| Trade of Metal Fabrication |  |
| ---: | :--- |
| Module 6: | Fabrication Drawing |
| Unit 7: | Orthographic Projection 3 |
|  | Phase 2 |

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## Module 6 - Fabrication Drawing

## Unit 7 - Orthographic Projection 3

## Duration - 1 Hours

## Learning Outcome:

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

- Read, interpret, construct and dimension using the $1^{\text {st }}$ angle method of orthographic projection

Key Learning Points:

| $\mathbf{R k} \mathbf{S k}$ | Orthographic projection. <br> (For more information see Module 5 Unit 8). |
| :--- | :--- |
| $\mathbf{R k} \mathbf{S k}$ | Abbreviations for sq-rounds. |
| $\mathbf{R k} \mathbf{S k}$ | Dimensioning (BS 308). |
| $\mathbf{P}$ | Neatness and presentation of drawings. |

## Training Resources:

- Classroom with full set of drawing equipment, instruments and paper


## Key Learning Points Code:

$\begin{array}{llrl}\mathrm{M} & =\text { Maths } & D=\text { Drawing } & R K \\ =\text { Related Knowledge } \mathrm{Sc}=\text { Science } \\ P=\text { Personal Skills } & S k=\text { Skill } & H=\text { Hazards }\end{array}$

## Square-To-Circle Transformer

A problem of very common occurrence in sheet metal work, particularly in pipe and ductwork, is that of the square-to-circle transformer, often called a tallboy. Its object in ductwork is to transform a square or rectangular pipe to a round pipe, or to connect a round pipe to a square or rectangular hole, such as the outlet of a centrifugal fan. This type of transformer also takes the form of hoods over hearths and furnaces to collect the fumes, which rise up through the pipe at the top. (See Figure 1 (a) and (b).) In general practice it is encountered in a variety of ways, almost too numerous to mention.


Figure 1 - Square to Circle and Rectangle to Circle Transformers

The simplest example of this class is such as that shown in Figure 2, in which the centre of the circle in the plan coincides with that of the square, and in which the diameter of the circle is smaller than the width of the square. The method of developing the pattern, however, is the same for every case, whether the circle is the same size or larger than the square, or whether the circle is off-centre one way or both ways with that of the square.


Figure 2 - Example of Square to Circle Transformer

To develop the pattern, divide the circle in the plan into twelve equal parts. Any other number would do as well, but twelve is very convenient, as the divisions can be obtained with the compasses without altering the radius. Assuming the seam to be up the middle of one side as at 1,2 , Figure 2, number the points, beginning at the seam, as shown at $1,2,3,4 \ldots 14,15,16,17$. Project a vertical height line from the elevation, and extend the base line sufficiently to accommodate the longest plan length.
For the first triangle, take the plan length 1,2 in the compasses, and mark it off from $B$ along the base line at right angles to the vertical height. Take the true length diagonal from 2 to the top $T$ of the vertical height, and set off $1^{\prime}, 2^{\prime}$, in the pattern. It will be observed that this first line in the pattern may be set off anywhere and in any position, since the rest of the pattern will follow accordingly. However, a little care and foresight are usually needed to place the first line so that the pattern following up will not run off the sheet or the paper. Next take 2, 3 from the plan, mark it off from B along the base line at right angles to the vertical height, take the true length diagonal from 3 to the top $T$, and from point $2^{\prime}$ in the pattern swing off an arc through point $3^{\prime}$. Next take the true distance 1,3 from the plan, and from the point $1^{\prime}$ in the pattern describe an arc cutting the previous arc in point $3^{\prime}$. Join $2^{\prime}, 3^{\prime}$ and $1^{\prime}, 3^{\prime}$.
For the second triangle, take 3, 4 from the plan, mark it off along the base line, take the true length diagonal, and from point 3 ' in the pattern swing off an arc through the point $4^{\prime}$. Next take the true length 2,4 direct from the plan, and from point $2^{\prime}$ in the pattern describe an arc cutting the previous arc in point $4^{\prime}$. Join $3^{\prime}$, $4^{\prime}$. For the third triangle, repeat this process with the plan lengths 3,5 and 4, 5; and again for the fourth triangle with plan lengths 3,6 and 5, 6. For the fifth triangle, repeat the process with plan lengths 6,7 and 3,7 ; but observe in this case that the triangle is reversed in position. The remainder of the pattern should now be quite easy to follow, since it is a repetition of these processes right through. The line from $2^{\prime}$ to $2^{\prime \prime}$ should be a curve, and not a series of short straight lines.

## Method of Numbering the Points

One of the best aids to clear development in triangulation is a satisfactory method of numbering the points of division in the plan and elevation. Many different methods are in use, but the author prefers one in which the consecutive numbers $1,2,3,4 \ldots$ and so on, can be used right round the body from seam to seam. In many cases of triangulation, the arrangement of the lines forming the triangles produces a continuous zigzag line on the surface between the top and bottom edges of the body, as shown at (a), Figure 3. Examples of this class were given in the previous section, on square-to-square transformers, and many other examples are to follow. The zigzag line need not be regular in form, as at (a), Figure 3, but may take almost any shape, such as the example at (b). The chief point to observe is that, beginning at the seam with 1 to 2 , the consecutive numbers are placed alternately at top and bottom as the zigzag line forming the triangle passes round the body. This is a very simple method of numbering, and has the advantage that, if the work of development were left for a time, it can be picked up with confidence at the exact spot where it was left off.
Square-to-circle transformers introduce a little variation on this arrangement, the principle of which is shown at (e), Figure 3. From this diagram it will be seen that the continuous zigzag line is formed by $1,2,3,6,7,10,11,14,15$.
But there are other lines radiating from points 3,7 and 11 , as 3,4 and 3, 5. The method of procedure, in a case like this, is to begin at 1 and follow up in zigzag form with 2,3 and 4 . From point 4 , there is no return to the base, other than back to 3 . Retrace back to 3 , and proceed to point 5 . Again retrace back to 3, and proceed to point 6.
It is now possible to get back to the base from 6 to 7 . From point 7 the process is repeated as from point 3 , but this time with 7,$8 ; 7,9$; and 7,10 ; and then back to 11. This is repeated again from point 11.

It will be found that this method of numbering can be applied to all cases, and will be of considerable advantage when complicated problems are dealt with.


Figure 3-Method of Numbering the Points

## Dimensioning Principles

A drawing should provide a complete specification of the component to ensure that the design intent can be met at all stages of manufacture. Dimensions specifying features of size, position, location, geometric control and surface texture must be defined and appear on the drawing once only. It should not be necessary for the craftsman either to scale the drawing or to deduce dimensions by the subtraction or addition of other dimensions. Double dimensioning is also not acceptable.
Theoretically any component can be analysed and divided into a number of standard common geometrical shapes such as cubes, prisms, cylinders, parts of cones, etc. The circular hole in Figure 4 can be considered as a cylinder through the plate. Dimensioning a component is the means of specifying the design intent in the manufacture and verification of the finished part.
A solid block with a circular hole in it is shown in Figure 4 and to establish the exact shape of the item we require to know the dimensions which govern its length, height and thickness, also the diameter and depth of the hole and its position in relation to the surface of the block. The axis of the hole is shown at the intersection of two centre lines positioned from the left hand side and the bottom of the block and these two surfaces have been taken as datums. The length and height have also been measured from these surfaces separately and this is a very important point as errors may become cumulative and this is discussed later in the chapter.


Figure 4 - Solid Block with Circular Hole

Dimensioning therefore, should be undertaken with a view to defining the shape or form and overall size of the component carefully, also the sizes and positions of the various features, such as holes, counterbores, tappings, etc., from the necessary datum planes or axes.
The completed engineering drawing should also include sufficient information for the manufacture of the part and this involves the addition of notes regarding the materials used, tolerances of size, limits and fits, surface finishes, the number of parts required and any further comments which result from a consideration of the use to which the completed component will be put. For example, the part could be used in sub-assembly and notes would then make reference to associated drawings or general assemblies.

British Standard 8888 covers all the ISO rules applicable to dimensioning and, if these are adhered to, it is reasonably easy to produce a drawing to a good professional standard.

1. Dimension and projection lines are narrow continuous lines 0.35 mm thick, if possible, clearly placed outside the outline of the drawing. As previously mentioned, the drawing outline is depicted with wide lines of 0.7 mm thick. The drawing outline will then be clearly defined and in contrast with the dimensioning system.
2. The projection lines should not touch the drawing but a small gap should be left, about 2 to 3 mm . depending on the size of the drawing. The projection lines should then continue for the same distance past the dimension line.
3. Arrowheads should be approximately triangular must be of uniform size and shape and in every case touch the dimension line to which they refer. Arrowheads drawn manually should be filled in arrowheads drawn by machine need not be filled in.
4. Bearing in mind the size of the actual dimensions and the fact that there may be two numbers together where limits of size are quoted, then adequate space must be left between rows of dimensions and a spacing of about 12 mm is recommended.
5. Centre lines must never be used as dimension lines but must be left clear and distinct. They can be extended, however, when used in the role of projection lines.
6. Dimensions are quoted in millimetres to the minimum number of significant figures. For example, 19 and not 19.0. In the case of a decimal dimension, always use a nought before the decimal marker, which might not be noticed on a drawing print that has poor line definition. We write 0,4 and not .4. It should be stated here that on metric drawings the decimal marker is a comma positioned on the base line between the figures, for example, 5,2 but never 5.2 with a decimal point midway.
7. To enable dimensions to be read clearly, figures are placed so that they can be read from the bottom of the drawing, or by turning the drawing in a clockwise direction, so that they can be read from the right hand side.
8. Leader lines are used to indicate where specific indications apply. The leader line to the hole is directed towards the centre point but terminates at the circumference in an arrow. A leader line for a part number terminates in a dot within the outline of the component. The gauge plate here is assumed to be part number six of a set of inspection gauges.

Figure 5 shows a partly completed drawing of a gauge to illustrate the above aspects of dimensioning.


Figure 5 - Partly Completed Gauge Drawing

When components are drawn in orthographic projection, a choice often exists where to place the dimensions and the following general rules will give assistance.

1. Start by dimensioning the view, which gives the clearest understanding of the profile or shape of the component.
2. If space permits, and obviously this varies with the size and degree of complexity of the subject, place the dimensions outside the profile of the component as first choice.
3. Where several dimensions are placed on the same side of the drawing, position the shortest dimension nearest to the component and this will avoid dimension lines crossing.
4. Try to ensure that similar spacings are made between dimension lines as this gives a neat appearance on the completed drawing.
5. Overall dimensions, which are given for surfaces that can be seen in two projected views, are generally best positioned between these two views.

Remember, that drawings are the media to communicate the design intent used to the manufacturing and verification units. Therefore always check over your drawing, view it and question yourself. Is the information complete? Ask yourself whether or not the machinist or fitter can use or work to the dimension you have quoted to make the item. Also, can the inspector verify the figure, in other words, is it a measurable distance?

Figure 14.3 shows a component, which has been partly dimensioned to illustrate some of the principles involved.
Careless and untidy dimensioning can spoil an otherwise sound drawing and it should be stated that many marks are lost in examinations due to poor quality work.


Figure 6 - Partly Dimensioned Component

## Dimensioning of Features not Drawn to Scale

This method of indication is by underlining a particular dimension with a wide line as indicated in Figure 7. This practice is very useful where the dimensional change does not impair the understanding of the drawing.


Figure 7 - Dimensioning of Features not Drawn to Scale

## Chain Dimensioning and Auxiliary Dimensioning

Chains of dimensions should only be used where the possible accumulation of tolerances does not endanger the function of the part.
A plan view of a twist drill stand is given in Figure 8 to illustrate chain dimensioning. Now each of the dimensions in the chain would be subject to a manufacturing tolerance since it is not possible to mark out and drill each of the centre distances exactly. As a test of drawing accuracy, start at the left hand side and mark out the dimensions shown in turn. Measure the overall figure on your drawing and check with the auxiliary dimension given. Note the considerable variation in length, which results from small errors in each of the six separate dimensions in the chain, which clearly accumulate. Imagine the effect of marking out say twenty holes for rivets in each of two plates, how many holes would eventually line up? The overall length is shown in parentheses (157) and is known as an auxiliary dimension. This dimension is not one that is worked to in practice but is given purely for reference purposes. You will now appreciate that it will depend on the accuracy with which each of the pitches in the chain is marked out.
(157)


Figure 8 - Twist Drill Stand

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## Parallel Dimensioning

Improved positional accuracy is obtainable by dimensioning more than one feature from a common datum, and this method is shown in Figure 9. The selected datum is the left hand side of the stand. Note that the overall length is not an auxiliary dimension, but as a dimensional length in its own right.


Figure 9 - Parallel Dimensioning

## Running Dimensioning

Is a simplified method of parallel dimensioning having the advantage that the indication requires less space. The common origin is indicated as shown (Figure 10) with a narrow continuous circle and the dimensions placed near the respective arrowheads.


Figure 10 - Running Dimensioning

## Staggered Dimensions

For greater clarity a number of parallel dimensions may be indicated as shown in Figure 11 and Figure 12.


Figure 11 - Staggered Dimensions 1


Figure 12 - Staggered Dimensions 2

## Dimensioning Circles

The symbol $\varnothing$ preceding the figure is used for specifying diameters and it should be written as large as the figures, which establish the size, e.g. Ø65. Alternative methods of dimensioning diameters are given below. The size of hole and space available on the drawing generally dictates which method the draughtsman chooses.


Figure 13 - Dimensioning Circles

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## Dimensioning Radii

Alternative methods are shown where the position of the centre of the arc need not be located. Note that the dimension line is drawn through the arc centre or lies in a line with it in the case of short distances and the arrowhead touches the arc.


Figure 14 - Dimensioning Radii

## Dimensioning Spherical Radii and Diameters



Figure 15 - Dimensioning Spherical Radii and Diameters

## Dimensioning Curves

A curve formed by the blending of several radii must have the radii with their centres of curvature clearly marked.

## Dimensioning Irregular Curves

Irregular curves may be dimensioned by the use of ordinates. To illustrate the use of ordinates, a section through the hull of a boat is shown (Figure 16). Since the hull is symmetrical about the vertical centre line it is not necessary to draw both halves in full and if the curve is presented in this manner then two short thick parallel lines are drawn at each end of the profile at right angles to the centre line. The outline is also extended slightly beyond the centre line to indicate that the shape is to be continued. Ordinates are then positioned on the drawing and the outline passes through each of the chosen fixed points.


Figure 16 - Dimensioning Irregular Curves

## Unidirectional and Aligned Dimensions

Both methods are in common use.

1. Unidirectional dimensions are drawn parallel with the bottom of the drawing sheet; also any notes that refer to the drawing use this method.
2. Aligned dimensions are shown in parallel with the related dimension line and positioned so that they can be read from the bottom of the drawing or from the right hand side (Figure 17).








Figure 17 - Unidirectional and Aligned Dimensions

## Angular Dimensions

Angular dimensions on engineering drawings are expressed as follows:
(a) Degrees, e.g. $30^{\circ}$.
(b) Degrees and minutes, e.g. $30^{\circ} 40^{\prime}$.
(c) Degrees, minutes and seconds e.g. $30^{\circ} 40^{\prime} 20^{\prime \prime}$.

For clarity a full space is left between the degree symbol and the minute figure also between the minute symbol and the second figure.

In the case of an angle less than one degree it should be preceded by $0^{\circ}$, e.g. $0^{\circ} 25^{\prime}$.
Figure 18 shows various methods of dimensioning angles.


Figure 18 - Various Methods of Dimensioning Angles

## Tapers

In Figure 19 the difference in magnitude between dimensions X and Y (whether diameters or widths) divided by the length between them defines a ratio known as a taper.


Figure 19 - Taper

Taper $=\quad \frac{\mathrm{X}-\mathrm{Y}}{\text { length }}=2 \tan \frac{\emptyset}{2}$
For example, the conical taper in Figure 20
$=\quad \frac{20-10}{40}=\quad \frac{10}{40}=0.25$
and may be expressed as rate of taper 0.25: 1 on diameter.
The ISO recommended symbol for taper is $\rightarrow$, and this symbol can be shown on drawings accompanying the rate of taper,

$$
\text { i.e. } \rightarrow 0.25: 1
$$

The arrow indicates the direction of taper.
When a taper is required as a datum, it is enclosed in a box as follows:

$$
\Longrightarrow 0,25: 1
$$



Figure 20 - Conical Taper

## Dimensioning Tapers

The size, form, and position of a tapered feature can be defined by calling for a suitable combination of the following:

1. the rate of taper, or the included angle;
2. the diameter or width at the larger end;
3. the diameter or width at the smaller end;
4. the length of the tapered feature;
5. the diameter or width at a particular cross-section, which may lie within or outside the feature concerned;
6. the locating dimension from the datum to the cross-section referred to above.

Care must be taken to ensure that no more dimensions are quoted on the drawing than are necessary. If reference dimensions are given to improve communications, then they must be shown in brackets, e.g. (1:5 taper).
Figure 2 1gives four examples of the methods used to specify the size, form, and position of tapered features.


Figure 21 - Methods used to Specify Size, Form and Position of Tapered Features

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## Dimensioning Two Mating Tapers

When the fit to a mating part or gauge is necessary, a tried and successful method used in manufacturing units is to add the following information to the feature(s).

1. 'To FIT PART NO. YYY'
2. 'TO FIT GAUGE (PART NO. GG)'

When note 2 is added to the drawing, this implies that a 'standard rubbing gauge' will give an acceptable even marking when 'blued'. The functional requirement whether the end-wise location is important or not, will determine the method and choice of dimensioning.

An example of dimensioning two mating tapers when end-wise location is important is shown in Figure 22.

For more accurate repeatability of location, the use of Geometric Tolerancing and a specific datum is recommended. Additional information on this subject may be found in BS ISO 3040.


Figure 22 - End-Wise Location

## Dimensioning Chamfers

Alternative methods of dimensioning internal and external chamfers are shown in Figure 23.


Figure 23 - Dimensioning Chamfers

## Dimensioning Squares or Flats

Figure 24 shows a square machined on the end of a shaft so that it can be turned by means of a spanner.

The narrow diagonal lines are added to indicate the flat surface.
Part of a spindle which carries the chain wheel of a cycle, secured by a cotter pin, illustrates a flat surface which is not at the end of the shaft (Figure 25).


Figure 24 - Dimensioning Squares or Flats 1


Figure 25 - Dimensioning Square or Flats 2

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## Dimensioning Holes

The depth of drilled holes, when stated in note form, refers to the depth of the cylindrical portion and not to the point left by the drill. If no other indication is given they are assumed to go through the material. Holes in flanges or bosses are generally positioned around a pitch circle (PCD) and may be spaced on the main centre lines of the component (on centres) or as shown below equally spaced off centres. Holes are usually drilled off centres to provide for maximum access to fixing bolts in the case of valves and pipeline fittings. Special flanges need to have each hole positioned individually and an example is given with three tapped holes (see Figure 26).


Figure 26 - Dimensioning Holes

## Dimensioning Counterbores

A drilling machine is used for this operation, and a typical counterboring tool is shown in Figure 27.


Figure 27 - Typical Counterboring Tool

The operation involves enlarging existing holes, and the depth of the enlarged hole is controlled by a stop on the drilling machine. The location of the counterbored hole is assisted by a pilot at the tip of the tool, which is a clearance fit in the previously drilled hole. A typical use for a counterbored hole is to provide a recess for the head of a screw, as shown in Figure 28 or a flat surface for an exposed nut or bolt, as in Figure 29. The flat surface in Figure 29 could also be obtained by spotfacing.


Figure 28 - Counterbored Hole Recess for Head of Screw


Figure 29 - Counterbored Hole - Flat Surface for Exposed Nut/Bolt

Figure 30 shows methods of dimensioning counterbores. Note that, in every case, it is necessary to specify the size of counterbore required. It is not sufficient to state 'COUNTERBORE FOR M10 RD HD SCREW', since obviously the head of the screw will fit into any counterbore, which is larger than the head.


Figure 30 - Methods of Dimensioning Counterbores

## Dimensioning Countersunk Holes

Countersinking is also carried out on a drilling machine, and Figure 31 and Figure 32 shows typical tools. Included angles of $60^{\circ}$ and $90^{\circ}$ are commonly machined, to accommodate the heads of screws and rivets to provide a flush finish.

Note. Refer to manufacturers' catalogues for dimensions of suitable rivets and screws.


Figure 31 - Taper-Shank Sountersink (With $60^{\circ}$ or $90^{\circ}$ included angle of Countersink)


Figure 32 - Straight-Shank Machine Countersink (With $60^{\circ}$ or $90^{\circ}$ included angle of Countersink)


Figure 33 - Dimensioning Countersunk Holes

## Dimensioning Spotfaces

Spotfacing is a similar operation to counterboring, but in this case the metal removed by the tool is much less. The process is regularly used on the surface of castings, to provide a flat seating for fixing bolts. A spotfacing tool is shown in Figure 34, where a loose cutter is used. The length of cutter controls the diameter of the spotface. As in the counterboring operation, the hole must be previously drilled, and the pilot at the tip of the spotfacing tool assists in location.


Figure 34 - Spotfacing Tool

Figure 35 shows the method of dimensioning.
Note that, in both cases, the depth of spotface is just sufficient to remove the rough surface of the casting over the 40 mm diameter area.


Figure 35-Method of Dimensioning

## Dimensioning for Manufacture

It should be emphasised that dimensioning must be performed with the user of the drawing very much in mind. In the case of the finished bearing housing shown in Figure 37 two different production processes are involved in its manufacture: namely casting and machining of the component. It is sometimes preferable to produce two separate drawings, one to show the dimensions of the finished casting and the other to show the dimensions, which are applicable to the actual machining operation. Figure 36 shows a suitable drawing for the casting patternmaker. Allowances are made for machining and also for the fact that the casting will shrink when it cools. The machinist will take the rough casting and remove metal to produce the finished component, all other surfaces having a rough finish. Figure 37 shows the required dimensions for machining. Note that the bore of the casting is required to be finished between the two sizes quoted for functional purposes.


Figure 36 - Suitable Drawing for Casting Patternmaker


Figure 37 - Finished Bearing Housing

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## Graphical Symbols to Indicate Surface Texture

The quality and type of surface texture has a direct connection with the manufacturing cost, function and wear of a component. Each of the symbols shown below has their own special interpretation. Individual surface texture values and text may be added to the symbols. The basic graphical symbol is shown in Figure 38. The centre line between the lines of unequal length is positioned square to the considered surface.

The symbol should not be indicated alone, without complementary information. It may, however be used for collective indication.


Figure 38 - Basic Graphical Symbol

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## Self Assessment

Questions on Background Notes - Module 6.Unit 7

1. In diagram form show Common Dimensioning of a radius on a given Arc, Curve or Circle.
$\square$
2. Using a diagram show what is meant by an Angular Dimension.
$\square$

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3. Give an example of Dimensioning Holes on a typical drawing.
$\square$
4. Using a diagram show the Dimensioning of a Countersunk Hole.
$\square$

## Answers to Questions 1-4. Module 6. Unit 7

1. 

Figure 15 - Dimensioning Radii:

2.

## Angular Dimensions:

Angular dimensions on engineering drawings are expressed as follows:
a. Degrees, e.g. $30^{\circ}$.
b. Degrees and minutes, e.g. $30^{\circ} 40^{\prime}$
c. Degrees, minutes and seconds e.g. $30^{\circ} 40^{\prime} 20^{\prime \prime}$.

Figure 16: Various Methods of Dimensioning Angles.


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Figure 17: Dimensioning Holes.


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Figure 18: Dimensioning Countersunk Holes.


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