UNIT 5
Multiview Drawings

After completing this unit, you will be able to:

- Explain the relationship between an orthographic projection and a multiview drawing.
- Identify and define the three dimensions of an object.
- Define the three regular views.
- Identify three principal planes of projection.
- Explain three visualization principles for multiview drawings.
- Identify the three types of flat surfaces.
- Explain characteristics of cylindrical surfaces.
- Identify differences between third-angle and first-angle projection.

The purpose of a drawing is to show the size and shape of the object. A drawing can also provide certain information on how an object is to be made. Various methods of presentation are available to the designer or drafter. However, the best way to show every feature of an object in its true size and shape is to use an arrangement of more than one view known as a multiview drawing. Multiview drawings are created using the principles of orthographic projection. Many drafting and print reading texts use the terms orthographic projection and multiview drawing interchangeably.

Orthographic Projections of Views

Any view of an object drawn by a drafter can be explained as the projection of an object’s features onto a two-dimensional plane. For a drawing, the plane is often a piece of paper or computer screen. Simply defined, orthographic projection is a system wherein parallel lines, called projectors, are used to project the object onto a projection plane.

The projectors are perpendicular to the projection plane, thus resulting in an exact and very precise view. If more than one projection plane is used, the result is a multiview projection. In general terms, a multiview drawing is a drawing based on the principles of orthographic projection.

The different views of a multiview drawing are systematically arranged. This allows anyone “reading” the drawing to “connect” the views together, thus forming a mental picture, Figure 5-1.

Projection Explained

A skilled technician reading a print must be able to visualize the object as a whole. This means they must be able to look at the views in a drawing and interpret those into a mental picture. Understanding how views are projected and arranged will help you later in the visualization process.

One way to help you understand the multiview system is to observe how a cardboard box unfolds. Each side of the box is oriented similar to orthographic projection views. The sides are at right angles to each other and have a definite relationship. See Figure 5-2. If the front of the box remains in position, the four adjoining sides unfold similar to how the views of a multiview drawing are arranged.

Now think of the cardboard box as made out of glass. Place an object inside of the glass box and imagine that the points of the object are projected onto the glass planes as views. See Figure 5-3. Imaginary projection lines are used to bring the separate views to each projection plane. If the glass box is unfolded like the cardboard box, six views are shown in an orthographic arrangement. Once you have perfected mentally projecting orthographic views using the glass box, you will be able to see orthographic views looking at any object, Figure 5-4.
Selection of Views

An orthographic projection can result in six normal views, as previously illustrated. Since there are three directions in space, an object can be viewed from the right or left, top or bottom, and front or back. However, only those views necessary to clearly describe the object need to appear in the drawing. Seldom is an object so complex that all six normal views are required. Usually, the necessary details can be shown in two or three views. Three views will almost always fully describe an object, but more views can be used if there is a lot of detail on the opposite sides of an object. Directions other than the six normal directions are defined as auxiliary views, which are discussed in Unit 7.
In educational settings, the front, top, and right side views are typically used to describe an object. This type of drawing can be referred to as a three-view drawing. Yet, many objects made of flat sheet metal require only one view, while cylindrical objects may only require two views. The following rules will help in the selection of views.

- Only views clearly describing the shape of the object should be drawn.
- Select views containing the fewest hidden lines. For reference, compare the two side views in Figure 5-3.
- If practical, draw the view best describing the shape of the object as the front view.

### Dimensions of an Object

One of the keys to reading a multiview drawing is familiarity with the terminology used for the dimensions of an object. It is critical to discuss the scientific explanation of projections using standard terms. As you have probably noticed, each projected view is two dimensional, even though the object is three dimensional.

### Visualization of Objects

Another necessary step on the road to successful print reading is understanding how views are created by projection. You will examine how flat, or planar, surfaces are oriented in space and how they appear in a multiview drawing. At this stage, three principal planes of projection will be established and only three regular views used. The front view will project onto a plane called the frontal plane, the top view will project onto a plane called the horizontal plane, and the right side view will project onto a plane called the profile plane. See Figure 5-5.

With these three planes of projection in mind, here are some principles to help you read the print.

- **Principle One.** A flat surface is oriented perpendicular, parallel, or inclined to a plane of projection. See Figure 5-6.
- **Principle Two.** As a result of Principle One, all flat surfaces appear in a multiview drawing as:
  - A) a line, if oriented perpendicular.
  - B) true size and shape, if oriented parallel.
  - C) foreshortened, if oriented inclined. See Figure 5-7.
- **Principle Three.** All surfaces appear in every view of a multiview drawing, even if only as a line and even if represented by a hidden line.

### Three Types of Surfaces

There are three basic types of flat surfaces in an orthographic projection. A normal surface is parallel to one of the three projection planes and, therefore, perpendicular to the other two. For example, each surface of a cube is normal and the top flat surface of a cylinder is normal. If normal surfaces are examined with respect to the three principles:

- A normal surface appears true size and shape in only one view.
- The normal surface appears as a line in two of the three regular views.

Think about this for a while. Very often, when you look at a line in a multiview drawing, you are looking at the edge view of a surface. When you look at the front view of a cube, you see the top and right side surfaces as lines. Study Figure 5-8A. With respect to the top surface of the cube in the front view, if you only “see” the front edge along the front surface, you are still thinking in two dimensions. As your visualization ability increases, you will see these lines as surfaces that extend back.
A second type of flat surface is the inclined surface. An inclined surface is perpendicular to one plane of projection, but inclined to the other two planes of projection. If inclined surfaces are examined with respect to the three principles:

- An inclined surface appears as a line in only one of the three regular views.
- An inclined surface appears as a foreshortened shape in two of the three regular views.
- A normal surface appears as true size and shape in all three regular views.

Study Figure 5-8B. Surface C is perpendicular to the frontal plane, so it appears as a line in the front view. However, it is inclined to the horizontal and profile planes, so it appears as a foreshortened shape in those two views. Analyze surfaces A and B in the same way. In summary, the shape of an inclined surface appears twice in three regular views, but a normal surface shape only appears once! The normal surface is true size and shape, but the inclined surface is never true size and shape in a regular view.

A third type of planar surface is the oblique surface. An oblique surface is not only inclined, but rotated. Therefore, it is inclined to all three planes of projection. It is not true shape and size in any view. In fact, it may appear a little distorted due to the projection angle it forms with the projection plane. It also does not appear as a line in any view. See Figure 5-9.

Cylindrical and Curved Surfaces

Cylindrical surfaces present another set of visual challenges to the print reader. Technically, cylindrical surfaces are made of thousands of “elements” that form a curved surface about an axis, Figure 5-10. The designer has often planned it so that a flat surface is tangent to a curved surface, thus making a smooth transition between the curve and the flat. See objects B and D in Figure 5-10. In these cases, no lines are shown at the element of tangency. Be aware, however, some CAD programs that automatically generate the views from the model show these elements of tangency. Also, when flat surfaces form intersections and cutouts with cylindrical surfaces, the projections can be tricky. Study Figure 5-11 to help you visualize how cylindrical surfaces are projected in multiview drawings.
Fillets, Rounds, and Runouts

Molded and cast objects have rounded edges called fillets and rounds. See Figure 5-12. Fillets are interior rounded edges. Rounds are exterior rounded edges. Most CAD programs have a command called FILLET to perform this task of rounding corners, both interior and exterior.

These rounded corners also create situations where the drafter has to decide whether or not to project the edge. Conventional practice calls for the lines to be shown if needed for clarity in describing the object. This is sometimes a judgment call. If the edge is shown, the line is projected as if the corner is sharp or square. When a rounded corner intersects a curved surface, the edge fades, or “tails” out. This is called a runout. Note, however, this is different than runout as defined in Unit 13, Geometric Dimensioning and Tolerancing. See Figure 5-13 for an example of how runouts may be drawn. This is another case wherein views automatically created from a 3D model by the CAD program may differ from views created by a CAD operator using two-dimensional CAD lines and conventional practice.

Meanings of a Multiview Line

In summary, there are many different perimeter shapes that a flat surface can have, from circular, to square, to polygonal. Yet, if the surface is perpendicular to the projection plane, it simply projects as a line. Therefore, many lines in a multiview drawing represent the edge view of planar surfaces. Curved surfaces also are seen as edge views if the curved surface is perpendicular to the projection plane. See Figure 5-14.

A second meaning a multiview line can have is simply an intersection—an edge where two surfaces meet and nothing more. A third meaning a multiview line can have is the maximum contour element of a curved surface. In some views, this will be represented by a line. These are the three meanings a line in a multiview drawing can have, whether it is visible or hidden. As you learn how to read prints, keep these three meanings in mind.

First-Angle and Third-Angle Projection

The system of projection explained earlier in the unit is common throughout the United States. The projection of a view is basically what the viewer sees when looking at the object through the glass projection plane. The glass box is unfolded in such a way as to place the top view above the front view. This is known as third-angle projection. In many countries, especially in Europe, a slightly different projection system is used that results in the views being located differently.

The two projection systems used in industrial drawings are identified as third-angle projection and first-angle projection. These two types result from a theoretical division of space into four quadrants by vertical and horizontal planes, Figure 5-15. The viewer of the four quadrants is considered to be in front of the frontal plane and above the horizontal plane. The views are arranged by folding the two planes into one by collapsing the second and fourth quadrants and the views are then seen from the front. As a result of this, there are no second or fourth angle projections. If there were, the views would overlap.
As presented earlier in the unit, in third-angle projection, the object resides in the third angle of space. So, the projection planes are considered to be between the viewer and the object. The views are projected toward the viewer onto the planes. See Figure 5-16. When quadrants two and four are collapsed, the top view appears above the front view.

In contrast, in first-angle projection, the object resides in the first angle of space. So, the projection planes are on the opposite sides of the object as the viewer. In other words, the object is between the viewer and the projection planes. See Figure 5-17. The individual views are the same as those obtained in third-angle projection, but their arrangement on the drawing is different. In essence, the top view ends up below the front view and a right side view is on the left side of the front view.

In summary, the individual views are the same for both angles of projection. The only difference between the two types is the arrangement of views on the drawing. The ASME and ISO standard symbols to indicate first-angle and third-angle projection are shown in Figure 5-18. One of the two versions of the symbol should be included in the title block for drawings that are read within the international community.

Figure 5-15.
The two types of projection are based on a theoretical division of space into four quadrants. Quadrants two and four are not used.

Figure 5-16.
In third-angle projection, the projection plane is considered to be between the viewer and the object and the views are projected toward the viewer onto the plane.

Figure 5-17.
In first-angle projection, the projection plane is on the opposite side of the object as the viewer and the views are projected onto the plane on the far side of the object.

Figure 5-18.
The type of projection for a drawing is indicated by one of these two symbols appearing in the title block.
Review Questions
Circle the answer of choice, fill in the blank, or write a short answer.

1. Multiview drawings are created using the principles of ________________ projection.

2. Any view of an object can scientifically be explained as the projection on a object’s features on to ____________________________.

3. True or False? In orthographic projection, the projectors are parallel with each other.

4. True or False? While multiview drawings are often arranged in a certain manner, it does not matter how they are arranged on the paper as long as they are correctly labeled.

5. There are ____ normal ways to view an object.
   A. two
   B. four
   C. six
   D. eight

6. List the three predominate terms used to define the three dimensions of an object: ____________________________

7. List the names given to the three principal planes of projection: ____________________________

8. True or False? A flat surface is oriented to a plane of projection in one of three ways: perpendicular, parallel, or inclined.

9. If a surface is perpendicular to a plane of projection, it projects on to that plane as ____________________________

10. Flat surfaces are defined by how they are oriented to the three principal planes of projection. List the three names given to flat surfaces: ____________________________

11. An inclined surface will appear as a(n) ____________________________ in one view and as a foreshortened shape in ____________________________ views.

12. True or False? When a flat surface transitions into a cylindrical surface, a line is shown at the element of tangency.

13. True or False? Interior rounded corners are called rounds and exterior rounded corners are called fillets.

14. Of the following, select the one statement that is not a meaning a line in a multiview drawing can have:
   A. Edge view of a flat surface.
   B. Maximum contour element of a curved surface.
   C. Intersection edge where two surfaces meet, nothing more.
   D. Tangency element between a curved surface and a flat surface.

15. In the United States, industrial prints use the ____________________________-angle projection system, whereas many other countries use ____________________________-angle projection.

Review Activity 5-1
Normal Surfaces
Study each pictorial (3D) drawing and the identification letters placed on, or pointing to, the normal surfaces. Match the ID letter to the corresponding number for each of the multiview (orthographic) callouts. Note: The letter I is not used.

Doohickey Block

Whatchamacallit Bracket

Note: In the pictorial view, arrows pointing directly to a line are referencing a surface that is not visible, rather “around the back” of the object.
Review Activity 5-2

Normal and Inclined Surfaces
Study each pictorial (3D) drawing and the identification letters placed on, or pointing to, the normal or inclined surfaces. Match the ID letter to the corresponding number for each of the multiview (orthographic) callouts. Note: The letter I is not used.

Note: In the pictorial view, arrows pointing directly to a line are referencing a surface that is not visible, rather “around the back” of the object.

Thingamabob Wedge

Gadget Corner Block

Review Activity 5-3

Sketching Missing Lines
Sketch the missing line(s) in the following multiview drawings. The final drawing should present a clear view of the object and all views must agree. Include all visible lines, hidden lines, and center lines.
Review Activity 5-4

True Size and Shape Identification

Analyze each of the multiview drawings. Place a T for true size and shape or an F for foreshortened size and shape in the blanks below each multiview. Remember, normal surfaces appear true size and shape in only one view. Inclined surfaces appear foreshortened in shape and size in two views. The first problem is done for you as an example.

1. [Diagram]
   A T B F
   C F D T
   E T F T

2. [Diagram]
   A ___ B ___
   C ___ D ___
   E ___ F ___

3. [Diagram]
   A ___ B ___
   C ___ D ___
   E ___ F ___

4. [Diagram]
   A ___ B ___
   C ___ D ___
   E ___ F ___

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Review Activity 5-5

Projection Plane Orientation and Surface Type Identification

For each of the four pictorial drawings, imagine a frontal projection plane in front of the object, a horizontal plane of projection above the object, and a profile projection plane to the right, as described in this unit. In the charts below, fill in the number of surfaces oriented to each of the three projection planes as indicated for each column (parallel, perpendicular, or inclined). Include all surfaces, even the bottom, back, and left-side surfaces. The first object has been done for you as an example. Also, enter the number of each type of surface in the second chart. Note: The total for each row of the first chart should be the same and it should also match the total of the second chart, as shown in the first problem.

1. [Diagram]
   Front
   Parallel: 2
   Perpendicular: 5
   Inclined: 0
   Total: 7

2. [Diagram]
   Front
   Parallel: 1
   Perpendicular: 4
   Inclined: 1
   Total: 6

3. [Diagram]
   Front
   Parallel: 2
   Perpendicular: 1
   Inclined: 3
   Total: 6

4. [Diagram]
   Front
   Parallel: 1
   Perpendicular: 2
   Inclined: 1
   Total: 4
**Review Activity 5-6**

**Piston**

Study the print and answer the questions.

1. Which view is represented by:
   A. ____________________________________________________________________________________________________________
   B. ____________________________________________________________________________________________________________
   C. ____________________________________________________________________________________________________________

2. How many visible lines are in view:
   A. ____________________________________________________________________________________________________________
   B. ____________________________________________________________________________________________________________
   C. ____________________________________________________________________________________________________________

3. How many hidden lines are in view:
   A. ____________________________________________________________________________________________________________
   B. ____________________________________________________________________________________________________________
   C. ____________________________________________________________________________________________________________

4. What are the three overall dimensions of the object:
   Height ________________________________________________________________________________________________________
   Width ________________________________________________________________________________________________________
   Depth ________________________________________________________________________________________________________

5. How many normal surfaces does this object have? ________________________________________________________

6. How many inclined surfaces does this object have? __________________________________________________________

7. How is the depth of surface X determined? ________________________________________________________________

8. How wide is surface X? ______________________________________________________________________________________

9. How wide is surface Z? ______________________________________________________________________________________

10. Given three choices (edge view, intersection, contour):
    A. What does line 10A mean? ________________________________________________________________________________
    B. What does line 10B mean? ________________________________________________________________________________
Industry Print Exercise 5-1

Refer to the print PR 5-1 and answer the questions below.

1. This drawing has the three regular views. What are they?

2. What term is applied to the dimension value of 2 1/8"?

3. The circular feature in the right side view is _______________ in the front view.

4. What is the height of this part?

5. The top view shows the true size and shape of a surface that encompasses four holes. What type of surface is it?

6. What is the total width of this part?

7. Which letter of the alphabet, M, H, or L, best describes the general shape of the normal surface facing the frontal plane?

8. How many hidden lines are there in the right side view?

9. How does the bottom, flat surface of the object appear in the top view: true size and shape, foreshortened shape, or edge view?

10. In the top view, the right-most vertical line has what meaning: edge view of a surface, intersection of two surfaces only, or maximum contour of a curved surface?

Review questions based on previous units:

11. What is the name of this part?

12. What is the drawing number or part number?

13. In what state is this company located?

14. What is the five-digit material code specified for this part?

15. What is the last name of the person who drew this drawing?
Industry Print Exercise 5-2

Refer to the print PR 5-2 and answer the questions below.

1. Not counting the removed view and pictorial views, how many regular views does this object have?  

2. How many of the regular views feature height?  

3. If the view that is closest to the center of the sheet is the front view, what is the name of the view directly below it?  

4. The flat surface that shows true size and shape in the top view is parallel to the ___________________ plane of projection.  

5. In which view is the viewing-plane line shown for the removed view?  

6. What two dimensions (names) are featured in the left side view?  

7. Does this object appear to have any inclined surfaces?  

8. Which dimension is greater, width or depth?  

9. What is the name of the removed view?  

10. Are hidden lines shown in the top view?  

Review questions based on previous units:  

11. Which view features cutting-plane lines?  

12. What is the drawing number or part number?  

13. How many views feature section lines?  

14. What is the most recent date associated with this drawing?  

15. The annotation on the left side view features a couple of ___________________ lines.
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**Bonus Print Reading Exercises**

The following questions are based on various bonus prints located in the folder at the back of this textbook. Refer to the print indicated, evaluate the print, and answer the question.

**Print AP-001:**
1. On the left side view of this print, there is a horizontal, straight-line segment that does not connect to other lines. In basic terms, explain why. _________________________________________________________________
   ___________________________________________________________________________________________________
   ___________________________________________________________________________________________________

**Print AP-004:**
2. If the view labeled Section B-B is a right side view, what name would be applied to the other four main views? __________________________________________________________________________________________________
   ___________________________________________________________________________________________________

**Print AP-005:**
3. This print features what appears to be a side view (Section G-G) that does not have an accompanying front view. Briefly explain where the front view is located. _____________________________
   ___________________________________________________________________________________________________

4. The view labeled Section J-J is a partial view, as indicated by the short break line. Does it appear to be an orthographic view? ___________________________________________________________________________________
   ___________________________________________________________________________________________________

**Print AP-006:**
5. The two views near the bottom of the print are called detail views. Which one of the views above (left side, front, or right side) shows the same geometry, but at the normal 1:1 scale? __________________
   ___________________________________________________________________________________________________

6. In general terms, what name is applied to the two groove views near the bottom of the print? ___________________________________________________________________________________________________

**Print AP-007:**
7. Carefully examine the drawing. With respect to the enlarged Detail C, how many times larger is it than the other multiview views? _____________________________
   ___________________________________________________________________________________________________

**Print AP-009:**
8. For this drawing, are there other views besides View E-E and View F-F? If so, where are they? _______________________________________________________________
   ___________________________________________________________________________________________________

**Print AP-012:**
9. What name is given on this print to the view that is not in multiview orientation or arrangement? _______________________________________________________________
   ___________________________________________________________________________________________________

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**Print AP-015:**
10. Is the left side view on this print a complete view or a partial view? _____________________________
   ___________________________________________________________________________________________________

**Print AP-016:**
11. Are the views of this assembly drawing arranged orthographically in proper third angle projection? _____________________________
   ___________________________________________________________________________________________________

**Print AP-021:**
12. What is the most likely reason the upper-right view features short break lines? _____________________________
   ___________________________________________________________________________________________________

**Print AP-022:**
13. One view features the depth measurements .300, .250, and .040. How many other main views (not including detail views) on this print feature the depth direction? _____________________________
   ___________________________________________________________________________________________________

**Print AP-024:**
14. If the lower view is considered to be a front view, what label would apply to the view located on the upper-right side of the print? _____________________________
   ___________________________________________________________________________________________________

**Print AP-025:**
15. Is the view labeled FORMED VIEW a normal view defined by multiview practice? _____________________________
   ___________________________________________________________________________________________________
CAD software typically has a tool that allows a section view to be quickly created from a solid model.