Trade of Metal Fabrication	
Module 6:	Fabrication Drawing
Unit 11:	Radial Line Development
	Phase 2

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# **Document Release History**

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## **Module 6 – Fabrication Drawing**

### Unit 11 – Radial Line Development

#### **Duration – 8 Hours**

#### **Learning Outcome:**

By the end of this unit each apprentice will be able to:

• Draw and develop the patterns for right conical frustums, pyramids and pipe/conical intersections

#### **Key Learning Points:**

Sk Rk	The right cone and pyramid.
Rk	Revision of orthographic projection. (For more information see Module 6 Unit 8).
Sk Rk	Position of joint lines.
Sk Rk	True view of cuts.
Rk M	Revision of true length lines.
Sk Rk	Procedure of pattern development.
Sk Rk	Use an additional radial line in the patterns.
Sk Rk	Methods of determining joint lines.
Р	Production of neat and accurate drawing of exercise.

#### **Training Resources:**

• Classroom and drawing equipment, drawing instruments

#### **Key Learning Points Code:**

M = MathsD = DrawingRK = Related Knowledge Sc = ScienceP = Personal SkillsSk = SkillH = Hazards

## **Surface Development**

### Introduction

In order to manufacture articles from sheet materials, such as cardboard, tinplate, sheet steel, sheet copper, etc., drawings showing the development of the surfaces of the articles will be required. The methods of surface developments rely upon:

- 1. Constructing the true lengths of edges of parts of the development.
- 2. Constructing the true shapes of surfaces of the development.

In this section you will learn how to construct the surface developments of some common solids - prisms, pyramids, cylinders and cones, and how to develop the surfaces of articles made from sheet materials - paper, cardboard, sheet metal.

When constructing surface developments it is very important to make sure that you have found correct true lengths of edges and true shapes of surfaces.

Pictorial views and the surface developments of three rectangular prisms, such as might be parts of packaging made from sheet cardboard, are shown in Figure 1. The dimensions of the prisms are:

Drawings 1 and 2 -	Base rectangle 20 mm x 12 mm; height 70 mm.
Drawings 3 and 4 -	Base rectangle 20 mm x 12 mm; height 75 mm; truncated at 45 degrees.
Drawings 5 and 6 -	Base rectangle 60 mm x 12 mm; height 65 mm; truncated top and bottom at 45 degrees.

Cardboard packages require gluing tabs to allow them to be held together. Drawing 2 includes a gluing tab. However it is unusual to include tabs in development drawings because many will be for sheet metal articles, the edges of which may be soldered or brazed or welded. In such cases the person making the articles must decide whether tabs (or other forms of additions) are required to manufacture the article from the development drawing.

The surface developments of the three prisms in Figure 1 are straightforward, requiring no explanations. The lines along which the parts of the developments are to be bent should be included in the drawings.

You are advised to work the three examples to the dimensions already given.



Figure 1 - Developments of Rectangular Prisms



Figure 2 - Developments of Surfaces of Rectangular Prisms

#### **Developments of Surfaces of Rectangular Prisms**

#### Drawings 1 and 2

- 1. Draw the Front view and Plan of the truncated prism to the given sizes.
- 2. Construct the development of the four sides of the prism.
- 3. Construct the true shape of the upper face (the top) of the truncated prism.
- 4. Complete the surface development of the sides and top of the prism as shown, including all bend lines.

#### Drawings 3 and 4

- 1. Draw the Front view and Plan of the truncated prism to the given sizes.
- 2. Construct the development of the four sides of the prism.
- 3. Construct the true shape of the two sloping faces of the truncated prism.
- 4. Complete the surface development of the sides and top of the prism as shown, including all bend lines.

#### *Notes*:

- Before constructing a surface development it is usually necessary to draw orthographic projections of the article and to project from the views in the projection to obtain the required true lengths and true shapes for the development. In these two examples Front view and Plans have been drawn. The Front views have been included as part of the finished development.
  - In these two examples, the true shapes of the vertical faces of the prisms are easily constructed from the Front view and Plan.
  - Surface developments are usually referred to as 'developments'.
  - All bend lines are included in the two developments.
  - No tabs are included in the drawings.
  - The term parallel development is often applied to this type of construction for obvious reasons lines within the development are drawn parallel to each other.

### **Development of Truncated Hexagonal Pyramid**

This type of development is often known as **radial development** because many of the lines in the development are radial from a point, requiring the use of compass arcs.

#### To Construct the Given Development

Figure 3

- 1. Draw the Front view, End view and Plan of the truncated pyramid to the given dimensions.
- 2. Note that the Front view does not include any true lengths or true shapes of any edges or faces. Thus the development is worked from the End view because the edge A1 and the lengths AB, AC and AD are true lengths.
- 3. With a compass centred at A and with a radius A1 draw an arc.
- 4. Set a compass to the edge length of the octagonal base of the pyramid (30 mm) and starting at 1, strike arcs along the arc centred at A to give the points 2, 3, 4, 5, 6 and 1. The two lines A1 are the edges, which would be joined together to form the pyramid from the development.
- 5. Join A to the divisions along the arc centred at A with straight lines.
- 6. Draw horizontal lines from intersecting points in the End view of the truncation surface to give B, C and D along line A1.
- 7. With a compass centred at A and set to AB, AC and AD in turn, draw arcs to the lines between A and the divisions along the arc centred at A.
- 8. Complete the development of the sides of the pyramid as shown.
- 9. Construct the true shape of the sloping face from the Front view.
- 10. The base of the pyramid will be a regular octagon of side lengths 30 mm.



Figure 3 - Development of Truncated Hexagonal Pyramid

### **Development of Surface of a Cylinder**

#### To Construct the Development

Figure 4

- 1. Draw the Front view and Plan of the cylinder to the dimensions given in Figure 4.
- 2. Draw a horizontal line of length equal to the circumference of the circle of the cylinder, using the formula:

Circumference =  $2 \times \pi \times R$  - in which:

 $\pi$  is taken as being 3.14, R is 35 - the radius of the circle of the cylinder.

- 3. Project verticals from each end of the line just drawn.
- 4. Project a horizontal line from the top of the Front view to complete the development of the vertical surface of the cylinder.
- 5. If required add circles for the top and bottom of the cylinder, each of cylinder radius.

#### Notes:

- The developments shown in this chapter have all been shaded in colour to distinguish them from other parts of the drawings. There is no need for the reader to shade his or her developments in this manner, although it is a fairly common practice to add shading to surface developments in this way either shading with a pencil, with crayons or with a water colour wash.
- The circumference of the cylinder in this example was found by using the formula  $2\pi R$  (or  $\pi D$ ). It must be remembered that many developments will be drawn for making articles from sheet metals such as copper. When the article is being made, it will often be necessary to beat the resulting cylinder into shape with mallets, hammers or some form of press machine. This working will cause some materials to stretch slightly. The more accurate method of finding a circumference by using a formula may not be as suitable as stepping off one twelfth of the circle in the Plan 12 times along a line forming the base line of the development. This in effect is stepping off 12 chord lengths and not 12 arc lengths and, as a result, is not as accurate as using the formula to find the required base length a chord length being slightly shorter than an arc length.



Figure 4 - Development of Surface of a Cylinder

## True Lengths of the Oblique Cone

One of the most important stages in the progress of pattern developing is that which deals with the oblique cone cut by a plane not parallel to the base. In the case of the right cone all the points on the cutting plane are transferred horizontally, or at right angles to the central axis, to the outside slant of the cone, but this cannot be done with the oblique cone. Bearing in mind the fact that true lengths only are required in the pattern, it is a simple matter to obtain these on the right cone, since any point on the cutting plane taken horizontally to the outside slant, on either side, thereby presents its true distance from the apex. On the oblique cone this would, on the one side, give a length too short and on the other side a length too long.

The method of obtaining true lengths on the oblique cone is shown at (a), Figure 5. A half-plan of the cone with the apex at A is attached direct to the base of the elevation. The line AB in the plan lies on the surface of the cone from the middle point of the semicircle to the apex. This line in the elevation is at A'B', and for convenience will be called the ELEVATION LINE of AB. To obtain the TRUE LENGTH LINE of AB, the PLAN LINE is swung round from the apex A to the base line, which thus places it at right angles to the vertical height of A' A. The diagonal A' B<sup>N</sup> is therefore the true length line. In the elevation, MN represents a cutting plane through the cone, which makes an acute angle with the base. The elevation line A'B' crosses the cutting plane at C', Now, the point C', when located on the true length line, should be exactly the same vertical height from the base. Therefore, a horizontal line drawn from C' on the elevation line to C<sup>N</sup> on the true length line will give the true distance of that point from the apex A'.



Figure 5 - True Lengths of Oblique Cone

Alternatively, if the plan point C were swung round to the base line, and then taken vertically upwards to the true length line, the same point, C", would be located. This method sometimes forms a convenient alternative to that of transferring C' horizontally to C", but for most cases the latter method has many advantages, and will be used in this course as occasion arises.

The two diagrams at (b) and (c), Figure 5, show a right cone and an oblique cone treated for true lengths from the apex to a cutting plane. In principle these two methods, although apparently different, are precisely the same. For instance, to obtain the elevation lines in the oblique cone, the division points on the semicircle are drawn vertically upwards to the base line, and then from the base line to the apex. To obtain the elevation lines on the right cone the process is exactly the same. Again, to obtain the true length lines on the oblique cone, the division points on the semicircle are swung round to the base line, using the plan apex A as centre, and then from the points on the base line the true length lines are drawn to the apex A'. In the case of the right cone, it will be observed that if the plan apex A be used as the centre for swinging round the division points on the semicircle, all of them will coincide with the outside point of the base. This means that the outside slant of the cone is the true length line for all the elevation lines. Hence the reason for transferring all the points on the cutting plane to the outside slant of the cone. If these principles were well digested, there should be no difficulty in following the developments of right or oblique conic frustums.

## The Radial Line Method

How simple it is to get into difficulties with problems of the cone! They present many pitfalls, which can only be avoided by careful discrimination. For instance, the legs of the breeches piece shown at Figure 6(a) might be mistaken for portions of oblique cones, but an oblique cone would present an ellipse at DE instead of the circle required.

Again, a body with an elliptical base, and which tapers obliquely to an apex, may not readily be identified as a right cone. Yet, when a cross-section, taken at right angles to the centreline, is known to be a circle, as at FG, Figure 6(b), then the object is assuredly a right cone, cut obliquely. A practical example of this problem is a rose for a watering can, of the type shown at Figure 6(c). The cross-section at HI, at right angles to the centreline, is circular, while the shape at the top, JK, is an ellipse.

It might be well at this point to make a distinction between the right cone and the oblique cone.

A right cone is a body, which has a circular base, and tapers uniformly from the base to a point or apex, which lies perpendicularly over the centre-point of the base. It follows from this that any cross-section parallel to the plane of the base, or at right angles to the centreline, is a circle. Conversely, any cross-section other than at right angles to the centreline presents an ellipse.

An oblique cone is a body, which has a circular base, and tapers to a point or apex, but the apex does not lie perpendicularly over the centre-point of the base. Hence, the oblique cone leans to one side. It may lean but slightly, or it may lean considerably, but the amount of its leaning does not alter its properties as an oblique cone. Arising out of this, any cross-section parallel to the plane of the base is a circle, but any cross-section at right angles to the centre line, and therefore not parallel to the plane of the base, is an ellipse.

These distinctions are important in assisting to discriminate between conical bodies and other tapering bodies such as commonly occur in sheet metal work.

The First Course of surface developments will deal with those problems, which involve first principles-not necessarily the simplest, but those that naturally take first place in a combined series. The course will include:

- a) Developments by the Radial Line method of patterns involving problems of the right cone and its frustums, right conic sections or right cone cut off in any plane.
- b) Developments by the Parallel Line method of patterns for tees, bends, and elbows, and intersections of pipes of equal diameters or equal oval cross-sections; the oblique cylinder; elementary examples of moulding such as curbs and spouting.
- c) Developments by the method of Triangulation, comprising patterns of transformers for change of section of various kinds between two parallel planes, such as tallboys, hoppers, and hoods, with either perpendicular or oblique axes. The condition that the transformers lie between two parallel planes is an important one as this simplifies the study of the method.



Figure 6 - Radial Line Method

#### **Development by Radial Lines**

The sides, or the sides produced, of any object belonging to the class of pyramids, and the cone in particular, must converge to an apex.



Figure 7 - Development by Radial Lines

Given that condition, it is possible to define a series of lines radiating from the apex down the sides of the pyramid to the base. It is further possible to unfold the surface so that it lies in a flat plane with the lines all radiating from one point, which was the apex.

### The Right Conic Frustum

The right cone is perhaps the most common body, belonging to Class 1, which finds application in sheet metal work.

To obtain the pattern for the frustum of a right cone, first draw the elevation, as at AOL, Figure 7, and mark off MN at the height of the frustum. With centre 0 and radius OA, describe the arc A' A" any length. To obtain the length of the perimeter, describe one quarter of the base of the cone and divide it into three equal parts, as at ABCD. Take one of these divisions, as AB, in the compasses, and mark off three similar distances along the arc A' B' C' D'. Four times the distance A' D' will then give the whole perimeter round the arc, as from A' to A". Join OA". To complete the pattern for the frustum, draw in the arc N'P.

The milk can and the funnel in the top and bottom corners are intended to provide further exercises on this problem.

### **True Lengths**

With reference to Figure 7, it will be seen that the radii of the arcs N' P and A' A" in the pattern are obtained from the slant of the cone, i.e. ON and OA. Distances down the slant of a cone always give true lengths from the apex. Any other lines shown on a cone, which do not appear on the outside slant, are not true lengths.

For instance, the line 0C on the cone shown in Figure 8 does not represent its true length, but is foreshortened both in the plan and in the elevation. The true length, however, may easily be obtained by rotating the cone on the centre-point of its base until the point C falls on the slant, as at the position of A. The line 0C then coincides with the slant of the cone and its true length is equal to OA.



Figure 8 - Right Cone Frustum

Furthermore, the true length of any portion of OC may be obtained from its new position on OA.

Take any point M on OC. The distance OM does not represent its true length, but by rotating the cone on its axis the point M may be made to coincide with the point M', when its true length will be seen to be equal to OM'. To obtain its true position on the pattern, locate the position of point C on the perimeter, as at C', and join to the apex O. Swing round an arc from M' until it cuts OC' in M". M" is the position of point M in the pattern.

This principle forms the basis of solution to all the problems of the right cone, and should be clearly grasped at the outset.

### The Right Cone Cut Obliquely

Set out the elevation of the cone AOG, Figure 9, and on its base draw the semicircle ADG. The semicircle thus represents half the perimeter of the base. Divide the semicircle into six equal parts, as at A,B,C,D,E,F,G, and from the points thus obtained draw perpendiculars to the base of the cone, as Bb, Cc, Dd, Ee, Ff. From the points b,c,d,e,f, on the base of the cone, draw lines to the apex O. Draw MN at the position and angle required for the cut-off.

The lines on the cone intersect the plane of the cut-off at M,1,2,3,4,5,N; then, to obtain the true distances of these points from the apex, project them horizontally on to the slant of the cone, and from the points thus obtained on the slant, swing arcs round into the pattern. Next, with radius OA, draw in the arc A' A" for the base of the cone and mark off twelve divisions equal to one of those on the perimeter, at as A',B',C',D', and so on. Connect these points to the apex O.

A curve now drawn through the diagonally opposite points of intersection will complete the pattern for the frustum.

The diagrams in the corners should provide additional examples for practice on this problem.



Figure 9 - Right Cone Cut Obliquely



Figure 10 - Right Cone Cut by a Curved or Angular Surface

### The Right Cone Cut by a Curved or Angular Surface

Set out the elevation of the cone AOG, Figure 10. From the point d on the centre of the base line describe the arc ST, representing a curved surface, so that it touches the sides of the cone, and would not cut through them if the arc were produced. The lines dS and dT, drawn perpendicular to the respective sides of the cone, will determine the positions of the points S and T. Draw MN at the position and angle required for the cut-off.

On the base of the cone AG describe the semicircle ADG and divide it into six equal parts, as at A,B,C,D,...G. From the points thus obtained draw perpendiculars to the base of the cone, and from the points on the base of the cone draw lines to the apex O.

The lines on the cone intersect the curved surface at S,6,7,8,9,10,T, and the inclined cut-off at M,1,2,3,4,5,N. To obtain the true distances of these points from the apex, project them horizontally, or parallel to the base AG, on to the slant of the cone, and from the points thus obtained on the slant, swing arcs round into the pattern. Next, with radius OA, draw in the arc A' A" for the base of the cone and mark off twelve divisions equal to one of those on the semicircle, as A',B',C',D', equal to AB, or BC, or CD, and so on. Connect the points in the pattern to the apex O.

The pattern may now be drawn in.

From the point M' in the pattern, draw in the curve through the diagonally opposite points M',1,2,3,4,5,N'. Repeat the curve to M". From the point S' in the pattern, draw in the curve through the diagonally opposite points S',6,7,9,8,10,T'. Repeat the curve to point S".

The dimensioned sketches accompanying Figure 10 provide additional exercises on this problem.

## The Pyramid Cut Obliquely

The body of the iron wheelbarrow shown in Figure 11 is often constructed as the frustum of a pyramid, and may then be developed by the radial line method. The elevation of the complete pyramid is obtained by producing the sides downwards until they meet, as at A, and upwards on the side AC until the base BC is at right angles to, and bisected by, the central axis.

To develop the pattern, set out the elevation as shown at CDEF, Figure 12, and produce the sides to CA and AB. On the base CB draw one half of the plan of the full base, as at CGHB. The centre-point A' then represents the apex in the plan. It will be observed that the half-plan and the elevation are drawn the reverse way up to that which is usual, but this should present no difficulty in the solution of the problem if that fact is borne in mind.

From the apex A' draw A'G and A'H. From D draw DI; from E draw EJ, from F draw FK, all vertically upwards. Join GK and IJ. Then CGKf is the half-plan of the actual top of the body, and dIJe the half-plan of the bottom of the body. From the apex A' describe the semicircle LGHM. Join AL and AM, each of which represents the true length projection of the corner lines A'G and A'H. Project the points D,E,F horizontally to the true length line AM, and from A swing them round into the pattern, together with point M.

Take the distance gG, which should be twice the length of CG, and mark off g'G' on the outer, or base, curve in the pattern. Next take GH and mark off G'H' in the pattern. Next mark off H'H" in the pattern equal to g'G'. Also mark off H"G" equal to G'H'. Join the points thus obtained to the apex A. It now remains to draw in the pattern, which should be evident from the illustration.



**Figure 11 - Iron Wheelbarrow** 



Figure 12 - Pyramid Cut Obliquely



Figure 13 - Example of Having the Joint Line on the Shortest Side

## Self Assessment

Questions on Background Notes - Module 6.Unit 11

#### No Suggested Questions and Answers.

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