2

Projection Methods

2.0 Introduction

In Chapter 1 it was stated that there are two sets of rules that apply to engineering drawing. Firstly, there are the rules that apply to the layout of a drawing and secondly the rules pertaining to the manufacture of the artefact. This chapter is concerned with the former set of rules, called the 'drawing layout rules'. These define the projection method used to describe the artefact and how the 3D views of it can be represented on 2D paper. These will be presented in terms of first and third angle orthographic projections, sections and cutting planes, auxiliary projections as well as trimetric, dimetric, isometric and oblique projections.

The chart in Figure 2.1 shows the types of drawing projections. All engineering drawings can be divided into either pictorial projections or orthographic projections. The pictorial projections are non-specific but provide visualisation. They can be subdivided further into perspective, axonometric and oblique projections. In pictorial projections, an artefact is represented as it is seen in 3D but on 2D paper. In orthographic projections, an artefact is drawn in 2D on 2D paper. This 2D representation, rather than a 3D representation, makes life very much simpler and reduces confusion. In this 2D case, the representation will lead to a specification that can be defined by laws. The word *ortho* means correct and the word *graphic* means drawing. Thus, *orthographic* means a correct drawing which prevents confusion and therefore can be a true specification which, because orthographic projections are clearly defined by ISO standards, are legal specifications. Orthographic projections can be subdivided into first and third angle projections. The two projection

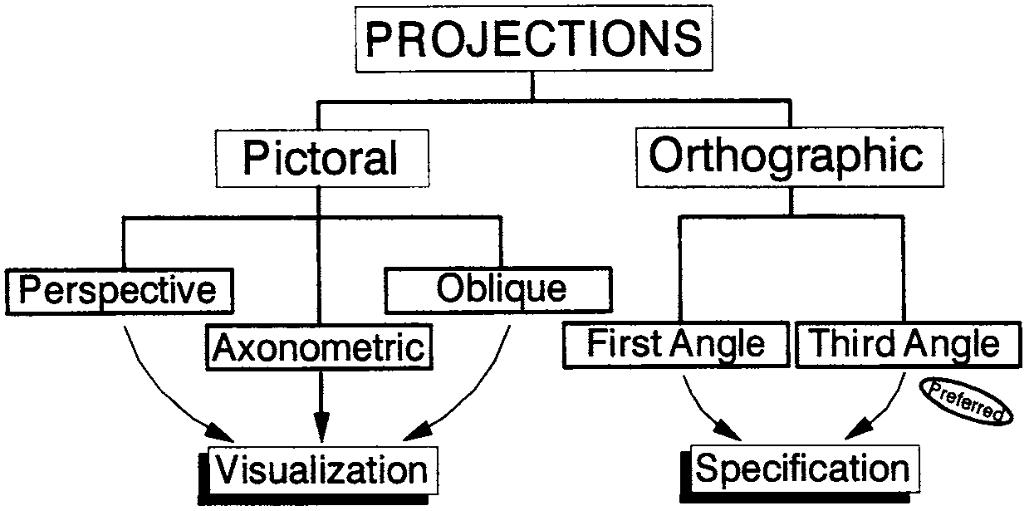

Figure 2.1 *The different types of engineering drawing projections*

methods only differ in the manner in which the views are presented. The third angle projection method is preferred.

Whichever projection method is used, the representation is achieved by projectors which are effectively rays of light whose sources are on one side of an artefact passing over the artefact and projecting its image onto a 2D drawing sheet. This is similar to the image or shadow an artefact would produce when a single light source projects the shadow of an artefact onto, say, a wall. In this case, the wall is the picture plane. The various types of pictorial and orthographic projections are explained in the following sections.

2.1 Perspective projection

Perspective projection is as shown in Figure 2.2. Perspective projection is reality in that everything we see in the world is in perspective such that the objects always have vanishing points. Perspective projection is thus the true view of any object. Hence, we use expressions like 'putting something in perspective'! Projectors radiate from a station point (i.e. the eye) past the object and onto the 2D picture plane. The station point is the viewing point. Although there is only one station point, there are three vanishing points. A good example of a vanishing point is railway lines that appear to meet in the distance. One knows in reality that they never really meet, it is just the perspective of one's viewing point. Although there are three vanishing points, perspective drawings can be simplified such that only two or indeed one vanishing point is used. The drawing in Figure 2.2 shows only two vanishing points.

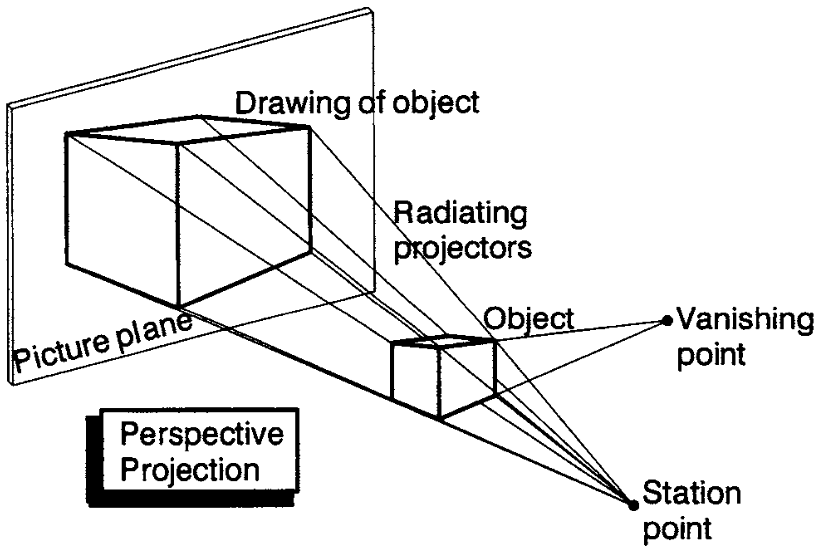

Figure 2.2 *Perspective projection*

Had the block shown been very tall, there would have been a need to have three vanishing points.

Although perspective projection represents reality, it produces complications with respect to the construction of a drawing in that nothing is square and care needs to be taken when constructing such drawings to ensure they are correct. There are numerous books that give details of the methods to be employed to construct perspective drawings. However, for conventional engineering drawing, drawing in perspective is an unnecessary complication and is usually ignored. Thus, perspective projection is very rarely used to draw engineering objects. The problem in perspective projection is due to the single station point that produces radiating projectors. Life is made much simpler when the station point is an infinite distance from the object so that the projectors are parallel. This is a situation for all the axonometric and orthographic projection methods considered below.

2.2 Axonometric projection

Axonometric projection is shown in Figure 2.3. This is the same as perspective projection except that the projectors are parallel. This means that there are no vanishing points. In axonometric projection, the object can be placed at any orientation with respect to the viewer. For convenience, axonometric projection can be divided into three classes depending on the orientation of the object. These are trimetric, dimetric and isometric projections (see Figure 2.4).

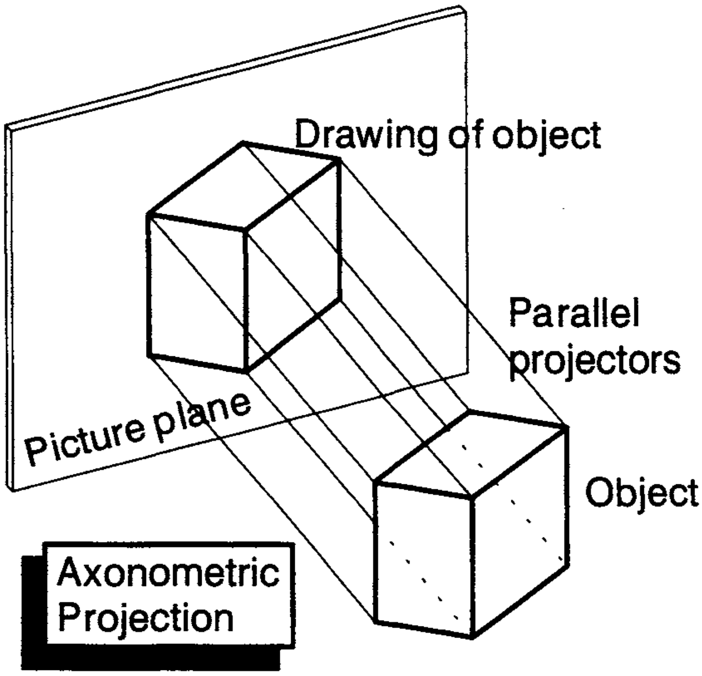

Figure 2.3 *Axonometric projection*

Trimetric projection is by far the most common in that the object is placed at any position with respect to the viewer such that the angles α and β are unequal and the foreshortening in each of the three axes is unequal. The three sides of the cube are of different lengths. This is shown in the left-hand drawing in Figure 2.4. The 'tri' in trimetric means three. In dimetric projection, the angles α and β are the same as shown in the middle drawing in Figure 2.4. This results in equal foreshortening of the two horizontal axes. The third vertical axis is foreshortened to a different amount. The 'di' in dimetric means there are two 'sets' of axes. The particular class of axonometric projection in which all the three axes are foreshortened to an equal amount is called isometric projection. In this case the foreshortening is the same as seen in the right-hand drawing in Figure 2.4. In this case, the angles α and β are the same and equal to 30°. The foreshortening of each of the three axes is identical. The term 'iso' in isometric projection means similar. Isometric projection is the most convenient of the three types of axonometric projection because of the convenience of using 30° angles and equal foreshortening. Isometric projection will be considered in detail in the following section.

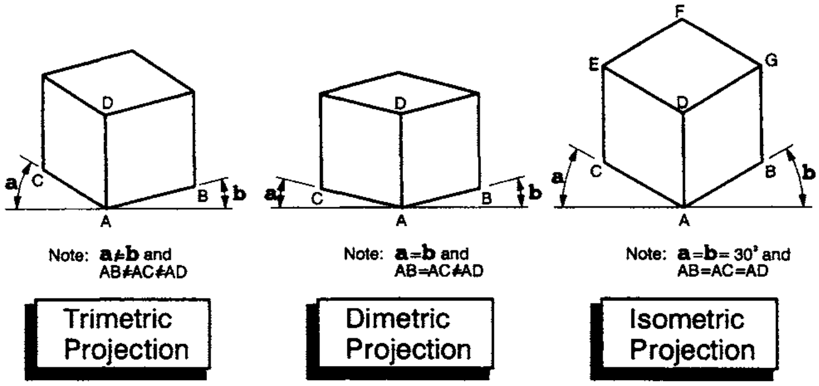

Figure 2.4 *The three types of axonometric projections*

2.3 Isometric projection

In *isometric projection*, the projection plane forms three equal angles with the co-ordinate axis. Thus, considering the isometric cube in Figure 2.4, the three cube axes are foreshortened to the same amount, i.e. AB = AC = AD. Two things result from this, firstly, the angles a = b = 30° and secondly, the rear (hidden) corner of the cube is coincident with the upper corner (corner D). Thus, if the hidden edges of the cube had been shown, there would be dotted lines going from D to F, D to C and D to B. The foreshortening in the three axes is such that AB = AC = AD = $(2/3)^{0.5}$ = 0.816. Since isometric projections are pictorial projections and dimensions are not normally taken from them, size is not really important. Hence, it is easier to ignore the foreshortening and just draw the object full size. This makes the drawing less complicated but it does have the effect of apparently enlarging the object by a factor 1.22 (1 ÷ 0.816). Bearing this in mind and the fact that both angles are 30°, it is not surprising that isometric projection is the most commonly used of the three types of axonometric projection.

The method of constructing isometric projections is shown in the diagrams in Figures 2.5 and 2.6. An object is translated into isometric projection by employing enclosing shapes (typically squares and rectangles) around important features and along the three axes. Considering the isometric cube in Figure 2.4, the three sides are three squares that are 'distorted' into parallelograms, aligned with the three isometric axes. Internal features can be projected from these three parallelograms.

The method of constructing an isometric projection of a flanged bearing block is shown in Figure 2.5. The left-hand drawing shows the construction details and the right-hand side shows the 'cleaned up' final isometric projection. An enclosing rectangular cube could be placed around the whole bearing block but this enclosing rectangular cube is not shown on the construction details diagram because of the complexity. Rather, the back face rectangle CDEF and the bottom face ABCF are shown. Based on these two rectangles, the construction method is as follows. Two shapes are drawn on the isometric back plane CDEF. These are the base plate rectangle CPQF and the isometric circles within the enclosing square LMNO. Two circles are placed within this enclosing square. They represent the outer and inner diameters of the bearing at the back face.

The method of constructing an isometric circle is shown in the example in Figure 2.6. Here a circle of diameter ab is enclosed by the square abcd. This isometric square is then translated onto each face of the isometric cube. The square abcd thus becomes a parallelogram abcd. The method of constructing the isometric circles within these squares is as follows. The isometric square is broken down further into a series of convenient shapes, in this case five small long-thin rectangles in each quadrant. These small rectangles are then translated on to the isometric cube. The intersection heights ef, gh, ij and kl are then projected onto the equivalent rectangles on the isometric projection. The dots corresponding to the points fhjl are the points on the isometric circles. These points can be then joined to produce isometric circles. The isometric

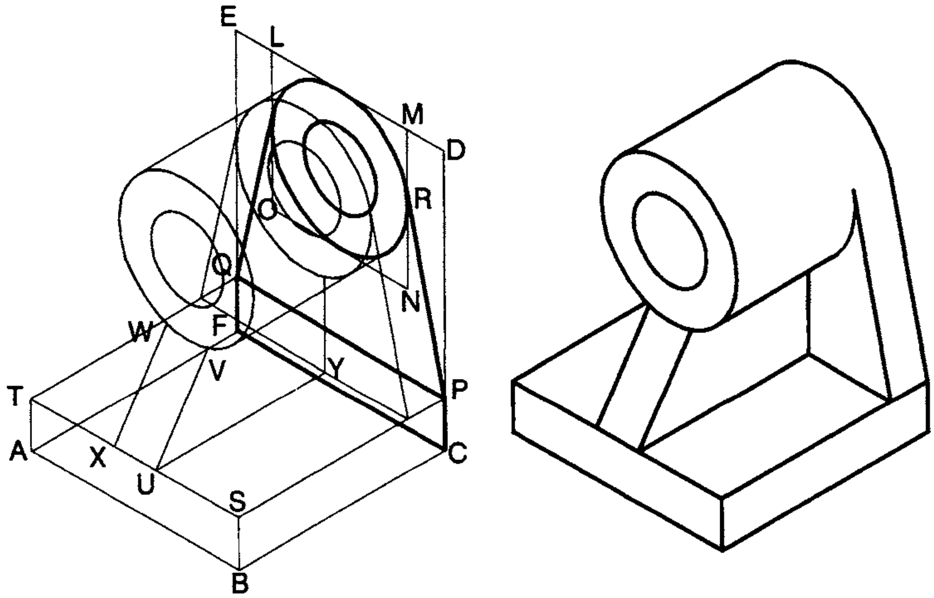

Figure 2.5 *Example of the method of drawing an isometric projection bearing bracket*

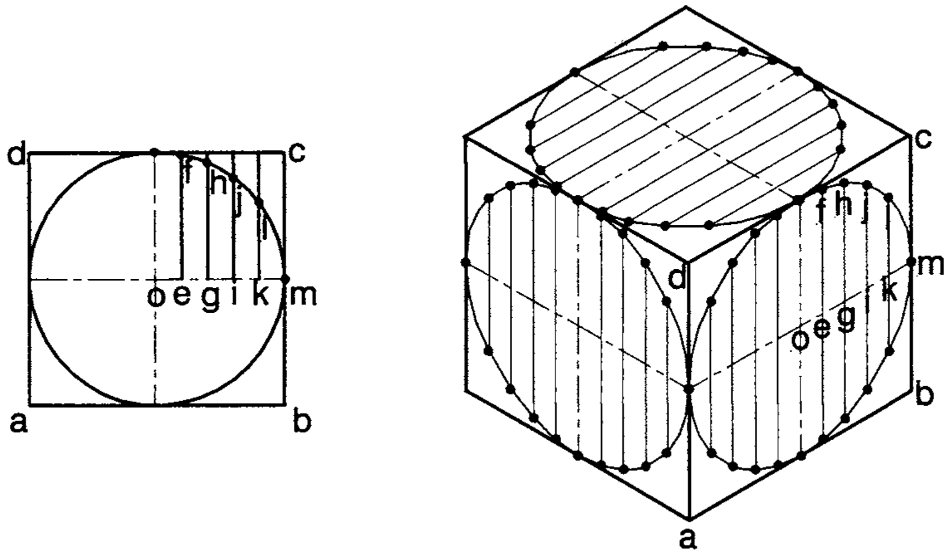

Figure 2.6 *Example of the method of drawing isometric projection circles*

circles can either be produced freehand or by using matching ellipses. Returning to the isometric bearing plate in Figure 2.5, the isometric circles representing the bearing outside and inside diameters are constructed within the isometric square LMNO. Two angled lines PR are drawn connecting the isometric circles to the base CPQF. The rear shape of the bearing bracket is now complete within the enclosing rectangle CDEF.

Returning to the isometric projection drawing of the flanged bearing block in Figure 2.5. The inside and outside bearing diameters in the isometric form are now projected forward and parallel to the axis BC such that two new sets of isometric circles are constructed as shown. The isometric rectangle CPQF is then projected forward, parallel to BC that produces rectangle ABST, thus completing the bottom plate of the bracket. Finally, the web front face UVWX is constructed. This completes the various constructions of the isometric bearing bracket and the final isometric drawing on the right-hand side can be constructed and hidden detail removed.

Any object can be constructed as an isometric drawing provided the above rules of enclosing rectangles and squares are followed which are then projected onto the three isometric planes.

2.4 Oblique projection

In oblique projection, the object is aligned such that one face (the front face) is parallel to the picture plane. The projection lines are still parallel but they are not perpendicular to the picture plane. This produces a view of the object that is 3D. The front face is a true view (see Figure 2.7). It has the advantage that features of the front face can be drawn exactly as they are, with no distortion. The receding faces can be drawn at any angle that is convenient for illustrating the shape of the object and its features. The front face will be a true view, and it is best to make this one the most complicated of the faces. This makes life easier! Most oblique projections are drawn at an angle of 45° and at this angle the foreshortening is 50%. This is called a Cabinet projection. This is because of its use in the furniture industry. If the 45° angle is used and there is no foreshortening it is called a Cavalier projection. The problem with Cavalier projection is that, because there is no foreshortening, it looks peculiar and distorted. Thus, Cabinet projection is the preferred method for constructing an oblique projection.

An oblique drawing of the bearing bracket in Cabinet projection is shown in Figure 2.8. For convenience, the front view with circles was chosen as the true front view. This means that the circles are true circles and therefore easy to draw. The method of construction for oblique projection is similar to the method described above for isometric projection except that the angles are not 30° but 45°. Enclosing rectangles are again used and transposed onto the 45° oblique planes using 50% foreshortening.

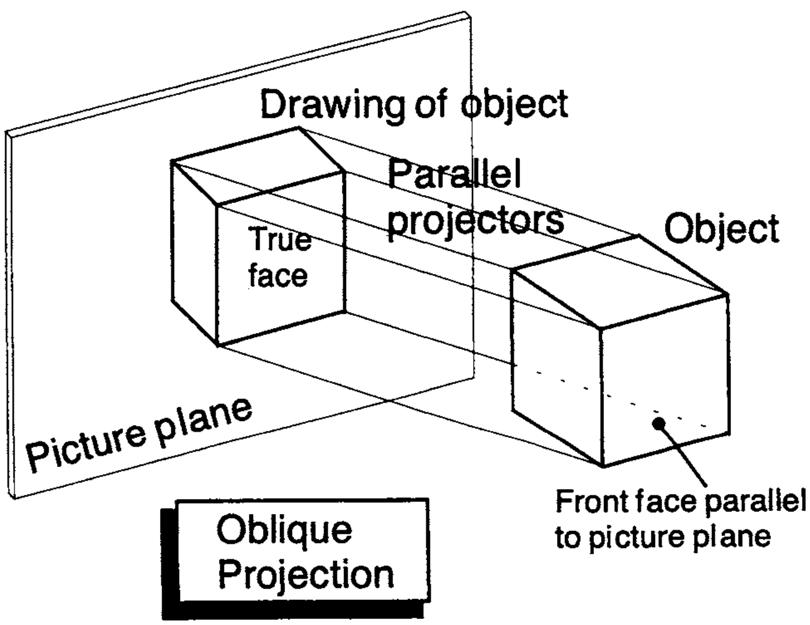

Figure 2.7 *Oblique projection*

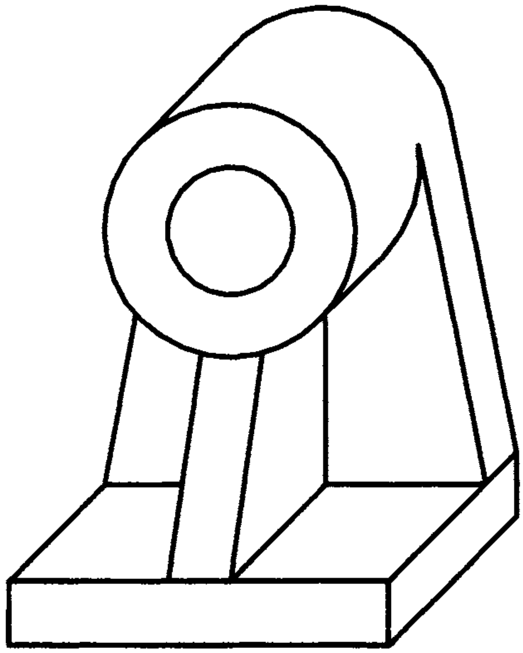

Figure 2.8 *Example of the method of drawing an oblique projection bearing bracket*

2.5 Orthographic projection

In orthographic projection, the front face is always parallel to the picture frame and the projectors are perpendicular to the picture frame (see Figure 2.9). This means that one only ever sees the true front face that is a 2D view of the object. The receding faces are therefore not seen. This is the same as on an oblique projection but with the projectors perpendicular rather than at an angle. The other faces can also be viewed if the object is rotated through 90°. There will be six such orthographic views. These are stand-alone views but if the object is to be 'reassembled' from these six views there must be a law that defines how they are related. In engineering drawing there are two laws, these are first or third angle projection. In both cases, the views are the same; the only thing that differs is the position of the views with respect to each other. The most common type of projection is *third angle projection*.

2.5.1 Third angle projection

Figure 2.10 shows a small cornflake packet (courtesy of Kellogg's) that has been cut and folded back to produce a development of a set of six connected faces. Each one of these faces represents a true view of the original box. Each face (view) is folded out from an adjacent

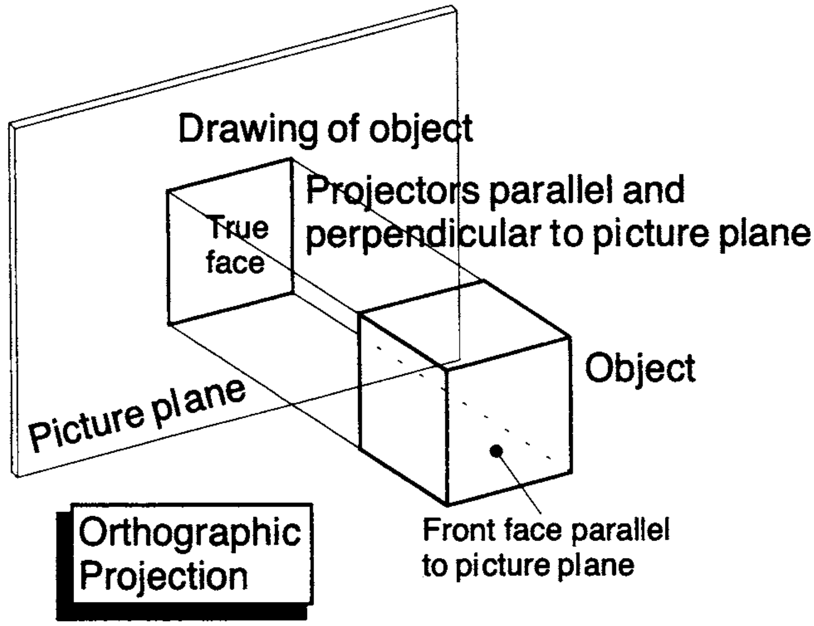

Figure 2.9 *Orthographic projection*

Figure 2.10 *A folded out cardboard cornflake packet (courtesy of Kellogg's)*

face (view). Folding the faces back and gluing could reassemble the packet. The development in Figure 2.10 is but one of a number of possible developments. For example, the top and bottom small faces could have been connected to (projected from) the back face (the 'bowl game' face) rather than as shown. Alternatively, the top and bottom faces could have been connected.

Figure 2.11 (courtesy of Kellogg's) shows the same layout but with the views separated from each other such that it is no longer a development but a series of individual views of the faces. The various views have been labelled. The major face of the packet is the one with the title 'Corn Flakes'. This face is the important one because it is the one that would be placed facing outwards on a supermarket shelf. This view is termed the 'front view' and all the other views are projected from it. Note the obvious names of the other views.

All the other five views are projected from the front face view as per the layout in Figure 2.10. This arrangement of views is called *third angle orthographic projection*. The reason why this is so is explained below. The third angle orthographic projection 'law' is

Figure 2.11 *Cornflake packet in third angle projection (courtesy of Kellogg's)*

that the view one sees from your viewing position is placed on the same side as you view it from. For example, the plan view is seen from above so it is placed above the front face because it is viewed from that direction. The right-side view is placed on the right-hand side of the front view. Similarly, the left-side view is placed to the left of the front view. In this case, the rear view is placed on the left of the left-side view but it could have also been placed to the right of the right-side view. Note that opposite views (of the packet) can only be projected from the same face because orthographic relationships must be maintained. For example, in Figure 2.11, the plan view and inverted plan view are both projected from the front view. They could just as easily have both been projected from the right-side view (say) but not one from the front face and one from the right-side view. It is doesn't matter which arrangement of views is used as long as the principle is followed that you place what you see at the position from which you are looking.

Figure 2.12 shows a third angle projection drawing of a small bracket. In this case, the plan view and the inverted plan view are projected from the front face. Note that the arrangements of the views are still in third angle projection but they are arranged differently from the views in Figure 2.11. Another example of third angle projection is seen in the truncated cone within the title box in Figure 2.12. Here, the cone is on its side and only two views are shown yet they are still in third angle projection. The reason the cone is shown within the box is that it is the standard symbol for third angle

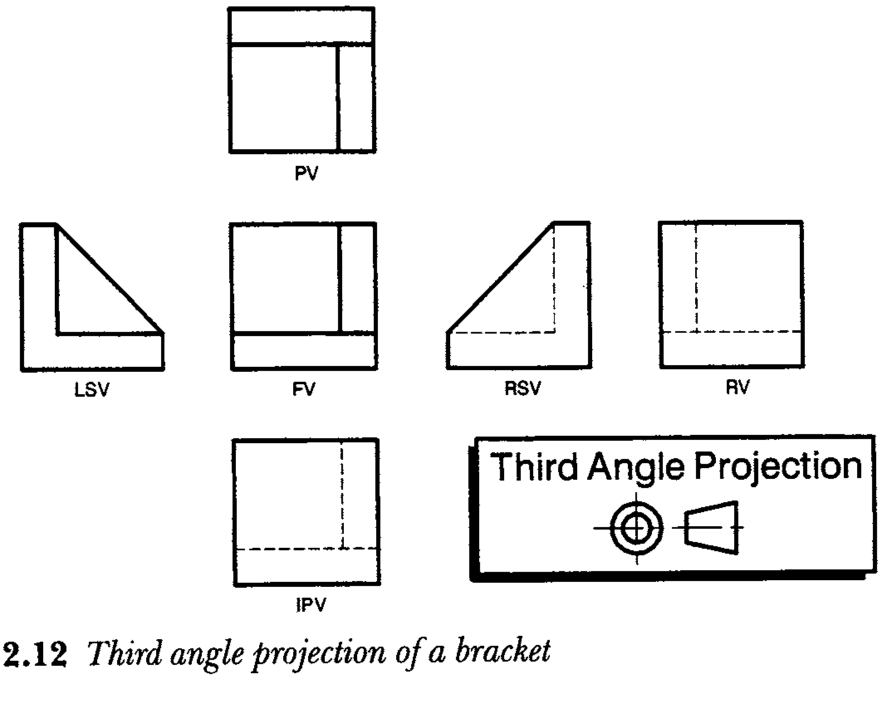

Figure 2.12 *Third angle projection of a bracket*

projection recommended in ISO 128:1982. The standard recommends that this symbol be used within the title block of an engineering drawing rather than the words '*third angle projection*' because ISO uses symbology to get away from a dependency on any particular language.

Third angle projection has been used to describe engineering artefacts from the earliest of times. In the National Railway Museum in York, there is a drawing of George Stephenson's 'Rocket' steam locomotive, dated 1840. The original is in colour. This is a cross between an engineering drawing (as described above) and an artistic sketch. Shadows can be seen in both orthographic views. Presumably this was done to make the drawings as realistic as possible. This is an elegant drawing and nicely illustrates the need for 'engineered' drawings for the manufacture of the Rocket locomotive.

Bailey and Glithero (2000) state, 'The Rocket is also important in representing one of the earliest achievements of mechanical engineering design'. In this context, the use of third angle projection is significant, bearing in mind that the Rocket was designed and manufactured during the transition period between the millwright-based manufacturing practice of the craft era and the factory-based manufacturing practice of the industrial revolution. However, third angle projection was used much earlier than this. It was used by no less than James Watt in 1782 for drawing John Wilkinson's Old Forge engine in Bradley (Boulton and Watt Collection at Birmingham Reference Library). In 1781 Watt did all his own drawing but from 1790 onwards, he established a drawing office and he had one assistant, Mr John Southern.

These drawings from the beginning of the industrial revolution are significant. They illustrate that two of the fathers of the industrial revolution chose to use third angle projection. It would seem that at the beginning of the 18th century third angle was preferred, yet a century later first angle projection (explained below) had become the preferred method in the UK. Indeed, the 1927 BSI drawing standard states that third angle projection is the preferred UK method and third angle projection is the preferred USA method. It is not clear why the UK changed from one to the other. However, what is clear is that it has changed back again because the favoured projection method in the UK is now third angle.

2.5.2 First angle projection

The other standard orthographic projection method is first angle projection. The only difference between first angle and third angle projection is the position of the views. First angle projection is the opposite to third angle projection. The view, which is seen from the side of an object, is placed on the opposite side of that object as if one is looking through it. Figure 2.13 shows the first angle projection layout of the bracket shown in Figure 2.12. The labelling of the views (e.g. front view, plan, etc.) is identical in Figures 2.12 and 2.13. Note that in first angle projection, the right-side view is not placed on the right-hand side of the front view as in third angle projection but rather on the left-hand side of the front view as shown in Figure 2.13. Similarly, the left-side view appears on the right-hand side of the front view. The other views are similarly placed. A comparison between Figures 2.12 and 2.13 shows that the views are identical but the positions and hence relationships are different.

Another first angle projection drawing is seen in the title box in Figure 2.13. This is the truncated cone. It is the standard ISO symbol for first angle projection (ISO 128:1982). It is this symbol which is placed on drawings in preference to the phrase 'first angle projection'.

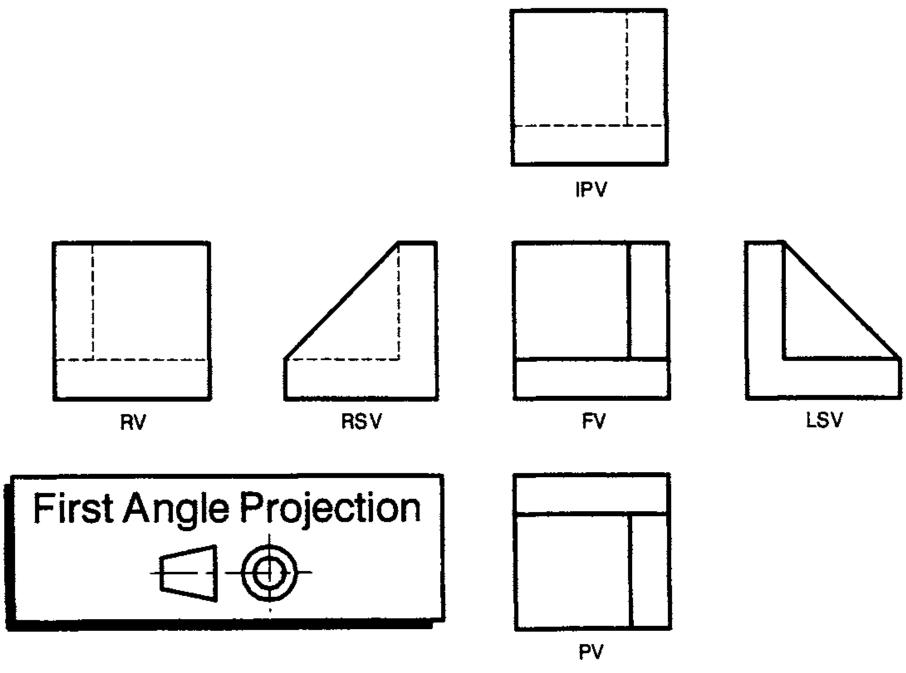

Figure 2.13 *First angle projection of a bracket*

First angle projection is becoming the least preferred of the two types of projection. Therefore, during the remainder of this book, third angle projection conventions will be followed.

2.5.3 Projection lines

In third angle projection, the various views are projected from each other. Each view is of the same size and scale as the neighbouring views from which it is projected. Projection lines are shown in Figure 2.14. Here only three of the Figure 2.12 views are shown. Horizontal projection lines align the front view and the left-side view of the block. Vertical projection lines align the front view and the plan view. The plan view and the left-side view must also be in orthographic third-angle projection alignment but they are not projected directly from one another. A deflector line is placed at 45°. This line allows the horizontal projection lines from the plan view to be rotated through 90° to produce vertical projection lines that align with the left-side view. These horizontal and vertical projection lines are very convenient for aligning the various views and making sure that they are in correct alignment. However, once the views are completed in their correct alignment, the projection lines are not needed because they tend to complicate the drawing with respect to the main purpose, which is to manufacture the artefact.

It is normal industrial practice to erase any projection lines such that the views stand out on their own. Often in engineering drawing

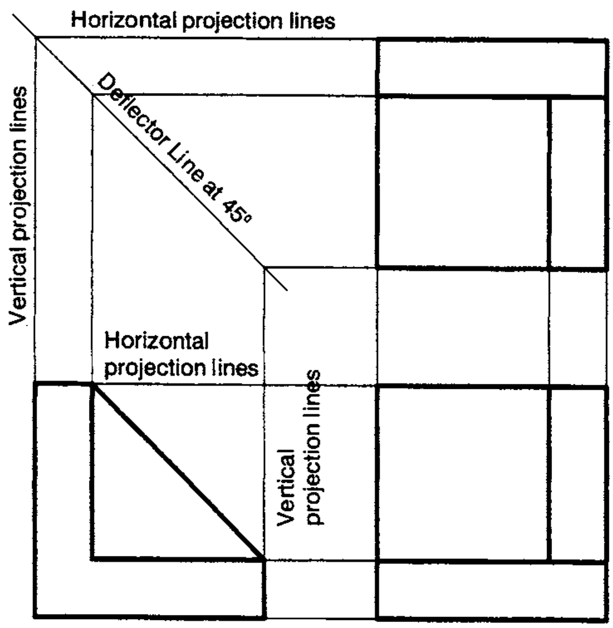

Figure 2.14 *Third angle projection of a bracket showing the projection lines*

lessons in a school, the teacher may insist projection lines be left on an orthographic drawing. This is done because the teacher is concerned about making sure the academic niceties of view alignment are completed correctly. Such projection lines are an unnecessary complication for a manufacturer and therefore, since the emphasis here is on drawing for manufacture, projection lines will not be included from here on in this book.

2.6 Why are first and third angle projections so named?

The terms *first angle projection* and *third angle projection* may seem like complicated terms but the reason for their naming is connected with geometry. Figure 2.15 shows four angles given by the planes OA, OB, OC and OD. When a part is placed in any of the four quadrants, its outline can be projected onto any of the vertical or horizontal planes. These projections are produced by viewing the parts either from the right-hand side or from above as shown by the arrows in the diagram.

In first angle projection the arrows project the shape of the parts onto the planes OA and OB. When the two planes are opened up to

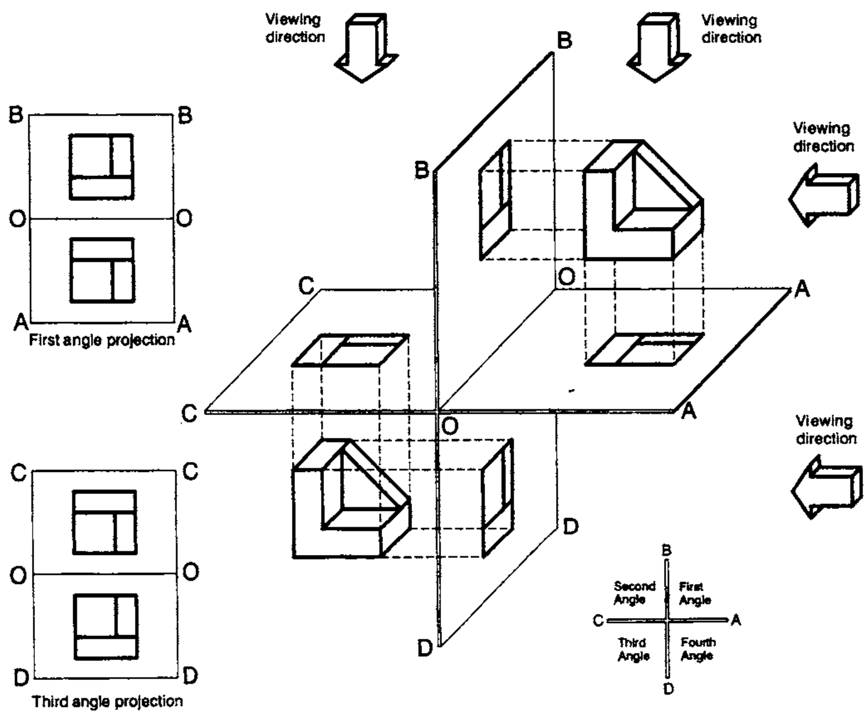

Figure 2.15 *Geometric construction showing the meaning of first and third angle projection*

180°, as shown in the small diagrams in Figure 2.15, the two views will be in first angle projection arrangement.

When the part in the third quadrant is viewed from the right-hand side and from above, the view will be projected forwards onto the faces OC and OD. When the planes are opened up to 180°, the views will be in third angle projection arrangement, as shown in the small diagrams in Figure 2.15.

If parts were to be placed in the second and fourth quadrant, the views projected onto the faces when opened out would be incoherent and invalid because they cannot be projected from one another. It is for this reason that there is no such thing as *second angle projection* or *fourth angle projection*.

There are several ISO standards dealing with views in first and third angle projection. These standards are: ISO 128:1982, ISO 128–30:2001 and ISO 128–34:2001.

2.7 Sectional views

There are some instances when parts have complex internal geometries and one needs to know information about the inside as well as the outside of the artefact. In such cases, it is possible to include a section as one of the orthographic views. A typical section is shown in Figure 2.16. This is a drawing of a cover that is secured to another part by five bolts. These five bolts pass through the five holes in the edge of the flange. There is an internal chamber and some form of pressurised system is connected to the cover by the central threaded hole. The engineering drawing in Figure 2.16 is in third angle projection. The top drawing is incomplete. It is only half the full flange. This is because the part is symmetrical on either side of the horizontal centre line, hence the 'equals' signs at either end. This means that, in the observer's eye, a mirror image of the part should be placed below the centre line. Note that the view projected (beneath) from this plan view is not a side view but a section through the centre. In museums, it is normal practice to cut or section complex parts like engines to show the internal workings. Parts that are sectioned are invariably painted red (or any other bright colour!). In engineering drawing terms, the equivalent of painting something red is to use cross-hatching lines which, in the case of Figure 2.16, are placed at 45°. The ISO rules concerning the form and layout of such section lines is given in Chapter 3. The method of indicating the fact that a section has been taken on the view, from which the section is projected, is shown in the plan view of the flange. Here, the centre line has two thicker lines at either end with arrows showing the direction of viewing. Against the arrows are the capital letters 'A', and it is along these lines and in the direction of arrows that the sectional view is taken. The third angle projection view beneath is a section along the line AA, hence it is given the title 'Section AA'. This method of showing the section position with a thickened line and arrows is explained further in the following chapter on ISO rules.

Other examples of sections are given in the assembly drawing of a small hand vice (see Figure 1.11) and the detailed drawing of the movable jaw of the vice (see Figure 1.12). In the case of the movable jaw detailed drawing in Figure 1.12, the front view is shown on the top-left and the right-hand side drawing view is a right-hand section through the centre line. In this instance there are no section lines or arrows to indicate that it is a section through the centre. However, in this case, it should be obvious that the section is through the centre and therefore it is not necessary to include the arrows. However, this is not the case for the inverted planned view, which is a complicated half-section with two section plane levels on the left-hand side and a

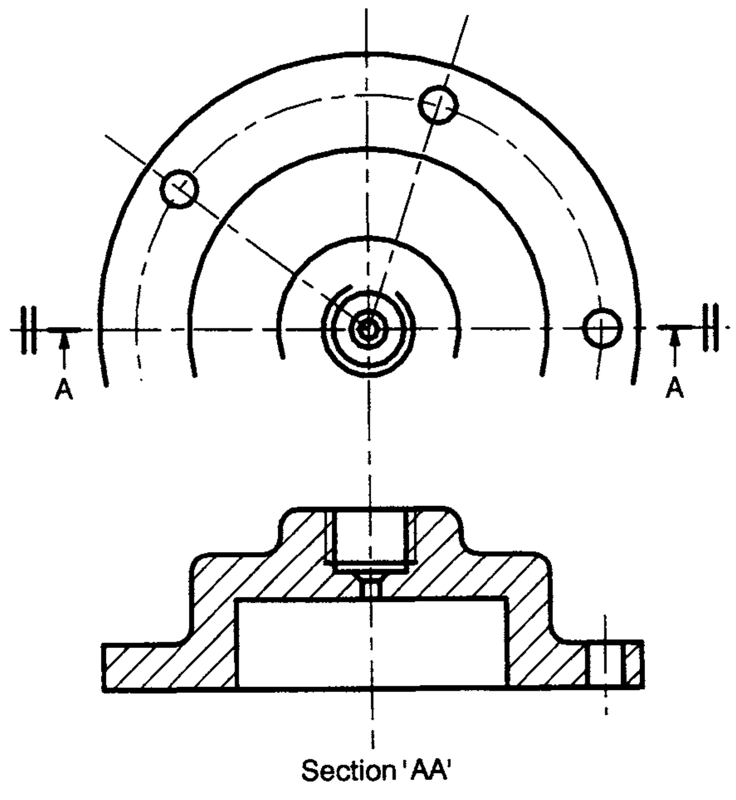

Figure 2.16 *Example of a sectional view of a flange*

conventional inverted plan (unsectioned) view on the right-hand side. Because this is a complicated inverted plan view, the section line and arrows are shown to guide the viewer. Note that the cross-hatched lines on the two different left-hand planes are staggered slightly.

A different type of section is shown in the assembly drawing in Figure 1.11. Here the movable jaw (part number 3), the hardened insert (part number 2), the bush (part number 4), the bush screw (part number 5) and part of the jaw clamp screw (part number 6) are shown in section. This is what is termed a 'local' section because the whole side view is not in section but a part of it. The various parts in the section are cross-hatched with lines at different slopes and different spacings. The section limits are shown by the zig-zag line on the movable jaw and a wavy line on the jaw clamp screw. Another type of section is shown on the tommy bar of the assembly drawing. This is a small circle with cross-hatching inside. This is called a 'revolved section' and it shows that, at this particular point along the tommy bar, the cross-sectional shape is circular. In this instance the cross-sectional shape would be the same at any point along the tommy so it doesn't really matter where the section appears.

The ISO standards dealing with sectional views are ISO 128–40:2001 and ISO 128–44:2001.

2.8 Number of views

In the examples of the cornflake packet shown in Figure 2.11 and the small bracket shown in Figure 2.12, six views of each component were shown. There can only ever be six views of an artefact in a full orthographic projection. The central view is invariably the front view.

Other views can be included but these will be auxiliary views. Such auxiliary views are placed remote from the orthographic views. If an artefact contains a sloping surface, the true view of the inclined surface will never be seen in orthographic projection. This can be seen in the small bracket in Figure 2.12. The bracket contains a stiffening wall which is shown on the right-hand side of the front view. This has a sloping surface as shown by the left-side view and the right-side view. However, there is no view that shows the true view of this place. This could be provided by an auxiliary view, projected from the left-side view or the right-side view that would be a view perpendicular to the inclined face. Such an inclined view would not fit comfortably within the six views of the bracket and therefore would be placed off at the side but with a note making clear that it was a view on an arrow perpendicular to the face. It is normal practice to label such arrows with some alphanumeric designation. There needs to be a title associated with the true view that relates the arrow to the view. A typical title would be 'View on arrow Z'.

Unless a part is very complex, six views of an artefact are unnecessary and over the top. The number of views will be dependent on the transmission of full and complete information of the artefact. Thus, considering the bracket in Figure 2.12, only three views would probably be needed. These would be the front view, the plan view and the left-side view. These three views would then be dimensioned and the three views plus the dimensions would be sufficient for the bracket to be made. Three such views are shown in Figure 2.14 (but the projection lines need to be rubbed out). Figure 2.16 shows two views of a flange. Since one view is a sectional view through the centre line, sufficient information can be transmitted when this part is dimensioned for it to be manufactured. In the small hand vice assembly drawing in Figure 1.11, three views are shown. The only reason that the left-hand view is shown is to give details of the screws (part number 8) which hold one of the hardened inserts to the body. An alternative method of drawing these bolts would be by adding dotted lines to the side view such that the hidden detail of the bolts was shown. In this case the balloon references would go to these dotted lines and the left-hand view would be unnecessary. However, I drew the three views because I thought it would be clearer than adding dotted lines.

The three drawings in Figure 1.11 are sufficient to assemble the various parts of the small hand vice. However, this cannot be said for the parts necessary to assemble George Stephenson's Rocket. In this case the two views would only give the barest of information about the outside shape and form. Numerous other views and indeed additional drawings would be needed to give full details on how to make and assemble the locomotive.

No hard and fast rules can be given with respect to the number of views required on any engineering drawing. The decision on the number required will be dependent on the complexity of the artefact and its internal features. In all cases the number of views will be driven by the need to give sufficient information for the part to be manufactured. One should try to avoid giving more views than is necessary because this just tends to complicate a drawing. On the other hand, if an extra view helps in the understanding of the part design, then it is a useful addition!

References and further reading

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