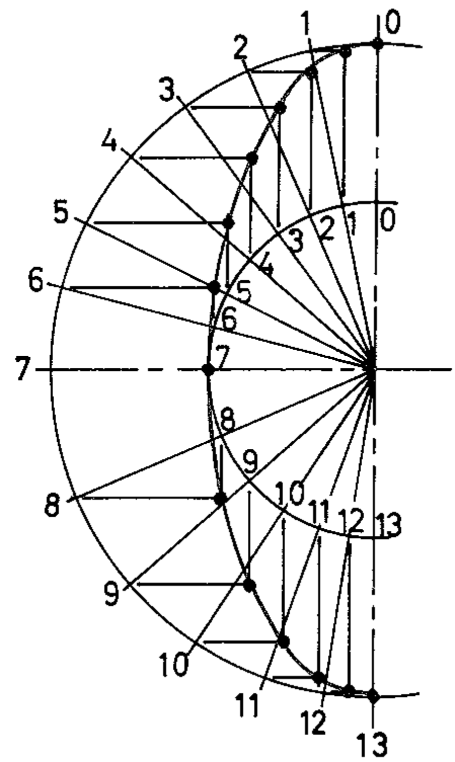



Figure 3.12 The ellipse, drawn using the two circle method

### 3.10.2 The development method

In development we find that we have to draw views not normal to the pipes i.e. cases where the end of the pipe would show as an ellipse.

To draw the ellipse, as seen in **Figure 3.13** below, divide the pipe in the front View and number division points. Project division points onto the normal end of the pipe marked X.X.

Now project points on X.X. in the direction of the view taken. Draw a centre line $X^1$ .$X^1$ normal to these projection lines to represent X.X.

Now we find, where points X and X cut the centre line $X^1$ .$X^1$ in the projection, we have two points.

Then project point 1 on the front view to centre line. $X^1$ .$X^1$ (extend beyond centre line),

Next, take measurement of 1.X. on the front view and place on both sides of the centre line $X^1$ .$X^1$ along point 1 projection line.

Repeat same procedure with all the points and join points obtained thus to complete the ellipse.

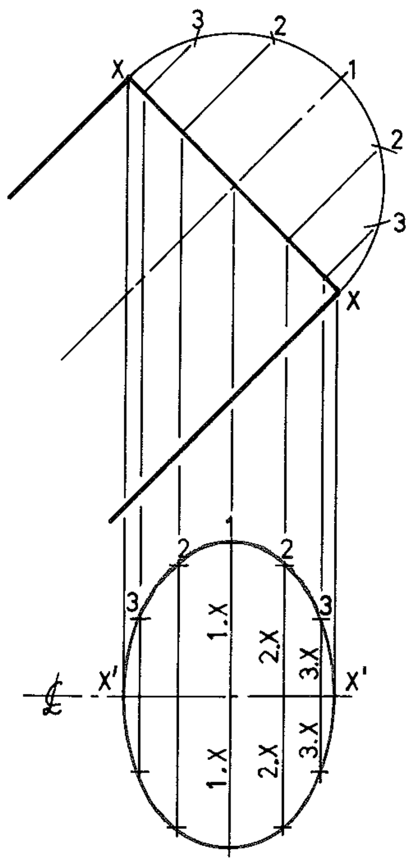



Figure 3.13 The ellipse drawn using the development method

## 3.11 Cutting planes:

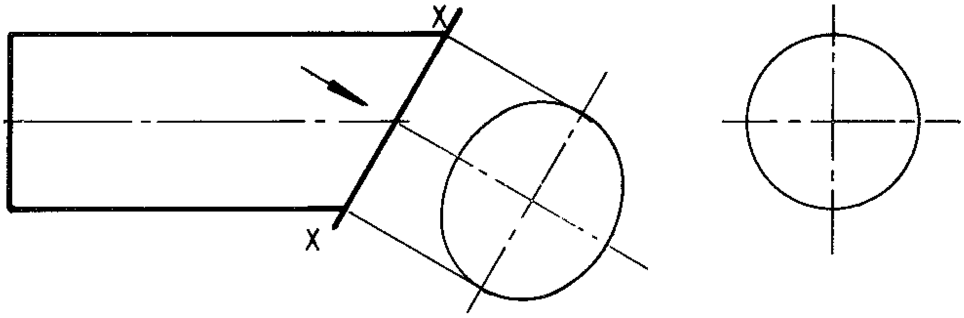



Figure 3.14 Cutting planes

### 3.11.1 Right pipe (round)

A right pipe (round), as seen in **Figure 3.15**, cut at any angle X.X. viewed normal to the cutting plane shows as an ellipse.

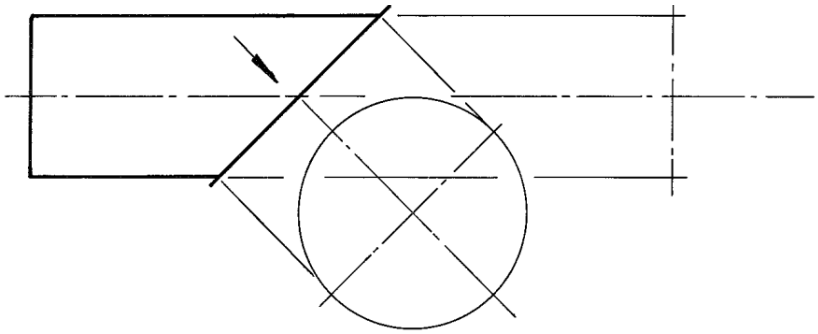


Figure 3.15 A right pipe (round)

### 3.11.2 Oblique pipe (elliptical)

It will be found that a cut at a specific angle viewed normal to the cutting plane shows as a circle.

**Important:**

From the points *3.11.1* and *3.11.2* we can state that;

If the view of a cutting plane (not normal to the pipe axis) shows as a circle, the pipe must be oblique.

### 3.11.3 Cones

| | | |
|---|---|---|
| X.X.(see **Figure 3.16**) | Normal to the centre line, cutting plane; | ROUND. |
| Y.Y.(see **Figure 3.16**) | Parallel to centre line, cutting plane; | HYPERBOLA. |
| Z.Z.(see **Figure 3.16**) | Parallel to side of cone, cutting plane; | PARABOLA. |

| | | |
|---|---|---|
| O.O.(see **Figure 3.16**) | Any cut between X.X. and Z.Z. cutting plane; | ELLIPSE. |

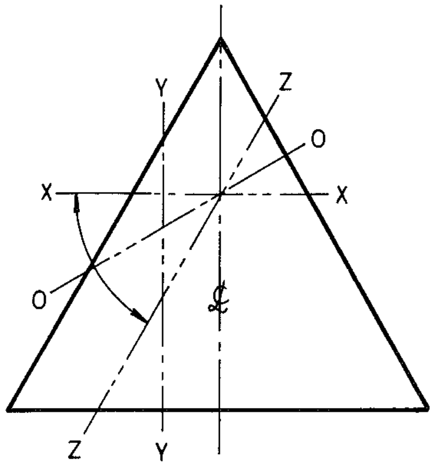



Figure 3.16 Cones

**3.11.4 Right cone**

a) When the base of a cone is normal to its centre line and shows as round in top view it is a *right cone,* as seen in **Figure 3.17**.

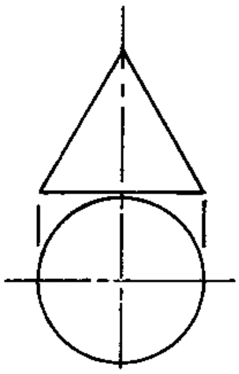


Figure 3.17 A right cone

b) When the base of a cone is not normal to its centre line and the centre line does not pass through the centre of the base of the cone it is a *right cone section,* as seen in **Figure 3.18**.

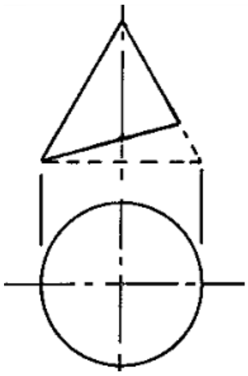


Figure 3.18 A right cone section

### 3.11.5 Oblique cone

a) When the base of a cone is not normal to its centre line and shows as round in top view it is an *oblique cone see* **Figure 3.19** below.

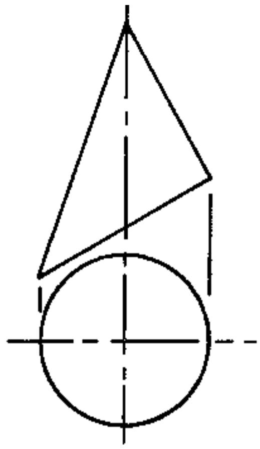


Figure 3.19 Oblique cone

b) When the base of a cone is normal to its centre line and the centre line does not pass through the centre of the base it is an *oblique cone,* as seen in **Figure 3.20** below.

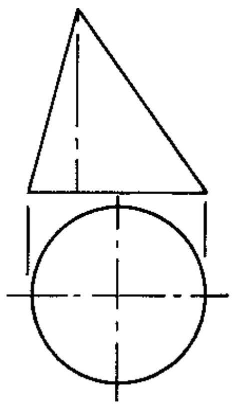


Figure 3.20 Oblique cone

## 3.12 Parabola (direct construction)

Consider **Figure 3.21,** on the following page, with the cutting plane A.O.

To construct the parabola draw a horizontal line Ai, A, Ai representing the base of the section as seen on the top view.

**Figure 3.21** shows a parabola drawn using direct construction.

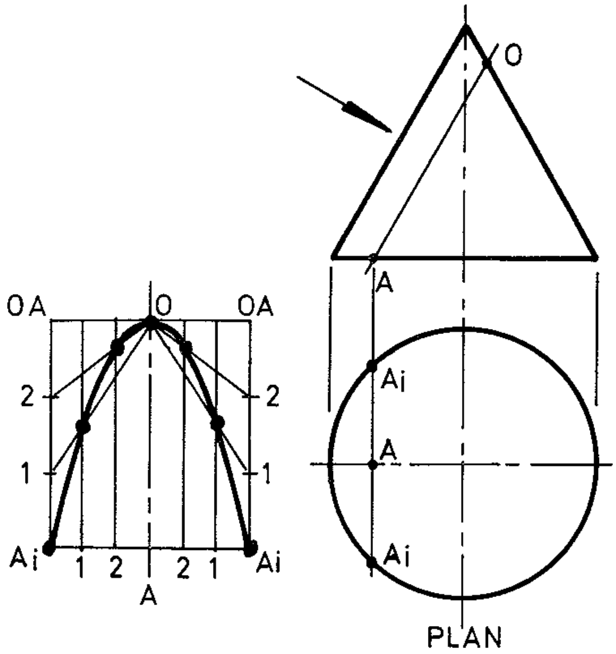



Figure 3.21 Parabola drawn, using direct construction

On A. construct a perpendicular with length A.O. Then draw a line parallel to Ai, A, Ai, through O, then from points Ai. draw lines vertical to cut line O, in points O.A.

Thus constructing a rectangular figure. Then divide Ai, A and Ai, OA, in equal number of divisions and number from point Ai. 1, 2, etc. From points on line A, Ai draw lines vertical up. From points on line Ai, OA draw lines to point O.

Where vertical line 1 intersects angular line 1, we have our first point of the curve.

Continue in the same manner with the other points and join all the points obtained thus freehand to complete the parabola.

## 3.13 Hyperbola (direct construction)

Consider **Figure 3.22** with the cutting plane X.O.A. To construct the hyperbola draw a horizontal line Ai, A, Ai, representing the base of the section as seen on the top view.

On A, construct a perpendicular with length A.O.X.

Then draw a line through O, parallel to Ai, A, Ai and from points Ai, draw lines vertical to cut line O in OA thus constructing a rectangular figure.'

Then divide Ai, A, and Ai, OA in equal number of parts and number from Ai, 1, 2, etc.

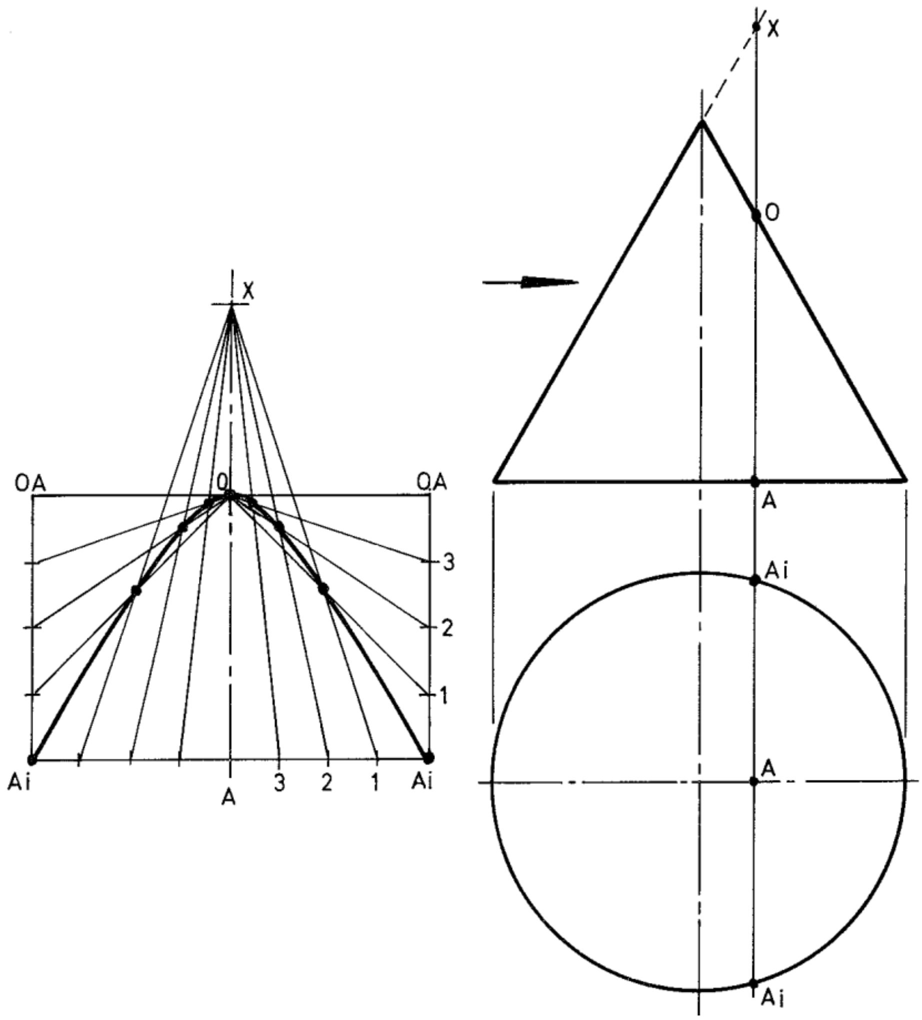



Figure 3.22 Hyperbola drawn, using direct construction

From points on Line A. Ai, draw lines to point X, and from points on line Ai, OA draw lines to point O. Where like numbered lines intersect we have our points of the curve, connect points to complete the hyperbola.

## 3.14 Cutting plane on cone (projection method)

In development the understanding of projections is very important, therefore we consider the following Cone.

Draw the front view and top view, divide and number the base in top view as shown then project these points to the base line of the front view of the cone.

Now draw lines from these points to the Apex of the cone marked Z in both the front view and top view to represent the bend lines.

Looking at the front view, take line O and where this line intersects cutting plane XX at $O^1$ project down to intersect line O in top view at $O^{11}$ which will be one point of the cutting plane in top view.

Continue this procedure with lines 1, 2, 4, 5 and 6 and obtain $1^{11}$, $2^{11}$, $4^{11}$, $5^{11}$ and $6^{11}$ in Top View, as seen in **Figure 3.23**.

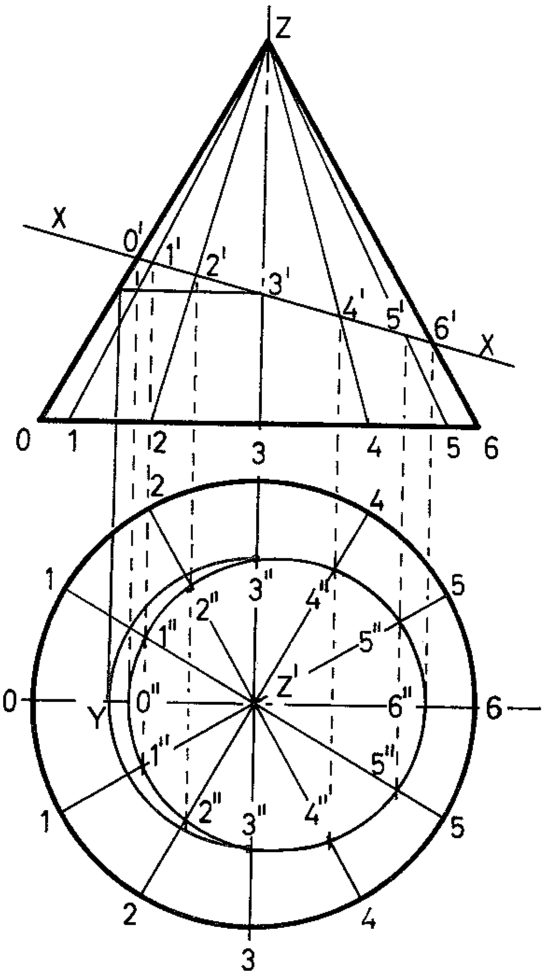



Figure 3.23 Cutting plane on cone; projection method

| | **NOTE:** |
|---|---|
| Point three was not done as you will find that by projecting the point $3^1$ down, you do not intersect the line three in top view.<br><br>We therefore have to turn the projection through 90° i.e. point $3^1$ in view is projected horizontally to the cone side line (turning through 90° in top view), where the line touches the side, project down to the top view on to the centre line 0.6 in top view to obtain point Y.<br><br>Then return this point through 90° by using $Z^1$ as centre and radius $Z^1$ Y, and scribing an arc to cut line 3 in top view at $3^{11}$. Connect all points obtained to from the cutting plane (Ellipse). | |

## Activity 3.1

1. From a line AB 40 mm long construct a perpendicular on a point C, 10 mm from point A.
2. From a line AB 60 mm long construct a perpendicular on a point midway between A and B.
3. With a line AB 80 mm long, construct the following: bisect line AB to obtain C from C draw a perpendicular line 30 mm long to end at D. Then bisect angle formed by DAC.
4. Divide a line AB 113 mm long into II equal parts.
5. Divide a line AB 103 mm long into 8 equal parts then bisect line AB.
6. From the following points find the centre and draw a circle to touch the three points, as seen in **Figure 3.24**.

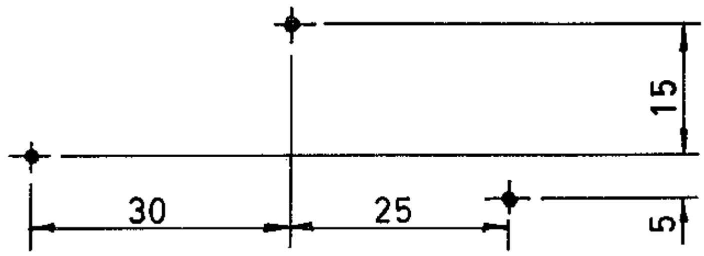



Figure 3.24

7. Construct a Hexagon with sides of 40 mm.
8. Construct a Pentagon with sides of 39 mm.
9. With a chord of 120 mm and mid-ordinate of 20 draw the curve (do not use a compass).
10. With a chord of II mm and a mid-ordinate of 50 draw the curve without using a compass. Then to check your construction, use the method of drawing a circle to touch three points.
11. Construct an ellipse with major axis 60 mm and minor axis 40 mm.
12. Complete the end view in the direction of arrow "A" of the pipe in **Figure 3.25,** shown by the development method.

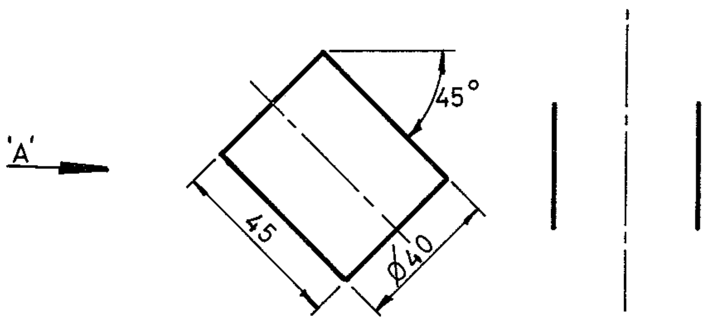



Figure 3.25

13. Draw the section in the direction of arrow "A" of **Figure 3.26**.

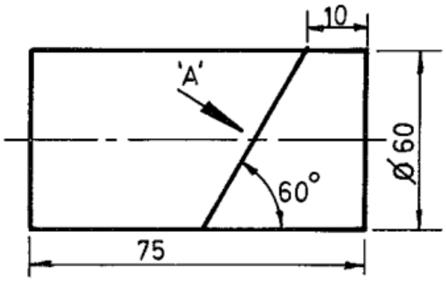



Figure 3.26

14. Which would be a right cone; **Figure 3.27** or **Figure 3.28**?

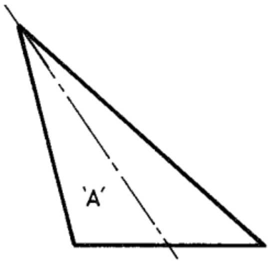



Figure 3,27

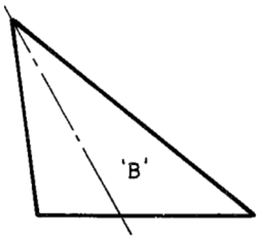



Figure 3.28

15. Name the four cutting planes found on a cone.
16. From **Figure 3.29** construct the parabola and the hyperbola and name each.

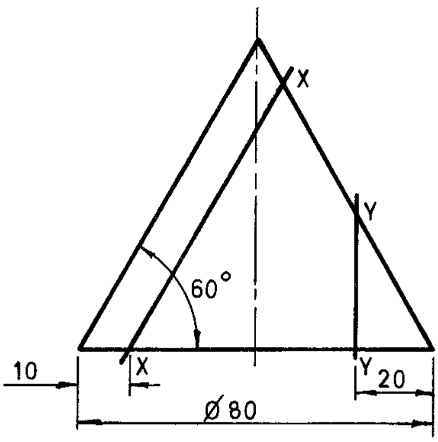



Figure 3.29

**Self-Check**

| **I am able to:** | **Yes** | **No** |
|---|---|---|
| • Describe the following; | | |
| o A right angle | | |
| o Bisecting | | |
| o Line division | | |
| o How to draw a circle to touch 3 points: | | |
| o Constructing a hexagon | | |
| o Constructing a pentagon | | |
| o Dividing a circle into 12 equal parts | | |
| o How to draw the curve of a segment if the chord | | |
| and mid-ordinate are given | | |
| o The ellipse | | |
| o Cutting planes: | | |
| o Right pipe (round) | | |
| o Oblique pipe (elliptical) | | |
| o Right cone | | |
| o Oblique cone | | |
| o Parabola (direct construction) | | |
| o Hyperbola (direct construction) | | |
| o Cutting plane on cone (projection method) | | |
| If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 4

# Parallel Line Developments

**Learning Outcomes**
On the completion of this module the student must be able to:

- Define the following drawing hints and pipe facts:
  - Circumference
  - Division and numbers
  - The central ball theorem
- Describe the following development of straight pipes:
  - Pipe with Angle Cut
  - Double Angle Cut pipe
- Explain the division on lobster back bends
- Describe the development of a Right "Y" piece
- Describe the development of an Oblique "Y" piece
- Describe the basic pipe to pipe interpenetration principles
- Describe the different pipe to pipe interpenetrations:
  - Pipe to pipe equal diameters
  - Pipe to pipe unequal diameters on centre
  - Pipe to pipe unequal diameters off centre
  - Rectangle to pipe on centre
  - Rectangle to pipe off centre
  - Pipe to rectangle on centre
  - Pipe gusset

## 4.1 Introduction

This module discusses in detail, parallel line developments. Make sure to grasp the drawing hints and pipe facts and to understand the basic principles involved for the various developments.

## 4.2 Drawing hints and pipe facts

### 4.2.1 Circumference

On development we cannot afford to work to approximations.

Therefore for all developments the circumference has to be calculated on the mean diameter.

**4.2.2 Division and numbers**

As can be seen from **Figure 4.1**, when a pipe is divided circumferentially, we cannot simply take the measurement of the division as the circumference will be too short.

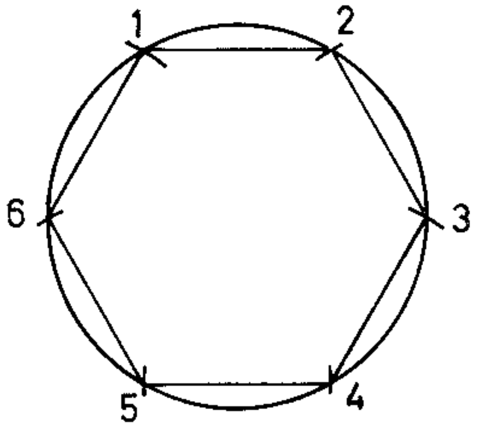



Figure 4.1 A pipe divided circumferentially

Consider a circle with radius 20 mm, from our geometry *section 3.8*, we know that the distance between points 1 to 2, etc., is equal to the radius if measured straight across as a chord, therefore, by measuring the circumference on the divisions we find that it would be a 6 X 20 = 120 mm.

But by calculation $2\pi r = 2 \times \pi \times 20 = 125{,}68$ mm or $\pi D = \pi \times 40 = 125{,}68$ mm, as can be seen on a circle of 40 mm diameter we have a difference of 5,68 mm.

**NOTE:**
If we look at **Figure 4.2** you will see why we use the mean diameter for calculations. When we bend a plate, we find that the outer side stretches and the inner side shrinks, while centrally we find an area that remains neutral. That is why we use the mean diameter.

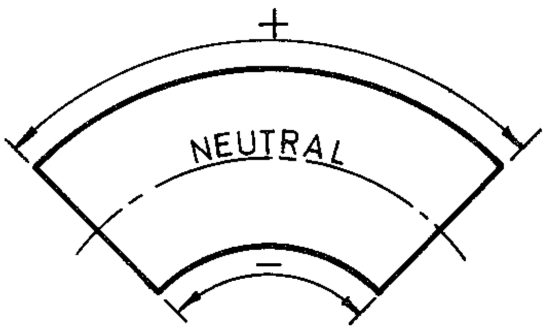



Figure 4.2 The mean diameter

**NOTE:**
When developing, we usually divide the pipe into equal divisions which denotes imaginary bend lines, these bend lines should be numbered to avoid losing a point when we start projecting and positioning.

The usual number of divisions is 12; this is not compulsory as the more divisions we use the more accurate will the development be. We use 12 because this is a simple division to use, see *section 3.8*.

### 4.2.3 The central ball theorem

This theorem states that if intersecting pipes have both sides in view, touching a common central ball, the lines of interpenetration will be straight lines, see **Figure 4.3** below:

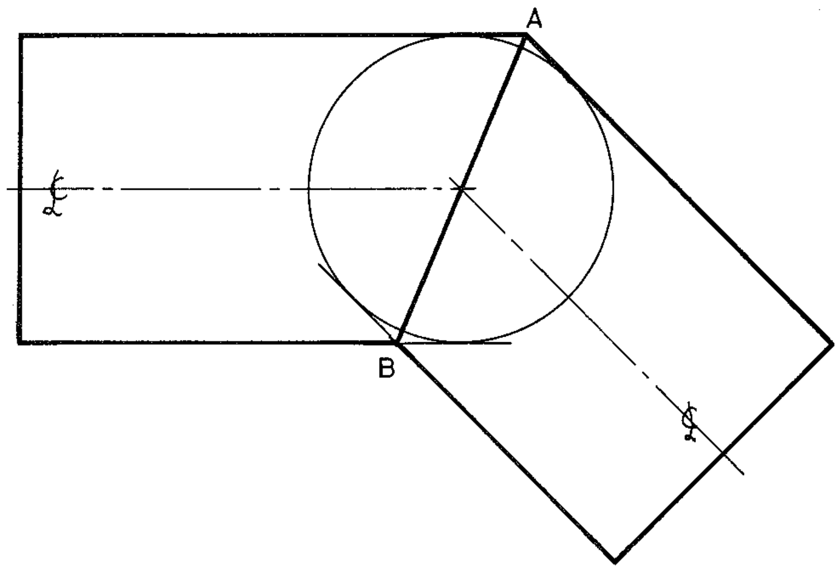



Figure 4.3 The central ball theorem illustrated

To find the line of interpenetration we use the point of intersection on the outside of the elbow formed by the pipes (A) and the point of intersection on the insides of the elbow (B). By connecting these points we have the lines of interpenetration

**NOTE:**
The intersection of the centre line of the pipes is also the centre of the ball.

**NOTE:**
When starting a development we require an accurate drawing of the development; if the drawing is wrong or inaccurate, the development will be wrong.

| | |
|---|---|
| | On development it is always advisable to start drawing from the centre lines as this should avoid the danger of drawing oblique pipes.<br><br>Your development can only be as neat, correct and accurate as your drawing. |

## 4.3 Developing straight pipes:

Considering **Figure 4.4** of a pipe below imagining that we cut through the pipe on line O.O we would be able to open up the pipe to form a straight plate.

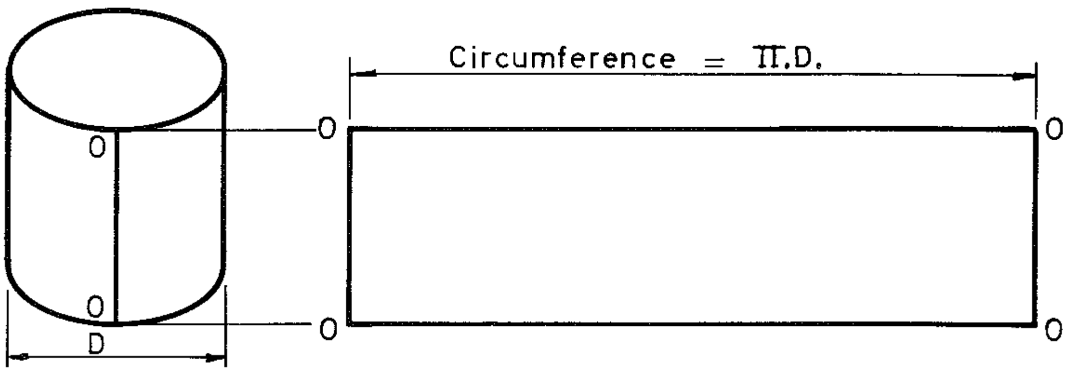



Figure 4.4 A pipe

We see from the **Figure 4.4** that the plate width would be the same as the length of the pipe and the length of the plate would be equal to the circumference of the pipe.

### 4.3.1 Pipe with Angle Cut

Draw the view as shown, divide pipe into 12 equal parts and number 0, 1, 2, etc., always starting at the shortest side, then project division lines through the whole length of the pipe, see **Figure 4.5**.

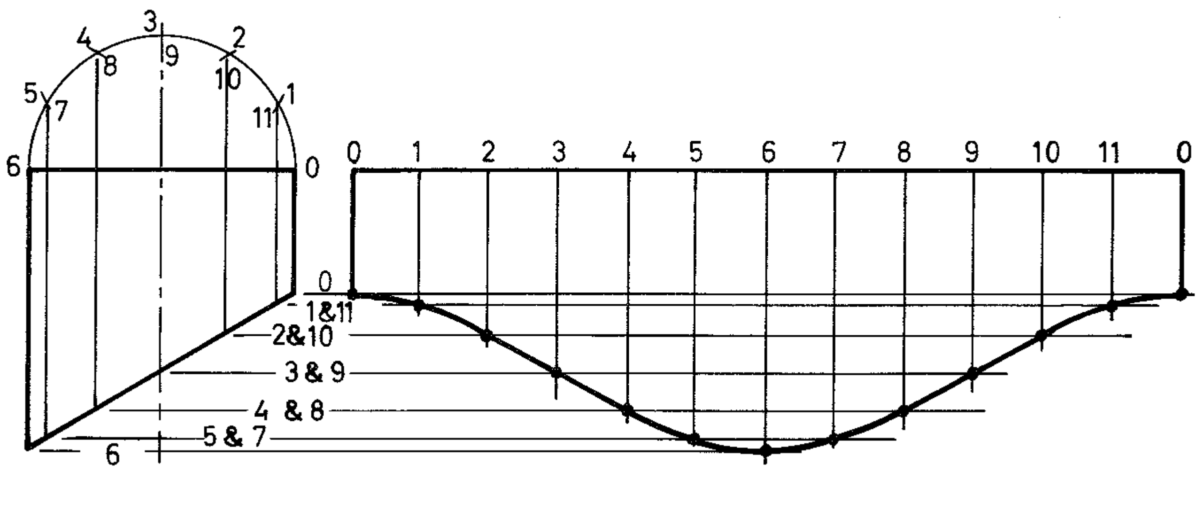



Figure 4.5 Pipe with an angle cut

Now project the points of the projection lines out normal to the pipe centre line and number these lines as well.

(You will notice that at the top where the pipe is cut normal all the points fall on the same line).

Now calculate and measure the circumference along the projection line to give us points O.O which is the length of the plate required to roll the pipe.

The following step is to divide this length O.O into 12 equal parts (see *section 3.4*) and number these divisions 0, 1, 2 etc. then project them down to intersect the projection lines drawn across from the view.

Where the like numbered projection lines cross1 we have the points of our development. Complete the development by joining these points with a continuous curved line.

**NOTE:**
On right pipes the circumference must always be measured along a line normal to the axis of the pipe.

**4.3.2 Double Angle Cut pipe**
As we have no straight cut on this pipe, we measure the circumference on any auxiliary line normal to the pipe. In this case, 0.6 in the view, and O.O in the development.

We also use this line to divide our pipe. Divide and project the division 'lines as for the previous example and number.

Complete similar to previous example by joining the like numbered line intersection points, as seen in **Figure 4.6**.

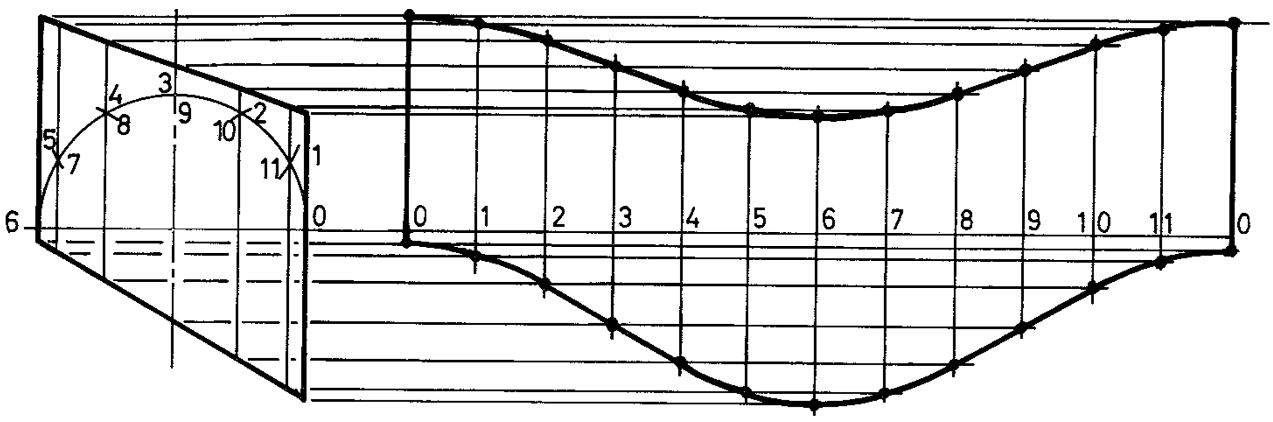



Figure 4.6 Double angle cut pipe

**NOTE:**
In this development you have two sets of intersection joints and you can now appreciate that if you do not number your division lines properly it could and most probably would confuse you, which would lead to a faulty development.

## 4.4 Division on lobster back bends

a) It should be noted that the two end segments of a lobster back bend are always half of the other segments regardless of the number of segments required as seen in **Figure 4.7**.

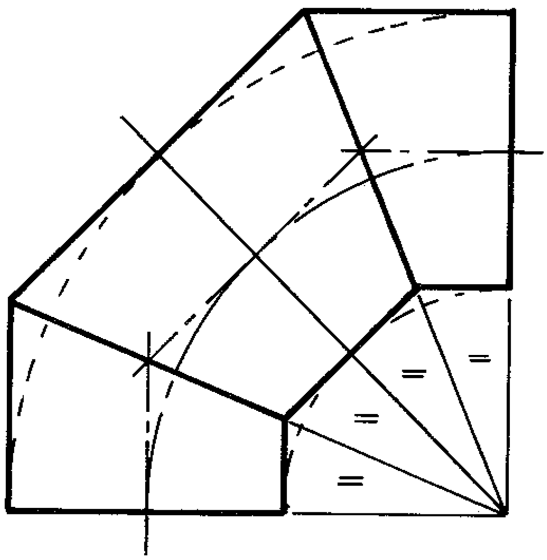


Figure 4.7 Division on lobster back bends

b) The golden rule for dividing on your development is: add all your half segments, i.e. add the full segments X 2 and add 2. Therefore, for this figure we would have 1 X 2 = 2 + 2 = 4.

   Therefore, on starting our drawing we would divide our bend area into four equal parts

c) Draw the bend as a continuous curve bend then divide the bend into four equal parts (we can do this by bisecting the Angle twice or by dividing 90° by 4).

   To complete the drawing we start at points marked X and draw lines normal to the face up to our first angle division line giving us points Y.

   This would give us our first segments. Then we couple the two segments by joining the joints marked Y together to complete the bend, as seen in **Figure 4.8**.

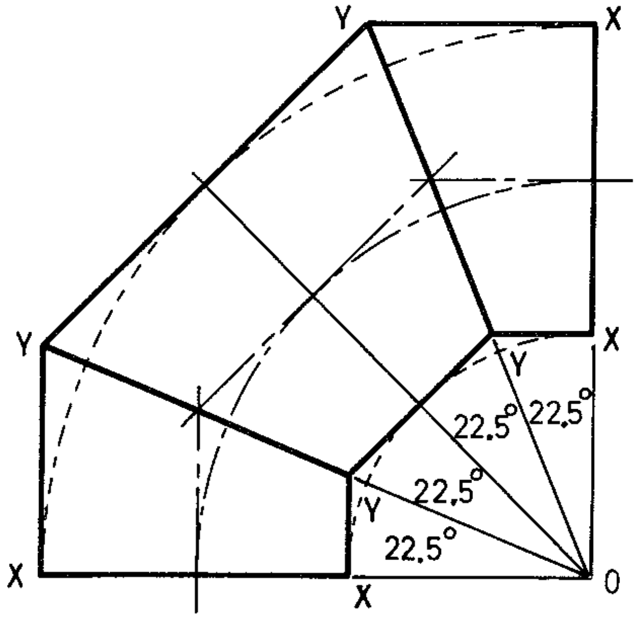



Figure 4.8 Dividing the bend angle into 4 different parts

d) Consider the following lobster back bend: (4 segments) first of all looking at the drawing we see that we have 2 full segments and 2 half segments.

   Therefore, we have 2 X 2 = 4 + 2 = 6 and we would therefore divide our bend angle into 6 equal parts (90° + 6 = 15°) as seen in **Figure 4.9** below.

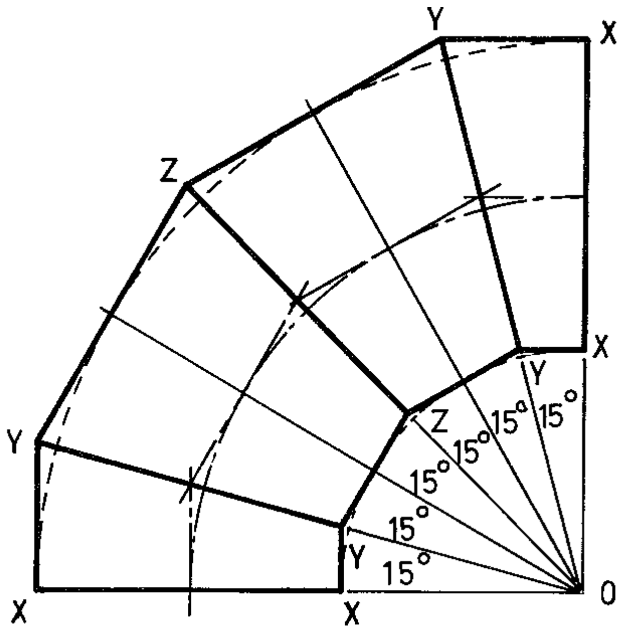



Figure 4.9 Dividing the bend angle into 6 equal parts

| | |
|---|---|
| ⚠ | **NOTE:**<br>For completing the full segments we draw a line from Y at a tangent to the continuous curve (touching the bend) and intersecting the division Z.Z.<br><br>Another method to obtain points, Z, we use centre of bend radius point O and radius on Y and scribe an arc to cut your division line at Z. |

## 4.5 Right "Y" piece

To draw the right "Y" it is always important to start by drawing the centre lines and with centre O where the centre lines join, we draw the central ball with diameter of the pipe required.

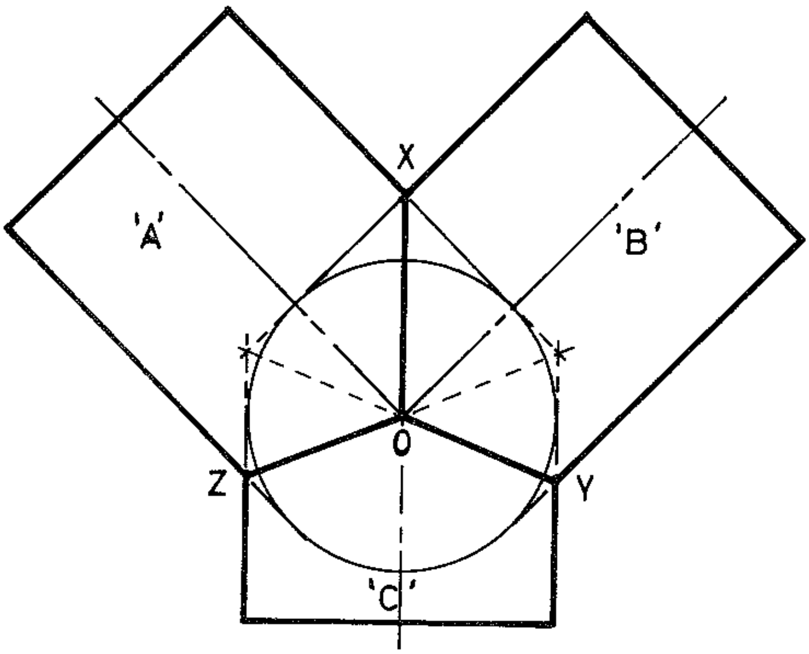



Figure 4.10 Right 'Y' piece

To complete the drawing as in **Figure 4.10**, draw tangent lines on the circle parallel to the centre lines.

On completing the drawing we see that pipes A and B are exactly the same, therefore, it is only required to do two developments i.e. pipes A and C.

To obtain the lines of interpenetration (cutting lines) we use the central ball theorem as described in *section 4.2.4*.

*We* then find that we start with the points where the pipe outlines intercept at X, Y and Z.

We draw these lines to the centre of our ball which is also where the centre lines of the pipe intercept. The lines are then our cutting lines. Now divide and number the pipes and develop as described in *section 4.3.1*.

## 4.6 Oblique "Y" piece

Looking at this drawing we see that the cut at Z.Z is not normal to the centre line of the pipe "B" but shows to be round.

From this and our notes on *section 3.11.2, we* know that the pipes A and B are not round pipes but oblique pipes (elliptical).

Therefore, we cannot apply the central ball theorem to develop the pipe "B" we will consider the pipe on its own.

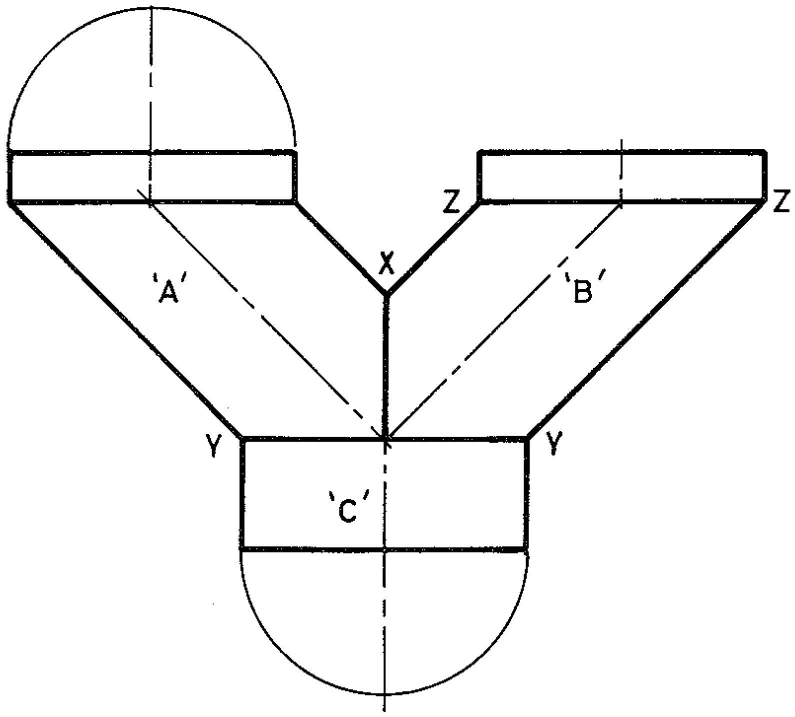



Figure 4.11 Oblique 'Y' piece

Divide the pipe and number as shown in **Figure 4.11**, then project the points obtained thus normal to the centre line of the pipe. As the pipe is not round we calculate the circumference at the cut Z.Z. and divide by 12.

Using one division set the compass and starting at a random point on line 6, we step off the distance with the compass from point 6 to line 5 and from 5 to line 4, etc., until we have 12 parts which brings us back to line 6.

This gives us the circumference. Now, project the points obtained thus down.

These lines now become our bend lines. Then project the numbered points on the pipe cutting line XCY across to intercept the numbered bend lines to give us the bottom points.

Connect all points with a curved line to complete the development as in **Figure 4.12**.

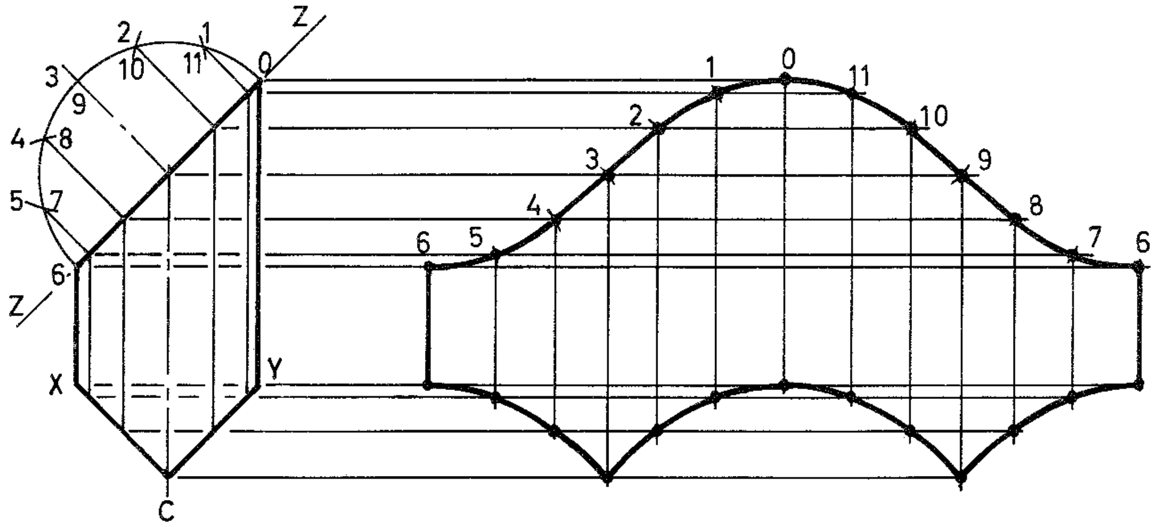



Figure 4.12 Completed development

## 4.7 Pipe to pipe interpenetrations

### 4.7.1 Basic Principles

a) Draw the front View as given, neatly and accurately.
b) Project and draw an auxiliary side View in line with the main pipe showing the branch pipe.
c) Divide branch pipe in both Views and number correctly (see **Figure 4.13**) using the watch notation to avoid confusion.
d) Project numbered division points of branch pipe in side View down to touch the main pipe
e) Where division lines touch main pipe project across to front View
f) Project numbered division points in front View down to intersect like numbered projection lines from the side Views to give us the points of interpenetration.
g) Join points to give line of interpenetration
h) Develop branch pipe as we have seen in *section 4.3.1,* by projecting from front View normal to pipe centre line.
i) Develop main pipe with hole for branch pipe by projecting from front View and taking circumferential dimensions from side View.
j) All circumferences must be calculated:
k) Note: On pipes with equal diameter the line of interpenetration is always a straight line and pipes of unequal diameter will have curved lines of interpenetration.

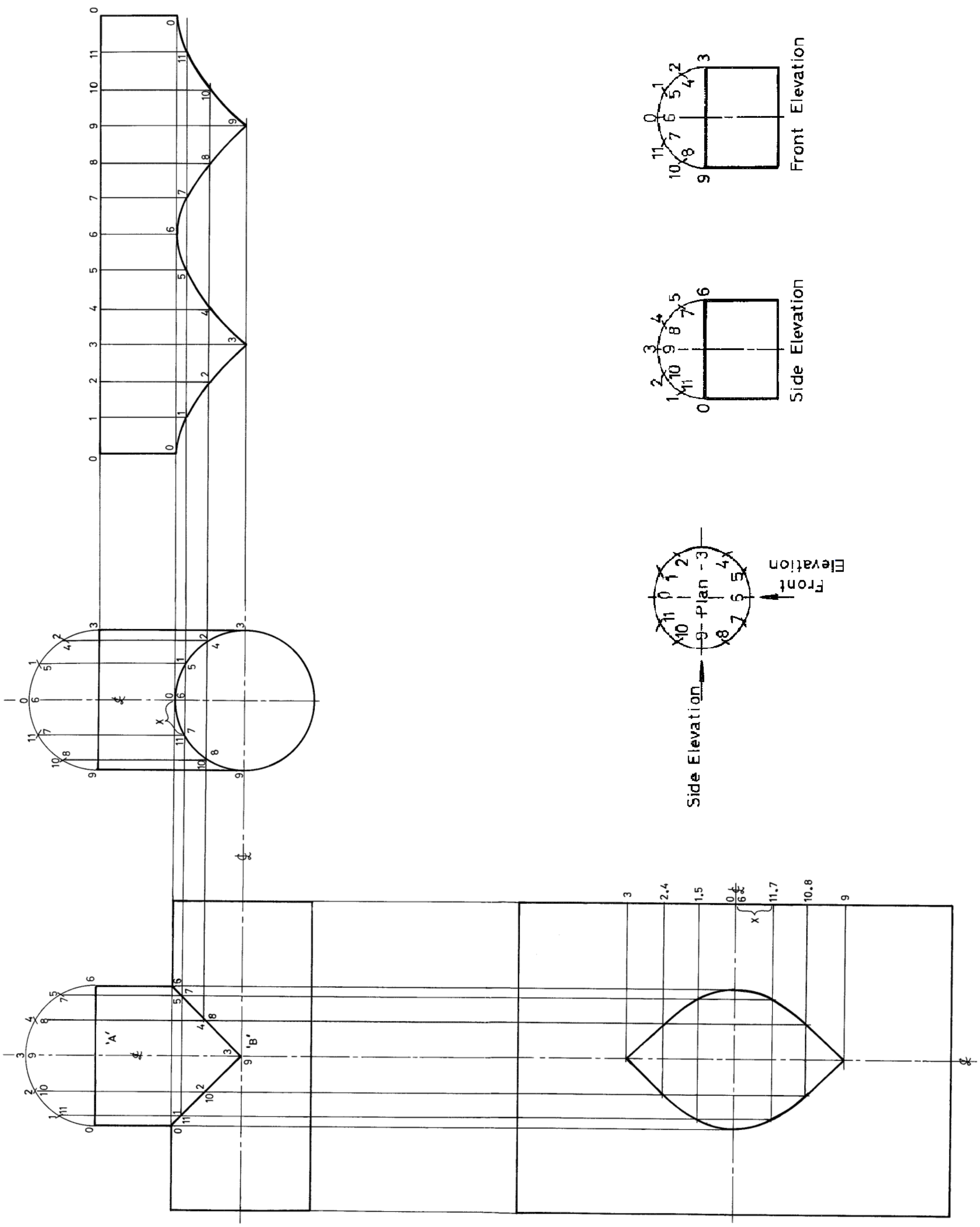



Figure 4.13 Pipe to pipe interpenetrations

### 4.7.2 Pipe to pipe equal diameters

Pipe to pipe equal diameters are illustrated in **Figure 4.14** below.

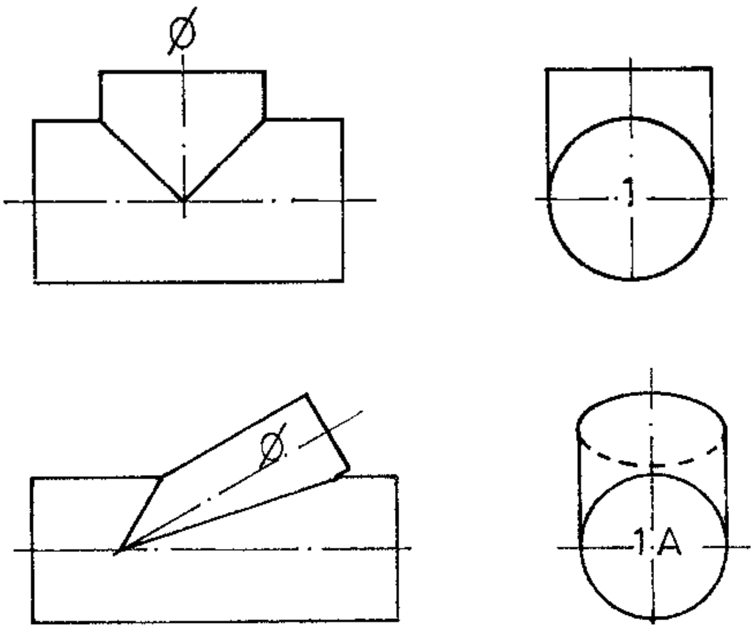



Figure 4.14 Pipe to pipe equal diameters

- **Development (1) Figure 4.15:**

a) Draw the front view as shown.
b) Draw auxiliary side view in line with main pipe.
c) Divide and number branch pipe 'A' in both Views.
d) Project numbered division points of the branch pipe in the auxiliary side view down to the main pipe 'B'.
e) Where division lines touch the main pipe, project across to front view.
f) Project numbered division points in front view down to intersect like numbered projection lines from the side view to give us the points of interpenetration.
g) Join these points to give the line of interpenetration (note where the pipes are of the same diameter, these interpenetration lines are always straight lines).
h) Calculate the circumference of the pipes.
i) Develop the branch pipe as we have seen in *section 4.3.1*, by projecting from front view normal to branch pipe centre line.
j) For developing the shape of the hole in pipe 'B' we project points of intersection on front view down.

   Then working from the centre line marked 'A' inside view drawn normal to projection lines from front view. We step off distance A to B, B to C and C to D on either side of the centre line A in the development.

**NOTE:**
For accuracy, these distances have to be calculated as follows: circumference ÷ 12.

Now project these points parallel to the centre line, to cut projections from the front view.

Now looking at the side view we see that point A is connected to points 6 and O, therefore, the same has to be true for the projection lines for the hole.

We thus mark the points where line A cuts lines 6 and O and similarly line B cut lines 11, 7, 1 and 5. The same goes for line C and D.

Connect points obtained thus to complete shape of the hole.

k) Note that on the pipes with equal diameters the line of interpenetration is always a straight line and pipes of unequal diameters will have curved lines of interpenetration.

**NOTE:**

1. It will be seen on the front view that we have a sharp corner on the line of interpenetration, therefore, the hole will also have a sharp corner.

2. It will be seen that the hole as well as the pipe development is symmetrical about the centre line, this is always the case where the branch is central on the main pipe.

3. By swinging the curved line XY on the branch pipe development about points X, we find that we have *the* shape of the hole - see dotted lines. This is always true for all pipe developments of equal diameter.

**Figure 4.15,** on the following page, illustrates the development (1) of pipe to pipe with equal diameters.

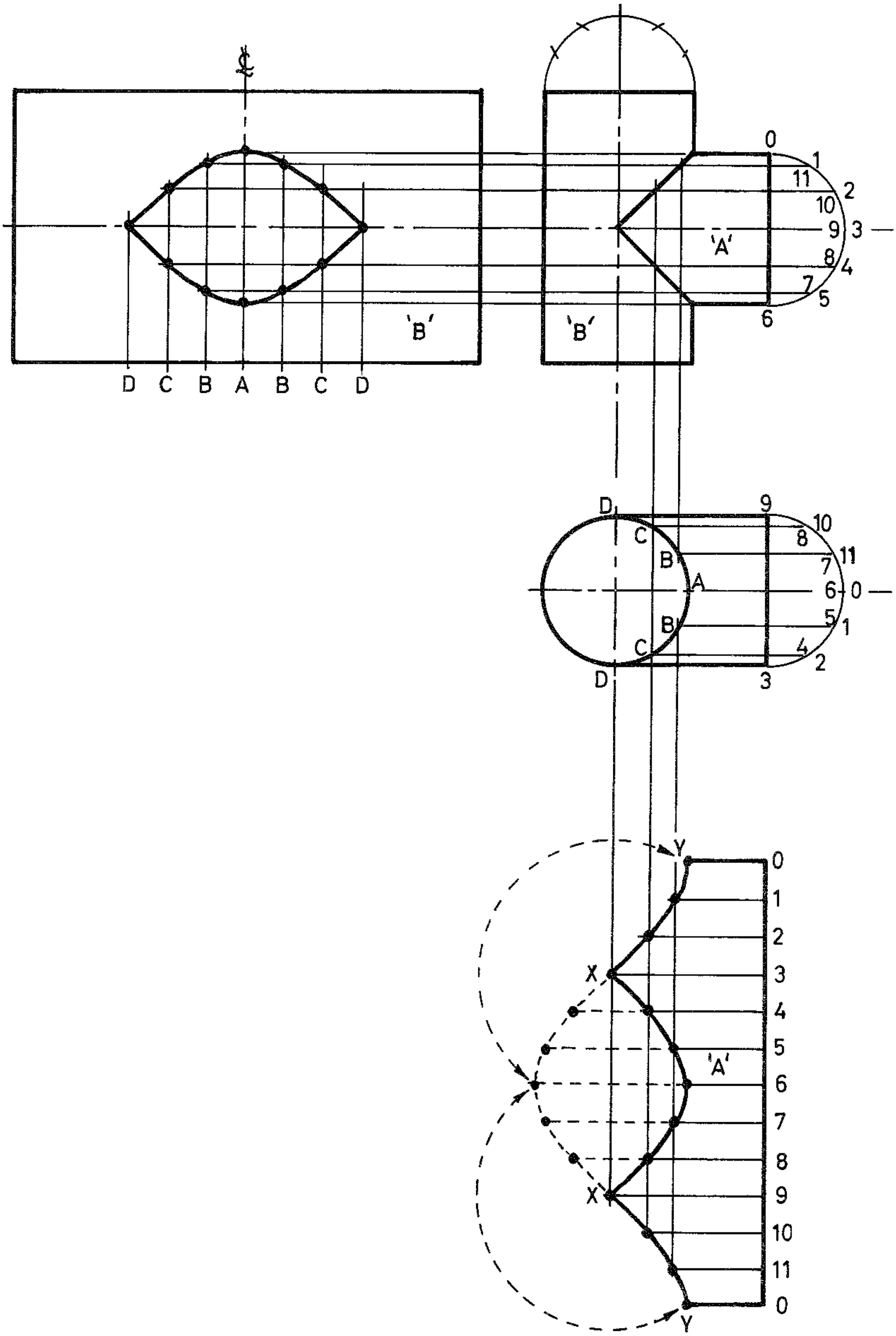



Figure 4.15 Development (1) of pipe to pipe with equal diameters

- **Development (1A)** as in **Figure 4.16:**

This development is done exactly as *section 4.7.2* point's a-k and the above *Note* bullet point '2'.

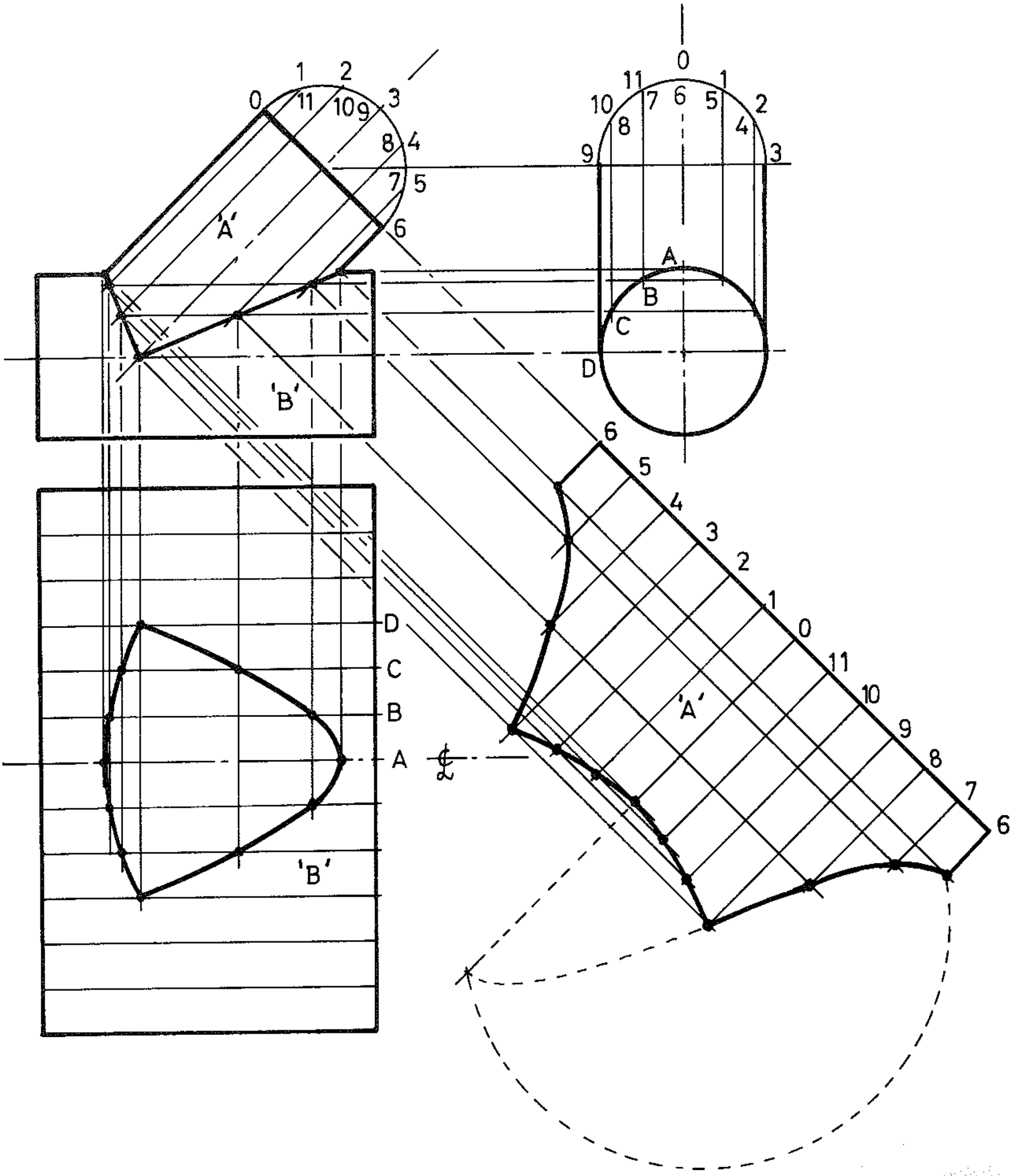



Figure 4.16 Development (1A) of pipe to pipe with equal diameters

### 4.7.3 Pipe to pipe unequal diameters on centre

Pipe to pipe unequal diameters on centre are illustrated in **Figure 4.17** below**.**

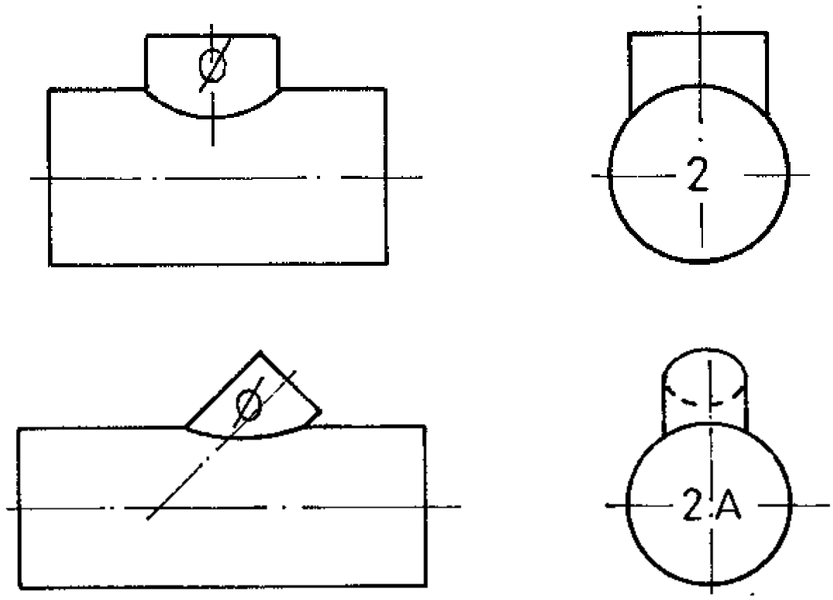



Figure 4.17 Pipe to pipe unequal diameters on centre

- **Development (2)** as in **Figure 4.18**:

This development is done exactly as *section 4.7.2* point's a-k and the previous *Note* bullet point '2'.

**NOTE:**

As we have pipes of unequal diameter, we will need to calculate the circumference of both the large pipe, for use when we develop pipe "B" with the hole and the smaller pipe for the development of pipe "A".

The dimension A to B, B to C and C to D for developing the hole in the pipe "B" is taken from the side View with a compass.

(Do not take dimensions from A to C and A to D as this increases the error that we have, considering the fact that we measure a straight line instead of around the curve).

**Figure 4.18**, on the following page, illustrates the development (2) of pipe to pipe unequal diameters on centre.

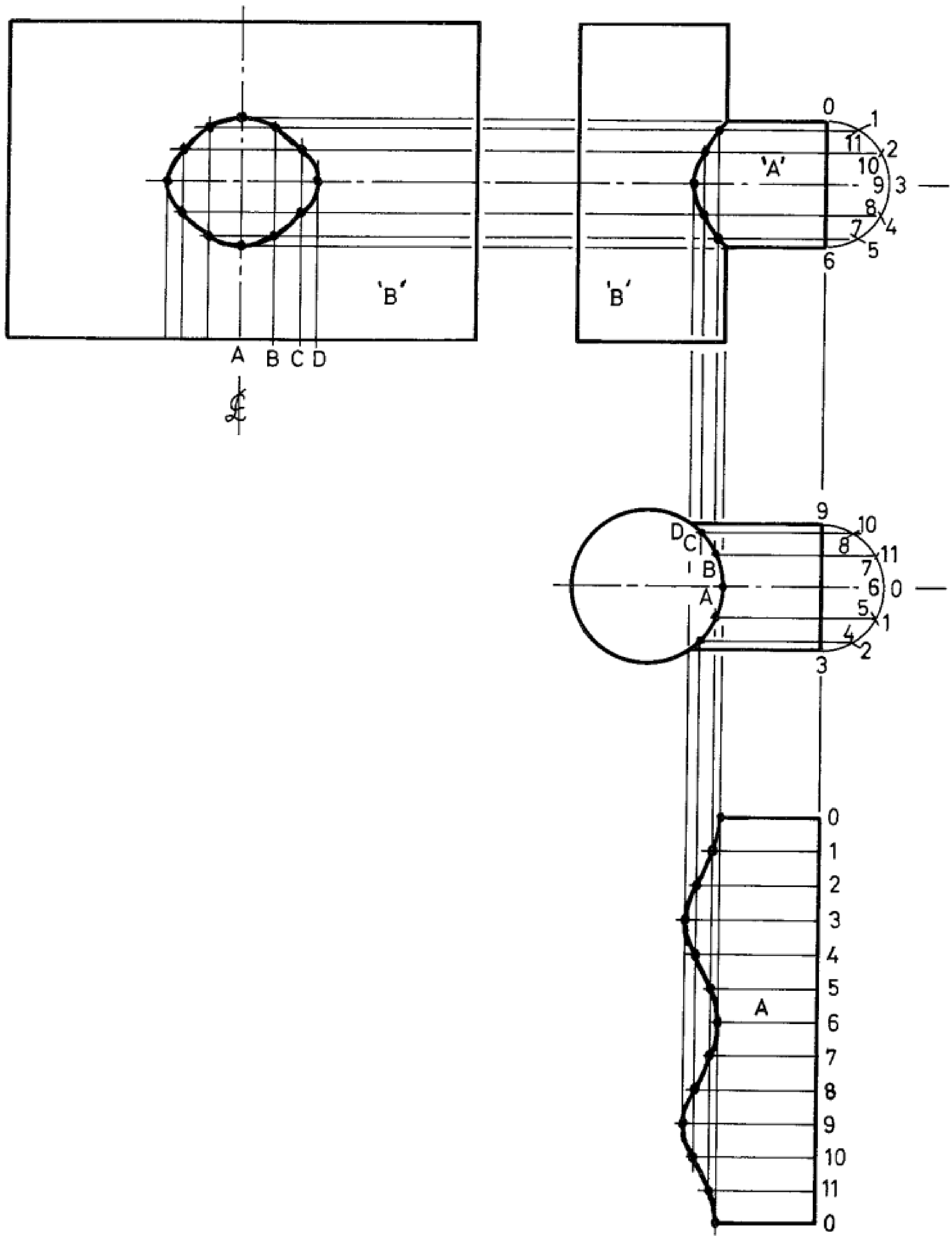



Figure 4.18 Development (2) of pipe to pipe unequal diameters on centre

- **Development (2A)** as in **Figure 4.19:**

This development is done as per *section 4.7.3*.

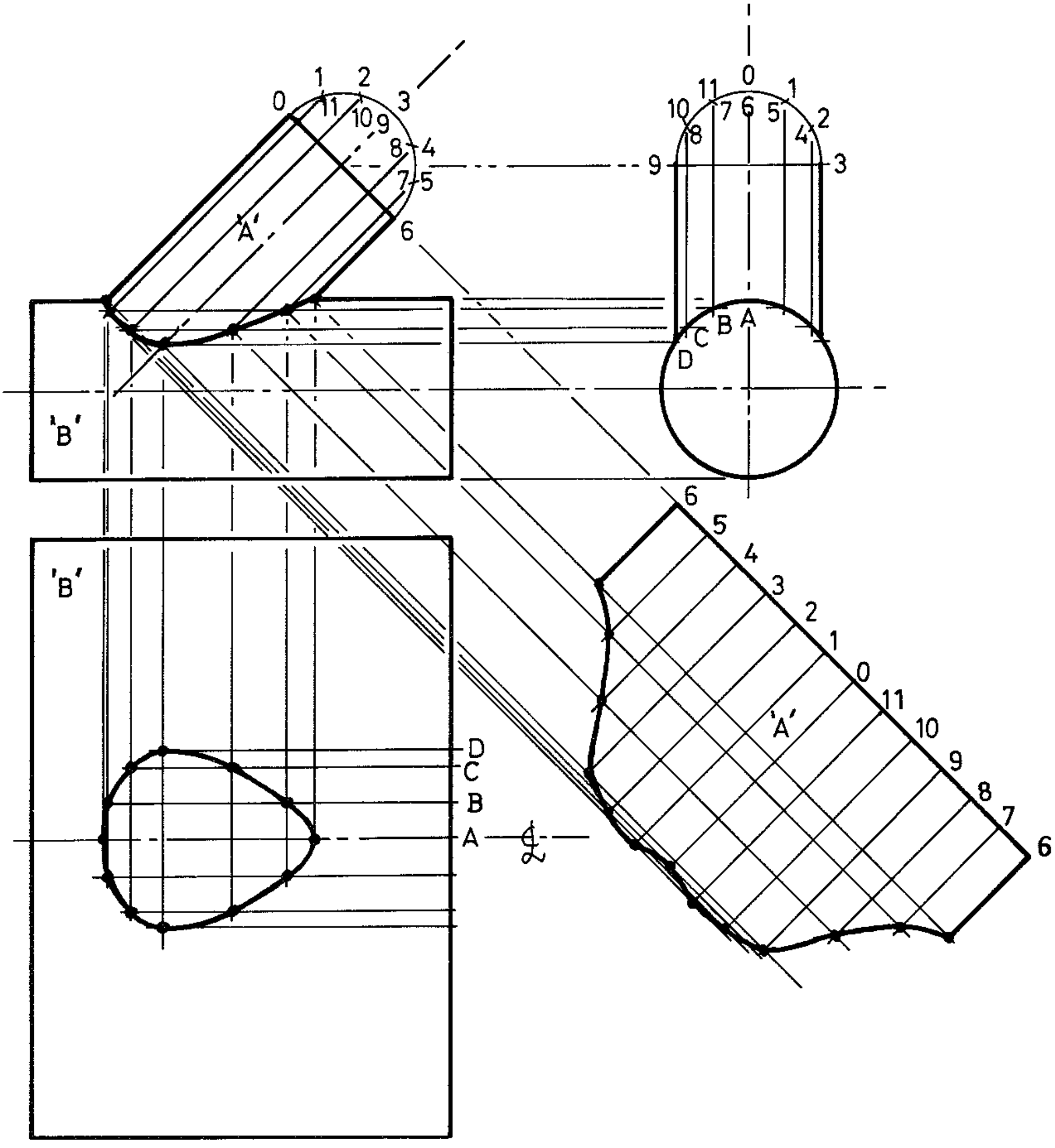



Figure 4.19 Development (2A) of pipe to pipe unequal diameters on centre

### 4.7.4 Pipe to pipe unequal diameters off centre

See **Figure 4.20.**

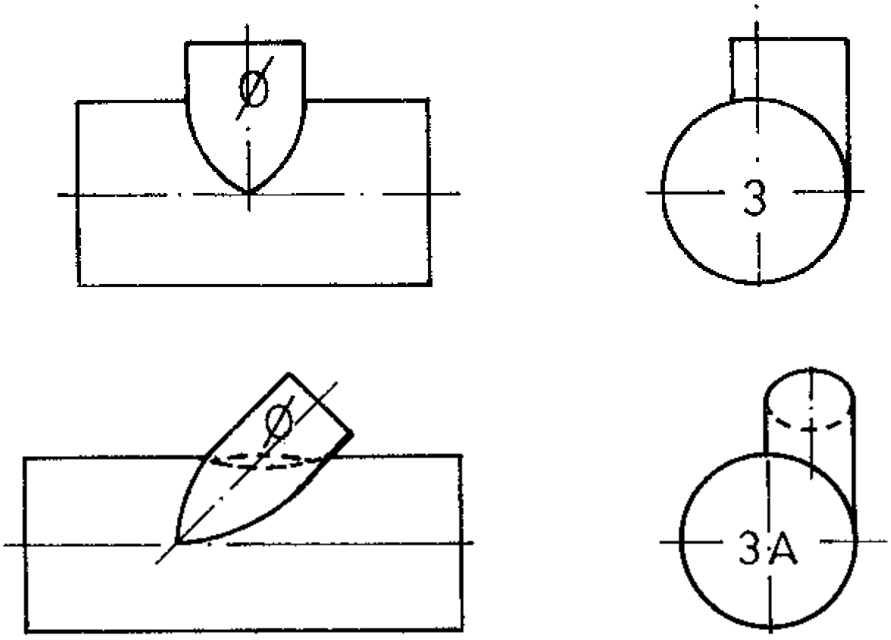



Figure 4.20 Pipe to pipe unequal diameters off centre

- **Development (3)** as in **Figure 4.21:**

This development is done as per development 2(A) above**.**

**NOTE:**
It will be seen that the dimension of the hole is not symmetrical about the centre line, but we still work about the centre line to take the dimensions although A is not on the centre line.

We therefore, place the centre line normal to the projection lines and mark off centre line to A, A to B, B to C, A to D, D to E, E to F and F to G.

**NOTE:**
On looking at this development it should be clear that it is of the utmost importance to number all points

As the projection lines come so close to each other, that you could very easily become confused.

**Figure 4.21,** on the following page, illustrates the development (3) of pipe to pipe unequal diameters off centre.

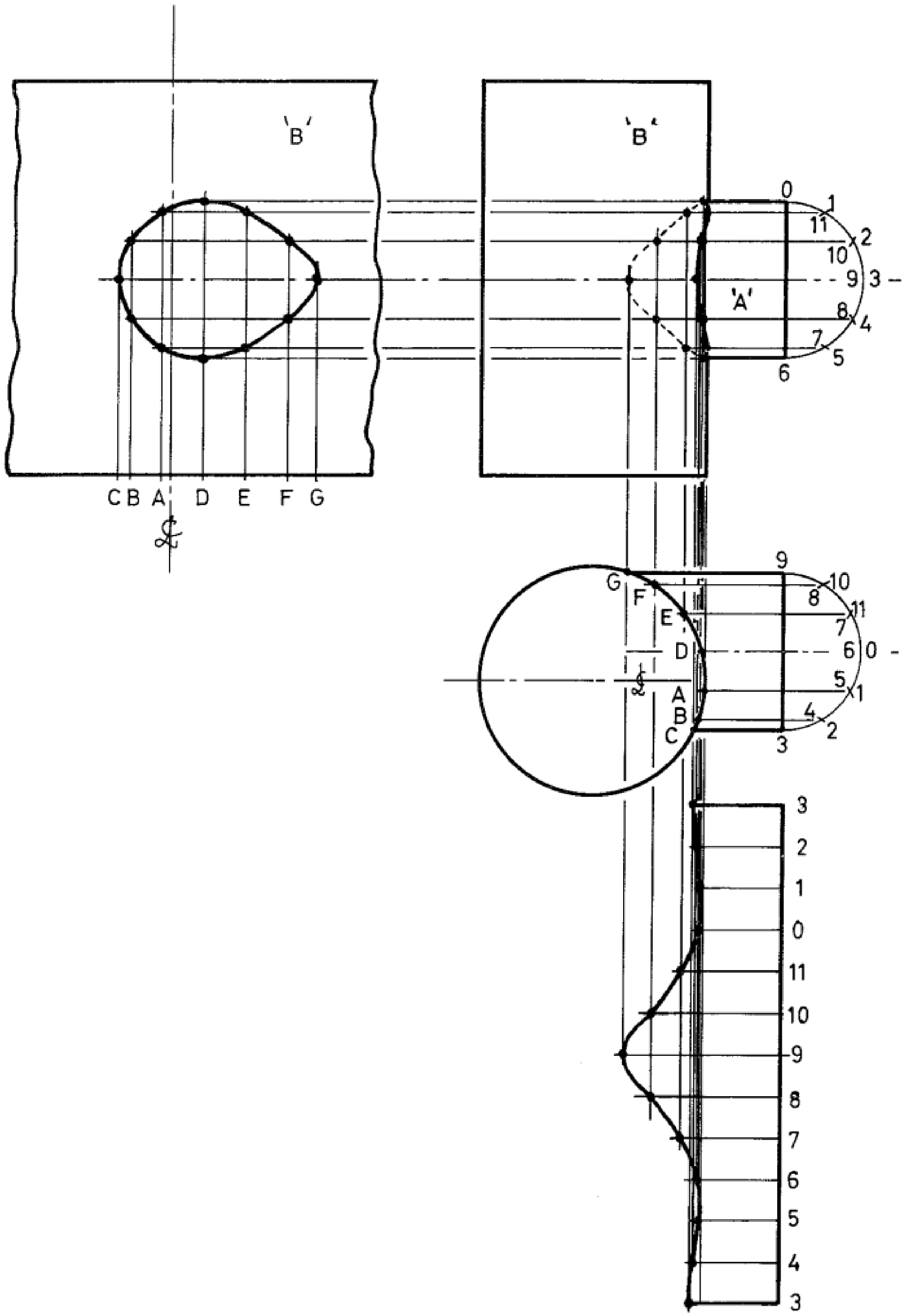



Figure 4.21 Development (3) of pipe to pipe unequal diameters off centre

- **Development (3A)** as in **Figure 4.22:**

Similar to development (3), *section 4.7.4*.

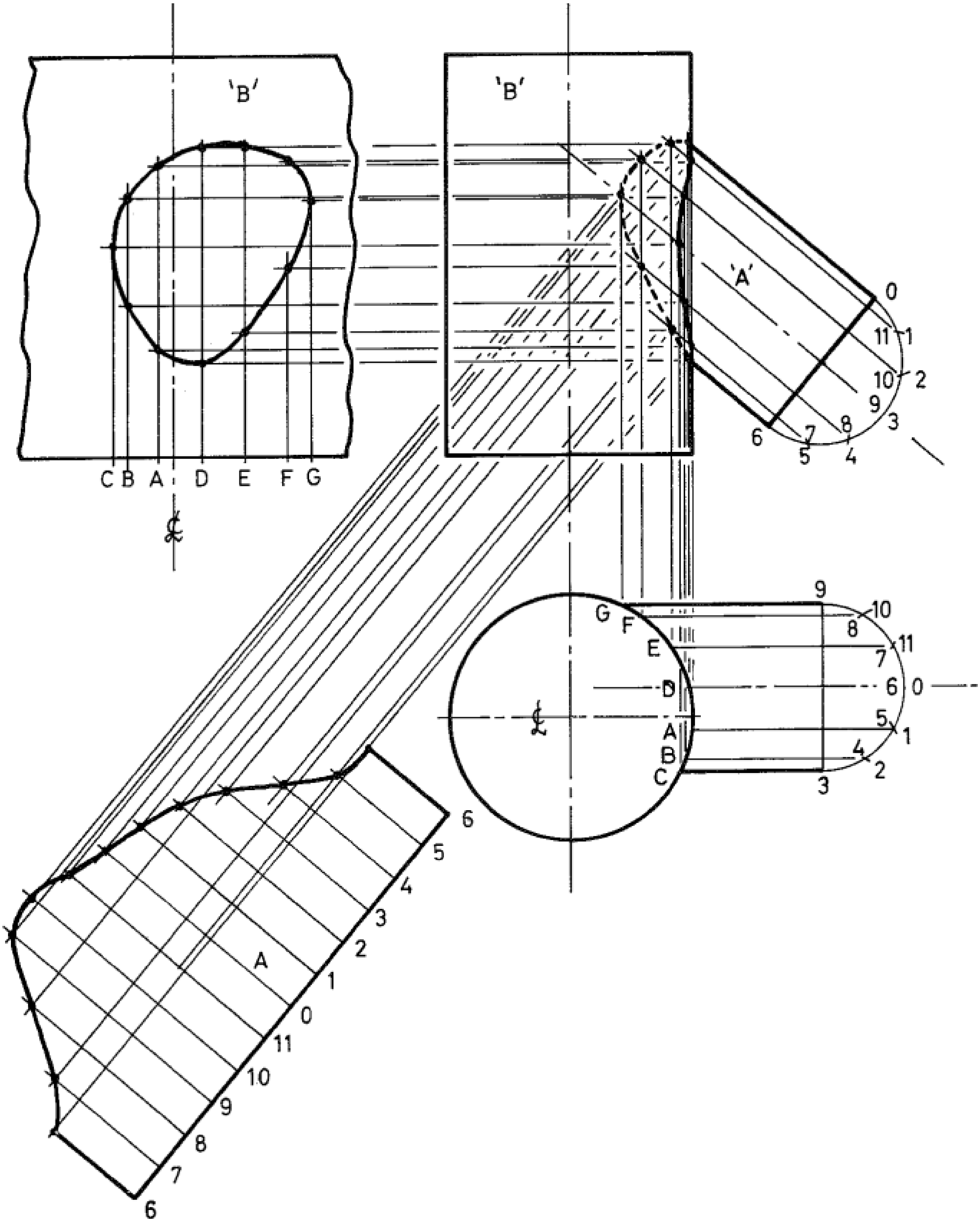



Figure 4.22 Development (3A) of pipe to pipe unequal diameters off centre

### 4.7.5 Rectangle to pipe on centre

Rectangle to pipe on centre is illustrated in **Figure 4.23** below.

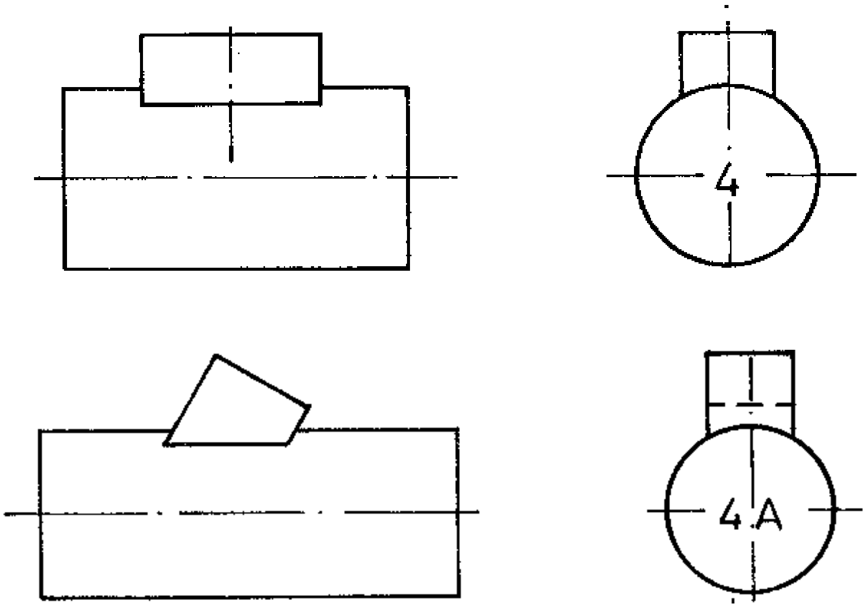



Figure 4.23 Rectangle to pipe on centre

- **Development (4)** as in **Figure 4.24:**

As we are now familiar with the basis of straight line developments, we will only look at the problem when developing with flat areas.

This is where our bend lines are so far apart that it would be impossible to draw a curve between the four bend lines 4 and 3 and 2 and 1 in this example.

We therefore, add auxiliary line BB and AA to help with curvature (The more lines, the more accuracy)

**NOTE:**
For branch pipe "A" we don't have a circumference but take the dimensions from the front view and the side view alternatively.

**NOTE:**
For the hole shape in pipe "B" the dimension X should be calculated for absolute accuracy.

**Figure 4.24**, on the following page, illustrates the development (4) of rectangle to pipe on centre.

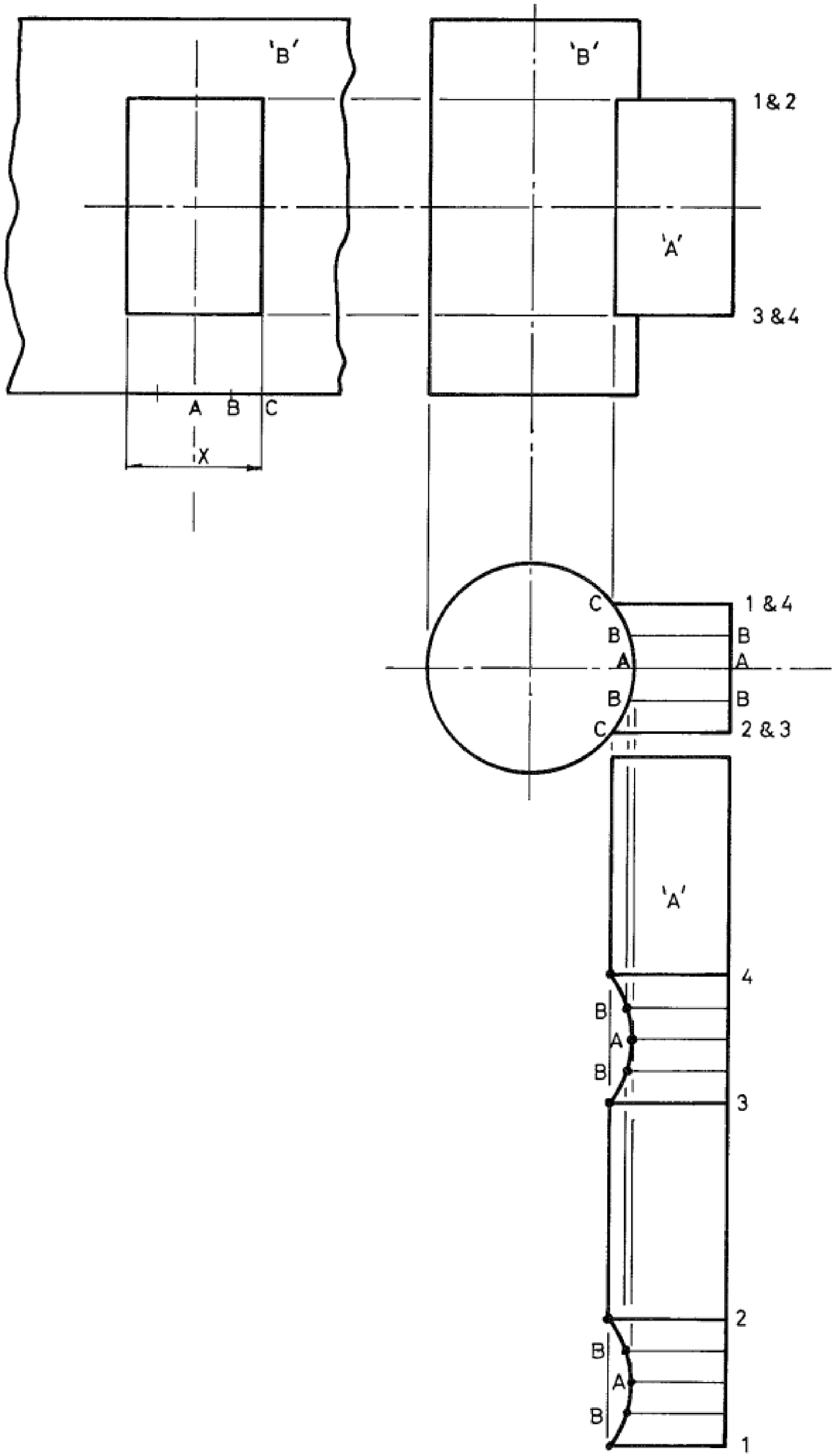



Figure 4.24 Development (4) of rectangle to pipe on centre

- **Development (4A)** as in **Figure 4.25:**

See *section 4.7.5* development (4).

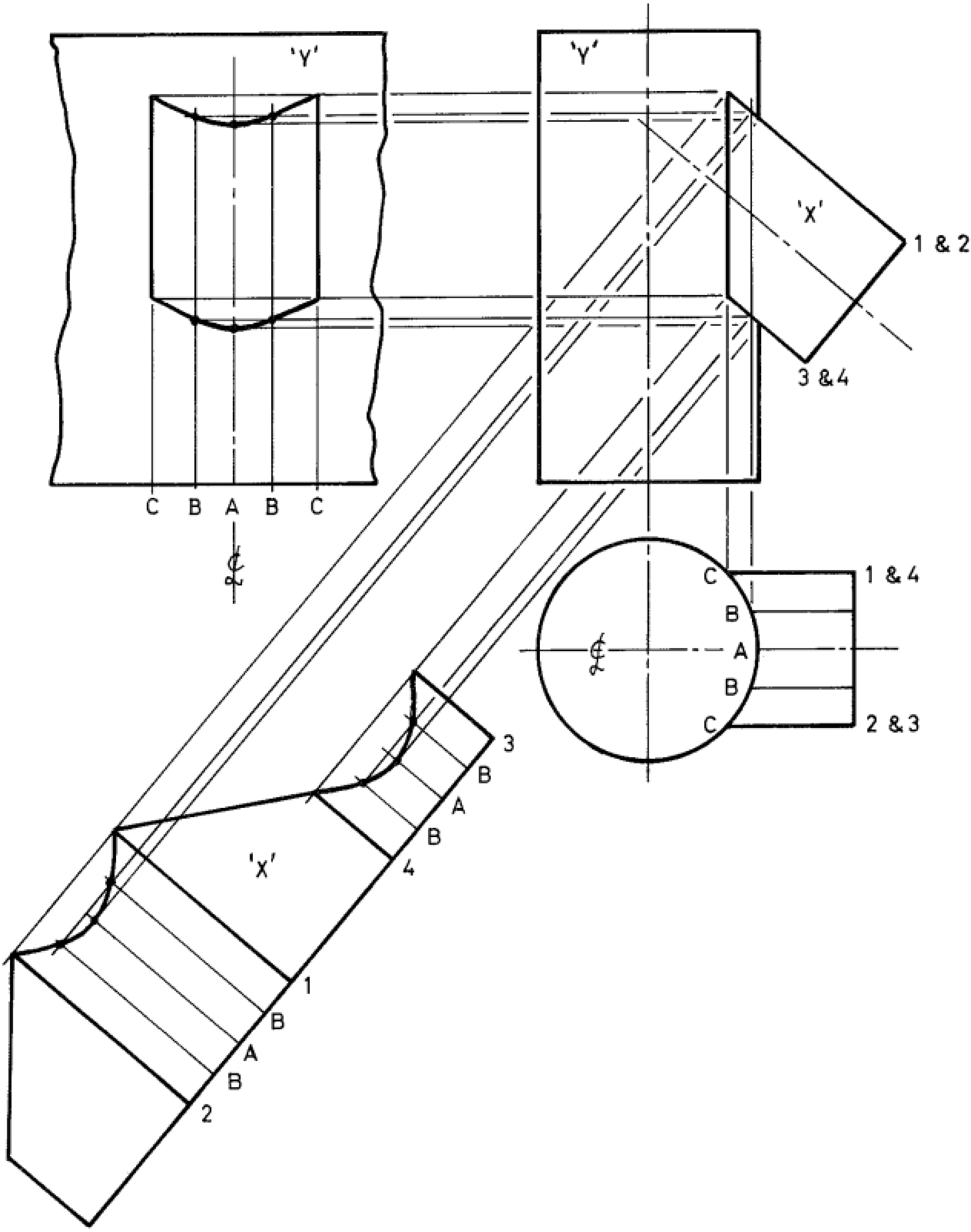



Figure 4.25 Development (4A) of rectangle to pipe on centre

**Figure 4.25**, on the previous page, illustrates the development (4A) of rectangle to pipe on centre

**4.7.6 Rectangle to pipe off centre**
Rectangle to pipe off centre is illustrated in **Figure 4.26** below**.**

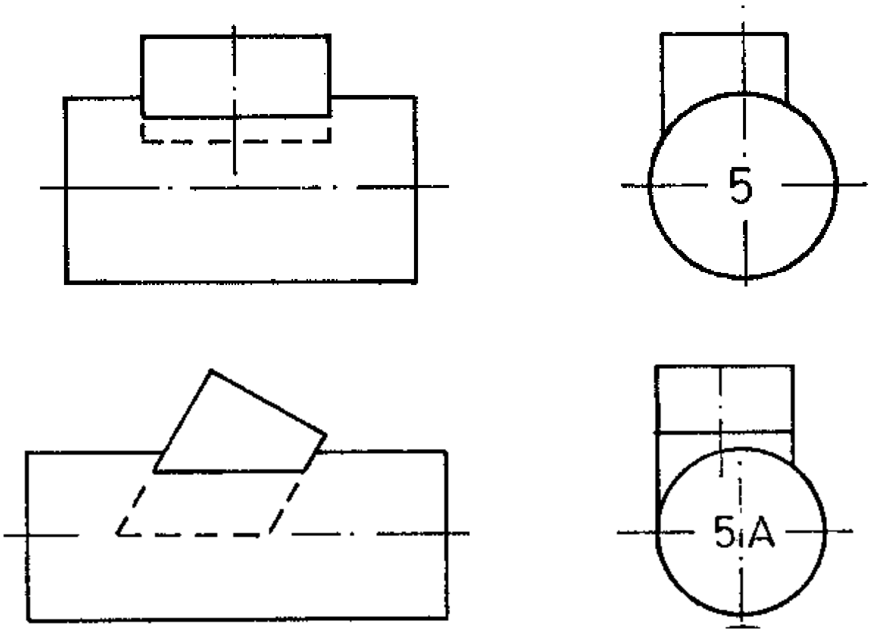



Figure 4.26 Rectangle to pipe off centre

We will now consider Development (5), as illustrated in **Figure 4.27** on the following page.

- **Development (5)** as in **Figure 4.27:**

See *section 4.7.5* development (4).

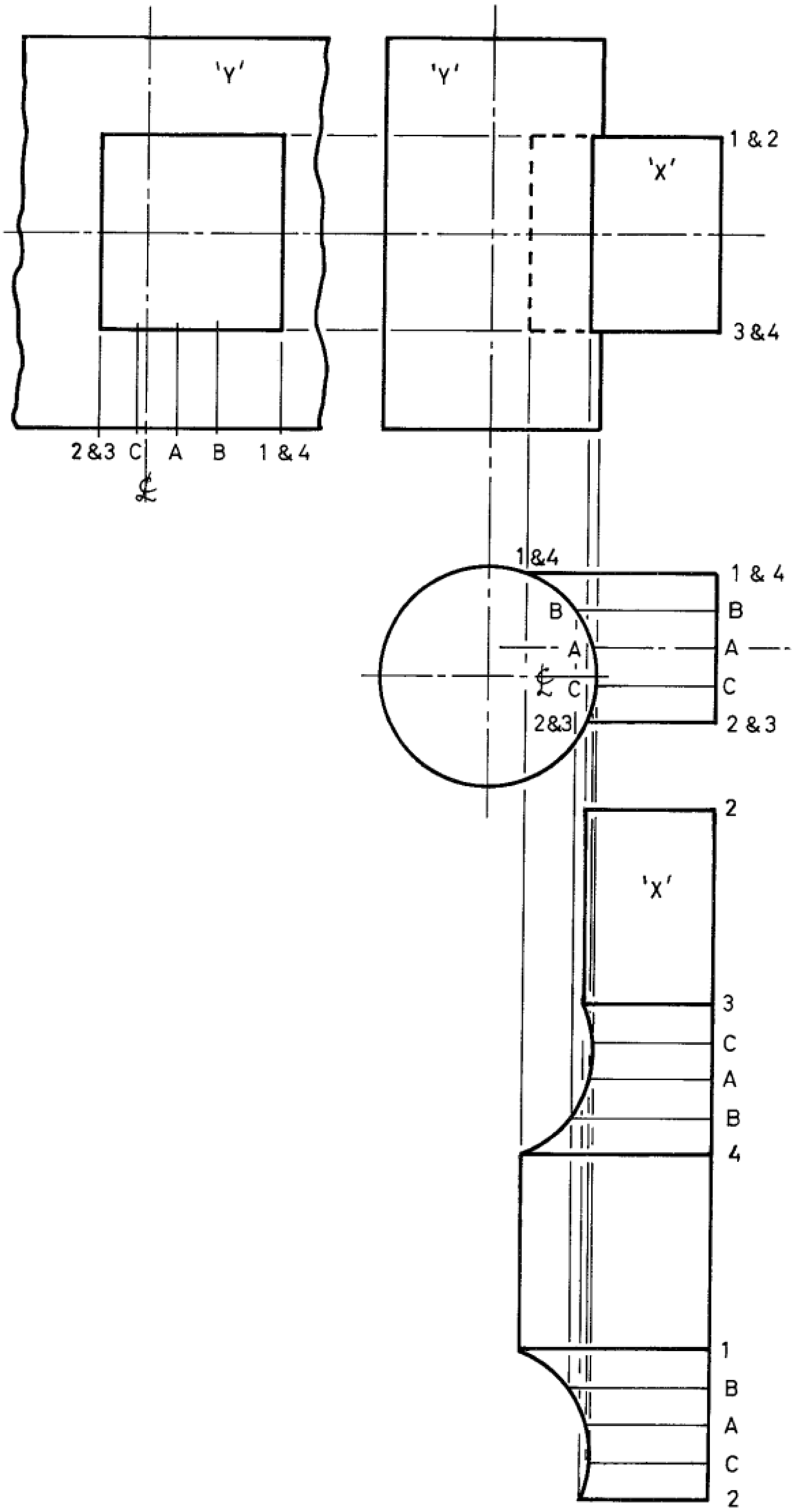



Figure 4.27 Development (5) of rectangle to pipe off centre

- **Development (5A)** as in **Figure 4.28:**

See section 3.6.5 page 29

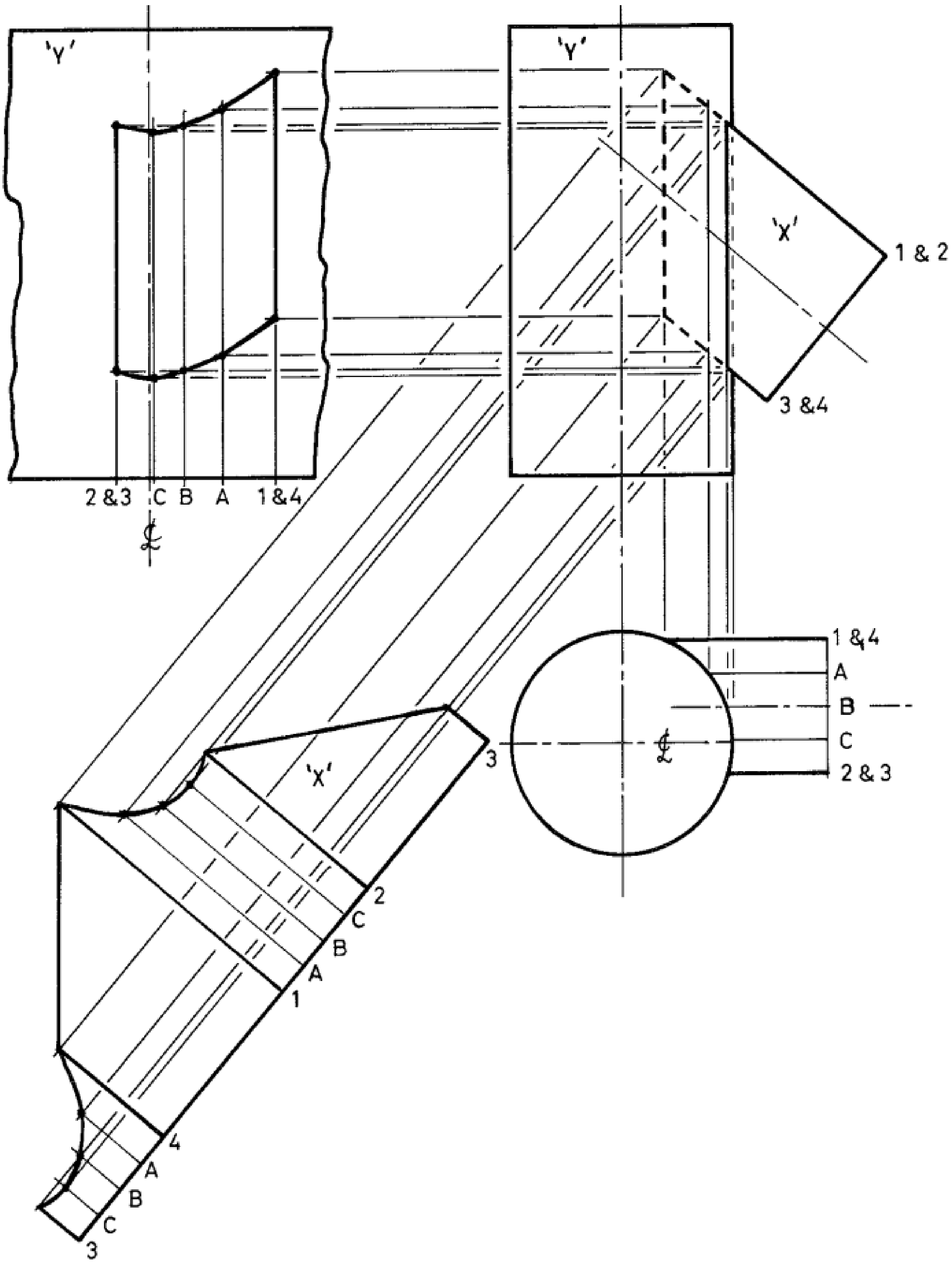



Figure 4.28 Development (5A) of rectangle to pipe off centre

On the previous page, **Figure 4.28** illustrates the development (5A) of rectangle to pipe off centre.

### 4.7.7 Pipe to rectangle on centre

Pipe to rectangle on centre is illustrated in **Figure 4.29** below**.**

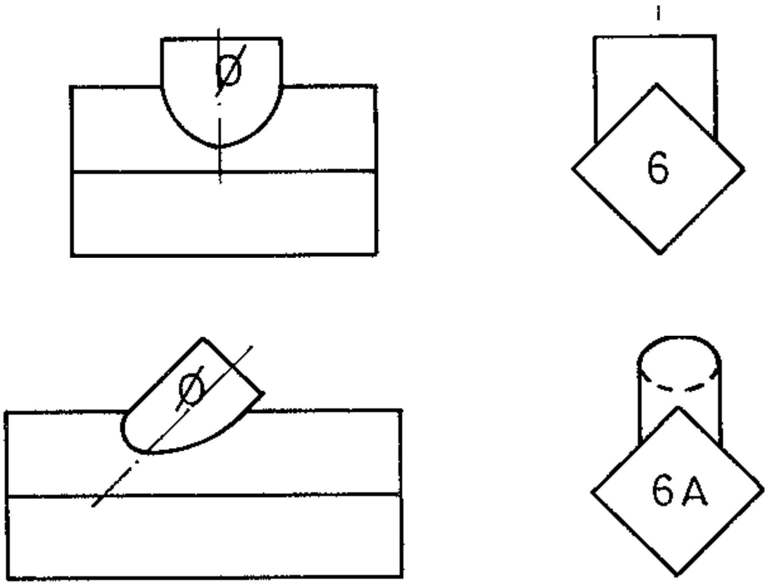



Figure 4.29 Pipe to rectangle on centre

We will now consider Developments (6) and (6A), as illustrated in **Figures 4.30** and **4.31** respectively.

- **Development (6)** as in **Figure 4.30:**

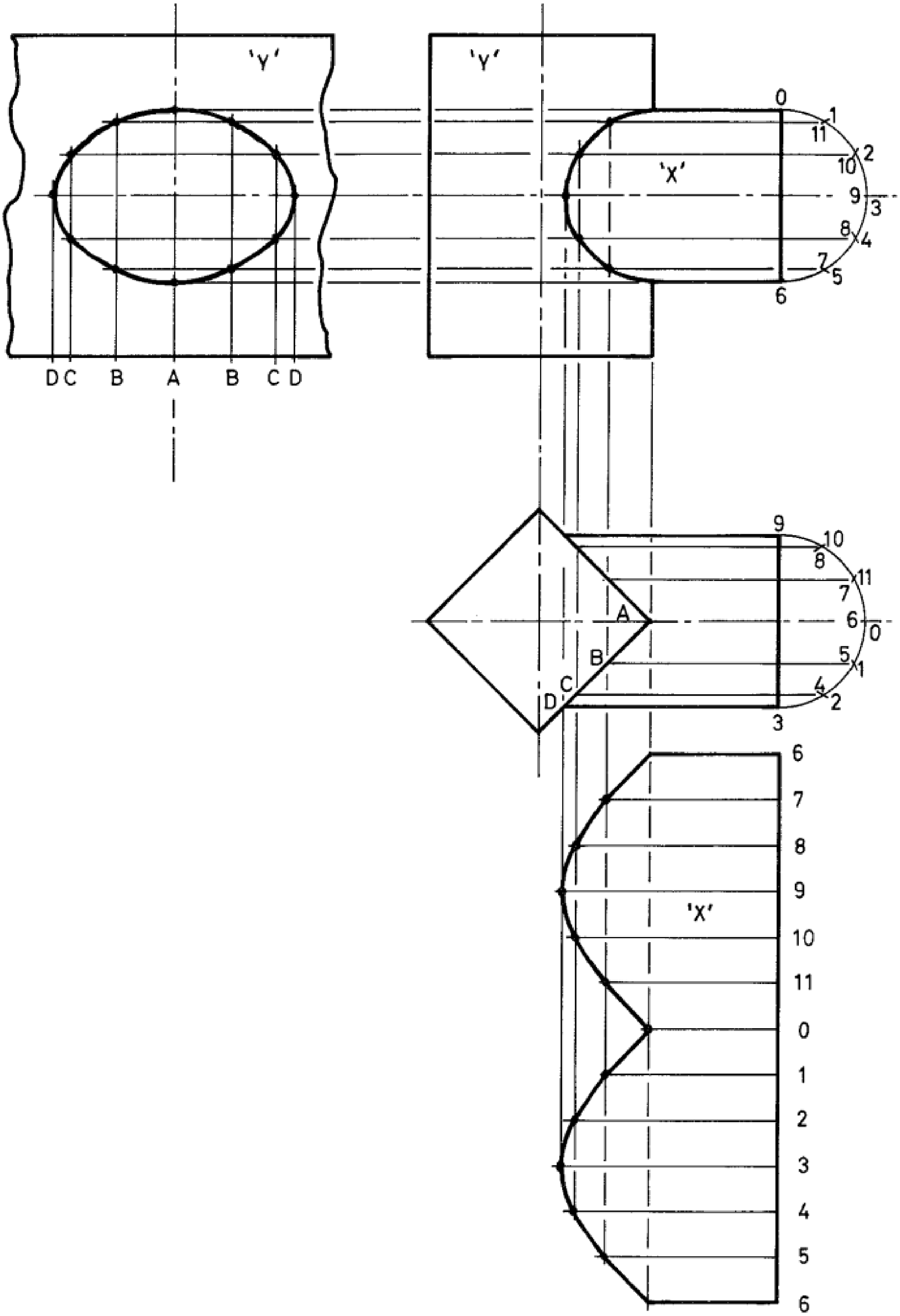



Figure 4.30 Development (6) of pipe to rectangle on centre

- **Development (6A)** as in **Figure 4.31:**

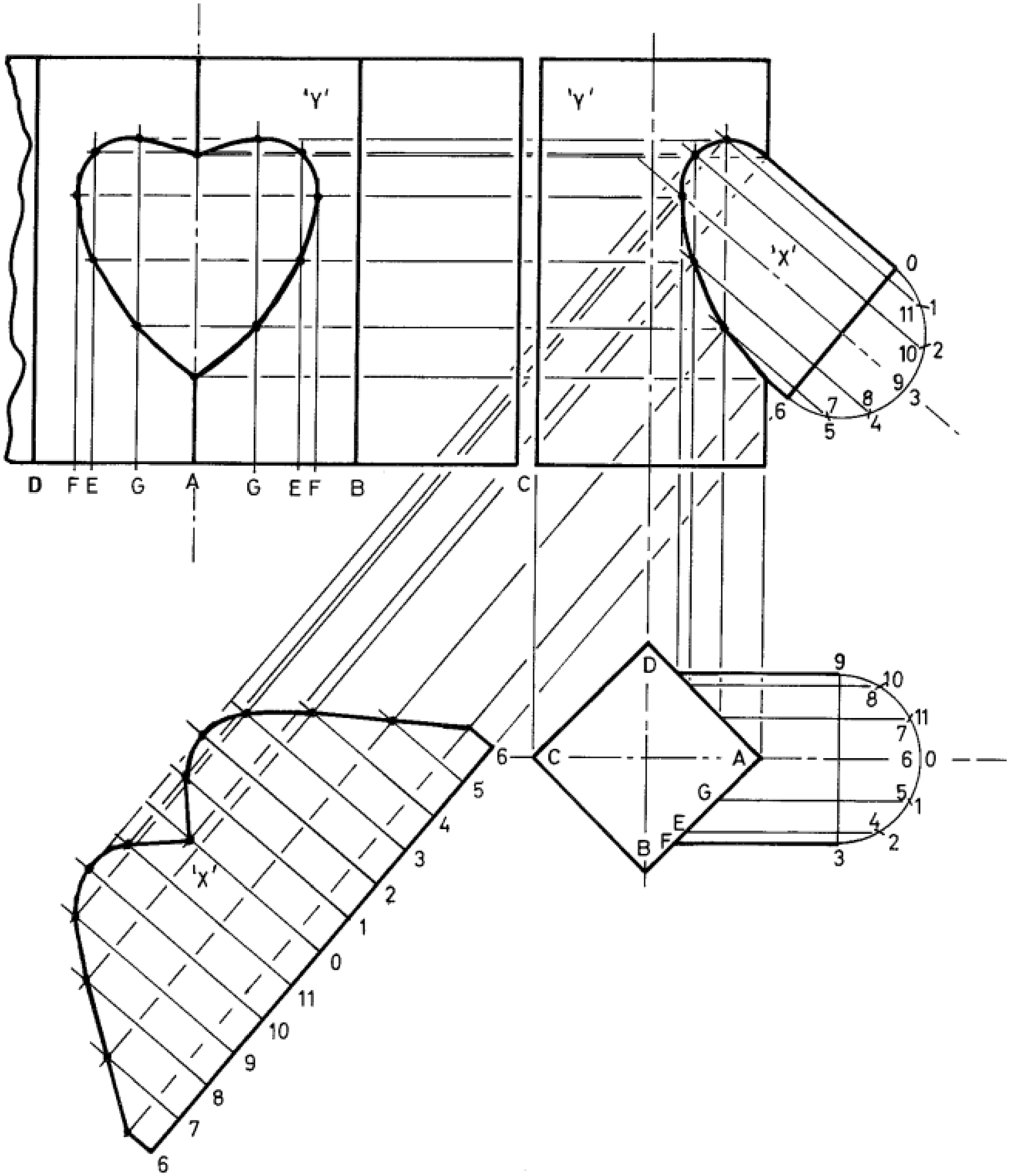



Figure 4.31 Development (6A) of pipe to rectangle on centre

### 4.7.8 Pipe gusset

With this development we combine pipes with flat sections and develop as such, as seen in **Figure 4.32** on the following page.

As can be seen from the drawing the Gusset "C" has to be round on the top edge as it has to follow the contour of the pipes (with the same diameter as the pipes).

Therefore, we have to mark a half circle with centre line normal to the edge of the gusset.

Then, divide and number and project these divisions points parallel to the top edge of the gusset to cut division line projected from the pipes to give us the lines of interpenetration.

**NOTE:**

1. These lines of interpenetration will be straight lines, as we are working with pipes of equal diameter.

2. From our central ball theorem (*section 4.2.3*), we can also say, to find the line of interpenetration we use the point of intersection on the outside of the pipes marked N and the point of intersection on the centre lines marked X and connect these points with straight lines.

   To develop Gusset "C" we simply project out normal to the gusset outside edge.

3. On this development the distance between A and B, B and C, etc., will be the calculated unit for the circumference (circumference ÷ 12).

4. In practice we would calculate half the circumference to give us A to A and divide this distance by 6 to minimise creeping error.

On the following page, an example of a pipe gusset is illustrated in **Figure 4.32**.

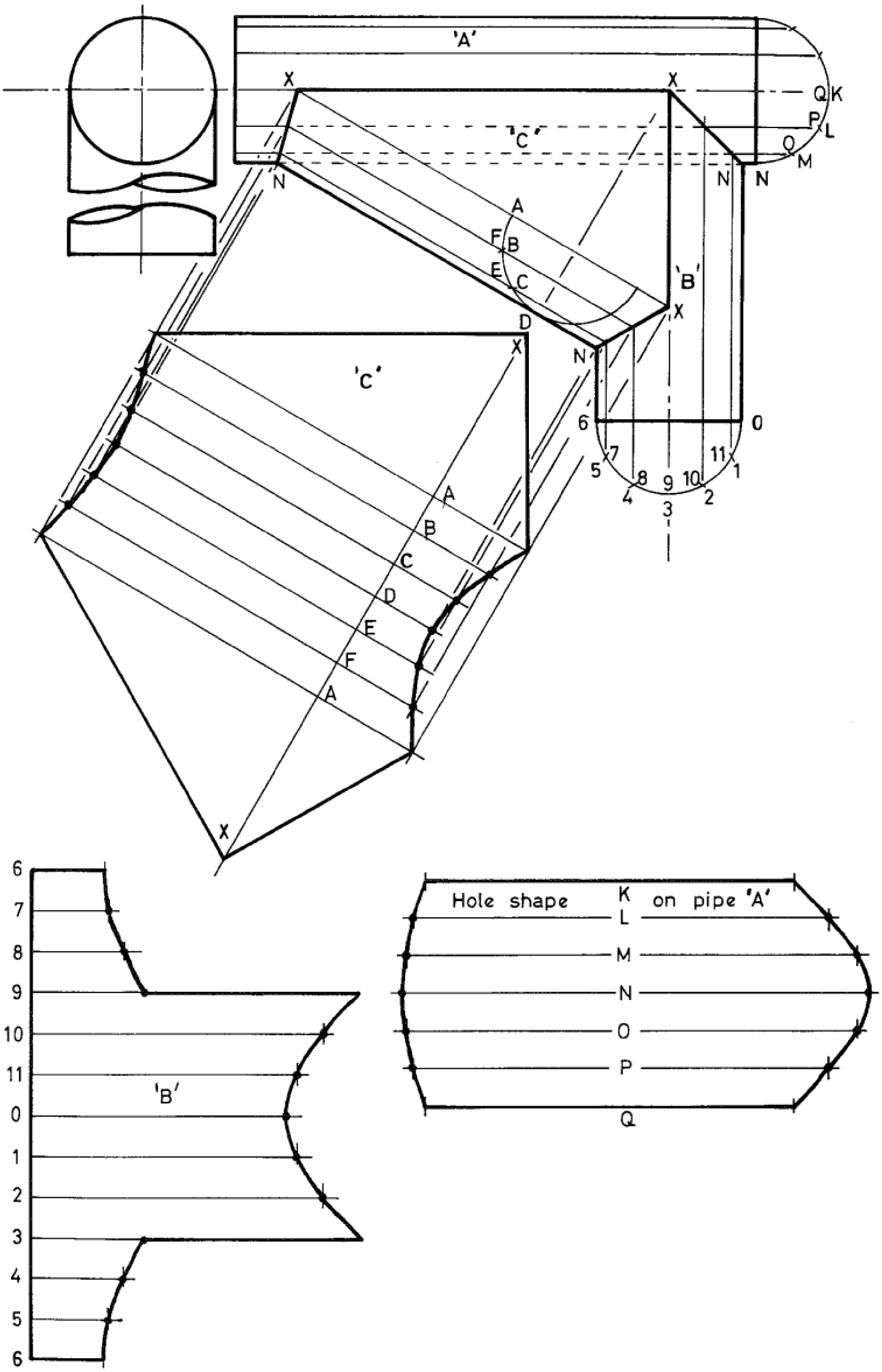



Figure 4.32 Pipe gusset

## Activity 4.1

1. Draw and develop the following right offset pipe bend (see **Figure 4.33**).

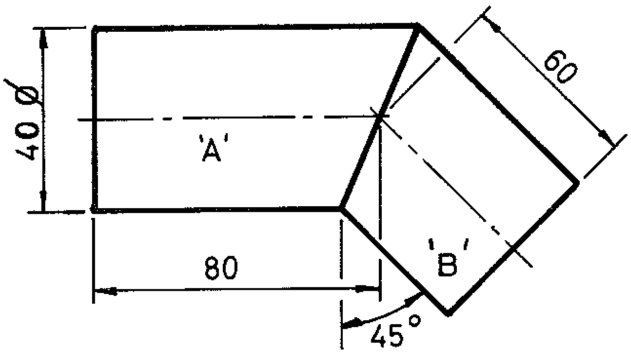



Figure 4.33 Right offset pipe bend

2. Draw and develop the following oblique offset pipe bend (see **Figure 4.34**).

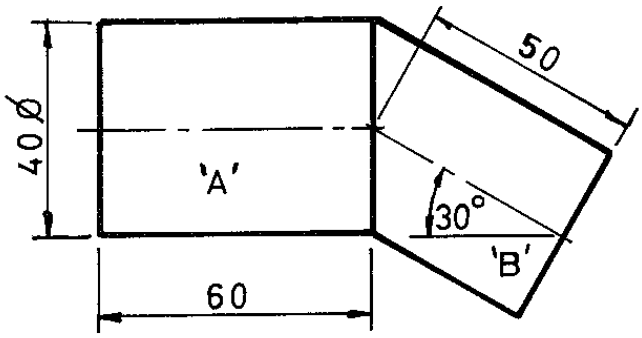



Figure 4.34 Oblique offset pipe bend

3. Develop the right "Y" piece as shown (see **Figure 4.35**).

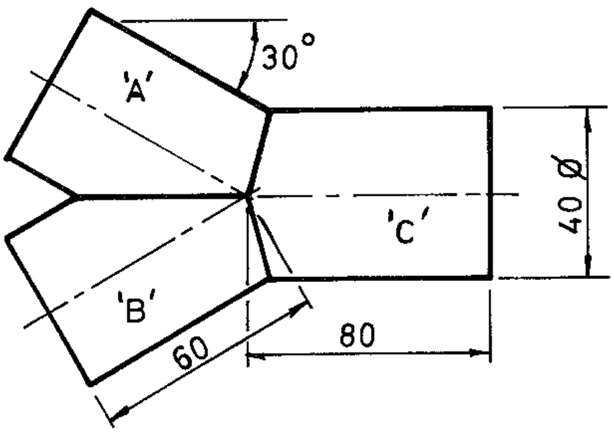



Figure 4.35 Right "Y" piece

4. Develop the lobster back bend with 4 segments (see **Figure 4.36**).

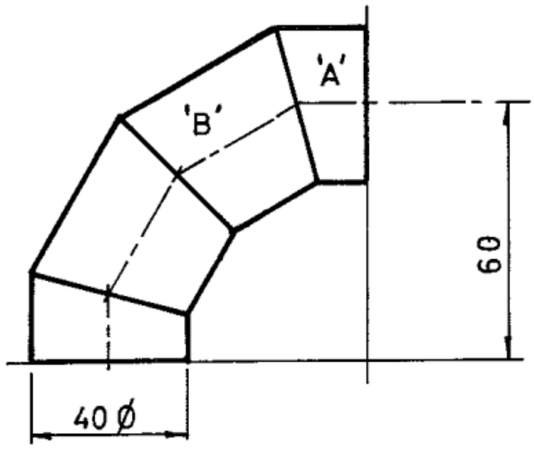



Figure 4.36 Lobster back bend

5. Develop the oblique "Y" piece as shown (see **Figure 4.37**).

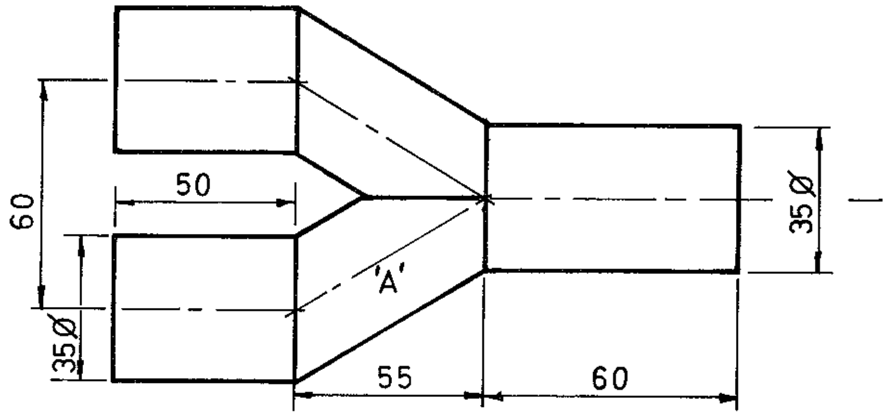



Figure 4.37 Oblique "Y" piece

6. Develop the lobster back bend with 6 segments (see **Figure 4.38**).

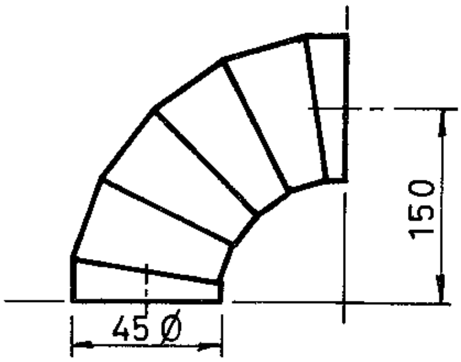



Figure 4.38 Lobster back bend

7. Develop the fo1lowing pipe to pipe interpenetration (see **Figure 4.39**).

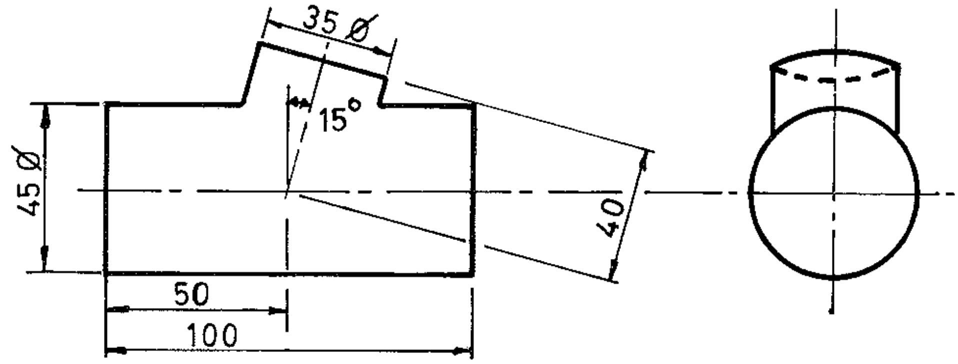



Figure 4.39 Pipe to pipe interpenetration

8. Develop the following pipe to pipe interpenetration (see **Figure 4.40**).

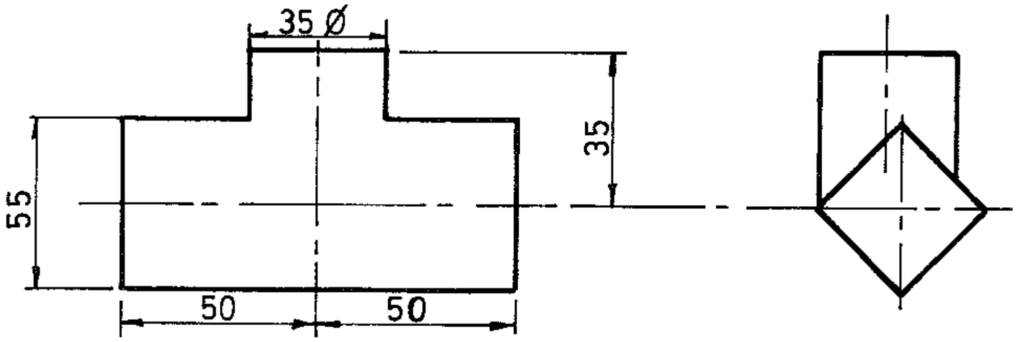



Figure 4.40 Pipe to pipe interpenetration

9. Develop the following pipe to pipe interpenetration, on centre (see **Figure 4.41**).

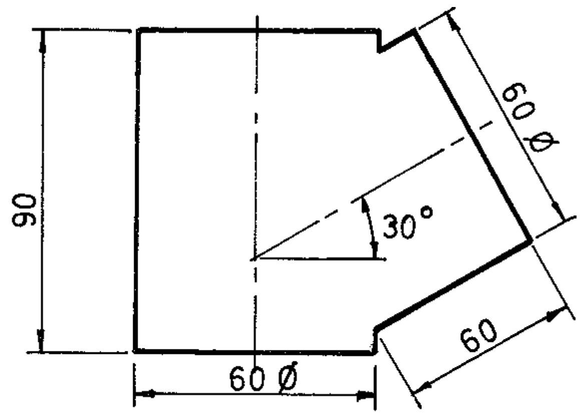



Figure 4.41 Pipe to pipe interpenetration, on centre

**Self-Check**

| I am able to: | Yes | No |
|---|---|---|
| • Define the following drawing hints and pipe facts: | | |
| o Circumference | | |
| o Division and numbers | | |
| o The central ball theorem | | |
| • Describe the following development of straight pipes: | | |
| o Pipe with Angle Cut | | |
| o Double Angle Cut pipe | | |
| • Explain the division on lobster back bends | | |
| • Describe the development of a Right "Y" piece | | |
| • Describe the development of an Oblique "Y" piece | | |
| • Describe the basic pipe to pipe interpenetration principles | | |
| • Describe the different pipe to pipe interpenetrations: | | |
| o Pipe to pipe equal diameters | | |
| o Pipe to pipe unequal diameters on centre | | |
| o Pipe to pipe unequal diameters off centre | | |
| o Rectangle to pipe on centre | | |
| o Rectangle to pipe off centre | | |
| o Pipe to rectangle on centre | | |
| o Pipe gusset | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 5

# Radial Line Development

**Learning Outcomes**
On the completion of this module the student must be able to:

- Define the following regarding Radial line development:
  - Divisions and numbers
  - True lengths
  - Central ball theorem
- Describe the general rules for a right cone
- Describe the development of right cone
- Describe the general rules for an oblique cone
- Describe the development of oblique Cone
- Describe the following cone frustrum's:
  - cut at top (right cone)
  - cut at bottom (right cone)
  - cut at top and bottom (right cone)
  - cut at top (oblique cone)
  - cut at bottom (oblique cone)
  - cut at top and bottom (oblique cone)

## 5.1 Introduction

This module will look in detail at the Radial line development method. Ensure to look at the examples given and to test your knowledge by doing the activities at the end of the module.

## 5.2 Radial line development: Cone hints and facts

### 5.2.1 Divisions and numbers

As with the pipe we usually divide the base of the cone into 12 equal parts and numbers. This is illustrated in **Figure 5.1** on the following page.

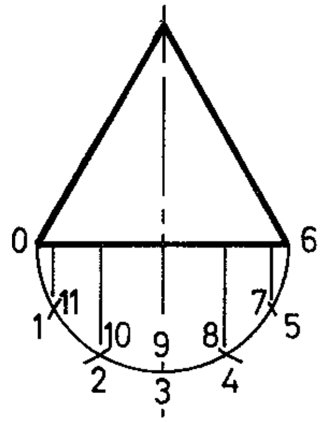



Figure 5.1 Base of cone divided into 12 equal parts

**5.2.2 True lengths**
If we consider the front view and top view of the cone drawn and we draw a line in the top view from the apex X to a point on the base as shown, the line XY would measure 15 mm.

But this would not be a true length as you will see if you project points X and Y to the front view.

Therefore, we would state that to obtain the true length on a right cone we should work on the side of the cone in view.

**NOTE:**
This line XY will always represent a bend line in all cone developments, as seen in **Figure 5.2**.

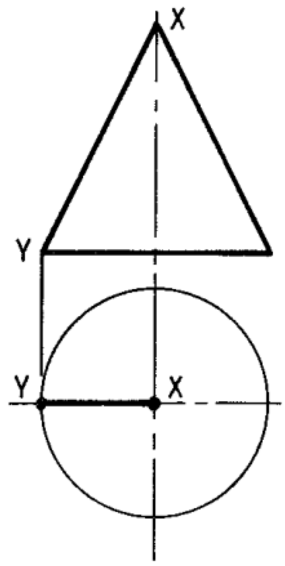



Figure 5.2 Bend line is line XY

### 5.2.3 Central ball theorem

When we consider the cone as drawn we should know that a cutting plane parallel to the base would give us a round shape hole.

We can prove this with the central ball theorem.

In **Figure 5.3** below, we have drawn a ball touching both sides of the cone, by now determining the exact points X.X where the ball touches the sides (Tangent point).

By joining these points, we will find that the line is parallel to the base and we all know that if we should cut a ball the cutting plane will be round.

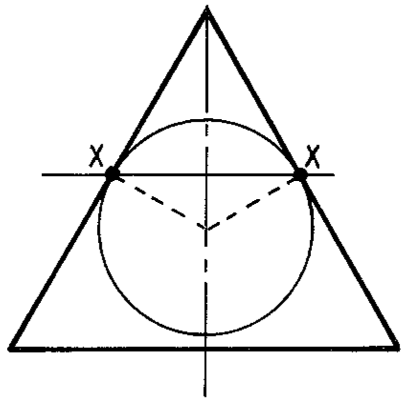



Figure 5.3 A ball touching both sides of the cone,

## 5.3 Right cone

### 5.3.1 General rules

1. Draw the view as shown neatly and accurately.
2. Draw a half top view on the base of the cone.
3. Divide and number the half top view.
4. Calculate circumference of the cone base.
5. Project top view divisions up to base of cone.
6. From points thus obtained on base, draw bend lines up to cone apex.
7. To obtain true lengths of all bend lines, project points on base normal to centre line to side of cone.

**NOTE:**
On right cone without cut away we find all the bend lines have the same length, as seen in **Figure 5.4** on the following page.

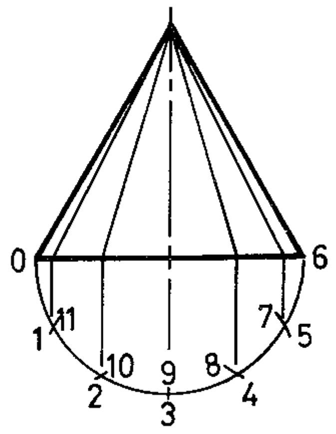



Figure 5.4 Right cone

**5.3.2. Development of right cone**

Draw the side view and half top view as shown in **Figure 5.5**, divide half top view in six equal parts and numbers 1, 2, 3, etc. and project vertical up to base line Y. Y of cone.

From the points obtained thus on the base line draw lines to apex of cone marked X. Next calculate the circumference of the cone base and divide by 12 to obtain one unit of the base.

(True length is found between; 1 and 2, 2 and 3, etc.) Set compass to radius XY and using a central point Z, draw an arc as shown, starting at a random point.

By using calculated unit of base, (distance between 1 and 2) step off 12 units along circle drawn and number 0, 1, 2, etc. Draw the bend lines from these points to centre Z to complete development.

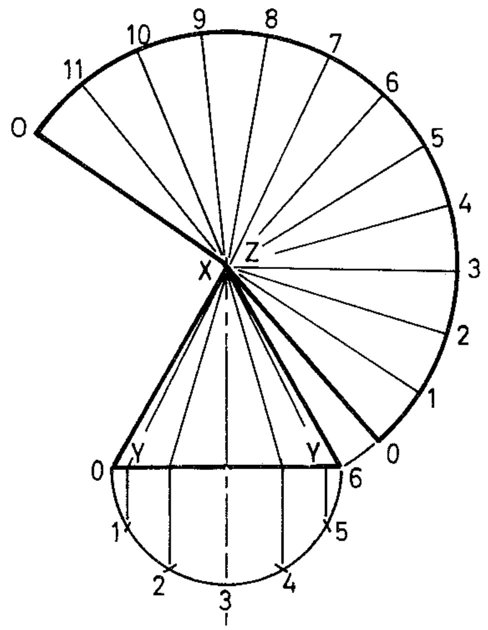



Figure 5.5 Development of right cone

## 5.4 Oblique cone

### 5.4.1 General rules

1. Draw the view as shown in **Figure 5.6** accurately and neatly.
2. Draw a half top view on the base of the cone.
3. Divide and number the half top view.
4. Calculate the circumference of the cone base.
5. To obtain apex offset, drop apex X onto extended base line *to* give you point A.
6. Using A as centre, scribe division lines on half top view to base of cone.
7. From points thus obtained on base, draw bend lines up to apex.
8. All bend lines shown on cone view are true lengths

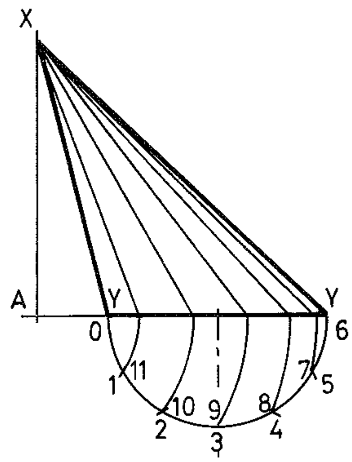



Figure 5.6 An oblique cone

### 5.4.2. Development of Oblique Cone

Draw the side view and half top view as shown, divide half top view in 6 equal parts and number 0, 1, 2, etc.

Then drop apex X of cone onto extended base line to obtain point A, using point A as centre, scribe numbered points on half top view onto base YY.

Then draw points obtained thus on cone base, to apex X. Next we calculate the circumference of the cone base and divide by 12 to obtain one unit of the base.

Set compass from apex X to points 0, 1, 2, etc., on base of view and using a central point X scribe arcs with radii XO, X1, X2, etc., and number these arcs.

Starting at a random point on arc numbered 0 and using a compass set to the calculated unit of base (distance between 1 and 2, etc.) step off 12 units from arc O to arc 1 to arc 2, etc., numbered 0, 1, 2, 3, etc., to correspond to arc numbers.

Draw bend lines from these points to centre Z and join all the points on the arc with a continuous curve to complete the development, as seen in **Figure 5.7** below.

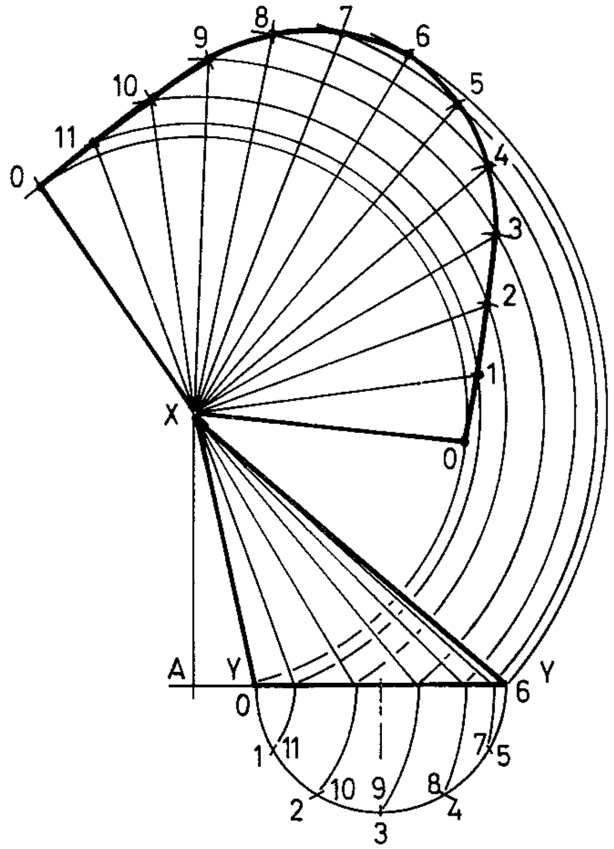



Figure 5.7 Development of oblique cone

## 5.5 Cone frustrum cut at top (right cone)

By applying our general rules (*Section 5.3.1 and 5.4.1)* we should be able to develop the cone without the cut off.

(a) Set compass to radius X6 along the cone side and with this radius we draw an arc with a random centre $X^1$.

On this arc we step Off 12 circumference units (calculated) and numbered from O to O. Draw lines from all these points to the centre $X^1$ to give us our bend lines.

This will give us the cone base development. To complete the development set your compass at radius XA on front View of *cone* and using this radius scribe an arc on the development with centre $X^1$ with the arc extremes being lines O and O.

**Figure 5.8**. illustrates the cone frustrum cut at top (right cone).

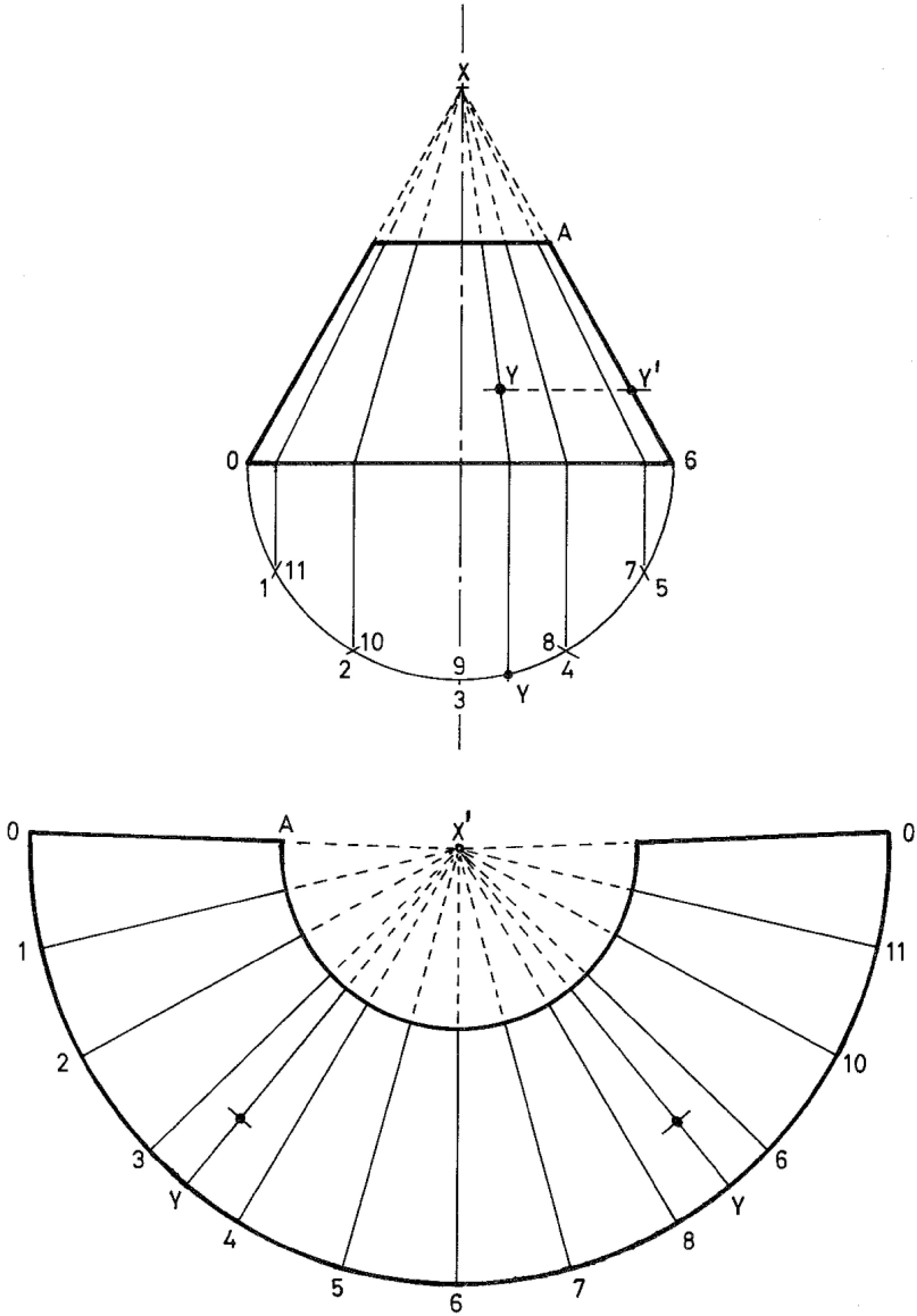



Figure 5.8 Cone frustrum cut at top (right cone)

**NOTE:**
It will be found that most cone developments will not be as simple as this as you will be required to find points that may no fall on the bend lines.

We therefore, now look at the method to ascertain where a specific point on the cone view will fall on development.

(b) Imagine that it is required to drill a hole at the position Y on the cone.

Draw an auxiliary bend line through the point Y down to the base then project this point down to the half top view and number Y.

You now set your compass to distance which is also 8Y and transfer this dimension on the base arc of your development from 4 towards 3 and 8 towards 9 and number these points thus obtained.

Make sure that you carry this dimension over so that Y is between 8 and 9 and 4 and 3.

Now draw the auxiliary bend line into your development by connecting point Y to centre $X^1$. It now only remains to find out how far this point lies from the cone apex.

Project point Y in the cone view normal to the centre line to the cone edge and number $Y^1$ then set compass to $XY^1$ and using $X^1$ on the development as centre and radius $XY^1$ draw arcs to cut auxiliary bend lines Y.

This intersection is the point Y required.

## 5.6 Cone frustrum cut at bottom (right cone)

Develop as per *section 5.3.2* that is the normal right cone as a base to work from. You will now see that it is necessary to find the true lengths of the bend lines as they are cut off.

Where the bend lines end at the cut off, project these points across to the side of the cone and measure the true lengths.

Then with a compass set to true lengths XO, X1, X2, etc., scribe arcs to cut bend line O, 1, 2, etc., on the development to give us the true points, O, 1, 2, etc.

Connect these points with a continuous curved line to complete the development, as seen in **Figure 5.9** on the following page.

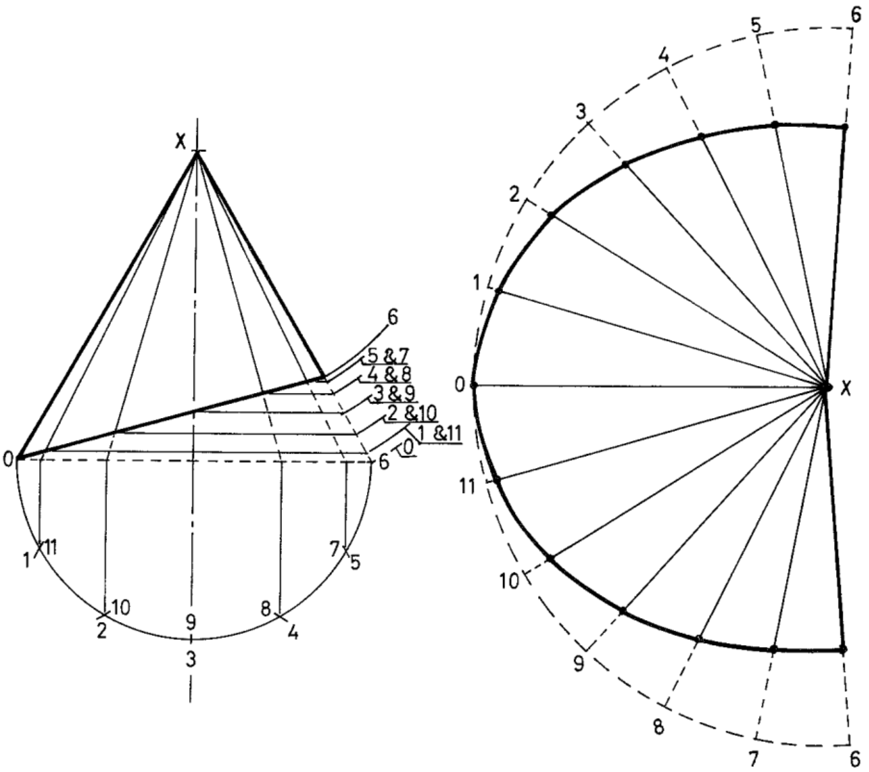



Figure 5.9 Cone frustrum cut at bottom (right cone)

## 5.7 Cone frustrum cut at top and bottom (right cone)

It will be seen on this development that it is necessary to obtain an auxiliary point Y (we have dealt with this in *section 5.5*). Develop as per *section 5.6, as* seen in **Figure 5.10** below.

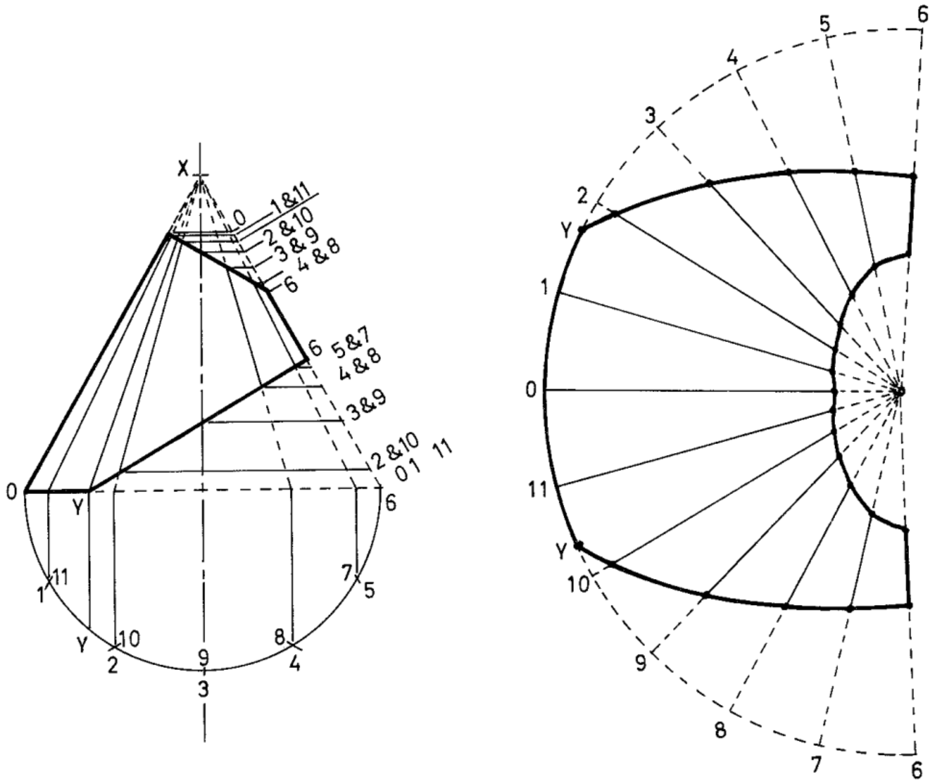



Figure 5.10 Cone frustrum cut at top and bottom (right cone)

## 5.8 Cone frustrum cut at top (oblique cone)

For the development of a cone frustrum cut at top (oblique cone), follow rules as per *section 5.4.1* and *section 5.4.2,* see **Figure 5.11.**

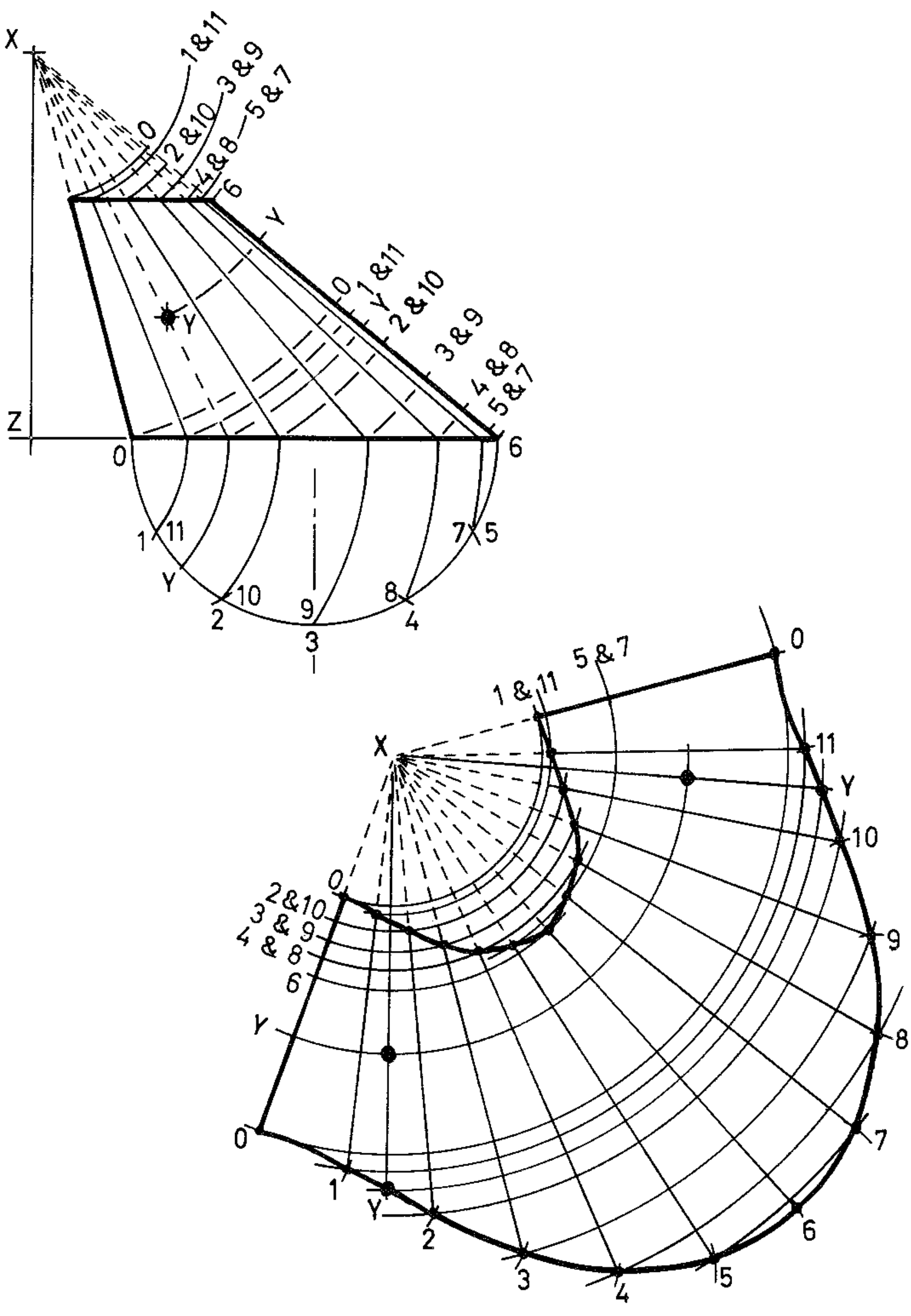


Figure 5.11 Cone frustrum cut at top (oblique cone)

**NOTE:**
All true lengths are taken direct XO, X1, X2, etc., as well as XY. To find point Y you use an auxiliary bend line as per *section 5.5***.**

## 5.9 Cone frustrum cut at bottom (oblique cone)

First develop basic outline of cone as if there is no cut as per *section 5.4.2*. Then use true lengths of bend lines from X to cut off line and place on the development to give you the true shape of the development.

**Figure 5.12** illustrates the cone frustrum cut at bottom (oblique cone).

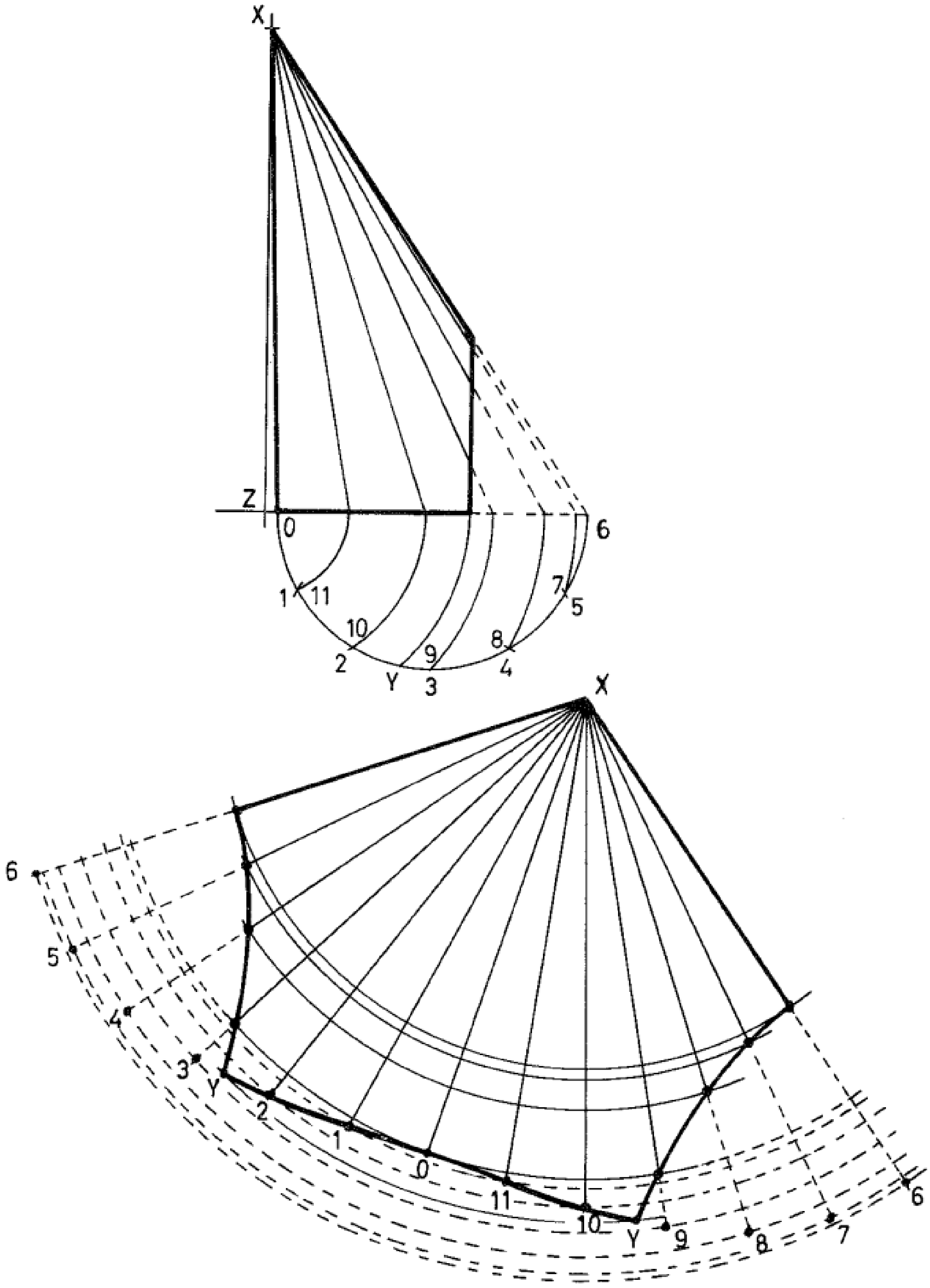



Figure 5.12 Cone frustrum cut at bottom (oblique cone)

**NOTE:**
- Auxiliary point Y has to be obtained (*section 5.5*).
- Joint in cone is now on bend line six in this case (shortest side).

## 5.10 Cone frustrum cut at top and bottom (oblique cone)

Develop basic outline of cone as if there is no cut then cut the bend lines with true lengths taken from the cone view, as seen in **Figure 5.13** below.

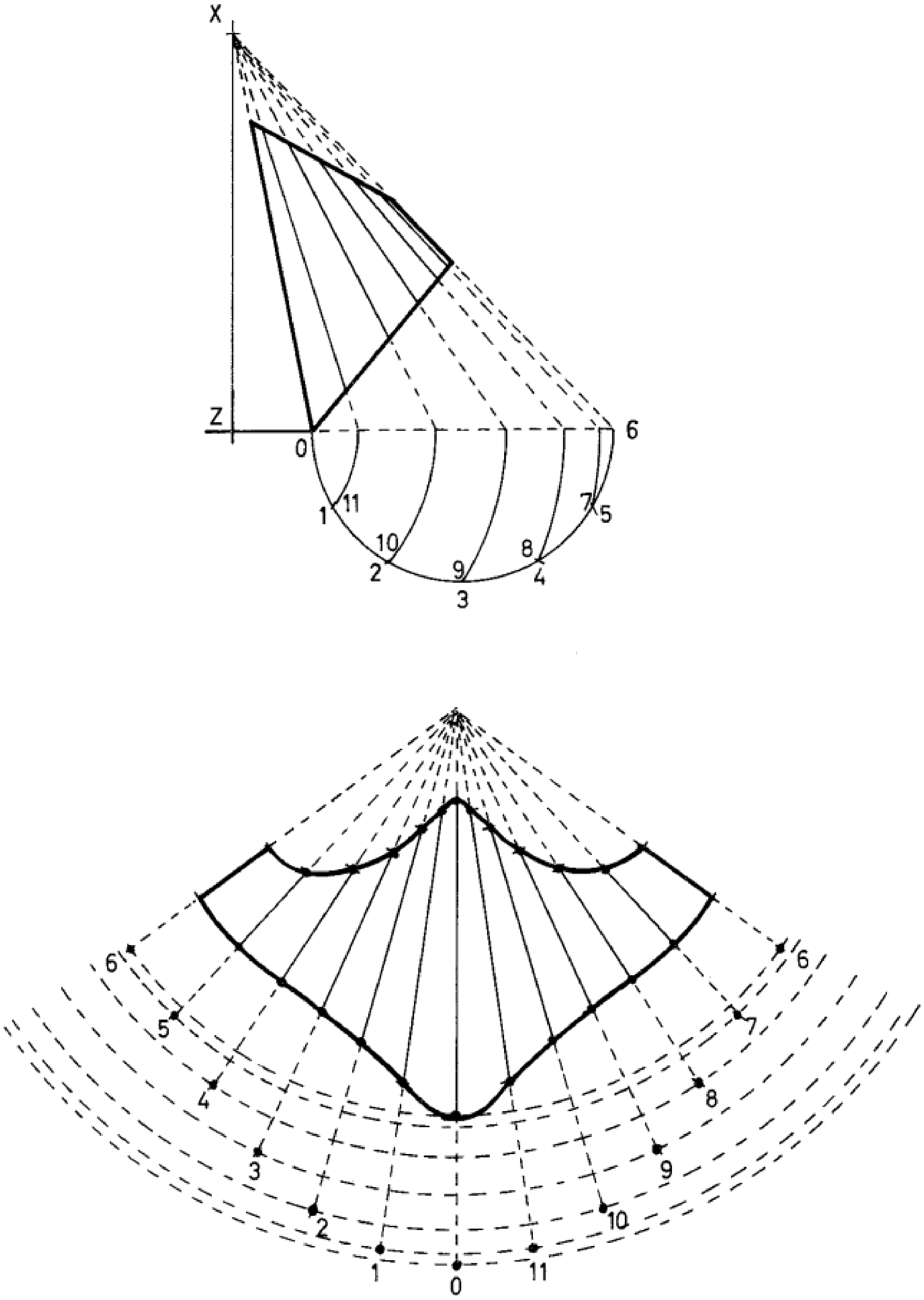



Figure 5.13 Cone frustrum cut at top and bottom (oblique cone)

**NOTE:**
Each bend line has 2 cut points (Top and bottom).

Now work carefully through **Worked Example 1**, below, which shows a front view of a Y-piece.

The solution is given on the following page.

## Worked Example 1

**Figure 5.14** shows a front view of a Y-piece.

Draw the given view and develop part 'A'.

Scale 1:2

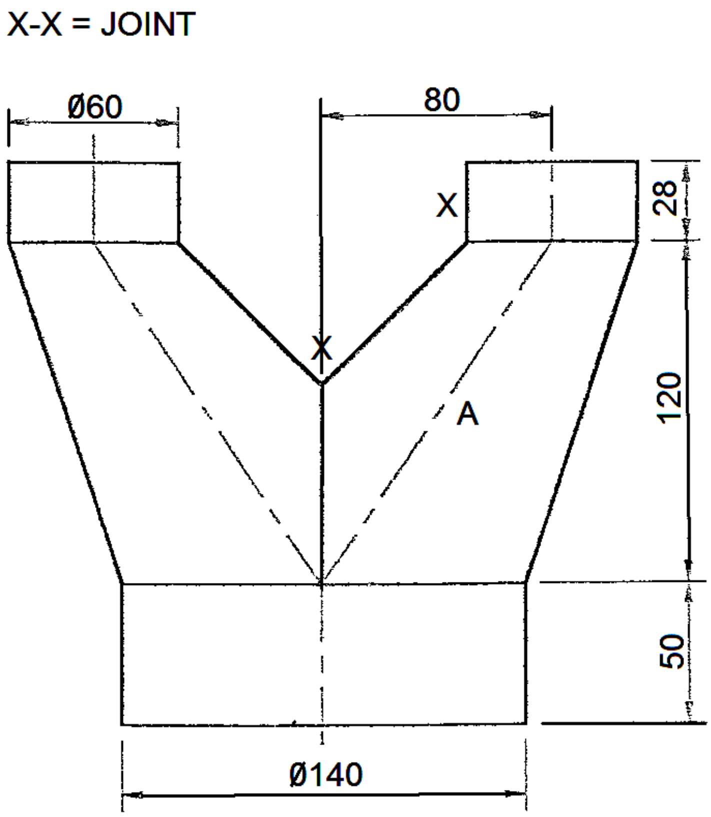



Figure 5.14 A front view of a Y-piece

Solution:

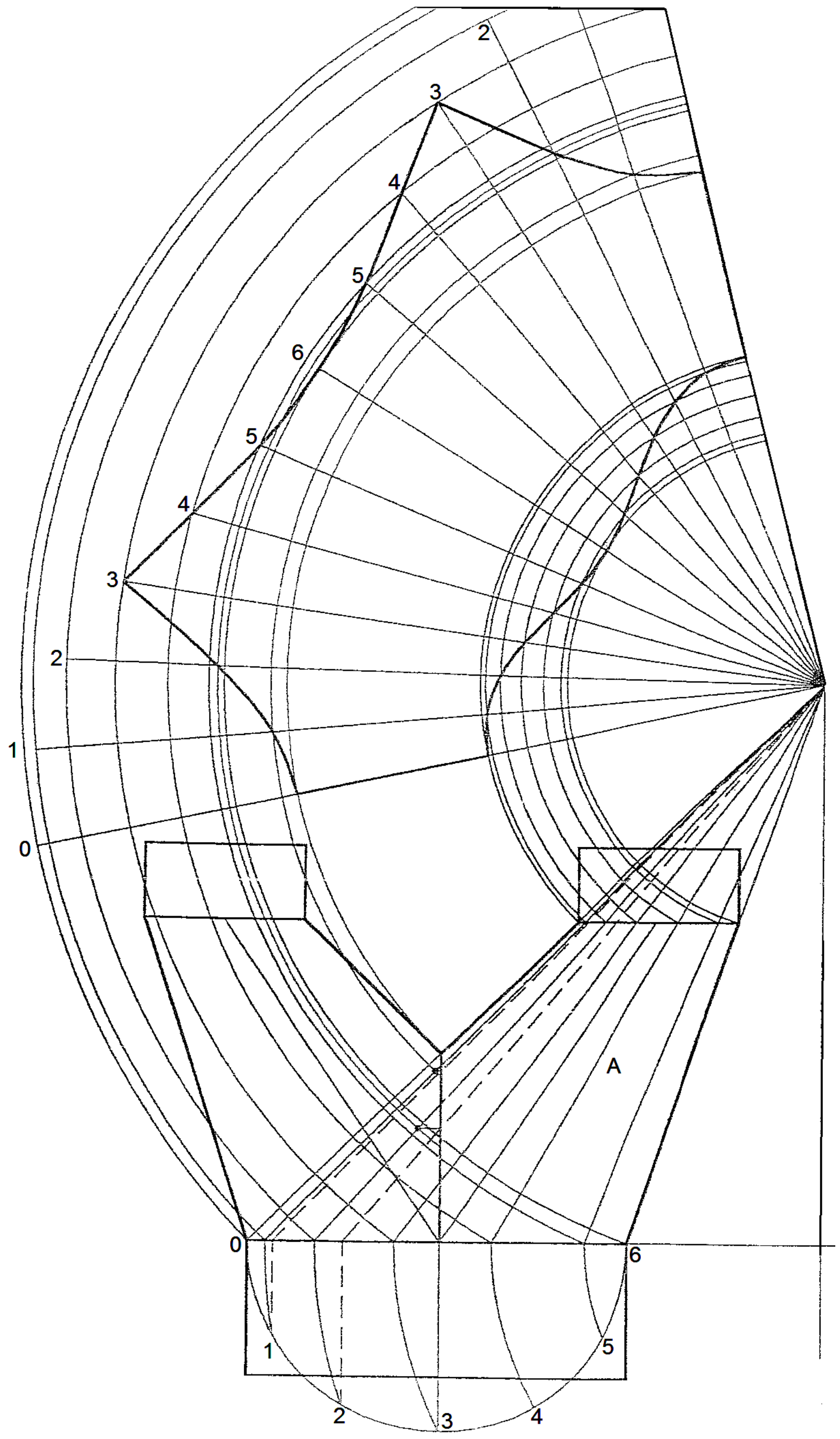



Figure 5.15 Solution

Now work carefully through **Worked Example 2**, below, which shows an intersection between a cone and a dome.

The solution is given on the following page.

## Worked Example 2

**Figure 5.16** shows an intersection between a cone and a dome.

Draw the given view, determine the line of penetration and develop the pattern for the cone.

Scale 1:10

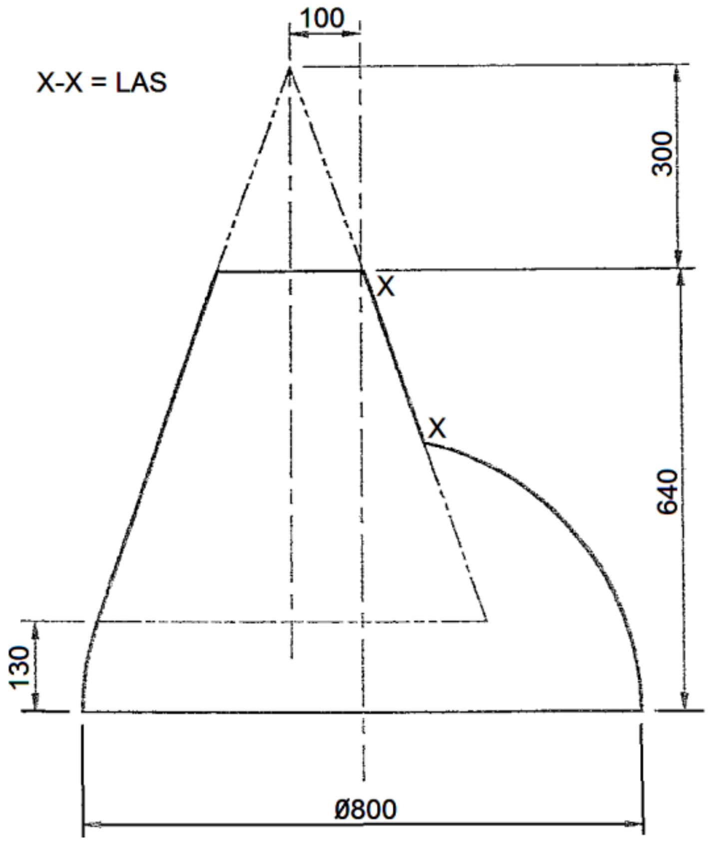



Figure 5.16 An intersection between a cone and a dome

Solution:

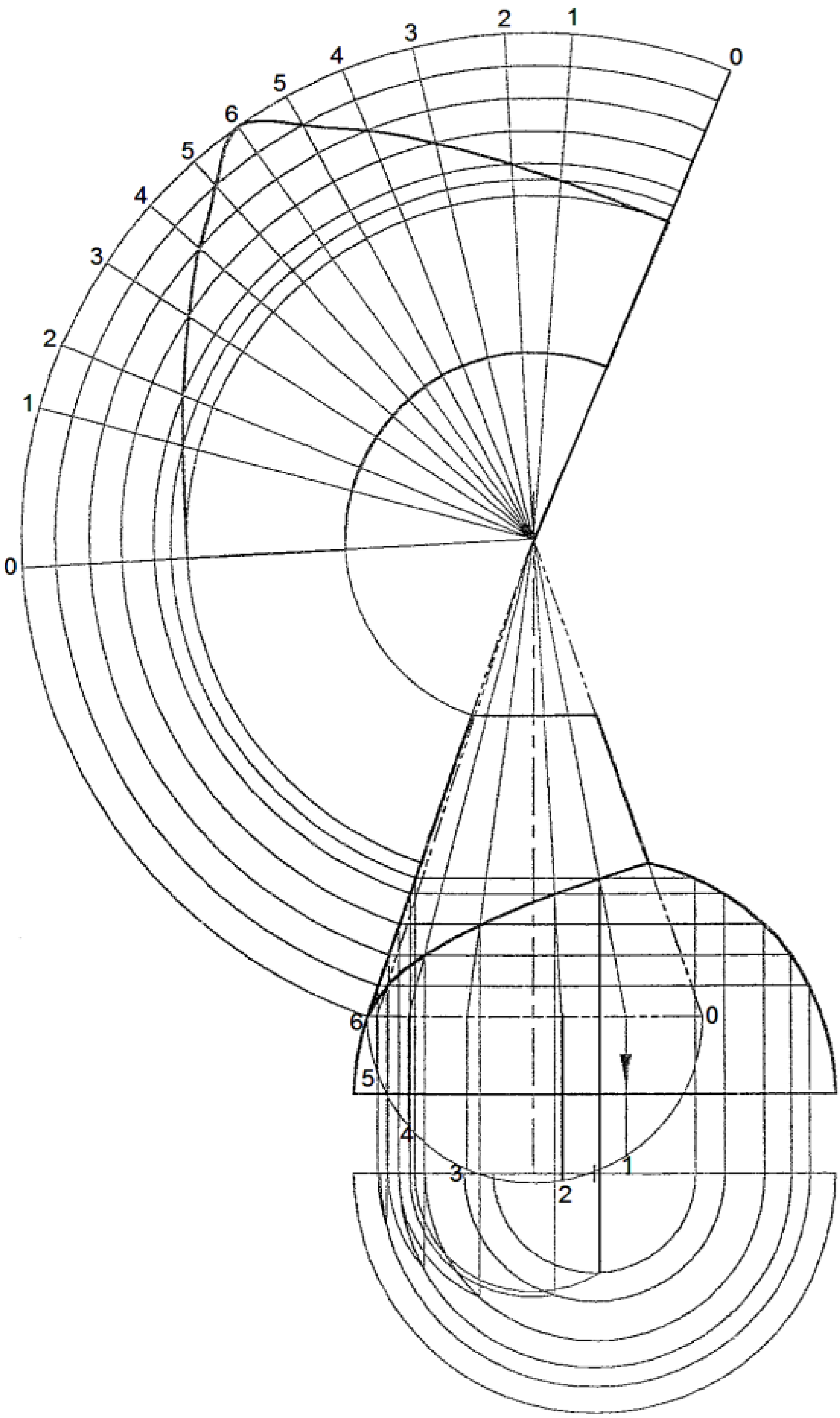



Figure 5.17 Solution

Now work carefully through **Worked Example 3**, below, which shows the tapered lobster back bend.

The solution is given on the following page.

## Worked Example 3

Use the common central sphere method to draw the tapered lobster back bend as shown in **Figure 5.18**.

Develop the pattern-for the segment marked 'S'.

Scale 1:1

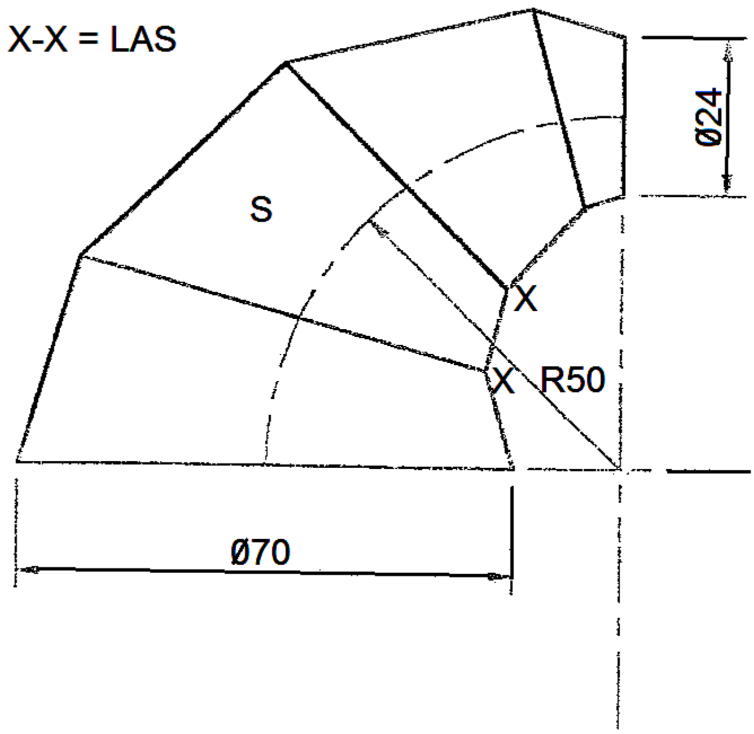



Figure 5.18 Tapered lobster back bend

Solution:

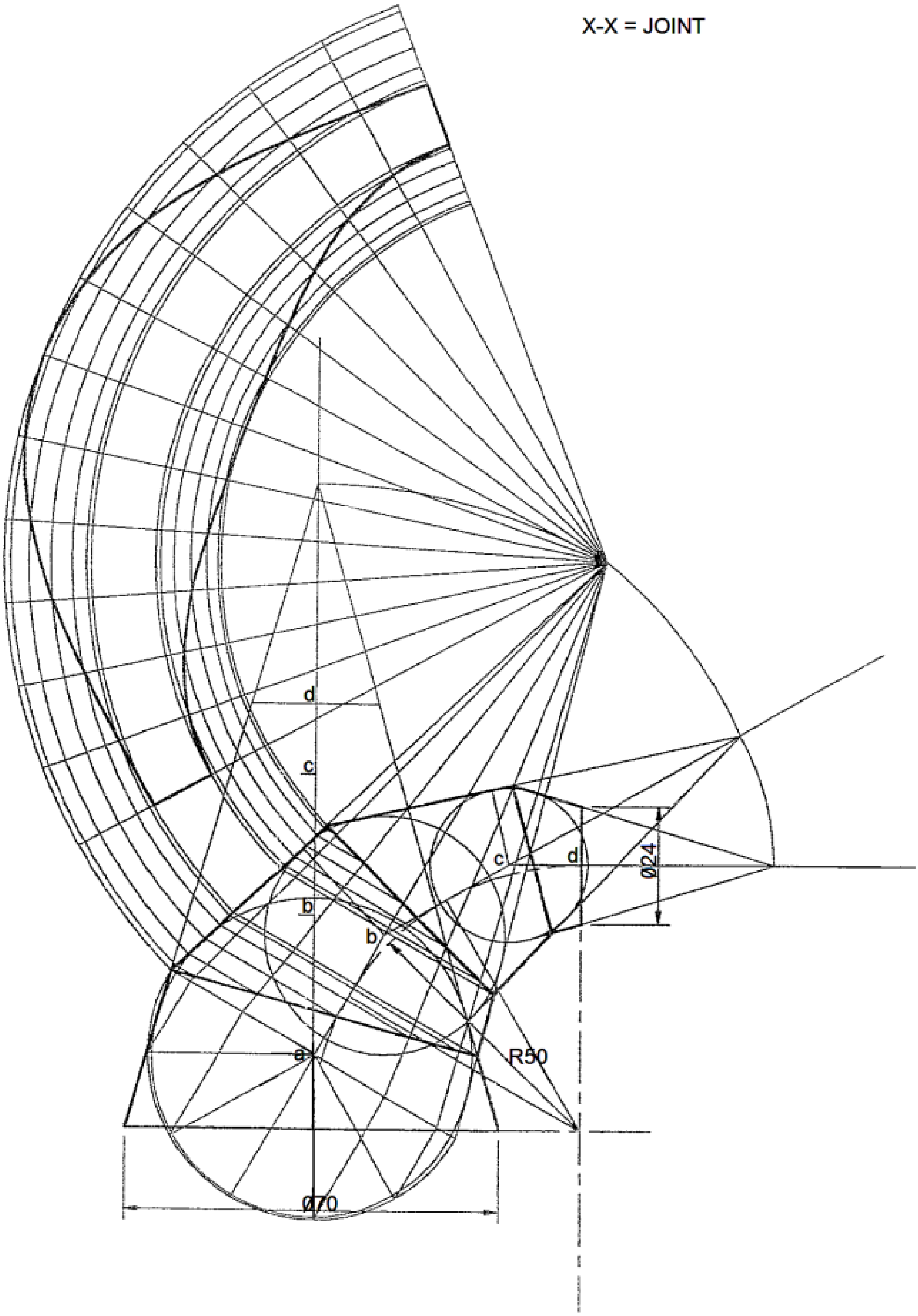



Figure 5.19 Solution

Now work carefully through **Worked Example 4,** below, which shows a junction between a cone and a cylindrical pipe.

The solution is given on the following page.

## Worked Example 4

**Figure 5.20** shows a junction between a cone and a cylindrical pipe.

Draw the given views and construct the line of penetration to complete the front view and the top view.

Develop the following:

The cylindrical pipe marked 'A'
The hole in the cone

Scale 1:10

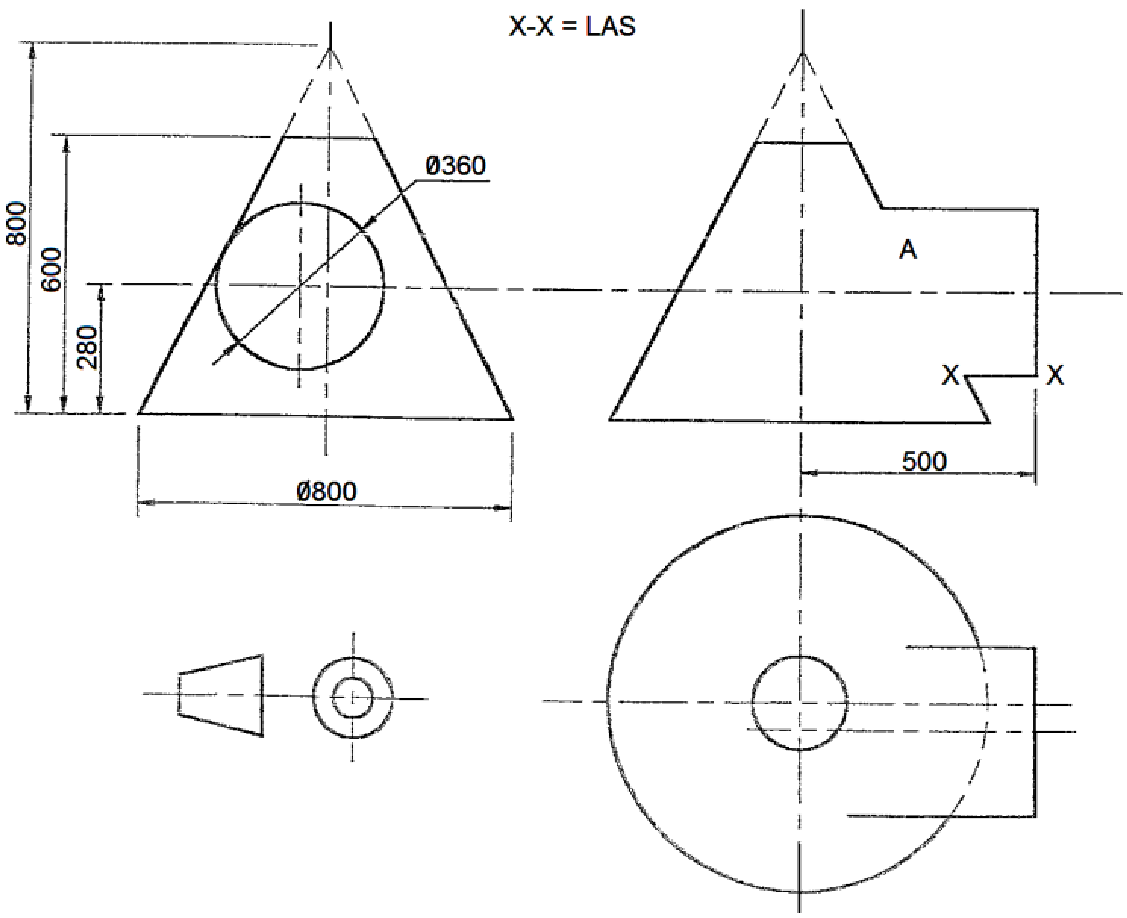



Figure 5.20 A junction between a cone and a cylindrical pipe

Solution:

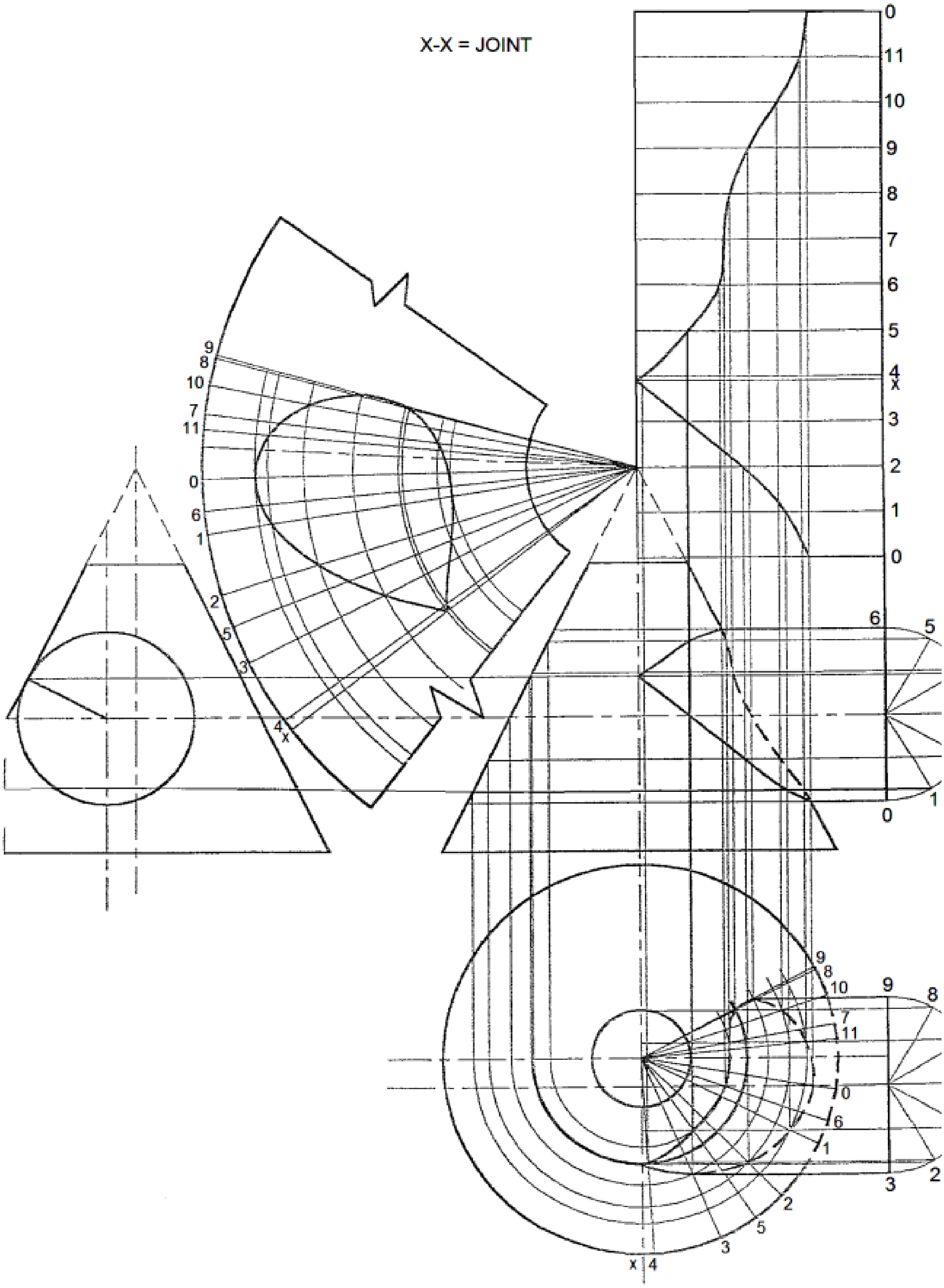



Figure 5.21 Solution

Now work carefully through **Worked Example 5**, below, which shows an oblique conical hopper fitting on a cylindrical duct.

The solution is given on the following page.

## Worked Example 5

**Figure 5.22** shows an oblique conical hopper fitting on a cylindrical duct.

Draw the given view and develop the hopper.

Scale 1:10

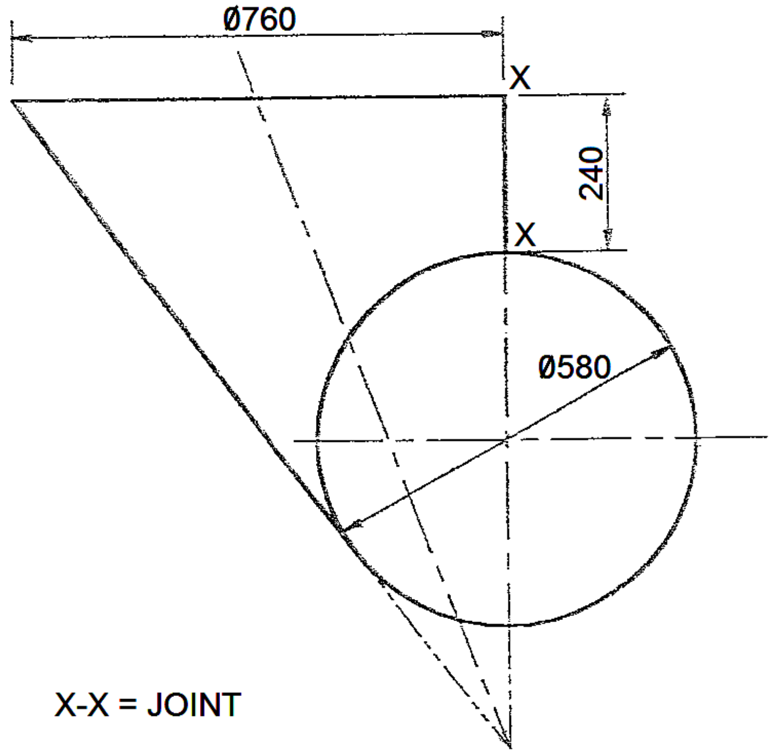



Figure 5.22 An oblique conical hopper fitting on a cylindrical duct

Solution:

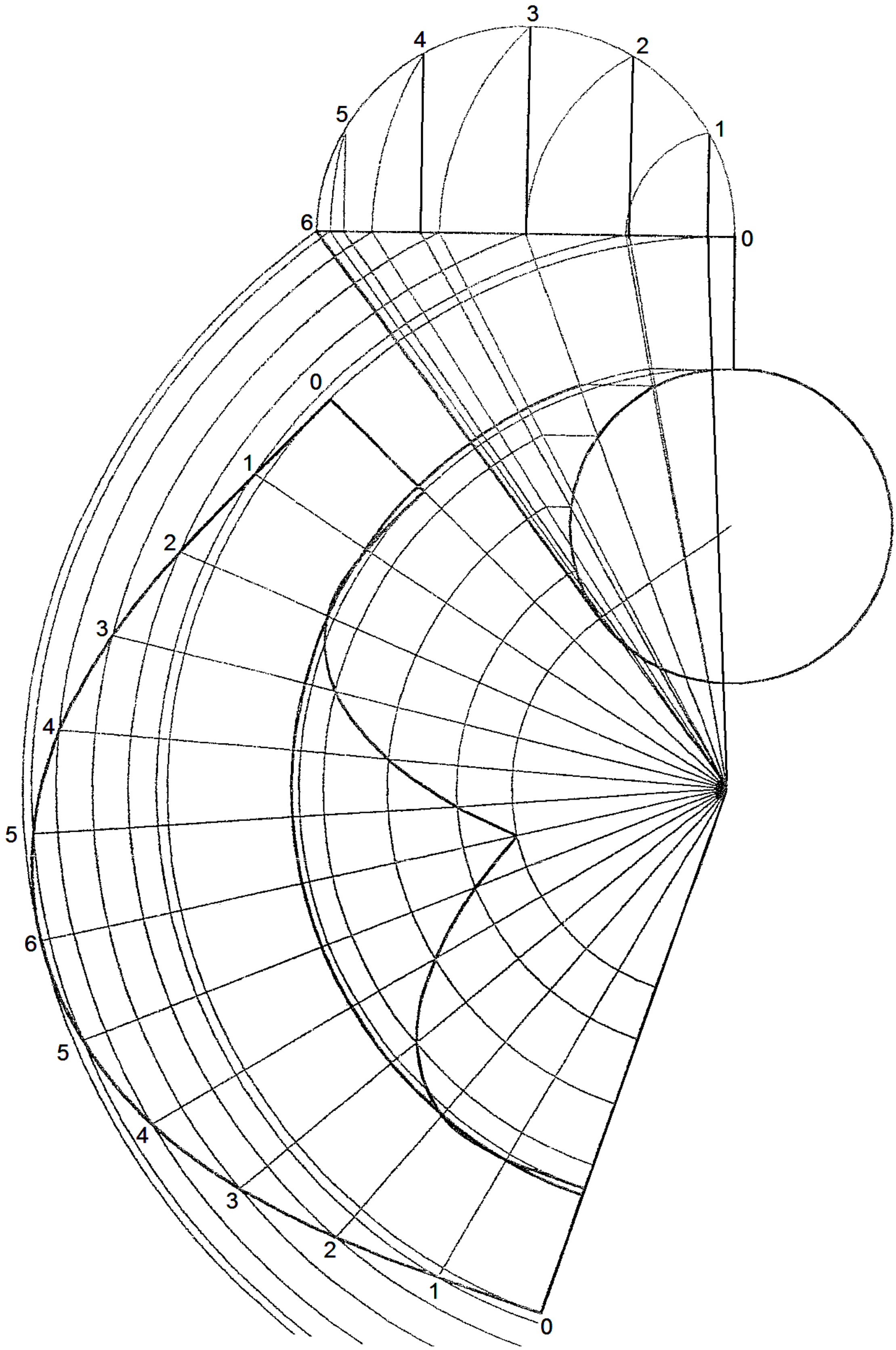



Figure 5.23 Solution

## Activity 5.1

Develop the following Right Cone (see **Figure 5.24**).

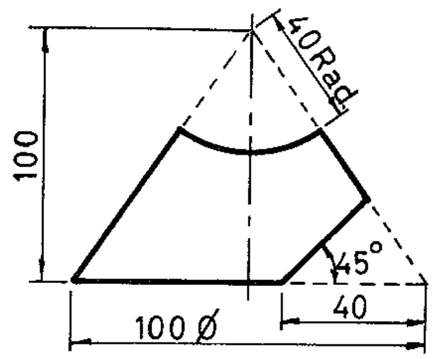



Figure 5.24 Right Cone

## Activity 5.2

Develop the following Oblique Cone (see **Figure 5.25**).

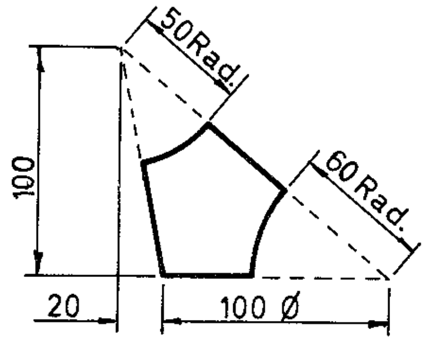



Figure 5.25 Oblique Cone

## Activity 5.3

Develop the following cone (see **Figure 5.26**).

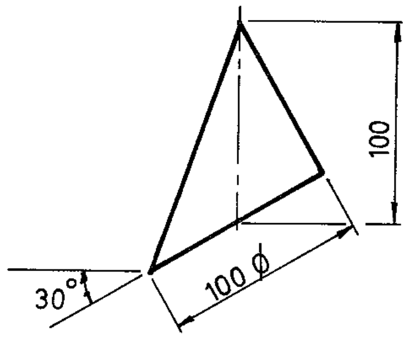



Figure 5.26 Cone

## Activity 5.4

Develop the following cone (see **Figure 5.27**).

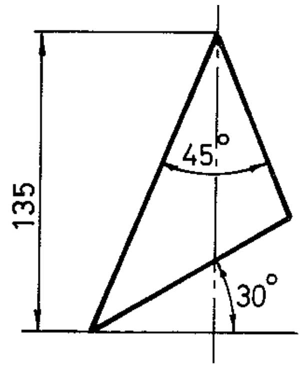



Figure 5.27 Cone

### Self-Check

| I am able to: | Yes | No |
|---|---|---|
| • Define the following regarding Radial line development: | | |
| o Divisions and numbers | | |
| o True lengths | | |
| o Central ball theorem | | |
| • Describe the general rules for a right cone | | |
| • Describe the development of right cone | | |
| • Describe the general rules for an oblique cone | | |
| • Describe the development of oblique Cone | | |
| • Describe the following cone frustrum's: | | |
| o cut at top (right cone) | | |
| o cut at bottom (right cone) | | |
| o cut at top and bottom (right cone) | | |
| o cut at top (oblique cone) | | |
| o cut at bottom (oblique cone) | | |
| o cut at top and bottom (oblique cone) | | |

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

# Module 6

# Triangulation

**Learning Outcomes**
On the completion of this module the student must be able to:

- Define the Triangulation Theorem
- Determine the bend lines
- Describe the following:
  - Square to round on parallel planes
  - Square to square on parallel planes
  - Cone frustrum on parallel planes (right cone)
  - Cone frustrum on parallel planes (oblique cone)
- Explain triangulation on converging planes; pyramid and cone frustrum
- Describe taper lobsterback bends
- Determine kinks and splays
- Describe the following Splays (by-projections):
  - Angle of bend line $A.A^1$
  - Angle of bend line $B.B^1$
  - Angle of kink bend line $A.B^1$
- Develop a hopper with converging planes (kink knuckle out)

## 6.1 Introduction

The triangulation method used for developing is the most versatile, as it is possible to do any development with triangulation, and in fact, as there are many developments that can only be done by triangulation.

It is therefore of the utmost importance to understand the basic principles of triangulation.

## 6.2 Triangulation Theorem

Imagine a round bar bent as shown in **Figure 6.1** with a string attached to points A and B.

If you look at a top view of this object it would seem that the length of the string between points A and B is 300 mm, but we know from the front view that the true length is 500 mm.

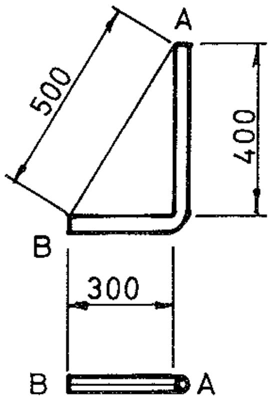



Figure 6.1 A round bent bar

It is not true to say that all lines in the front view are true lengths as they might be sloping away from you or towards you. To overcome all these problems we always work from the top view of an object to obtain the true length.

## Worked Example 1

Please see **Figure 6.2** while reading the following:

a) Draw a vertical line with height corresponding to vertical height of the cone.
b) Take top view length of XY and place normal to the vertical line drawn to represent the vertical height.
c) Now set compass to the length across the hypotenuse of the triangle formed thus. This will represent the true length X. Y (Check with front View.)

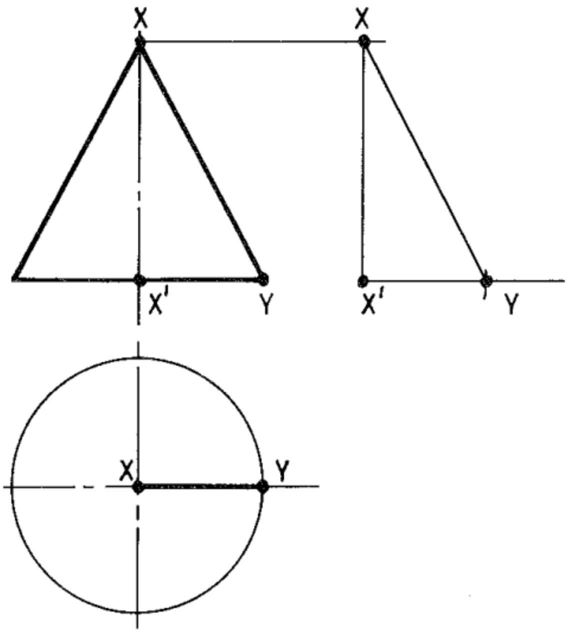



Figure 6.2

**Important rule:**
To obtain the true length of a line:

Place the top view length against the vertical height and measure the slant length which is the true length, as seen in **Figure 6.3** below.

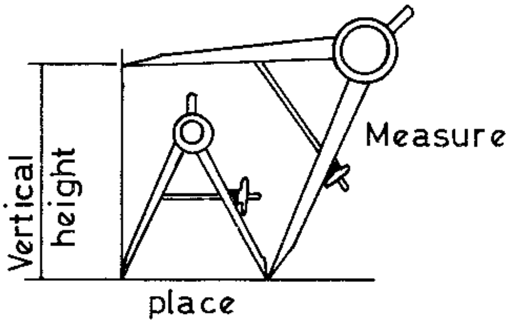



Figure 6.3 True length

The example that was used can be seen to conform to Pythagoras' theorem (which you will be required to know and use later on).

**6.2.1 Main points to observe**

- Draw neatly and accurately.
- Top View is of most importance.
- Draw front view.
- Determine the bend lines.
- Number each plane differently i.e. bottom plane A, B, C, etc., and top plane, 1, 2, 3, etc.
- Calculate the circumference and obtain unit length (circumference ÷ 12).
- Obtain true lengths.
- Start developing on the opposite side of the required joint and work symmetrical about the starting points.
- As you complete each successive triangle, mark the points and draw in the appropriate lines.

**NOTE:**
By numbering the two planes differently, you immediately know which dimensions taken from the top view are true and for which we should find the true lengths.

Measuring between A, B, C, etc., and 1, 2, 3, etc., will be true lengths, whereas if we measure from letters to numbers we have to find the true lengths.

## 6.3 Determining the bend lines

After being able to determine the true length, the second and last very important point is to determine the bend lines on development.

We basically have to do with straight lines combined with curved lines or straight lines as shown in top view.

- Determine the bend lines by placing your rule or "T" square along a straight line having two ends marked.
- Move the rule towards the second shape (straight or curved) ensuring that the rule stays parallel with the straight line, until you touch the second shape and mark these touch point or points (see examples).

Now work carefully through **Worked Example 2,** below**,** which shows a square with bend lines. The solution is given.

### Worked Example 2

1. Mark the square A.B.C.D, as seen in **Figure 6.4** below.
2. Now move the rule parallel to AB until you touch the circle and mark. We now have the 2 points A and B and 1 point on the circle.
3. By connecting them we have our first two bend lines.
4. Continue in this manner with the other three sides to complete the outline. This gives us four points on the circle and as we have seen, we require more points for accuracy.
5. We therefore divide the circle into 12 parts in the usual way using the existing points.

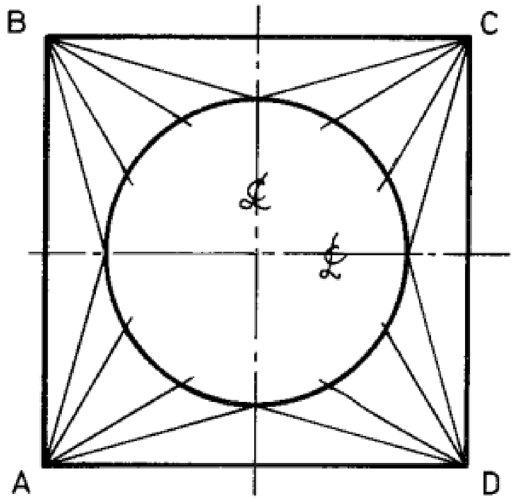



Figure 6.4 A square with bend lines

**NOTE:**
From our notes on tangent lines it will be found that the points on the circle will always be on the centre lines of the circle.

Now work carefully through **Worked Example 3,** below**,** which shows a square with bend lines and four points on the inside square. The solution is given on this page.

## Worked Example 3

By applying the method in *Worked Example 2*, we once again see that from points AB we get one point on the inside square. Continue in this manner until all four sides have been done, as seen in **Figure 6.5** below.

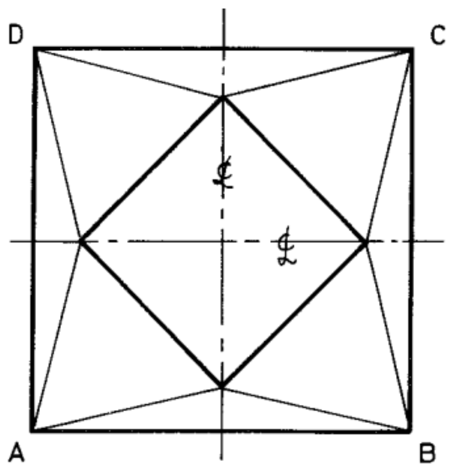



Figure 6.5 A square with bend lines

## 6.4 Square to round on parallel planes

After drawing front view, top view and true height scale, the drawing has to be numbered, each plane differently.

Start developing at the opposite side of the joint; in this case between points D and C.

Draw a line D.Y.C. as taken from top view which is a true length and construct a perpendicular on point Y.

Measure Y.6 on top view and obtain the true length, then place on development and draw in the bend lines C.6 and D.6. The next point C; to 5 obtain true length and scribe on arc with centre C.

Then use unit length 6 to 5 calculated and with centre 6 scribe an arc to cut arc C, at point 5.

Number this point and draw in the bend line C.5.

Similarly work around on both sides until you have completed points 5, 4 and 3 on the one side and points 7, 8 and 9 on the other side.

You should have seen, by this time that we are continually completing triangles such as 6.Y.D.6, 6.C.Y.6, C.6.5.C, etc.

The next triangle we have to complete is A.D.9.A (looking at the top view).

Set compass on A.D. (true length) and with centre D on development scribe an arc, then measure A.9 and obtain true length.

Then with 9 as centre on the development, scribe an arc to cut arc A.D and mark point A obtained.

Complete the triangle by drawing in the lines A.D and A.9. Proceed in this manner until you have done the last two triangles A.O.X.A and B.O.X.B.

To check whether your development is correct and true, the angles O.X.A. and O.X.B. must be right angles 90°).

Complete the development by connecting all the points O to 11 with a continuous curve.

**NOTE:**
It is also possible when working with round areas to see when you are making a mistake, as the points on the curve will always form a flowing curve. There should never be any radical change in direction.

**NOTE:**
For this development it was in actual fact necessary to obtain the true lengths only three times as the following should be noted for this development.

C.6, D.6, D.9, A.9, A.0, B.0, B.3 and C.3, were of the same length and C.4, C.5, D.7, D.8, A.1O, A.11, B.1, B.2, were of the same length, it was also necessary to obtain Y.6 and X.O, which was the same length.

On the following page, **Figure 6.6** illustrates a square to round on parallel planes.

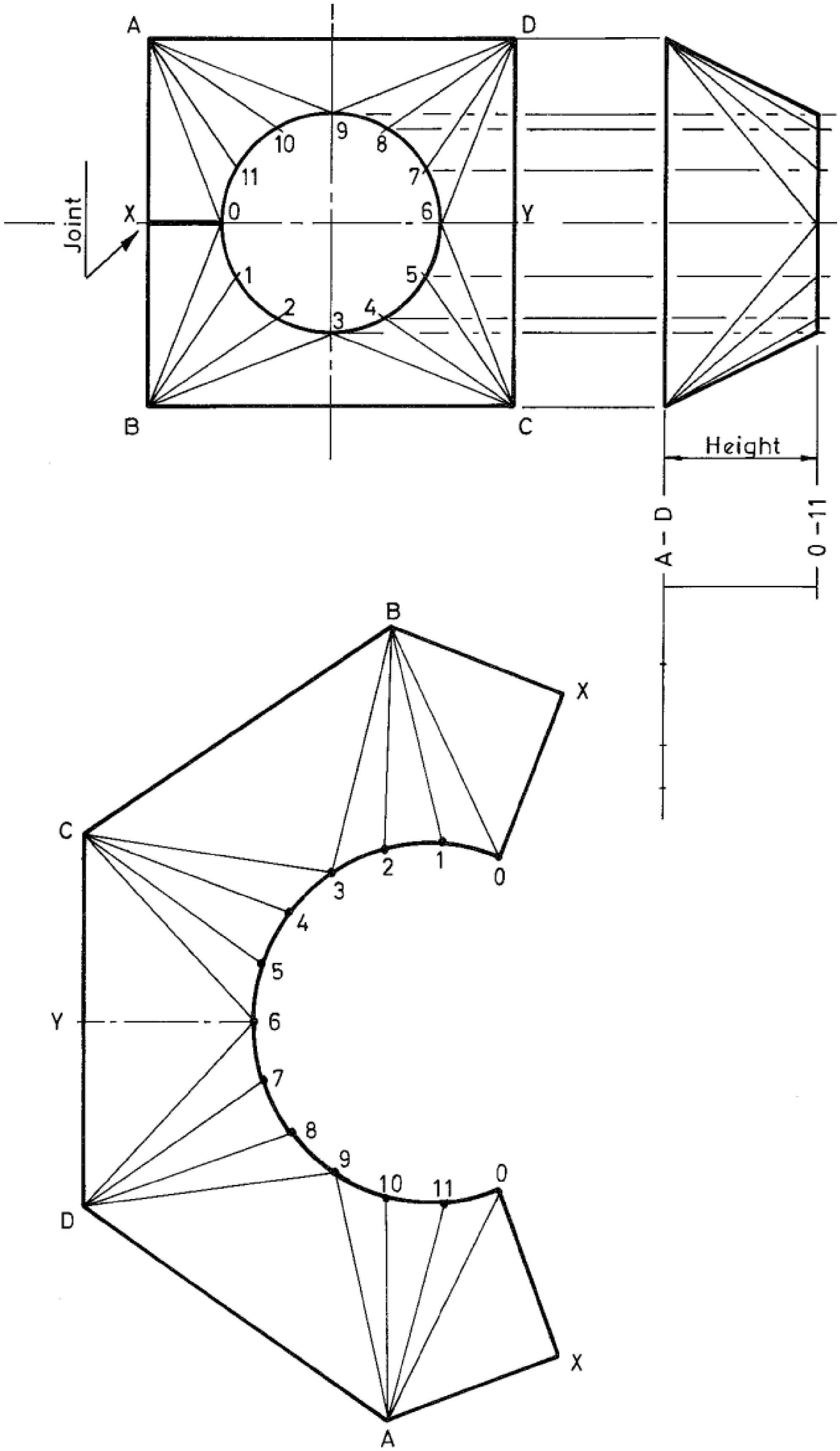



Figure 6.6 Square to round on parallel planes

## 6.5 Square to square on parallel planes

As for *section 5.5* you start off by drawing the front view, top view and the true length scale.

Then number with letters on one plane and numbers on the other plane.

Looking at **Figure 6.7(a)** below, you will note that we have no triangles formed by the bend lines.

And the outside lines and as we need triangles we have to add auxiliary lines to form triangles.

This can be seen by the dotted lines in the **Figure 6.7(b)** on the following page.

Commence by drawing D.C (opposite to joint), then complete triangle D.C.4.D. and draw in the lines. D.4 and D.C. will be full lines and 4.C will be dotted as shown on the top view.

Next we do triangle 4.3.C.4 and the other triangles are then done in sequence until you have completed triangles A.X.XO.A and X.XO.B.X.

This can be seen in **Figure 6.8** on the following page too, which shows a square to square on parallel planes.

**NOTE:**
To check development, the angles A.X,XO and B.X.XO should be right angles.

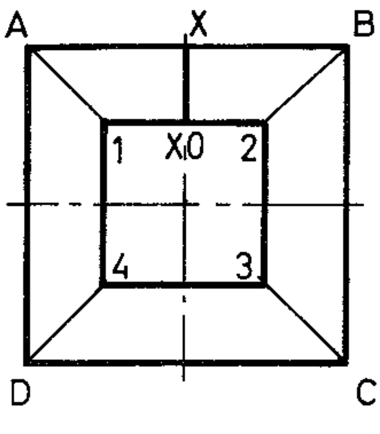



Figure 6.7(a) No triangles by bend lines

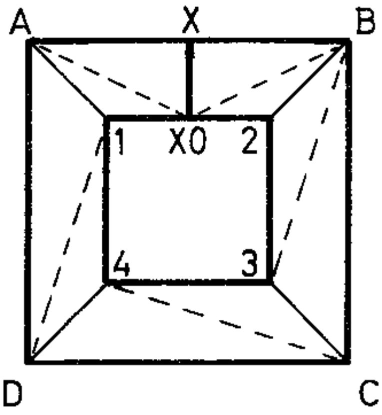
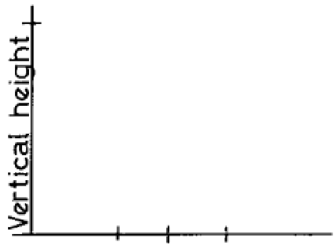



Figure 6.7(b) Auxiliary lines form triangles



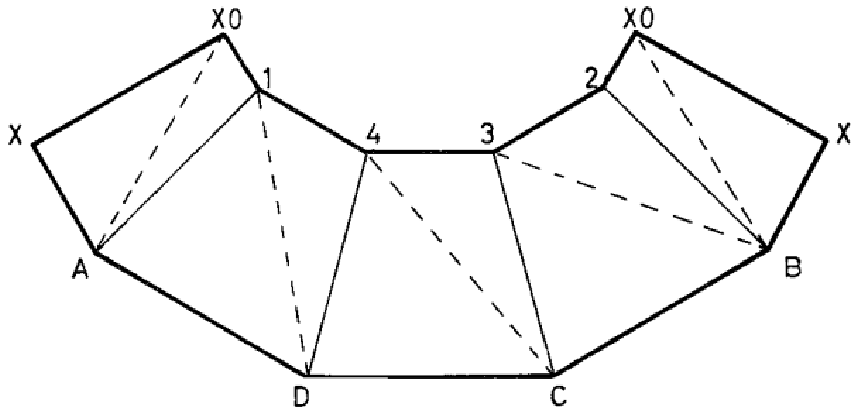




Figure 6.8 Square to square on parallel planes

## 6.6 Cone frustrum on parallel planes (right cone)

Draw the front view, top view and true length scale, obtain bend lines by dividing the circles and number the planes using different notations.

You once again find that you have no triangles and have to add auxiliary lines (dotted).

Calculate the two circumferences and get the unit lengths (circumference + 12).

Then complete the development by completing each successive triangle until done, as seen in **Figure 6.9** below.

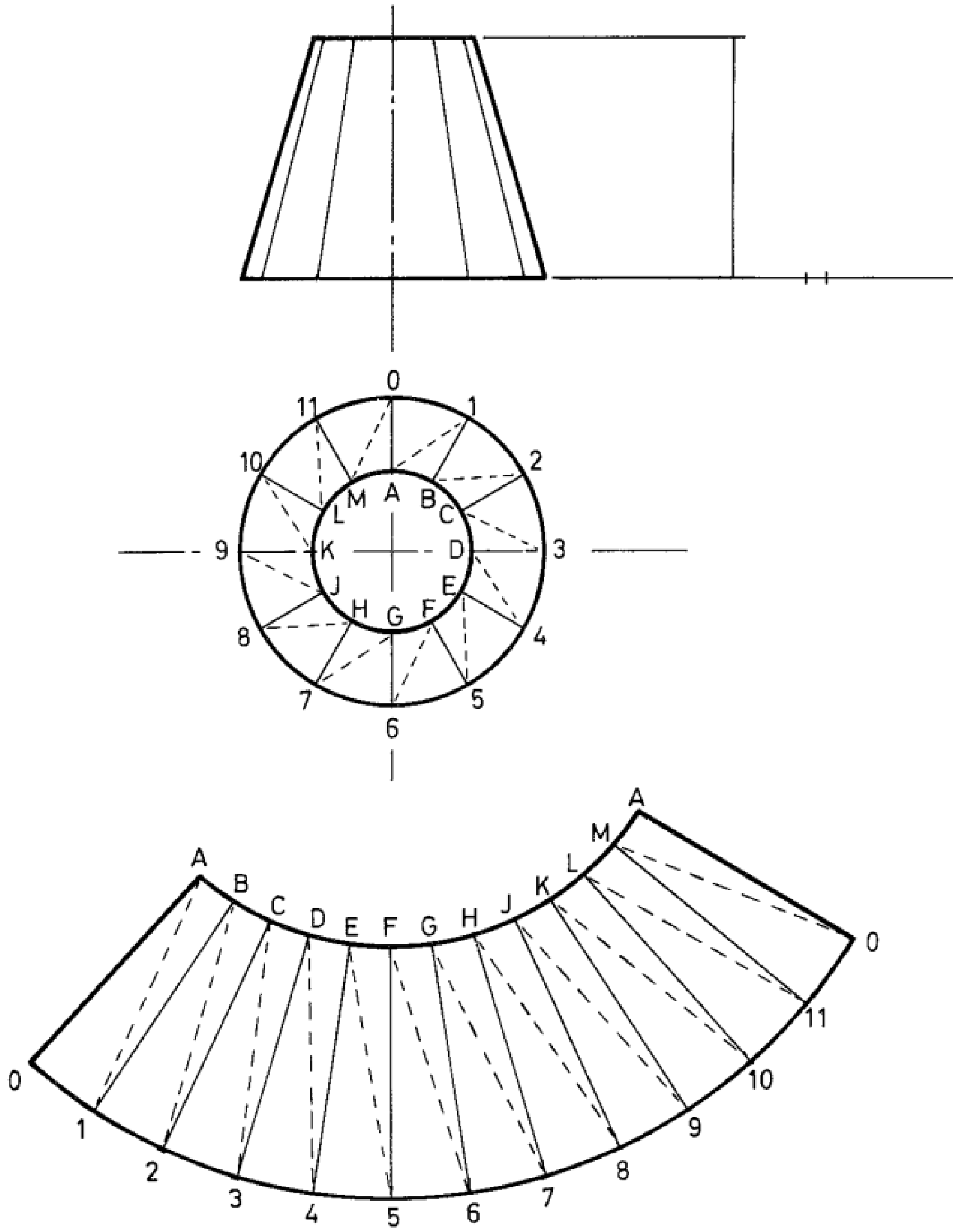



Figure 6.9 Cone frustrum on parallel planes (right cone)

## 6.7 Cone frustrum on parallel planes (oblique cone)

As per *section 5.7*, see **Figure 6.10** on the following page which shows the cone frustrum on parallel planes (oblique cone).

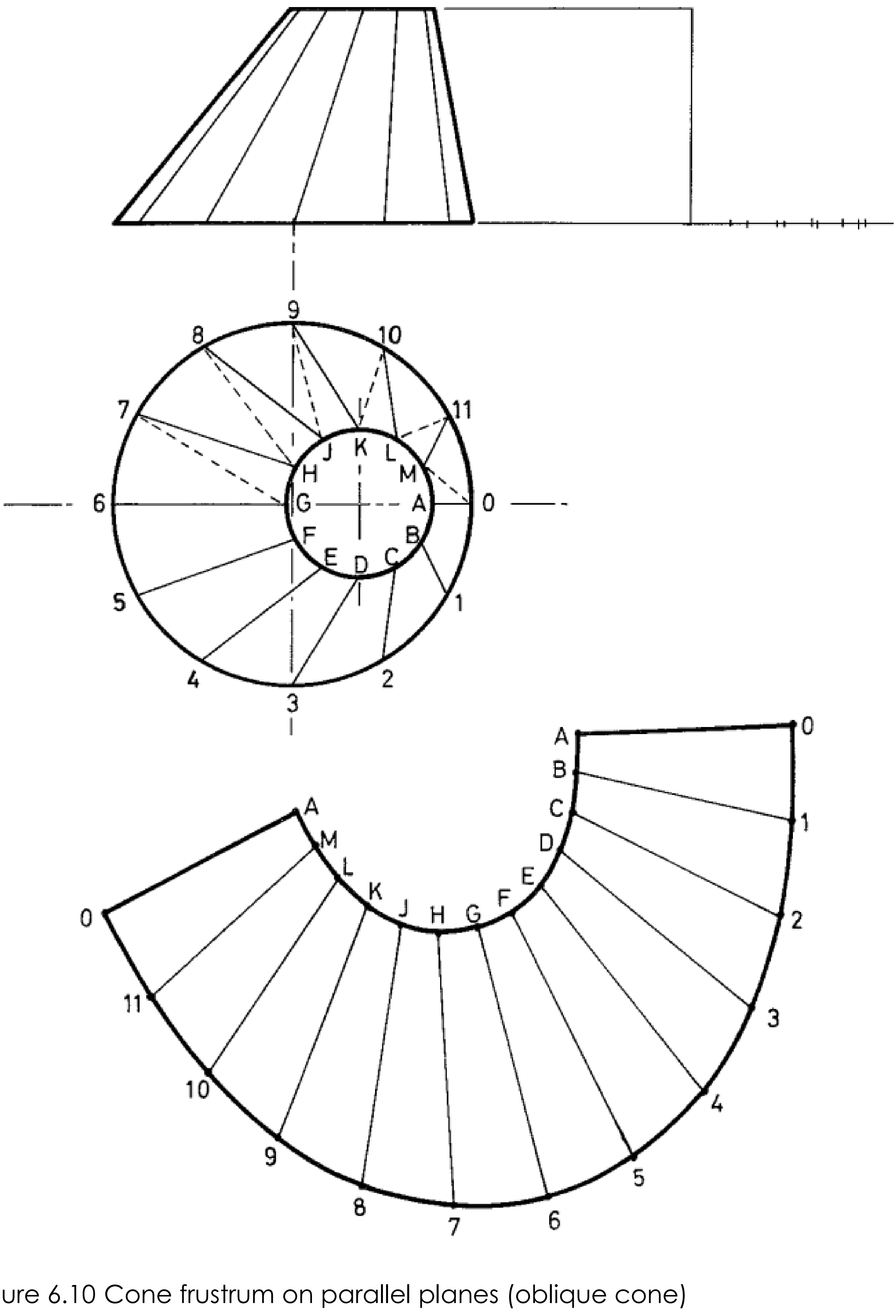



Figure 6.10 Cone frustrum on parallel planes (oblique cone)

## 6.8 Triangulation on converging planes (pyramid frustrum)

We start developing at line A.1 by obtaining the true length, see **Figure 6.11,** take top view length A.1 and place on the plane line of point A (see true length diagram) and measure the true length to the apex of the triangle on the plane line of point 1.

Now complete triangle A.1.B (note: AB is a true length as they are on the same plane). Then complete triangle 1.B.2 (note: 1.2. is a true length). The following triangle to do will be B.2.C.

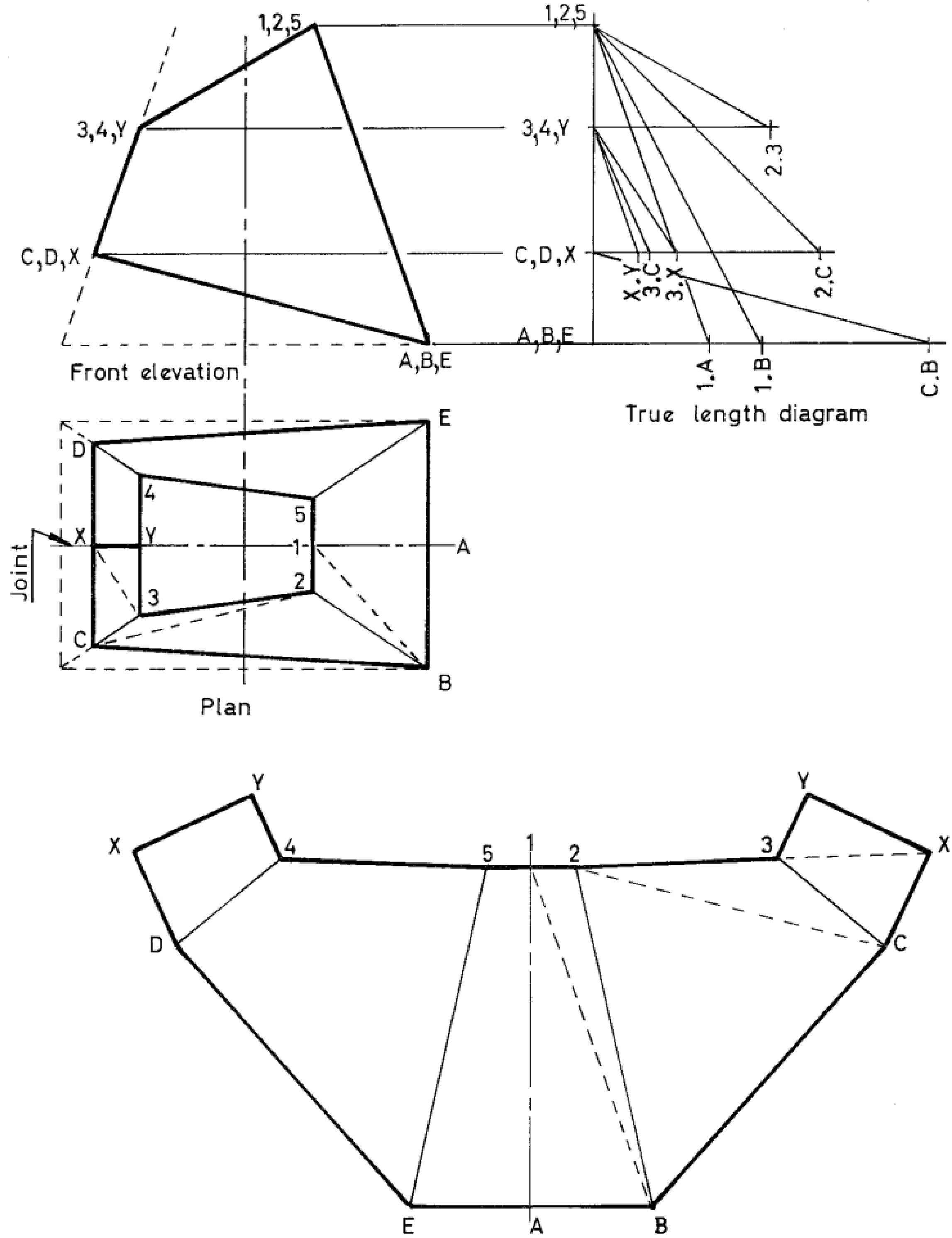



Figure 6.11 True length diagram

**NOTE:**
C. B. is not a true length as they are not on the same plane line and should be obtained between plane lines C and B (see true length diagram). The rest of the development is done on the same basis.

## 6.9 Triangulation on converging planes (cone frustrum)

This development is done on the same pattern but it is important to note that none of the dimensions used are true lengths as all the points lie on different planes.

**Figure 6.12**, below and on the following page, shows triangulation on converging planes (cone frustrum).

In a development of this kind it is very important to mark your true length diagram with the utmost care to avoid any errors.

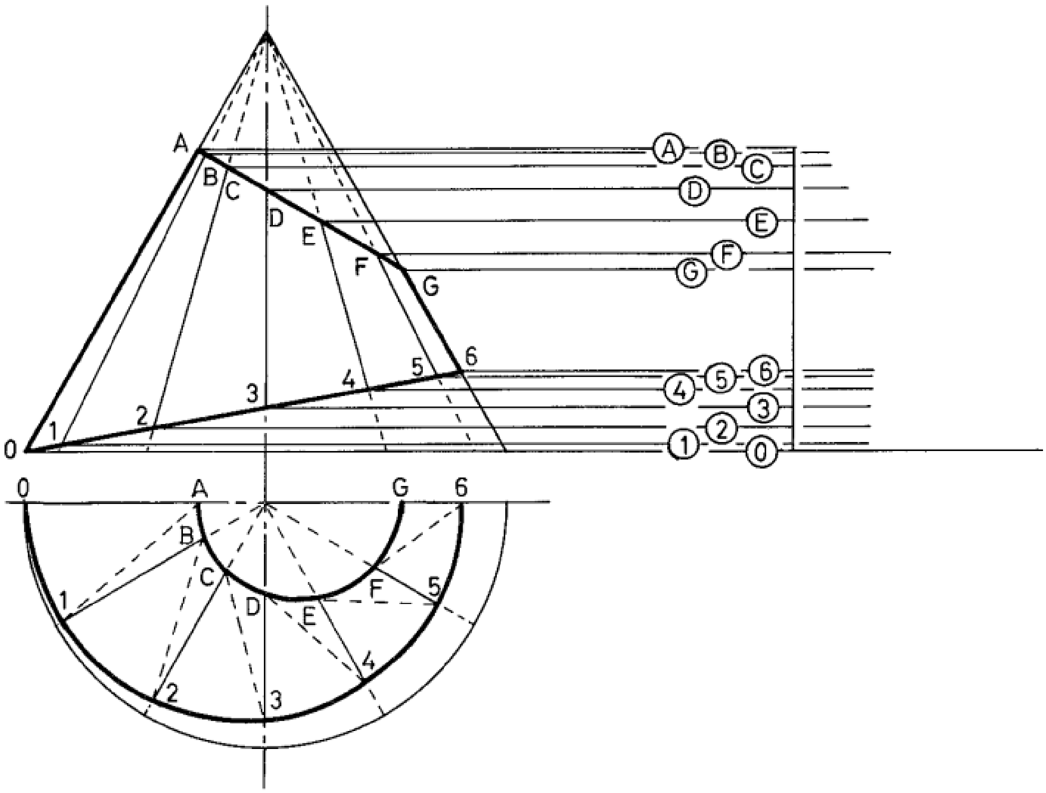



Figure 6.12 Triangulation on converging planes (cone frustrum)

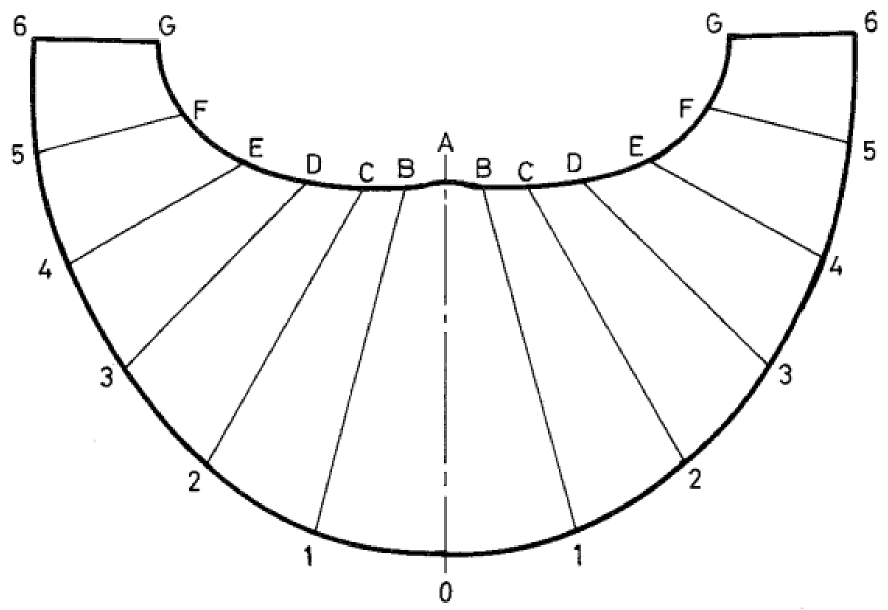



Figure 6.12 Triangulation on converging planes (cone frustrum) (continued)

## 6.10 Taper lobsterback bend

The only problem in the development of the taper lobsterback bend is the layout and segment divisions, as the actual development is as for right conical segments.

We will now consider the layout and divisions of a four segment taper lobsterback bend with predetermined diameters, centre radius and numbers of segments, as seen in **Figure 6.13** later.

First we layout the centre Radius line; AE, with large diameter XX and small diameter YY, at the base with the 90° lines.

The Centre radius should be divided according to the number of segments required similar to the division methods for the straight lobster bends.

For a 4 segment bend we need 2 full segments. Therefore, we divide the centre radius line AE into 4 + 2 (halves) = 6 halves.

Then project point A perpendicular to XX. To cut the first division line at B from B draw a tangent line to the centre radius line AE to cut the 3rd division line at C.

From C we do the same to obtain D and we complete this centre line sequence by projecting E normal to YY to connect to D.

Now extend point A projection to obtain the apex point O, along this centre line step of the centre line distances AB, BC, CD, and DE and mark $C^1$, $D^1$, $E^1$ through point $E^1$.

Draw and extend a line normal to $E^1$ A and mark small diameter dimension $Y^1$ $E^1$ $Y^1$.

From points X through $Y^1$ obtain apex O on centre line AO. This will give us the complete cone frustrum that will be required.

To obtain the cut-off points and segments we commence as follows: Using the central ball theorem with centre B, draw a circle to touch the cone frustrum XX $Y^1Y^1$.

Then from B extend the tangent line B.C. to represent the next conical section centre line, then with B as centre and radius B.O. scribe to cut new centre line at $O^1$.

If we now continue (following the central ball theorem) draw tangent lines from $O^1$ to circle B to form a new cone with centre line $O^1B$.

Where outsides at cone AO touch cone $O^1B$ we obtain F&G which when connected forms interpenetration line (centre ball theorem).

Following the same procedure with centre C, draw a circle to touch the cone $O^1$ .FG. then, from C, extend the tangent line CD to represent the next conical section centre line.

Then with C as centre and radius $C^1O$ scribe to cut new centre line at $O^{11}$.

From $O^{11}$ draw tangent lines to touch the circle about centre C to form new cone with centre line O C.

Where outsides of cone $O^{11}$ C touch outsides of cone $O^1$ B at points H&J. we have our second line of interpenetration.

Follow the same procedure with centre D to obtain the last intersection line K.L.

It should now be clear to you that all these segments are cone frustum's and could be developed as such.

**NOTE:**
If we place all the segments together by rotating each alternate segment 180° it will be seen that they form the cone frustrum $XXY^1Y^1$ see red lines in drawing.

On the following page, **Figure 6.13** illustrates taper lobsterback bends.

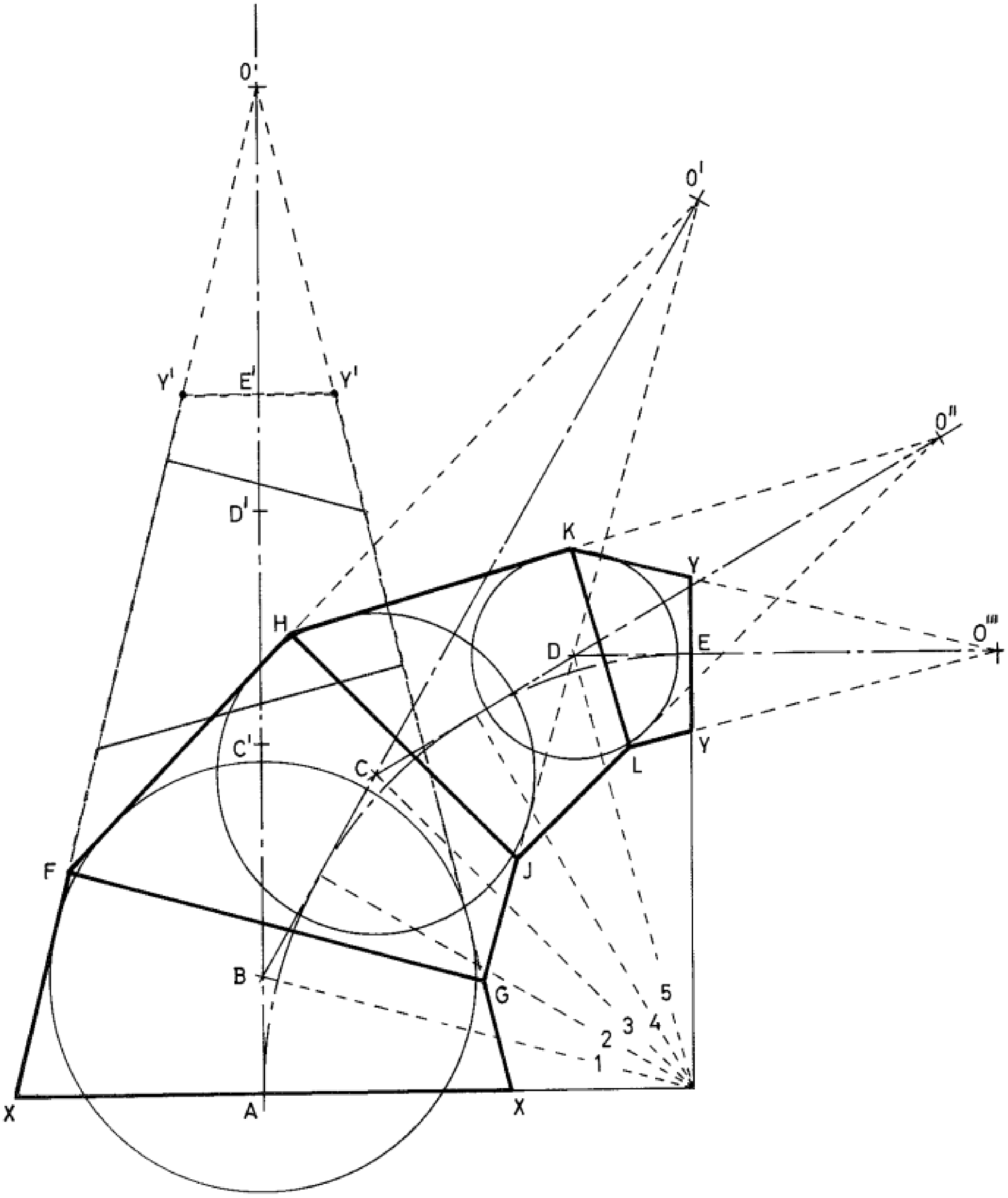



Figure 6.13 Taper lobsterback bends

## 6.11 Determining kinks and splays

All development problems are not as simple as you will see in the projections opposite.

In drawing A, in **Figure 6.14** on the following page, we find that the plates have the top and bottom parallel and as can be seen from the shading lines the plate shows straight.

But note in drawing B, in **Figure 6.15** on the following page, plate (1) shows straight but side plate shows a bend.

This is due to the fact that the top and bottom planes are not parallel. This bend is referred to as a kink.

In drawing C, in **Figure 6.16** on the following page, we have a similar hopper except that the kink has now been moved across the other diagonal.

**NOTE:**

- If a pyramid frustrum has a base and top not parallel and shows in top view as rectangle there will be a kink.
- The kink can either knuckle in or knuckle out giving a different appearance and development pattern but achieving the same goal.
- The kink is always marked from either top corner to the diagonally opposite bottom corner and is a *bend line*.
- The pattern development is carried out similar to the normal pyramid development see *section 5.9*.

On developments of this type, it is sometimes required to ascertain the angle of the splays of the corner bends and the kink bends:

**Figure 6.14** shows drawing A.

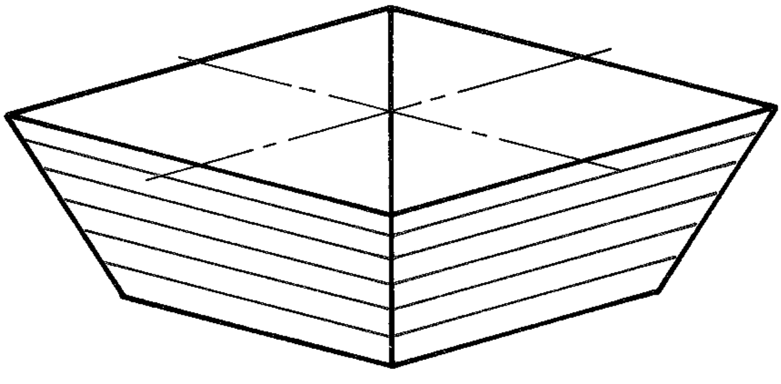



Figure 6.14 Plates top and bottom are parallel

**Figure 6.15** illustrates drawing B (kink knuckle in).

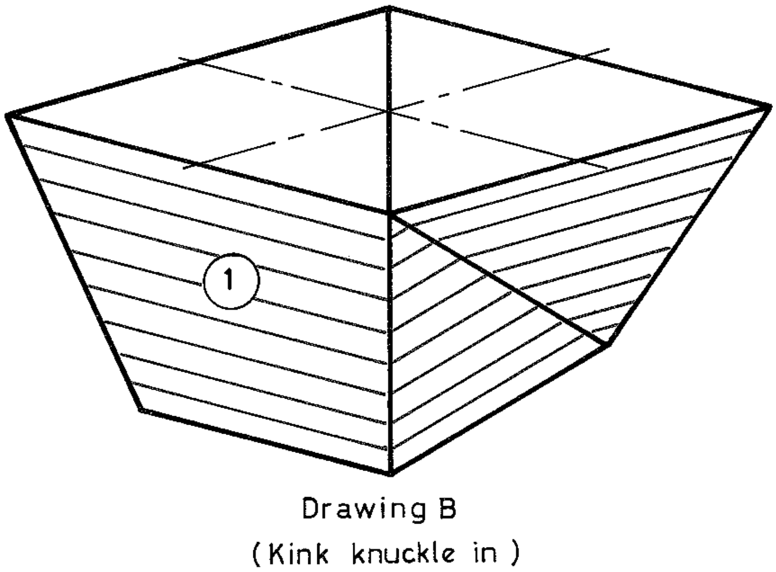



Figure 6.15 Plate 1 is straight, while side plate shows a bend

**Figure 6.16** shows drawing C (kink knuckle out).

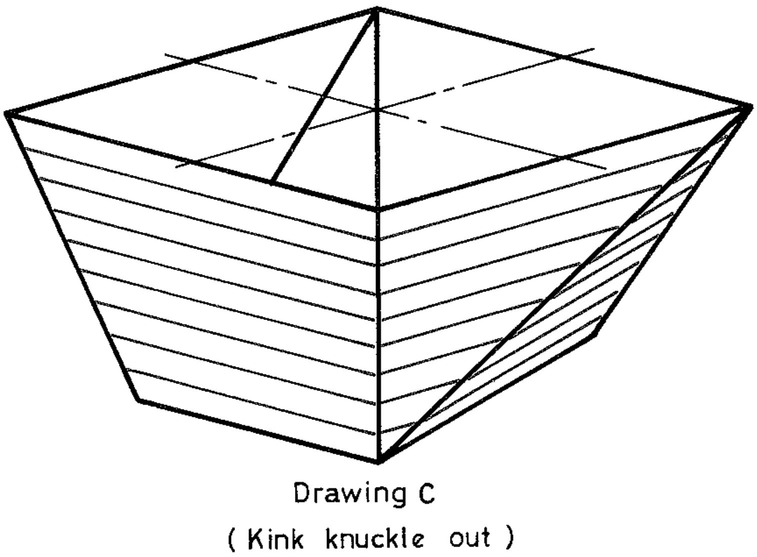



Figure 6.16 Hopper with a kink

## 6.12 Splays (by-projections)

Considering the figure, we obtain the splays by cutting plane projections.

**NOTE:**

- Cutting planes always normal to the bend considered.
- Project cutting points to top view and measure to centre line.
- Projects in line with bend under consideration.
- Always work to a datum centre line to obtain the bend angle.
- It will be noticed that the kink bend will always have three points from the centre line.

### 6.12.1 Angle of bend line A.$A^1$

Take a cutting plane (1) anywhere normal to the bend considered and mark Y.$B^1$. Project in line with bend line points Y and $B^1$.

Now, normal to these projection lines, draw the datum centre line OO.

Then project points Y and $B^1$ down to top view, measure the distances from Y and $B^1$ to the top view centre line and place them on the projections from the datum centre line giving the points 0, Y, $B^1$.

Join these points to give the angle of the bend, as seen in **Figure 6.17** on the following page, which shows splays (by-projections).

### 6.12.2 Angle of bend line B.$B^1$

Carry out the same procedure as shown in *section 6.12.1,* and as seen in **Figure 6.17** on the following page.

### 6.12.3 Angle of kink bend line A.$B^1$

This is similar to the procedure shown in *section 6.12.1*, and as seen in **Figure 6.17** on the following page.

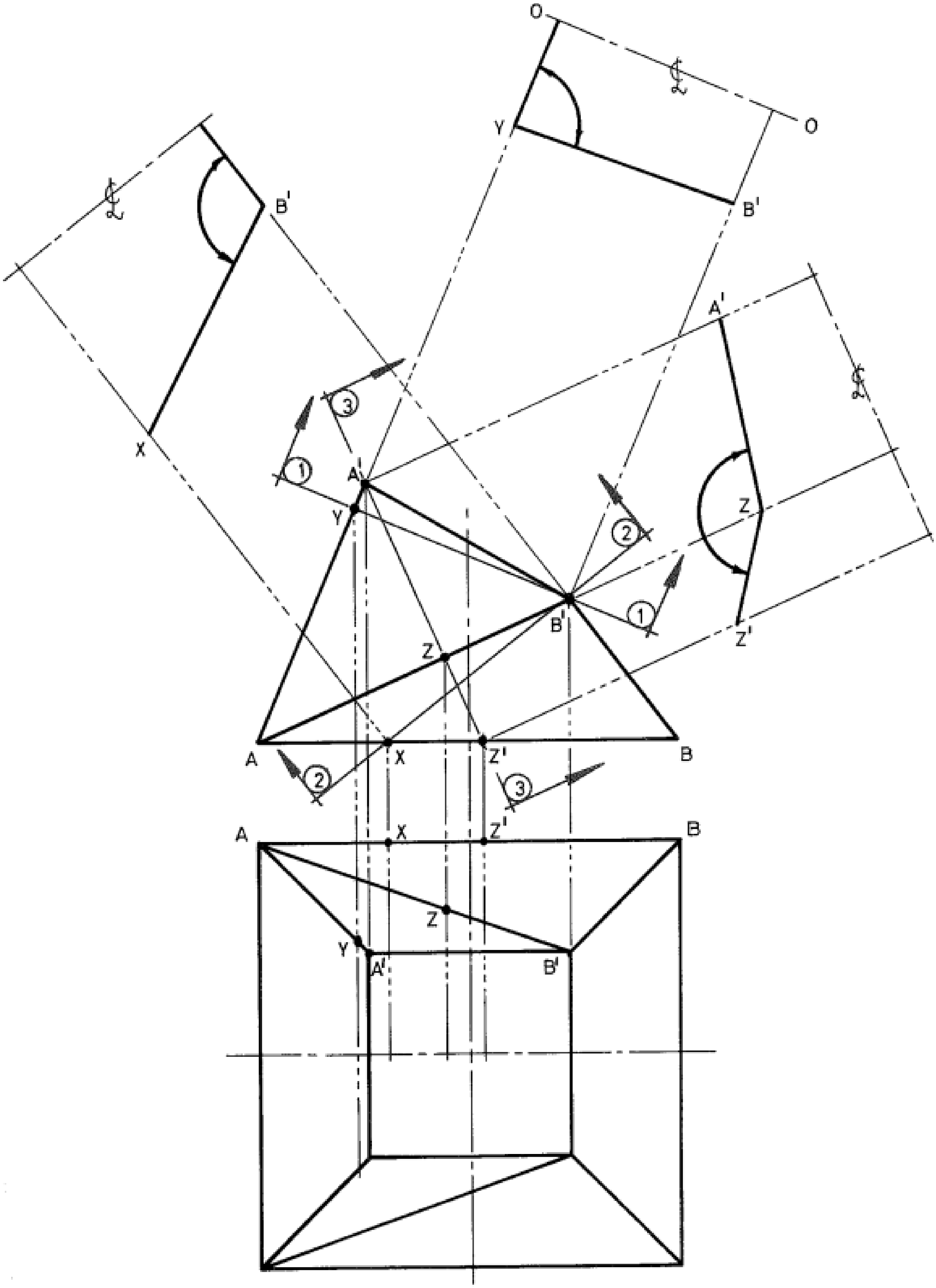



Figure 6.17 Splays (by-projections)

## 6.13 Developing hopper with converging planes (kink knuckle out)

If this development is compared to *section 6.8* it will be seen that it will be required to place kinks on the side plates as per *section 6.11*, see **Figure 6.18**.

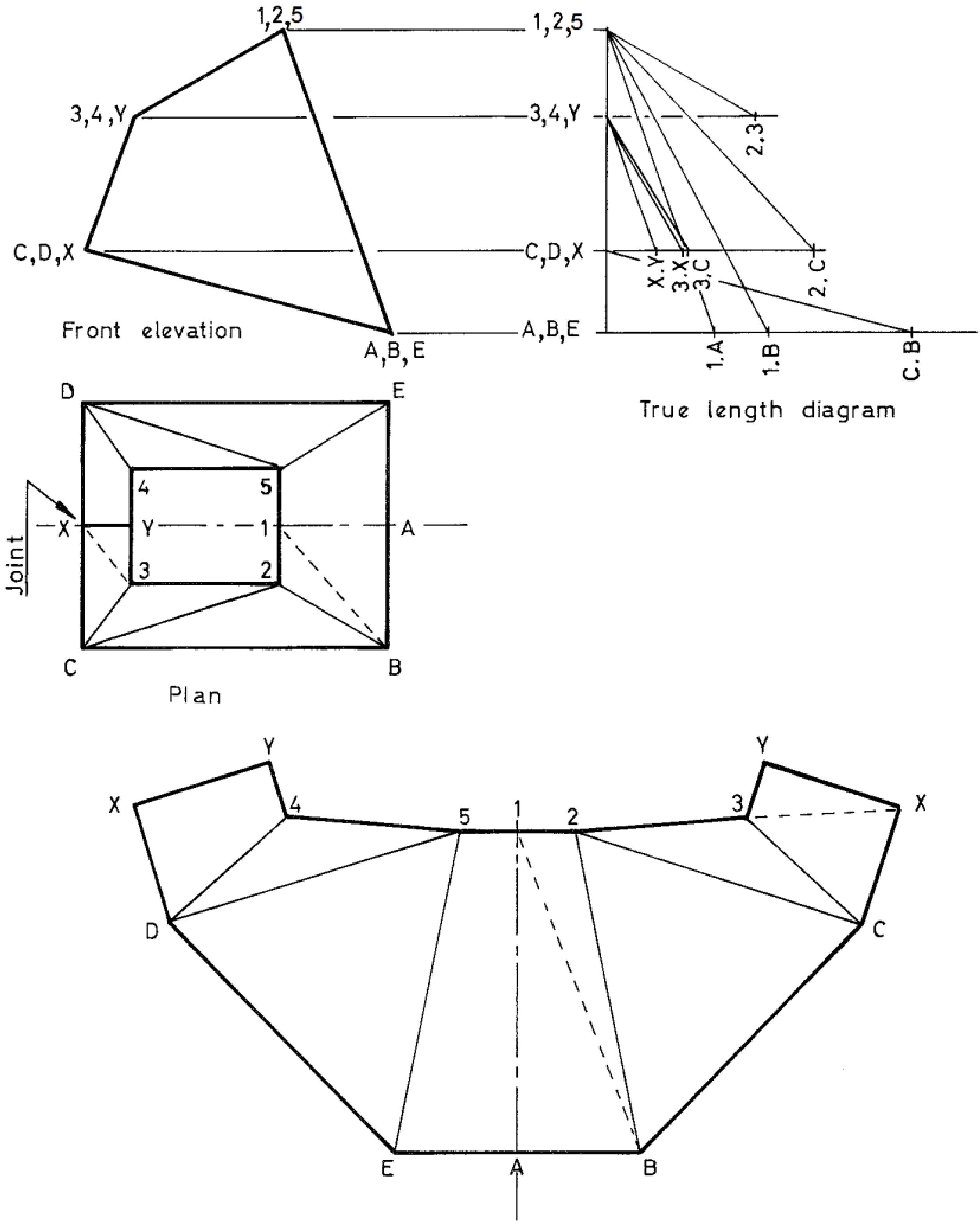



Figure 6.18 Developing hopper with converging planes (kink knuckle out)

## Worked Example 1

**Figure 6.19** shows two views of a twisted square transformer. Calculate the true lengths and use these true lengths to develop the pattern for the transformer.

All calculations must be shown on a drawing sheet. (Note, no marks will be allocated for lengths taken from a drawing to scale.)

Scale 1:1

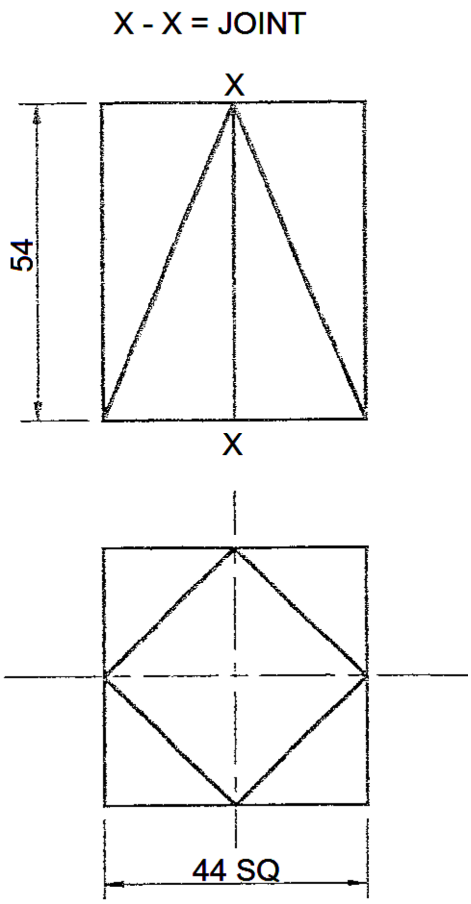



Figure 6.19 Two views of a twisted square transformer

<u>True Lengths:</u>

$$1 - 2 = \sqrt{22^2 + 22^2}$$
$$= \sqrt{484 + 484}$$
$$= \sqrt{968}$$
$$= 31{,}113\text{mm} \rightarrow \quad (4)$$

$$A1 = B1 = \sqrt{22^2 + 54^2}$$
$$= \sqrt{484 + 2916}$$
$$= \sqrt{3400}$$

$= 58{,}31\text{mm} \rightarrow \quad (4)$

$\text{E}4 = 54\text{mm} \quad (1)$

Solution:

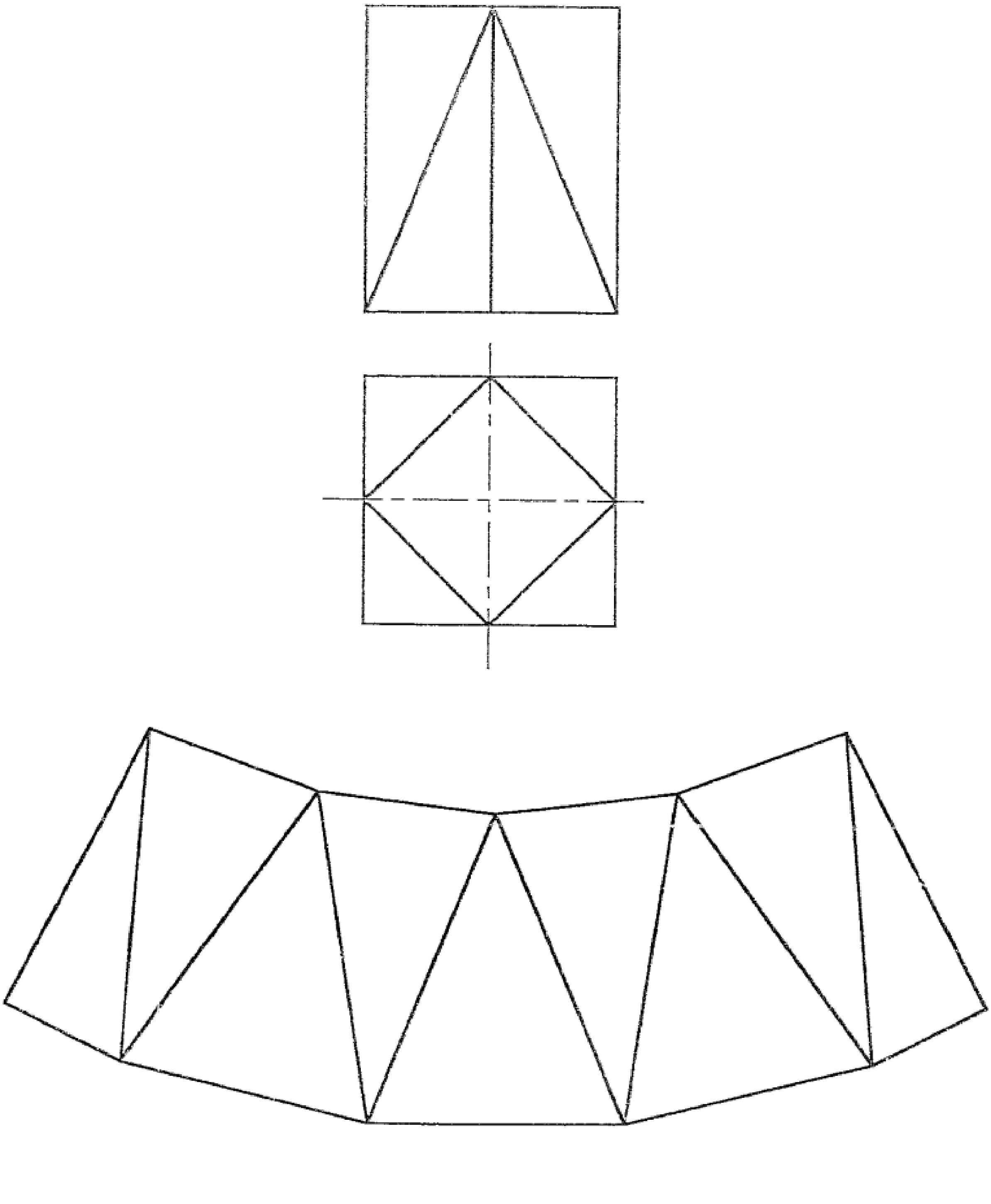


Figure 6.20 Two views of a twisted square transformer.

Now work carefully through **Worked Example 2**, below, which shows two views of a square to round. The solution is given on page 136.

## Worked Example 2

**Figure 6.21** shows two views of a square to round.

Calculate the true lengths and use these true lengths to develop the pattern.

All calculations must be shown on your drawing sheet.

(Note: No marks will be allocated for lengths taken from a drawing to scale.)

Scale 1:1

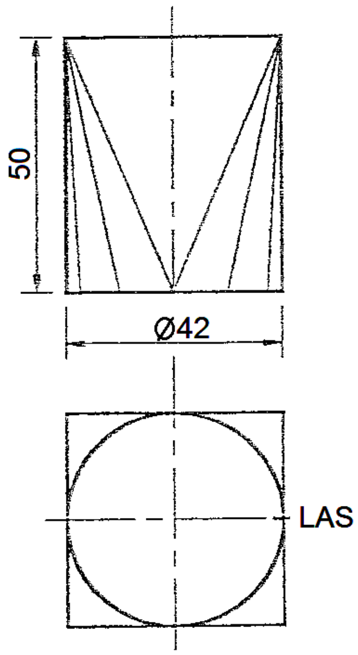



Figure 6.21 Two views of a square to round

$$\text{Arc Lengths} = \frac{\pi D}{12}$$
$$= \frac{\pi \times 42}{12}$$
$$= 10{,}996\text{mm} \rightarrow (2)$$
$$E6 = 50\text{mm} \quad (1)$$

$$AO = BO = \sqrt{50^2 + 21^2}$$
$$= \sqrt{2500 + 441}$$
$$= \sqrt{2941}$$
$$= 54{,}231\text{mm} \rightarrow (2)$$

Top View Lengths:

$$\begin{aligned}
A1 = A2 &= \sqrt{(21 - r\sin\theta)^2 + (21 - r\cos\theta)^2} \\
&= \sqrt{(21 - 21\sin 30°)^2 + (21 - 21\cos 30°)^2} \\
&= \sqrt{(21 - 10{,}5)^2 + (21 - 18{,}187)^2} \\
&= \sqrt{10{,}5^2 + 2{,}813^2} \\
&= \sqrt{118{,}163} \\
&= 10{,}87\text{mm} \rightarrow
\end{aligned}$$

$Or$:

$$\begin{aligned}
A1 = A2 &= \sqrt{(AD - 0{,}866r)^2 + (AC - 0{,}5r)^2 + h^2} \\
&= \sqrt{(21 - 0{,}866.21)^2 + (21 - 0{,}5.21)^2 + 50^2} \\
&= \sqrt{(21 - 18{,}186)^2 + (21 - 10{,}5)^2 + 50^2} \\
&= \sqrt{2814^2 + 10{,}5^2 + 50^2} \\
&= \sqrt{7{,}919 + 110{,}25 + 2500} \\
&= \sqrt{2618{,}169} \\
&= 51{,}168\text{mm} \rightarrow
\end{aligned}$$

True Lengths:

$$\begin{aligned}
A1 = A2 &= \sqrt{50^2 + 10{,}87^2} \\
&= \sqrt{2500^2 + 118{,}157^2} \\
&= \sqrt{2618{,}157} \\
&= 51{,}168\text{mm} \rightarrow
\end{aligned}$$

Solution:

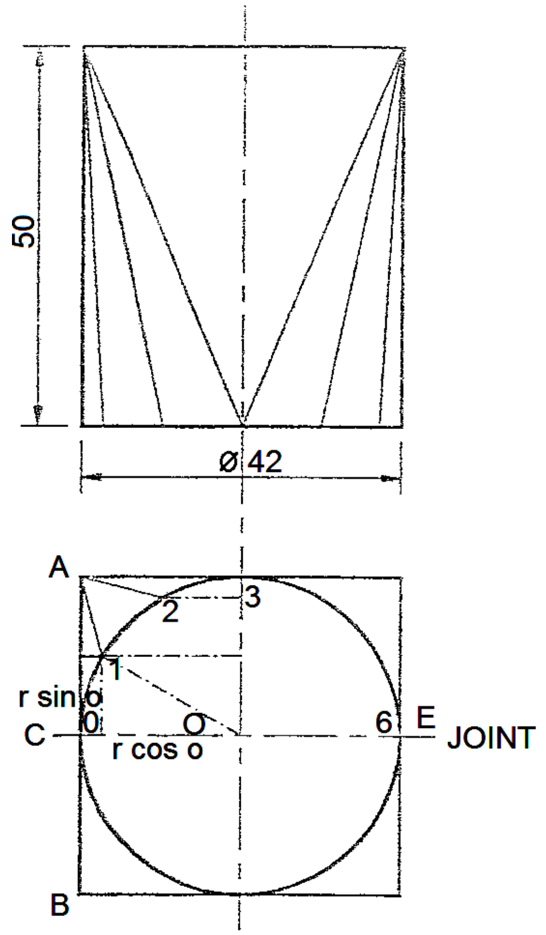



Figure 6.22 Solution

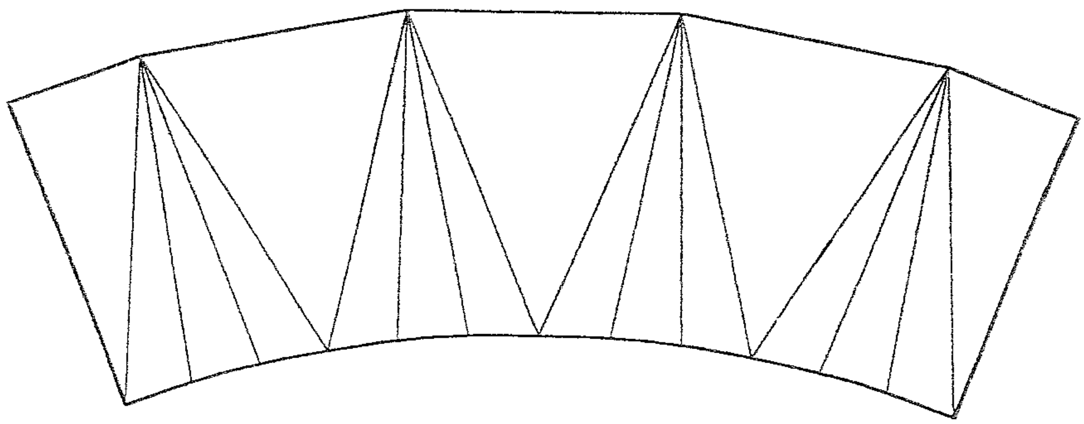


Figure 6.23 Solution

Now work carefully through **Worked Example 3**, below, which shows two views of a square to square.

Take note of the specifications. The solution is given on the following pages.

## Worked Example 3

**Figure 6.24** shows two views of a square to square.

Calculate the true lengths and use these true lengths to develop the pattern. All calculations must be shown on a drawing sheet.

(Note: No marks will be allocated for lengths taken from a drawing to scale.)

Scale 1:1

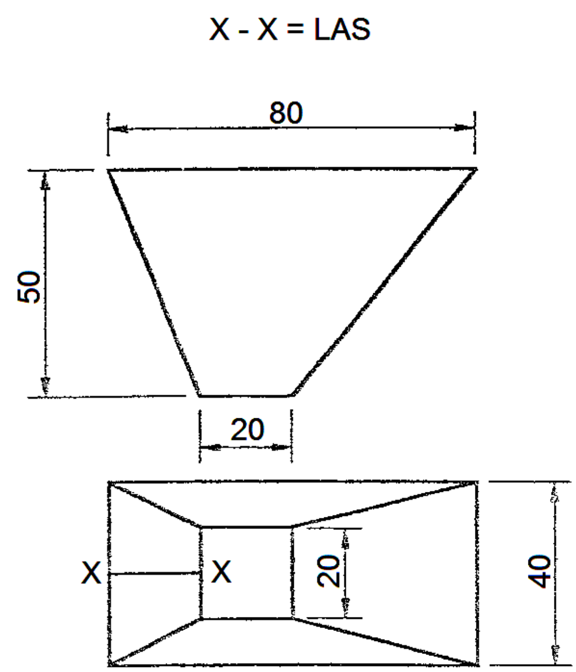
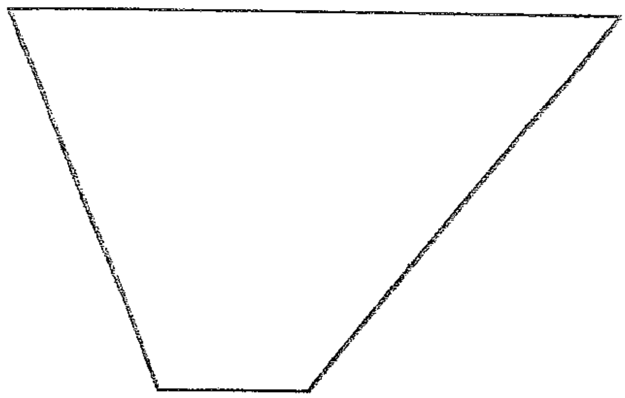



Figure 6.24 Two views of a square to square

Solution:



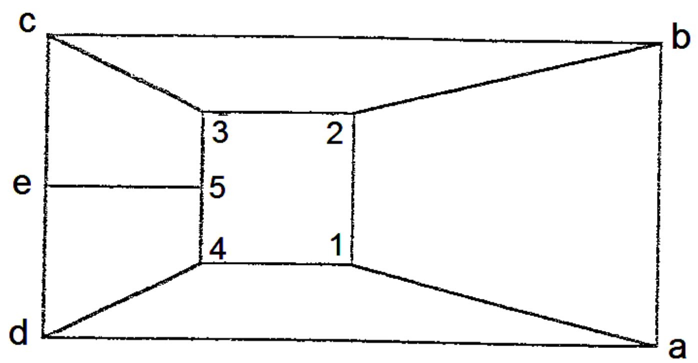



Figure 6.25 Solution

Top View Lengths:

$\text{BX} = 40\text{mm} \rightarrow \quad (\frac{1}{2})$

$\text{X2} = 10\text{mm} \rightarrow \quad (\frac{1}{2})$

$$\begin{aligned} \text{B2} &= \sqrt{\text{BX}^2 + \text{X2}^2} \\ &= \sqrt{40^2 + 10^2} \\ &= 41{,}231\text{mm} \rightarrow \quad (1) \end{aligned}$$

$\text{CY} = 20\text{mm} \rightarrow \quad (\frac{1}{2})$

$\text{Y3} = 10\text{mm} \rightarrow \quad (\frac{1}{2})$

$$\begin{aligned} \text{C3} &= \sqrt{\text{CY}^2 + \text{Y3}^2} \\ &= \sqrt{20^2 + 10^2} \\ &= 22{,}361\text{ mm} \rightarrow \quad (1) \end{aligned}$$

$A2 = \sqrt{Z2^2 + AZ^2}$
$= \sqrt{40^2 + 30^2}$
$= 50mm \rightarrow$ (1)

True lengths:

$B2 = \sqrt{41{,}231^2 + 50^2}$
$= 64{,}807 \text{ mm} \rightarrow$ (1)

$C3 = \sqrt{22{,}361^2 + 50^2}$
$= 54{,}772 \text{ mm} \rightarrow$ (1)

$E5 = \sqrt{20^2 + 50^2}$
$= 53{,}852 \text{ mm} \rightarrow$ (1)

$A2 = \sqrt{50^2} + 50^2$
$= 70{,}711mm \rightarrow$ (1)

$B3 = \sqrt{BY^2 + Y3^2}$
$= \sqrt{60^2 + 10^2}$
$= 60, 828mm \rightarrow$

Or:

$C2 = \sqrt{CX^2 + X2^2}$
$= \sqrt{40^2 + 10^2}$
$= 41{,}231mm \rightarrow$ (1)

$C5 = \sqrt{CE^2 + E5^2}$
$= \sqrt{20^2 + 20^2}$
$= 28{,}284mm \rightarrow$

Or:

$E3 = \sqrt{20^2 + 10^2}$
$= 22{,}361mm \rightarrow$ (1)

$C2 = \sqrt{41{,}231^2 + 50^2}$
$= 64, 807mm \rightarrow$

Or:

$$B3 = \sqrt{60{,}828^2 + 50^2}$$
$$= 78{,}74\text{mm} \rightarrow$$

$$E3 = \sqrt{22{,}361^2 + 50^2}$$
$$= 54{,}772\text{mm} \rightarrow$$

<u>Or:</u>

$$C5 = \sqrt{28{,}284^2 + 50^2}$$
$$= 57{,}445\text{mm} \rightarrow$$

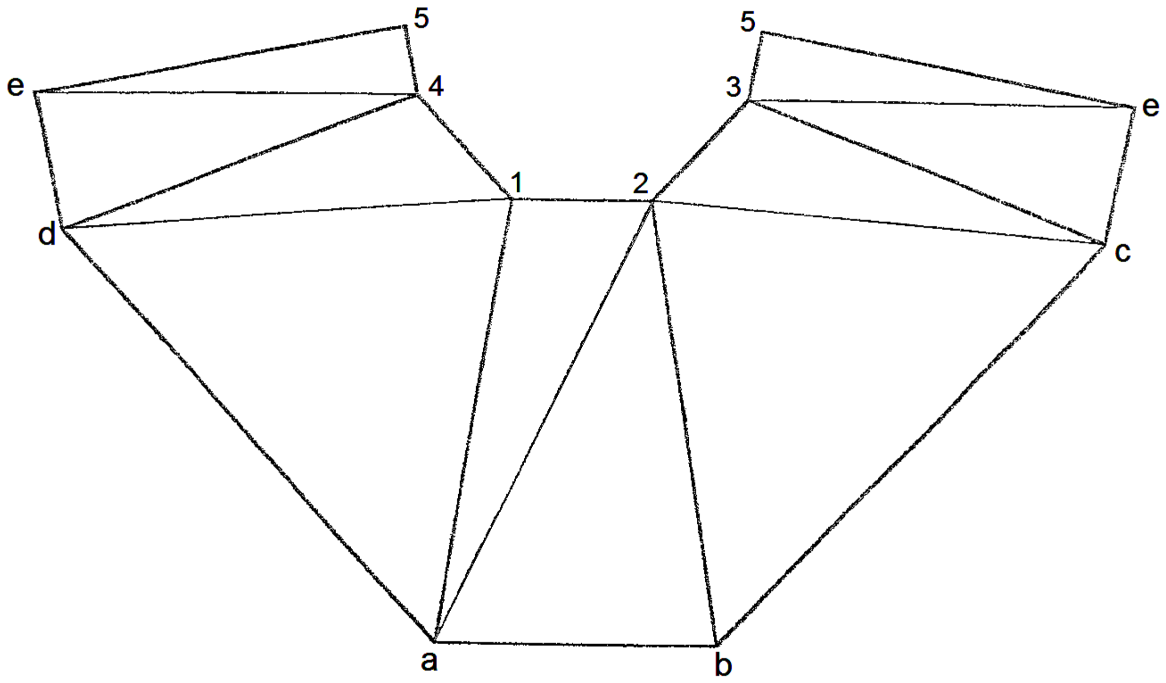



Figure 6.26 Solution

Now work carefully through **Worked Example 4**, below, which shows a rectangular to round transformer with the circular top at an incline.

Take note of the specifications. The solution is given on the following page.

## Worked Example 4

**Figure 6.27** shows a rectangular to round transformer with the circular top at an incline.

Draw the given views and develop the pattern for the transformer.

Scale 1:10

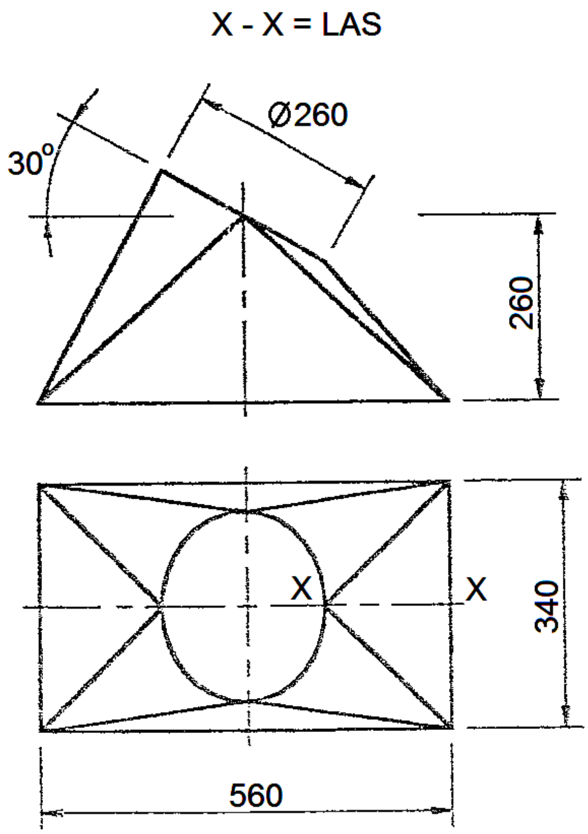



Figure 6.27 A rectangular to round transformer with the circular top at an incline.

Solution:

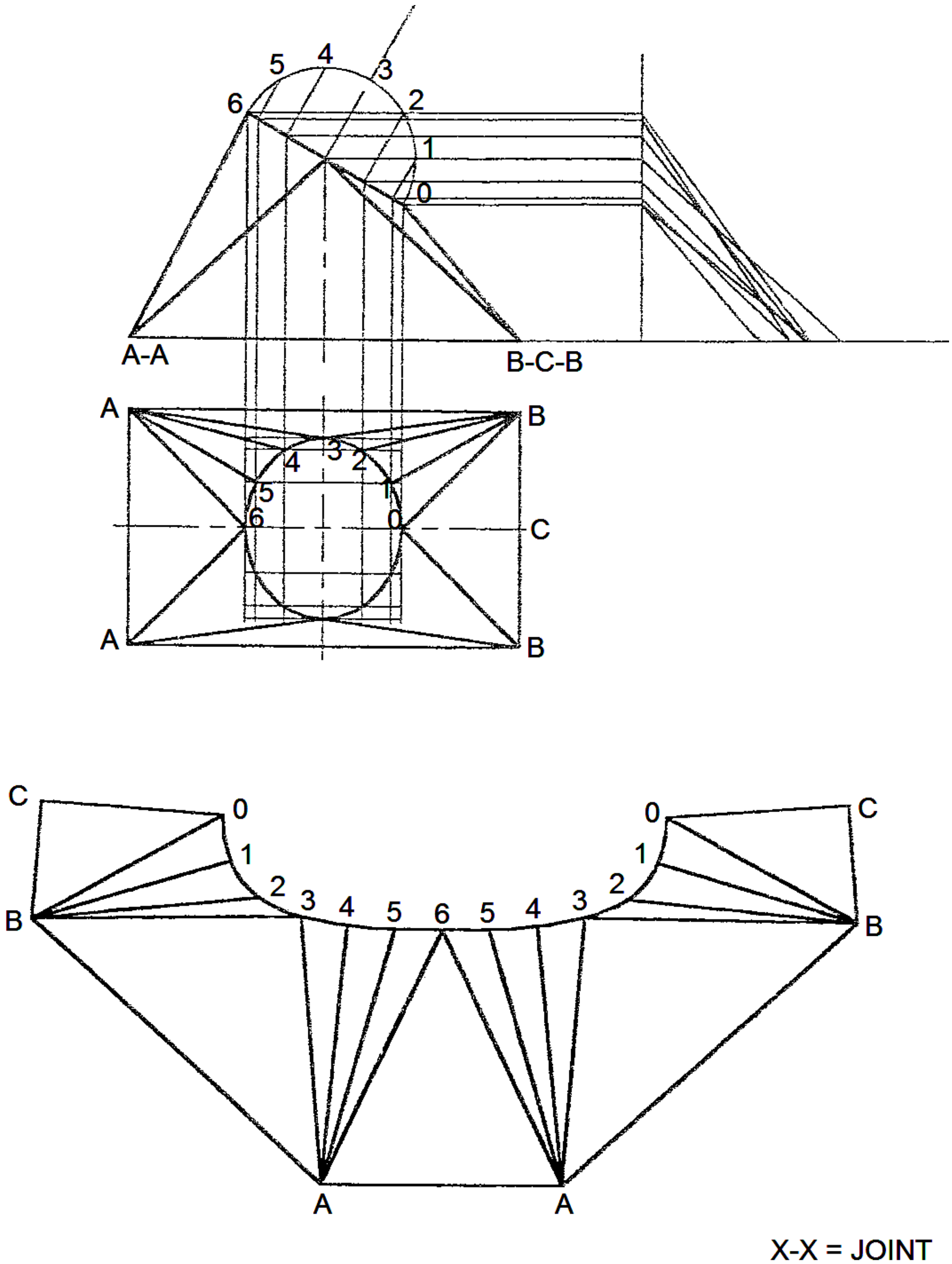



Figure 6.28 Solution

Now work carefully through **Worked Example 5**, below, which shows a front view and a top view of a cone Frustum.

Take note of the specifications. The solution is given on the following page.

## Worked Example 5

**Figure 6.29** shows a front view and a top view of a cone Frustum.

Calculate the true lengths and use these true lengths to develop the cone Frustum. All calculations must be shown on a drawing sheet.

(Note, no marks will be allocated for lengths taken from a drawing to scale.)

Scale 1:1

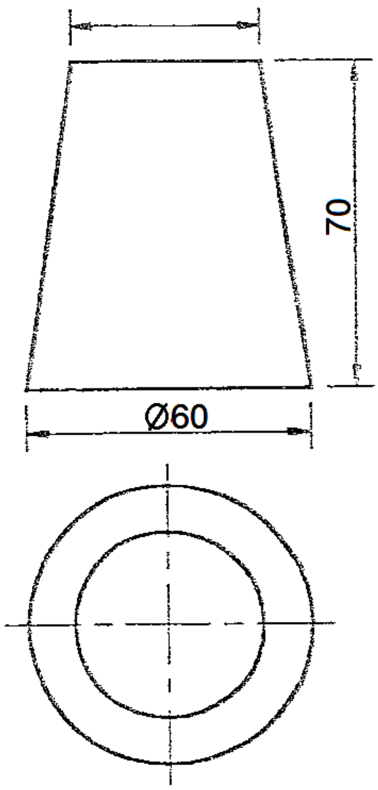



Figure 6.29 A front view and a top view of a cone Frustum.

Solution:

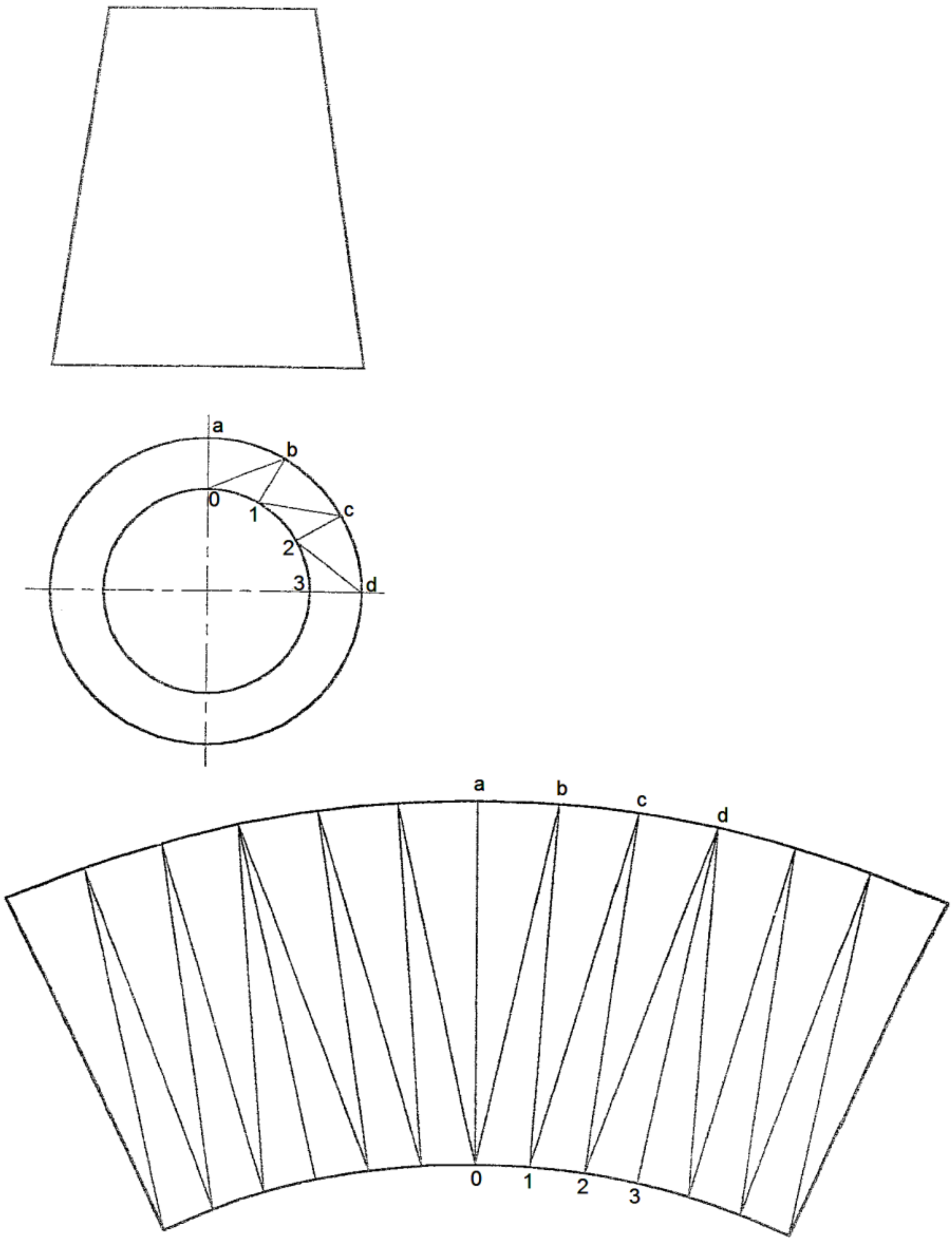



Figure 6.30 Solution

Now work carefully through **Worked Example 6**, below, which shows a front view and a top view of an oblique cylindrical hopper.

Take note of the specifications. The solution is given on the following page.

## Worked Example 6

**Figure 6.31** shows a front view and a top view of an oblique cylindrical hopper.

Draw the two views and develop the pattern for the hopper.

Scale 1:10

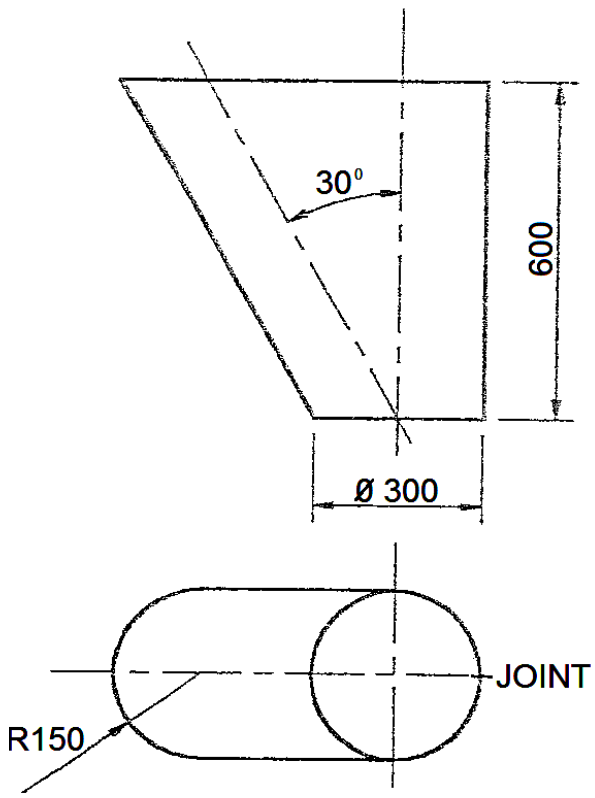



Figure 6.31 A front view and a top view of an oblique cylindrical hopper

Solution:

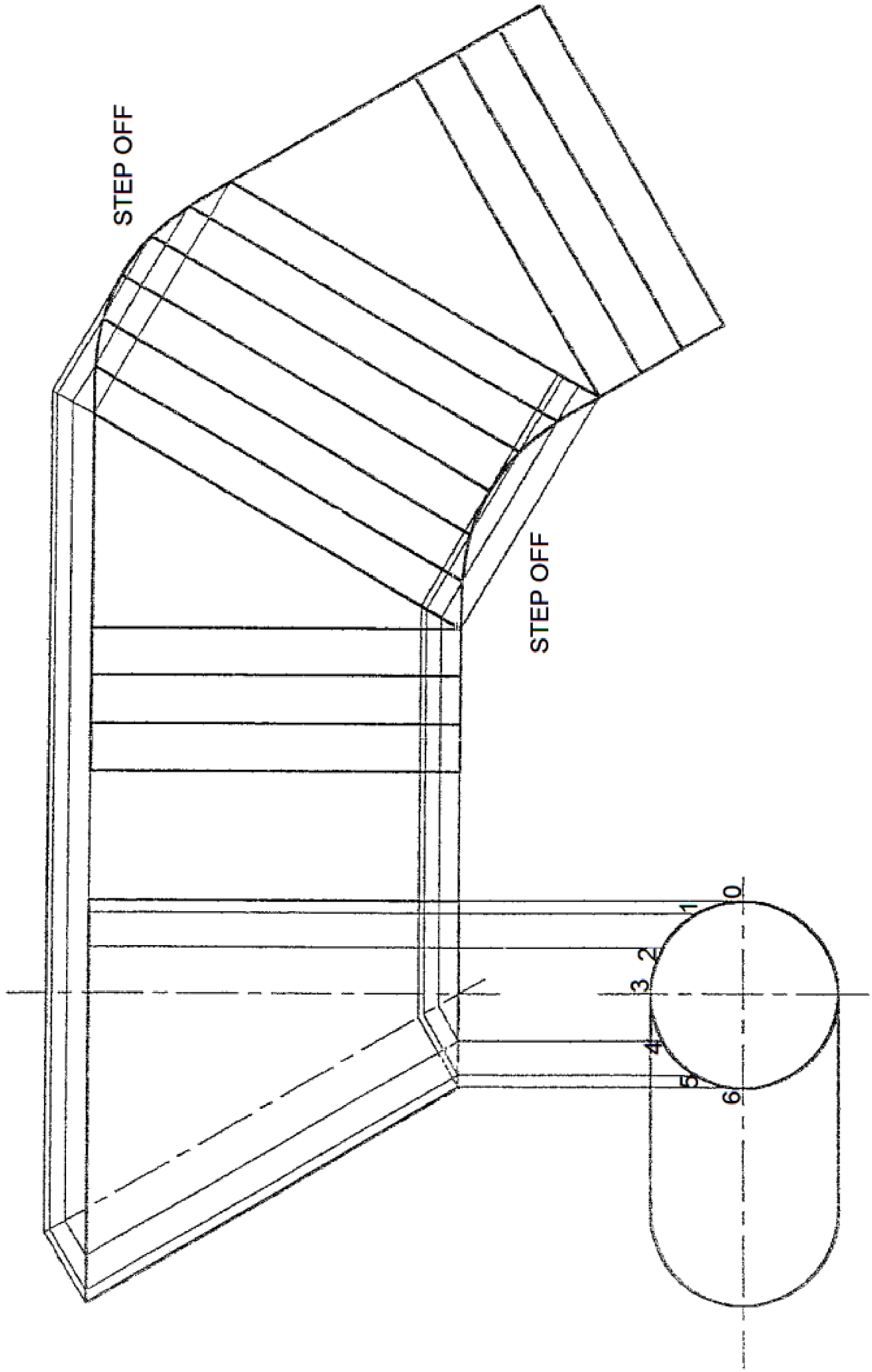



Figure 6.32 Solution

Now work carefully through **Worked Example 7**, below, which shows two views of a rectangular-to-round transformer.

Take note of the specifications. The solution is given on the following page.

## Worked Example 7

**Figure 6.33** shows two views of a rectangular-to-round transformer.

Draw the given views and develop the pattern for the transformer.

Scale 1:10

X-X = JOINT

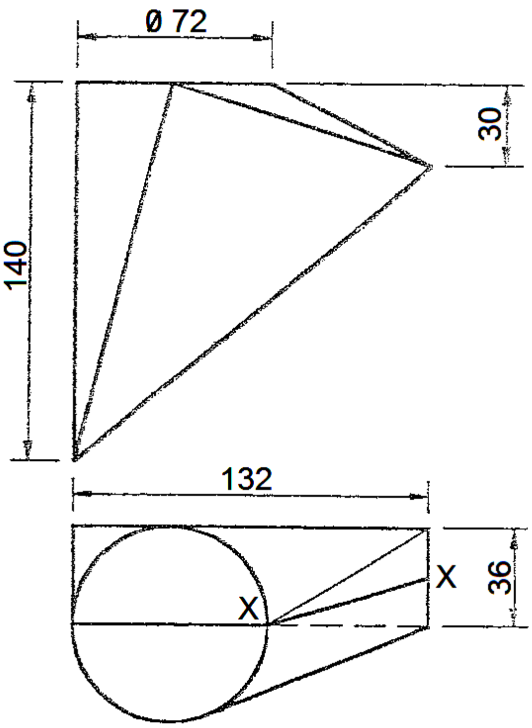



Figure 6.33 Two views of a rectangular-to-round transformer

Solution:

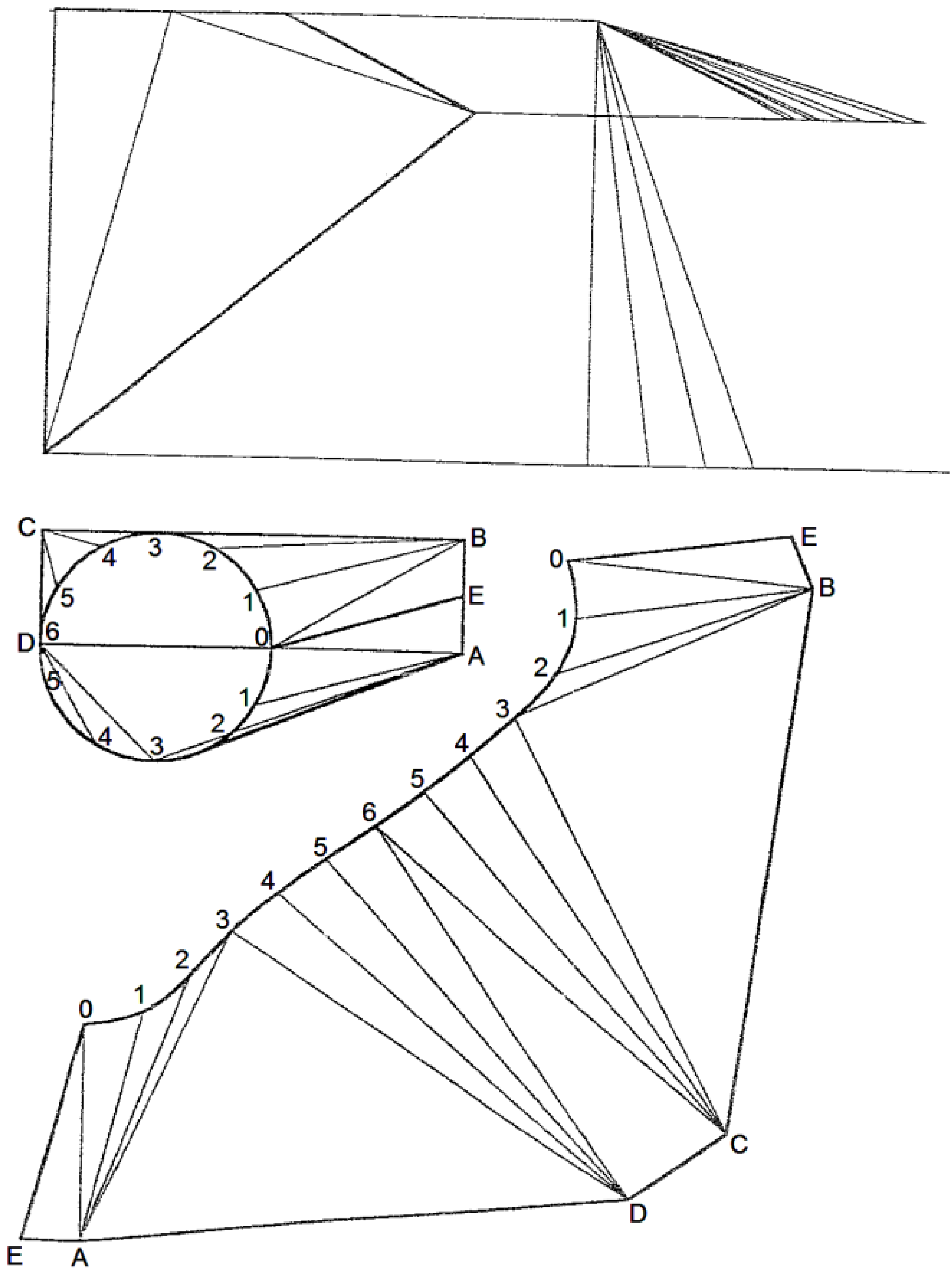



Figure 6.34 Solution

Now work carefully through **Worked Example 8**, below, which shows a rectangular-to-round transformer.

Take note of the specifications. The solution is given on the following page.

## Worked Example 8

**Figure 6.35** shows a rectangular-to-round transformer.

Draw the given views and develop the pattern for the transformer.

Scale 1:10

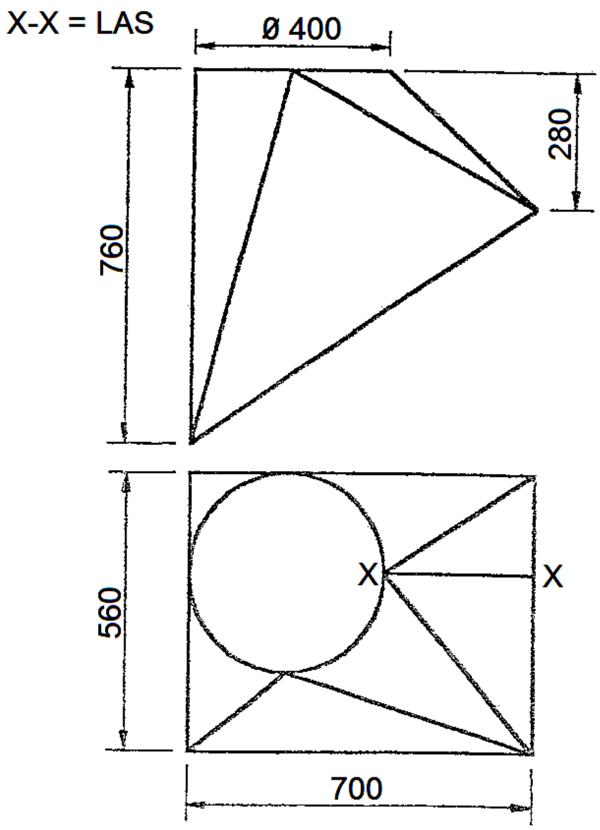



Figure 6.35 A rectangular -to-round transformer

Solution:

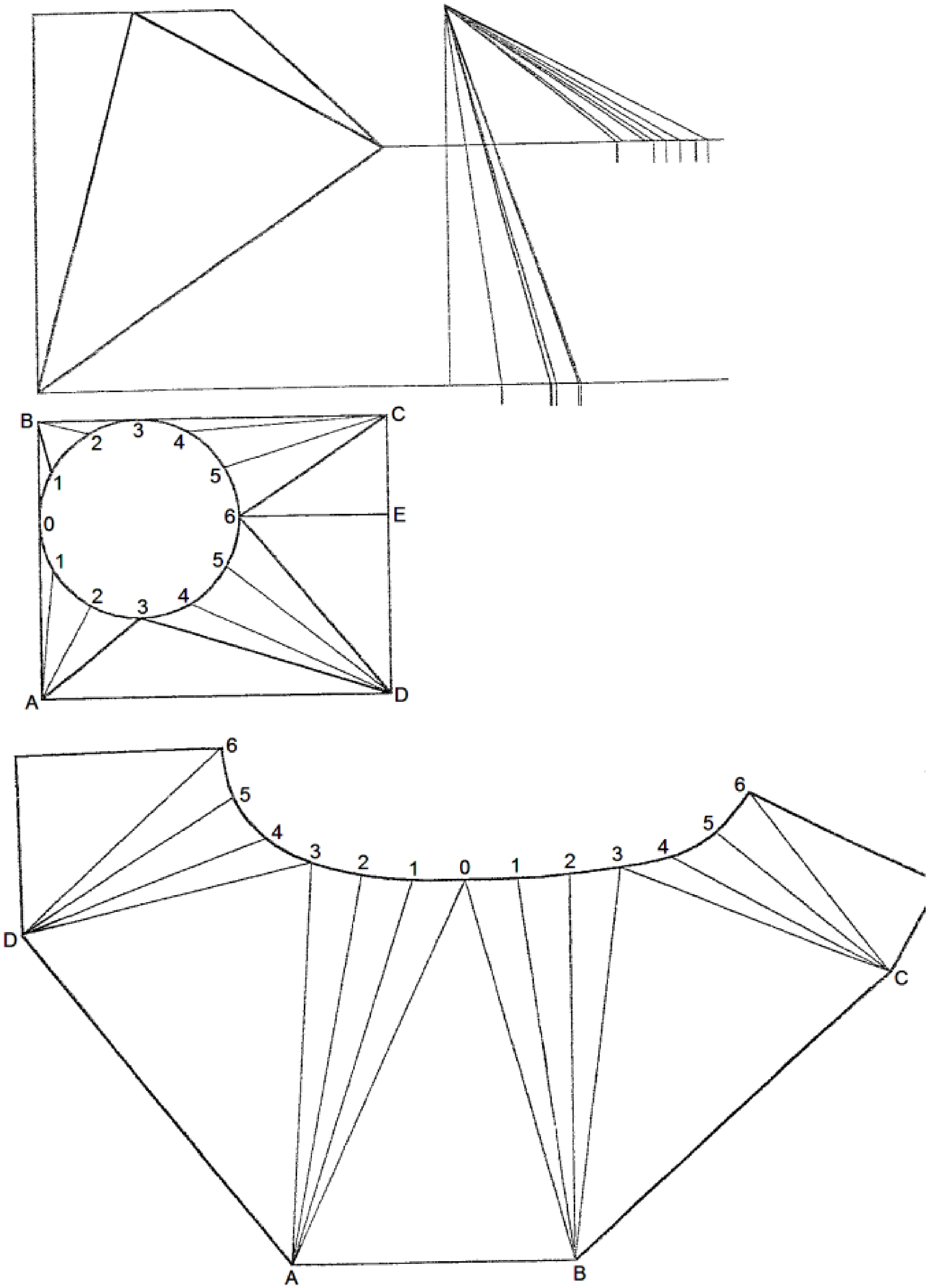



Figure 6.36 Solution

Now work carefully through **Worked Example 9**, below, which shows a two-way junction piece.

Take note of the specifications. The solution is given on the following page.

## Worked Example 9

**Figure 6.37** shows a two-way junction piece.

Draw the given views and develop half a pattern as indicated on the given top view.

Scale 1:5.

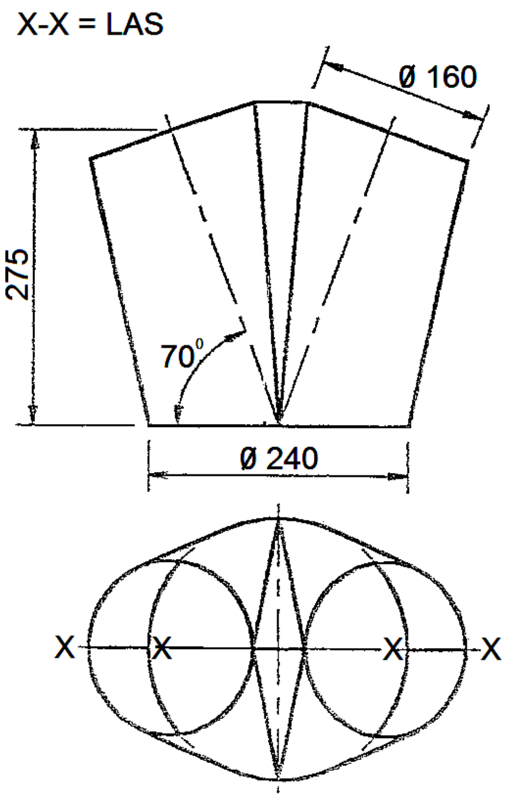



Figure 6.37A two-way junction piece

Solution:

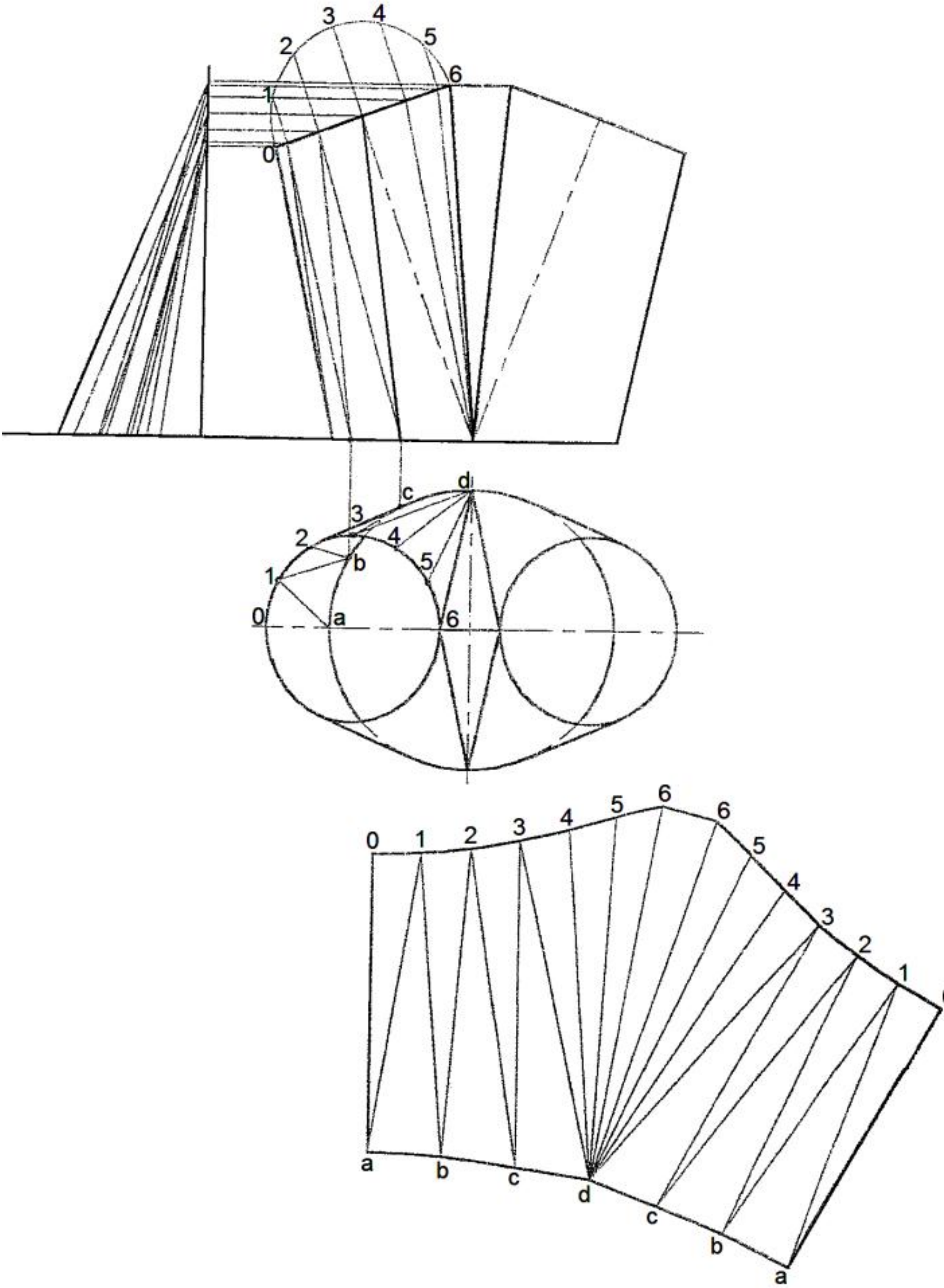



Figure 6.38 Solution

Now work carefully through **Worked Example 10**, below, which shows a cone and pipe Intersection.

Take note of the specifications. The solution is given on the following two pages.

## Worked Example 10

**Figure 6.39** shows a cone and pipe Intersection.

Draw the given views and develop the pattern for the cone and pipe.

Scale 1:2

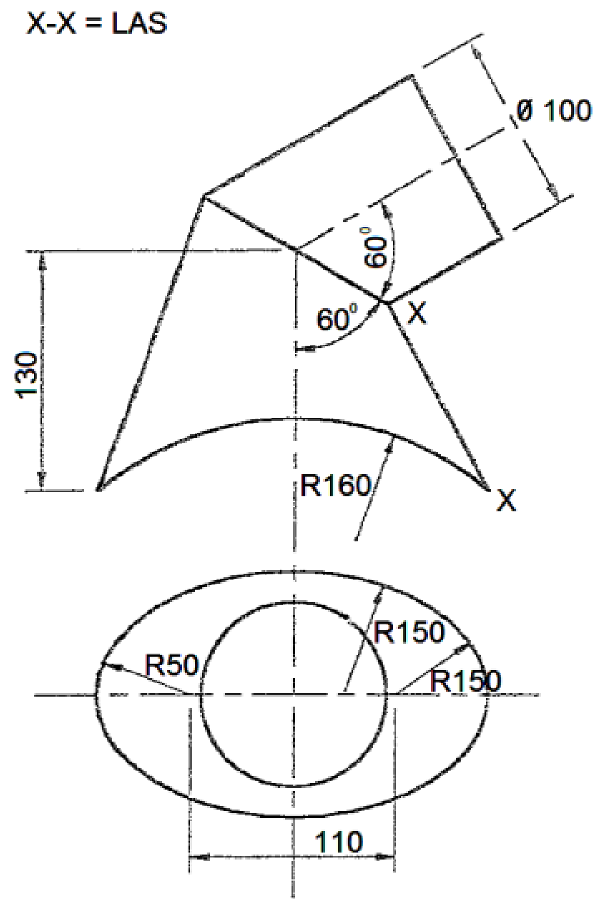



Figure 6.39 A cone and pipe intersection

Solution:

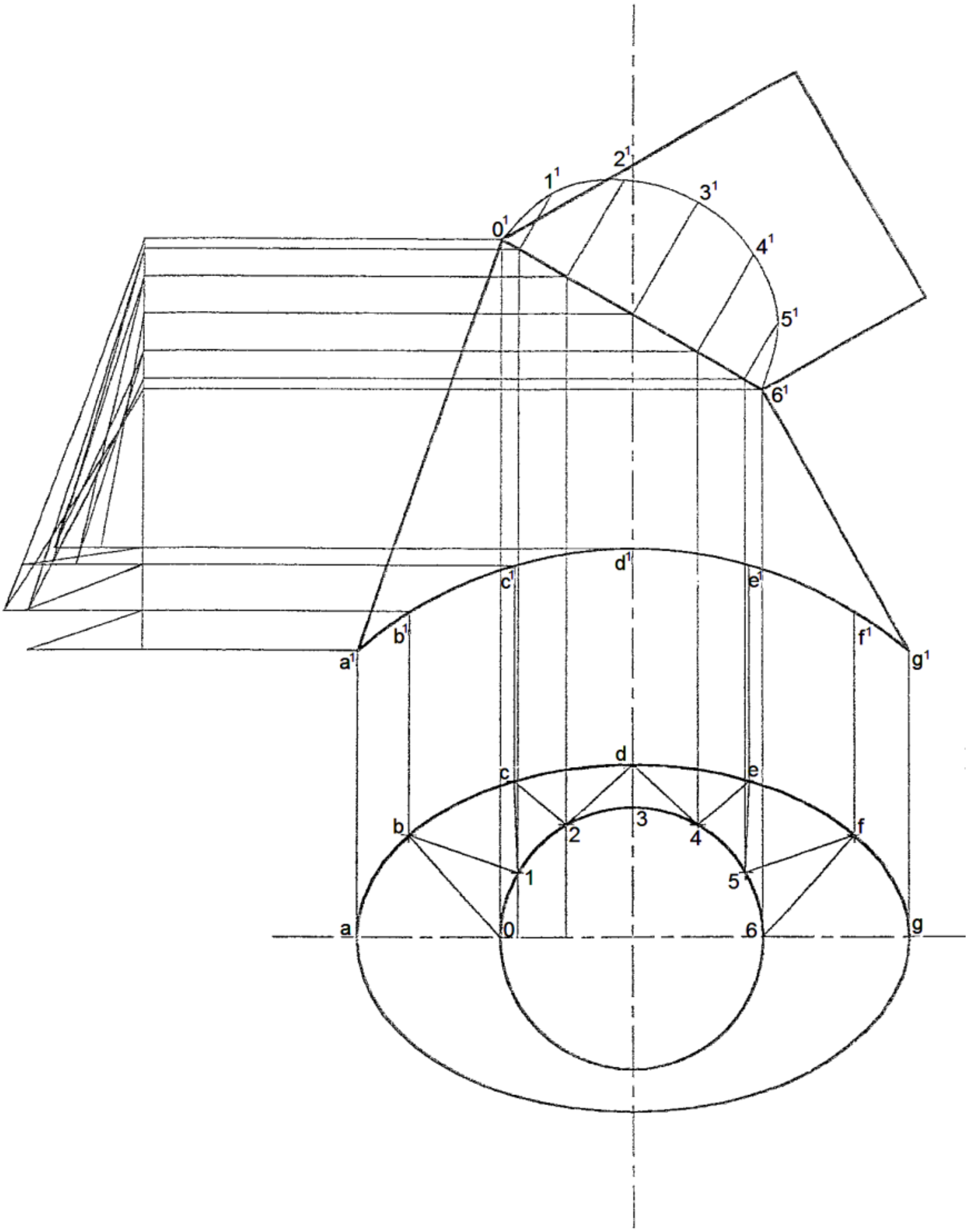



Figure 6.40 Solution

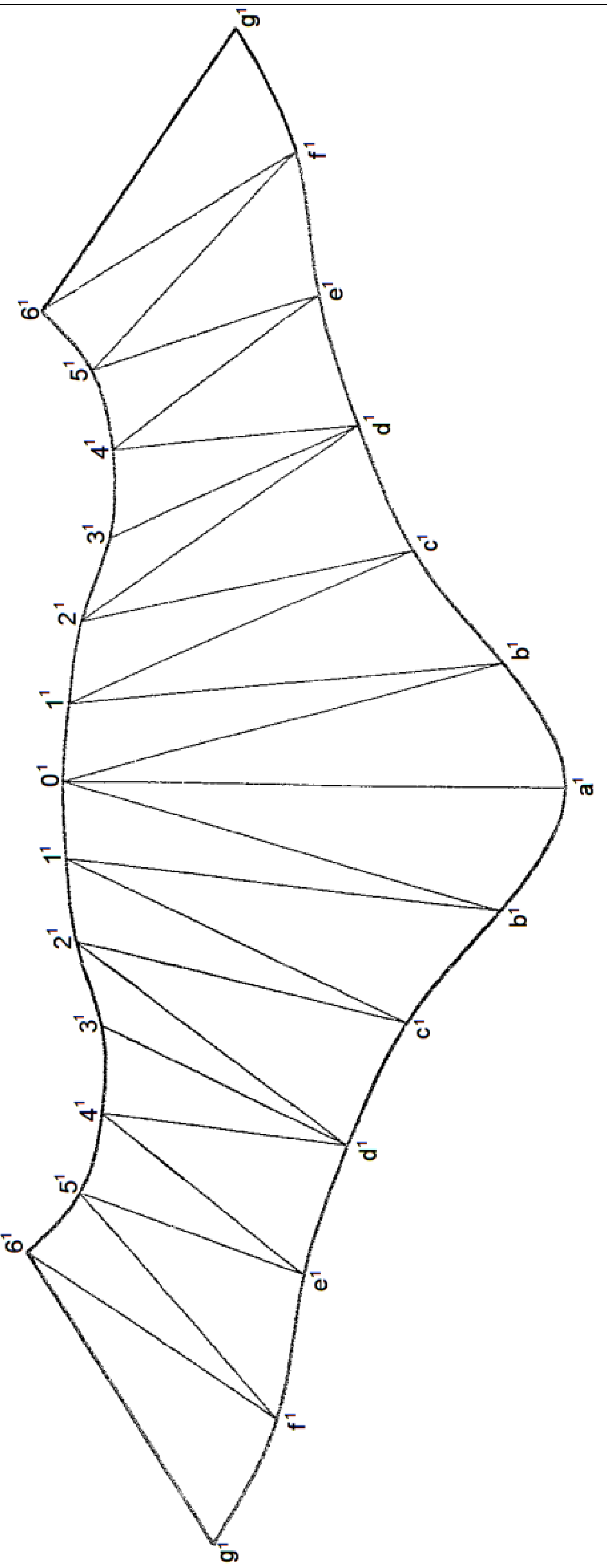


Figure 6.41 Solution

Now work carefully through **Worked Example 11**, below, which shows two views of a rectangular to rectangular transformer.

Take note of the specifications. The solution is given on the following page.

## Worked Example 11

**Figure 6.42** shows two views of a rectangular to rectangular transformer.

Draw the given views and develop the pattern fur the transformer.

Scale 1:5

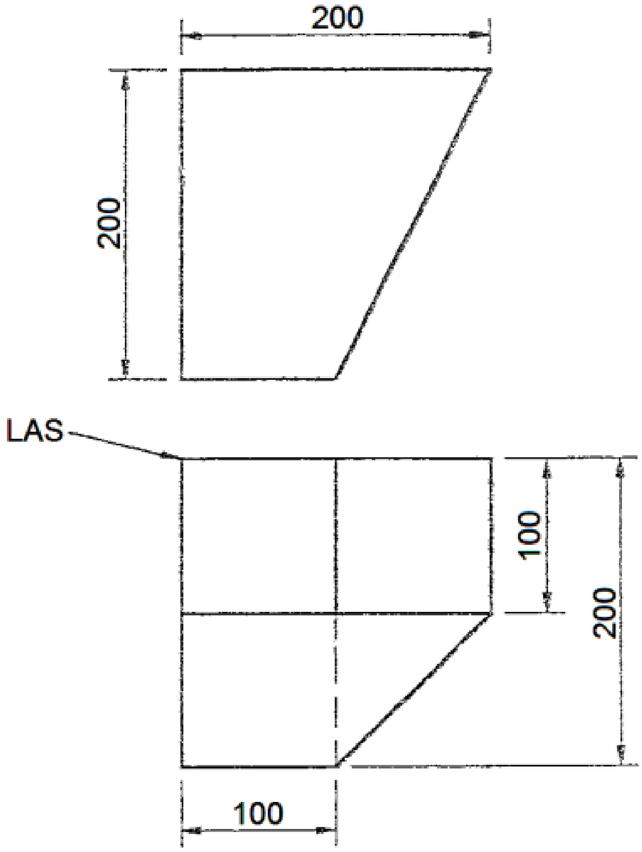



Figure 6.42 Two views of a rectangular to rectangular transformer

Solution:

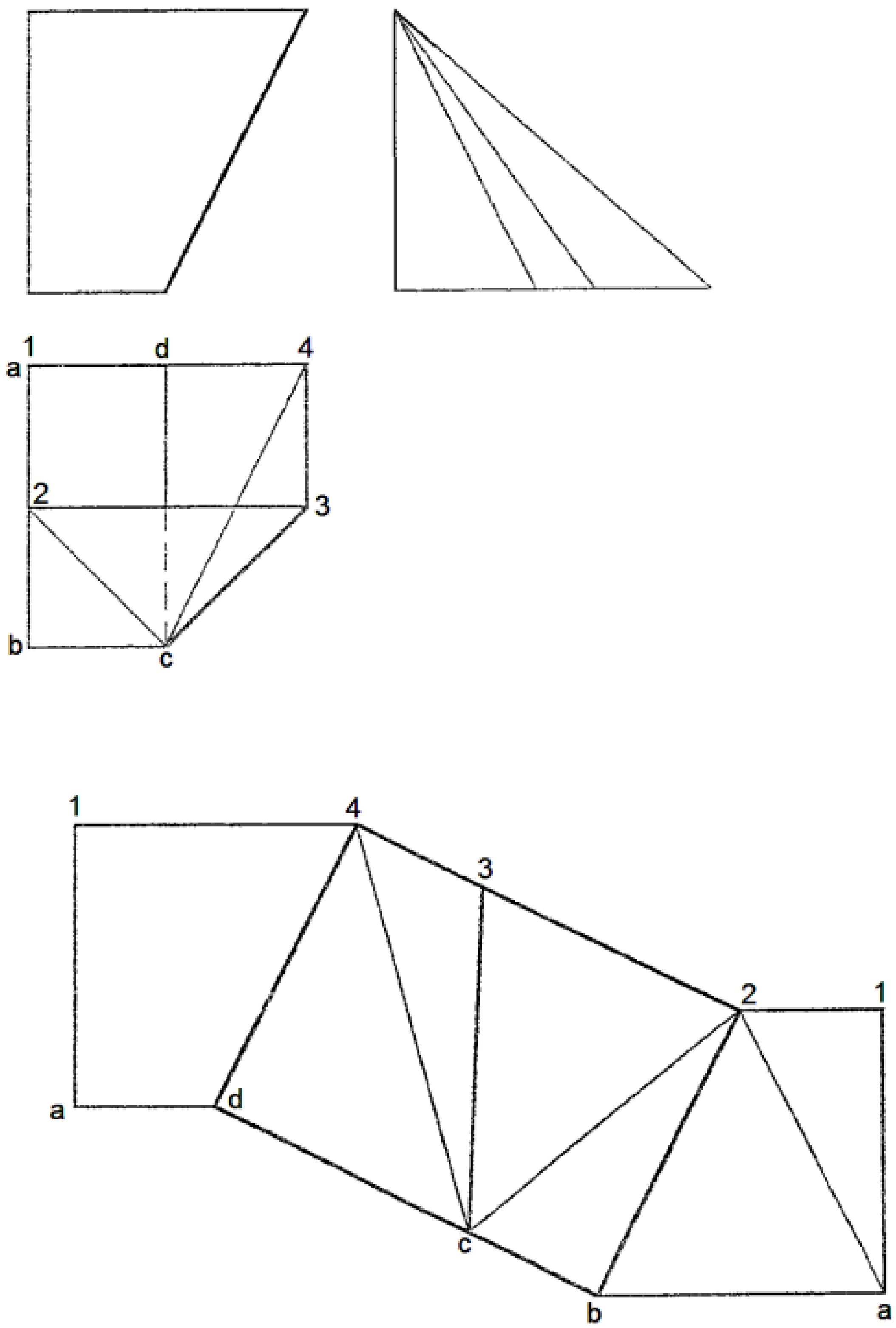



Figure 6.43 Solution

Now work carefully through **Worked Example 12**, below, which shows a front view and a top view of a cone Frustum.

Take note of the specifications. The solution is given on the following pages.

## Worked Example 12

A front view and a top view of a cone Frustum are shown in **Figure 6.44**.

Calculate the true lengths and use these true lengths to develop the cone frustum.

All calculations must be shown on a drawing sheet ·

(Note: No marks will be awarded for lengths taken from a drawing to scale)

Scale 1:1

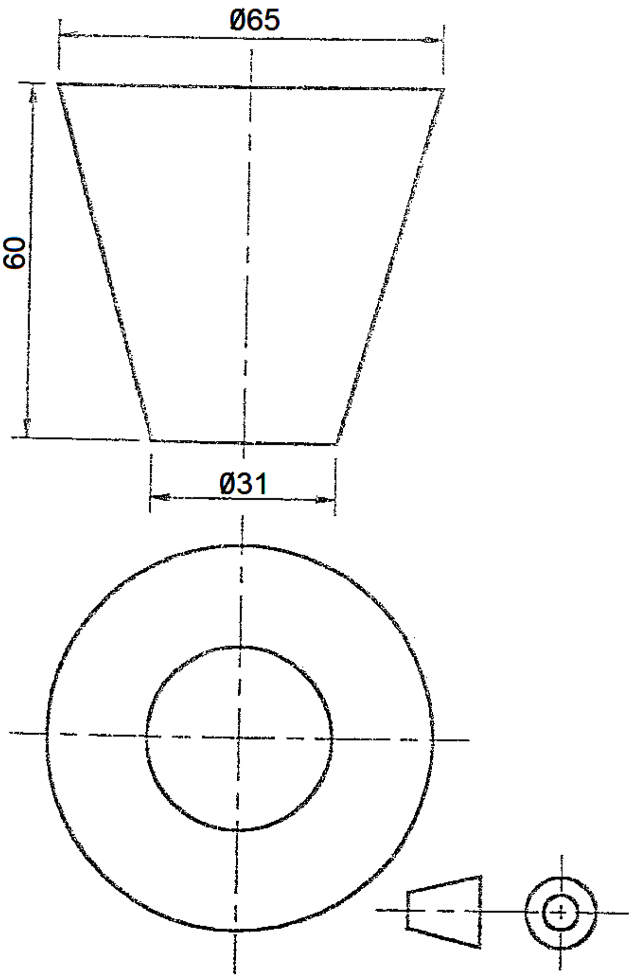



Figure 6.44 A front view and a top view of a cone Frustum

Solution:

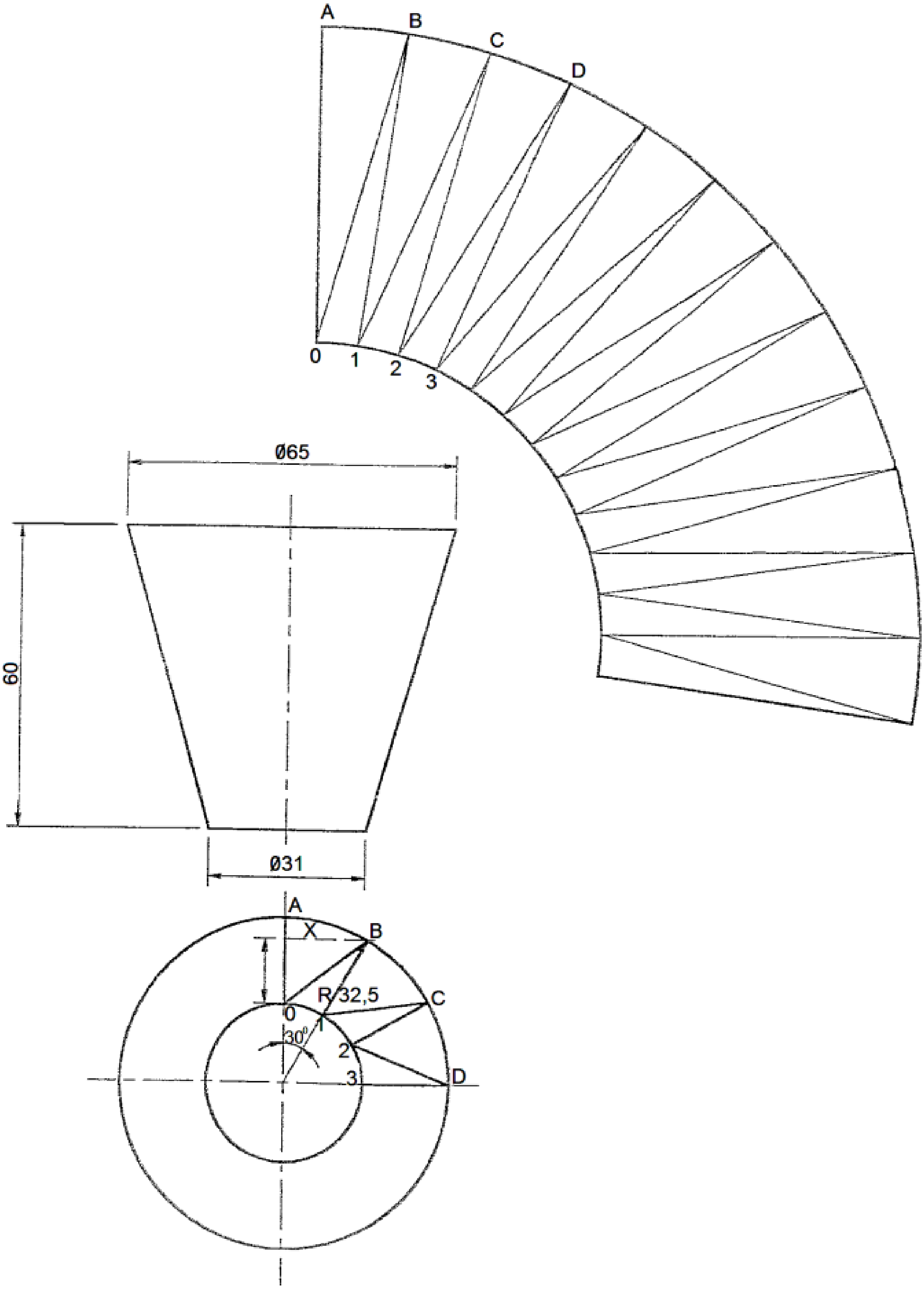



Figure 6.45 Solution

Top View Lengths:

$$x = R\sin 30^\circ$$
$$= 32{,}5 \times 0{,}5$$
$$= 16{,}25\text{mm} \quad (2)$$

$$y = R\cos 30^\circ - 15{,}5$$
$$= 32{,}5 \times 0{,}866 - 15{,}5$$
$$= 12{,}646\text{mm} \quad (3)$$

$$B - 0 = \sqrt{16{,}25^2 + 12{,}646^2}$$
$$= \sqrt{264{,}063 + 159{,}921}$$
$$= \sqrt{423{,}984}$$
$$= 20{,}591\text{mm} \quad (3)$$

$$B - O = \sqrt{(0{,}866R - r)^2 + (0{,}5R)^2 + h^2}$$
$$= \sqrt{(0{,}866 \times 32{,}5 - 15{,}5)^2 + (0{,}5 \times 32{,}5)^2 + 60^2}$$
$$= \sqrt{159{,}896 + 264{,}063^2 + 3600^2}$$
$$= \sqrt{4023{,}959}$$
$$= 63{,}435\text{mm} \rightarrow$$

True Lengths:

$$B - O = \sqrt{20{,}591^2 + 60^2}$$
$$= \sqrt{423{,}984 + 3600}$$
$$= \sqrt{4023{,}984}$$
$$= 63{,}435\text{mm} \rightarrow \quad (3)$$

$$A - O = \sqrt{17^2 + 60^2}$$
$$= \sqrt{289 + 3600}$$
$$= \sqrt{3889}$$
$$= 62{,}362\text{mm} \rightarrow \quad (3)$$

Or:

$$A - O = \sqrt{(R - r)^2 + h^2}$$
$$= \sqrt{(32{,}5 - 15{,}5)^2 + 60^2}$$
$$= \sqrt{17^2 + 60^2}$$
$$= \sqrt{289 + 3600}$$
$$= \sqrt{3889}$$
$$= 62{,}362\text{mm} \rightarrow \quad (3)$$

$$\text{ARC/BOOG } A - B = \frac{\pi D}{12} = \frac{\pi \times 65}{12} = 17{,}017\text{mm} \rightarrow (1)$$

$$\text{ARC/BOOG } 0 - 1 = \frac{\pi D}{12} = \frac{\pi \times 31}{12} = 8{,}116\text{mm} \rightarrow$$
(1)

Now work carefully through **Worked Example 13**, below, which shows a two-way breeches piece in a ventilation system.

Take note of the specifications. The solution is given on the following page.

## Worked Example 13

**Figure 6.46** shows a two-way breeches piece in a ventilation system.

Draw the given views and develop limb 'A'.

Scale 1:5

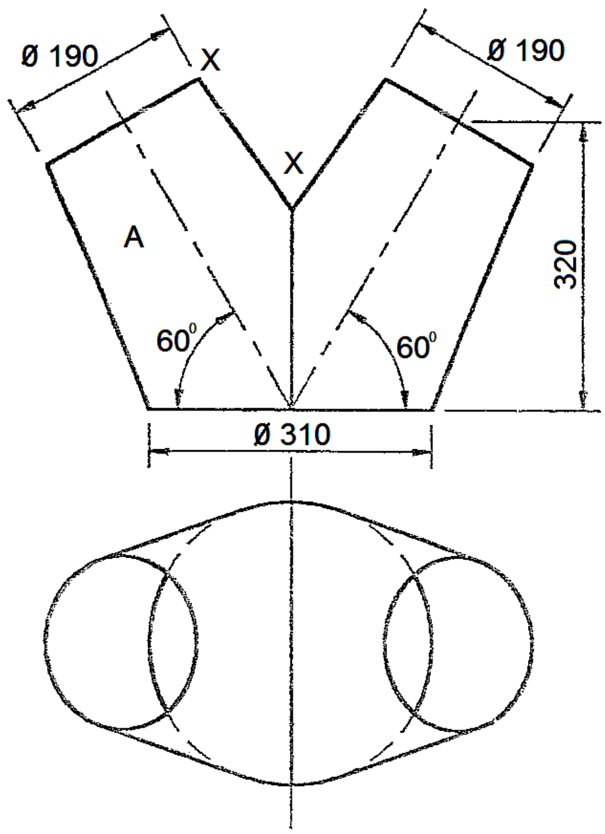



Figure 6.46 A two-way breeches piece in a ventilation system

Solution:

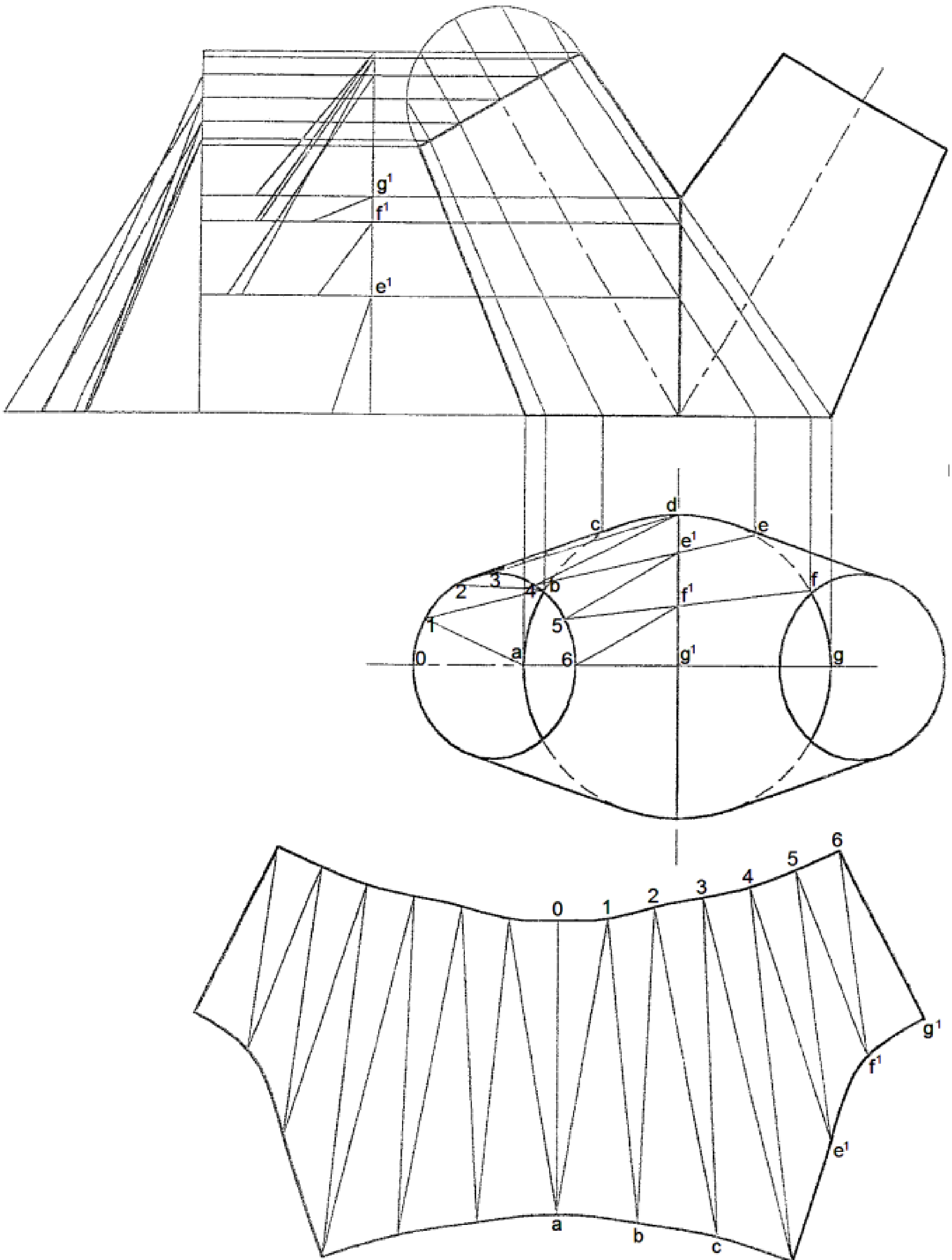



Figure 6.47 Solution

Now work carefully through **Worked Example 14**, below, which shows two views of a straight-backed junction piece.

Take note of the specifications. The solution is given on the following page.

## Worked Example 14

**Figure 6.48** shows two views of a straight-backed junction piece.

Draw the given views and develop half a pattern as indicated on the given top view.

Scale 1:2

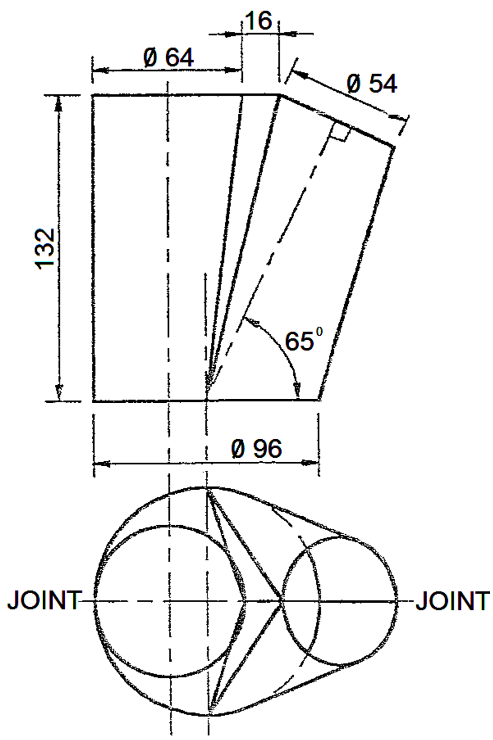



Figure 6.48 Two views of a straight-backed junction piece

Solution:

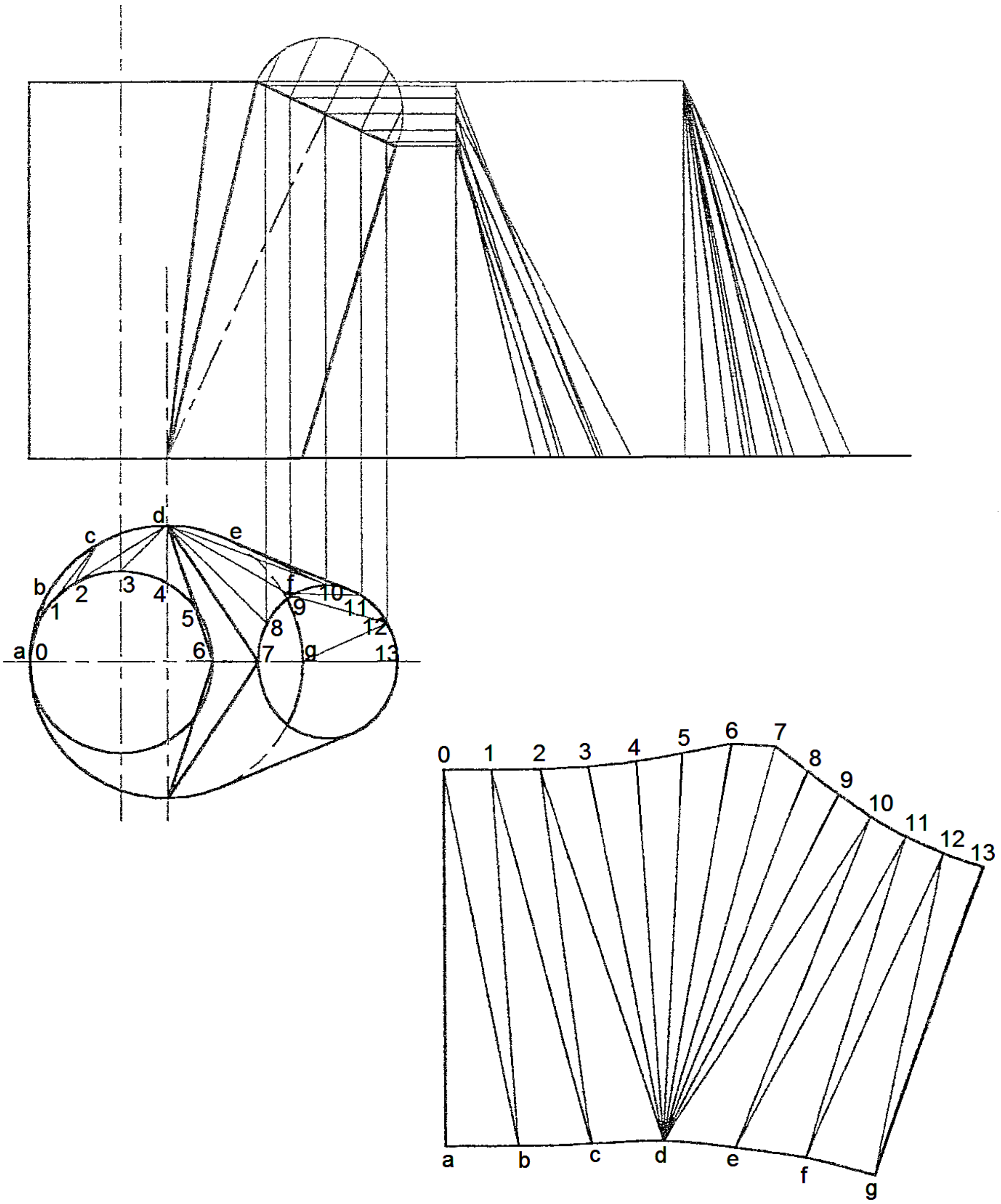



Figure 6.49 Solution

## Activity 6.1

Develop the following spiral chute in **Figure 6.50**.

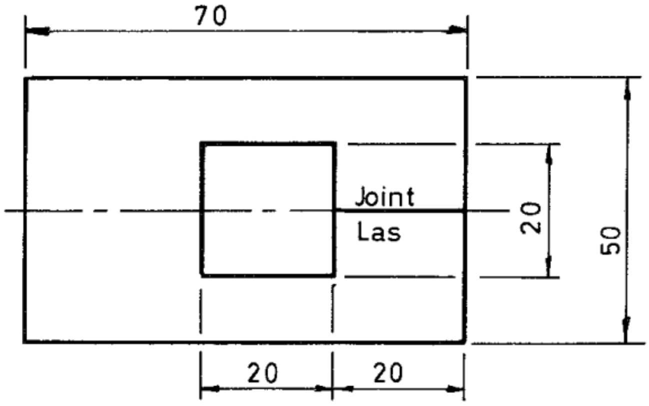



Figure 6.50 A spiral chute

## Activity 6.2

Develop the following spiral chute in **Figure 6.51**.

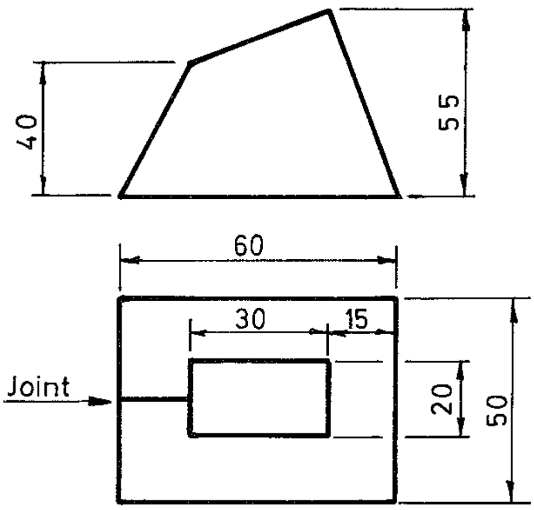



Figure 6.51 A spiral chute

## Activity 6.3

Develop the following spiral chute in **Figure 6.52**.

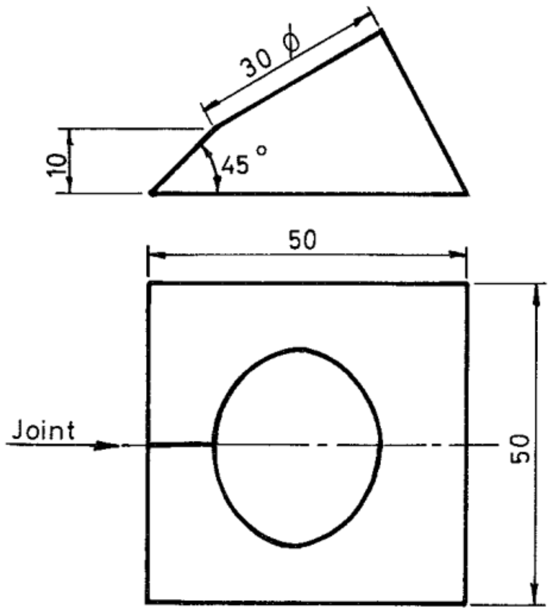



Figure 6.52 A spiral chute

### Self-Check

| I am able to: | Yes | No |
|---|---|---|
| • Define the Triangulation Theorem | | |
| • Determine the bend lines | | |
| • Describe the following: | | |
| o Square to round on parallel planes | | |
| o Square to square on parallel planes | | |
| o Cone frustrum on parallel planes (right cone) | | |
| o Cone frustrum on parallel planes (oblique cone) | | |
| • Explain triangulation on converging planes; pyramid and cone frustrum | | |
| • Explain triangulation on converging planes(cone frustrum) | | |
| • Describe taper lobsterback bends | | |
| • Determine kinks and splays | | |
| • Describe the following Splays (by-projections): | | |
| o Angle of bend line A.A[1] | | |
| o Angle of bend line B.B[1] | | |
| o Angle of kink bend line A.B[1] | | |
| • Develop a hopper with converging planes (kink knuckle out) | | |

If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.

# Module 7

# Spiral Developments

**Learning Outcomes**
On the completion of this module the student must be able to:

- Understand the facts concerning spirals
- Draw the spiral (horizontal/vertical plane)
- Use the Radial line development (horizontal plane)
- Use Triangulation to develop spirals
- Use Straight line development (vertical plane)

## 7.1 Introduction

Spiral developments are usually considered the most awesome and difficult developments but are in actual fact quite simple to develop.

It is once again important to note that accuracy in the layout is accuracy in the development.

## 7.2 Spiral facts

- Horizontal spirals have no bend lines but are pulled or pressed over a jig to form the complete article.
- Vertical spirals have bend lines and can also be rolled.
- On spiral developments, accuracy is of the utmost importance therefore, all circumferential and diagonal dimensions have to be calculated.
- The pitch of a spiral is the height of rise a spiral has in 360°.

## 7.3 Drawing the spiral (horizontal plane)

Draw the pitch line to length as the centre line of the spiral and at the bottom, draw the half Top View of the spiral (both inside and outside diameter).

Divide and number as shown in **Figure 7.1.** (Note: the more divisions, the more accurate the drawing will be). Then divide the spiral pitch into the same number, the same as the top view.

Now project the number up from the top view to cut the pitch divisions to give the points of the spiral.

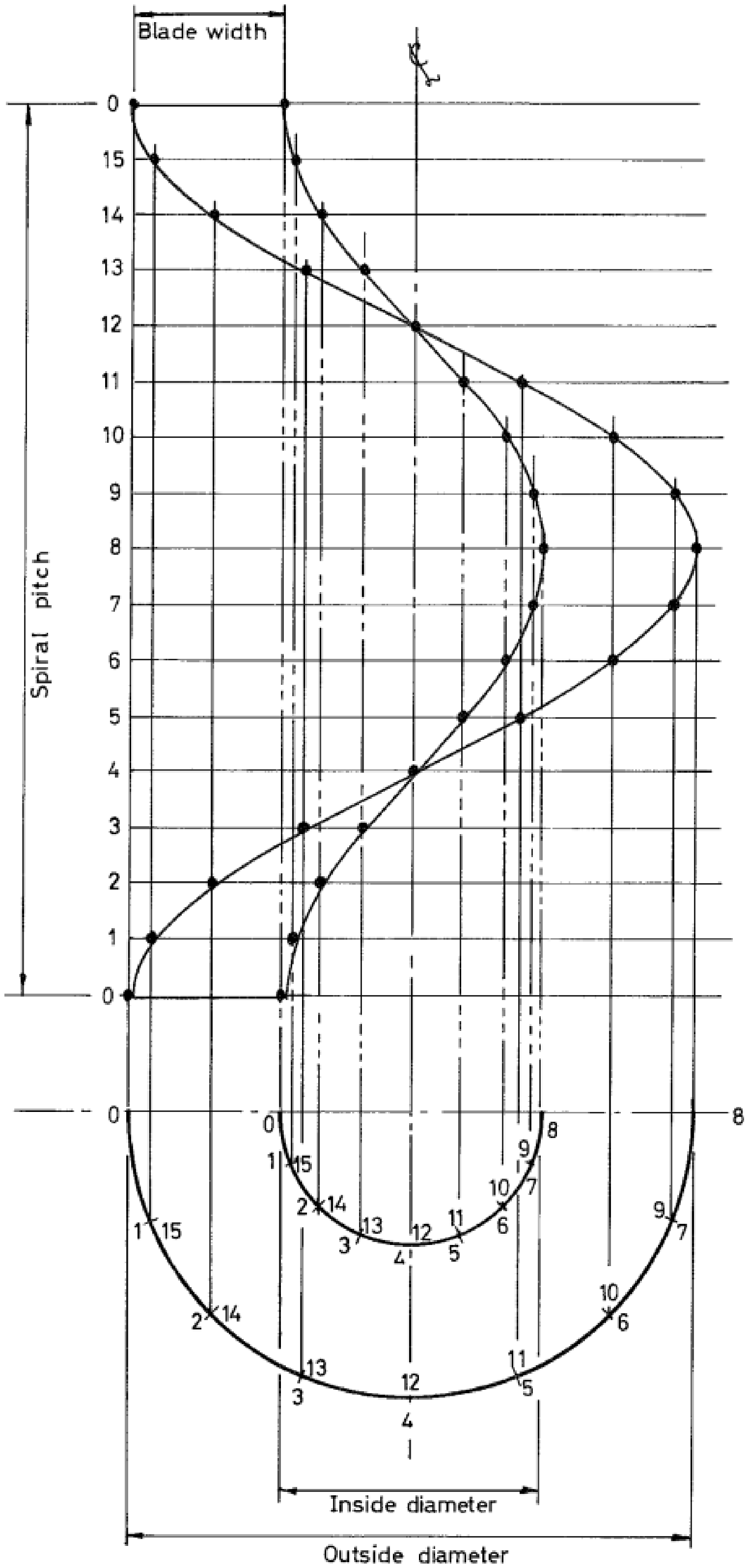



Figure 7.1 The spiral (horizontal plane)

| | |
|---|---|
|  | **NOTE:**<br>It is advisable to first complete the outer diameter spiral and then only project up the inner diameter spiral as this will lead to less errors due to all the projection lines that can confuse you. |

## 7.4 Drawing the spiral (vertical plane)

Follow the same procedure as in *section 7.3* for the first spiral, then add on the height of the spiral blade to the projection lines and complete the second spiral, see **Figure 7.2**.

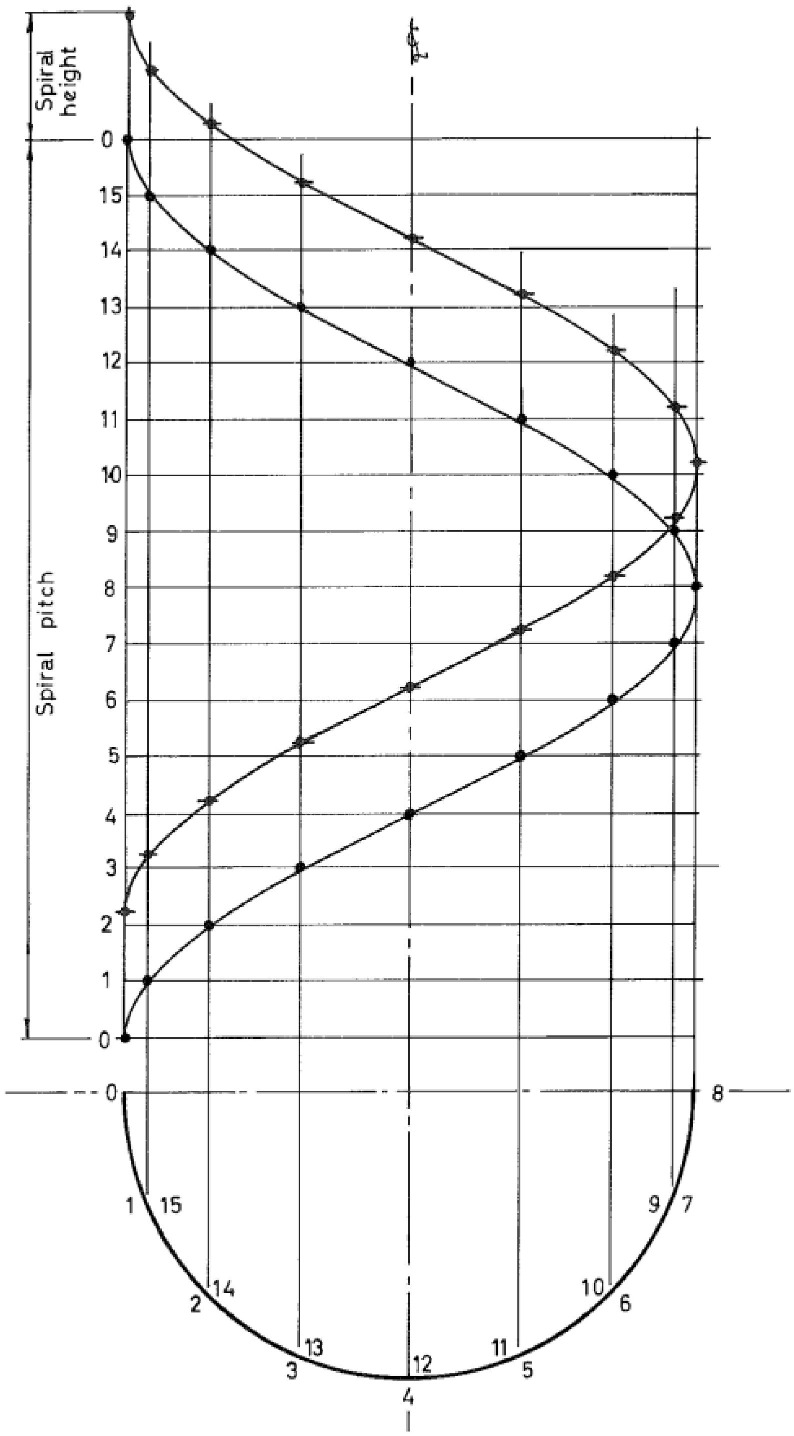



Figure 7.2 The spiral (vertical plane)

## 7.5 Radial line development (horizontal plane)

For the development of the horizontal spiral it is not necessary to draw the spiral.

We need only know the outer diameter, the inner diameter and the pitch of the spiral.

Commence by drawing the true length diagram as a triangle with the vertical leg being the pitch and the horizontal leg being the inner and outer circumference of the spiral diameters (calculated).

**NOTE:**
This diagram need not be to scale as it is much safer to calculate these dimensions to reduce errors.

The true lengths can now be calculated as the diagonals of these triangles by means of Pythagoras's theorem: $A^2 + B^3 = C^2$

Therefore true inner circumference will be:

$C^2 = 100^{2+} + 157,079^2$
$C^2 = 10000\ 24673,81$
$C^2 = 34673,81$
$C = \sqrt{34673,81}$
$C = 186,2$ mm

Similarly the outer true circumference will be 329,69 mm. We commence by marking down the width of the blade on a centre line and marking AB.

Now, we consider the number of development segments, which can be any number but 10 will be the most convenient as we have to divide the circumferences by the number of segments required.

Taking one segment length of outer circumference i.e. 329,69 ÷ 10 = 32,96 mm. Round it off to 33 mm. Set compass to size and with centre A scribe a circle. Similarly we take the inner circumference and divide by 10 i.e. 18,6, round it off to: $18\frac{1}{2}$ mm.

Set compass to size and with centre B scribe circle now draw tangent lines touching the circles and extend to cut the centre line at O. With O as centre, set compass to A and scribe a circle.

Now set compass to outer circumference segment size and starting at point A step off 5 paces to the left along the circle and 5 paces to the right along the circle and mark the last points XX to O.

Then scribe in the inner circle with centre O and radius OB from lines XO to XO to complete the development; as seen in **Figure 7.3** on the following page.

**NOTE:**
The development pattern will never be a full circle.

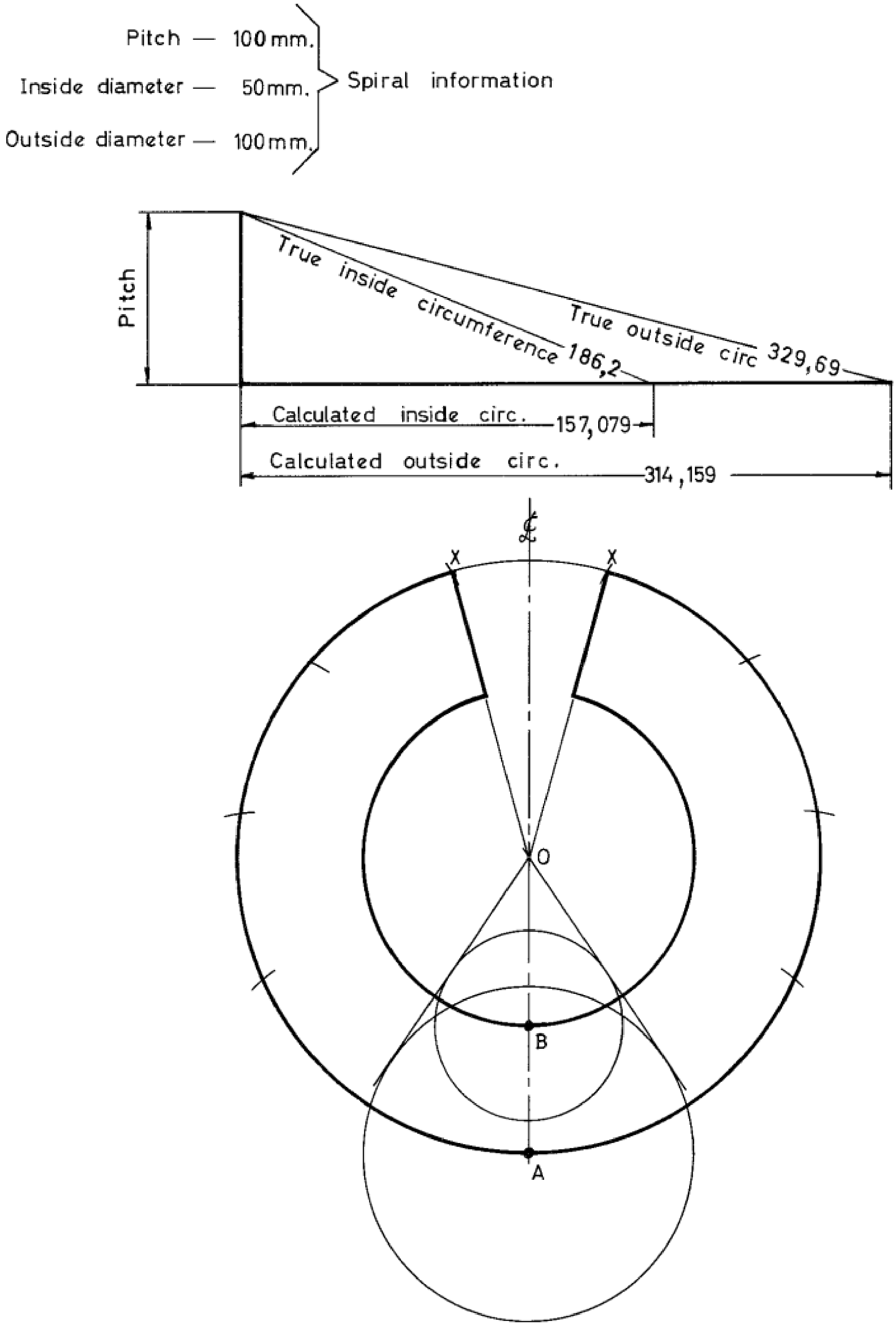



Figure 7.3 Radial line development (horizontal plane)

## 7.6 Straight line development (vertical plane)

To develop the vertical spiral we commence exactly the same as the horizontal spiral.

The only difference is that we do not have an inside and outside circumference, but we have only one which is the mean circumference.

Draw the true length diagram preferably to full scale with the vertical leg AB the pitch of the spiral and the horizontal leg AC the calculated circumference.

Draw in the diagonal between points B and C then we add the height of the spiral blade to the extension of the vertical leg and mark D. Then from D parallel to BC draw a line to E to complete the development, see **Figure 7.4**.

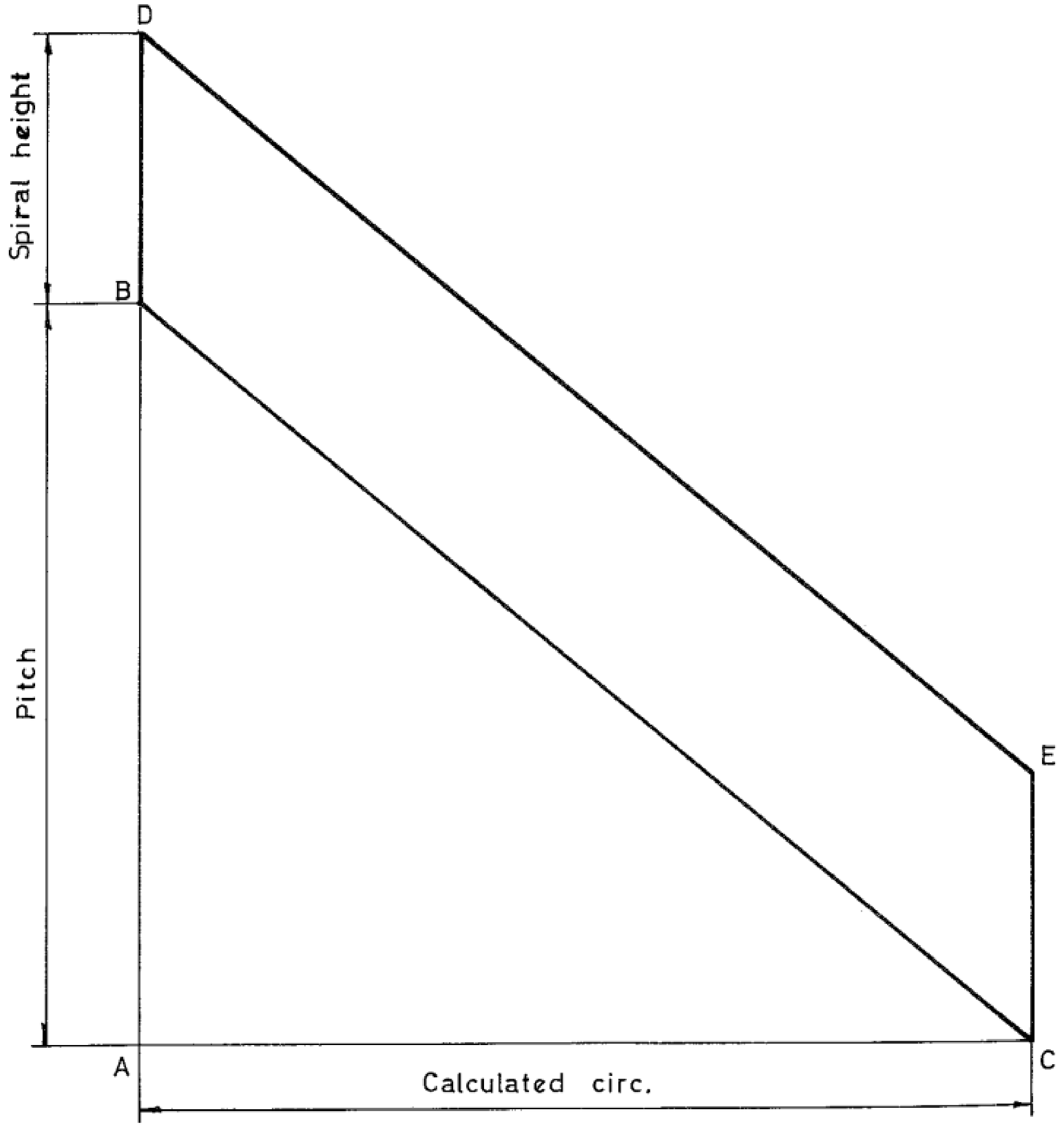



Figure 7.4 Straight line development (vertical Top View)

## 7.7 Triangulation to development of spirals

As the triangulation method is dependent on 4 dimensions repeated by means of a compass, the possible accumulated error does not warrant the consideration of triangulation on the spiral development.

Now work carefully through **Worked Example 1**, below, which shows a ventilator head that fits on a square due.

Take note of the specifications. The solution is given on the following page.

### Worked Example 1

**Figure 7.5** shows a ventilator head that fits on a square duel.

Draw the given views and develop:

- The pattern fur the back panel
- The pattern for the throat panel
- The pattern for the side panels.

Scale 1:5

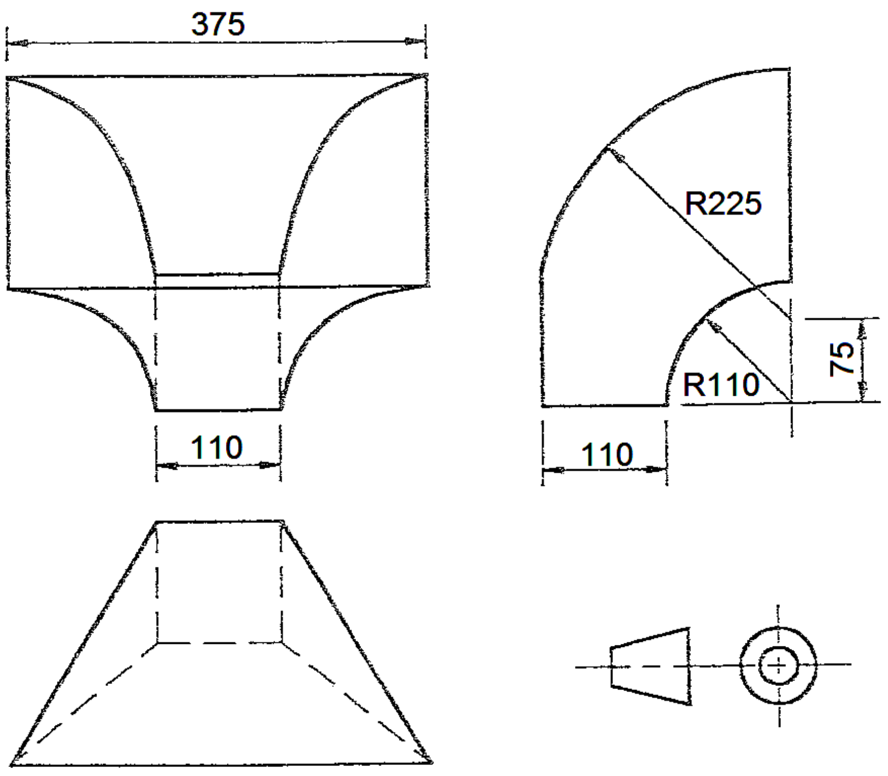



Figure 7.5 A ventilator head that fits on a square duel

Solution:

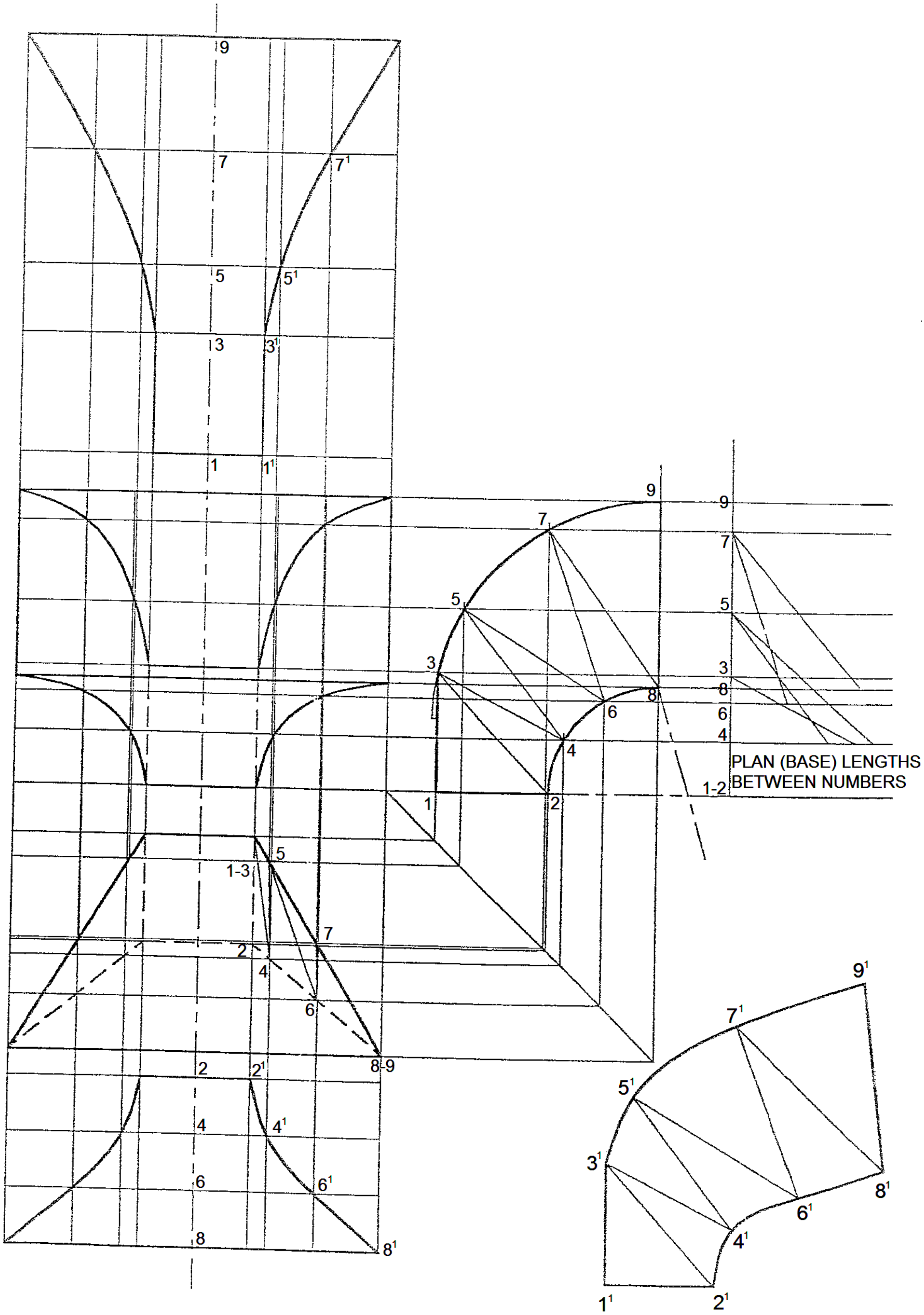



Figure 7.6 Solution

Now work carefully through **Worked Example 2**, below, which shows a front view and a top view of a 90° spiral.

Take note of the specifications. The solution is given on the following page.

## Worked Example 2

**Figure 7.7** shows a front view and a top view of a 90° spiral.

Draw the top view, construct the front view and develop the shape of the plate required to manufacture the spiral.

Scale 1:5

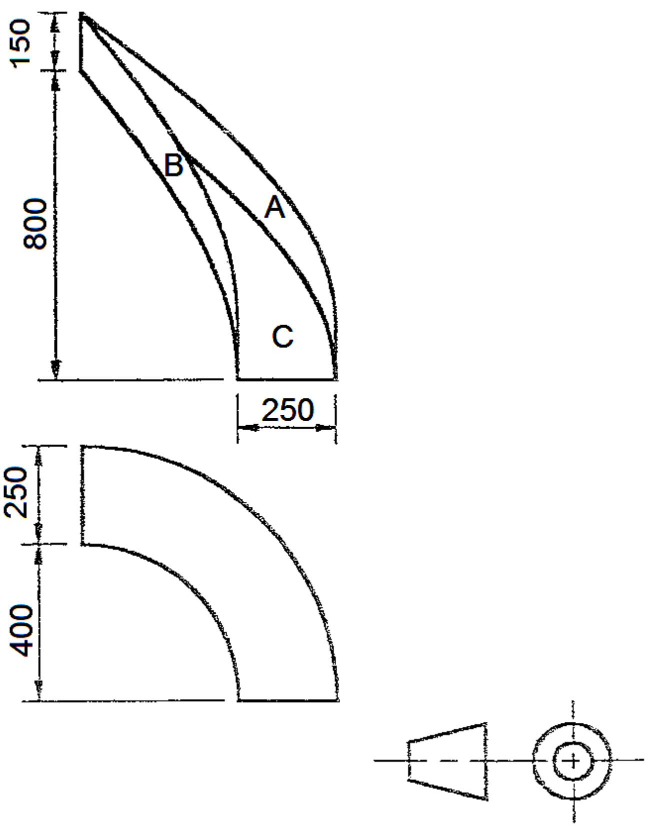



Figure 7.7 A front view and a top view of a 90° Spiral

Solution:

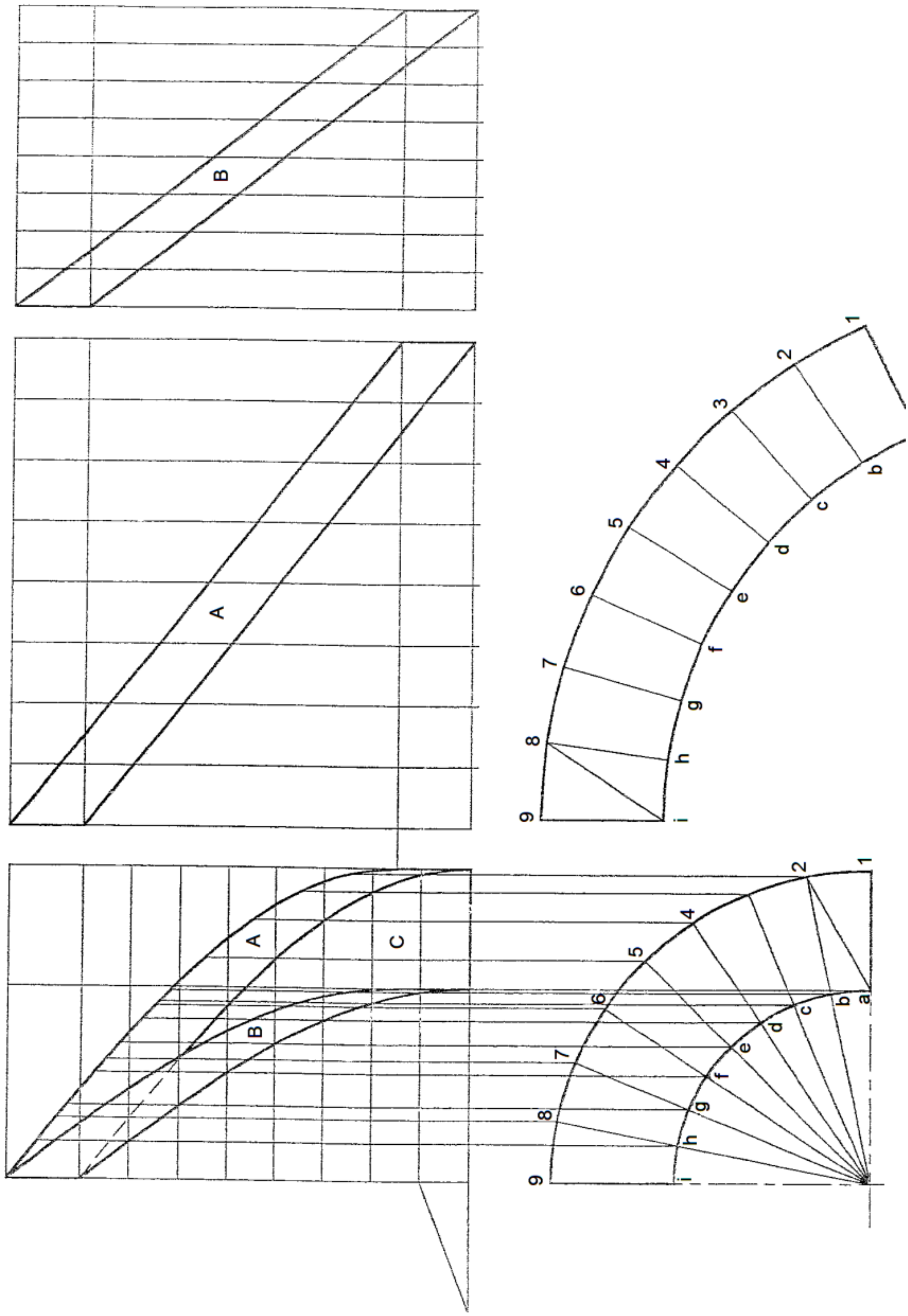



Figure 7.8 Solution

Now work carefully through **Worked Example 3**, below, which shows a front view and a top view of a 360° spiral.

Take note of the specifications. The solution is given on the following two pages.

## Worked Example 3

**Figure 7.9** shows a front view and a top view of a 360° spiral.

Draw the top view, construct the front view and develop the shape of the plate required to manufacture the spiral

Scale 1:5

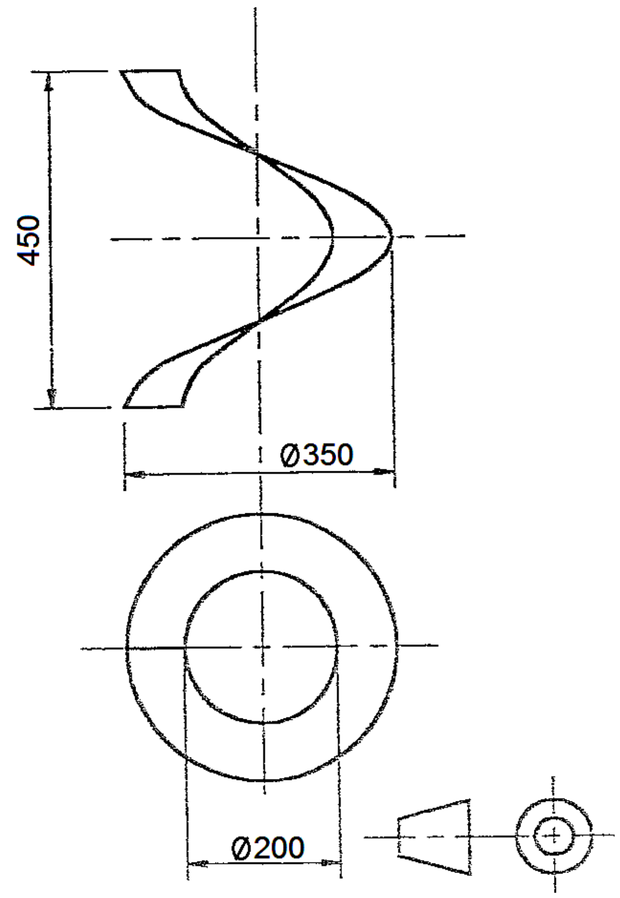



Figure 7.9 A front view and a top view of a 360° spiral

Solution:

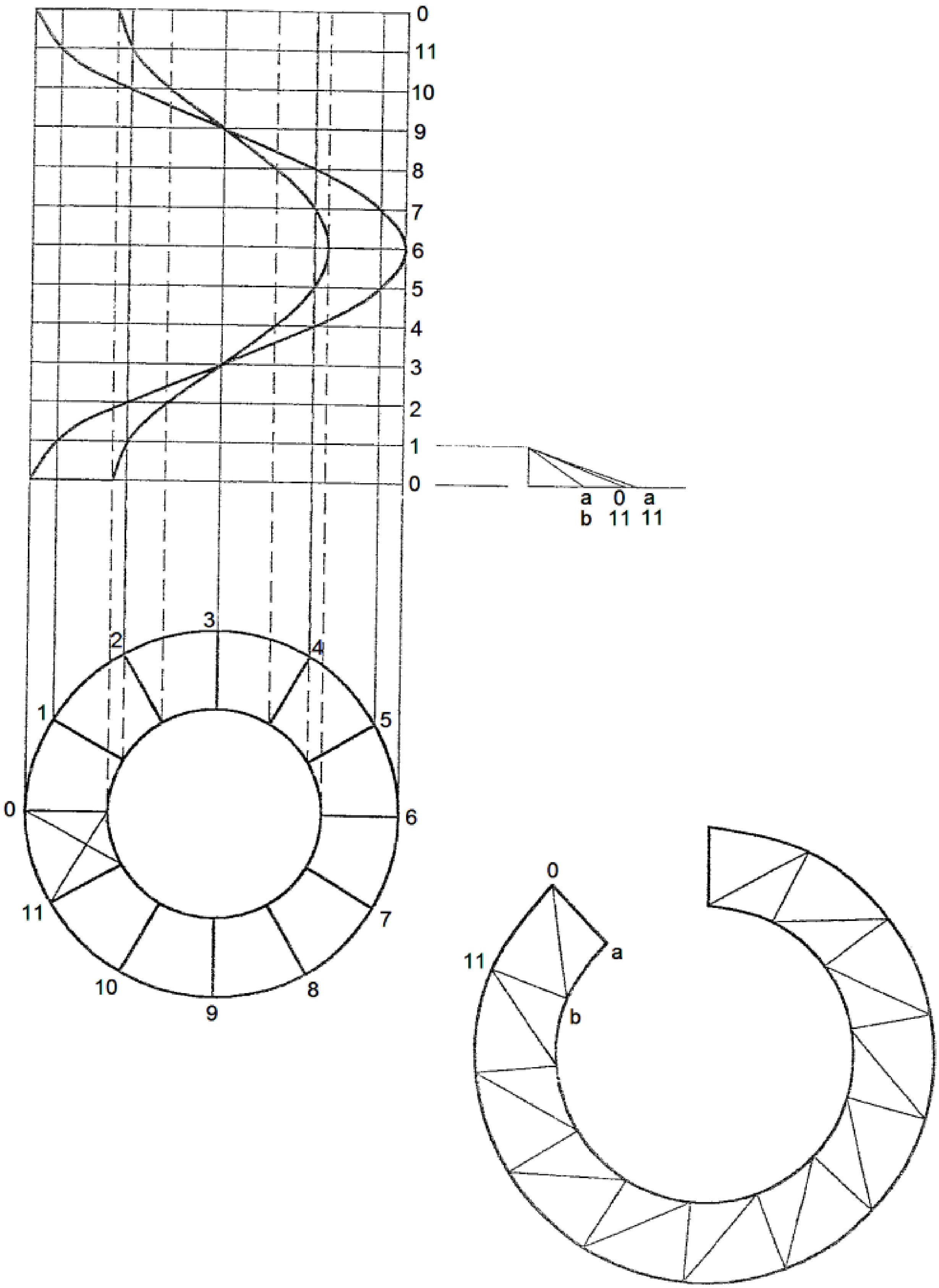



Figure 7.10 Solution

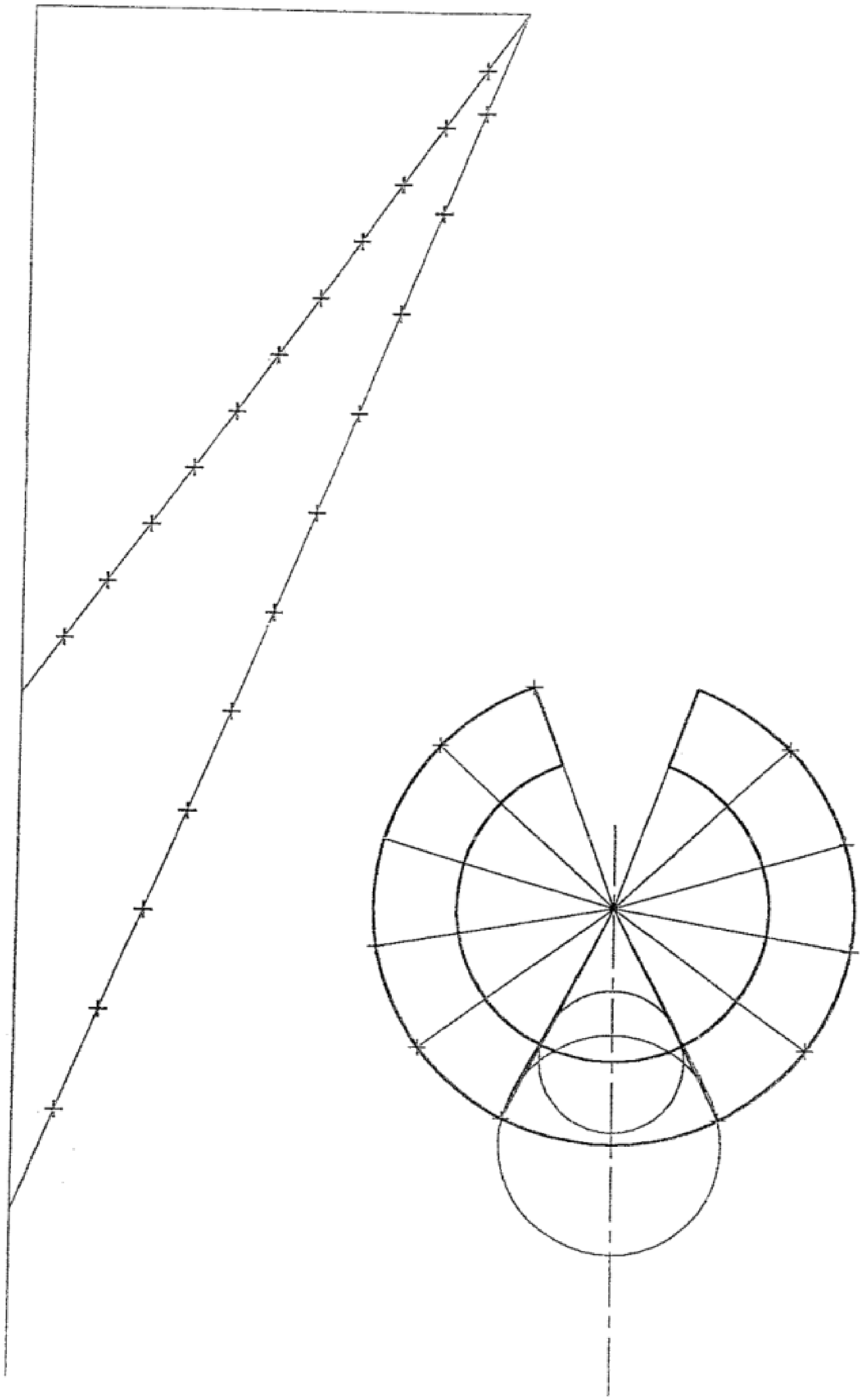


Figure 7.11 Solution

## Activity 7.1

Draw a full pitch of the following horizontal spiral.

- Pitch 120;
- Outside diameter 80;
- Inside diameter 40.

## Activity 7.2

Develop a half pitch horizontal spiral with the following dimensions:

- Pitch 120;
- Outside diameter 75:
- Blade width 25.

## Activity 7.3

Develop the following spiral chute, see **Figure 7.12**.

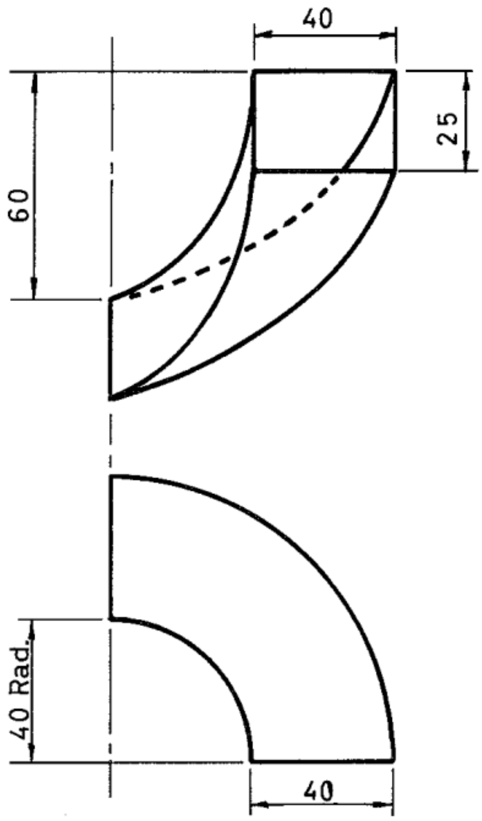



Figure 7.12 Spiral chute

**Self-Check**

| **I am able to:** | **Yes** | **No** |
|---|---|---|
| • Understand the facts concerning spirals | | |
| • Draw the spiral (horizontal/vertical plane) | | |
| • Use the Radial line development (horizontal plane) | | |
| • Use Triangulation to develop spirals | | |
| • Use Straight line development (vertical Top plane) | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 8

# Interpenetrations

**Learning Outcomes**
On the completion of this module the student must be able to:

- Define the cutting plane and central ball theorem
- Describe the following development of pipes to cones:
  - Horizontal pipe cutting plane method:
  - Horizontal pipe (basic central ball theorem)
  - Horizontal pipe (advanced central ball theorem)
  - Pipe at an angle (cutting plane method)
  - Pipe at an angle (cutting plane method, alternative)
- Describe the following development of cones to cones (cutting planes):
  - Pipe off centre (cutting plane method)
- Describe the following development of cones to pipes:
  - Pipe at an angle (central ball theorem)

## 8.1 Introduction

Interpenetrations are of such a varied nature that it would be an impossible task to show all the different interpenetrations that are possible. Therefore, only the basic theorems and some of their applications will be shown.

It is of interest to note that, with a little consideration, the draughtsman or designer can in some cases simplify interpenetrations to straight line joints by applying the central ball theorem concept.

## 8.2 Cutting plane theorem

Due to the fact that the cutting plane method of obtaining interpenetrations is the most common method used and in some cases the only method that can be used, we will consider this method first.

This method is based on the concept that, if two bodies intercept, whether of the same shape or not, each body has to be cut to find points of mutual dimension to fit.

Thereby giving a perfect joint that would not require a filler to close up any gaps or steps formed by the joint.

**NOTE:**

**Rules to follow:**

1. Draw the side view.
2. Draw the top view (it is not necessary to draw the full top view if the interpenetration is symmetrical about the central line).
3. Divide up the penetrating object and number as for developing i.e. bend lines. (Note that in the view as well as the top view)
4. Where the line in view meets the side of the cone, drop the point to the top view and with cone centre as centre. Scribe the radius with this point until it intercepts the correspondingly numbered line in the top view. This is the intercepting point.
5. Then project this intercepting point straight up to again intercept the correspondingly numbered line in view to give the point in view.
6. When we have all the intercepting points the following should be noted:
   a) The penetrating body must be developed from the view.
   b) The hole in the penetrated body is picked up from the base top view as well as from the view.

Now work carefully through **Worked Example 1,** below**,** which shows a cone and an intercepting hexagon.

Take note of the specifications. The solution is given on the following page.

## Worked Example 1

Considering **Figure 8.1**, of a cone and an intercepting hexagon, we find:

a) Points O and 3 in View will automatically join the cone where they touch the side of the cone as they are single lines on the centre.

b) Lines X and Y will not stop at the side as seen in view but will move straight past until they touch the cone, as seen in **Figure 8.1**.

   To show this, we draw a sectional top view along lines X and Y.

   If these touch points are now projected straight back to the view, we have our true points of interpenetration in view.

c) The other lines can be similarly constructed.

Solution:

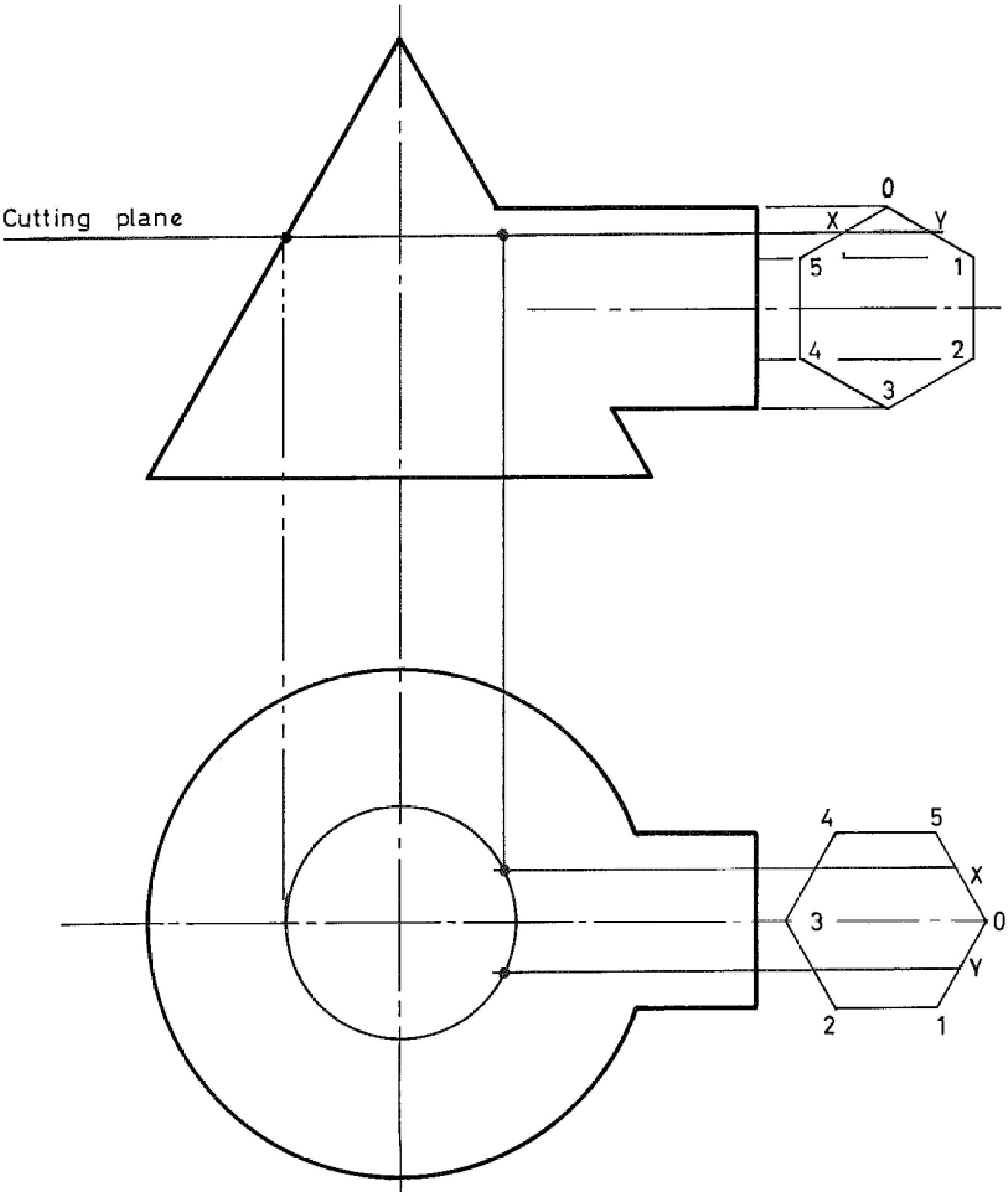



Figure 8.1 A cone and an intercepting hexagon

## 8.3 Central Ball Theorem

If intercepting bodies have both sides in view touching a common central ball with centre on a mutual centre, the lines of interpenetration will be straight lines.

> **NOTE:**
> The critical criteria, is that the centre lines of the separate bodies must intercept in view and in top view.
>
> The line of interpenetration is found by drawing a straight line across the points formed where the outside body lines intercept.

This basic theorem should be designed in as it is very seldom found possible to use it in its basic concept on problems arising.

## 8.4 Pipes to cones

Under this heading we will only consider three basic problems that can be encountered.

But it must be understood that these theorems can be applied to any development.

At this stage, it is expected that the fundamentals of cone and pipe developments are understood, therefore, the concentration falls on the lines of interpenetration.

In this regard, there are seven different methods that can be implemented. We will now discuss each of these seven methods in detail.

Take note of the differences involved in each method to follow.

### 8.4.1 Horizontal pipe cutting plane method:

Starting from the drawn view and top view, it should be noted that the pipe divisions have been properly numbered in both views, as seen in **Figure 8.2**.

**Figure 8.2**, on the following page, illustrates in detail the development of a cone.

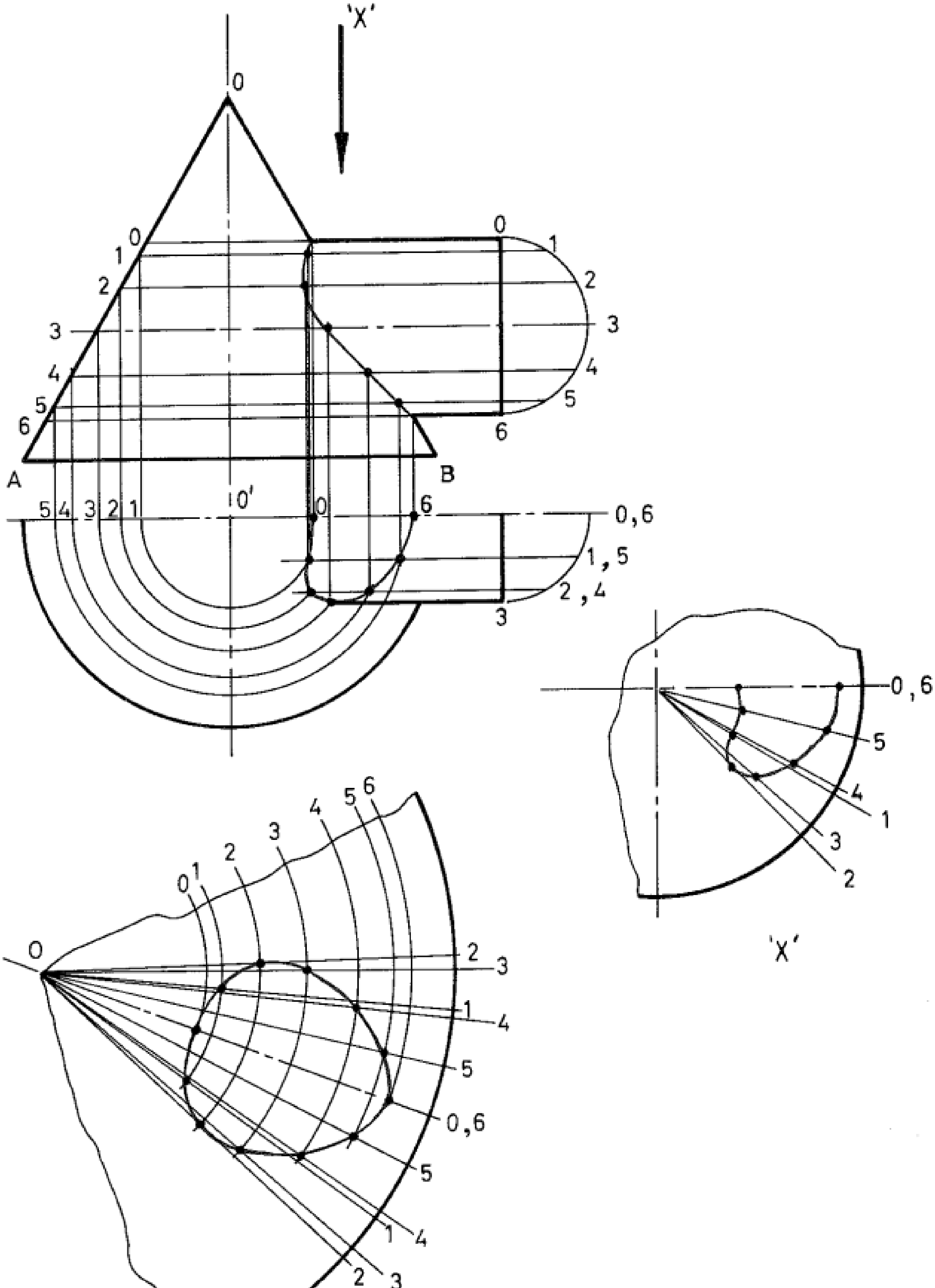



Figure 8.2 Development of cone

Project division pipe lines in view right through to the far side of the cone and then number to 6.

| | |
|---|---|
| ⚠ | **NOTE:**<br>We use the far side for clarity to avoid too many lines in an area that could lead to confusion. |

Now project these points down to centre line of top view and number.

Then, with centre $O^1$ of the cone as centre and with radii 01, 02, 03, 04, 05, scribe arcs to cut corresponding numbered pipe division lines.

This shows the cutting plane of the cone in top view as circles.

This forms points of interpenetration. By connecting these points we have the top view of the hole in the cone.

Now project these interpenetration points straight up to cut the corresponding numbered division lines in the view.

This in turn gives us the pipe cut of points (point of interpenetration) for development.

By connecting these points we have the line of interpenetration.

On developing the cone the hole has to be added.

This can be done by transferring the points of interpenetration in the top view onto the actual development pattern of the cone.

For transferring the hole onto the cone pattern we use apex O as centre and radii OO, O1, O2, etc., to scribe arcs on the pattern and number each, as seen in the part development of a cone.

It now remains to fix the points on these arcs as follows: (see part top view X for clarity).

Join all the points of interpenetration with centre of cone and extend these lines to the base line of the cone and number.

Then working from a centre line 0,6 on the cone pattern, we take the arc measurements on the base in the part top view and step them off on the pattern in sequence and number.

It now only remains to connect these points on the cone pattern base to the cone centre.

Where these lines cut the corresponding numbered arc lines we have the points of the hole.

**8.4.2. Horizontal pipe (basic central ball theorem)**
Draw the outline of the cone, then the central ball touching the sides of the cone; now we draw in the pipe with sides touching the central ball.

This method can only be used when the ball touches the sides of the cone and the sides of the pipe.

We now extend the pipe outside lines to touch the far side of the cone, where the pipe outside lines 0 and 6 cut the cone outside lines XB and XA we get points C, F, D and E.

We then connect C to E and D to F and where these lines cross at Z we mark out turning point in our interpenetration line.

To complete the line of interpenetration connect points C, Z, F.

Only now do we divide and number the pipe in both view and top view, then project the division lines in the view to touch the line of interpenetration

Then down to intercept the correspondingly marked pipe division lines in the top view to give us the shape of the hole in the top view.

**NOTE:**
In some cases it is possible to have alternative interpenetration lines. See **Figure 8.3**, in this case the top of the cone falls away.

On the following page, **Figure 8.3** illustrates alternative interpenetration, as described above.

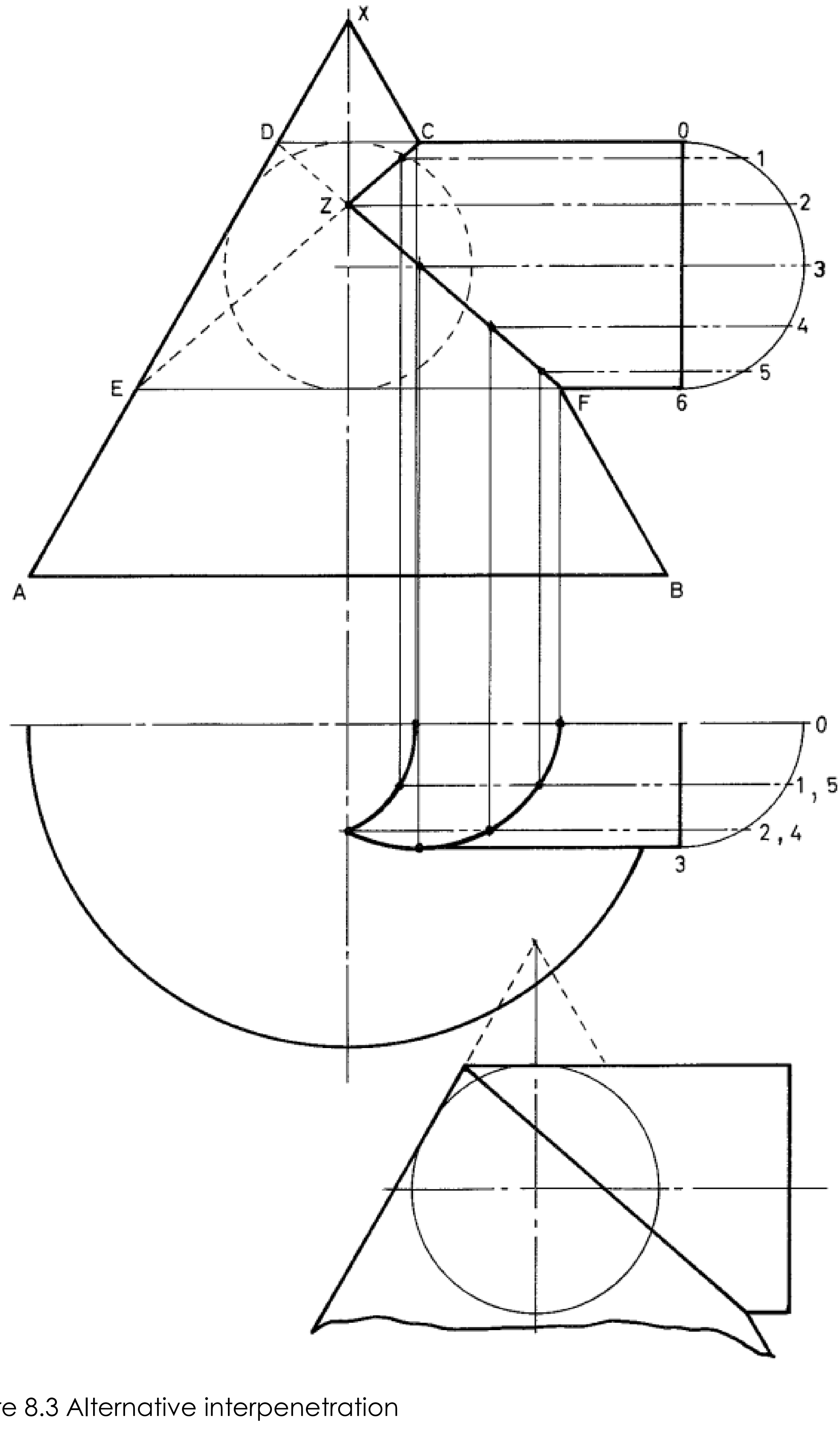



Figure 8.3 Alternative interpenetration

**8.4.3 Horizontal pipe (advanced central ball theorem)**

It is seen in **Figure 8.4** that there is in fact not one central ball that touches the sides of the cone and the side of the pipes. This is why the line of interpenetration will not be a straight line.

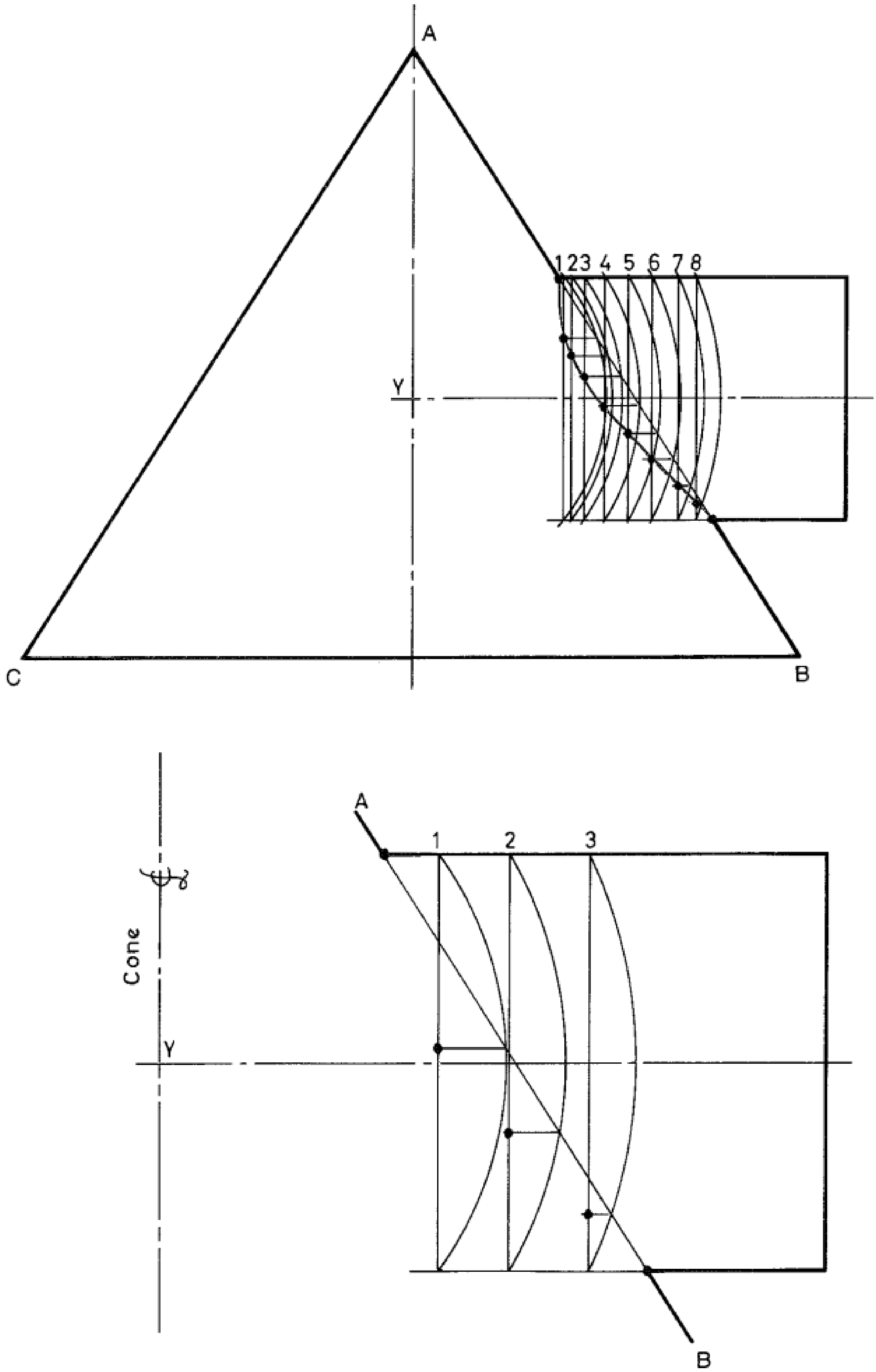



Figure 8.4 Horizontal pipe

This is also why it is advisable not to use this method on any but horizontal pipe to cone connection.

After drawing the side view without the normal pipe divisioning we put in points at random along the side of the cone line A, B.

This is done between the pipe outside lines (see enlarged section for clarity) and lines are then drawn vertical from pipe side to pipe side and number these 1, 2, etc.

Now with the centre line's intersection marked Y as centre and radius Y1, scribe an arc.

Where the arc cuts the side of the cone line AB draw a line horizontally back to cut the vertical line 1; this intersection is your point of interpenetration.

Continue on the same pattern with points 2, 3, 4, 5, 6, 7, and after completion join the points to form the line of interpenetration.

**8.4.4 Pipe at an angle (cutting plane method)**

In this development, we use cutting plane along the bend lines of the pipe i.e. not normal to the cone centre line.

We should, by now, know that the cutting plane on the cone will show in Top View as an ellipse.

We now see that as we intend taking cutting planes marked 1, 2, 3, 4 and 5 on the pipe divisions, we will have to construct 5 ellipses.

**NOTE:**

As a reminder in **Figure 8.5** we show the method of drawing ellipses.

After the 5 ellipses have been drawn and numbered in the top view, we project the numbered pipe division lines across to cut the like-numbered ellipses to give us the points of interpenetration.

These points are then- in turn projected up to the like-numbered pipe division lines in view to give the line of interpenetration in view.

On the following page, **Figure 8.5** illustrates the development of ellipses.

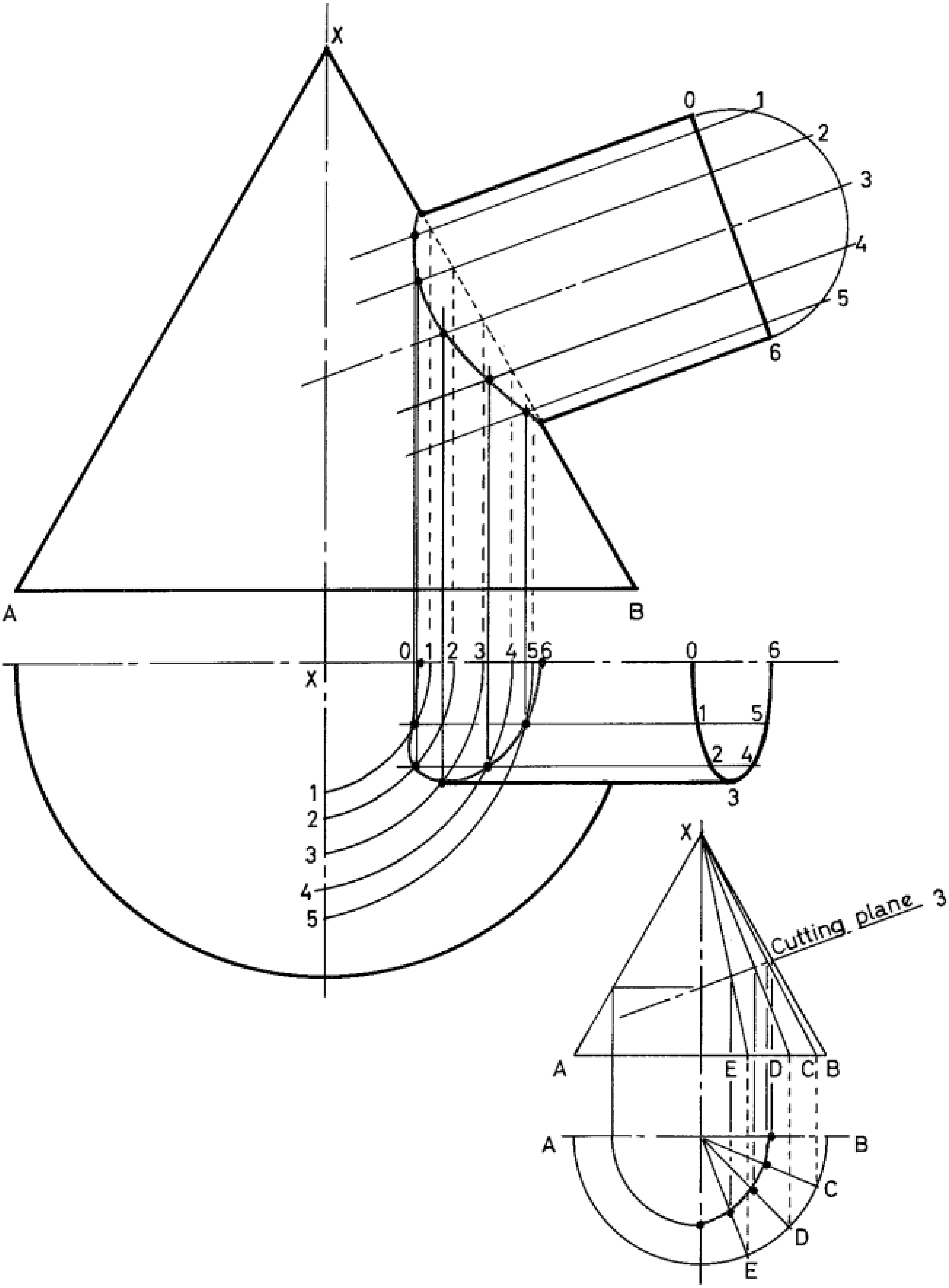



Figure 8.5 Ellipses

**NOTE:**
The construction lines of the ellipses in top view are not shown for clarity of the actual points of interpenetration.

### 8.4.5 Pipe at an angle (cutting plane method, alternative)

In this development we take cutting planes normal to the cone centre lines.

This, of course, will show the cone cutting planes in top view as circles but the pipe cutting plane will be an ellipse.

This method is sometimes considered preferable as it is only necessary to draw 1 ellipse instead of 5, as in the previous case.

This is because we can make a template of this elliptical cutting plane and use this on the various positions as required.

To clarify this idea, see the inset drawing. To avoid misunderstanding in this explanation, we consider only one line i.e. the pipe division line 2.

Where this line touches the side of the cone, we draw the cutting plane 2.

By projecting down to top view the point where the cutting plane cuts the side of the cone and using X on top view as centre, scribe circle marked 2 to show cutting plane of cone.

Now where cutting plane 2 in view cuts the centre line of the pipe we have the centre of the elliptical cutting plane of the pipe.

Project this down to the top view and with the aid of the elliptical template placed on the centre, draw the ellipse to cut the circle, marked 2, giving the point of interpenetration.

By repeating this procedure for all the cutting planes you are assured of an accurate and easy conclusion to this development, as seen in **Figure 8.6**.

These last 2 examples indicate clearly that the cutting plane method is very versatile and can be used in different ways.

On the following page, **Figure 8.6** illustrates the part top view and view with the pipe at an angle and showing the cutting plane.

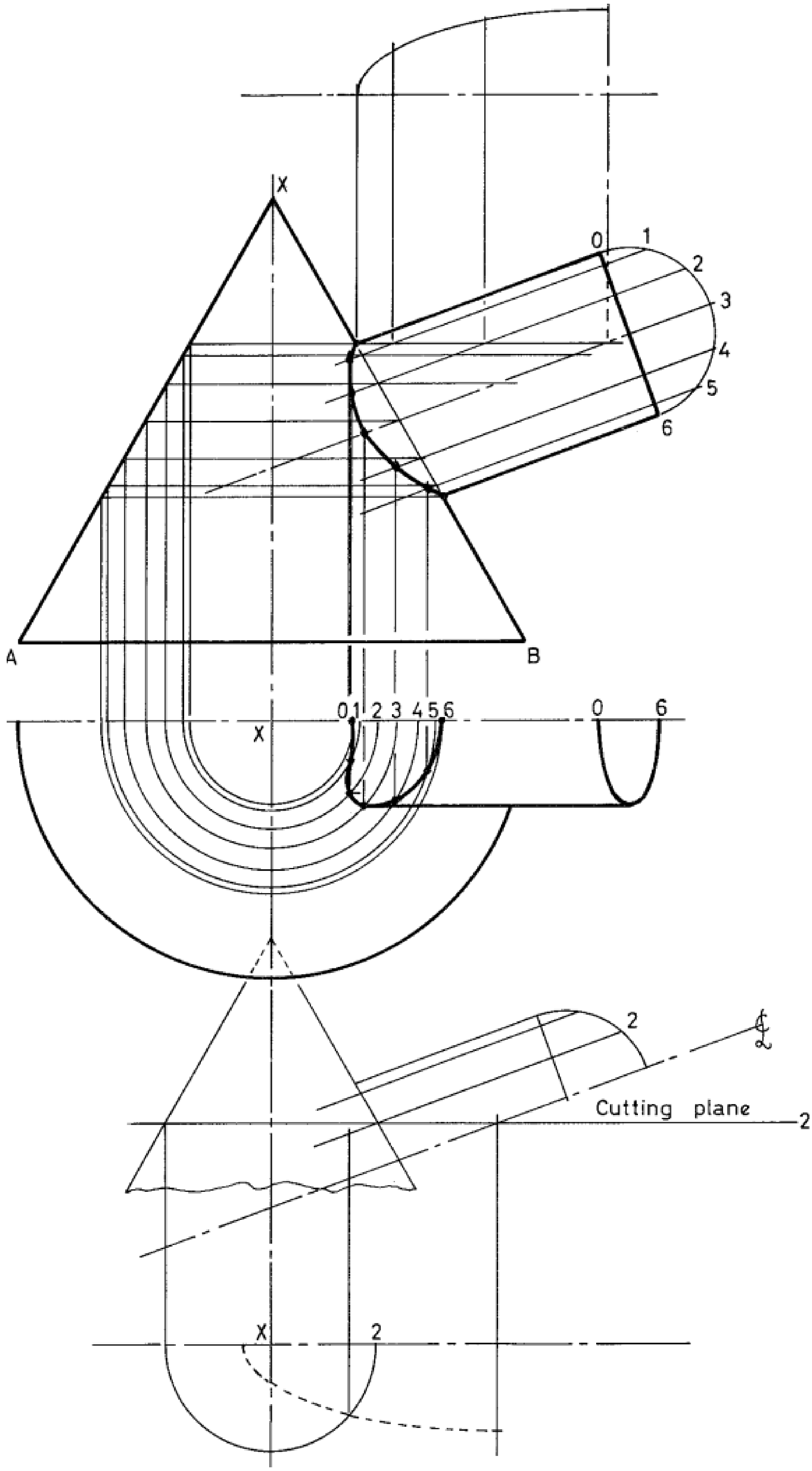



Figure 8.6 Part top view and view

**8.4.6 Pipe at an angle (central ball theorem)**
This development is carried out as in *section 8.4.2*

**8.4.7 Pipe off centre (cutting plane method)**
In this development we use the same principles as shown in *section 8.4.1* with one difference, i.e. that we draw the full pipe in top view as this pipe development is not symmetrical.

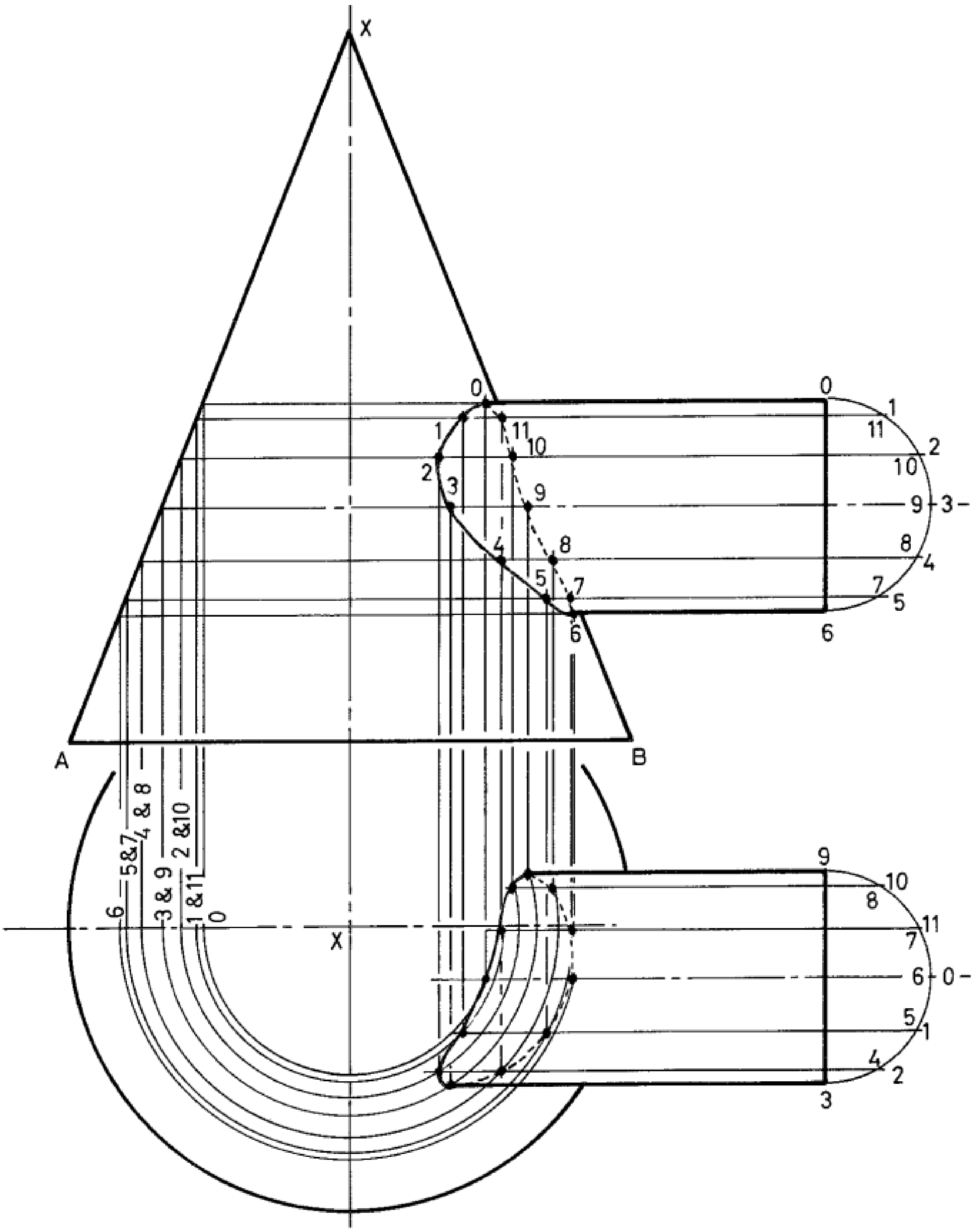



Figure 8.7 Pipe off centre (cutting plane method)

It is necessary to have all the pipe lines numbered, see **Figure 8.7**. Care should also be taken when projecting these points in top view to the view to ensure the correct placing of two points.

## 8.5 Cones to Pipes

This developments is done the same basic principles as in *section 4.7.1* and *4.7.2*, see **Figure 8.8.**

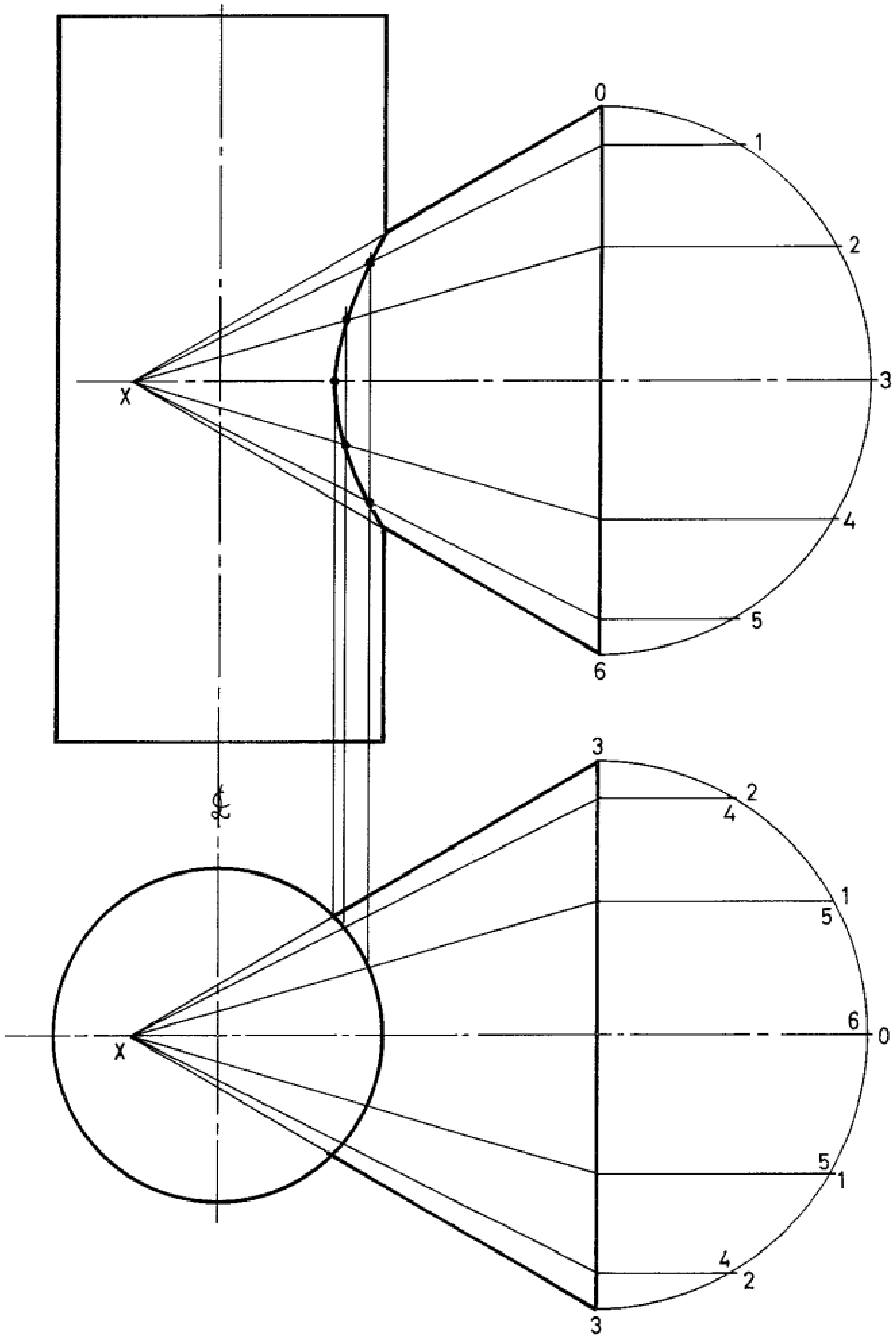



Figure 8.8 Cones to pipes

## 8.6 Cones to cones (cutting planes)

As for *section 8.44* and *8.4.5* this development can be done in different ways by considering what cutting plane to use.

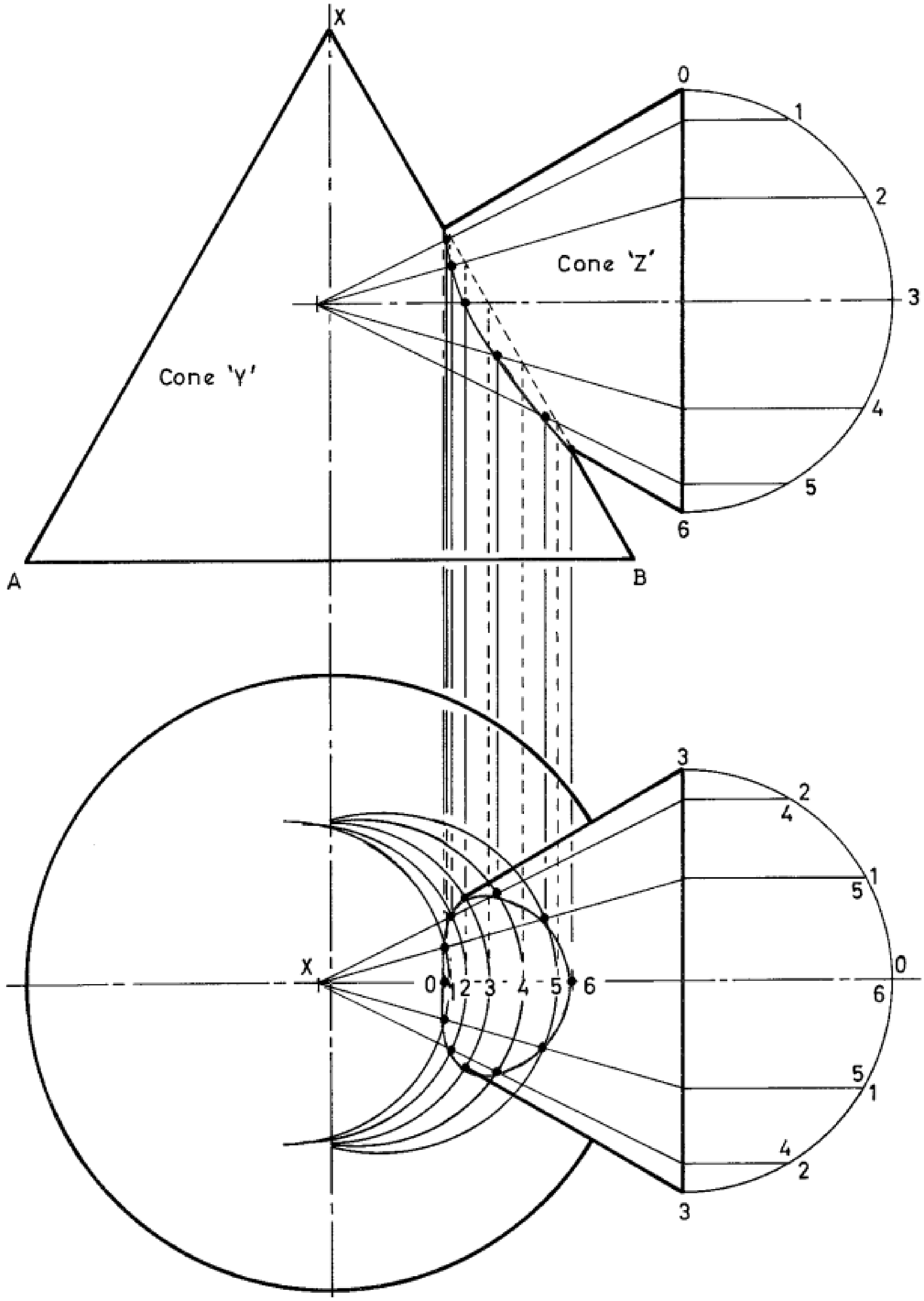



Figure 8.9 Cones to cones (cutting planes)

a) Cutting planes in line with cone "Z" bend lines which will give cutting plane shapes in top view as follows: cone Z will be triangles (3 in number). Cone Y will be 4 ellipses and 1 circle (line 3).

b) Cutting planes normal to cone "Y" centre line which in turn will give cutting plane shapes in top view as follows:

- Cone Z will be 4 hyperbolas and 1 triangle (Line 3).
- Cone Y will be 5 circles.

Choice (a) is preferred. As shown in **Figure 8.9**, use cutting planes in line with cone Z bend lines. Except for different cutting plane shapes continue as for *section 8.4.4*.

## Worked Example 2

**Figure 8.10** shows a front view and a left view of an off-centre, oblique T - piece. Draw the given views, determine the line of penetration and develop the following:

- The branch pipe
- The hole in the main pipe.

Scale 1:5

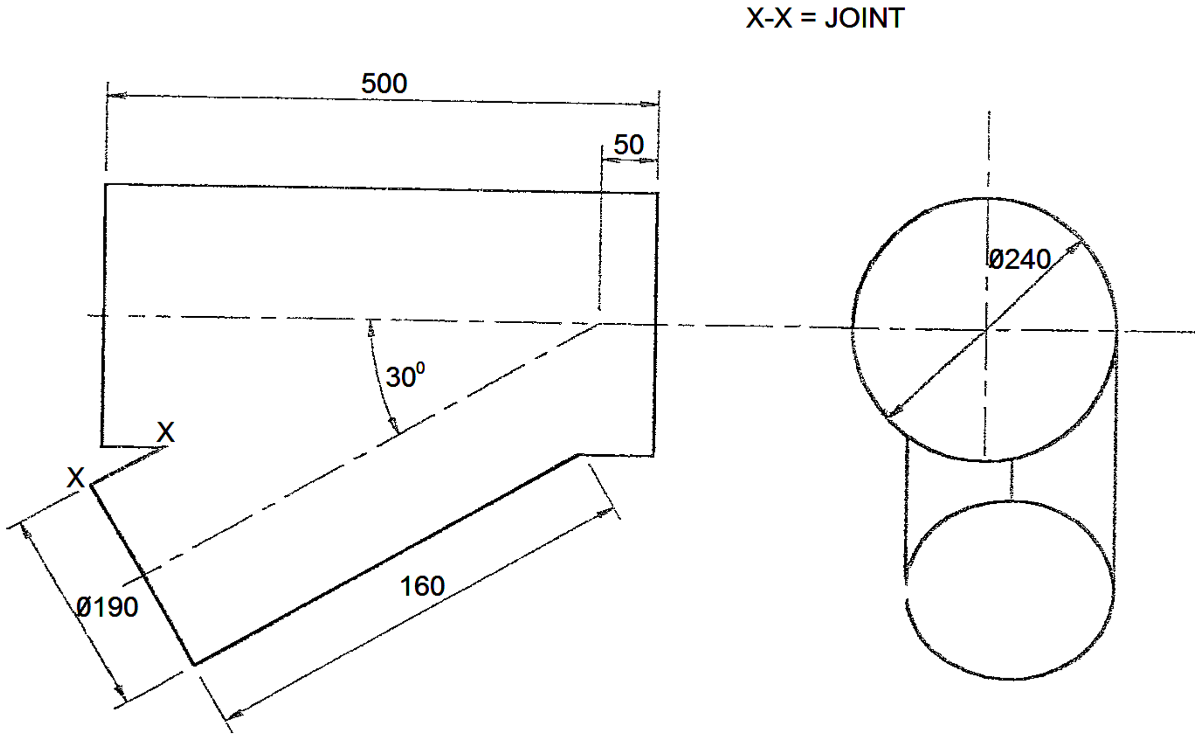



Figure 8.10 A front view and a left view of an off-centre, oblique T -piece

Solution:

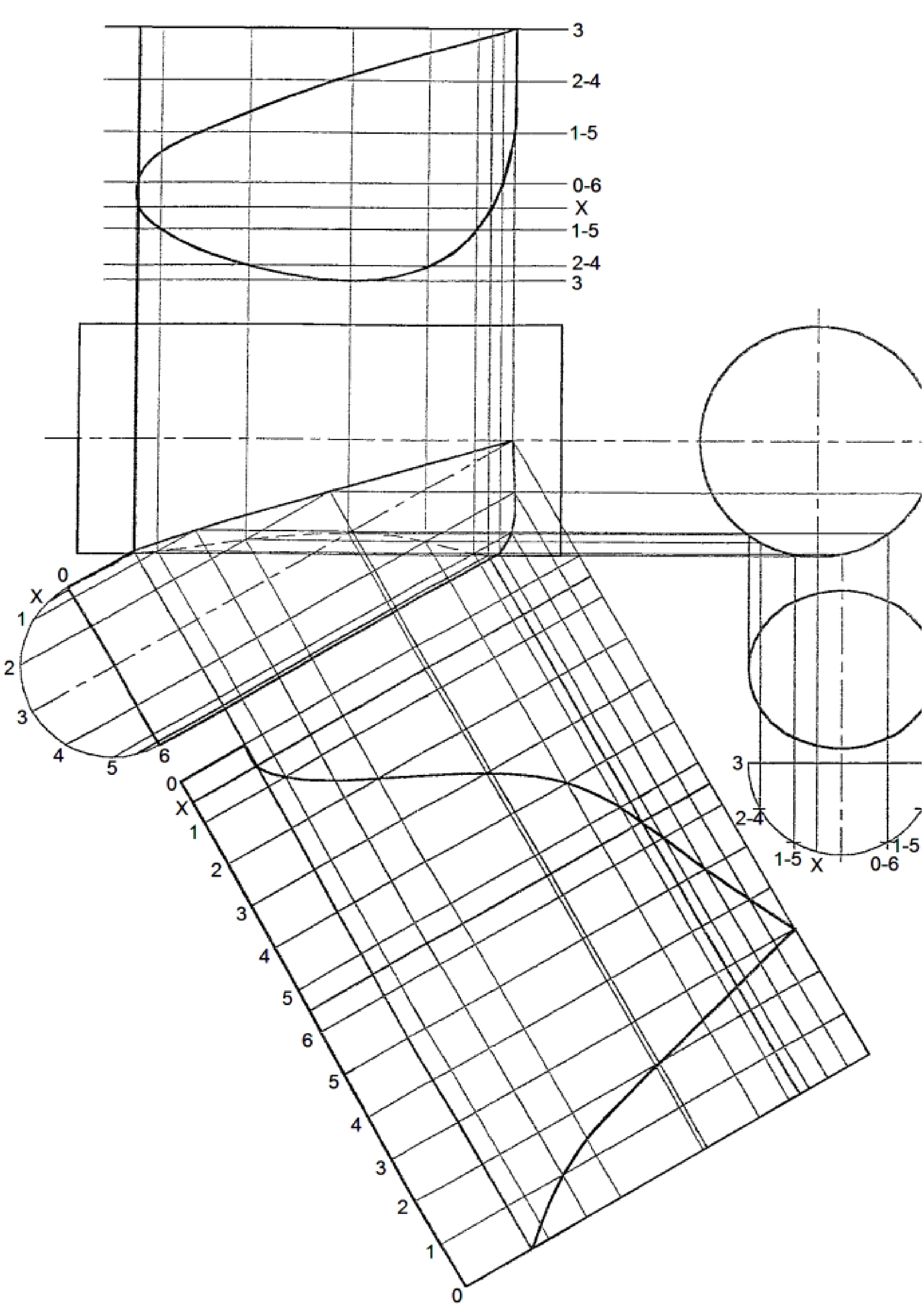



Figure 8.11 Solution

Now work carefully through **Worked Example 3**, below, which shows a conical spout on a cylindrical duct.

Take note of the specifications. The solution is given on the following page.

## Worked Example 3

**Figure 8.12** shows a conical spout on a cylindrical duct.

Draw the given views, determine the line of penetration and develop the shape of the plate required for the spout.

Scale 1:2

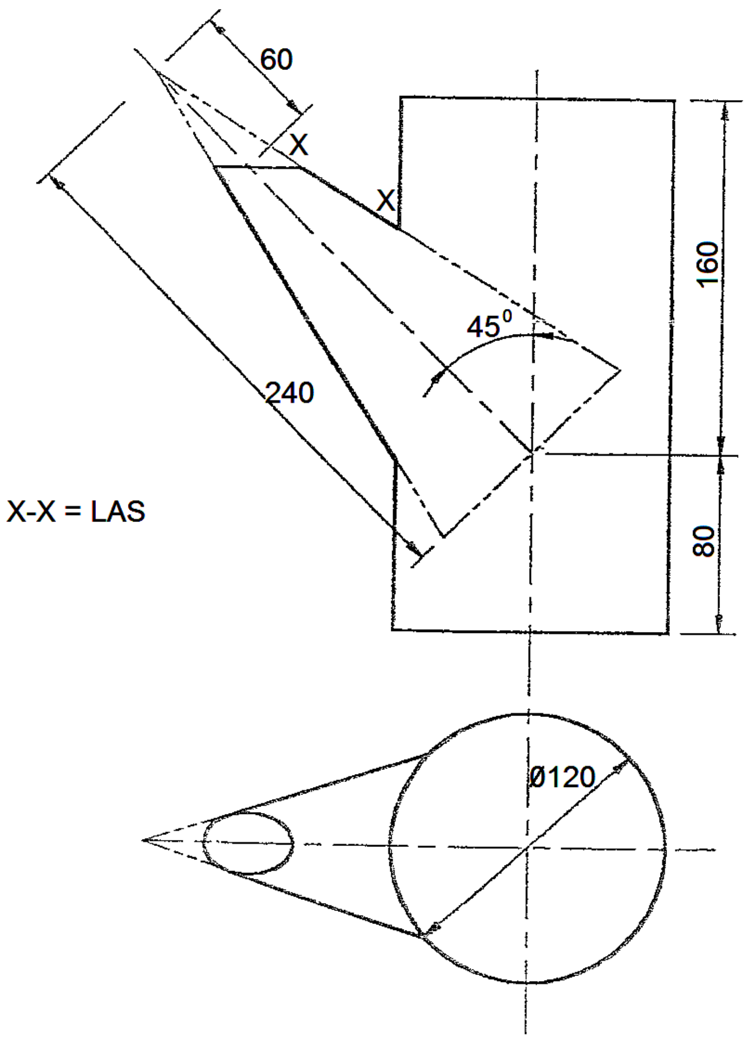



Figure 8.12

Solution:

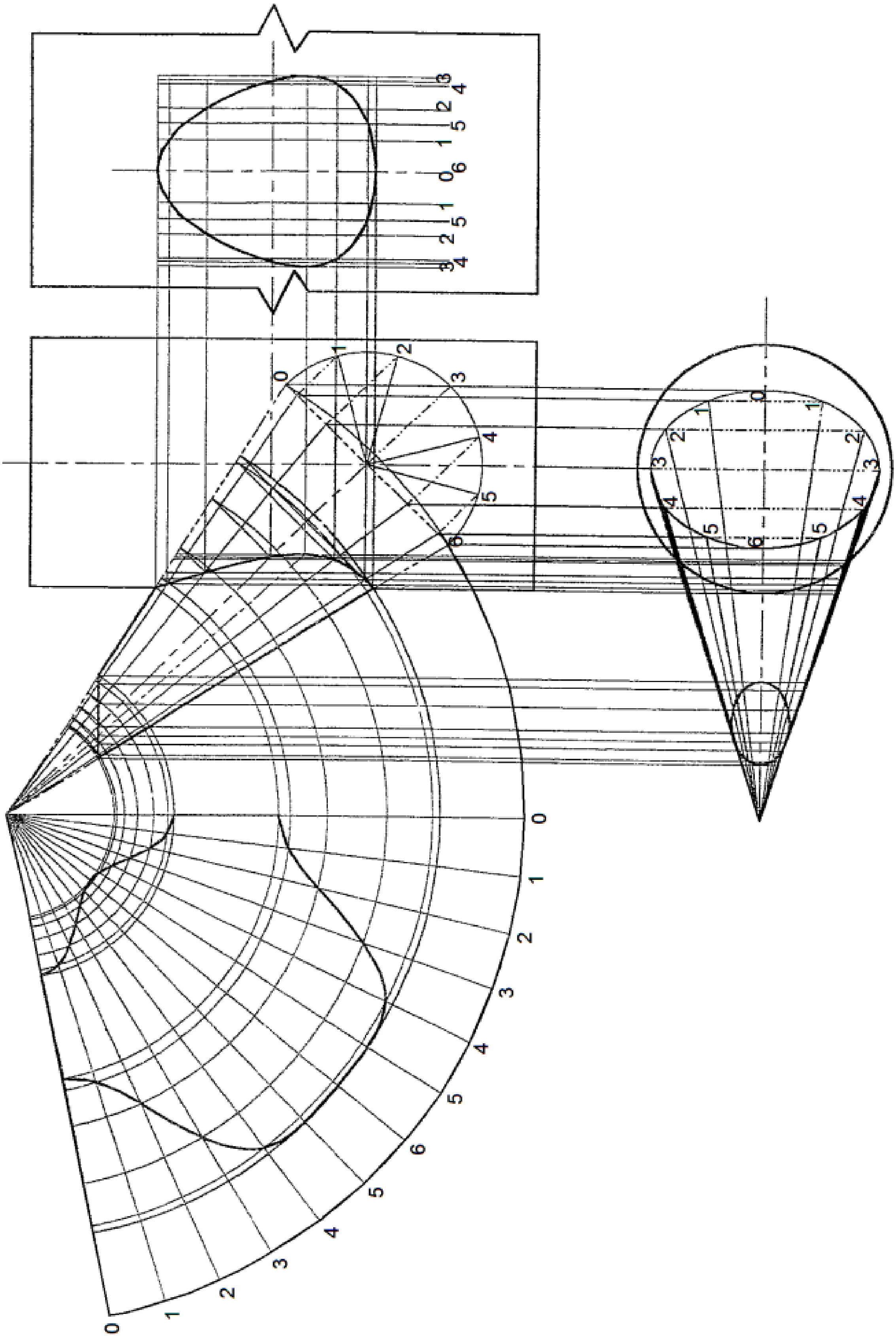


Figure 8.13 Solution

Now work carefully through **Worked Example 4**, below, which shows an intersection between a cylindrical pipe and a dome.

Take note of the specifications. The solution is given on the following page.

## Worked Example 4

**Figure 8.14** shows an intersection between a cylindrical pipe and a dome.

Draw the given view, determine the line of penetration and develop the pattern for the pipe.

Scale 1:5

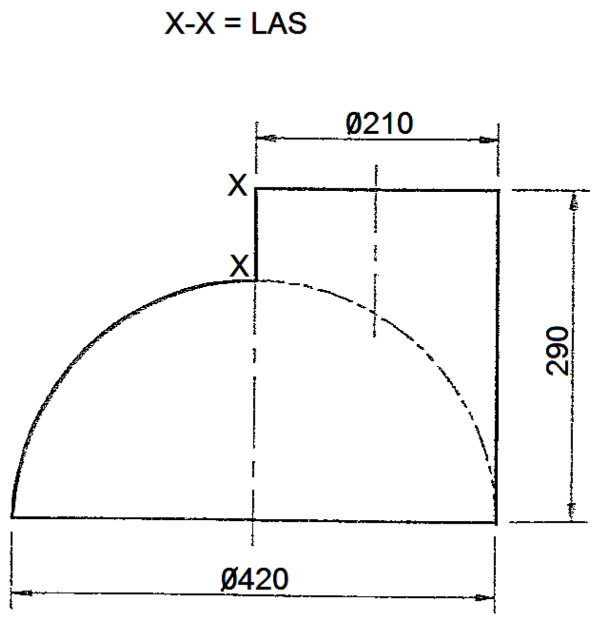



Figure 8.14 An intersection between a cylindrical pipe and a dome

Solution:

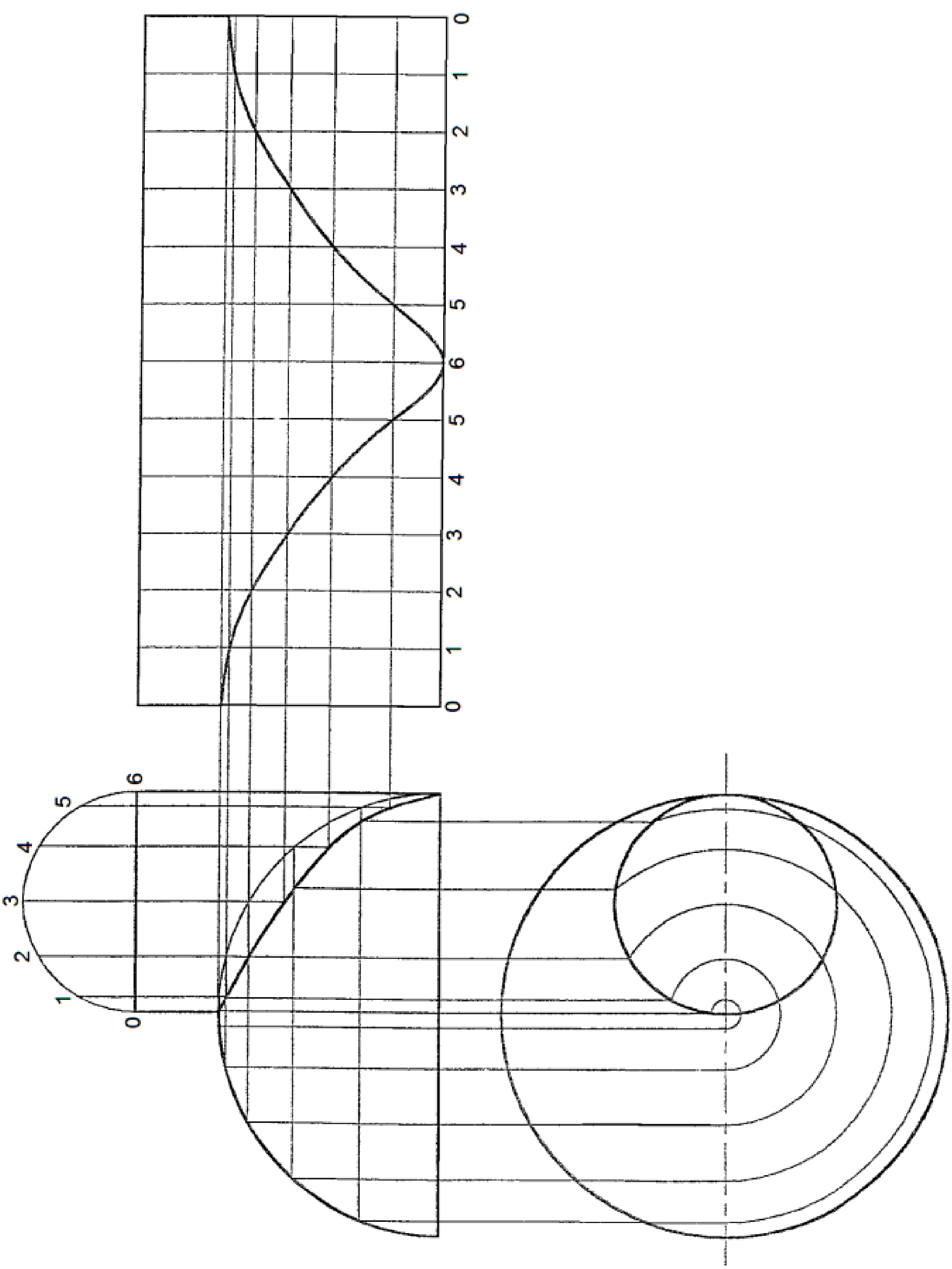



Figure 8.15 Solution

Now work carefully through **Worked Example 5,** below, which shows a front view and a right view of a T-piece. The branch pipe is off-centre.

Take note of the specifications. The solution is given on the following page.

## Worked Example 5

Figure 8.16 shows a front view and a right view of a T-piece. The branch pipe is off-centre.

Draw the given views, determine the line of penetration and develop the following:

- The branch pipe.
- The hole in the main pipe.

Scale 1:5

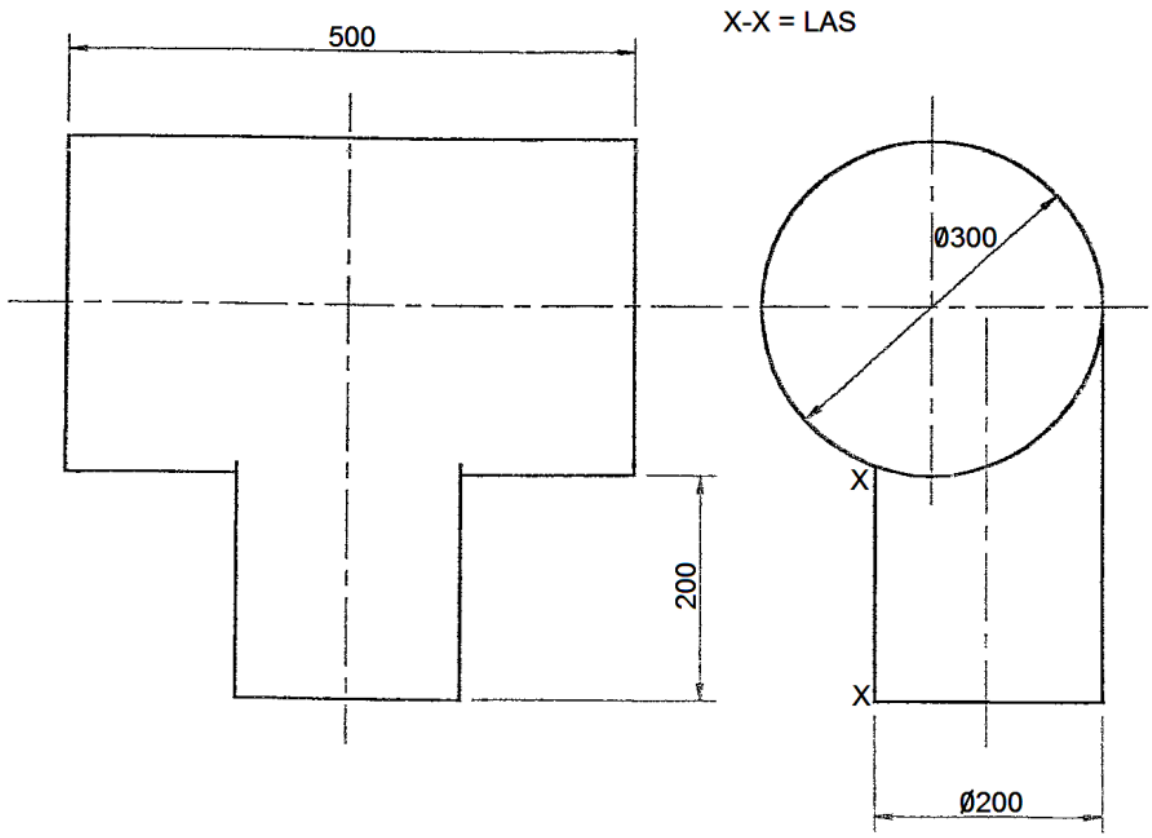



Figure 8.16 a front view and a right view of a T-piece

Solution:

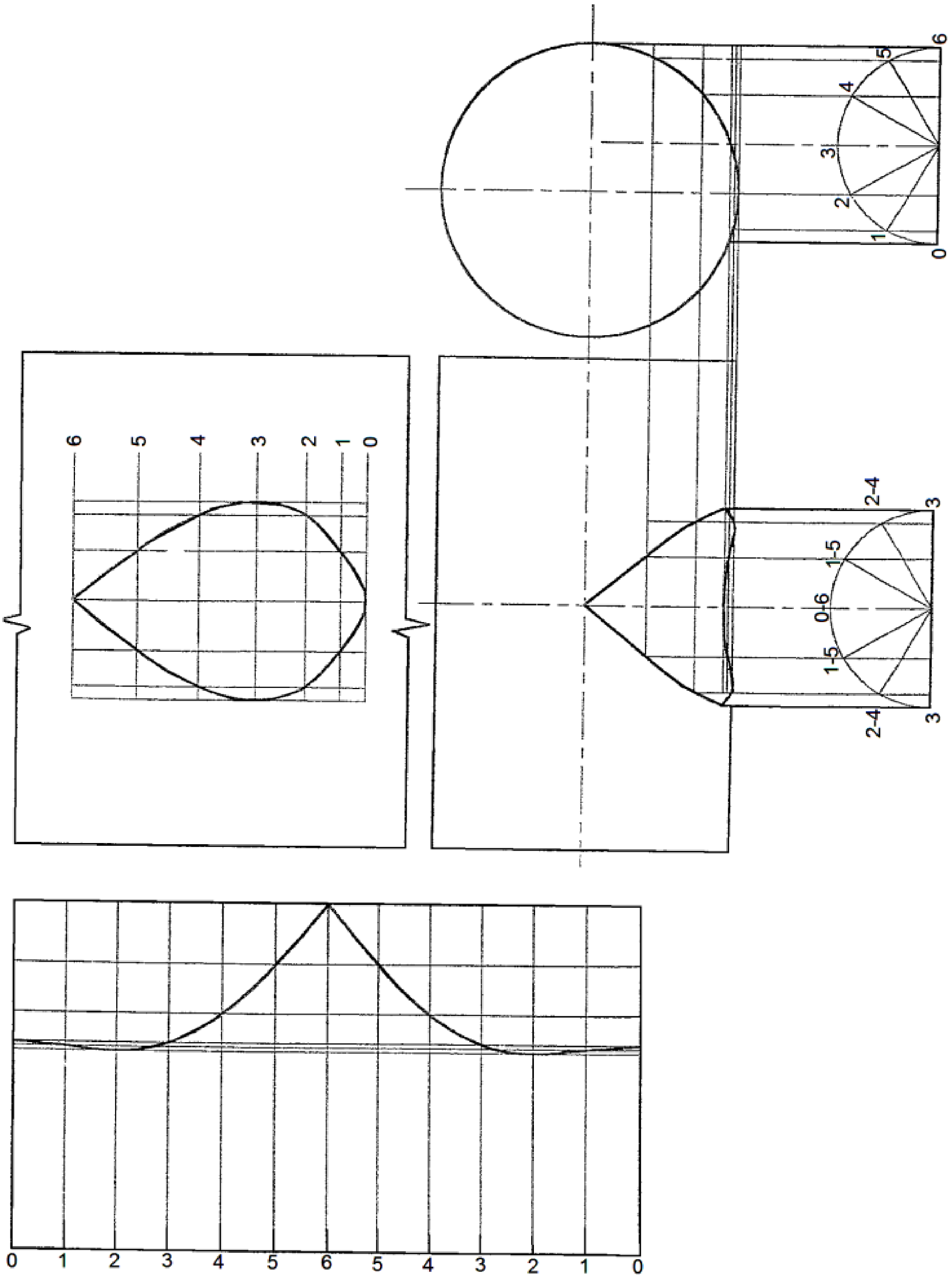



Figure 8.17 Solution

Now work carefully through **Worked Example 6,** below, which shows a front view and a right view of an oblique T -piece. The square branch pipe is off-centre.

Take note of the specifications. The solution is given on the following page.

## Worked Example 6

**Figure 8.18** shows a front view and a right view of an oblique T -piece. The square branch pipe is off-centre.

Draw the given views, determine the line of penetration and develop the following:

- The branch pipe.
- The hole in the main pipe.

Scale 1:1

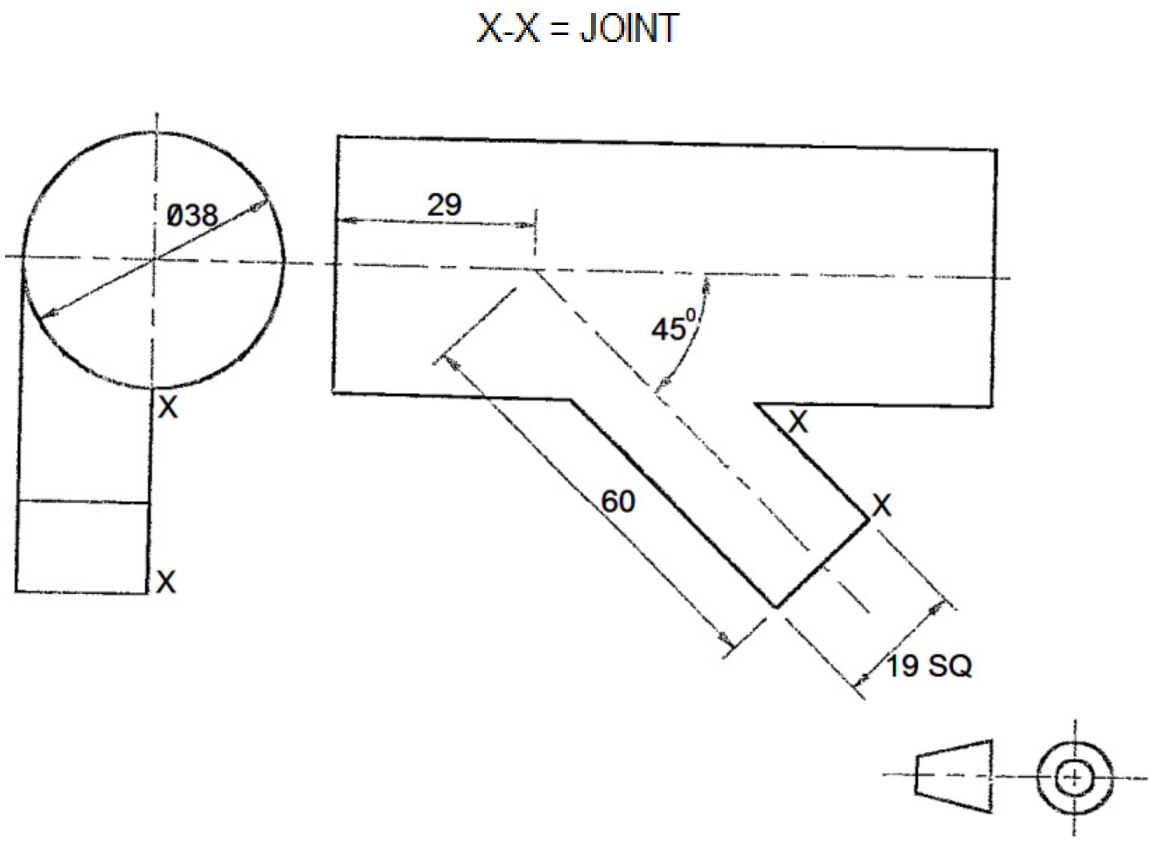



Figure 8.18 A front view and a right view of an oblique T –piece

Solution:

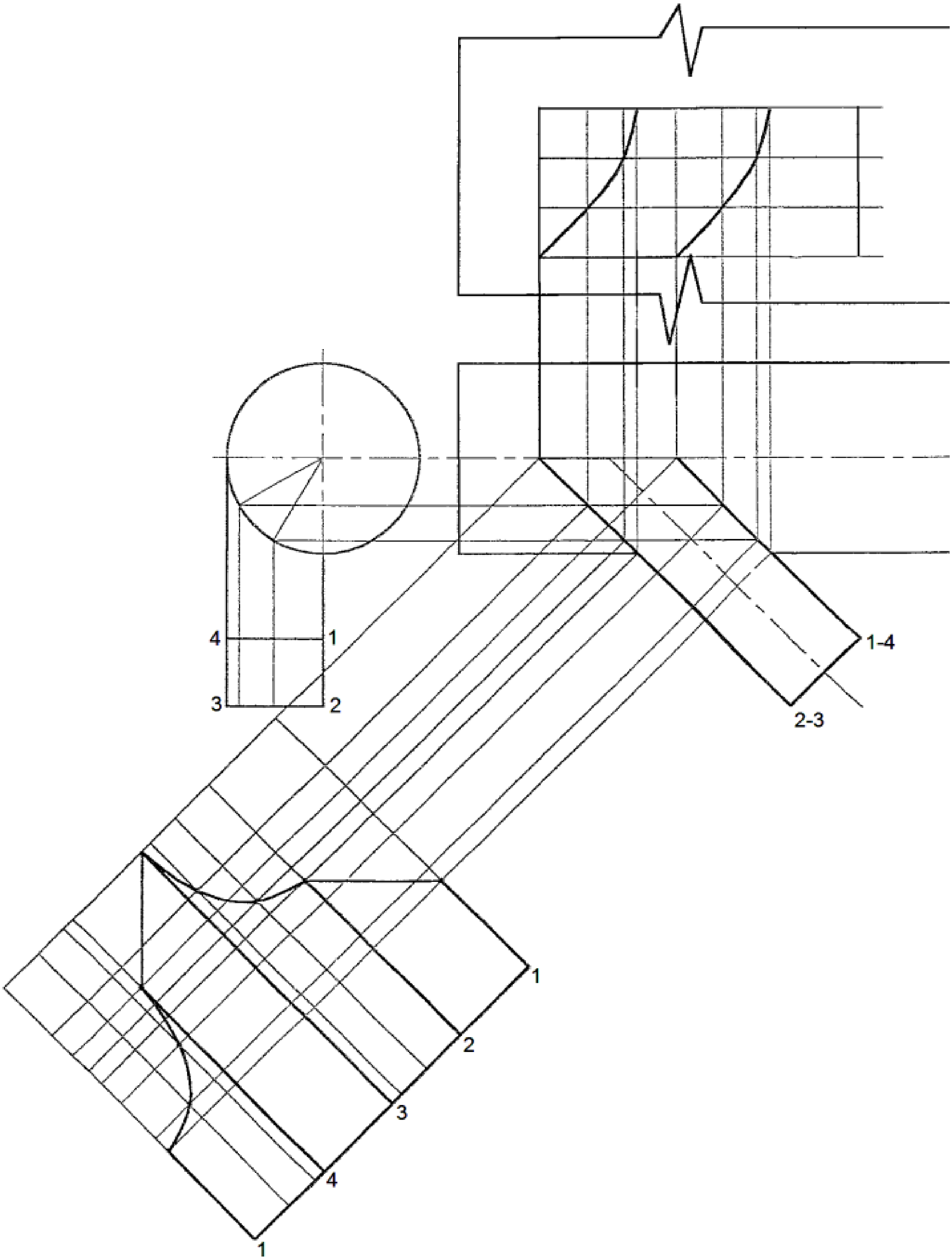



Figure 8.19 Solution

## Activity 8.1

Draw the following cutting planes as seen in top view (**Figure 8.20**).

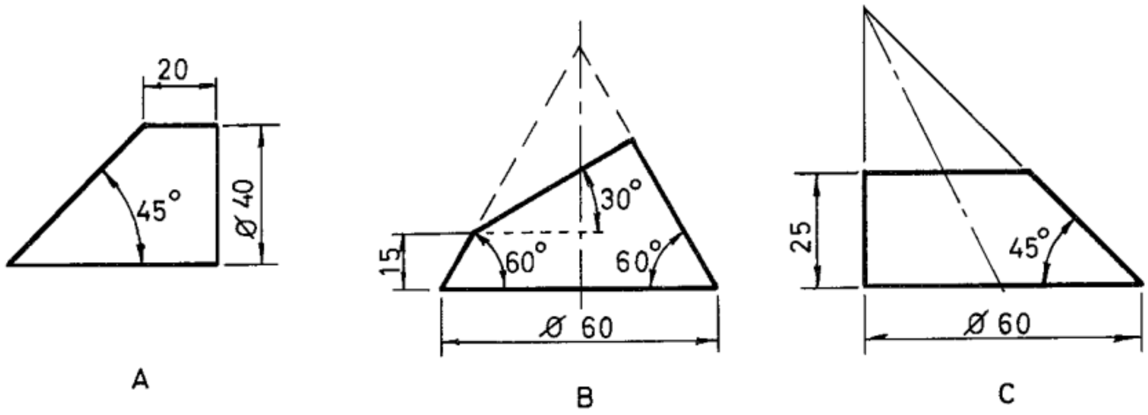



Figure 8.20 Cutting planes

## Activity 8.2

Determine the lines of interpenetration of the following as seen in **Figure 8.21**.

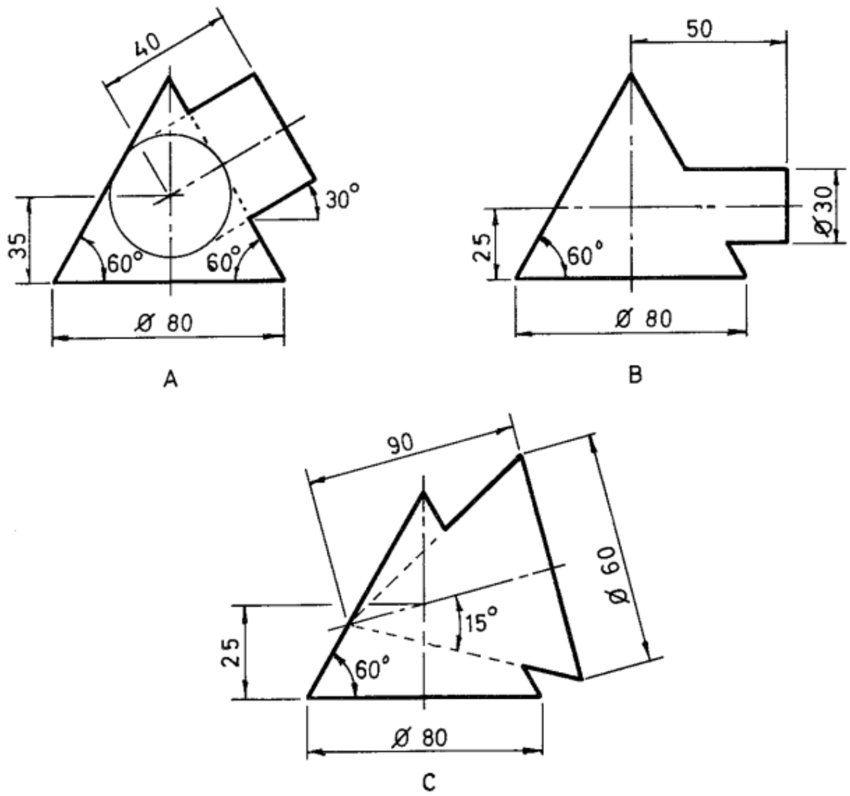



Figure 8.21

## Activity 8.3

Develop the cone and the pipe in development *'B', Activity 8.2*.

**Self-Check**

| **I am able to:** | **Yes** | **No** |
|---|---|---|
| • Define the cutting plane and central ball theorem | | |
| • Describe the following development of pipes to cones: | | |
| o Horizontal pipe cutting plane method | | |
| o Horizontal pipe (basic central ball theorem) | | |
| o Horizontal pipe (advanced central ball theorem) | | |
| o Pipe at an angle (cutting plane method) | | |
| o Pipe at an angle (cutting plane method, alternative) | | |
| • Describe the following development of cones to cones (cutting planes): | | |
| o Pipe off centre (cutting plane method) | | |
| • Describe the following development of cones to pipes: | | |
| • Pipe at an angle (central ball theorem) | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 9

# Advanced Penetrations

**Learning Outcomes**
On the completion of this module the student must be able to:

- Explain the development of a cutting plane on square to round
- Describe pipes to square to rounds
- Describe multiple breeches
- Understand the specific consideration for advanced penetrations

## 9.1 Introduction

The purpose of this module is to show that although we talk about advanced penetration, there is nothing new.

It is the same principles that will be used namely the cutting plane method for obtaining the lines of interpenetrations and triangulation for developing.

## 9.2 Cutting plane on square to round

Although we should by now be able to obtain cutting plane projections, it is necessary to note the varying radii projections as found in the square to round development.

As can be seen in the drawing on the following page, in **Figure 9.1,** the radius of the square to round varies from O.B at the top to zero at point A.

Of course, from this it is logical to determine that a cutting plane anywhere on the development will vary between O,B and Zero.

Therefore, it follows that the centre line for these radii lies between O and A (see top view).

It also follows that the radii fall on the area between the bend lines of the radial parts of the development.

The procedure to obtain the cutting plane is thus as follows:

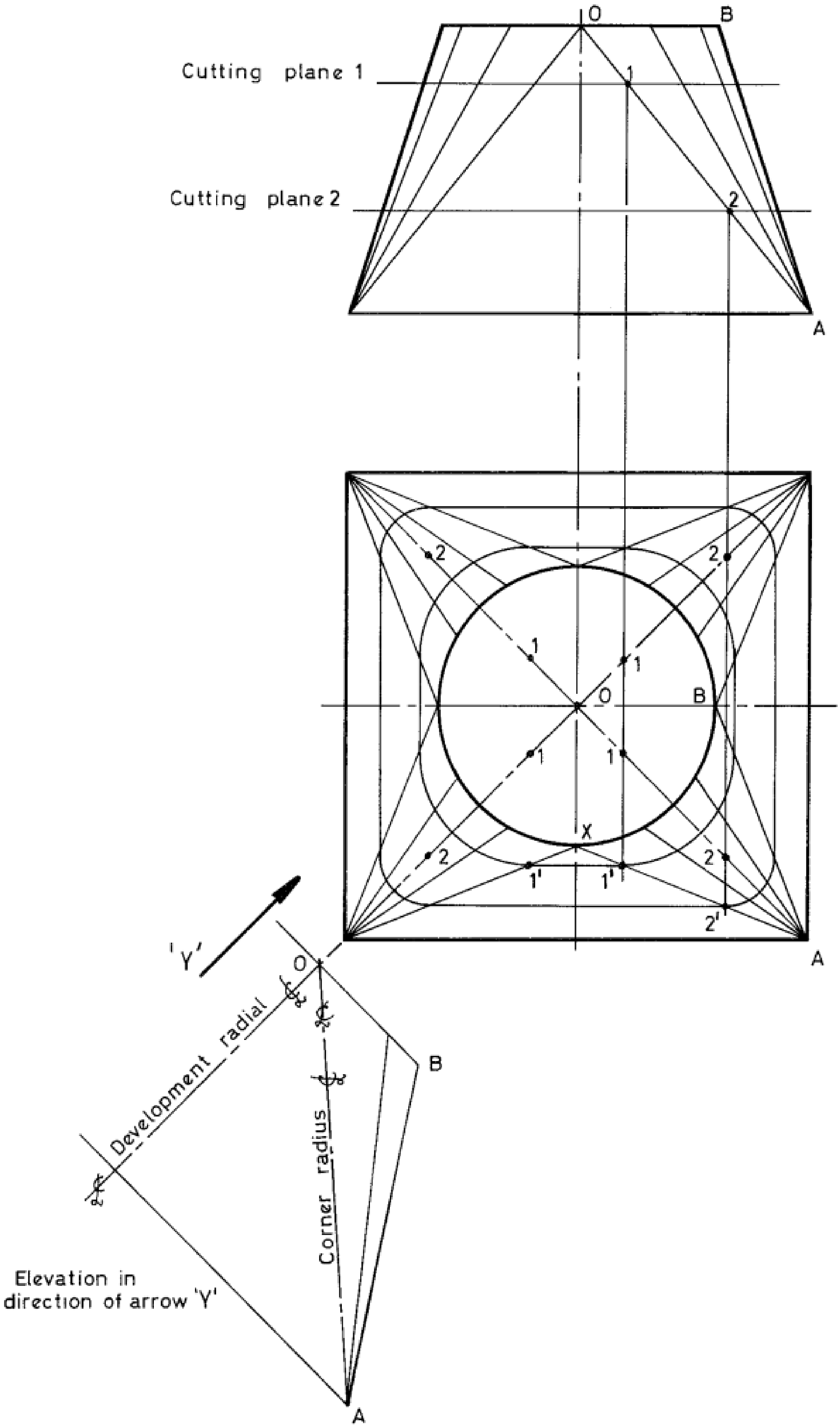



Figure 9.1 Cutting plane on square to round

Where the cutting plane 1 cuts the line A.O. (which in view presents both the centre line of the radii and the bend line where the radius start) we project down to top view to cut line AO in top view and the bend line AX, giving points 1 and $1^1$.

This represents the centre of the radius and the start of the curve i.e. using the centre 1 and radius $1,1^1$, scribe arc between bend lines.

Thus, with all 4 corners then draw tangent lines between these radii to complete the cutting plane.

Similarly we have the cutting plane 2 which will clearly show that the radii reduces as we move nearer point A.

## 9.3 Pipes to square to rounds

By following the standard cutting plane method it will now be seen that this development is done similarly to any other development using the cutting plane method.

It is important to note that in various developments it is necessary to have additional points to enable you to ascertain the exact point of plane or line of interpenetration direction change.

See points X and Y. It will be seen that the area between YOY falls on the flat area of the development as well as the area between the points XX at the bottom of the pipe.

These points are determined on the top view and then projected to the view, as seen in **Figure 9.2**.

> **NOTE:**
> The points X and Y should be taken on the last bend line i.e. where the radius ends and the flat area begins.

By projecting these onto the pipes they in actual fact become new cutting planes that are used to determine the line of interpenetration.

On the following page, **Figure 9.2** illustrates pipes to square to rounds.

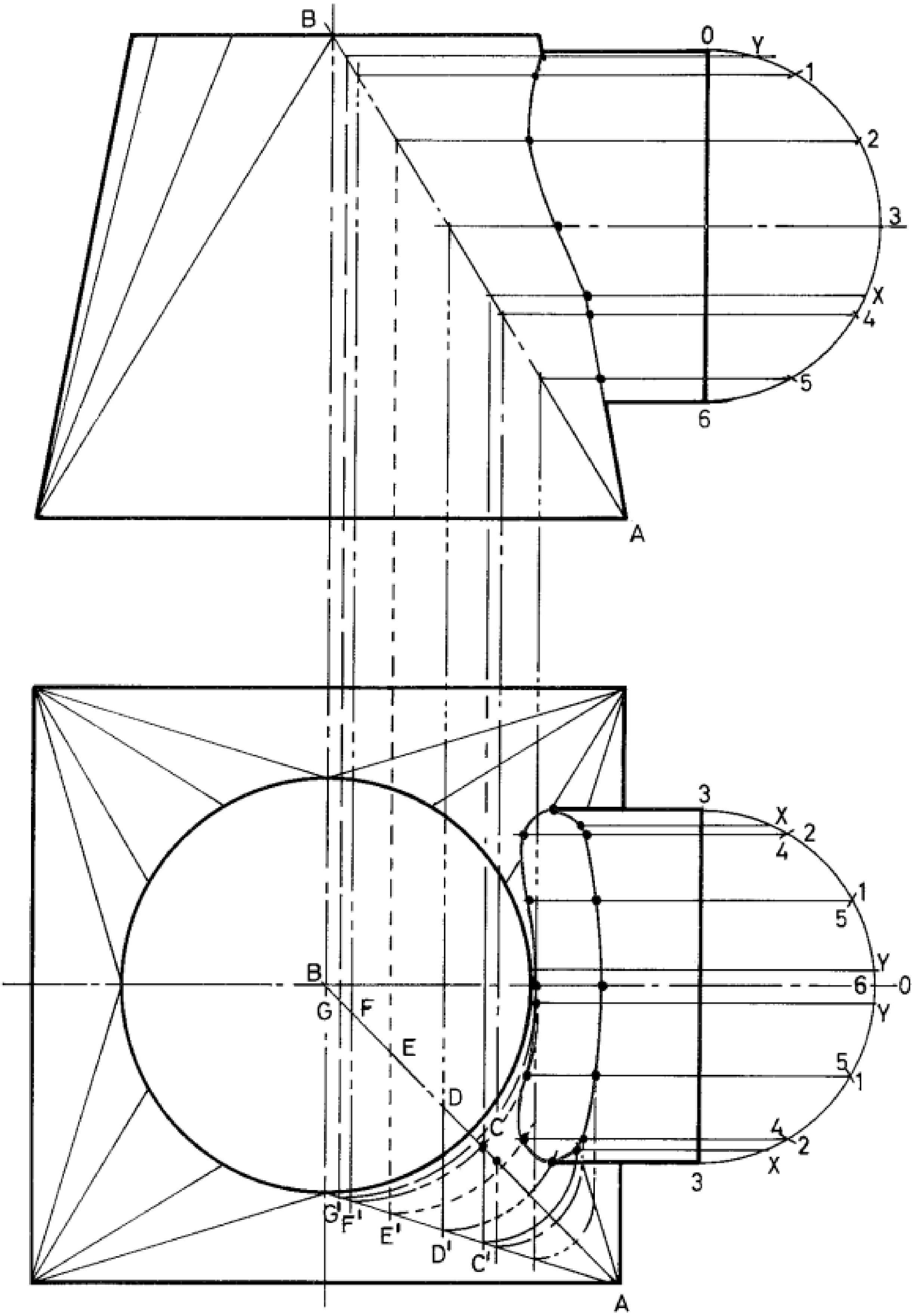



Figure 9.2 Pipes to square to rounds

## 9.4 Multiple breeches

In **Figure 9.3** under consideration we have a three way breech of round to round.

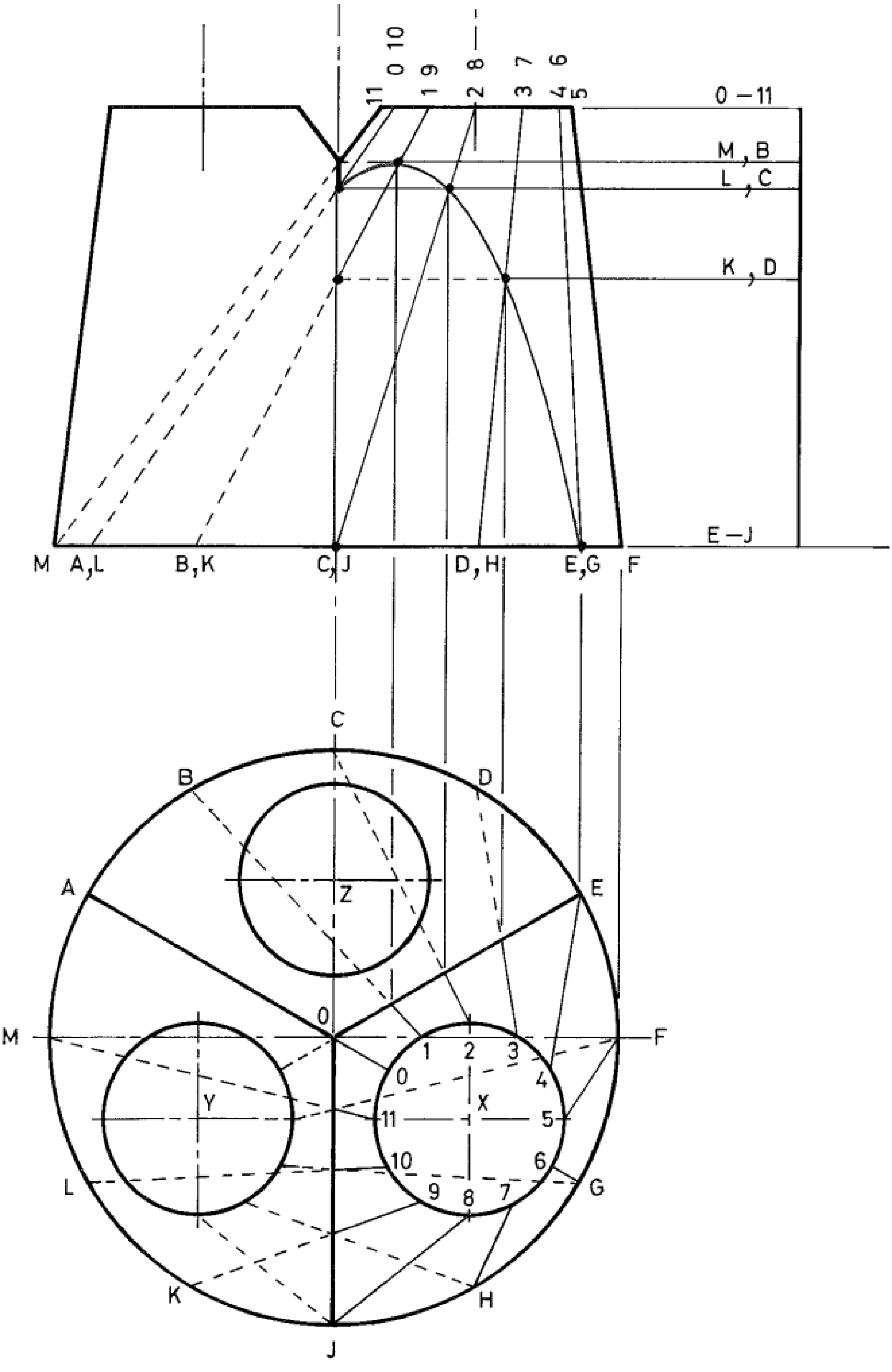



Figure 9.3 Multiple breeches

This development is done on cutting planes, but in this case, as it is possible to have three identical sections,

It is possible to predetermine the sections as shown AO, EO, JO, being the lines of interpenetration (this is usually the case in conical sections in this nature of development).

> **NOTE:**
> The developments can be done with triangulation or as frustrum of an oblique cone, with the radial line method.

## 9.5 Specific consideration

To show the versatility of the basic theorems of development the following design is done in **Figure 9.4** below.

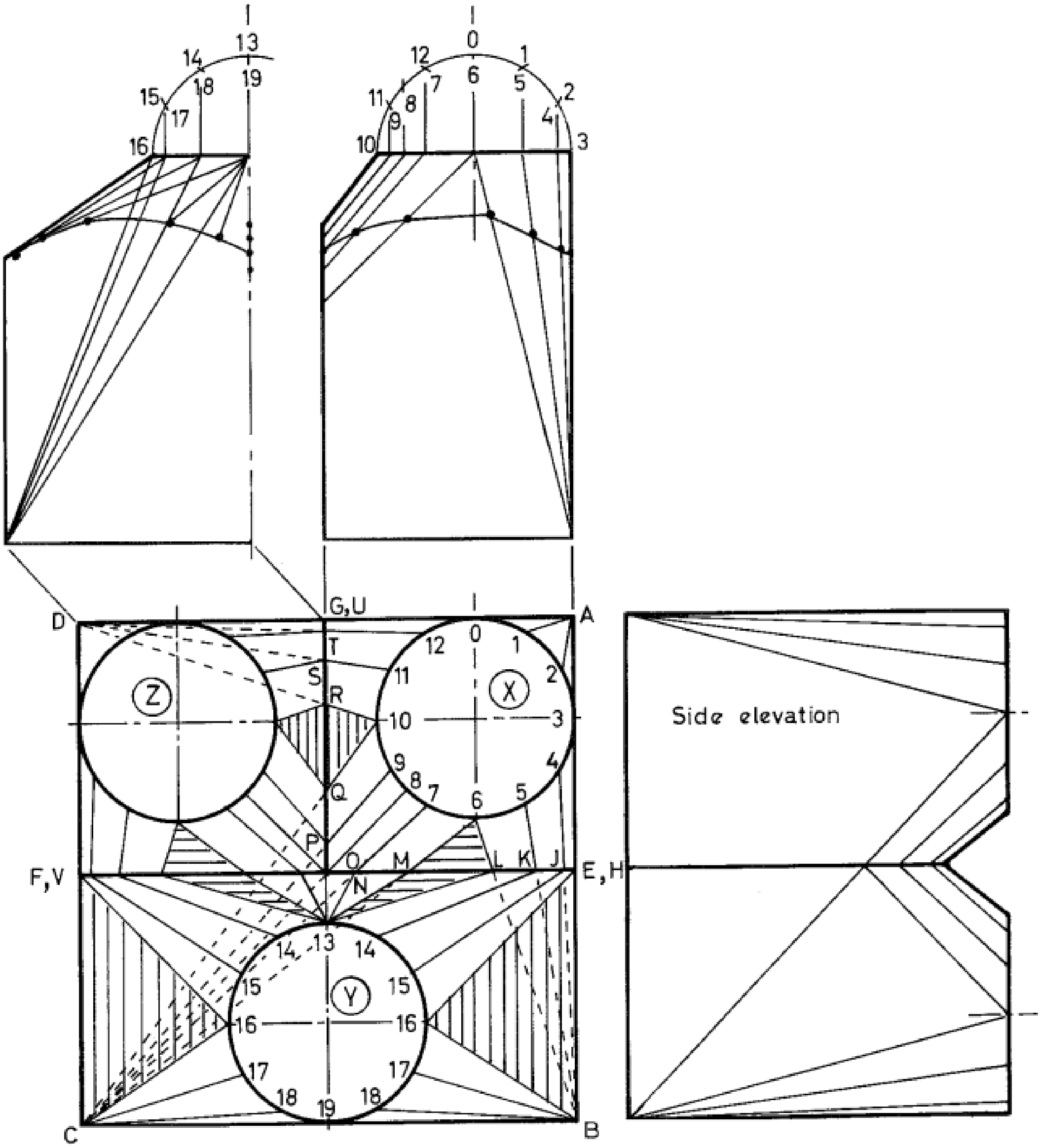



Figure 9.4 Design showing side elevation

The aim is a dividing transition piece from a square feed to round outlets, with one outlet drawing half the feed and the other two dividing the remainder.

**Points to note:**

a) Opening Z and X were' taken as two square to rounds with the square base ABCD interpenetrating symmetrically along the centre line GO.

b) Then the half of the top view section below FV, EH was cut away and replaced by a special development of a square to round nature to suit the cut away part.

Below, **Figures 9.5** and **9.6,** on the following page, are extensions of **Figure 9.4.** These figures illustrate in detail specific considerations involved in the basic theorems of development.

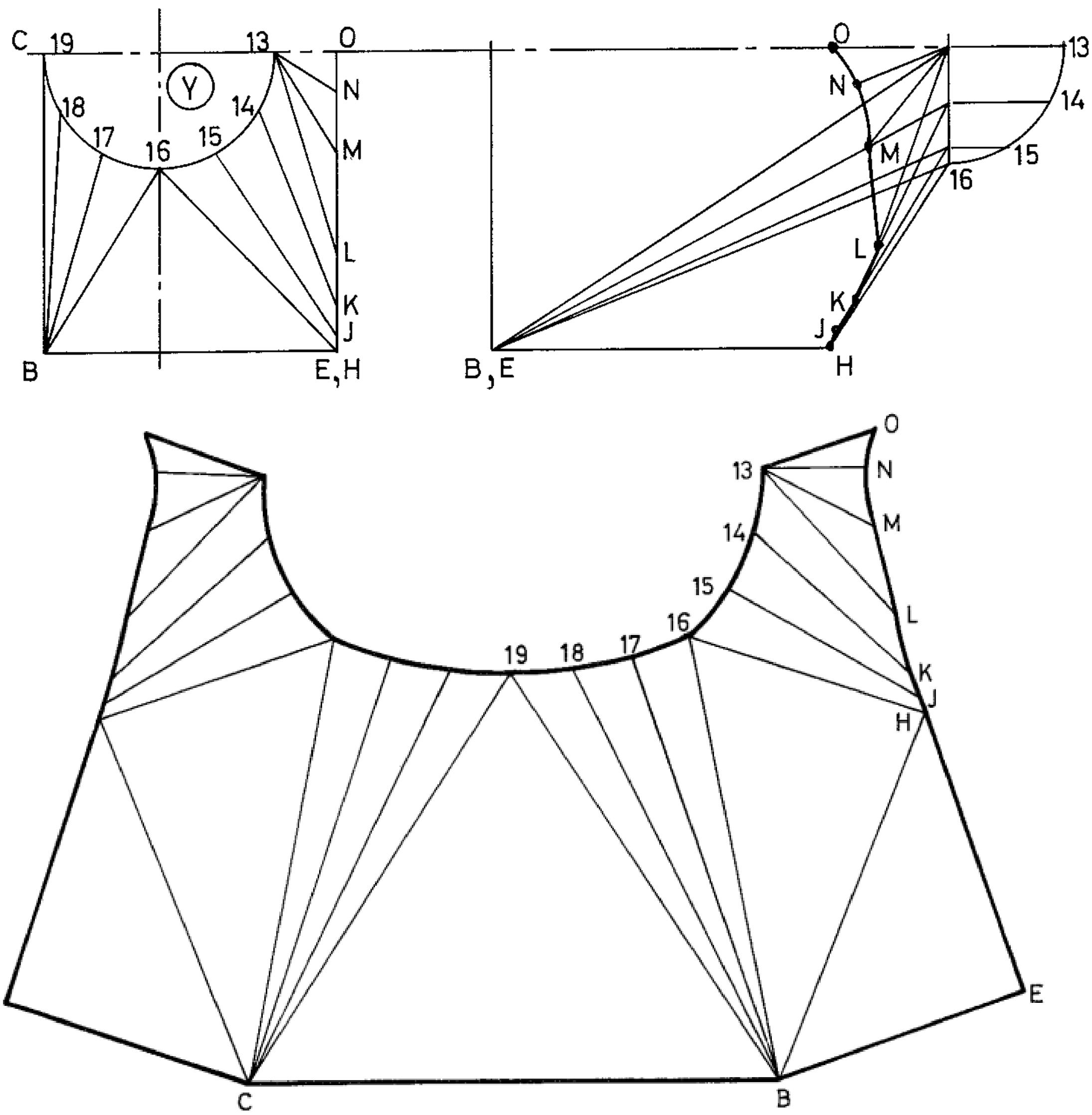
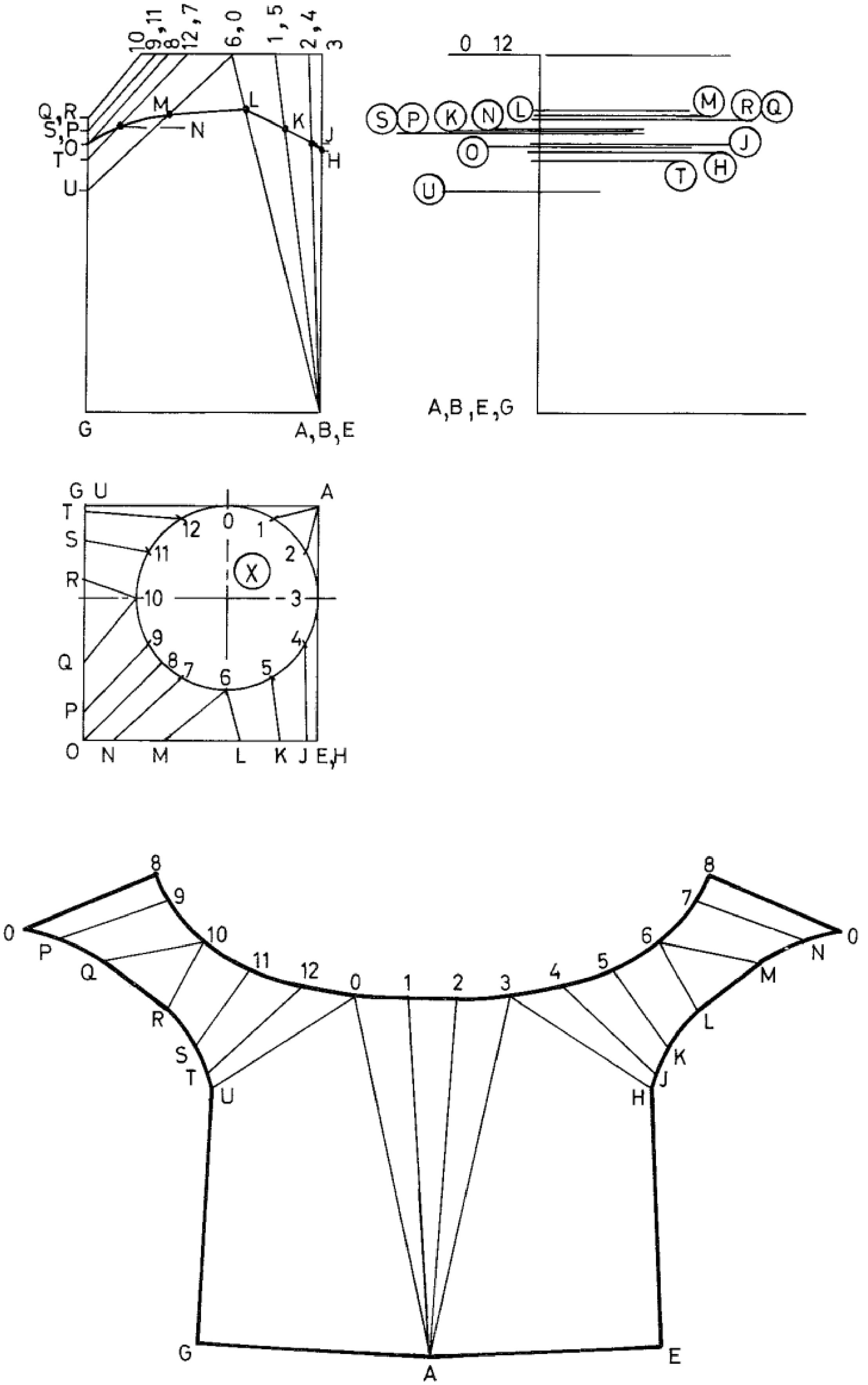



Figure 9.5


10
9,11
8
12,7
6,0
1,5
2,4
3
Q,R
S,P
O
T
U
M
N
L
K
J
H
G
A,B,E
0 12
S P K N L
M R Q
O
J
T H
U
A,B,E,G
G U
A
T
S
R
Q
P
O N M L K J E,H
0 1 2 3 4 5 6 7 8 9 10 11 12
X
8
9
10
11
12
0 1 2 3 4 5 6 7
8
0
P
Q
R
S
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U
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A
E

Figure 9.6

## Activity 9.1

Draw the following cutting plane as seen in top view (**Figure 9.7**).

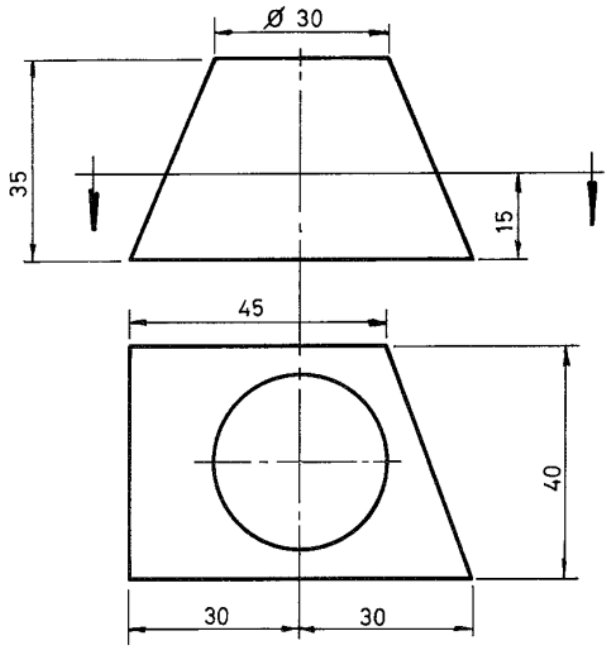



Figure 9.7 Cutting plane

## Activity 9.2

Develop the following drawing, see **Figure 9.8**.

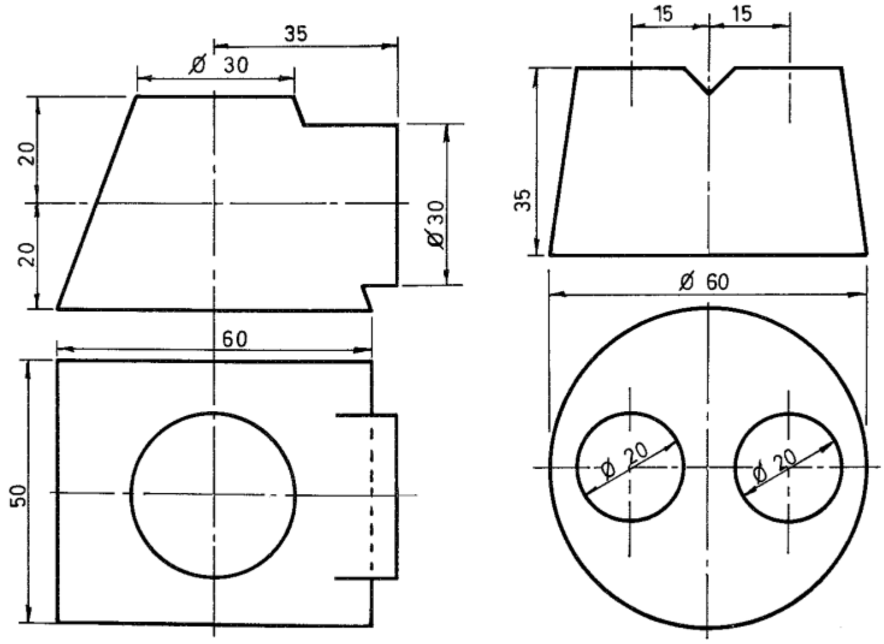



Figure 9.8

**Self-Check**

| **I am able to:** | **Yes** | **No** |
| --- | --- | --- |
| • Explain the development of a cutting plane on square to round | | |
| • Describe pipes to square to rounds | | |
| • Describe multiple breeches | | |
| • Understand the specific consideration for advanced penetrations | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 10

# Double Projection on Pipes

**Learning Outcomes**
On the completion of this module the student must be able to:

- Describe the general procedure when given:
  - The front view and top view
  - The front and side view

## 10.1 Introduction

If there is a difficult section in development, the double projections can be said to be it, as a tremendous difficulty exists to do any problem where double projections are required.

**NOTE:**

Although the above statement is valid, it must be made clear that it is not the development that is difficult, as they are usually simple straight line pipe developments.

The problem arises where our drawing knowledge on projections fails us, and we fail to "see" what is required.

It must also be noted that here it is of the utmost importance to know the principles in projections and to be able to "turn" a view to present a single plane.

The problems arise at the design and Draughting stage as drawings are made in accordance to the orthographic principles and the draughtsman rarely goes to the trouble of placing the views on the drawing to help the artisan.

This brings about that many simple problems of developments involve a difficult set of projections.

As the draughtsman does not usually go to the trouble to obtain the true lines of interpenetration it is necessary to "turn" the drawing to obtain these.

**Figure 10.1** shows a pipe elbow leaning towards you, as can be seen from the top view. To be able to develop the patterns for this pipe, it will be necessary in this case to turn the drawing as shown in **Figure 10.2**.

**NOTE:**
From the front view in **Figure 10.1** it is also interesting to note that the angle is not seen true, and will not be the actual development angle as in **Figure 10.2**, as it is seen as a complex angle

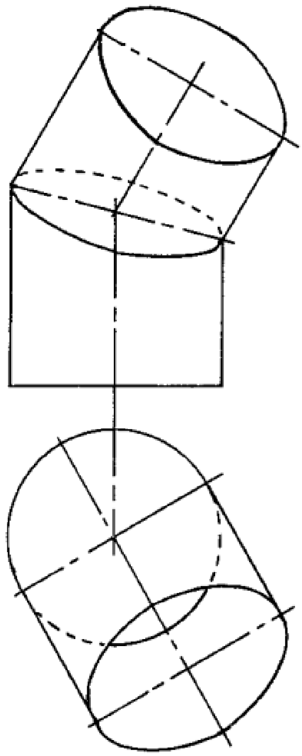


Figure 10.1 Pipe elbow

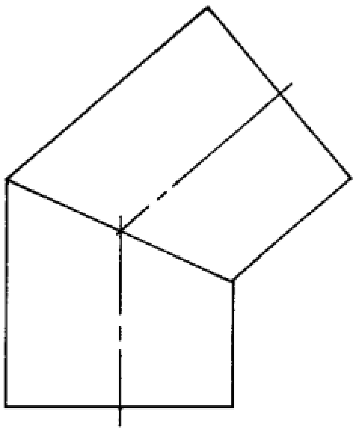


Figure 10.2 Actual development angle

## 10.2 General Procedure

1. Draw front view and top view centre line construction only with dimensional points.
2. Do the first projection from these centre line views.
3. Complete this first projection by adding the pipe dimensions.
4. Divide and number the first projection.
5. Project bend lines up to the top view and then to the front view.
6. To draw the line of interpenetration in the front view take the lengths of the bend lines in the first projection and measure off on the like numbered lines in front view.
7. Do the pattern development from the first projection as this is the true "Flat" view.

**Note:**
For practical pattern development it is not necessary to, and is in-actual fact much simplified, if the pipe is not drawn completely in the views as this tends to lead to confusion in the numbering of the bend line and of line of interpenetration.

## 10.3 Given front view and top view

In this exercise it will *be* found that we only need one projection as shown, see **Figure 10.3,** and the following procedure is followed:

Draw front view centre line construction ABC and the top view centre line construction $B^1$ $C^1$.

Then project points $A^1$ $B^1$ and $C^1$ out normal to centre line $A^1$ $B^1$ $C^1$.

Mark line $A^{11}$ $B^{11}$ to dimension AB given in view. From point $B^{11}$ normal to line $A^{11}$ $B^{11}$ project a line to cut projection line from $C^{11}$ at $X^{11}$ and from $X^{11}$ along projection line; mark the rise C.X of the elbow taken from front view and mark $C^{11}$.

Now connect centre points $A^{11}$ $B^{11}$ $C^{11}$ this will be the true centre line construction. The first projection is now completed by marking in the pipe diameter, divide and number.

The pattern development can now be done from this. If it is required to obtain the line of interpenetration and complete the front view of the top view, the General procedure as shown in *section 10.2* should be followed.

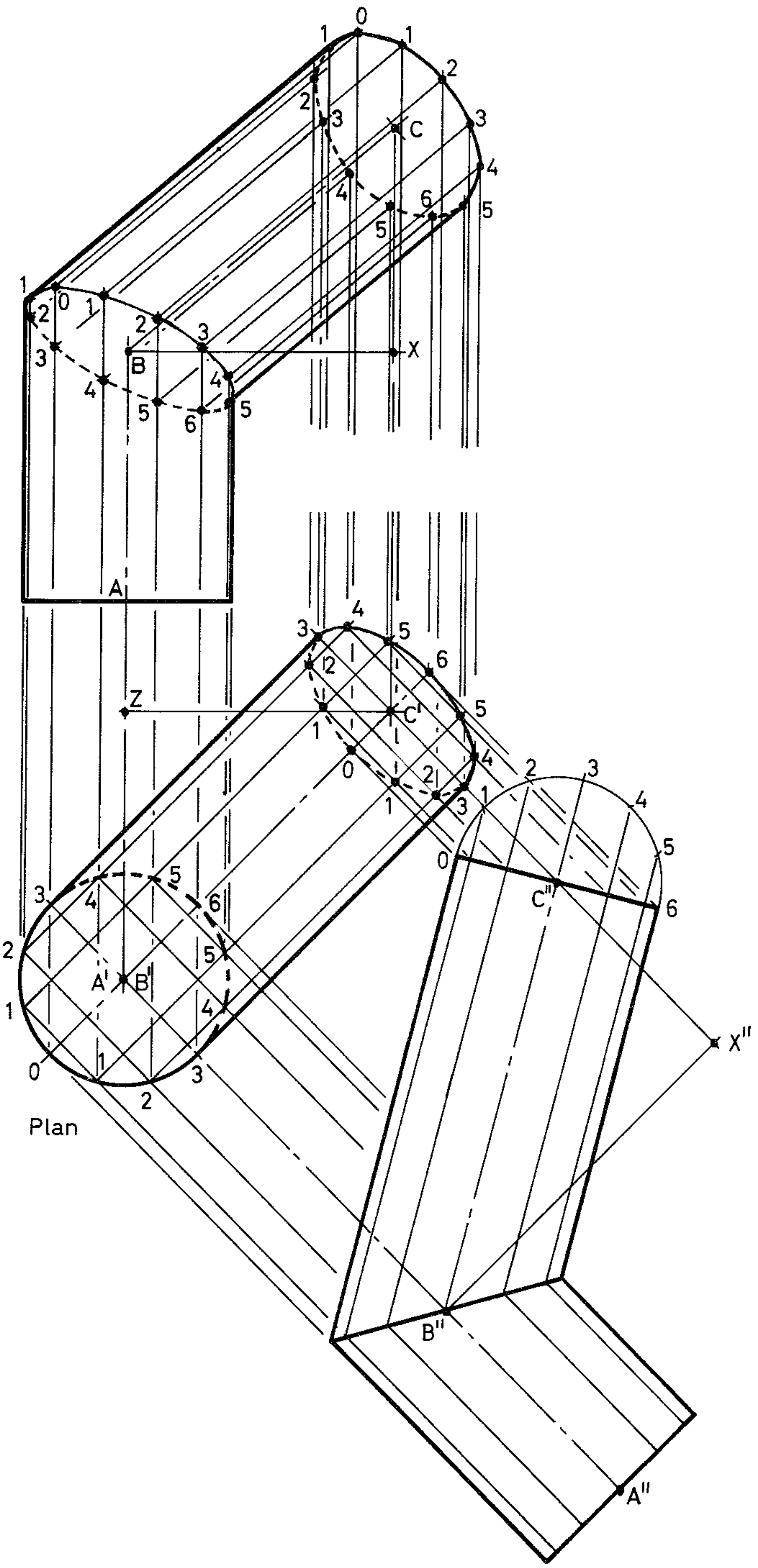



Figure 10.3 Front view and top view

## 10.4 Given front and side view

In this exercise we once again start by drawing the centre line construction for the front and side view, then we have to first complete the top view by projecting from the two views.

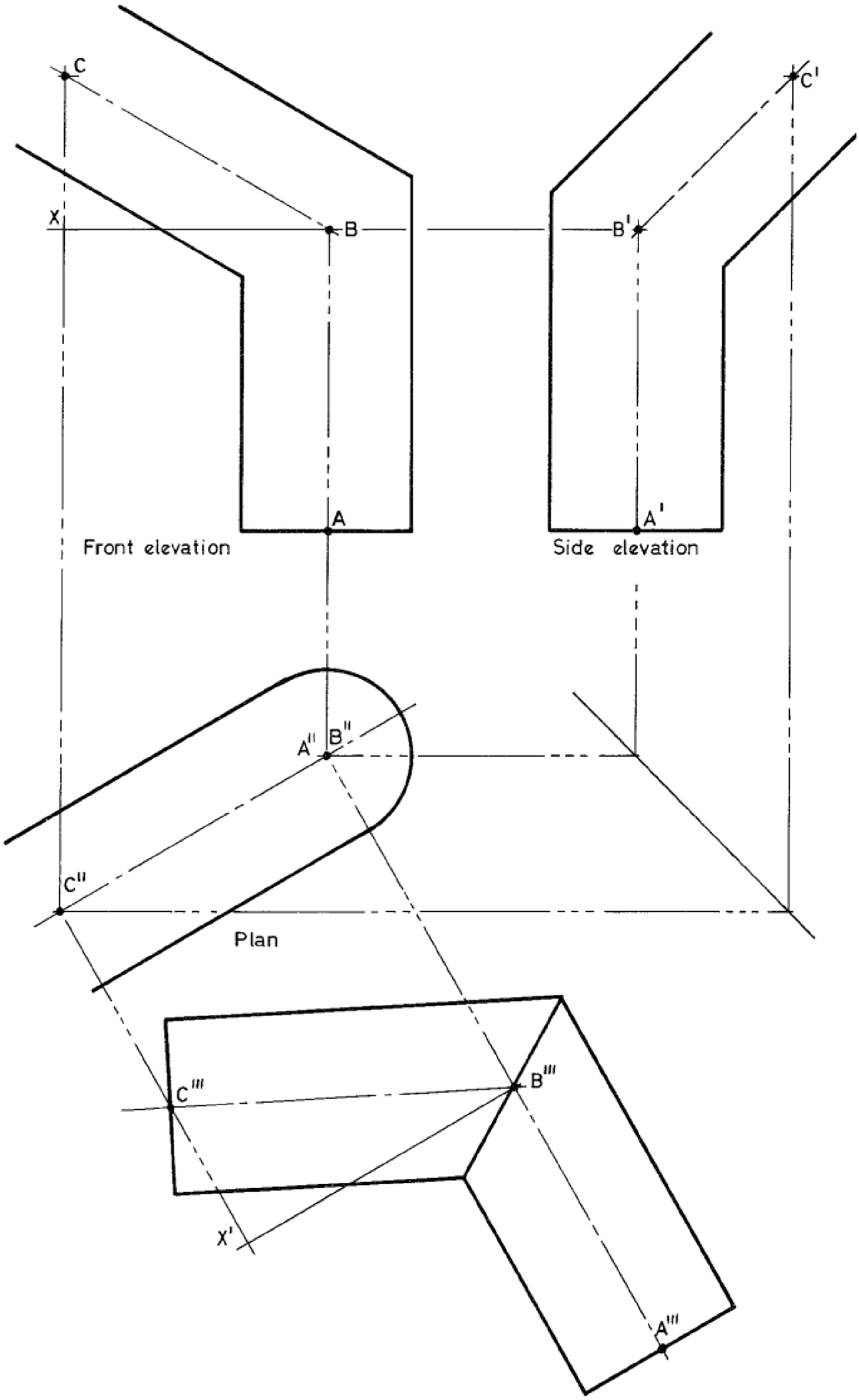



Figure 10.4 First projection

The true "flat" projection can now be done from the top view by projections as in *section 10.3*.

**Note:**
In this case we have not completed the front and side view and the top view as we are only interested in developing the pattern and this is done from the first projection, as seen in **Figure 10.4** above.

## Activity 10.1

Draw the views as shown in **Figure 10.5-6** and project the second (Flat) projection from which you could develop the elbow. Show the true line of interpenetration on all the views.

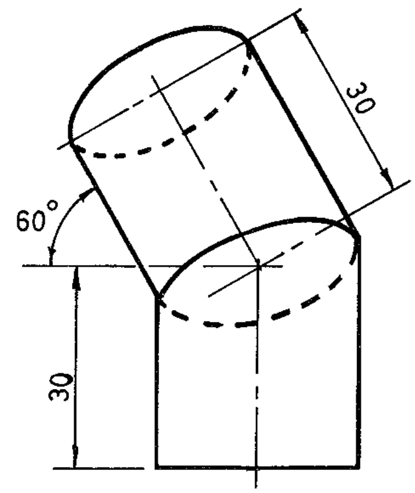



Figure 10.5

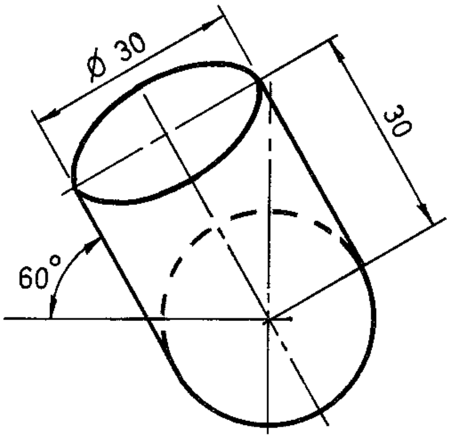



Figure 10.6

## Activity 10.2

Complete all the views required to develop the pipe to pipe interpenetration and show the lines of interpenetration, see **Figure 10.7**.

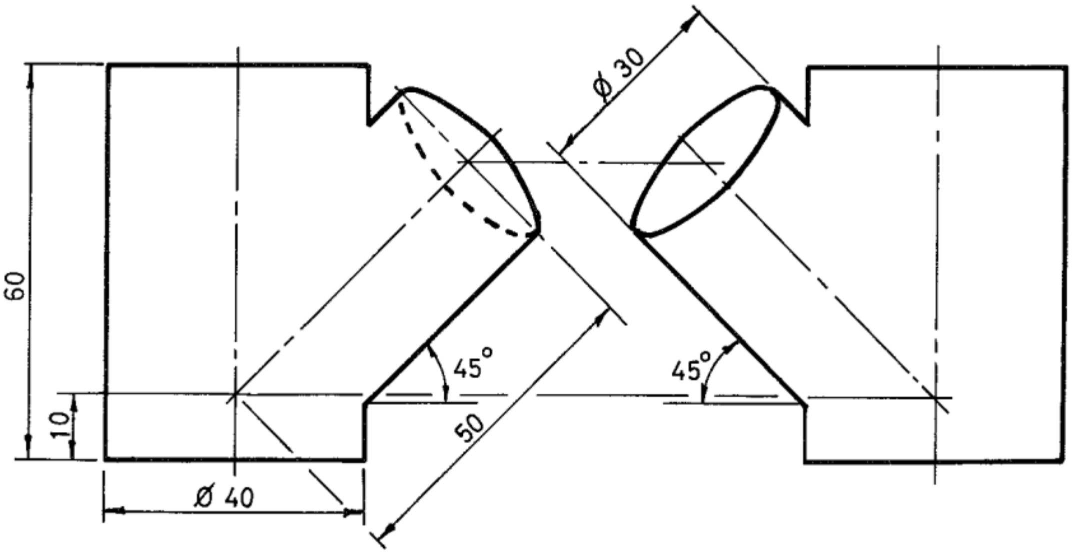



Figure 10.7 Pipe to pipe

### Self-Check

| I am able to: | Yes | No |
|---|---|---|
| • Describe the general procedure when given: | | |
| o The front view and top view | | |
| o The front and side view | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 11

# Calculations

| **Learning Outcomes** |
|---|
| On the completion of this module the student must be able to: |
| • Calculate the following: |
| o Standard calculations |
| o Right Cone calculation (with apex) |
| o Right Cone frustrum calculation |
| o Right Cone Calculations with Smoleys tables |
| o Right Cone frustum calculations with Smoleys tables |
| o Square to Round Calculation (Triangulation) |

## 11.1 Introduction

## 11.2 Calculations

### 11.2.1 Calculation Standards

The following are some standards that are necessary to know:

(a) Circumference: $\pi \times$ Diameter

Or

$2 \times \pi \times$ Radius

(b) Pythagoras theorem:
See **Figure 11.1**

$a^2 + b^2 = c^2$

$c^2 - b^2 = a^2$

$c^2 - a^2 = b^2$

**Note:**
Note this theorem applies to right angle triangles only.

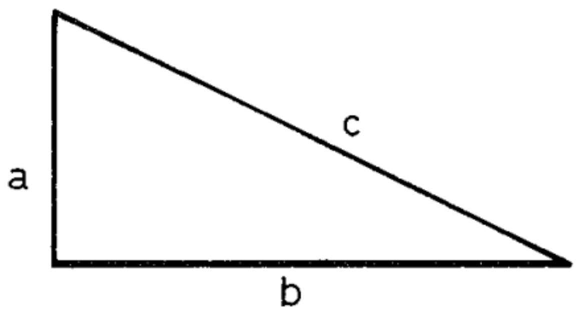



Figure 11.1 Right-angled triangle

(c) Trigonometric ratios
See **Figure 11.2**

$$\sin = \frac{\text{opposite}}{\text{hypotenuse}} \quad \sin A = \frac{}{c}$$

$$\cos = \frac{\text{adjacent}}{\text{hypotenuse}} \quad \text{Cos}A = \frac{b}{c}$$

(d) Sine Rule
See **Figure 11.2**

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

(e) Cosine Rule
See **Figure 11.2**

$$\cos B = \frac{a^2 + c^2 - b^2}{2ac} \quad \text{or} \quad b^2 = a^2 + c^2 - 2ac\cos B$$

$$\cos C = \frac{a^2 + b^2 - c^2}{2ab} \quad \text{or} \quad c^2 = a^2 + b^2 - 2ab\cos C$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} \quad \text{or} \quad a^3 = b^2 + c^2 - 2bc\cos A$$

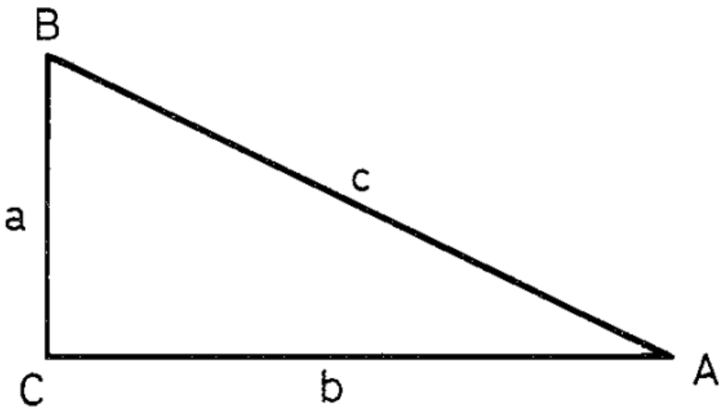



Figure 11.2 Right-angled triangle

(f) Inverse Notation
See **Figure 11.3**

$$\alpha = 2\ [\text{Sine}^{-1}(\frac{C}{2R})]$$

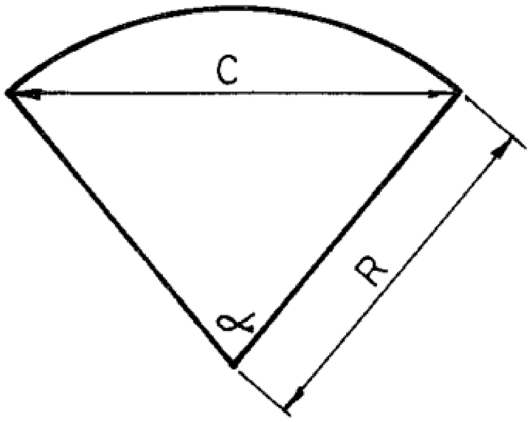



Figure 11.3

(g) Radian measure
See **Figure 11.4**

1. Degrees to radians;
$\text{Angle in degrees} \times \frac{\pi}{180} \times = \text{Radians}$

2. Radians to degrees;
$\text{Radians} \times \frac{180}{\pi} = \text{Angle in degrees}$

3. $A = R \times \alpha$
where $\alpha$ is in *Radians*

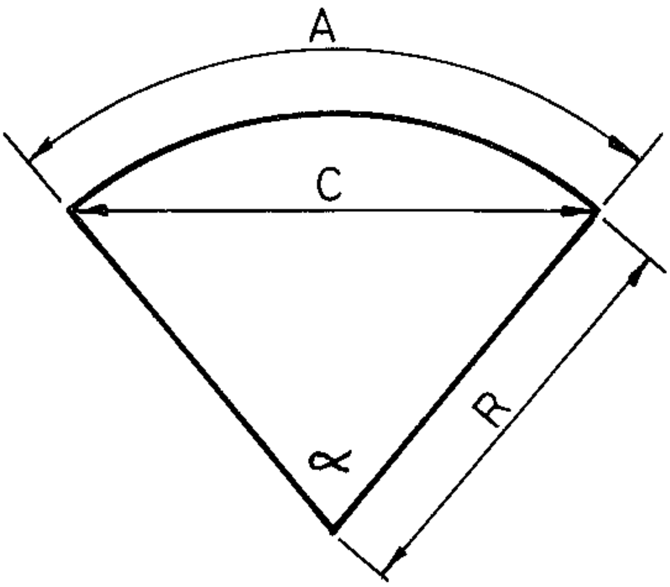



Figure 11.4

(h) Standard 12 Division Constants
See **Figure 11.5**

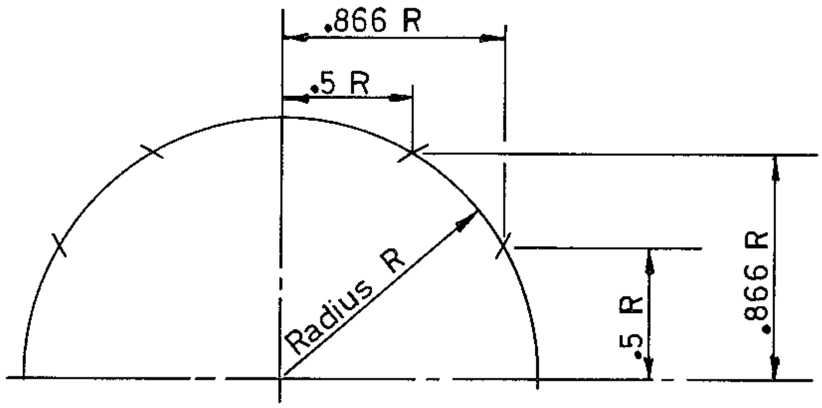



Figure 11.5

(j) To calculate the cord 'C' with Radius 'R' and Angle '$\alpha$' given, see **Figure 11.6**:

i) Make use of the Cosine rule

$$C^2 = 2R^2 - 2R^2 \cos\alpha$$

$$C = \sqrt{2R^2 - 2R^2 \cos\alpha} \rightarrow$$

ii) Make use of the Sine rule; note the sum of the included angles of a tri-angle is equal to 180° and in these cases:

$$\beta_1 = \beta_2$$

$$\frac{C}{\sin\alpha} = \frac{R}{\sin\beta_1}$$

$$C = \frac{R.\sin\alpha}{\sin\beta_1} \rightarrow$$

III (Half the Angle $\alpha$ so that angle $\theta = \frac{1}{2}\alpha$)

$$\sin\frac{1}{2}\alpha = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin\theta = \frac{\frac{1}{2}C}{R}$$

$$C = 2\,(R\ \sin\theta) \rightarrow$$

(k) To calculate the radius 'R,' with cord 'C' and angle '$\alpha$' given:

(i) $R = \frac{C\sin\beta_1}{\sin\alpha}$

See **Figure 11.6**

(ii) $R = \frac{C}{2\sin\frac{1}{2}\alpha}$

or

$R = 2\,\frac{C}{\sin\theta}$

(l) To calculate the angle '$\alpha$,' with chord 'C' and radius 'R' given, see **Figure 11.6**:

$\alpha = 2\ \sin^{-1}(\frac{C}{2R})$

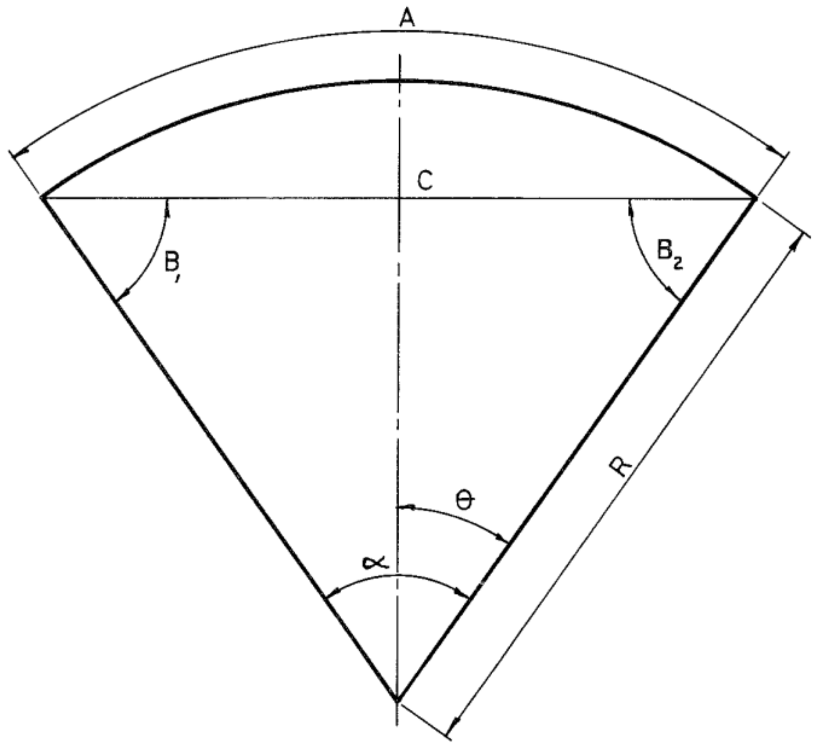



Figure 11.6

(m) To calculate arc 'A,' radius 'R' and angle 'α' with Radial geometry. See **Figure 11.7**

| | |
|---|---|
| ⚠ | **Note:** In Radial geometry the angle 'α' must always be in Radians. |

$\alpha \times \frac{\pi}{180} = x$ Radians and

$\frac{\text{Radians} \times 180}{\pi} = \alpha$ in degrees

i) $A = R\alpha$ where $\alpha$ is in Radians

By manipulation the following is also true:

ii) $R = \frac{A}{\alpha}$ where $\alpha$ is in Radians

iii) $\alpha \text{ Rad} = \frac{A}{R}$

As can be seen from these points ii and iii above.

The radius 'R' can be calculated given the arc 'A' and the angle α (note, that the angle will have to be converted to radians).

As well as the angle 'α' given the arc 'A' and radius 'R' (note, the angle will be in radians and will have to be converted to degrees).

(n) To Calculate the Mid-Ordinate 'M' given the angle 'α' and the radius 'R', see **Figure 11.7**:

$\text{H} + \text{M} = \text{R equation (1)}$
But $\cos\theta = \frac{H}{R}$
$\text{H} = \text{R} \cos\theta \text{ equation (2)}$

Now substitute H in equation (2) with H in equation (1).

$\text{H} = \text{R} \cos\theta + \text{M} = \text{R}$
$\text{M} = \text{R} - \text{R} \cos\theta$

You will also find that given any other two knowns such as 'C' and 'R' or 'A,' the mid-ordinate 'M' can be calculated by using the formulae as given in (j) to (m).

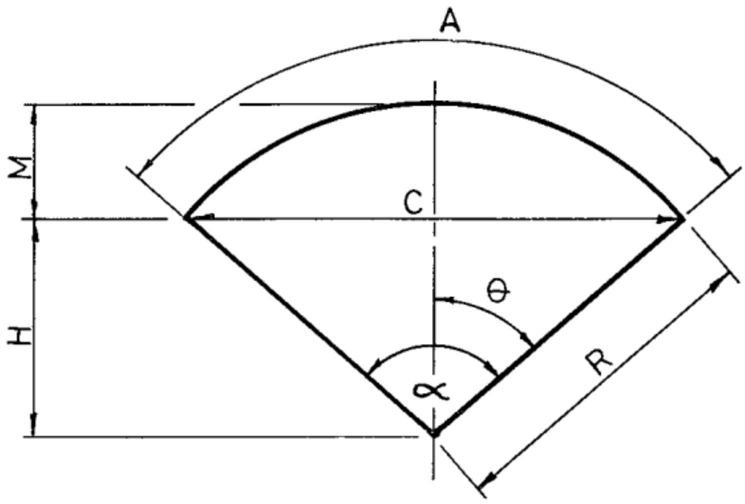



Figure 11.7

(o) Calculating 'R' where the apex of the Cone is not given See **Figure 11.8**:

i) Given a) $r_1$ and $r_2$ and W. With the ratios of equal triangles we find:

$$\frac{R - W}{r_2} = \frac{R}{r_1}$$

$r_1 (R - W) = Rr_2$
$r_1R - r_1 W = Rr_2$
$r_1W = r_1R - r_2R$
$r_1W = R(r_1 - r_2)$

$$R = \frac{r_1W}{r_1 - r_2}$$

$$R = \frac{W}{1 - r_2} \rightarrow$$

ii) Given $r_1$ and $r_2$ and the height H. We have to calculate 'W' as follows:

$W^2 = H^2 + (r^1 - r^2)^2$

$$W = \sqrt{H^2 + (r_1 - r_2)^2} \text{ (Pythagoras)} \rightarrow$$

When 'W' has been calculated the previous formula is used.

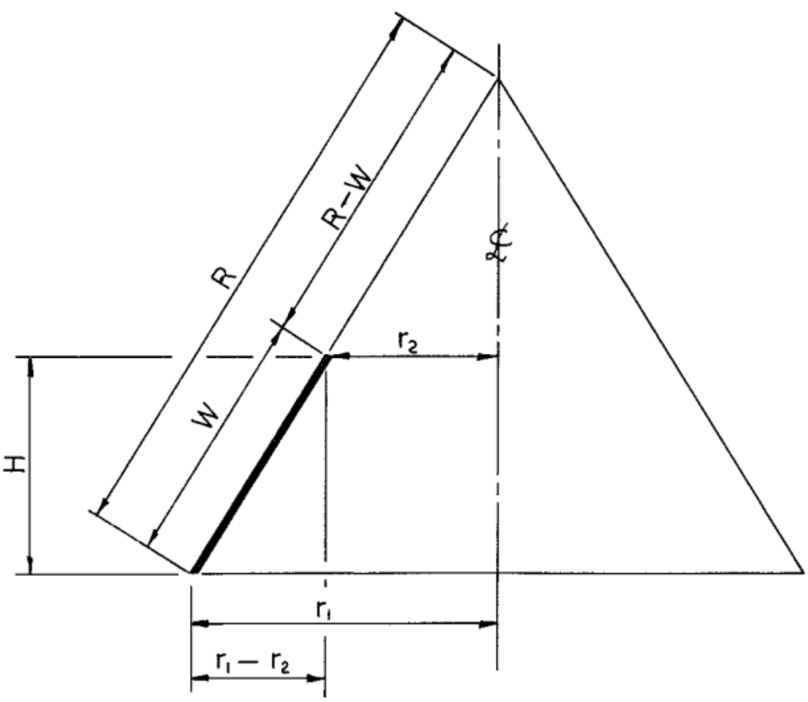



Figure 11.8

## 11.3 Right Cone calculation (with apex)

See **Figure 11.9**.

Given;

a) Vertical height 'H'
b) Diameter 'D' or Radius 'R'

1) Calculate "Development pattern radius 'R' — $R = \sqrt{H^2 + r^2}$ (Pythagoras)

2) Calculate Circumference (Development pattern arc 'A' — $2\pi r$ Or $\pi D$

3) Develop pattern in any number of segments 2,3 ext. by dividing the arc 'A' by the number of segments required.

4) Calculate Development pattern angle 'α' — $\alpha = \frac{A}{R} \times \frac{180}{\pi}$ (*section* 11.2)

5) Calculate the cord length 'C' — $C = \sqrt{2R^2 - 2R^2 \cos \alpha}$ (Cosine rule)

6) Calculate the Mid-ordinate 'M' — $M = R - R \cos \theta$ (where $\theta$ is half $\alpha$)

7) Complete the development pattern by drawing the curve required between the three points obtained as the extremes of the Cord 'C' and the Mid-ordinate 'M'.

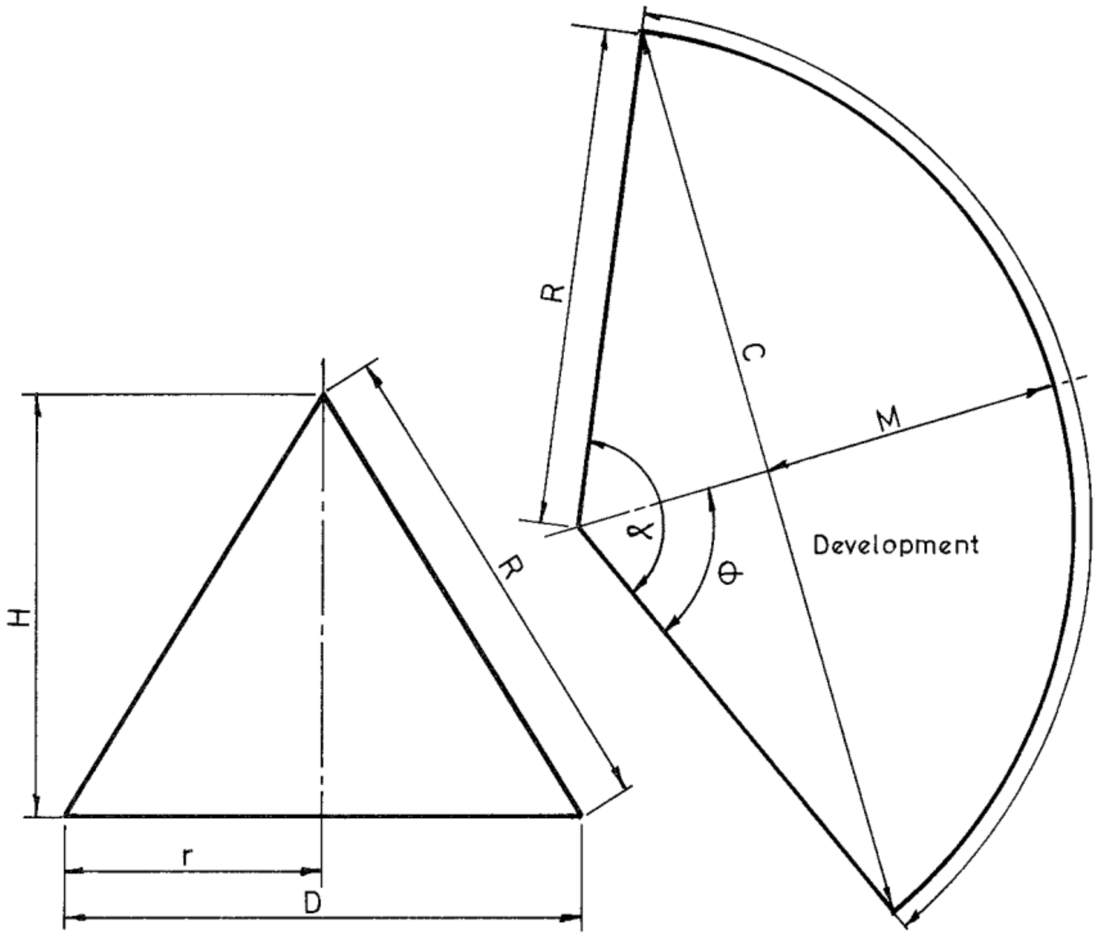



Figure 11.9 Right Cone calculation (with apex)

## 11.4 Right Cone frustrum calculation

See **Figure 11.10.**

Given;

a) Vertical height 'H'
b) Diameters $D_1$, $D_2$ or Radii $r_1$ and $r_2$.

1) Calculate the width of the development pattern 'W'

$$W = \sqrt{H^2} + (r_1 - r_2)^2$$
(Pythagoras)

2) Calculate development pattern outside radius '$R_2$'

$$r_2 = \frac{W}{1 - \frac{r_2}{r_1}}$$
(*section* 11.2)

3) Calculate development pattern inside radius $R_1$

$$R_1 = R_2 - W$$

4) Calculate circumferences (Pattern Arc's $A_1$ and$A_2$)

5) Remembering that you now have to work with 2 Arc's, 2 Cords and 2 Mid-ordinates follow the same procedure as *section 11.3* for both the cords and mid-ordinates.

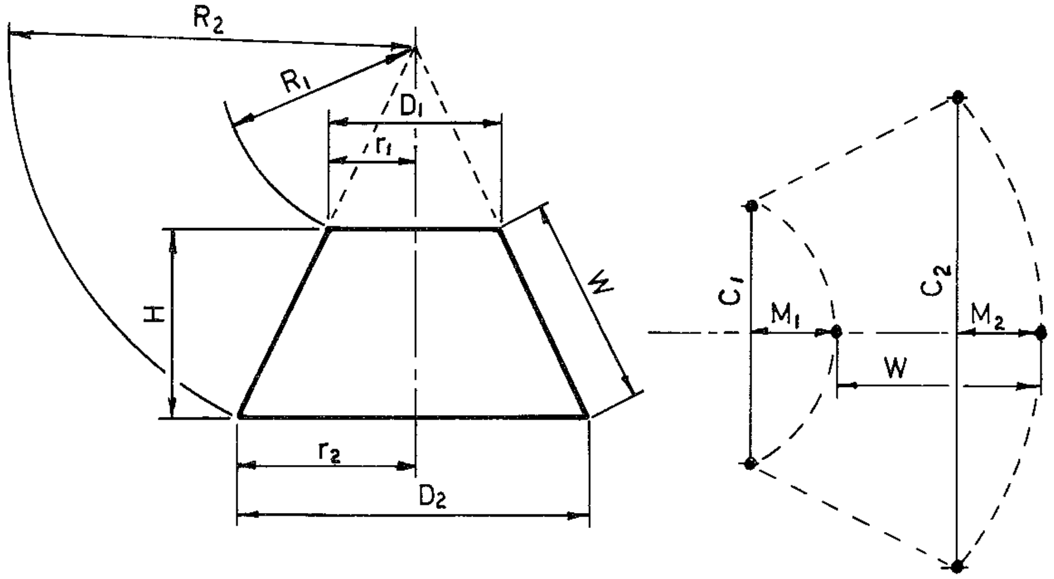



Figure 11.10 Right Cone frustrum

## 11.5 Right Cone Calculations with Smoleys tables

For simplicity and better understanding this example is done with figures (see **Figures 11.11-12**) to enable you to follow the method in the Smoleys tables.

1)

$R^2 = 5^2 + 15^2$
$R^2 = 250$
$\underline{R = 15{,}81}$ log in Smoley's 1.19893 →

2) Circumference:

$= \pi \times D$
$= 3{,}142 \times 10$
$\underline{Arc} = 31{,}42 \rightarrow$

3) Now you have to decide on the number of segments, in this example we use 4 segments.

$Arc \div 4$
$\frac{31{,}42}{4}$
$\underline{Arc = 7{,}86}$
log in Smoley's 0.89542 →

4) With the radius 'R' and the arc "A" we find in the Smoleys tables under "Digest of Solutions" on segments in the Segmental functions preamble the following formula for radius and arc given:

$\log a = \log A - \log R$...... equation a

$\log C = \log A - \log \alpha$..... equation b

$\log M = \log A + \log \sigma - \log R$.. equation c

5)

a) $\log a = \log A - \log R$

$\log a = 0.89542 - 1.19893$ (see points i and ii)

$\underline{= 9.69646 \rightarrow}$

in Segmental functions section under $a = \frac{A}{R}$ in tables we look up 0.69649 and find the angle in the pages as $28° - 29' - 6" \rightarrow$

$\log a = 9.69649$

$\underline{a = 28° - 29' - 6" \rightarrow}$

b) $\log C = \log A - \log\alpha$

$\log C = 0.89542 - 0.00448$ (on the angle $28° - 29' - 6"$ (in the same line as, $a = \frac{A}{R}$ under $\frac{A}{C}$ we find 0.0048)

$\underline{C = 7.7792}$ (find antilog under logs and squares)

c) $\log M = 2 \log A + \log \sigma - \log R$

$\log M = (2 \text{ X } 0.89542) + 9.09467 - 1.19893$ note $\log \sigma$ is found on the angle $28° - 29' - 6"$ in the same line as, $a = \frac{A}{R}$ under, $\sigma\ \frac{r}{a}$

$\log M = 1.68658$

$\underline{M = 0.48593 \rightarrow}$ (find antilog under logs and Squares)

With these answers we complete the layout as in drawing A opposite

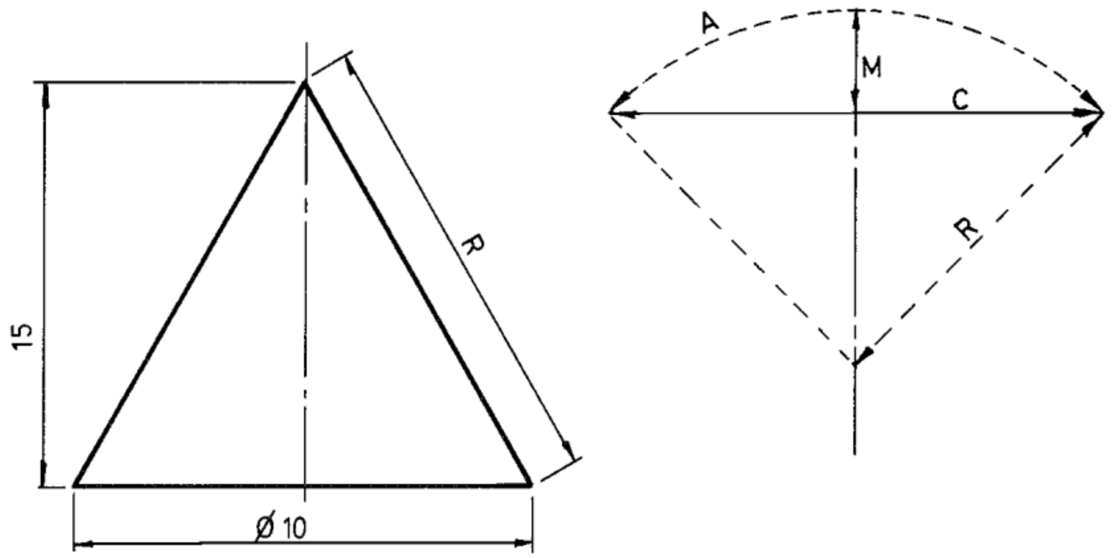



Figure 11.11

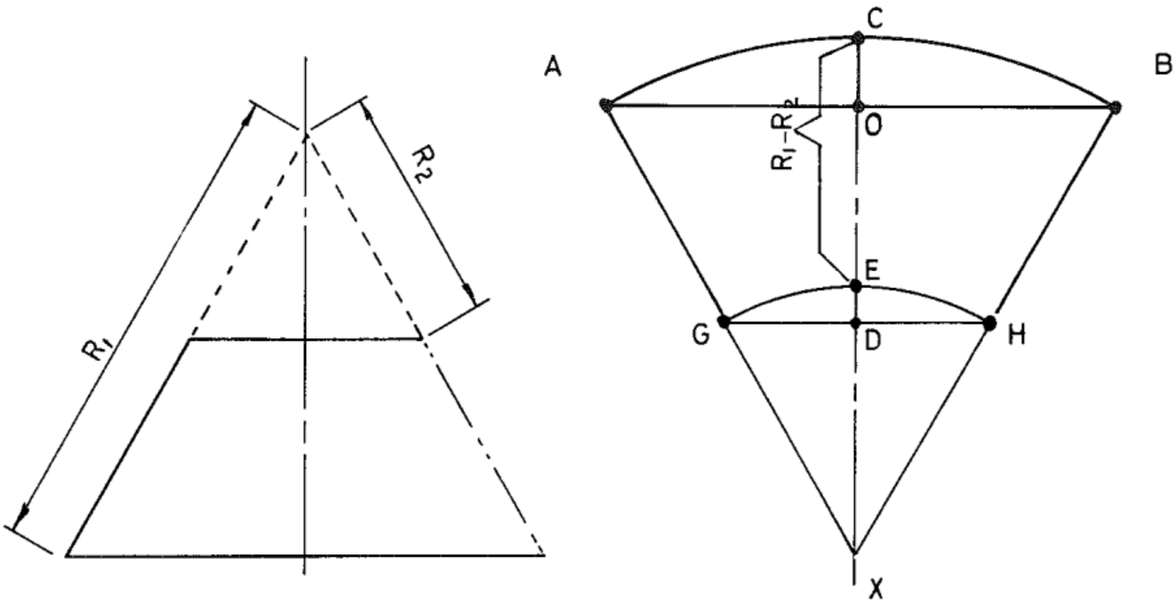



Figure 11.12

## 11.6 Right Cone frustum calculations with Smoleys tables

For calculating the cone frustum we follow the same procedure considering the top cut off as a cone:

i.e. We calculate the bottom diameter, Arc, Cord and Mid-ordinate as one section (see **Figure 11.12**), then the top diameter, Arc Cord and Mid-ordinate (see **Figure 11.11**), and construct as follows:

On centre line OX through 0 place the Cone Bottom Cord AB, from 0 normal to cord AB; add the Mid-ordinate to give point C.

Taking the difference between the two radii $R_1$ and $R_2$, as the width of the cone frustum plate and using centre C scribe to cut centre line OX at E and with E as centre and compass set to the top mid-ordinate dimension.

Scribe to cut centre line OX at D, then through D normal to centre line OX draw a line to represent the top cord and mark G.H.

Connect points G to A and H to B, then draw Arcs G.E.H. and A.C. B.

## 11.7 Square to Round Calculation (Triangulation) Vertical Height = 75 m

The basis of this and similar calculations on triangulation is Pythagoras' Theorem.

As you should know by now, this is the same procedure as used in ordinary triangulation developments except that we now calculate the diagonals, instead of measuring them graphically from our true length diagram as applied in the developments.

i) Calculate circumference of circle and divide by number of divisions. Circumference = $\pi$D. See, **Figure 11.13**

$$\text{Length } 1-2, 2-3, 3-4 \text{ ext} = \frac{\pi D}{12} = \frac{\pi \times 90}{12}$$

$\underline{1-2 = 23{,}5619}$ →

ii) Calculate Ae and Ah (Ae = Ah = f3) See, **Figure 11.13**

$$\begin{aligned} \text{Ae} &= \text{AC} - .5\text{Rad} \\ &= 60 - (.5 \times 45) \\ &= 60 - 22.5 \end{aligned}$$

$\underline{\text{f3, Ae and Ah} = 37.5}$ →

iii) Calculate Af and Ag (Ag = ag = e2) See, **Figure 11.13**

$$\begin{aligned} \text{Af} &= \text{AC} - 0.866\ \text{Rad} \\ &= 60 - (.866 \times 45) \\ &= 60 - 38.97 \end{aligned}$$

$\underline{\text{e2, Af and Ag} = 21.03}$ →

iv) Calculate A1 (A1 = A4) See, **Figure 11.13**

$$\text{A1} = \sqrt{\text{AC}^2 + \text{C1}^2 + \text{H}^2}$$
$$\text{A1} = \sqrt{60^2 + 15^2 + 75^2}$$
$$\text{A1} = \sqrt{9450}$$

$\underline{\text{A1 and A4} = 97.2111}$ →

v) Calculate A2 (A2 = A3)

$$\text{A1} = \sqrt{\text{Ae}^2 + \text{e2}^2 + \text{H}^2}$$

See, **Figure 11.13**

$$A1 = \sqrt{37.5^2 + 21.03^2 + 75^2}$$
$$A1 = \sqrt{7473.5109}$$
$$\underline{A2 \text{ and } A3 = 86.44947} \rightarrow$$

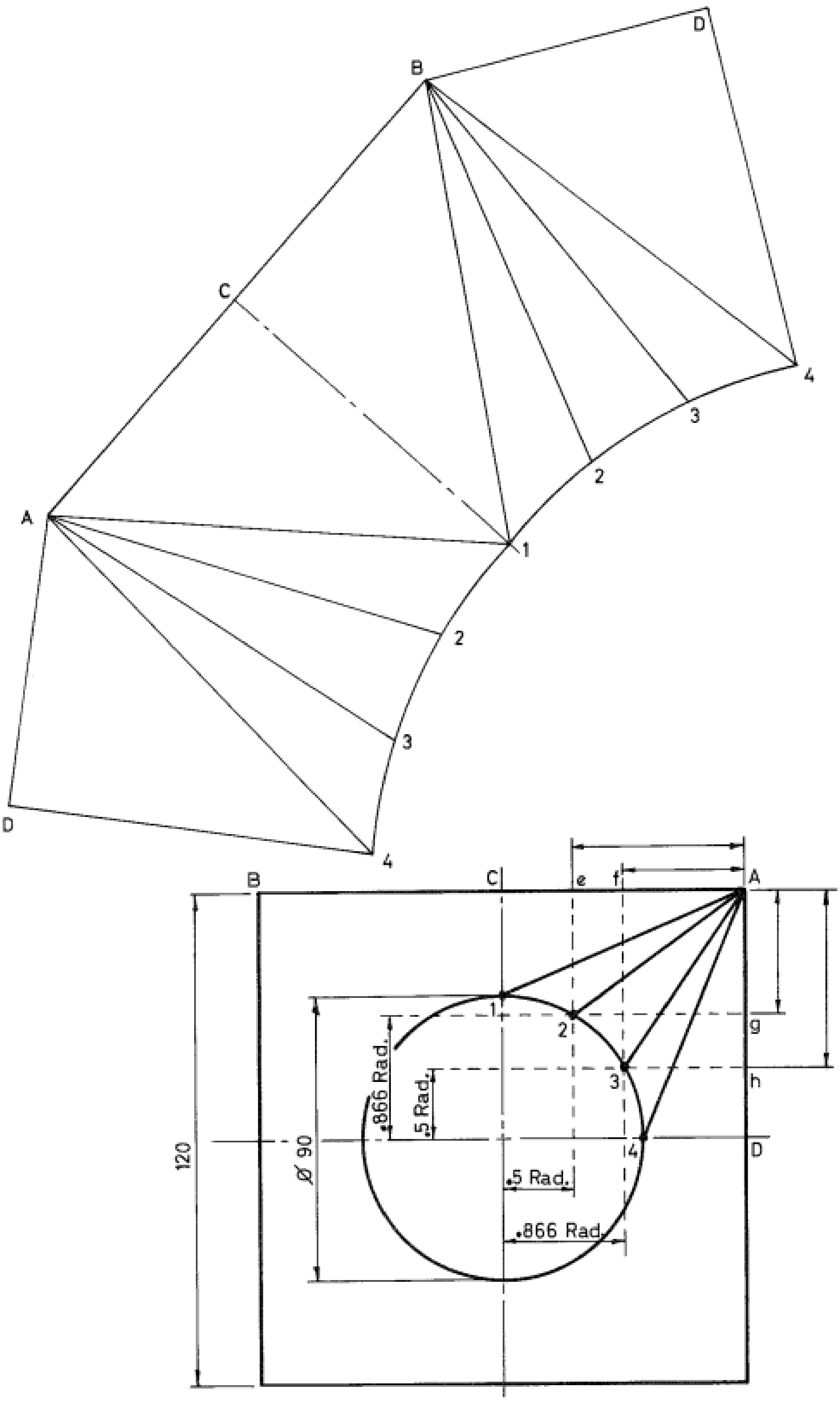



Figure 11.13

## 11.8 Summary

As calculated:

$$A1 \text{ and } A4 = 97.2111 \rightarrow$$
$$A2 \text{ and } A3 = 86.44947 \rightarrow$$
$$1-2, 2-3, 3-4, \text{ext.} = 23{,}5619 \rightarrow$$

True length on Top View:

$$ACB = 120 \rightarrow$$
$$ADB = 120 \rightarrow$$

Using these figures, it is now possible to complete the development pattern by completing triangles similar to the graphical method, as in *section 6.4*.

| **Self-Check** | | |
|---|---|---|
| **I am able to:** | **Yes** | **No** |
| • Calculate the following: | | |
| o Standard calculations | | |
| o Right Cone calculation (with apex) | | |
| o Right Cone frustrum calculation | | |
| o Right Cone Calculations with Smoleys tables | | |
| o Right Cone frustum calculations with Smoleys tables | | |
| o Square to Round Calculation (Triangulation) | | |
| If you have answered ‘no’ to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 12

# Plate Thickness Considerations

**Learning Outcomes**
On the completion of this module the student must be able to:

- Describe quadrant compensation
- Describe cones and hoppers with regard to plate thickness

## 12.1 Introduction

Where you should now be well conversed with the theory of development, as well as the practical layout and pattern development of various methods of development.

We will now consider the last but not the least important aspects of the Art of developments.

In all explanations, we have considered line developments; a line representing plate thickness and considered to be the mean thickness line.

To enable us to practically apply the knowledge obtained by this book the following should be noted:

(a) Always use the mean thickness line when working with plates (Mean line for steel is in the centre of the plate).

(b) When plates and pipes are flame or machine cut (shearing) the cut face of the material will under "usual" conditions be normal to the plane considered.

**Figures 12.1**, **12.2** and **12.3** on the following page, illustrate the cut face and plate thickness considerations.

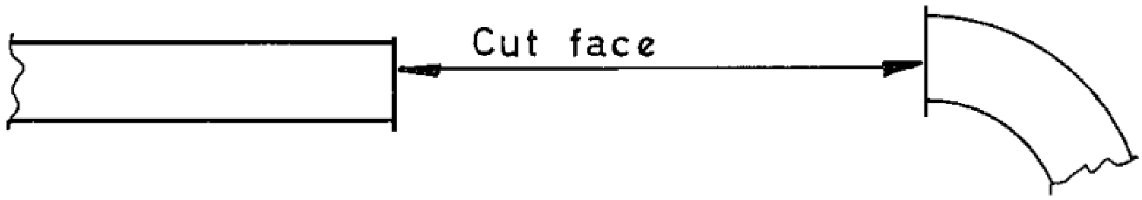



Figure 12.1

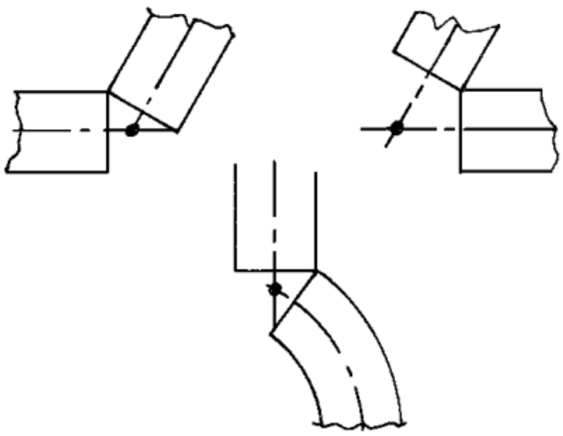


Figure 12.2

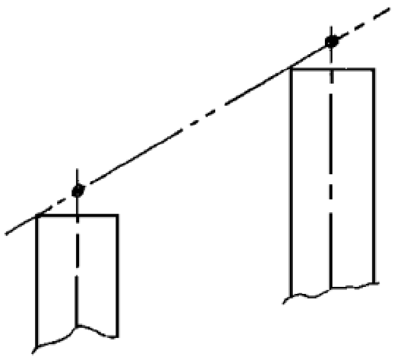


Figure 12.3

(c) It is usually not practical to cut the material on an angle as this is costly and in most cases a further cutting operation will then be required for weld preparations.

This can be clearly seen by looking at **Figure 12.1, 12.2 and 12.3,** and noting the difference in the positions of the mean line intersections as developed in theory and the normal cutting plane intersections.

In practice various ways are used to compensate for this varian in cutting plane and meanline intersections, but we will only consider one method; Quadrant compensation method.

## 12.2 Quadrant compensation

As can be deducted from the name, the variants at the quarter division lines are established by adding the thicknesses at the joint lines at the points under consideration, and use the variants to compensate on the pattern developed.

To demonstrate this technique, consider the drawing in **Figure 12.4** and proceed as follows:

(a) Develop the pattern on mean lines as if no thickness is taken into account.

(b) Now draw in plate and pipe thicknesses on the quarter lines marked 0, 3, 6 and 9 in the front view and the auxiliary view, when this has been done it will be seen that there is a small varian on line 0 and much larger varians at line 6 (see front view).

In the auxiliary view it will be seen that there is no varians at points 3 and 9.

(c) The varians is now added to the pattern development on their respective bend lines. It now remains to mark in the intermediate bend line varians.

(d) The intermediate bend lines varians found in this case by taking as an example the quarter lines 3 and 6. At line 3 we have no varians and at 6 the varians is taken, say 7 mm.

We now find the difference between these line i.e. 7 (7-0= 7), then we divide this difference by the number of spaces between these two lines marked 3 and 6, in this case 3.

Therefore we have $7 \div 3 = 2.33$; then working from line 3 which is as shown with no varians towards line 6 with - 7 varians in steps of a variance of 2.33 as calculated. i.e. line 3 = no varians, line 4 = 2.33, line 5 = 4.66, line 6 = .

As calculated by taking the difference between the varians of the 2 quadrant lines 3 and 6 and dividing a number of divisions between these two quarter lines.

**NOTE:**
Follow the same procedure with line 0-3 and 6-9 and 9-0.

**NOTE:**
For the shape of the hole we follow the same procedure, i.e. first mark the hole pattern as per meanline development; then correct by using varians as shown on front view and auxiliary view.

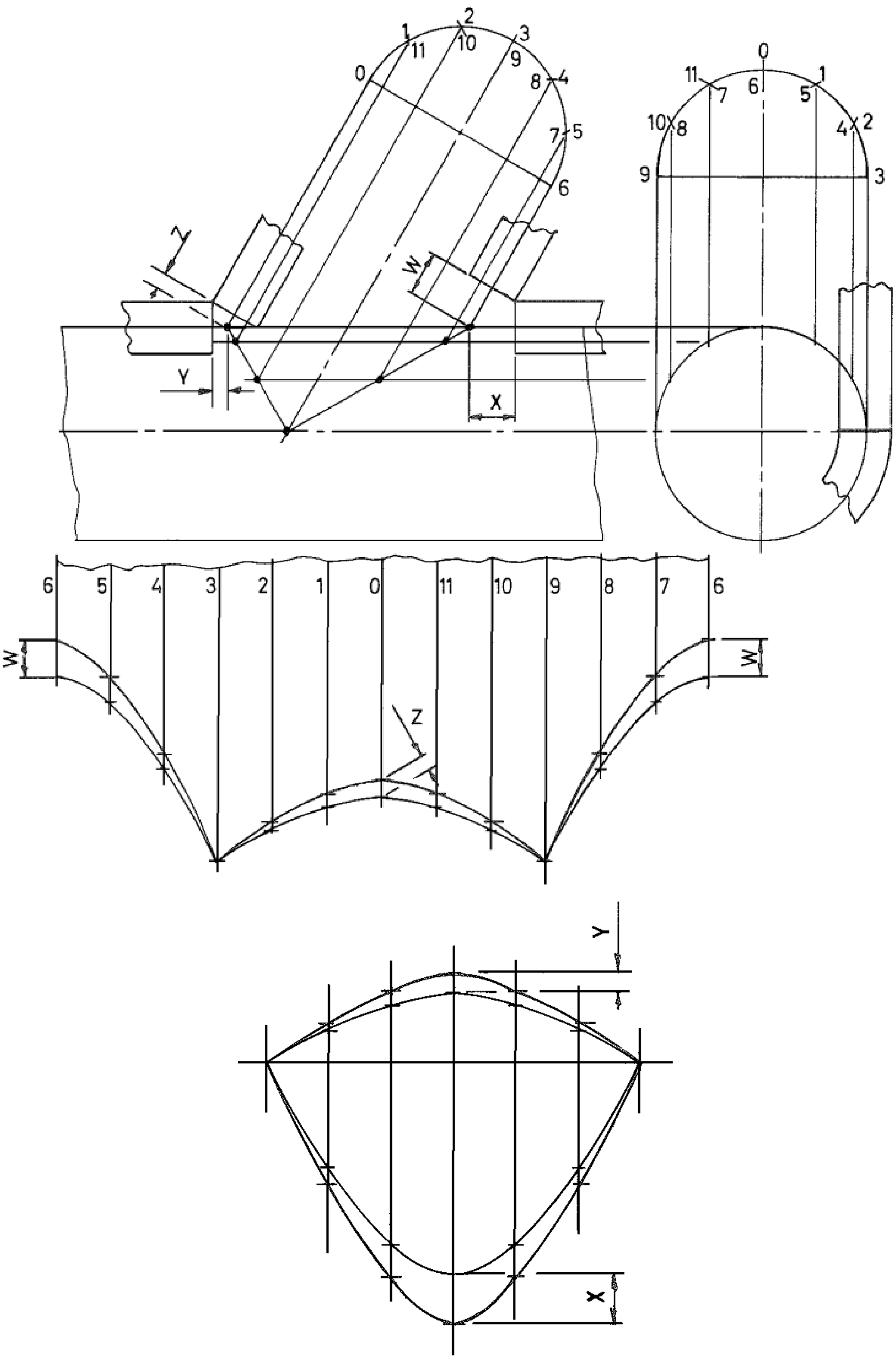



Figure 12.4 Quadrant compensation

## 12.3 Cones and hoppers

When considering cones and hoppers it should be remembered that as with any other job the most practical approach should be used as this will save time and subsequently money.

It should also be remembered that we hardly ever make use of rivets nowadays as welding has proven to be more reliable and cheaper if applied in the right manner.

Another point that should be considered is the fact that a normal cut is always square.

**Figure 12.5** clearly shows that a normal cone cannot simply be made to a height given as the angle formed by the plate and the plate thickness has to be considered.

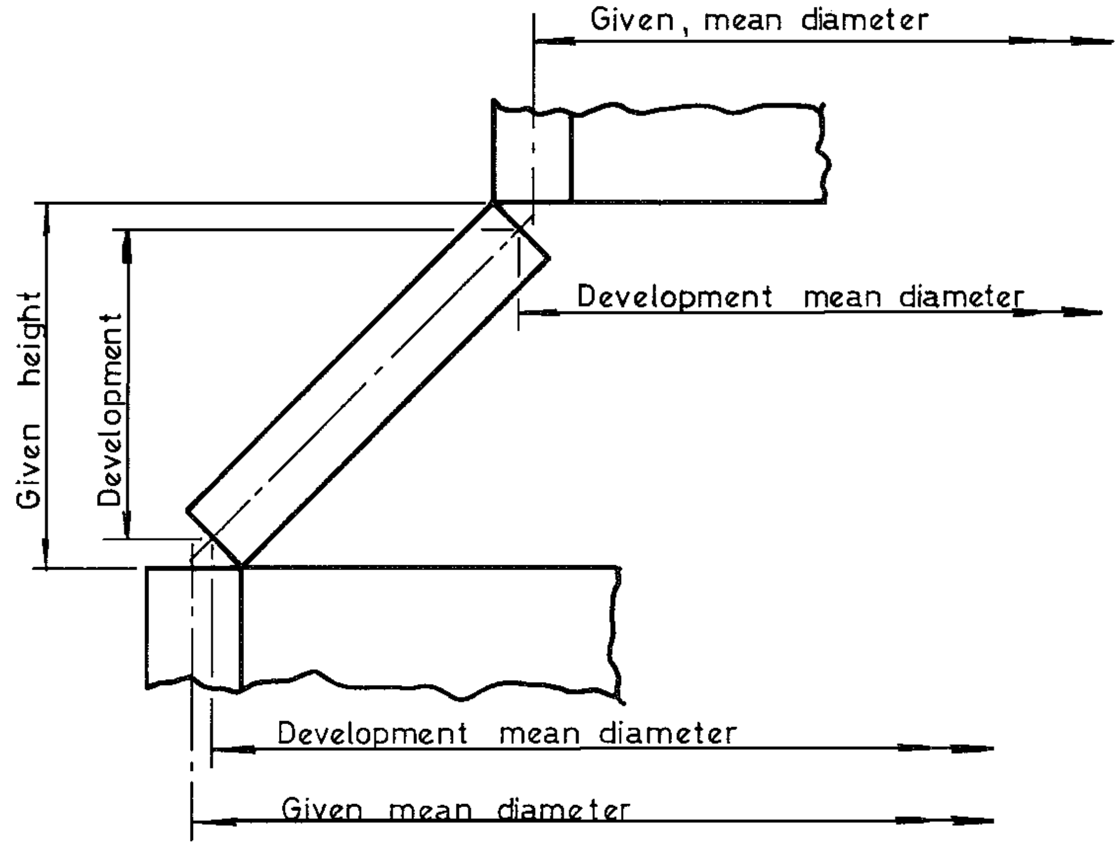



Figure 12.5 Cones

It should also be noted that we virtually have a weld preparation without additional work involved. Looking at this example it should be clear that it is necessary to draw the ends of a cone to establish the correct development dimensions.

**NOTE:**
For the hopper we have the same situation as the plates also lie at an angle, as seen in **Figure 12.6** below.

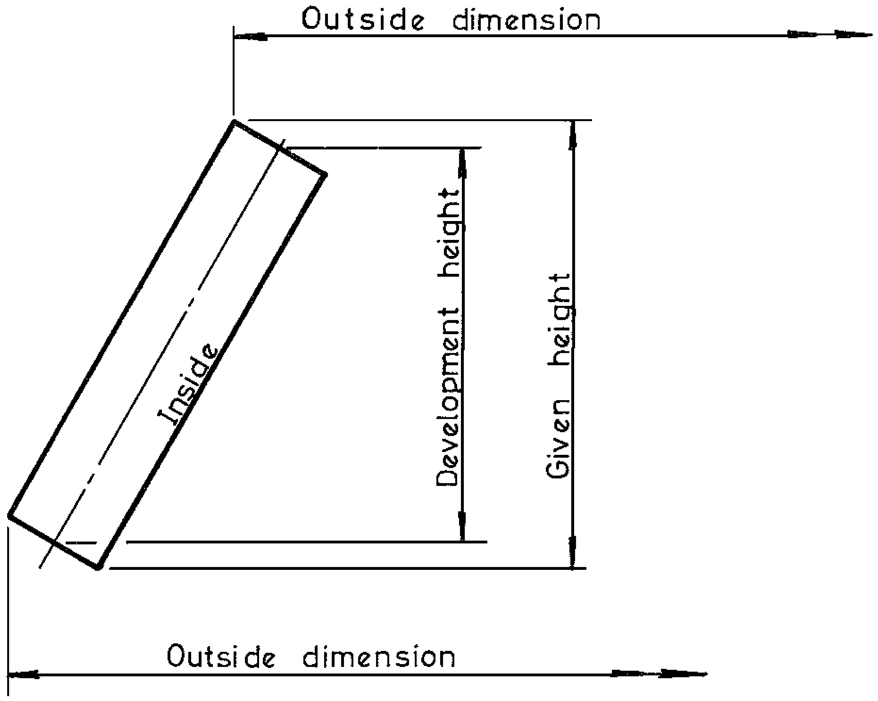



Figure 12.6 Hoppers

**NOTE:**
When working on the hopper with loose plates the inside dimensions should be used as the corner joints will be corner to corner.

| **Self-Check** | | |
|---|---|---|
| **I am able to:** | **Yes** | **No** |
| • Describe quadrant compensation | | |
| • Describe cones and hoppers with regard to plate thickness | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Module 13

# Structural Steel Detailing

**Learning Outcomes**
On the completion of this module the student must be able to:

- Practically apply my knowledge, with regards to structural steel detailing

## 13.1 Introduction

This module will take you through 3 worked examples of structural steel detailing. Take care to go through them thoroughly.

### Worked Example 1

**Figure 13.1** shows the details of a column base. The list of parts is as follows:

| | | | |
|---|---|---|---|
| Item 1 | Column | 178 × 85,5 I-profile (Parallel flange)<br>(5 mm thick flanges and 5 mm thick web) | 1 off |
| Item 2 | base plate | 8 mm thick plate | 1 off |
| Item 3 | side plate | 5 mm thick plate | 2 off |
| Item 4 | side angles | 75 x 45 x 5 angle irons | 2 off |

ø 12 foundation bolt holes

Draw as an assembly drawing, according to scale 1:5 and in first angle orthographic projection, the following views:

- The front view as seen looking at the flange of the column ·
- The left view
- The top view

Print the title and scale centrally beneath the views. Add four dimensions and show the projection symbol.

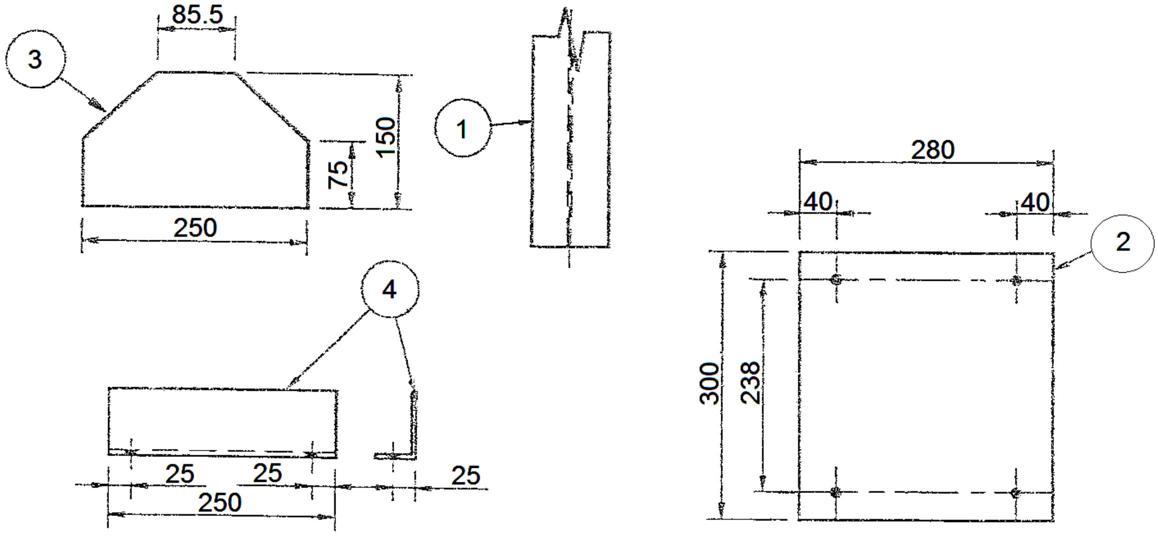



Figure 13.1 The details of a column base

Solution:

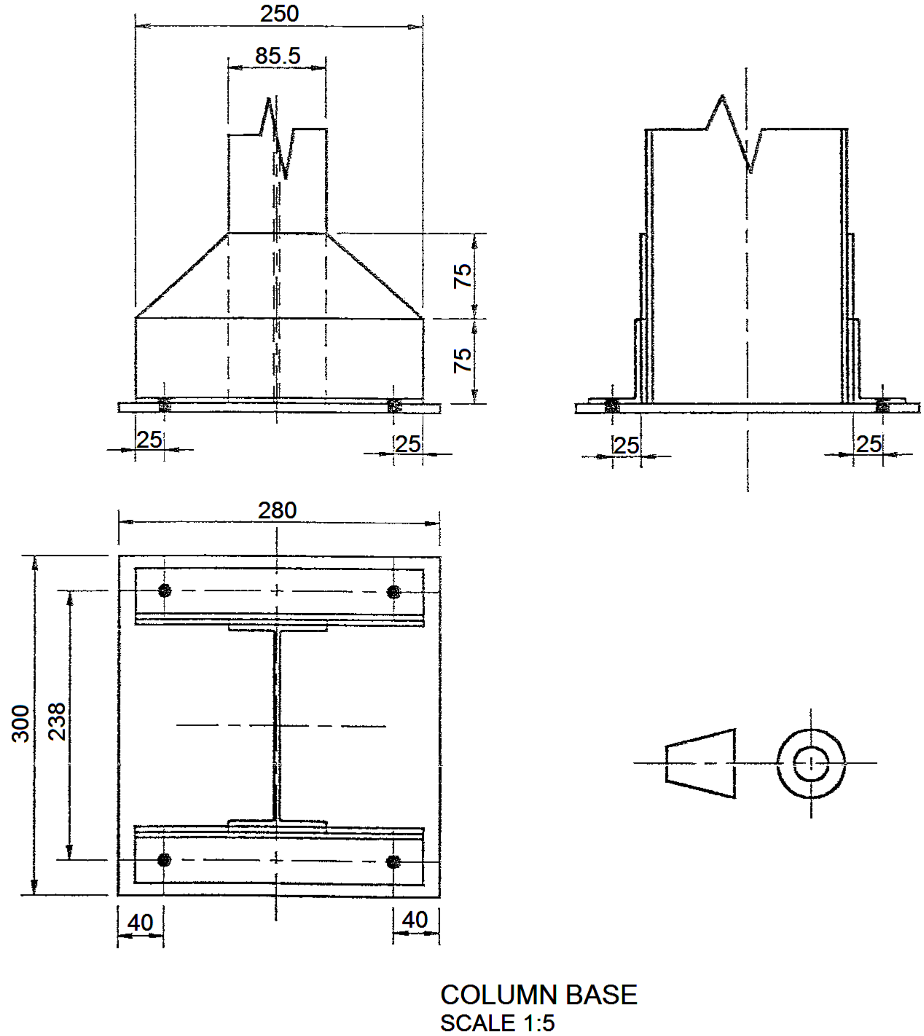



Figure 13.2 Solution

## Worked Example 2

**Figure 13.3** shows a scribe line diagram of a lattice girder for one of the sides of a footbridge. Make a detailed drawing of the lattice girder to conform to structural steel practice showing the gusset plates and rivet positions. (Note all the dimensions are between the back marks.) Scale 1:20

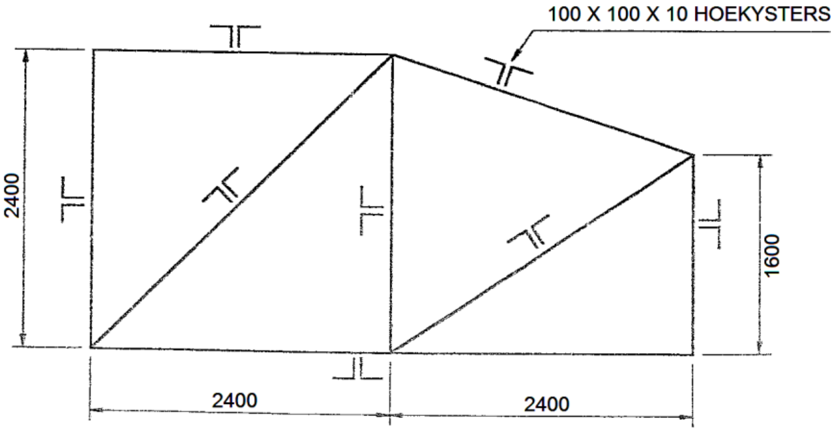



Figure 13.3 A scribe line diagram of a lattice girder for one of the sides of a footbridge

<u>Solution:</u>

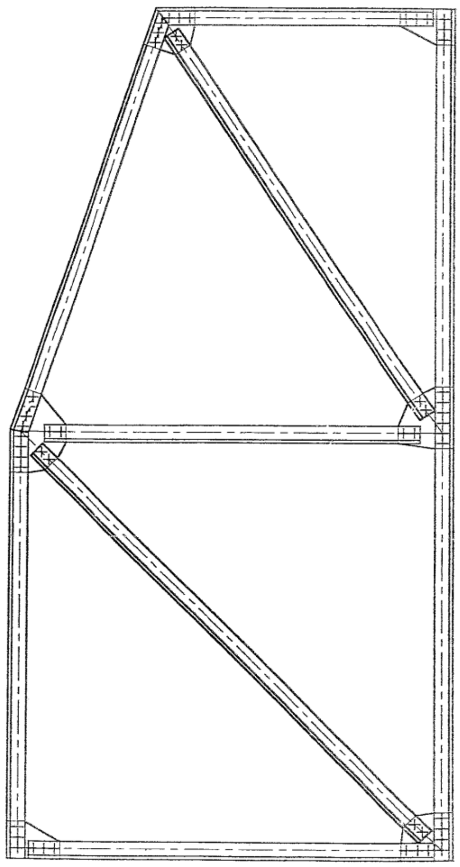


Figure 13.4 Solution

## Worked Example 3

**Figure 13.5** shows part of a line diagram of a hip-roof frame. To a scale of 1:100, determine:

- The true length of the hip rafter
- The dihedral angle of the hip rafter

To a scale of 1:2, develop the template for the end bevels of two 80 × 80 × 6mm angle iron purlins which abut on the hip rafter.

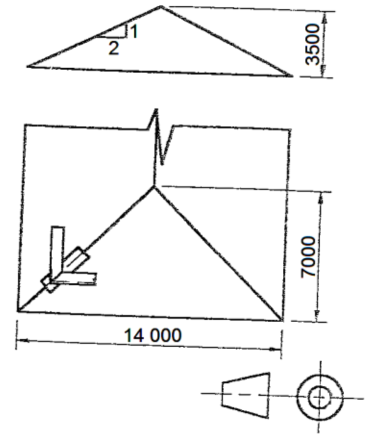



Figure 13.5 A part of a line diagram of a hip-roof frame

Solution:

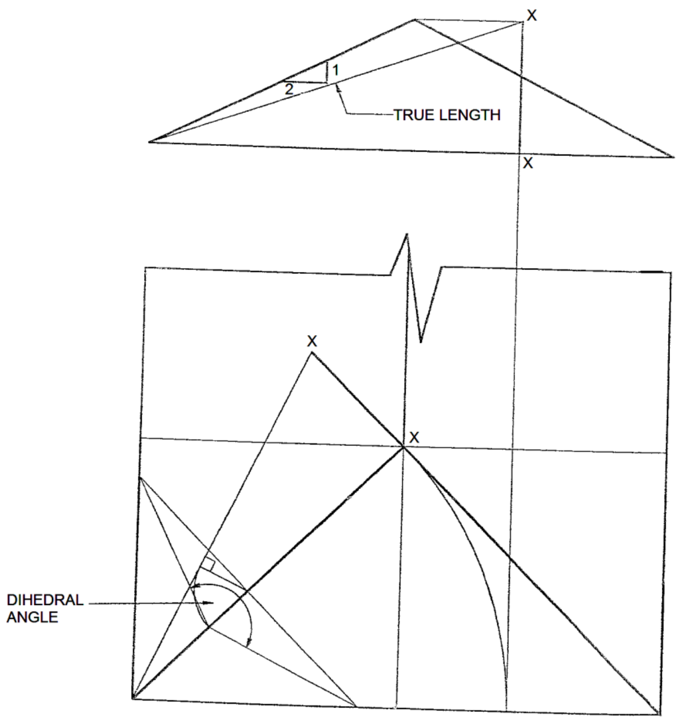



Figure 13.6 Solution

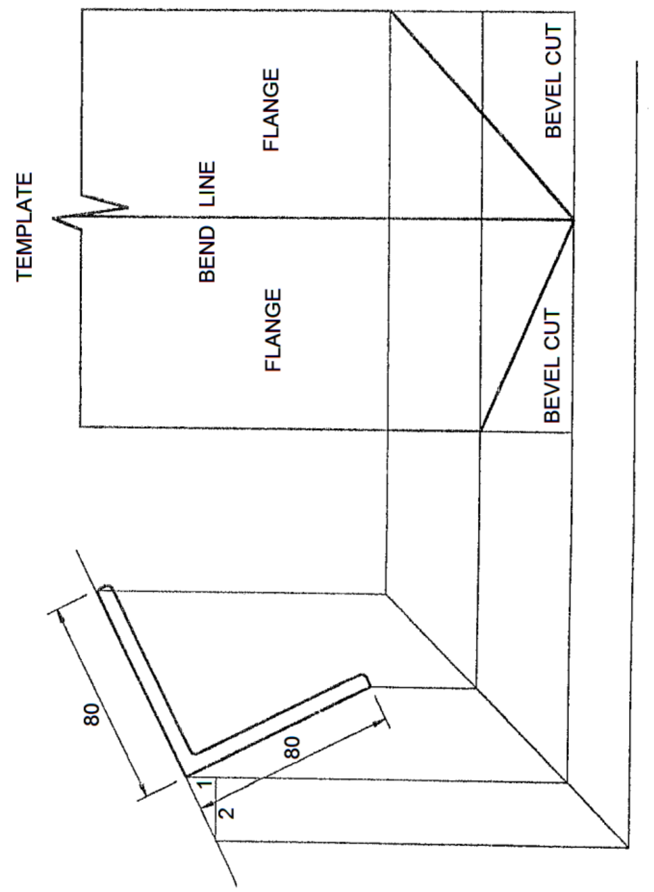
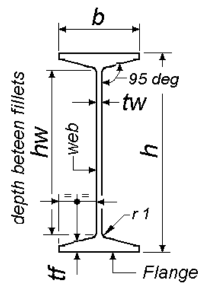


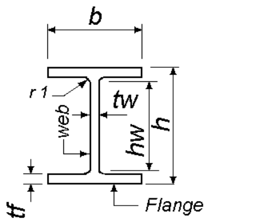

Figure 13.6 Solution continued

| **Self-Check** | | |
|---|---|---|
| **I am able to:** | **Yes** | **No** |
| • Practically apply my knowledge, with regards to structural steel detailing | | |
| If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development. | | |

# Structural Steel Tables

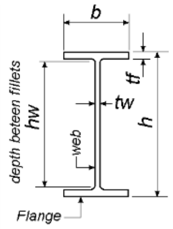



| Structural Steel Sections | | | | | | | |
|---|---|---|---|---|---|---|---|
| I –section (Taper flange) | | | | | | | |
| Dimensions | | | | | | | |
| | *mass* | *h* | *b* | *tw* | *tf* | *r1* | *hw* |
| **Designation**<br>***h* x *b* x *kg/m*** | *kg/m* | *mm* | *mm* | *mm* | *mm* | *mm* | *mm* |
| 127 x 76 x 13 | 13,4 | 127,0 | 76,2 | 4,5 | 7,6 | 7,9 | 96,0 |
| 152 x 89 x 17 | 17,1 | 152,4 | 88,9 | 4,9 | 8,3 | 7,9 | 120 |
| 178 x 102 x 22 | 21,4 | 177,8 | 101,6 | 5,3 | 9,0 | 9,4 | 141 |
| 203 x 102 x 25 | 25,3 | 203,2 | 101,6 | 5,8 | 10,4 | 9,4 | 164 |
| 203 x 152 x 52 | 52,1 | 203 | 152 | 8,9 | 16,5 | 15,5 | 139 |
| 254 x 152 x 59 | 59,4 | 254 | 152 | 9,1 | 18,0 | 15,5 | 187 |
| 305 x 152 x 66 | 65,8 | 305 | 152 | 10,2 | 18,2 | 15,5 | 238 |

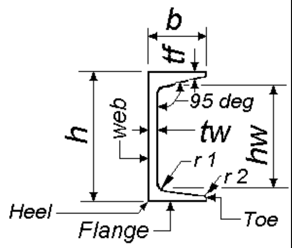



| Structural Steel Sections | | | | | | | |
|---|---|---|---|---|---|---|---|
| H –section (parallel flange) | | | | | | | |
| Dimensions | | | | | | | |
| | *mass* | *h* | *b* | *tw* | *tf* | *r1* | *hw* |
| **Designation**<br>**H x b x kg/m** | *kg/m* | *mm* | *mm* | *mm* | *mm* | *mm* | *mm* |
| 152 x 152 x 23 | 23,3 | 152,4 | 152,4 | 6,1 | 6,8 | 7,6 | 124 |
| 30 | 30,1 | 17,5 | 152,9 | 6,6 | 9,4 | 7,6 | 124 |
| 37 | 37,1 | 161,8 | 154,4 | 8,1 | 11,5 | 7,6 | 124 |
| 203 x 203 x 46 | 46,2 | 203,2 | 203,2 | 7,3 | 11,0 | 10,2 | 161 |
| 52 | 52,1 | 206,2 | 203,9 | 8,0 | 12,5 | 10,2 | 161 |
| 60 | 59,7 | 209,6 | 205,2 | 9,3 | 14,2 | 10,2 | 161 |
| 71 | 71,4 | 215,9 | 206,2 | 10,3 | 17,3 | 10,2 | 161 |
| 86 | 86,4 | 222,3 | 208,9 | 13,0 | 20,5 | 10,2 | 161 |
| 254 x 254 x 73 | 73,0 | 254,2 | 254,0 | 8,6 | 14,2 | 12,7 | 200 |
| 89 | 89,2 | 260,4 | 255,9 | 10,5 | 17,3 | 12,7 | 200 |
| 107 | 107 | 266,7 | 258,3 | 13,0 | 20,5 | 12,7 | 200 |
| 132 | 132 | 276,4 | 261,0 | 15,6 | 25,1 | 12,7 | 200 |
| 167 | 167 | 289,1 | 264,5 | 19,2 | 31,7 | 12,7 | 200 |
| 305 x 305 x 97 | 96,8 | 307,8 | 304,8 | 9,9 | 15,4 | 15,2 | 247 |
| 118 | 118 | 314,5 | 306,8 | 11,9 | 18,7 | 15,2 | 247 |
| 137 | 137 | 320,5 | 308,7 | 13,8 | 21,7 | 15,2 | 247 |

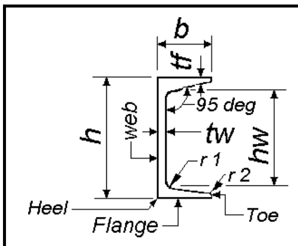
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 158 | 158 | 327,2 | 310,6 | 15,7 | 25,0 | 15,2 | 247 |
| 198 | 198 | 339,9 | 314,1 | 19,2 | 31,4 | 15,2 | 247 |
| 240 | 240 | 352,6 | 317,9 | 23,0 | 37,7 | 15,2 | 247 |
| 283 | 283 | 365,3 | 321,8 | 26,9 | 44,1 | 15,2 | 247 |

|   | Structural Steel Sections | | | | | | |
|---|---|---|---|---|---|---|---|
| | I –section (parallel flange) | | | | | | |
| | Dimensions | | | | | | |
| | *mass* | *h* | *b* | *tw* | *tf* | *r1* | *hw* |
| **Designation** *h x b x kg/m* | *kg/m* | *mm* | *mm* | *mm* | *mm* | *mm* | *mm* |
| 152 x 89 x 16 | 16,1 | 152,4 | 88,9 | 4,6 | 7,7 | 7,6 | 122 |
| 178 x 102 x 19 | 19 | 177,8 | 101,6 | 4,7 | 7,9 | 7,6 | 147 |
| 203 x 133 x 25 | 25,3 | 203,2 | 133,4 | 5,8 | 7,8 | 7,6 | 172 |
| 30 | 29,8 | 206,8 | 133,8 | 6,3 | 9,6 | 7,6 | 172 |
| 31 | 31,3 | 251,5 | 146,1 | 6,1 | 8,6 | 7,6 | 219 |
| 37 | 37,2 | 256 | 146,4 | 6,4 | 10,9 | 7,6 | 219 |
| 43 | 43,2 | 259,6 | 147,3 | 7,3 | 12,7 | 7,6 | 219 |
| 305 x 102 x 25 | 24,5 | 304,8 | 101,6 | 5,8 | 6,8 | 7,6 | 276 |
| 29 | 28,6 | 308,9 | 101,9 | 6,1 | 8,9 | 7,6 | 276 |
| 33 | 32,8 | 312,7 | 102,4 | 6,6 | 10,8 | 7,6 | 276 |
| 41 | 40,5 | 303,8 | 165,1 | 6,1 | 10,2 | 8,9 | 266 |
| 46 | 46,1 | 307,1 | 165,7 | 6,7 | 11,8 | 8,9 | 266 |
| 54 | 53,5 | 301,9 | 166,8 | 7,7 | 13,7 | 8,9 | 266 |
| 356 x 171 x 45 | 44,8 | 352 | 171 | 6,9 | 9,7 | 10,2 | 312 |
| 51 | 50,7 | 355,6 | 171,5 | 7,3 | 11,5 | 10,2 | 312 |
| 57 | 56,7 | 358,6 | 172,1 | 8 | 13 | 10,2 | 312 |
| 67 | 67,2 | 364 | 173,2 | 9,1 | 15,7 | 10,2 | 312 |
| 406 x 140 x 39 | 38,6 | 397,3 | 141,8 | 6,3 | 8,6 | 10,2 | 360 |
| 46 | 46,3 | 402,3 | 142,4 | 6,9 | 11,2 | 10,2 | 360 |
| 54 | 53,8 | 402,6 | 177,6 | 7,6 | 10,9 | 10,2 | 360 |
| 60 | 59,7 | 406,4 | 177,8 | 7,8 | 12,8 | 10,2 | 360 |
| 67 | 67,1 | 409,4 | 178,8 | 8,8 | 14,3 | 10,2 | 360 |
| 75 | 74,8 | 412,8 | 179,7 | 9,7 | 16 | 10,2 | 360 |
| 457 x 191 x 67 | 67,1 | 453,6 | 189,9 | 8,5 | 12,7 | 10,2 | 408 |
| 75 | 74,7 | 457,2 | 190,5 | 9,1 | 14,5 | 10,2 | 408 |
| 82 | 82,0 | 460,2 | 191,3 | 9,9 | 16 | 10,2 | 408 |
| 90 | 89,7 | 463,6 | 192 | 10,6 | 17,7 | 10,2 | 408 |
| 98 | 98,4 | 467,4 | 192,8 | 11,4 | 19,6 | 10,2 | 408 |
| 533 x 210 x 82 | 82,2 | 528,3 | 208,7 | 9,6 | 13,2 | 12,7 | 477 |
| 93 | 92,5 | 533,1 | 209,3 | 10,2 | 15,6 | 12,7 | 477 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 101 | 101 | 536,7 | 210,1 | 10,9 | 17,4 | 12,7 | 477 |
| 109 | 109 | 539,5 | 210,7 | 11,6 | 18,8 | 12,7 | 477 |
| 122 | 122 | 544,6 | 211,9 | 12,8 | 21,3 | 12,7 | 477 |
| 610 x 229 x 101 | 102 | 602,2 | 227,6 | 10,6 | 14,8 | 12,7 | 547 |
| 113 | 113 | 607,3 | 228,2 | 11,2 | 17,3 | 12,7 | 547 |
| 125 | 125 | 611,9 | 229 | 11,9 | 19,6 | 12,7 | 547 |
| 140 | 140 | 617 | 230,1 | 13,1 | 22,1 | 12,7 | 547 |

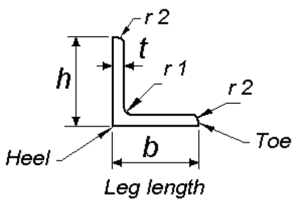



| | Structural Steel Sections | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Channels | | | | | | | | | |
| | Dimensions | | | | | | | | | |
| | mass | h | b | tw | tf | r1 | r2 | b1 | hw | β | A |
| Designation H x b x kg/m | kg/m | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| DIN taper flange | | | | | | | | | | | |
| 100 x 50 x 11 | 10,5 | 100 | 50,0 | 6,0 | 8,5 | 8,5 | 4,5 | 25,6 | 66,0 | 94,57 | 1,34 |
| 120 x 55 x 13 | 13,3 | 120 | 55,0 | 7,0 | 9,0 | 9,0 | 4,5 | 27,5 | 84,0 | 94,57 | 1,70 |
| 140 x 60 x 16 | 16,0 | 140 | 60,0 | 7,0 | 10,0 | 10,0 | 5,0 | 30,0 | 100 | 94,57 | 2,04 |
| 160 x 65 x 19 | 18,9 | 160 | 65,0 | 7,5 | 10,5 | 10,5 | 5,5 | 32,5 | 118 | 94,57 | 2,40 |
| 180 x 70 x 22 | 22,0 | 180 | 70,0 | 8,0 | 11,0 | 11,0 | 5,5 | 35,0 | 136 | 94,57 | 2,80 |
| 200 x 75 x 25 | 25,3 | 200 | 75,0 | 8,5 | 11,5 | 11,5 | 6,0 | 37,5 | 154 | 94,57 | 3,22 |
| 220 x 80 x 29 | 29,4 | 220 | 80,0 | 9,0 | 12,5 | 12,5 | 6,5 | 40,0 | 170 | 94,57 | 3,74 |
| 240 x 85 x 33 | 33,2 | 240 | 85,0 | 9,5 | 13,0 | 13,0 | 6,5 | 42,5 | 188 | 94,57 | 4,23 |
| 260 x 90 x 38 | 37,9 | 260 | 90,0 | 10,0 | 14,0 | 14,0 | 7,0 | 45,0 | 204 | 94,57 | 4,83 |
| 280 x 95 x 42 | 41,9 | 280 | 95,0 | 10,0 | 15,0 | 15,0 | 7,5 | 47,5 | 220 | 94,57 | 5,34 |
| 300 x 100 x 46 | 46,1 | 300 | 100 | 10,0 | 16,0 | 16,0 | 8,0 | 50,0 | 236 | 94,57 | 5,88 |
| BS taper flange | | | | | | | | | | | |
| 76 x 38 x 7 | 6,72 | 76,2 | 38,1 | 5,1 | 6,8 | 7,6 | 2,4 | 16,5 | 47,4 | 95 | 0,855 |
| 127 x 64 x 15 | 14,9 | 127 | 63,5 | 6,4 | 9,2 | 10,7 | 2,4 | 28,5 | 87,2 | 95 | 1,90 |
| 152 x 76 x 18 | 17,9 | 152,4 | 76,2 | 6,4 | 9,0 | 12,2 | 2,4 | 34,9 | 110 | 95 | 2,28 |
| 178 x 54 x 15 | 14,6 | 177,8 | 54,0 | 5,8 | 8,3 | 8,3 | 3,2 | 24,1 | 145 | 92 | 1,85 |
| 381 x 102 x 55 | 55,0 | 381,0 | 101,6 | 10,4 | 16,3 | 15,2 | 4,8 | 45,6 | 318 | 95 | 7,01 |

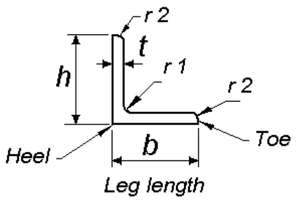


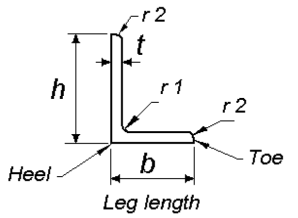

| | Structural Steel Sections | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channels | | | | | | | | | | |
| | Dimensions | | | | | | | | | | |
| | mass | h | b | tw | tf | r1 | r2 | b1 | hw | β | A |
| Designation H x b x kg/m | kg/m | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| SA Parallel flange | | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PCF 100 x 50 | 10,1 | 100,0 | 50,0 | 5,0 | 8,4 | 8,4 | - | - | 66,4 | - | 1,29 |
| PCF 120 x 55 | 12,5 | 120,0 | 55,0 | 5,5 | 9,1 | 9,1 | - | - | 83,6 | - | 1,60 |
| PFC 140 x 60 | 15,3 | 140,0 | 60 | 6,0 | 9,9 | 9,9 | - | - | 100 | - | 1,95 |
| PCF 160 x 65 | 18,1 | 160,0 | 65 | 6,5 | 10,4 | 10,4 | - | - | 118 | - | 2,30 |
| PCF 180 x 70 | 21,1 | 180,0 | 70 | 7,0 | 10,9 | 10,9 | - | - | 136 | - | 2,68 |
| PCF 200 x 75 | 24,3 | 200,0 | 75 | 7,5 | 11,4 | 11,4 | - | - | 154 | - | 3,09 |
| PCF 220 x 80 | 28,3 | 220,0 | 80 | 7,9 | 12,5 | 12,5 | - | - | 170 | - | 3,61 |
| PCF 240 x 85 | 32,0 | 240,0 | 85 | 8,4 | 13,0 | 13,0 | - | - | 188 | - | 4,08 |
| PCF 260 x 90 | 36,3 | 260,0 | 90 | 8,8 | 13,9 | 13,9 | - | - | 204 | - | 4,63 |
| PCF 280 x 95 | 40,9 | 280,0 | 95 | 9,2 | 14,8 | 14,8 | - | - | 221 | - | 5,21 |
| PCF300 x 100 | 45,4 | 300,0 | 100 | 9,6 | 15,5 | 15,5 | - | - | 238 | - | 5,79 |




| | Structural Steel Sections | | | |
|---|---|---|---|---|
| | Angles (equal leg) | | | |
| | Dimensions | | | |
| | *mass* | *r1* | *r2* | *A* |
| Designation (mm) *h x b x t* | *kg/m* | *mm* | *mm* | *$10^3$ $mm^2$* |
| 25 x 25x 3 | 1,11 | 3,5 | 2 | 0,142 |
| 5 | 1,77 | 3,5 | 2 | 0,226 |
| 30 x 30 x 3 | 1,36 | 5 | 2,5 | 0,174 |
| 5 | 2,18 | 5 | 2,5 | 0,278 |
| 35 x 35 x 3 | 1,60 | 5 | 2,5 | 0,204 |
| 5 | 2,57 | 5 | 2,5 | 0,328 |
| 40 x 40 x 3 | 1,85 | 6 | 3 | 0,235 |
| 5 | 2,97 | 6 | 3 | 0,379 |
| 6 | 3,52 | 6 | 3 | 0,448 |
| 45 x 45 x 3 | 2,10 | 7 | 3,5 | 0,268 |
| 5 | 3,38 | 7 | 3,5 | 0,430 |
| 6 | 4,00 | 7 | 3,5 | 0,509 |
| 50 x 50 x 3 | 2,34 | 7 | 3,5 | 0,298 |
| 4 | 3,06 | 7 | 3,5 | 0,389 |
| 5 | 3,77 | 7 | 3,5 | 0,480 |
| 6 | 4,47 | 7 | 3,5 | 0,569 |
| 8 | 5,82 | 7 | 3,5 | 0,741 |

|   | **Structural Steel Sections** | | | |
|---|---|---|---|---|
| | **Angles (equal leg)** | | | |
| | **Dimensions** | | | |
| | ***mass*** | ***r1*** | ***r2*** | ***A*** |
| **Designation (mm)**<br>***h x b x t*** | ***kg/m*** | ***mm*** | ***mm*** | ***$10^3$ mm$^2$*** |
| 60 x 60 x 4 | 3,70 | 8 | 4 | 0,471 |
| 5 | 4,57 | 8 | 4 | 0,582 |
| 6 | 5,42 | 8 | 4 | 0,691 |
| 8 | 7,09 | 8 | 4 | 0,903 |
| 10 | 8,69 | 8 | 4 | 1,11 |
| 70 x 70 x 6 | 6,38 | 9 | 4,5 | 0,813 |
| 8 | 8,36 | 9 | 4,5 | 1,06 |
| 10 | 10,3 | 9 | 4,5 | 1,31 |
| 80 x 80 x 6 | 7,34 | 10 | 5 | 0,935 |
| 8 | 9,63 | 10 | 5 | 1,23 |
| 10 | 11,9 | 10 | 5 | 1,51 |
| 12 | 14,0 | 10 | 5 | 1,79 |
| 90 x 90 x 6 | 8,30 | 11 | 5,5 | 1,06 |
| 8 | 10,9 | 11 | 5,5 | 1,39 |
| 10 | 13,4 | 11 | 5,5 | 1,71 |
| 21 | 15,9 | 11 | 5,5 | 2,03 |
| 100 x 100 x 8 | 12,2 | 12 | 6 | 1,55 |
| 10 | 15,0 | 12 | 6 | 1,92 |
| 12 | 17,8 | 12 | 6 | 2,27 |
| 15 | 21,9 | 12 | 6 | 2,79 |
| 120 x 120 x 8 | 14,7 | 13 | 6,5 | 1,87 |
| 10 | 18,2 | 13 | 6,5 | 2,32 |
| 12 | 21,6 | 13 | 6,5 | 2,75 |
| 15 | 26,6 | 13 | 6,5 | 3,39 |
| 150 x 150 x 10 | 23,0 | 16 | 8 | 2,93 |
| 12 | 27,3 | 16 | 8 | 3,48 |
| 15 | 33,8 | 16 | 8 | 4,30 |
| 18 | 40,1 | 16 | 8 | 5,10 |
| 200 x 200 x 16 | 48,5 | 18 | 9 | 6,18 |
| 18 | 54,2 | 18 | 9 | 6,91 |
| 20 | 59,9 | 18 | 9 | 7,63 |
| 24 | 71,1 | 18 | 9 | 9,06 |




| | Structural Steel Sections | | | |
|---|---|---|---|---|
| | Angles (un-equal leg) | | | |
| | Dimensions | | | |
| | *mass* | *r1* | *r2* | *A* |
| **Designation (mm)** *h x b x t* | *kg/m* | *mm* | *mm* | *$10^3$ $mm^2$* |
| 65 x 50 x 6 | 5,16 | 6 | 3 | 0,658 |
| 8 | 6,75 | 6 | 3 | 0,860 |
| 75 x 50 x 6 | 5,65 | 7 | 3,5 | 0,719 |
| 8 | 7,39 | 7 | 3,5 | 0,941 |
| 80 x 60 x 6 | 6,37 | 8 | 4 | 0,811 |
| 8 | 8,34 | 8 | 4 | 1,06 |
| 90 x 65 x 6 | 7,07 | 8 | 4 | 0,901 |
| 8 | 9,29 | 8 | 4 | 1,18 |
| 10 | 11,4 | 8 | 4 | 1,46 |
| 100 x 65 x 8 | 9,94 | 10 | 5 | 1,27 |
| 10 | 12,3 | 10 | 5 | 1,56 |
| 100 x 75 x 6 | 8,04 | 10 | 5 | 1,02 |
| 8 | 10,6 | 10 | 5 | 1,35 |
| 10 | 13,0 | 10 | 5 | 1,66 |
| 12 | 15,4 | 10 | 5 | 1,97 |
| 125 x 75 x 8 | 12,2 | 11 | 5,5 | 1,55 |
| 10 | 15,0 | 11 | 5,5 | 1,55 |
| 12 | 17,8 | 11 | 5,5 | 2,27 |
| 150 x 75 x 10 | 17,0 | 11 | 5,5 | 2,16 |
| 12 | 20,2 | 11 | 5,5 | 2,57 |
| 15 | 24,8 | 11 | 5,5 | 3,16 |
| 150 x 90 x 10 | 18,2 | 12 | 6 | 2,32 |
| 12 | 21,6 | 12 | 6 | 2,75 |
| 15 | 26,6 | 12 | 6 | 3,39 |

# Past Examination Papers

higher education & training

Department: Higher Education and Training REPUBLIC OF SOUTH AFRICA

**NOVEMBER 2010**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

**(8090102)**

**(X-Paper)**
**09:00 – 13:00**

**REQUIREMENTS:**

**One sheet of A-2 drawing paper**

**Calculators may be used.**

**This question paper consists of 4 pages and 2 diagram sheets.**

**TIME: 4 HOURS**
**MARKS: 100**

---

**NOTE:** If you answer more than the required **FOUR** questions, only the first four questions will be marked. All work you do not want to be marked must be clearly crossed out.

**INSTRUCTIONS AND INFORMATION**

1. Answer any **FOUR** questions.
2. Read ALL the questions carefully.
3. ALL the construction lines must be shown.
4. Do **TWO** questions on the front and **TWO** questions on the reverse side of the drawing sheet.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Add dimensions to the answers.
7. Write neatly and legibly.

---

**QUESTION 1**

FIGURE 1 on the attached **DIAGRAM SHEET 1** shows an oblique truncated pyramidal hopper with a down pipe. Draw the following:

1.1 The given view

1.2 The pattern of the plate for the hopper 'L'

1.3 The pattern of the plate for the down pipe 'M'

SCALE 1:10

**[25]**

**QUESTION 2**

FIGURE 2 on the attached **DIAGRAM SHEET 1** shows a lobster-back bend with a branch pipe. Determine the line of penetration and develop the following:

2.1 The pattern for segment 'L'

2.2 The pattern for segment 'M'

SCALE 1:2

**[25]**

**QUESTION 3**

FIGURE 3 on the attached **DIAGRAM SHEET 1** shows a T-piece consisting· of cylindrical pipes that fit onto a roof. Draw the given view, determine the line of penetration and develop the following:

3.1 The pattern of the branch pipe 'A'

3.2 The shape of the hole in the roof plate 'B'

SCALE 1:1

**[25]**

**QUESTION 4**

FIGURE 4 on the attached **DIAGRAM SHEET 2** shows an intersection between a right cone and a cylinder. Draw the given views and develop the following:

4.1 The line of penetration

4.2 The pattern for the cylinder

4.3 The shape of the hole in the right cone

SCALE 1:5

**[25]**

**QUESTION 5**

FIGURE 5 on the attached **DIAGRAM SHEET 2** shows two views of a transformer. Draw the following:

5.1 The given views

5.2 The pattern of the plate for the transformer

SCALE 1:5

**[25]**

**QUESTION 6**

FIGURE 6 on the attached **DIAGRAM SHEET 2** shows a 'welded base' of a column. Draw, according to first-angle orthographic projection, the following views:

6.1 The given view

6.2 The left view

6.3 The top view

SCALE 1:5

Print the title and scale centrally beneath the layout.

**General Information:**

| | | |
|---|---|---|
| Item 1 | 203 x 203 H-beam<br>(the flanges and the web have a thickness of 8 mm) | 1 off |
| Item 2 | 10 mm thick plate 250 x 500 | 2 off |
| Item 3 | 10 mm thick plate 100 x 203 | 2 off |
| Item 4 | 20 mm thick plate 360 x 500 | 1 off |

**[25]**

**TOTAL: 100**

**NOVEMBR 2010**

**DIAGRAM SHEET 1**

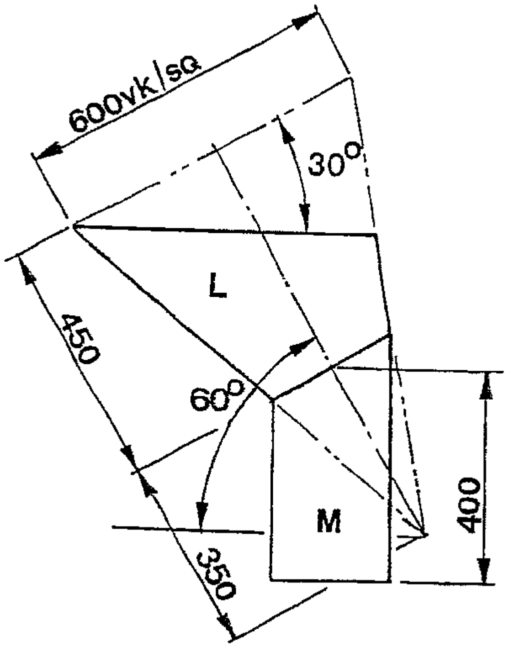



**FIGURE 1**

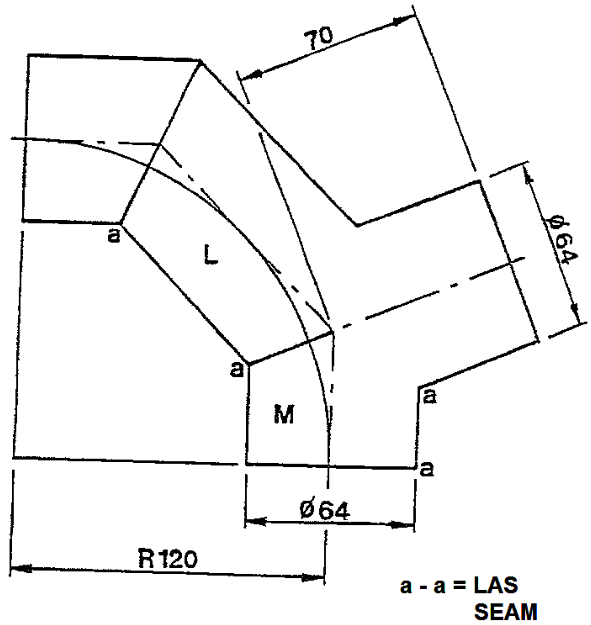



**FIGURE 2**

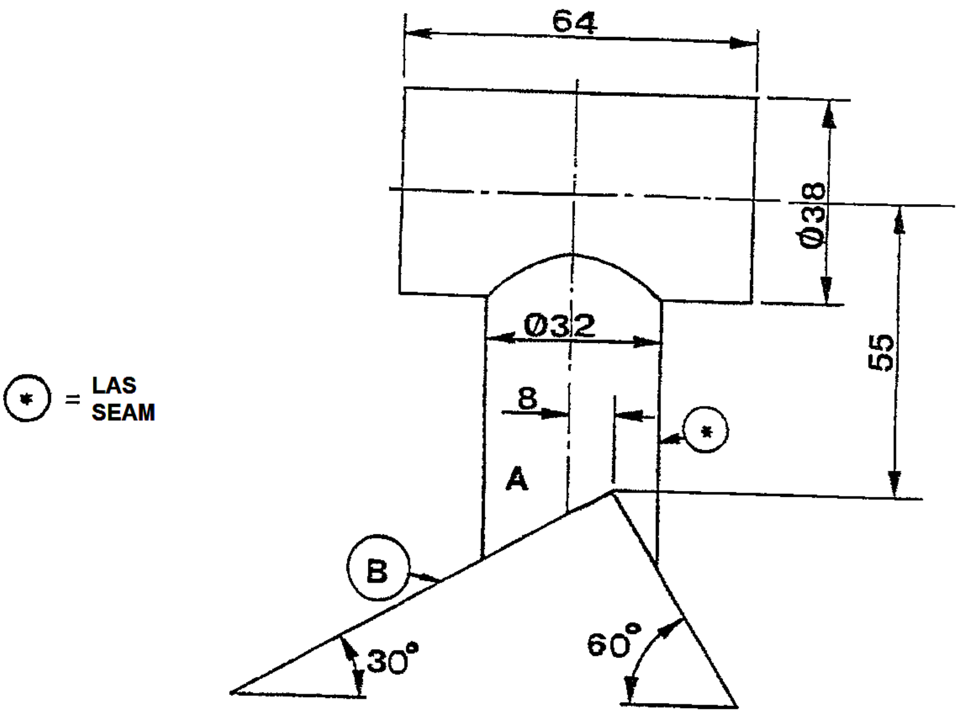



**FIGURE 3**

**NOVEMBR 2010**

## DIAGRAM SHEET 2

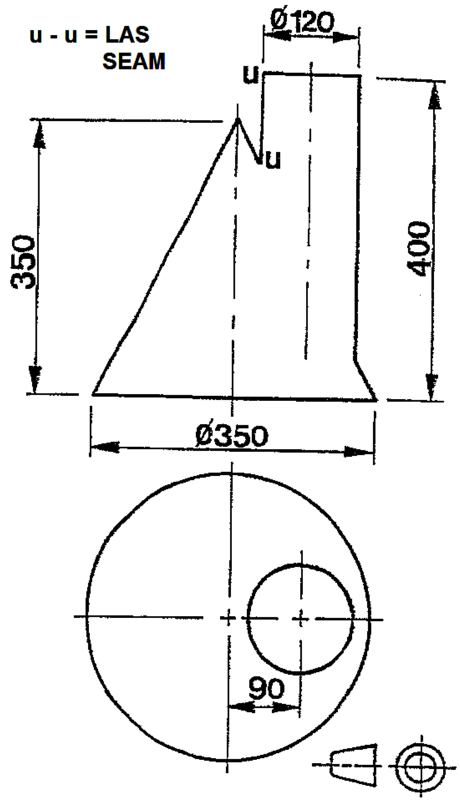



FIGURE 4

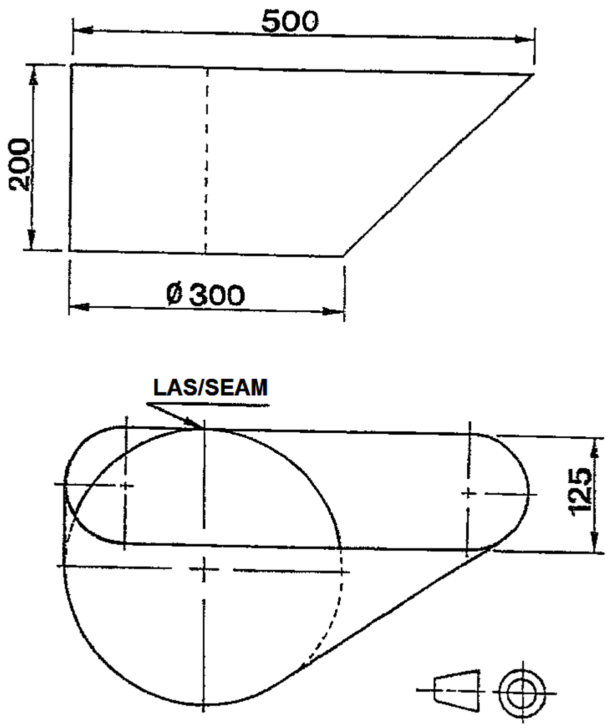



FIGURE 5

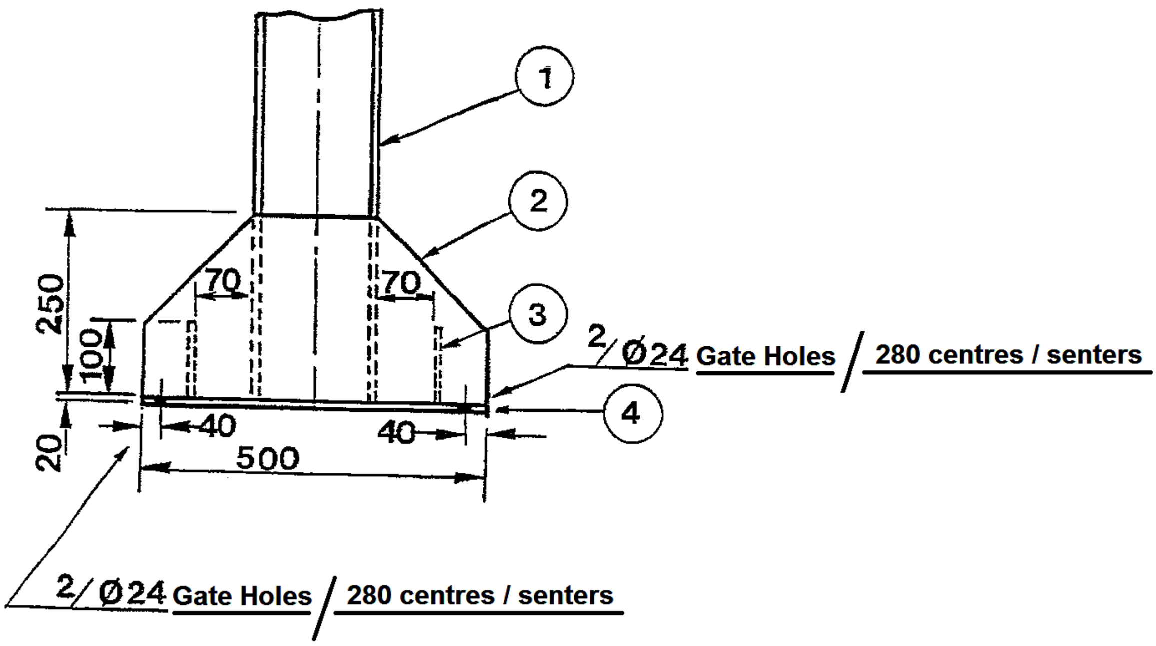



FIGURE 6

# Marking Guidelines

higher education
& training
Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

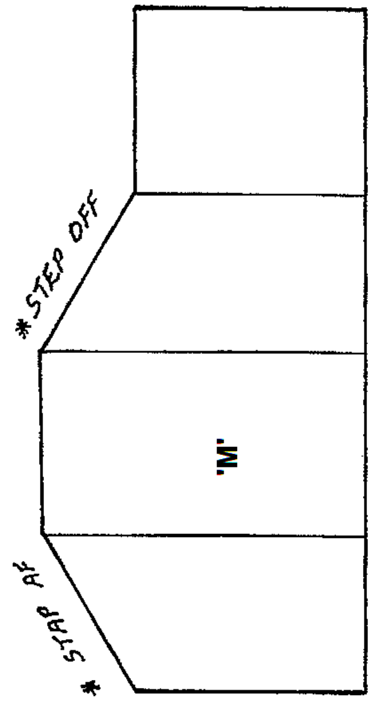
**NOVEMBER 2010**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

(**8090102**)

**(X-Paper)**
**09:00 – 13:00**



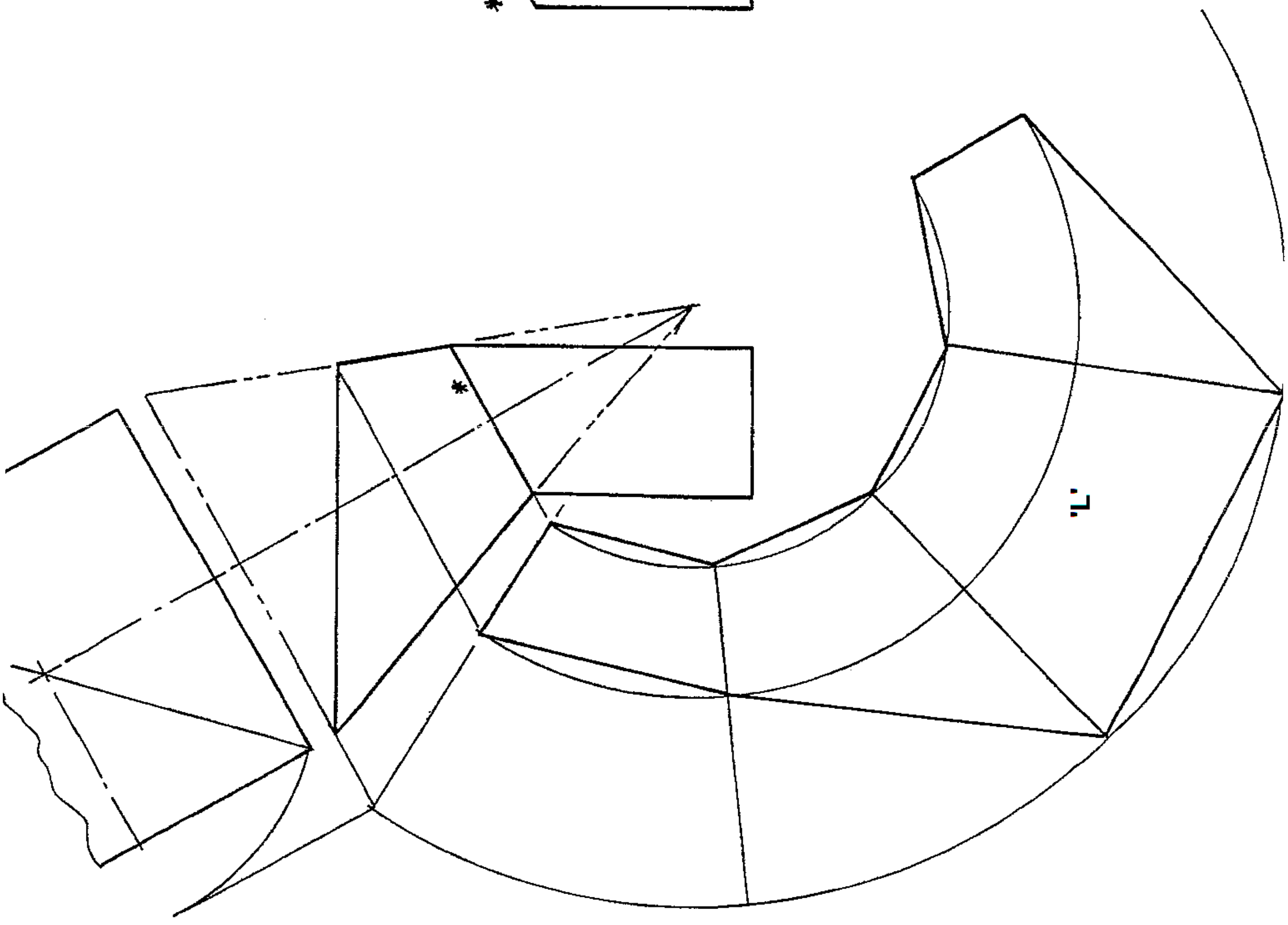
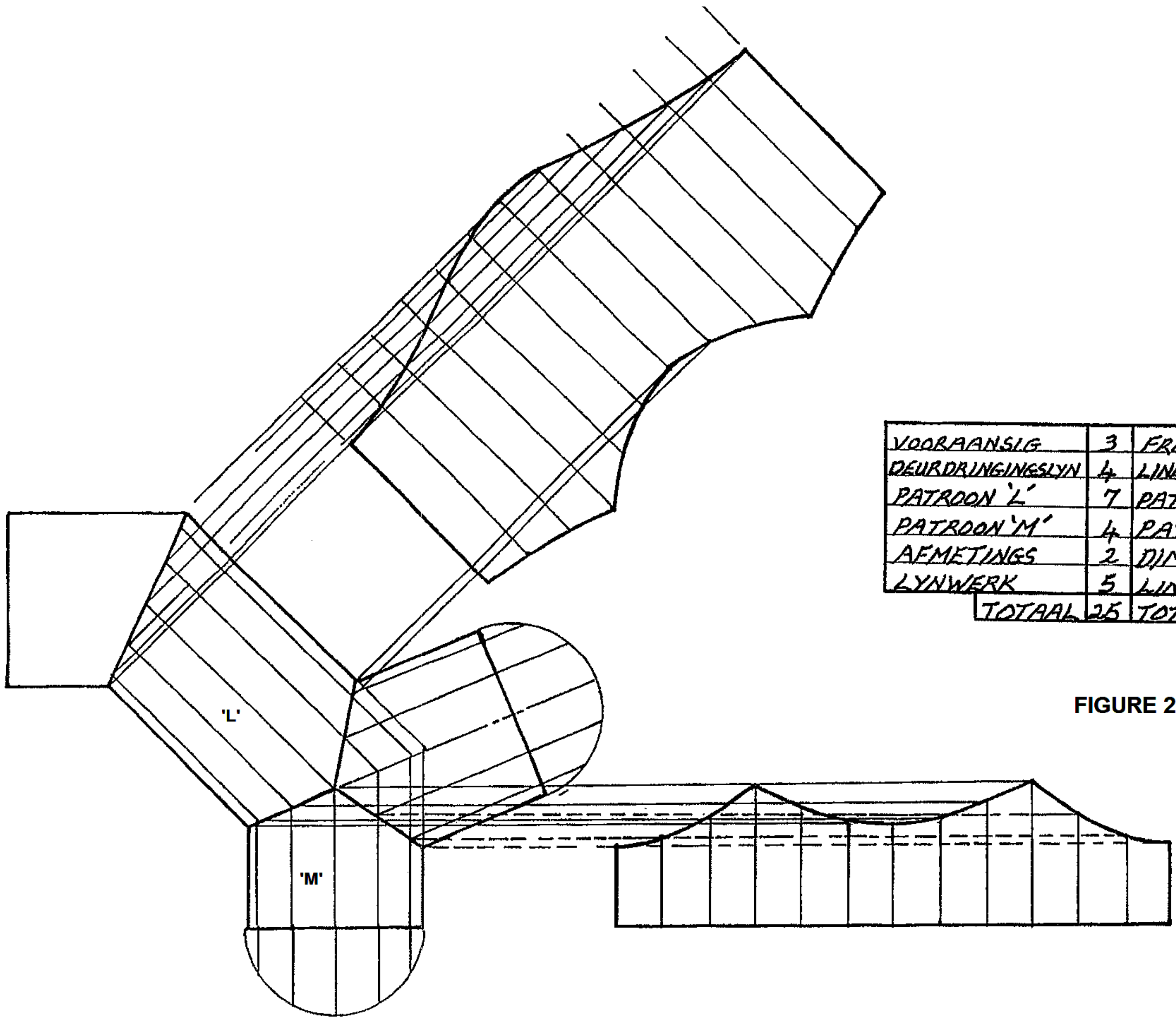




FIGURE 1

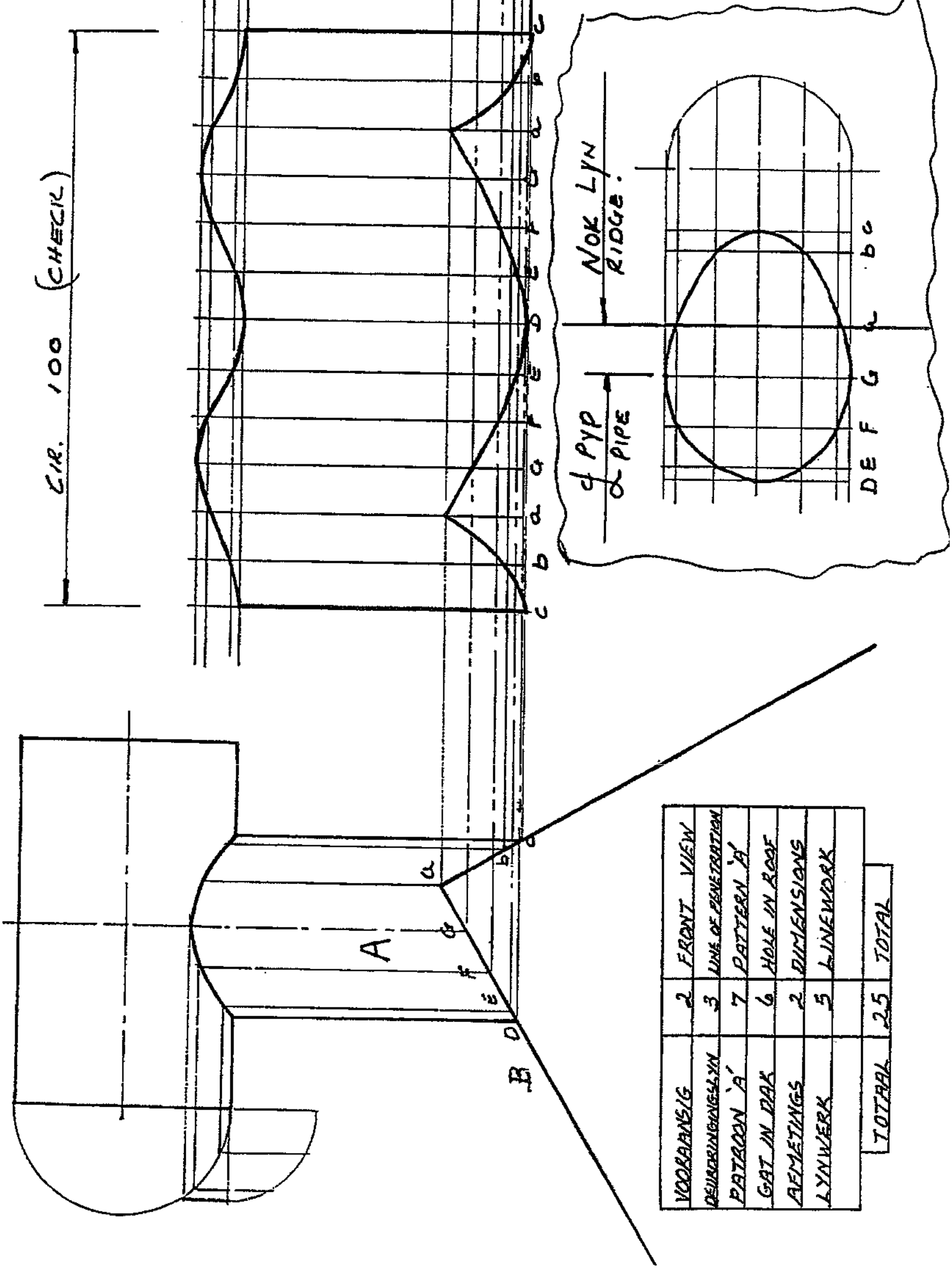
| | | |
|---|---|---|
| VOORAANSIG | 2 | FRONT VIEW |
| PATROON 'L' | 10 | PATTERN 'L' |
| PATROON 'M' | 6 | PATTERN 'M' |
| AFMETINGS | 2 | DIMENSIONS |
| LYNWERK | 5 | LINEWORK |
| | 25 | |



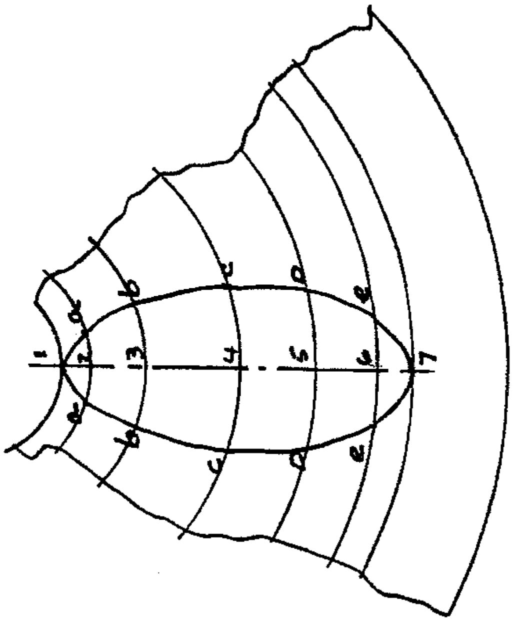

| | | |
|---|---|---|
| VOORAANSIG | 3 | FRONT VIEW |
| DEURDRINGINGSLYN | 4 | LINE OF PENETRATION |
| PATROON 'L' | 7 | PATTERN 'L' |
| PATROON 'M' | 4 | PATTERN 'M' |
| AFMETINGS | 2 | DIMENSIONS |
| LYNWERK | 5 | LINEWORK |
| TOTAAL | 25 | TOTAL |

FIGURE 2

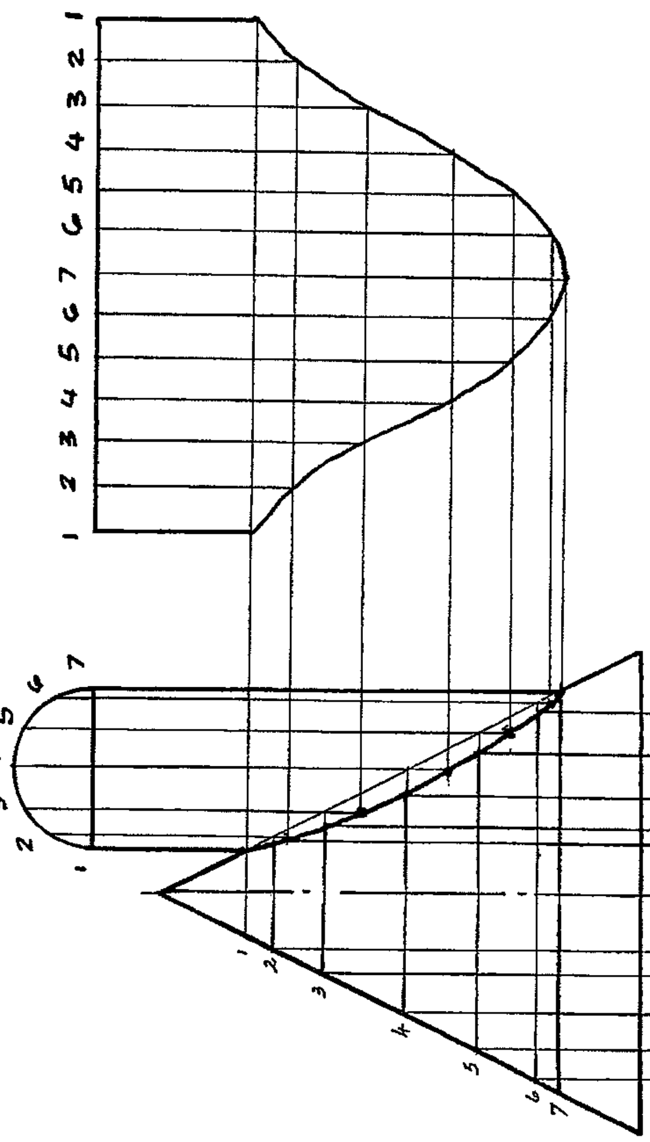
FIGURE 3




| | | |
|---|---|---|
| VOORAANSIG | 2 | FRONT VIEW |
| DEURDRINGINGSLYN | 3 | LINE OF PENETRATION |
| PATROON 'A' | 7 | PATTERN 'A' |
| GAT IN DAK | 6 | HOLE IN ROOF |
| AFMETINGS | 2 | DIMENSIONS |
| LYNWERK | 5 | LINEWORK |
| TOTAL | 25 | TOTAL |



| | | |
|---|---|---|
| VOORAANSIG | 1 | FRONT VIEW |
| BOAANSIG | 1 | TOP VIEW |
| PENETRASIEKROMME | 4 | LINE OF PENETRATION |
| PATROON 'SILINDER' | 6 | PATTERN 'CYLINDER' |
| PATROON 'GAT' | 6 | PATTERN 'HOLE' |
| AFMETINGS | 2 | DIMENSIONS |
| LYNWERK | 5 | LINEWORK |
| | 25 | |



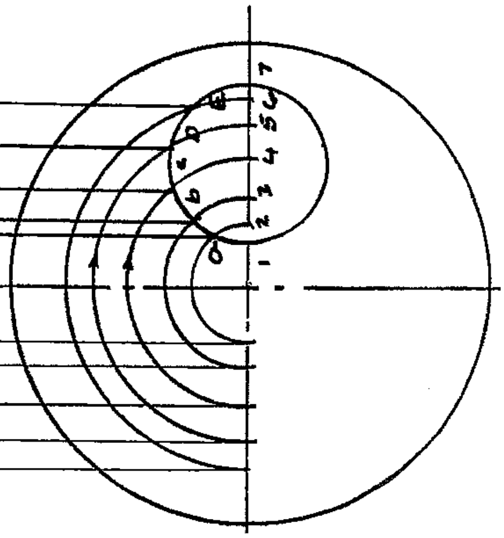


**FIGURE 4**

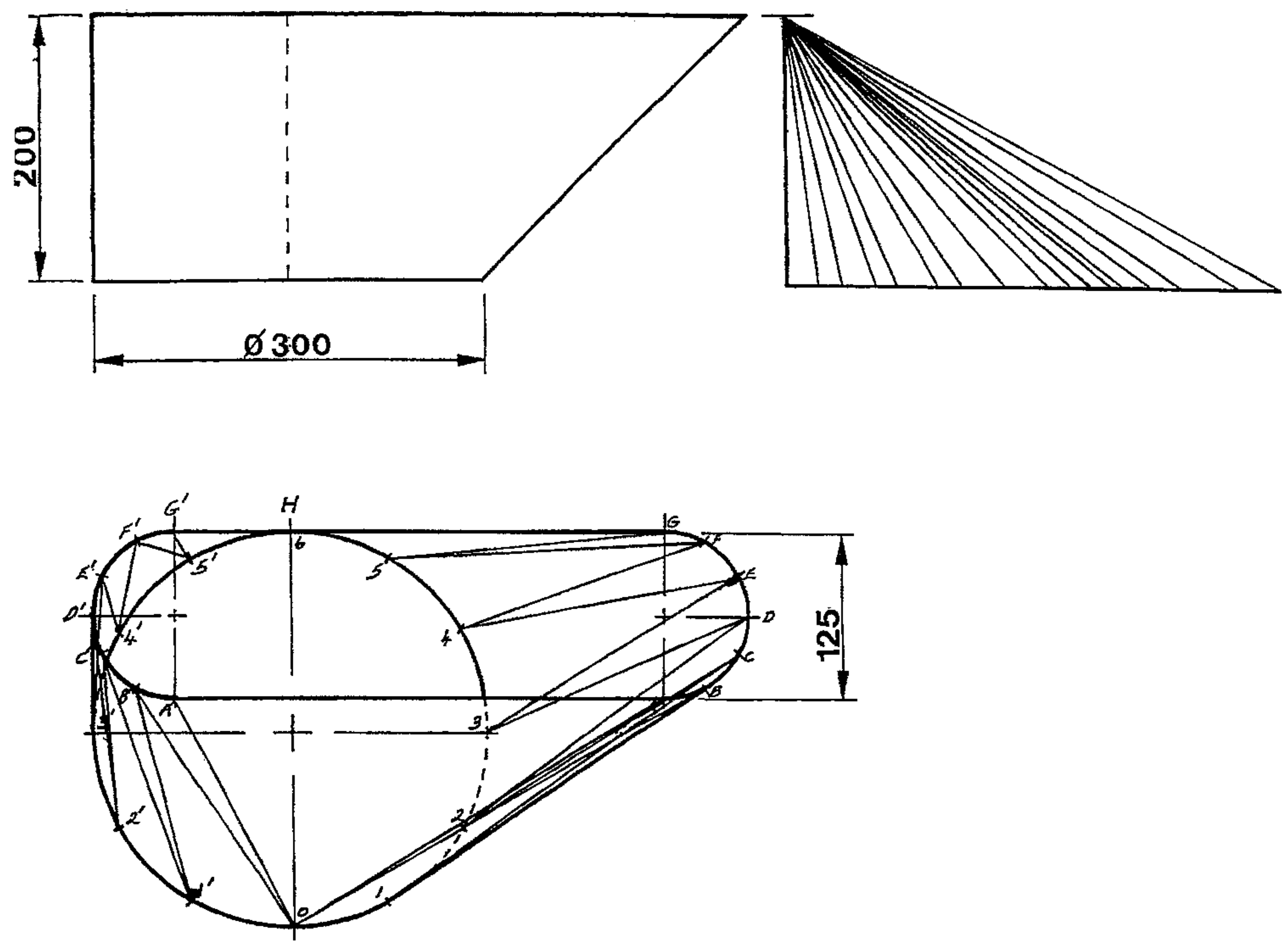
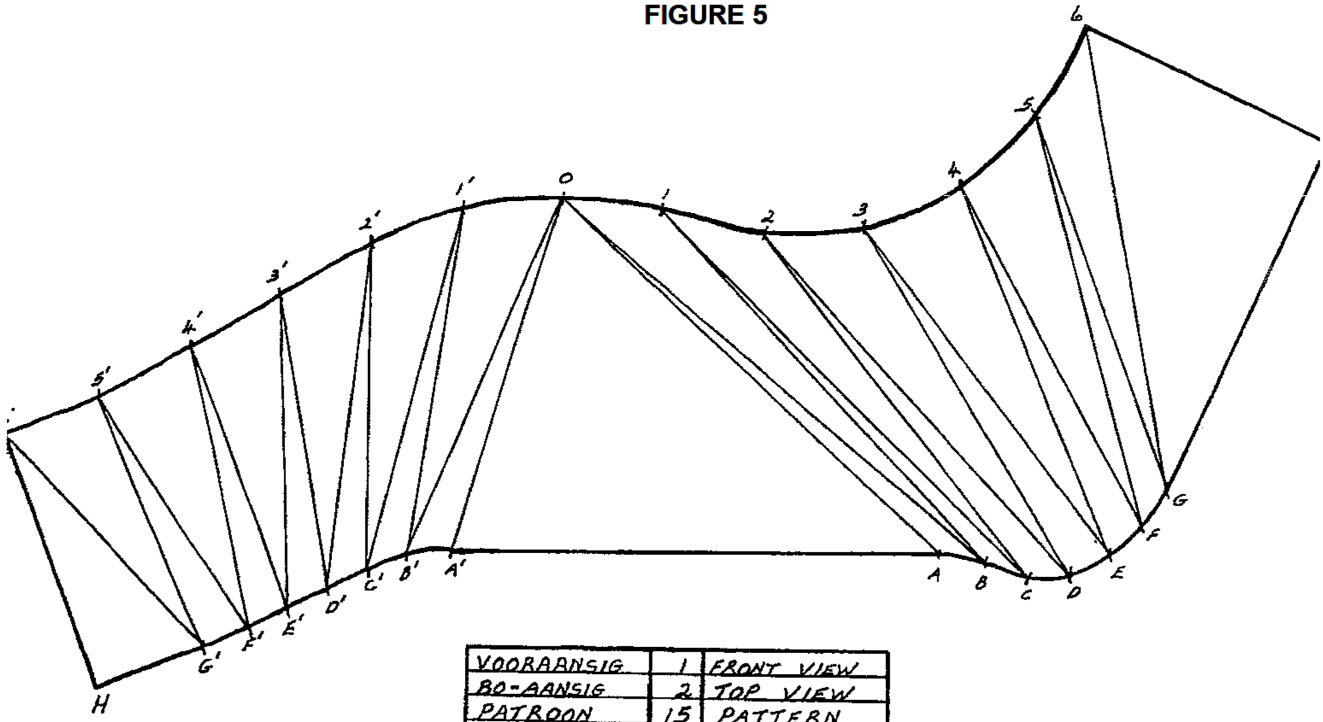
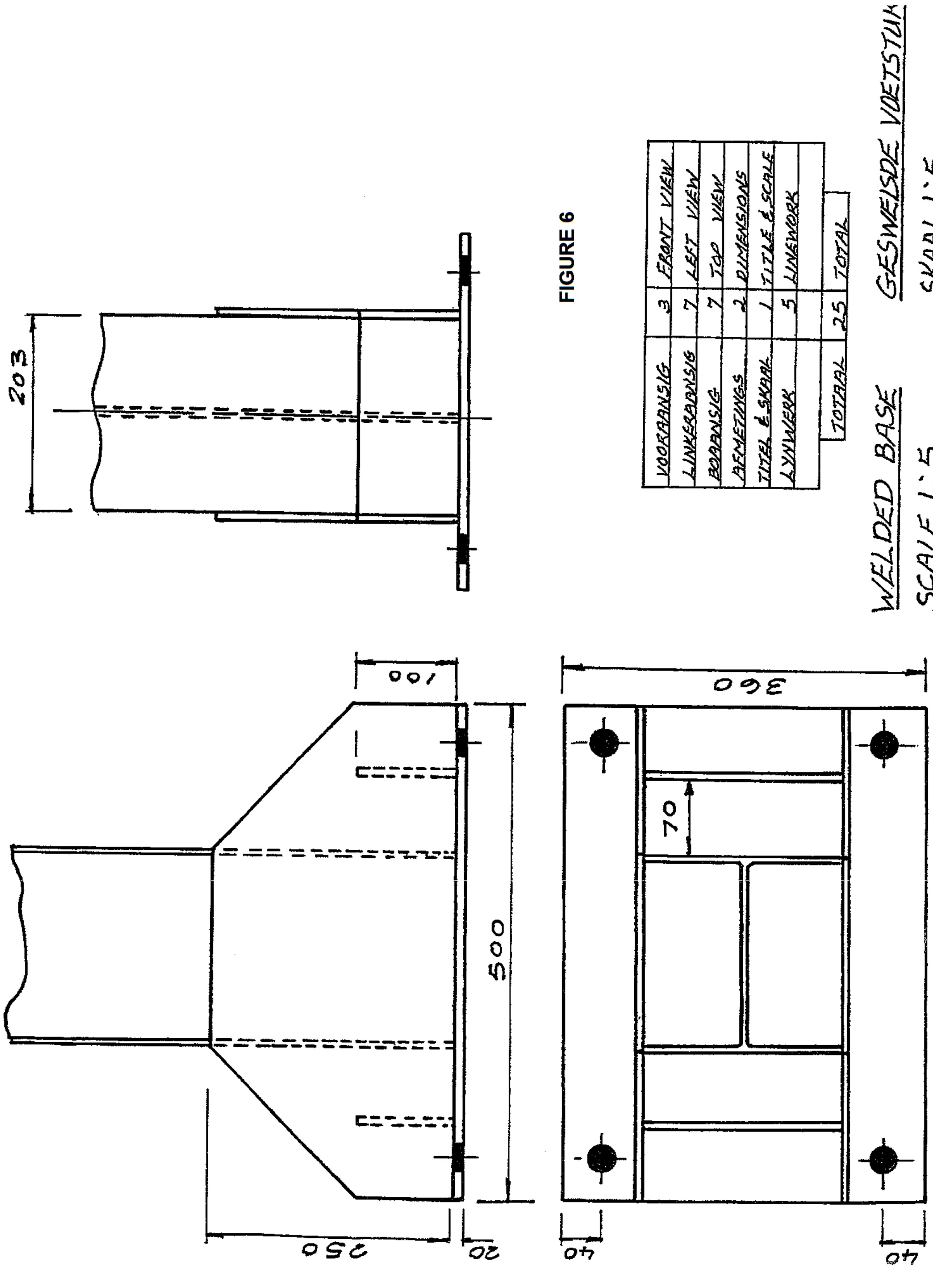



**FIGURE 5**




| | | |
|---|---|---|
| VOORAANSIG | 1 | FRONT VIEW |
| BO-AANSIG | 2 | TOP VIEW |
| PATROON | 15 | PATTERN |
| LYNWERK | 5 | LINEWORK |
| AFMETINGS | 2 | DIMENSIONS |
| TOTAAL | 25 | TOTAL |




| | | |
|---|---|---|
| VOORAANSIG | 3 | FRONT VIEW |
| LINKERAANSIG | 7 | LEFT VIEW |
| BOBAANSIG | 7 | TOP VIEW |
| AFMETINGS | 2 | DIMENSIONS |
| TITEL & SKAAL | 1 | TITLE & SCALE |
| LYNWERK | 5 | LINEWORK |
| TOTAAL | 25 | TOTAL |

FIGURE 6

# Past Examination Papers

higher education & training

Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

**APRIL 2011**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

(**8090102**)

**(X-Paper)**
**09:00 – 13:00**

**REQUIREMENTS:**

**One sheet of A-2 drawing paper**

**Calculators may be used.**

**This question paper consists of 4 pages and 2 diagram sheets.**

**TIME: 4 HOURS**
**MARKS: 100**

**NOTE:** If you answer more than the required number of questions, only the required number of questions will be marked. All work you do not want to be marked, must be clearly crossed out.

**INSTRUCTIONS AND INFORMATION**

1. Answer any **FOUR** questions.
2. Read ALL the questions carefully.
3. ALL the construction lines MUST be shown.
4. Do **TWO** questions on the FRONT and **TWO** questions on the REVERSE side of the DRAWING SHEET.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Add dimensions to the answers.
7. Write neatly and legibly.

**QUESTION 1**

FIGURE 1, **DIAGRAM SHEET 1** (attached), shows a twisted rectangular duct with a round corner. Draw the given views and develop the shape of the plate for the duct.

SCALE 1:1

**[25]**

**QUESTION 2**

FIGURE 2, **DIAGRAM SHEET 1** (attached), shows an oblique T-piece with a square branch pipe.

2.1 Draw the given views.

2.2 Develop the pattern for the branch pipe 'A'.

2.3 Develop the shape of the hole in the main pipe '8'.

SCALE 1:2

**[25]**

**QUESTION 3**

FIGURE 3, **DIAGRAM SHEET 1** (attached), shows an intersection between a right cone and a cylindrical pipe.

3.1 Draw the given view.

3.2 Determine the line of penetration.

3.3 Develop the pattern for the right cone.

SCALE 1:2

**[25]**

**QUESTION 4**

FIGURE 4, **DIAGRAM SHEET 2** (attached), shows the front and top views of a pyramidal cover. Draw the **TWO** views and develop the pattern of the plate for the pyramidal cover.

SCALE 1:1

**[25]**

**QUESTION 5**

FIGURE 5, **DIAGRAM SHEET 2** (attached), shows part of a rectangular tank fitted with an oblique pipe at an angle of $60°$ to the horizontal. Draw the given view and develop the following:

5.1 The pattern of the oblique pipe

5.2 The true shape of the hole as seen in the direction of T-T

SCALE 1:2

**[25]**

**QUESTION 6**

FIGURE 6, **DIAGRAM SHEET 2** (attached), shows the following parts of a column base:

| | | |
|---|---|---|
| Item 1 | Column 356 x 171 !-section | 1 off |
| Item 2 | Base plate 600 x 560 x 16 mm | 1 off |
| Item 3 | Side plate 500 x 300 x 10 mm (shaped) | 2 off |
| Item 4 | Side angle 150 x 90 x 10 mm angle iron | 2 off |

Draw an assembly drawing in first-angle orthographic projection of the following views:

6.1 The top view with the flange of the column in view

6.2 The top view

Print the title 'COLUMN BASE' and scale centrally beneath the views and insert the projection symbol.

SCALE 1:5

**[25]**

**TOTAL:100**

## APRIL 2011

## DIAGRAM SHEET 1

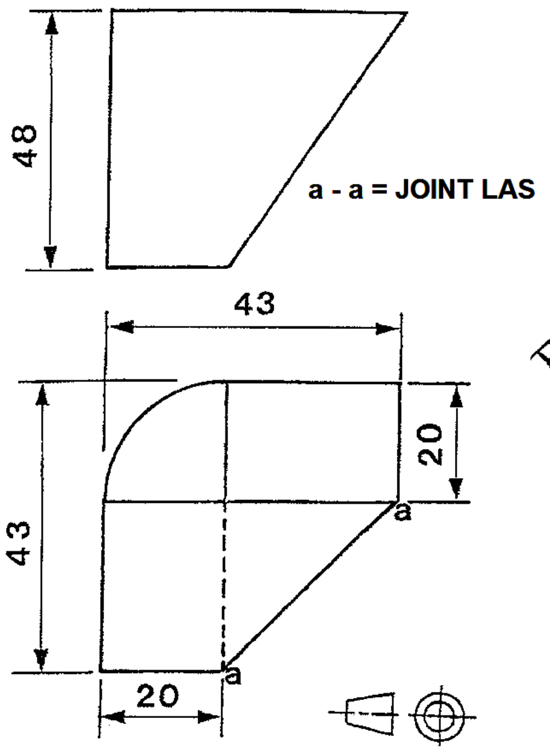



FIGURE 1

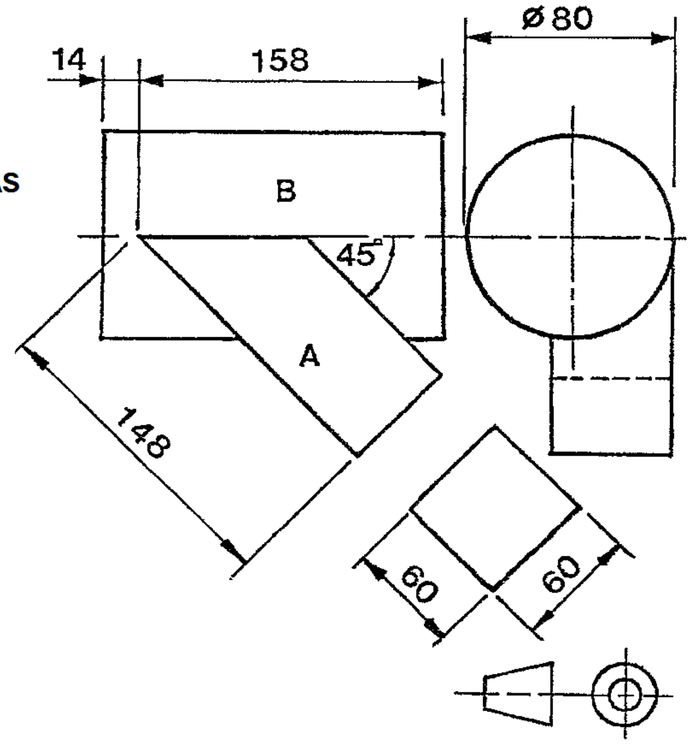



FIGURE 2

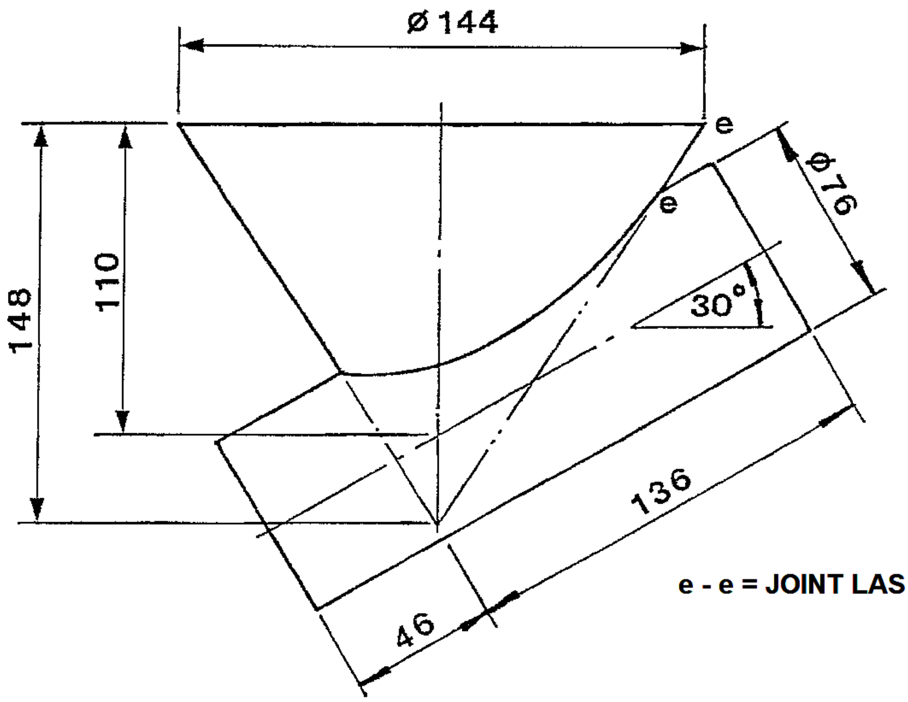



FIGURE 3

**APRIL 2011**

## DIAGRAM SHEET 2

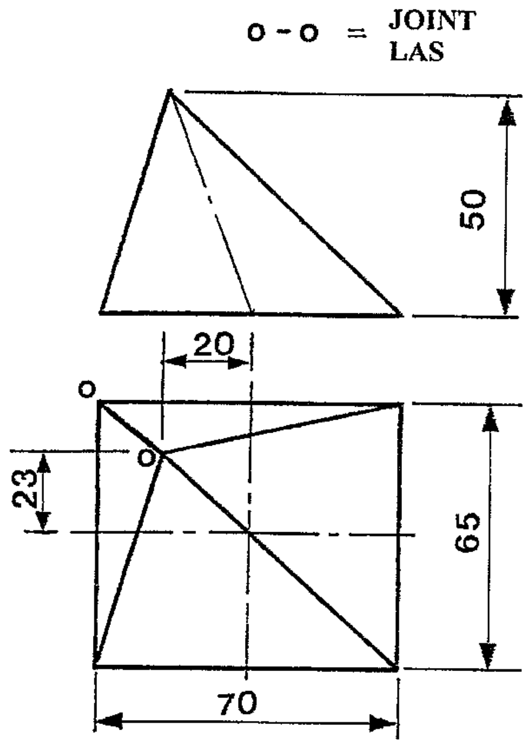



**FIGURE 4**

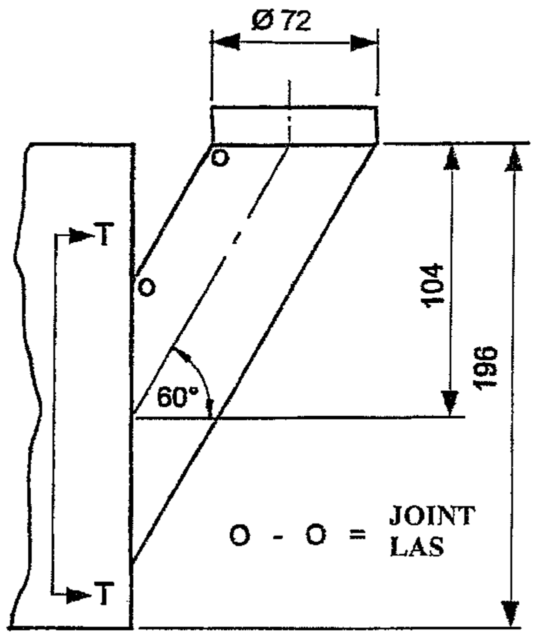



**FIGURE 5**

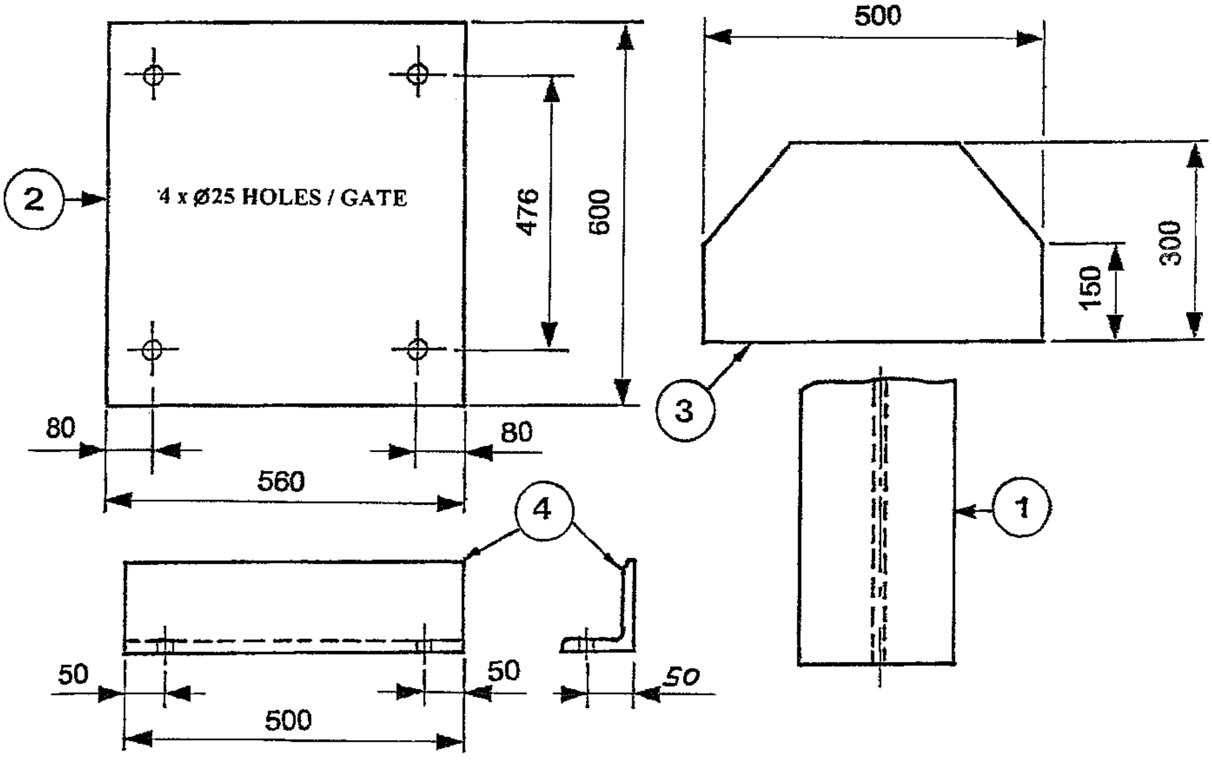



**FIGURE 6**

# Marking Guidelines

higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

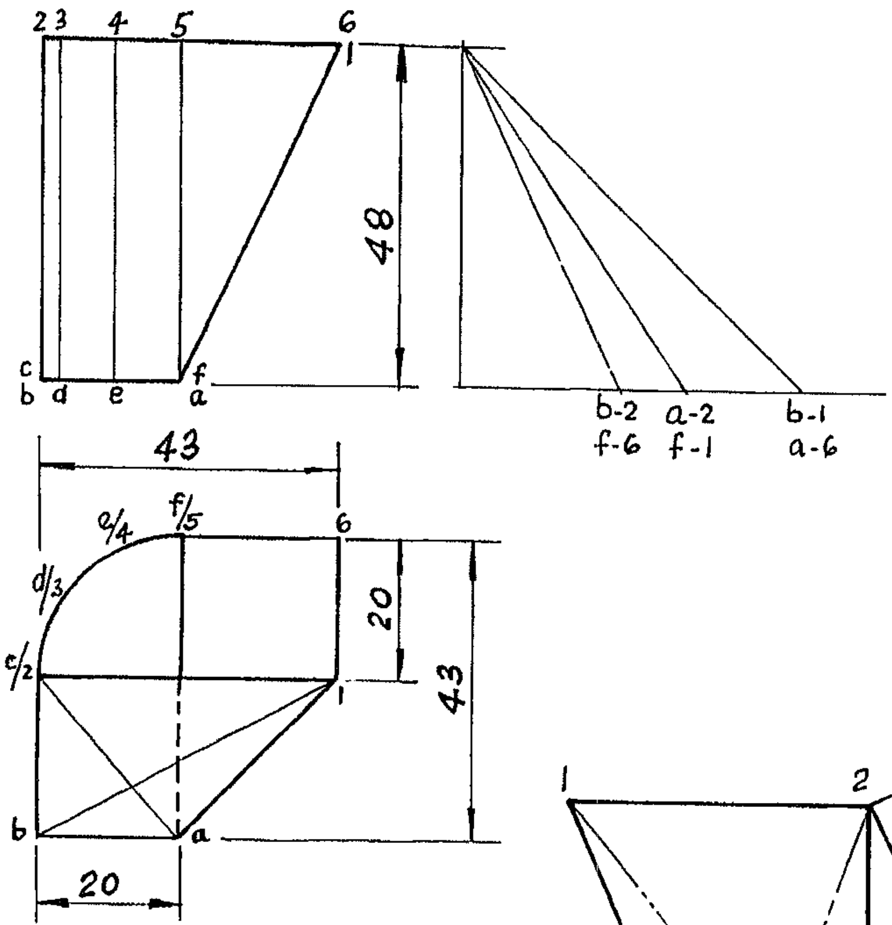
**APRIL 2011**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

(**8090102**)

**(X-Paper)**
**09:00 – 13:00**




| FRONT VIEW | 1 | VOORAANSIG |
|---|---|---|
| TOP VIEW | 1 | BOAANSIG |
| DEVELOPMENT | 18 | ONTWIKKELING |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |

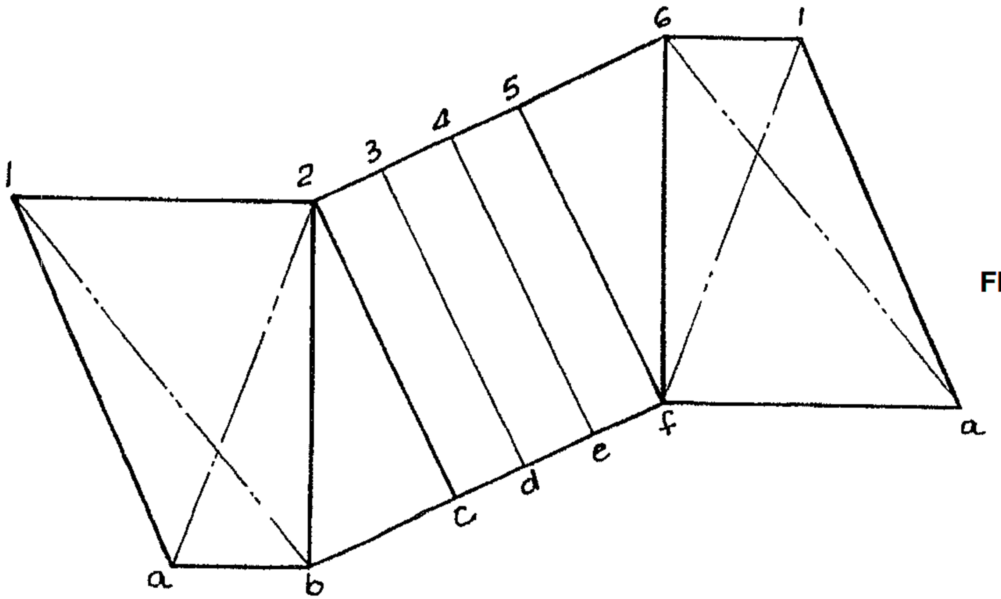



**FIGURE 1**

| | | |
|---|---|---|
| FRONT VIEW | 2 | VOORAANSIG |
| LEFT VIEW | 2 | LINKERAANSIG |
| DEVELOPMENT 'A' | 8 | ONTWIKKELING 'A' |
| HOLE IN 'B' | 8 | GAT IN 'B' |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |

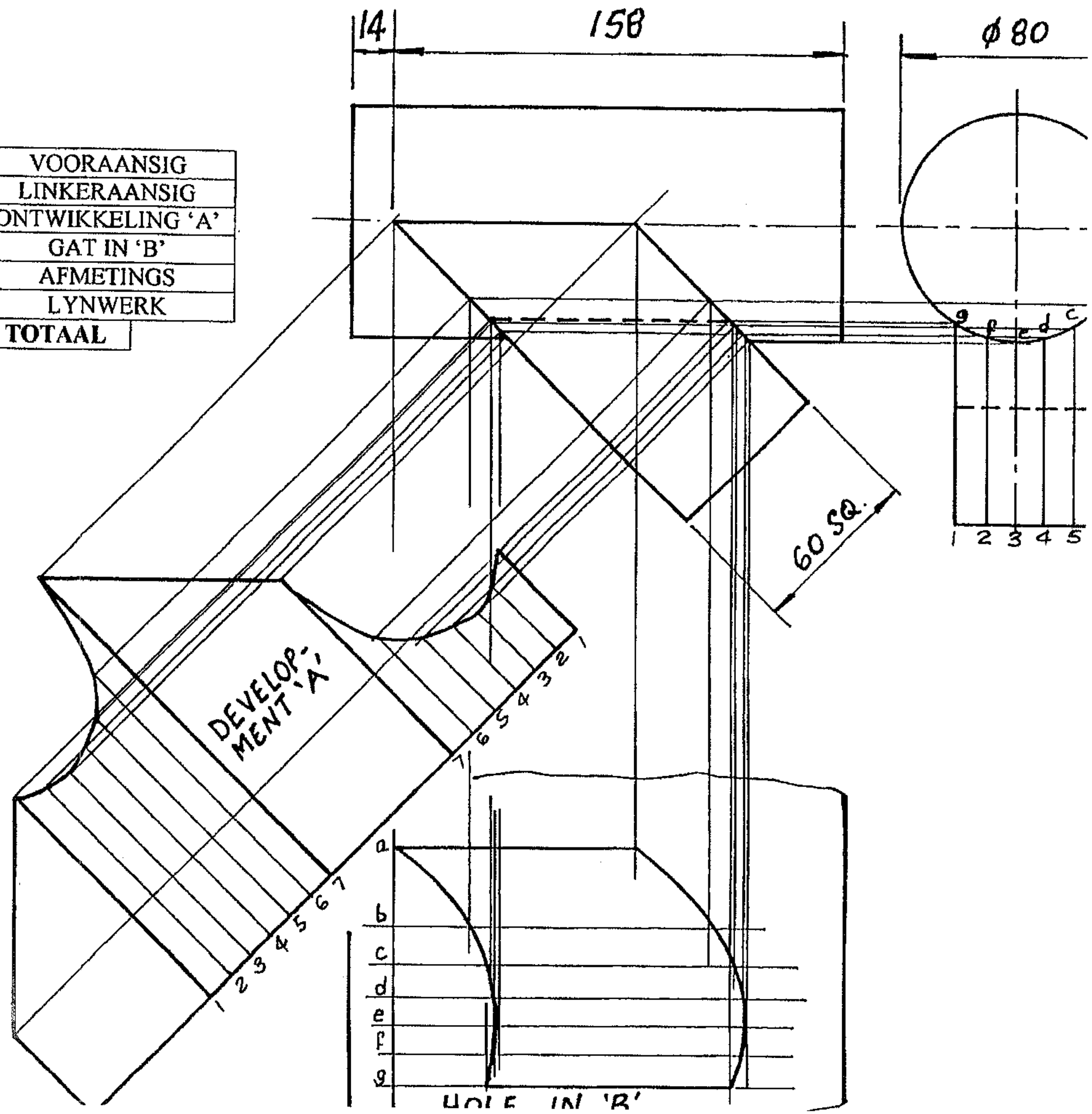
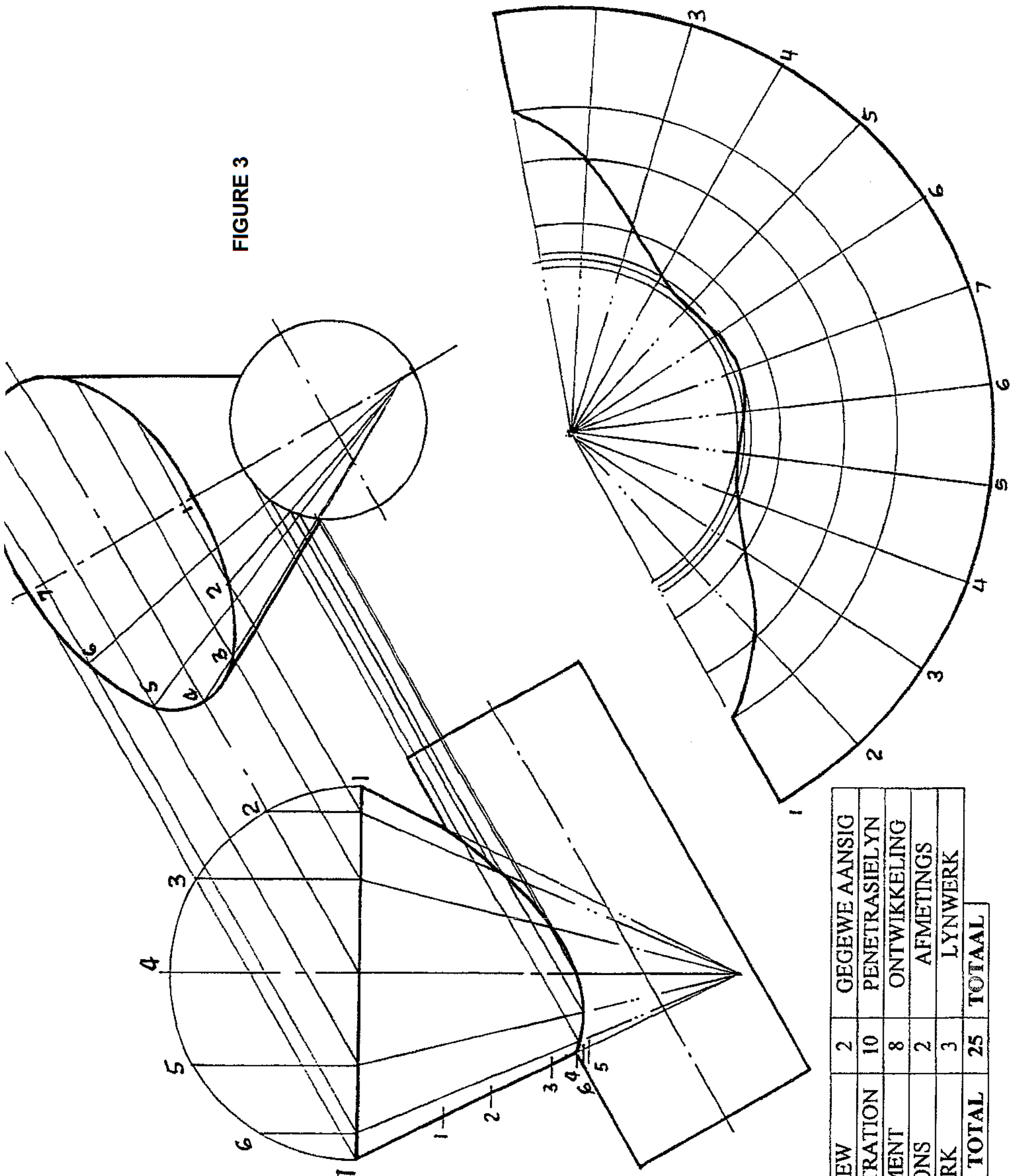



**FIGURE 2**

FIGURE 3




| | | |
|---|---|---|
| GIVEN VIEW | 2 | GEGEWE AANSIG |
| LINE OF PENETRATION | 10 | PENETRASIELYN |
| DEVELOPMENT | 8 | ONTWIKKELING |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| TOTAL | 25 | TOTAAL |

| | | |
|---|---|---|
| GIVEN VIEWS | 3 | GEGEWE AANSIGTE |
| PATTERN | 17 | PATROON |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| TOTAL | 25 | TOTAAL |

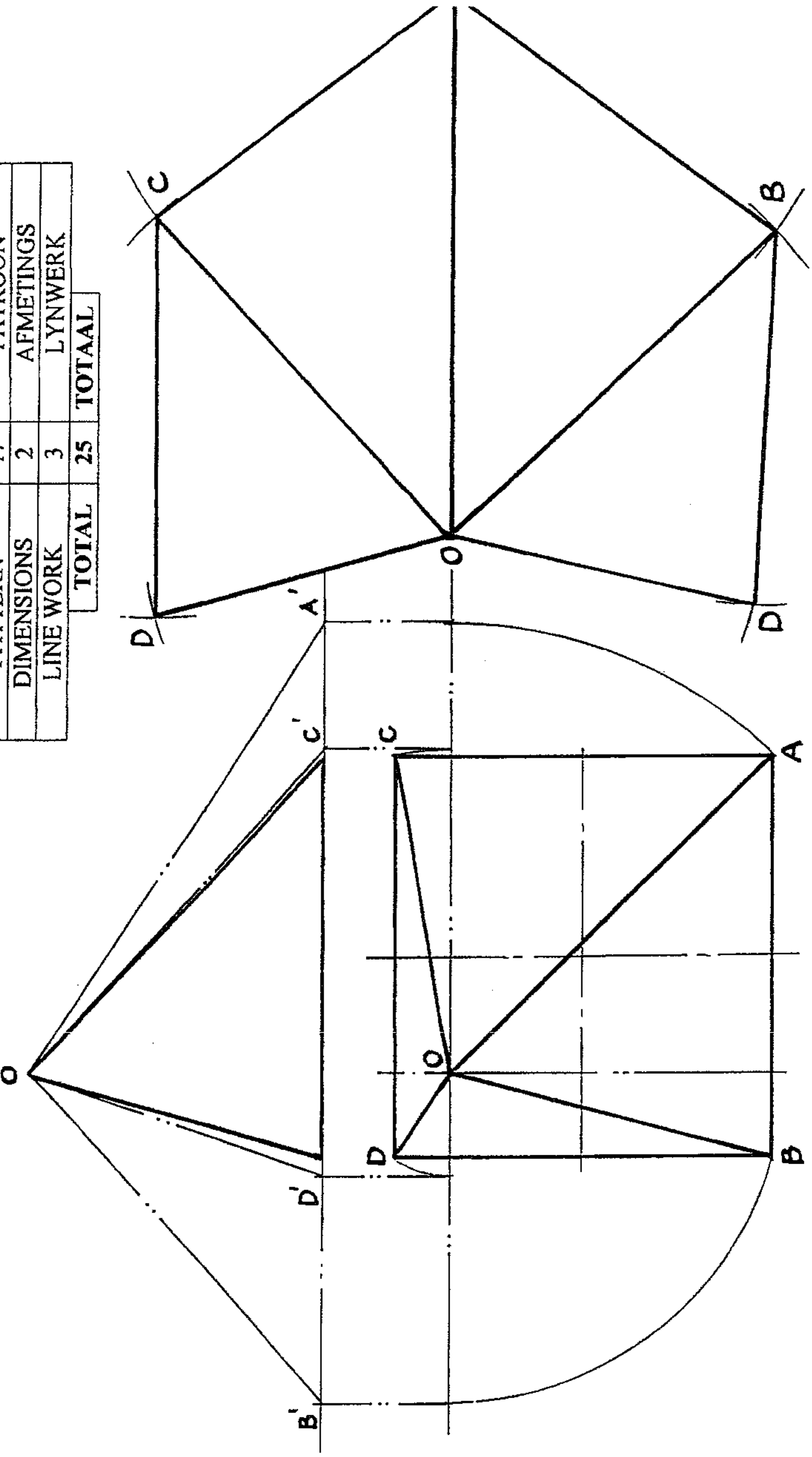
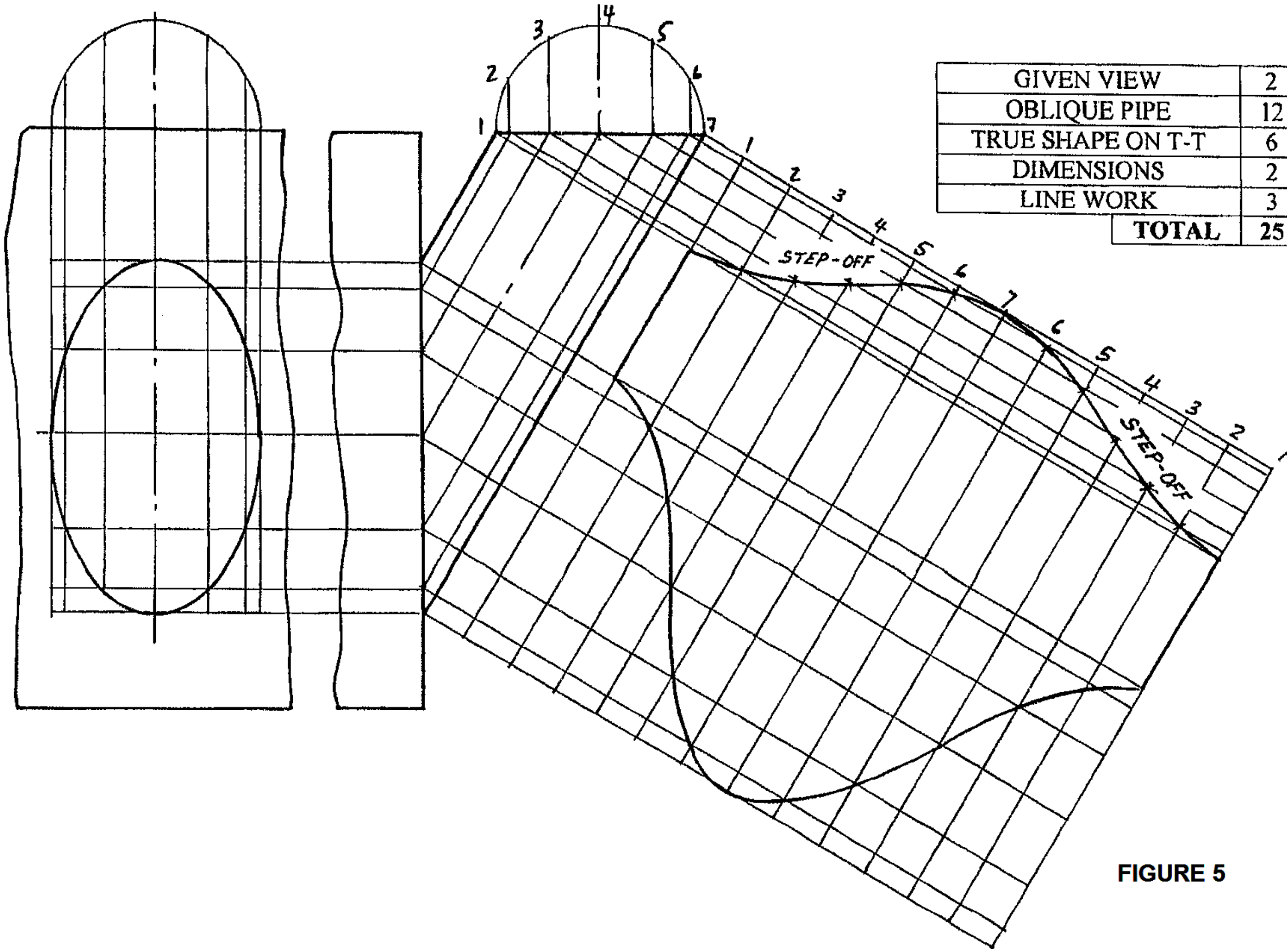



FIGURE 4




| | | |
|---|---|---|
| GIVEN VIEW | 2 | GEGEWE AANSIG |
| OBLIQUE PIPE | 12 | SKUINSPYP |
| TRUE SHAPE ON T-T | 6 | WARE FATSOEN OP T-T |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |

FIGURE 5

| | |
|---|---|
| FRONT VIEW | 8 |
| TOP VIEW | 9 |
| TITLE AND SCALE | 2 |
| PROJECTION SYMBOL | 1 |
| DIMENSIONS | 2 |
| LINE WORK | 3 |
| **TOTAL** | **25** |

| | |
|---|---|
| 8 | VOORAANSIG |
| 9 | BOAANSIG |
| 2 | TITEL EN SKAAL |
| 1 | PROJEKSIESIMBOOL |
| 2 | AFMETINGS |
| 3 | LYNWERK |
| **25** | **TOTAAL** |

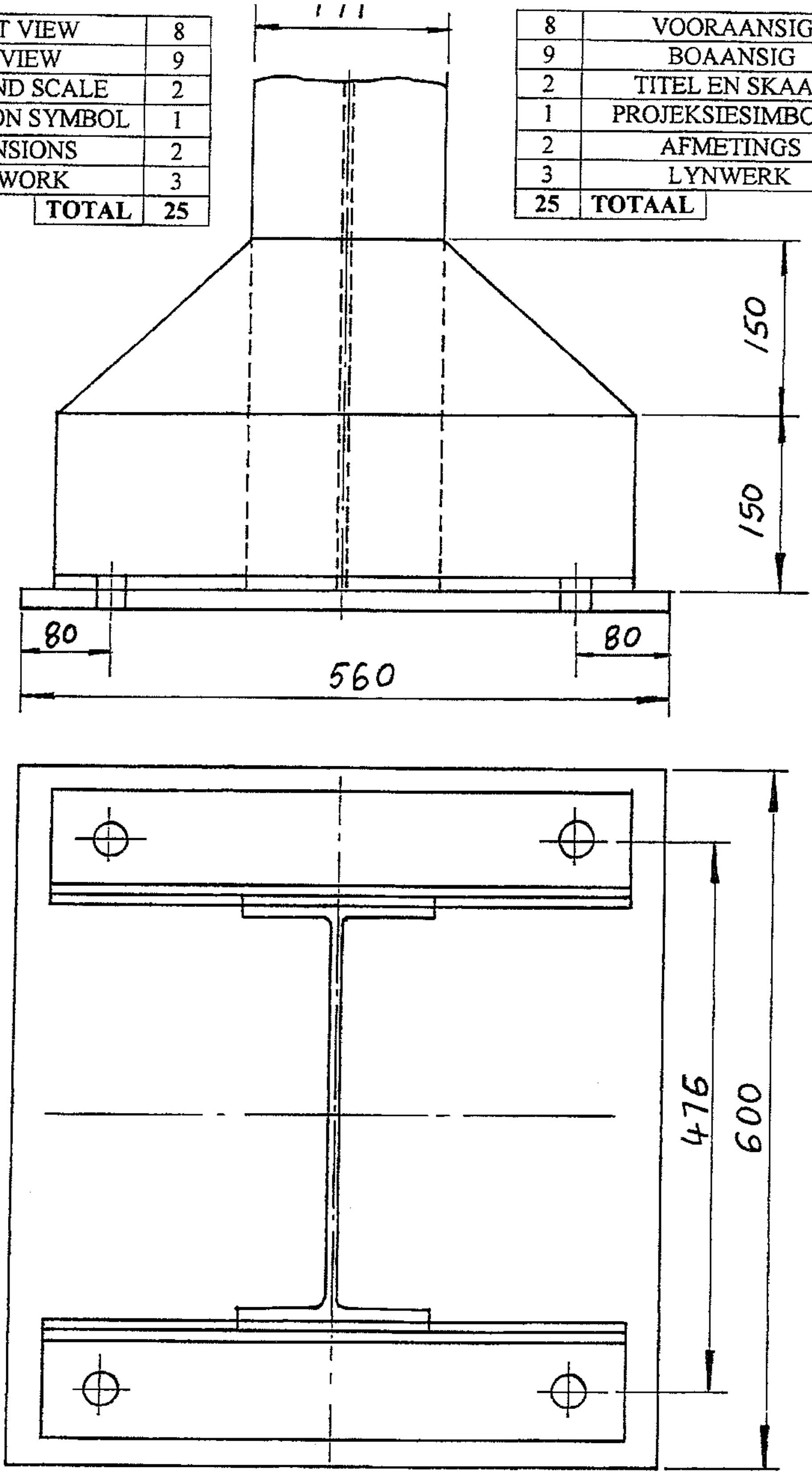
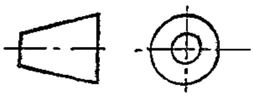



**FIGURE 6**

COLUMN BASE

SCALE 1:5



# Past Examination Papers

higher education & training

Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

**NOVEMBER 2011**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

(**8090102**)

**(X-Paper)**
**09:00 – 13:00**

**REQUIREMENTS:**

**One sheet of A2 drawing paper**

**Calculators may be used.**

**This question paper consists of 4 pages and 3 diagram sheets.**

**TIME: 4 HOURS**
**MARKS: 100**

---

**NOTE:** If you answer more than the required number of questions, only the required number of questions will be marked. All work you do not want to be marked must be clearly crossed out.

**INSTRUCTIONS AND INFORMATION**

1. Answer any **FOUR** questions.
2. Read ALL the questions carefully.
3. Number the answers correctly according to the numbering system used in this question paper.
4. ALL the construction lines MUST be shown.
5. Answer **TWO** questions on the front and **TWO** questions on the reverse side of the drawing sheet.
6. Add dimensions to the answers.
7. Write neatly and legibly.

---

**QUESTION 1**

FIGURE 1, **DIAGRAM SHEET 1** (attached), shows a T-piece made of unequal diameter cylindrical pipes. Draw the given views and do the following:

1.1 Determine the line of penetration

1.2 Develop the pattern for the branch pipe marked 'B'

1.3 Develop the shape of the hole in the main pipe marked 'M'

SCALE 1:2

**[25]**

**QUESTION 2**

FIGURE 2, **DIAGRAM SHEET 1** (attached), shows two views of a rectangular-to-round transformer. Draw the **TWO** views and develop the pattern for the transformer.

SCALE 1:5

**[25]**

**QUESTION 3**

FIGURE 3, **DIAGRAM SHEET 2** (attached), shows an intersection between a cone and a triangular pipe. Do the following:

3.1 Draw the given views

3.2 Determine the line of penetration

3.3 Draw the pattern of the plate for the triangular pipe

3.4 Develop the shape of the hole in the cone

SCALE 1:1

**[25]**

**QUESTION 4**

FIGURE 4, **DIAGRAM SHEET 2** (attached), shows a lobster back bend with a horizontal inlet pipe of equal diameters. Draw the given view and do the following:

4.1 Determine the line of penetration

6.1 Develop the pattern for the segment marked 'B'

4.3 Develop the pattern for the horizontal inlet pipe marked 'C'

SCALE 1:2

**[25]**

**QUESTION 5**

FIGURE 5, **DIAGRAM SHEET 3** (attached), shows a truncated conical hopper with a vertical down pipe.

5.1 Draw the given view

5.2 Develop the pattern of the plate for the hopper 'H'

5.3 Develop the pattern of the plate for the down pipe 'P'

SCALE 1:

**[25]**

**QUESTION 6**

FIGURE 6, **DIAGRAM SHEET 3** (attached), shows the front view of a welded stanchion connection. One 1-beam and a gusset plate are welded to the web of the Rolled Steel Joist (R.S.J.) on the nearside only as indicated.

One 1-beam and a gusset plate, on the centre line, are welded to each flange of the Rolled Steel Joist (R.S.J.). Draw in first- angle orthographic projection the following:

6.1 The given front view

6.2 The left view

6.3 The top view

Print the title 'WELDED STANCHION CONNECTION' and the scale· centrally beneath the top view.

MATERIAL:

| | | |
|---|---|---|
| Item 1 | 350 X 150 R.S.J. 400 mm long required | 1 off |
| Item 2 | 200 x 1 00 1-Beam 200 mm long required | 3 off |
| Item 3 | 125 x 125 Gusset plate 15 mm thick plate required | 3 off |

SCALE 1:5 **[25]**

**TOTAL: 100**

## NOVEMBER 2011

### DIAGRAM SHEET 1

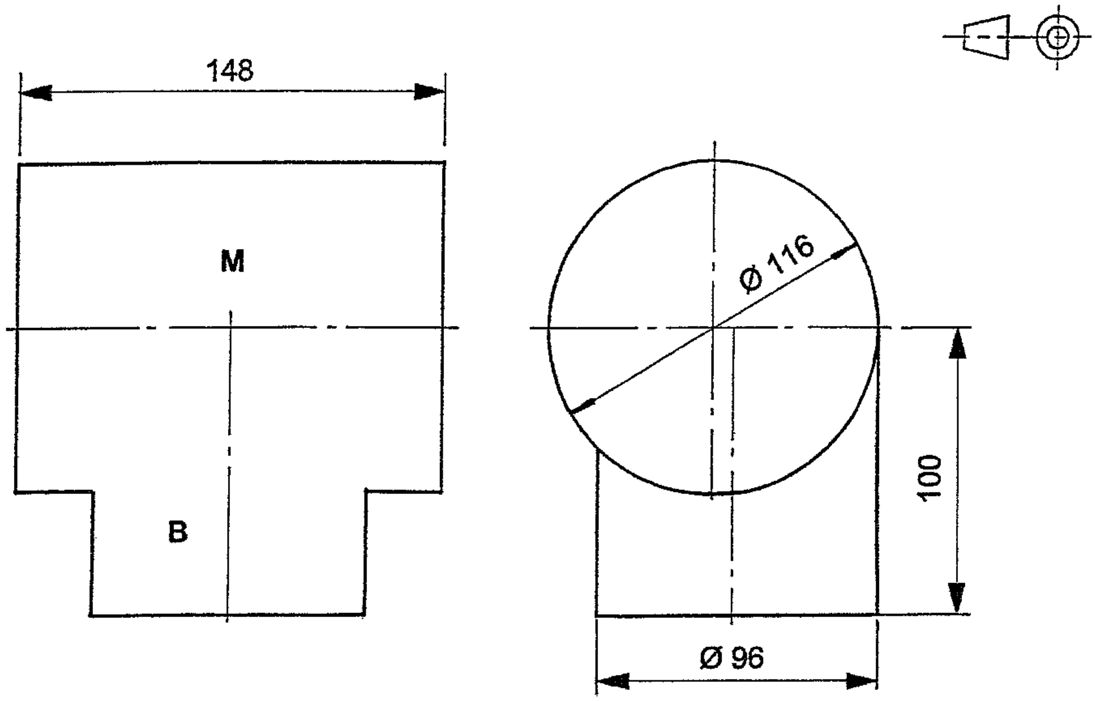



**FIGURE 1**

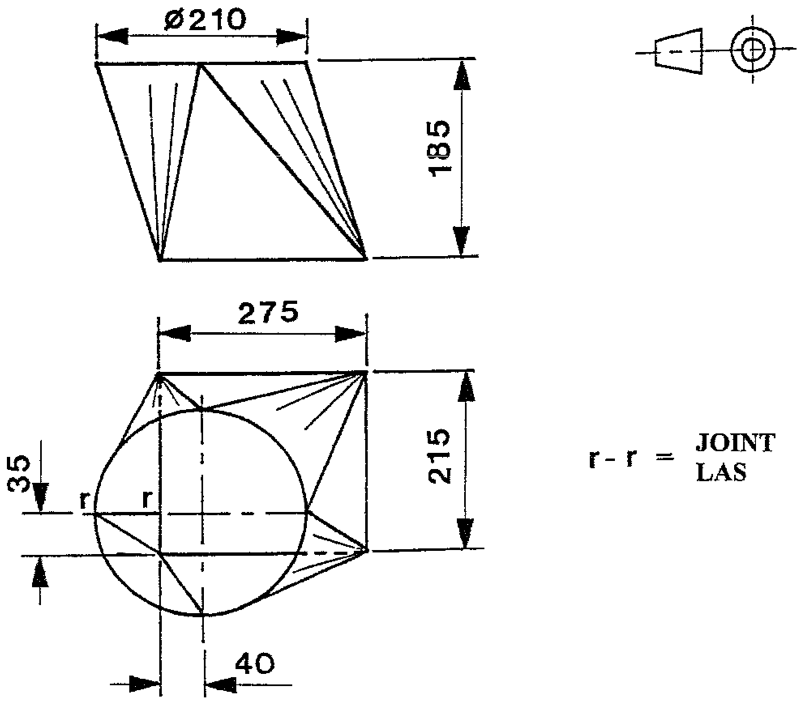



**FIGURE 2**

**NOVEMBER 2011**

**DIAGRAM SHEET 2**

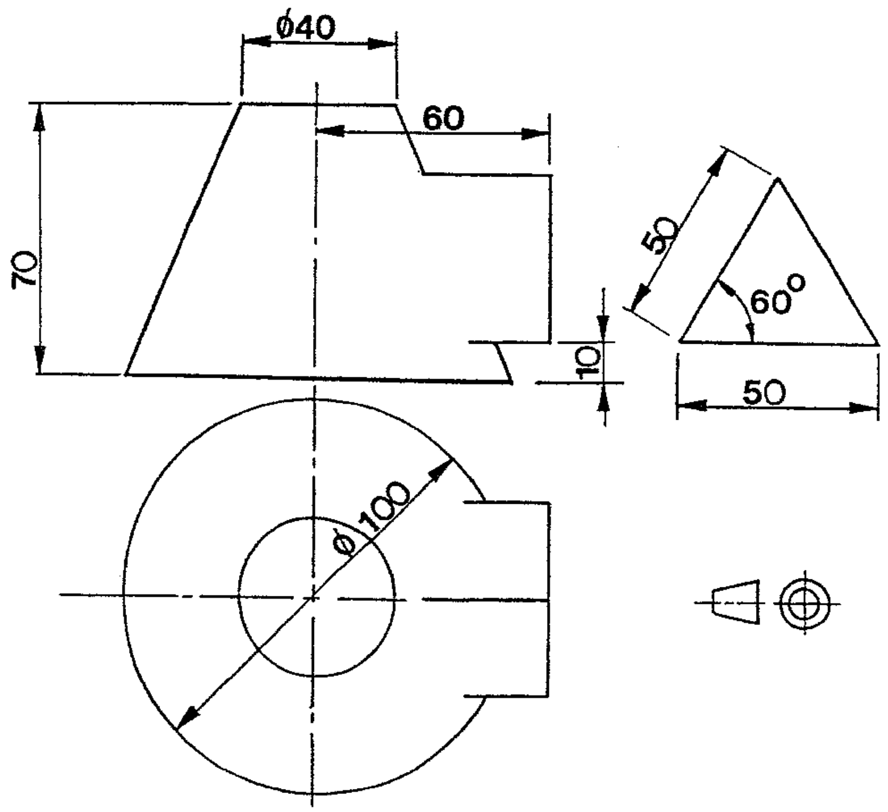



**FIGURE 3**

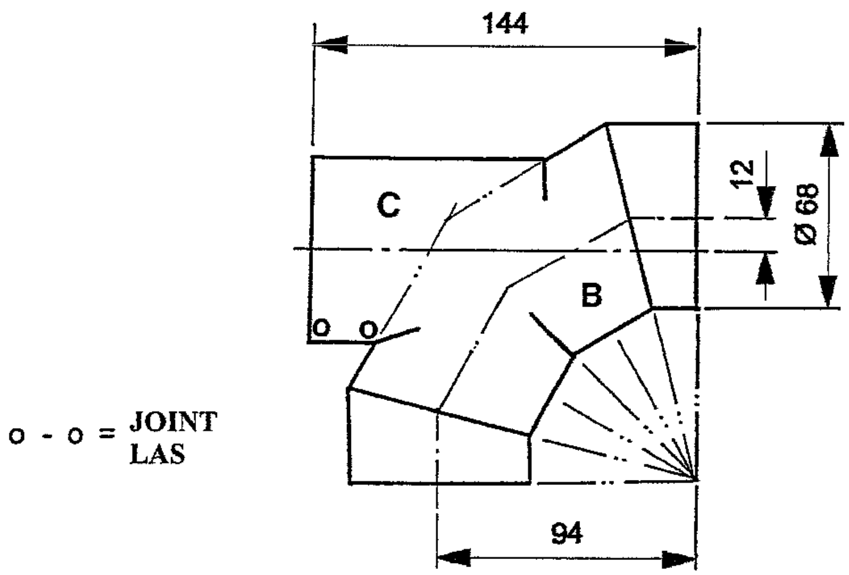



**FIGURE 4**

**NOVEMBER 2011**

**DIAGRAM SHEET 3**

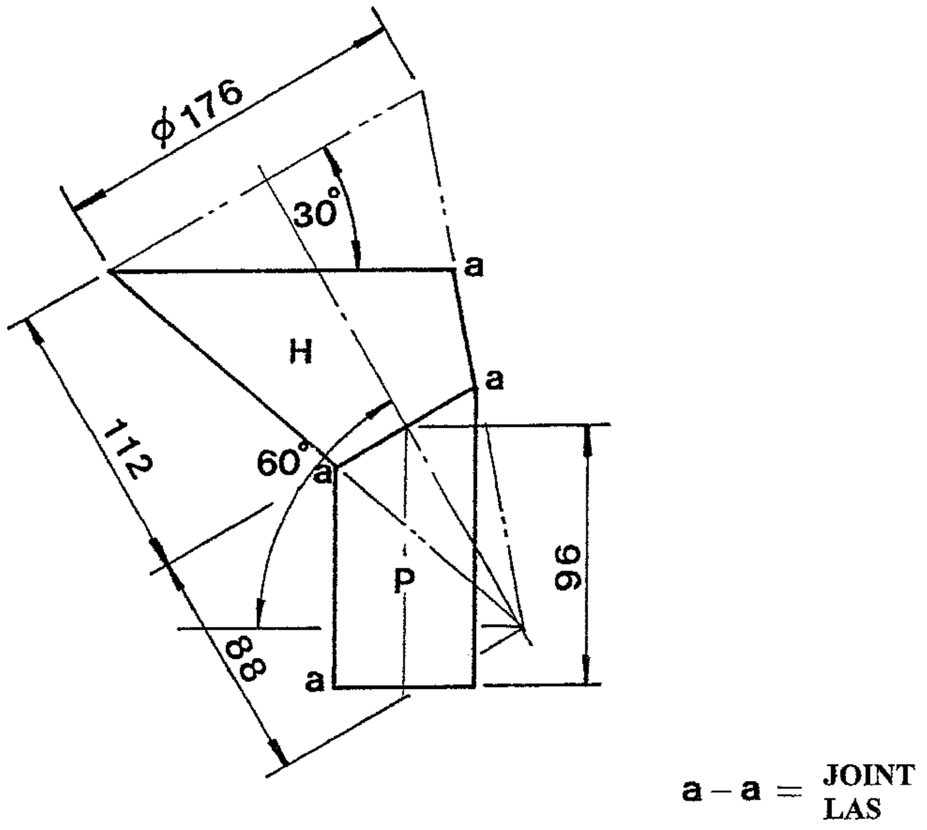



**FIGURE 5**

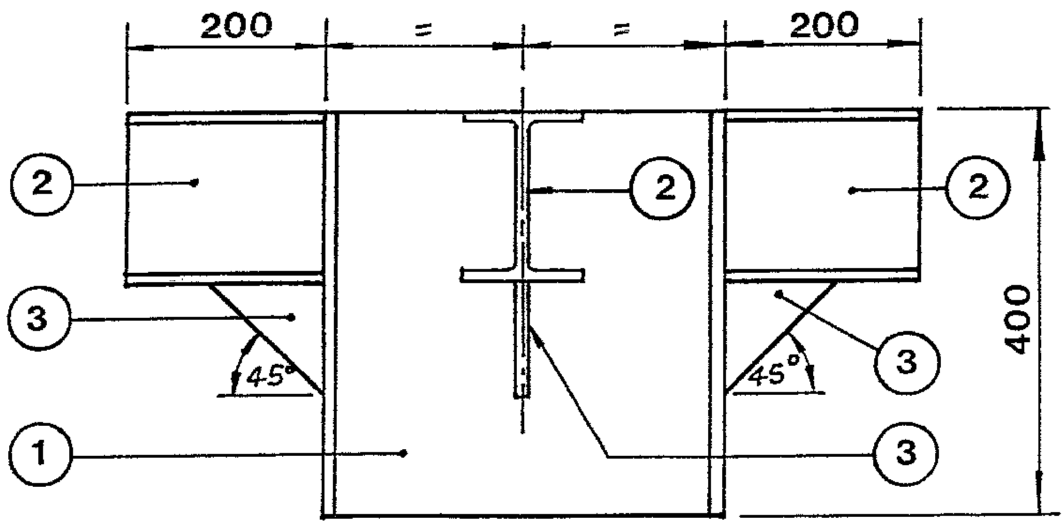



**FIGURE 6**

# Marking Guidelines

higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

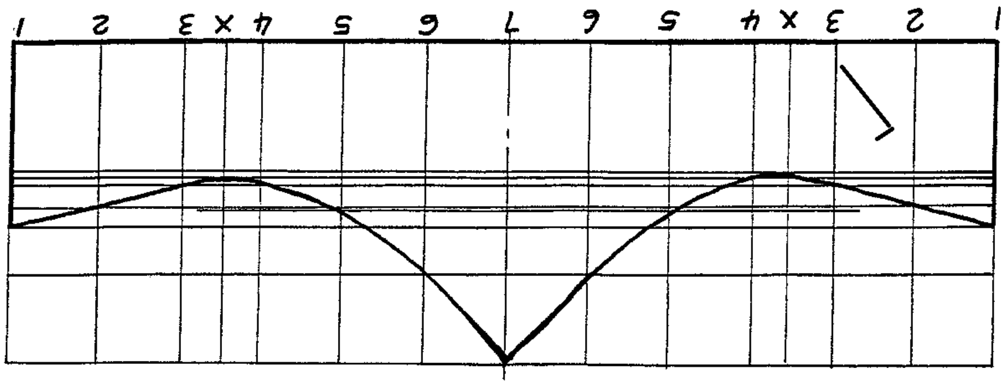
**NOVEMBER 2011**

NATIONAL CERTIFICATE

**PLATING AND STRUCTURAL STEEL DRAWING N2**

(**8090102**)

**(X-Paper)**
**09:00 – 13:00**



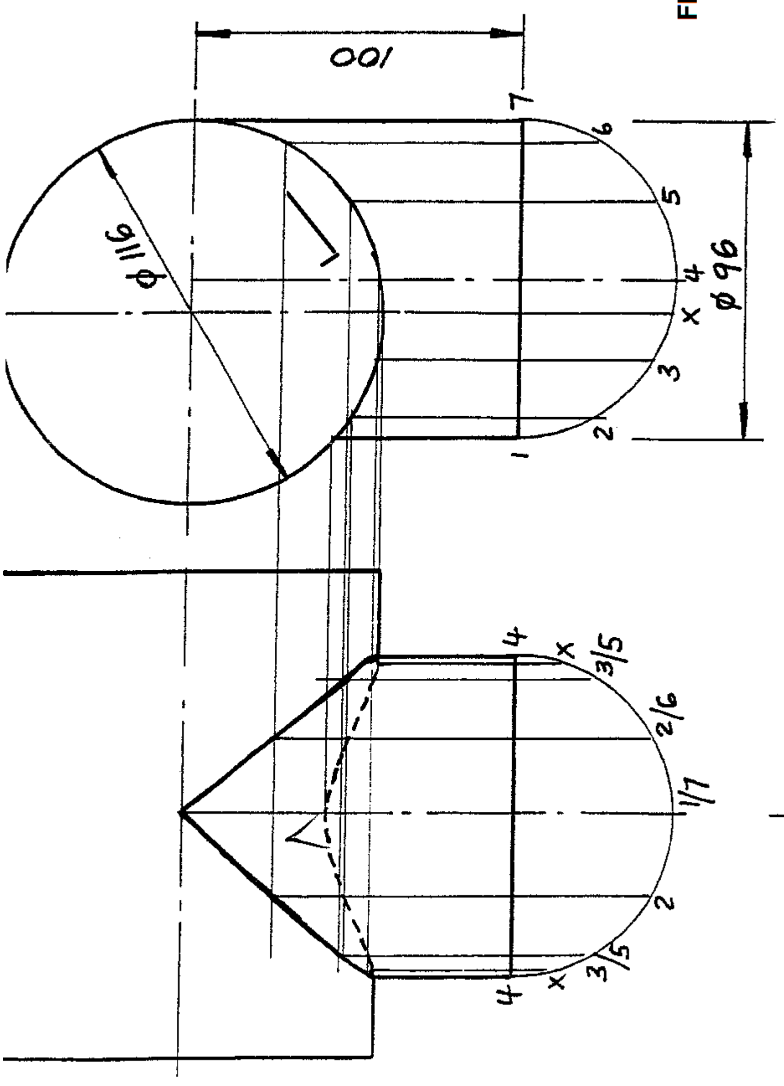
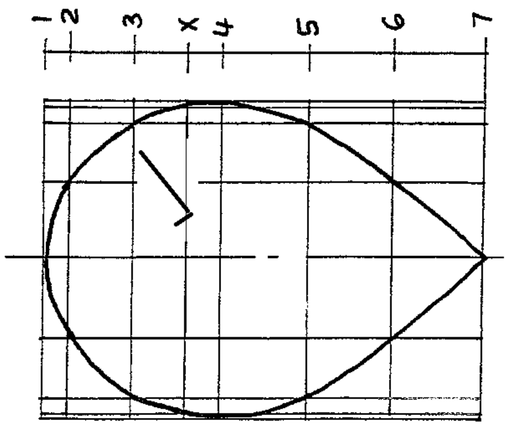




FIGURE 1

| | | |
|---|---|---|
| GIVEN VIEWS | 2 | GEGEWE AANSIGTE |
| LINE OF PENETRATION | 8 | PENETRASIELYN |
| BRANCH PIPE | 5 | TAKPYP |
| HOLE | 5 | GAT |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| TOTAL | 25 | TOTAAL |



| | | | |
|---|---|---|---|
| FRONT VIEW | 1 | VOORAANSIG | |
| TOP VIEW | 2 | BOAANSIG | |
| PATTERN | 17 | PATROON | |
| DIMENSIONS | 2 | AFMETINGS | |
| LINE WORK | 3 | LYNWERK | |
| TOTAL | 25 | TOTAAL | |

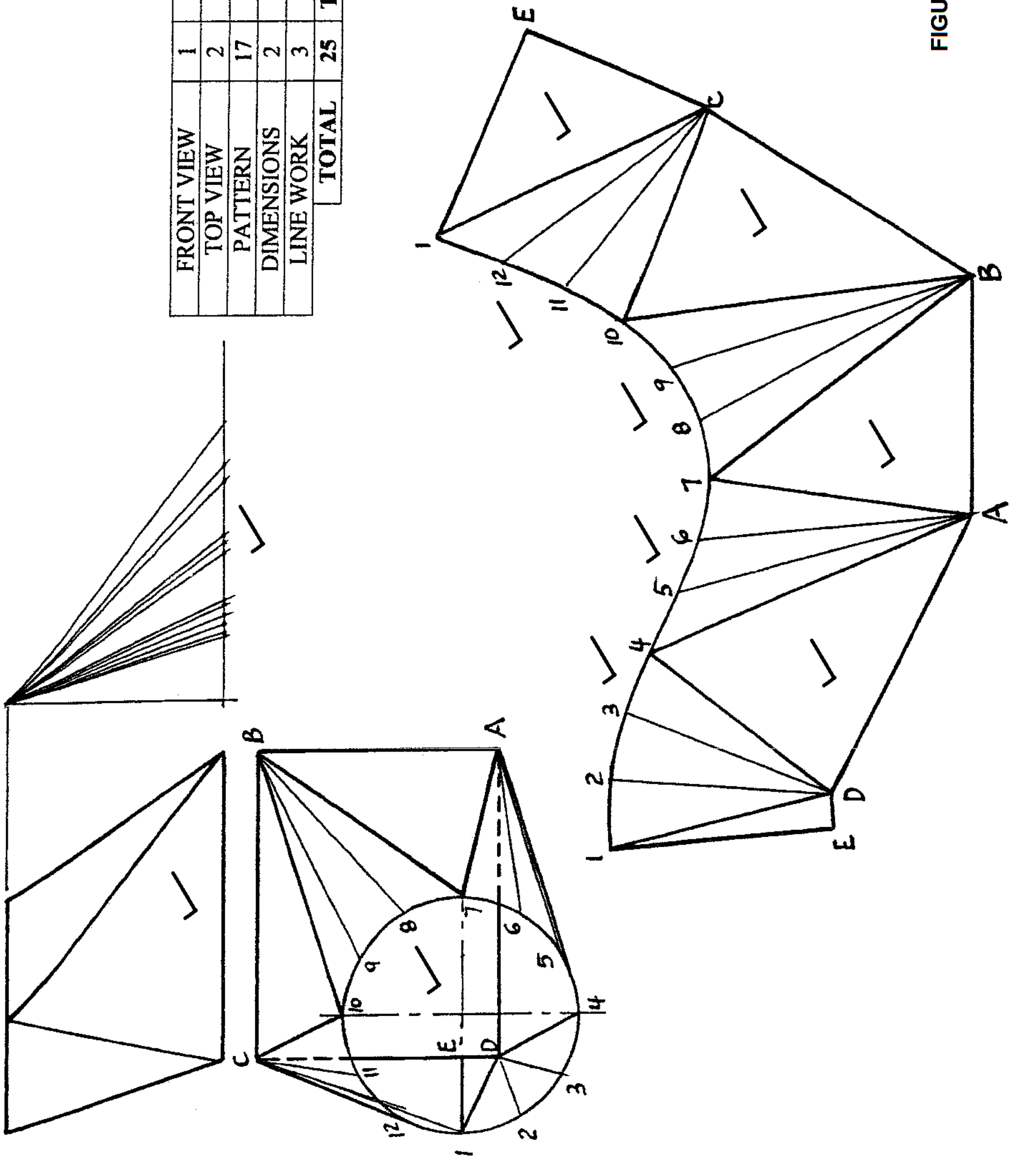
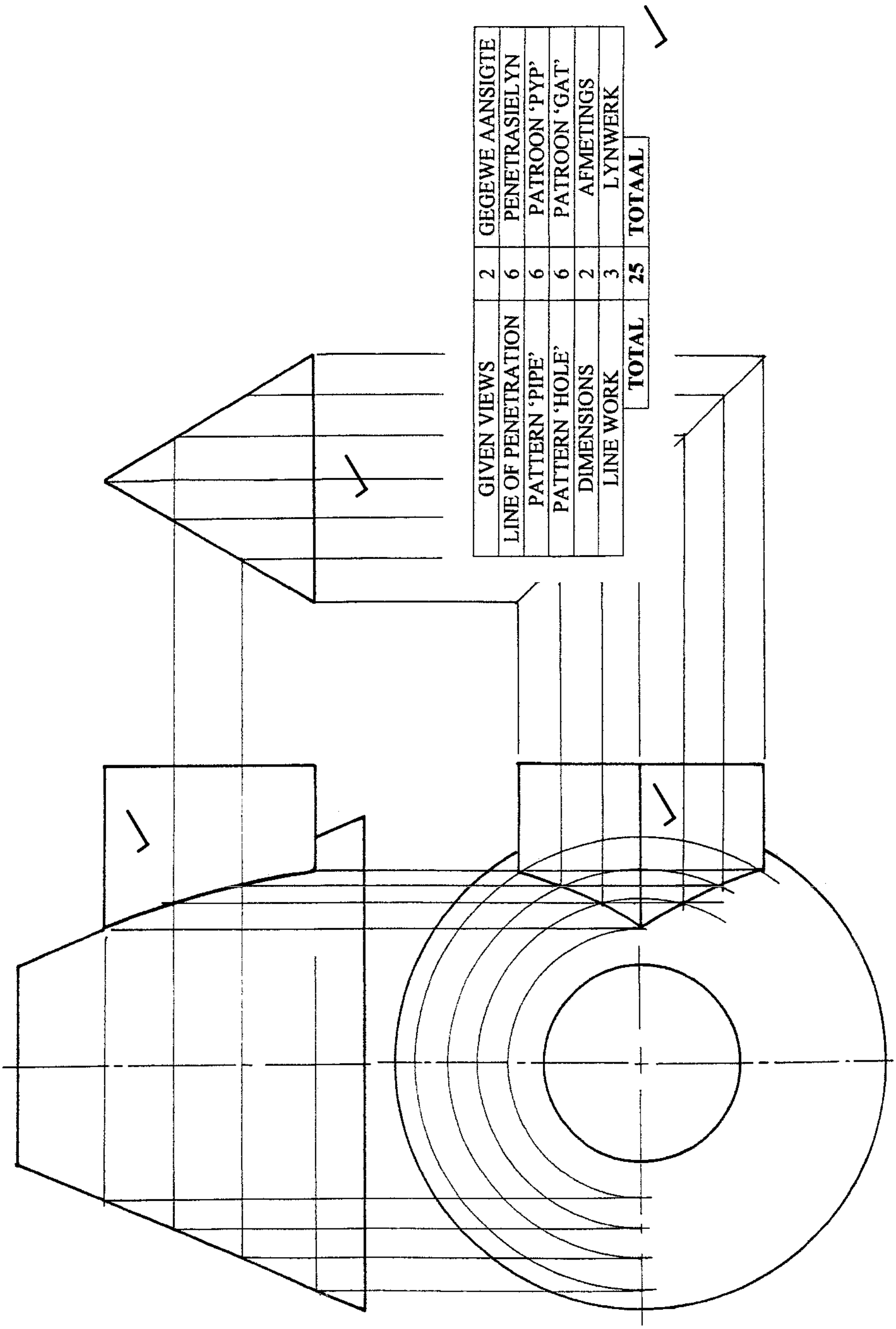
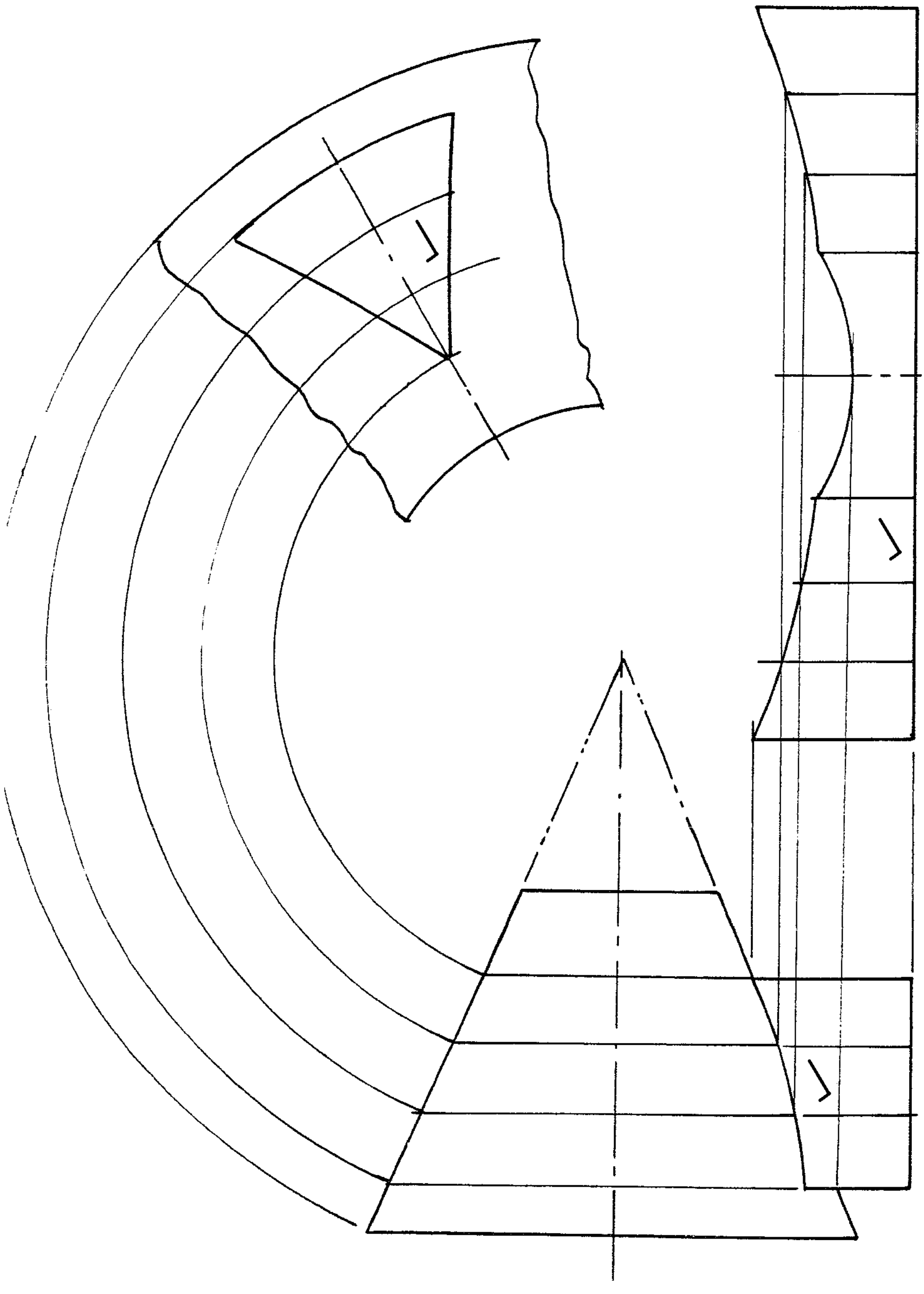



FIGURE 2



| | | |
|---|---|---|
| GIVEN VIEWS | 2 | GEGEWE AANSIGTE |
| LINE OF PENETRATION | 6 | PENETRASIELYN |
| PATTERN 'PIPE' | 6 | PATROON 'PYP' |
| PATTERN 'HOLE' | 6 | PATROON 'GAT' |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |



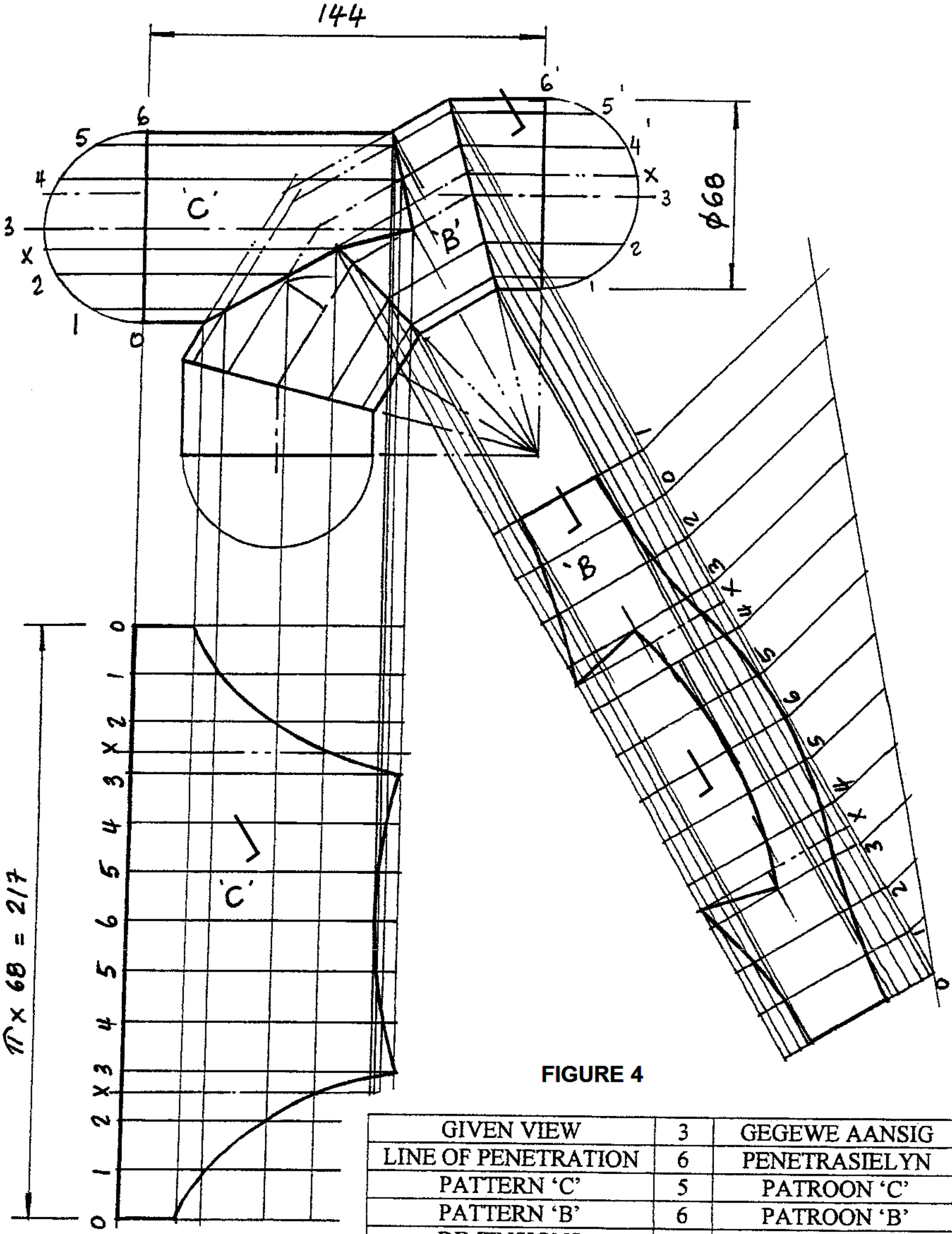
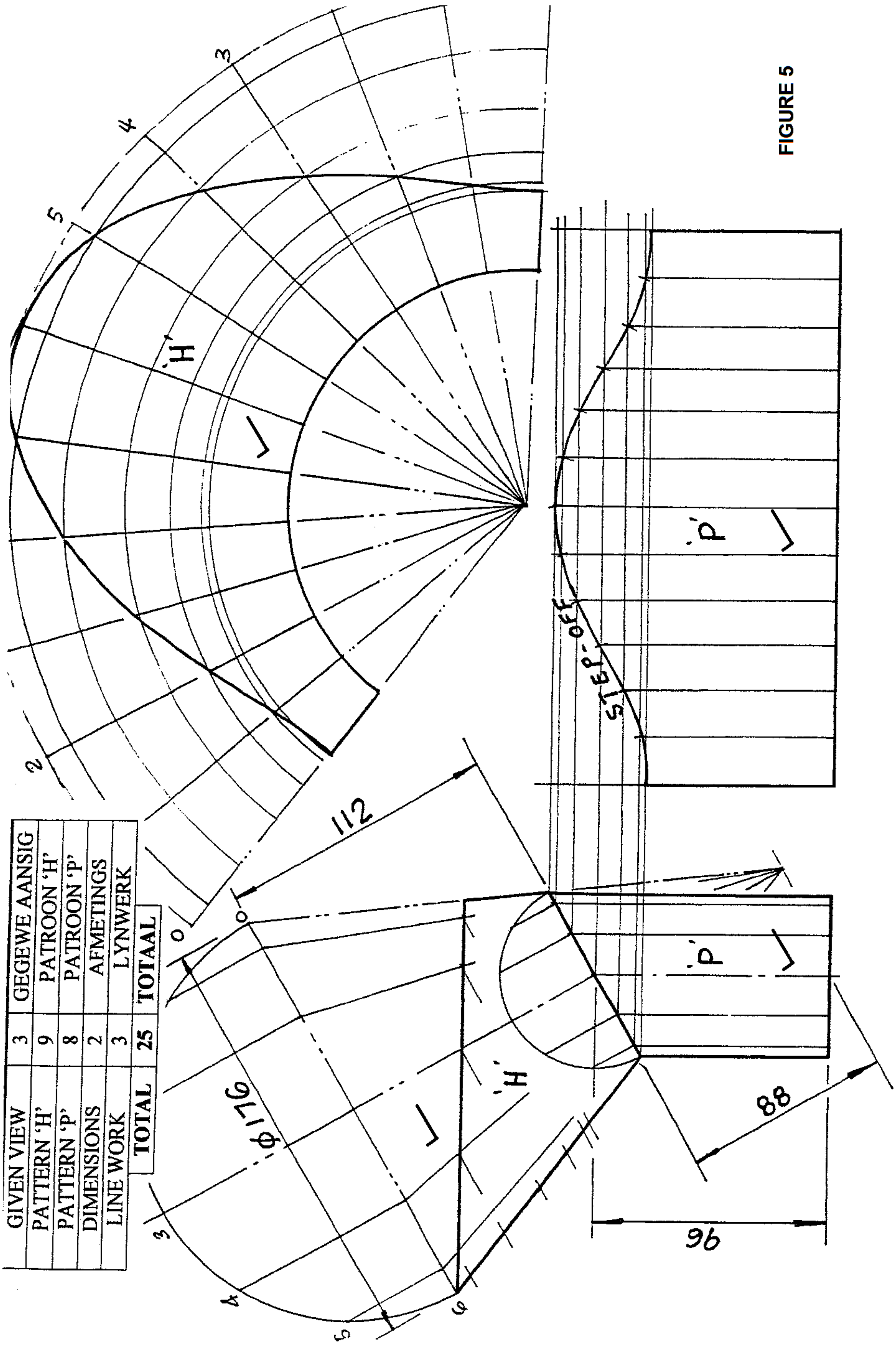


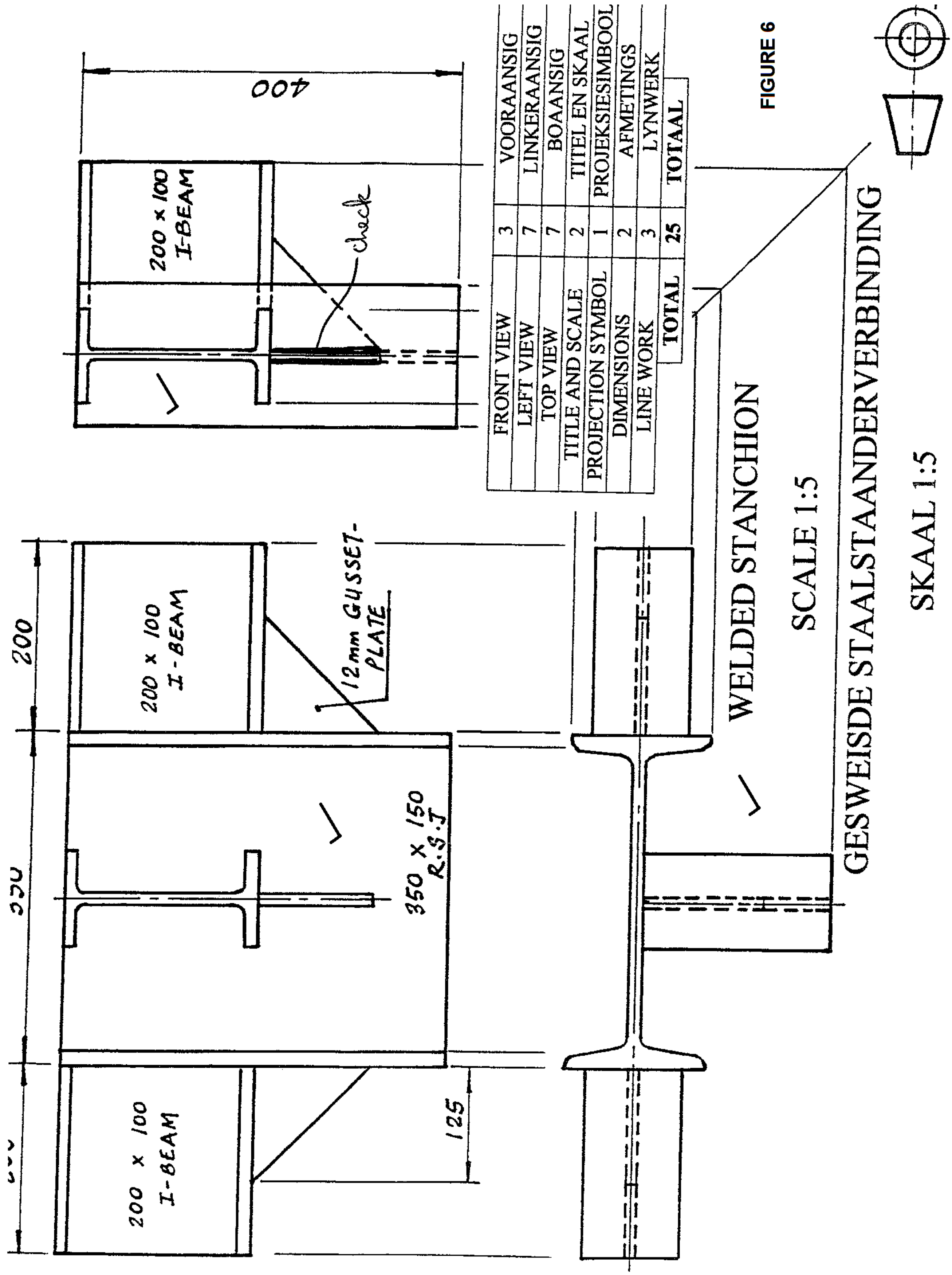

FIGURE 4

| | | |
|---|---|---|
| GIVEN VIEW | 3 | GEGEWE AANSIG |
| LINE OF PENETRATION | 6 | PENETRASIELYN |
| PATTERN 'C' | 5 | PATROON 'C' |
| PATTERN 'B' | 6 | PATROON 'B' |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |




| | | |
|---|---|---|
| GIVEN VIEW | 3 | GEGEWE AANSIG |
| PATTERN 'H' | 9 | PATROON 'H' |
| PATTERN 'P' | 8 | PATROON 'P' |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |

**FIGURE 5**




| | | |
|---|---|---|
| FRONT VIEW | 3 | VOORAANSIG |
| LEFT VIEW | 7 | LINKERAANSIG |
| TOP VIEW | 7 | BOAANSIG |
| TITLE AND SCALE | 2 | TITEL EN SKAAL |
| PROJECTION SYMBOL | 1 | PROJEKSIESIMBOOL |
| DIMENSIONS | 2 | AFMETINGS |
| LINE WORK | 3 | LYNWERK |
| **TOTAL** | **25** | **TOTAAL** |

**FIGURE 6**

**N3 Plating and Structural Steel Drawing is one of many publications introducing the gateways to Engineering Studies. This course is designed to develop the skills for learners that are studying toward an artisanship in the water and waste water treatment and related technology fields and to assist them to achieve their full potential in an engineering career.**

**This book, with its modular competence-based approach, is aimed at assisting facilitators and learners alike. With its comprehensive understanding of the engineering environment, it assists them to achieve the outcomes set for course.**

**The subject matter is presented as worked examples in the problem-solving-result methodology sequence, supported by numerous and clear illustrations. Practical activities are included throughout the book.**

**The author, Chris Brink, is well known and respected in the manufacturing, engineering and related technology fields. His extensive experience gives an excellent base for further study, as well as a broad understanding of technology and the knowledge to success.**

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- N3 Electrotechnology

- N1 Refrigeration Trade Theory
- N2 Refrigeration Trade Theory
- N3 Refrigeration Trade Theory

- N1 Metalwork Theory

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- N1 Plating & Structural Steel Drawing
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- N3 Industrial Electronics

- NCOR Industrial Communication

- N1 Motor Trade Theory
- N2 Motor & Diesel Trade Theory
- N3 Motor & Diesel Trade Theory

- N3 Supervision in the Industry
- N4 Supervisory Management
- N5 Supervisory Management

- N3 Industrial Organisation & Planning

- N1 Water & Wastewater Treatment Practice
- N2 Water & Wastewater Treatment Practice
- N3 Water Treatment Practice
- N3 Wastewater Treatment Practice

- N1 Plant Operation Theory
- N2 Plant Operation Theory
- N3 Plant Operation Theory

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