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Structural Journeyman

Volume 1. Sheet Metal Layout and Fabrication

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CDC E3E351, *Structural Journeyman*, is the second course that you will complete to gain the required knowledge of a Structural Journeyman. This course contains four volumes and builds upon the foundation of the first course to provide you with the required knowledge on your quest to become a Structural Journeyman. When you complete this course, you will have gained the knowledge needed to perform duties and progress in this career field. When you master this course and combine this knowledge with practical experience you get from working in the shop, you can earn success, prestige, and promotions.

Volume 1 covers sheet metal layout and fabrication. Volume 2 focuses on metal/fiberglass components and overhead/rollup doors. Volume 3 deals with oxyacetylene applications. Volume 4 explains electric arc welding.

Volume 1 consists of 3 units. Unit 1 discusses sheet metal and structural steel layout, including pattern transfers and allowances. Unit 2 covers folding, forming, and seaming equipment. Unit 3 examines seams and joint connections, including lap and lock seams as well as using fasteners.

A glossary of terms, abbreviations, and acronyms is included for your use.

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This volume is valued at 15 hours and 5 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Unit 1. Sheet Metal and Structural Steel Layout

AS A STRUCTURAL JOURNEYMAN, you'll be using various methods to layout flat patterns from working drawings and blueprints. You will use three basic layout methods: parallel line, radial line, and triangulation. These layout methods develop flat patterns for sheet metal components of different shapes. For example, to select a layout method you need to know why true lengths are different from tapered lengths. Why parallel lines are used to develop patterns for square and rectangular ducts? Why triangles are important when laying out transitions? Why radial lines are used when laying out cone-shaped or pyramid-shaped components? These layout methods are important because you'll be using them to develop patterns to fabricate new or replacement components.

The layout methods discussed in this unit will be used later in the course as you study the fabrication, installation, and repair of sheet metal components. During the fabrication and repair of different components, you'll be developing and using patterns to make items such, as round, square, and rectangular ducts, as well as elbows, offsets, ventilators, and transitions. First, we'll consider how to make flat patterns from working drawings.

In the following lessons, you'll learn how compasses and dividers are used to develop graphic solutions that will be useful when laying out patterns for sheet metal objects.

001. Performing graphic solutions and flat pattern layouts

In addition to scribing arcs and transferring measurements, compasses and dividers can be used for stepping off the circumference of a circle into equal parts for constructing polygons. But for now, let's think about ways these handy layout tools can be used for graphic solutions that do not require mathematical figuring. In sheet metal work, you will lay out circles, diameters, radii, perpendicular lines, various polygons, and so forth.

Drawing a perpendicular bisector

In figure 1–1 you can see how a line can be bisected (divided into two equal parts). You could measure the line with a rule and mathematically divide it into two parts, but you can also bisect it with a compass or a divider. To divide line AB into two equal parts, use the compass to form a radius greater than one-half of line AB, and draw two arcs with A and B as the centers. Then, draw a straight line through the two intersections of the arcs to divide line AB into two equal parts. This line is also perpendicular to line AB.

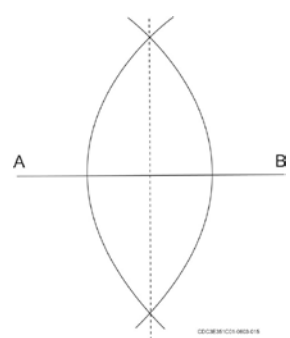


Figure 1–1. Drawing a perpendicular bisector.

Drawing a perpendicular line from a straight line at a given point

Figure 1–2 shows how a perpendicular line can be drawn from a given point on a line. With point C as a center, draw two arcs the same distance from point C, crossing the horizontal line at A and B; then, draw two arcs with points A and B as centers. The line you draw from C to D will be perpendicular to the horizontal line at point C.

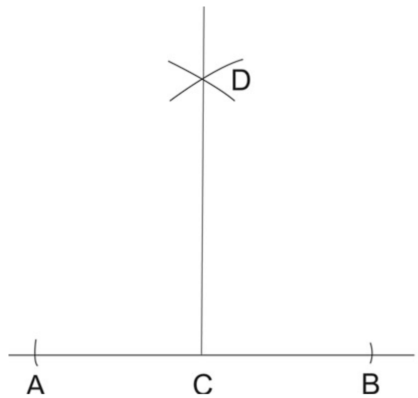


Figure 1–2. Drawing a perpendicular line to a straight line at a given point.

Drawing a line parallel to a given line

Figure 1–3 shows how to draw a line parallel to a given line. First, draw two perpendicular lines from points A and B; then, with points A and B as centers and any given radius (the desired distance between the parallel lines), draw two arcs CD and EF. The line you draw from point G through H will be parallel to line AB.

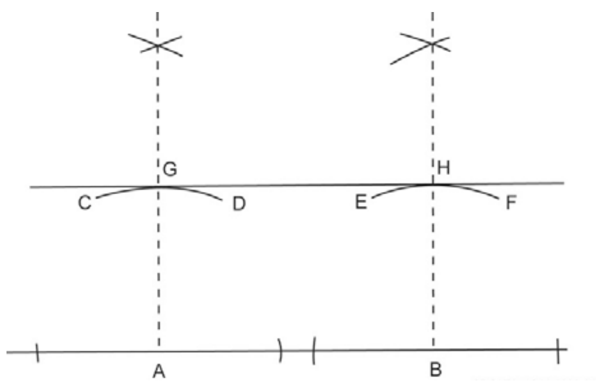


Figure 1–3. Drawing a line parallel to a given line.

Bisecting an angle

Figure 1–4 shows how any angle can be bisected. With point O as the center and using any radius, draw the arc AB. Using points A and B as centers, now draw two arcs that meet at point C. The line drawn between points O and C will bisect the angle AOB.

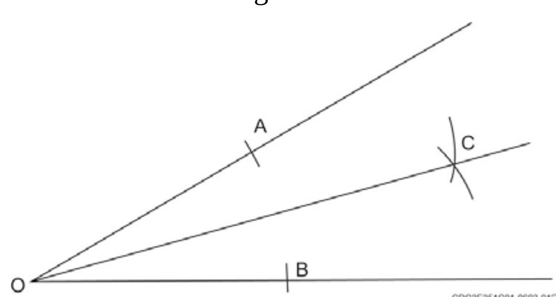


Figure1–4. Bisecting an angle.

Locating a circles center

Figure 1–5 demonstrates how to find the center of a circle. You do this by drawing two chords such as AB and CD, then bisecting each with perpendicular lines. The two perpendicular lines will cross at the circle's center.

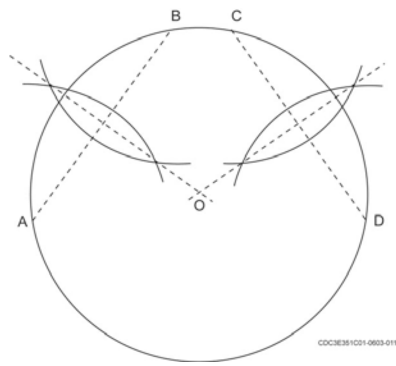


Figure 1–5. Locating the center of a circle.

Drawing ogee curves

Figure 1–6 shows how two parallel lines are connected with an ogee (S) curve. This is done by first connecting points B and C with a straight line, then selecting a point such as E through which to pass the curve. Then, bisect lines BE and CE and construct two arcs—arc BE from center point F, and arc CE from center point G. These two arcs connect the parallel lines AB and CD. In sheet metal work, ogees are used to form rain gutters, the cheeks of ductwork, and anywhere sheet metal is formed into an S-curve.

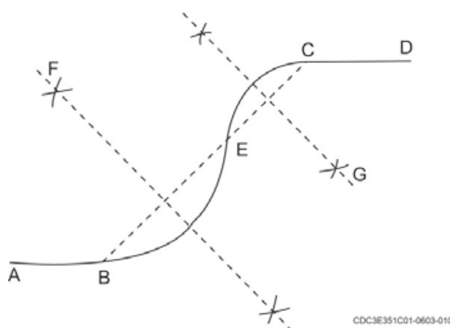


Figure 1–6. Drawing ogee curves.

Drawing a pentagon inside a circle

Figure 1–7 shows how to construct a pentagon inside a circle. First, draw a diameter line AB with radius line OC perpendicular to it. Line OB is bisected with point D at the center. Draw arc CE from center D. Then, draw arc EF from center C. The radius CF is the length of each of the five sides, which can be stepped off and connected with chords.

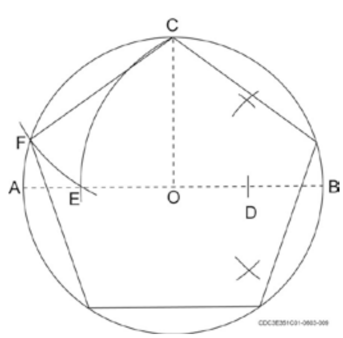


Figure 1–7. Drawing a pentagon in a circle.

Inscribing any regular polygon in a circle

Using figure 1–8 you see how to inscribe any regular polygon in a circle. First, scribe the diameter AB, then divide it into as many equal parts as there are polygon sides. (In figure 1–8, there are seven sides to the polygon.) Starting at point B, identify point No. 1 (the second point on the diameter).

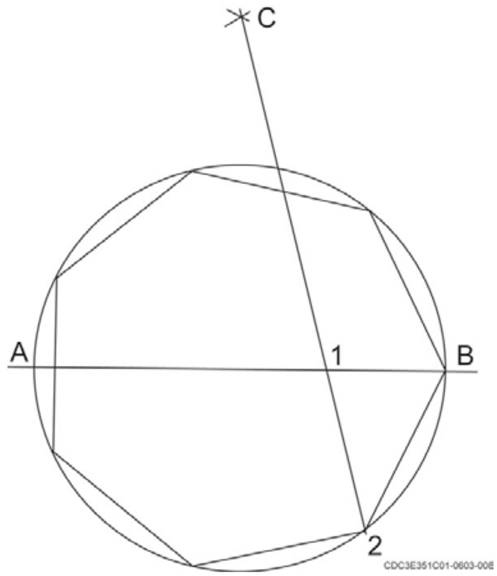


Figure 1–8. Inscribe any regular polygon in a circle.

With points A and B as centers and a radius equal to line AB, scribe intersecting arcs at point C. Draw a line from C through point 1 on the diameter, extending to the circumference of the circle at point 2. A line drawn from point 2 to point B is one side of the polygon. Follow this same procedure for inscribing a polygon with any number of sides.

Constructing a regular polygon from a given side

Knowing the length of one side, you can construct a regular polygon with any number of sides. You do this by following the six simple steps in the table below. Refer to figure 1–9 as you read the directions for each step and see how they are applied.

Constructing a Regular Polygon From a Given Side	
Step	**Action**
1	With the side AB (equal to the desired length of one side of the polygon) as radius and A as center, draw a semicircle and divide it into as many equal parts as there are sides of the polygon. In this case seven.
2	Through the second division from the left, draw radial line A–2.
3	Through points 3, 4, 5, and 6, extend radial lines as shown.
4	With the length of line AB as the radius and B as center, swing an arc that intersects line A–6 at C.
5	With C as center of the same radius, swing an arc that intersects line A–5 at D. Continue to use each succeeding point as a new center for an arc as shown.
6	Connect the points you've obtained

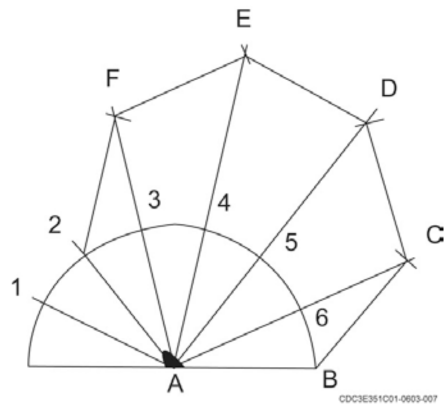


Figure 1–9. Constructing a regular polygon from a given side.

Drawing a hexagon inside a circle

Figure 1-10 shows how a hexagon may be constructed inside a circle. With points A and B as centers, draw two arcs equal to the radius. The points where these arcs cross the circle will be the corners of the hexagon. Draw the chords between AC, CD, BD, BF, EF, and AE.

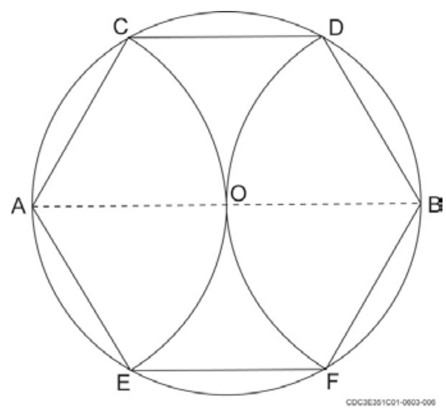


Figure 1–10. Drawing a hexagon in a circle.

Drawing a square inside a circle

Figure 1–11 shows how a square is drawn inside a circle. Divide the circle into quarters, with two diameters at right angles to each other. When points A, B, C, and D are connected with chords, a square is formed.

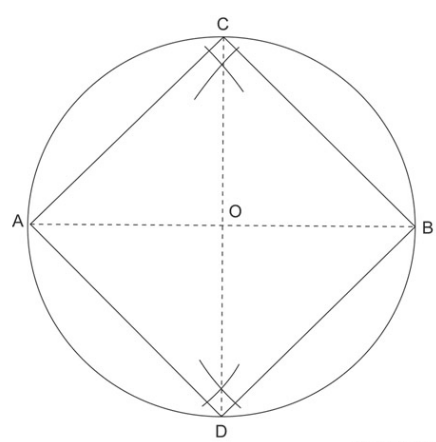


Figure 1–11. Drawing a square in a circle.

Drawing an octagon inside a circle

Figure 1–12 shows how to draw an octagon inside a circle. Divide the circle into quarters and bisect an angle, such as AOC. The length of chord AE will be the same as each of the eight sides stepped off with the compass. Connect each point with chords.

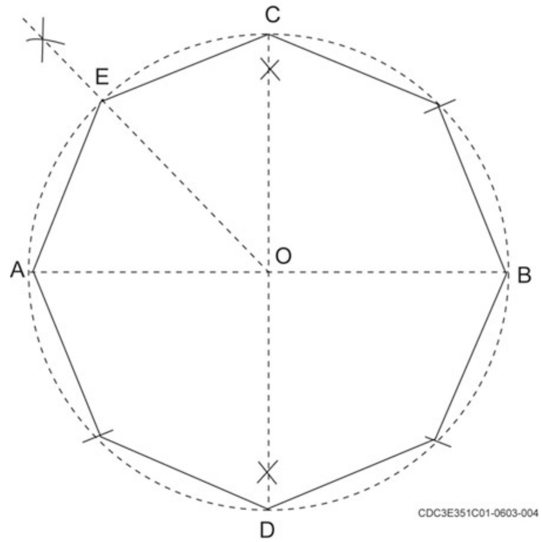


Figure 1–12. Drawing an octagon in a circle.

Many other graphic solutions are possible using a compass or dividers. However, the examples that we discussed above are those used most often. Your knowledge of these basic solutions can lead you to other combinations required when you lay out patterns for sheet metal objects. Later in this unit we'll discuss additional uses for the compass and dividers with graphic solutions used to develop and layout sheet metal patterns.

Making patterns for sheet metal components

Working drawings, in most cases, are drawings that you, your supervisor, or an engineering assistant, has drafted from prints, sketches, or a component you are replacing. Drawings with correct and accurate measurements are essential to making accurate layout.

Before laying out a pattern for a component, you'll need to determine what layout method to use. A drawing or print will show the dimensions of the component. If a drawing is not available, and a duplicate or like item is available, take measurements and make a sketch of the component. The sketch should include all needed descriptive information.

When using a blueprint or working drawing, item descriptions are found from the plan view and/or elevation view. If the component is shown only in the plan and/or elevation view, the measurements will give a good description. However, the detail views on a drawing or print illustrate the component on a much larger scale.

Getting measurements and a component description are the first steps in making a flat pattern. Blueprints and drawings are important because they are the guide for developing flat patterns. In the following paragraphs, you'll learn how to use plan and elevation views to develop flat patterns for sheet metal components.

Flat pattern layouts

Flat pattern layouts are drawings that show the shape of components in the flat or stretched-out position. Let's look at a few pattern stretch outs. Figure 1–13, view A, shows a rectangular metal duct section. View B shows a flat pattern or stretch-out of the same duct. *Note that the stretch-out is a series of rectangles*. Figure 1–14, shows the stretch-out of a square duct. Figure 1–15, view A, shows the *half plan and elevation views* of a round duct; view B, shows the *stretch-out* of a round duct (cylinder).

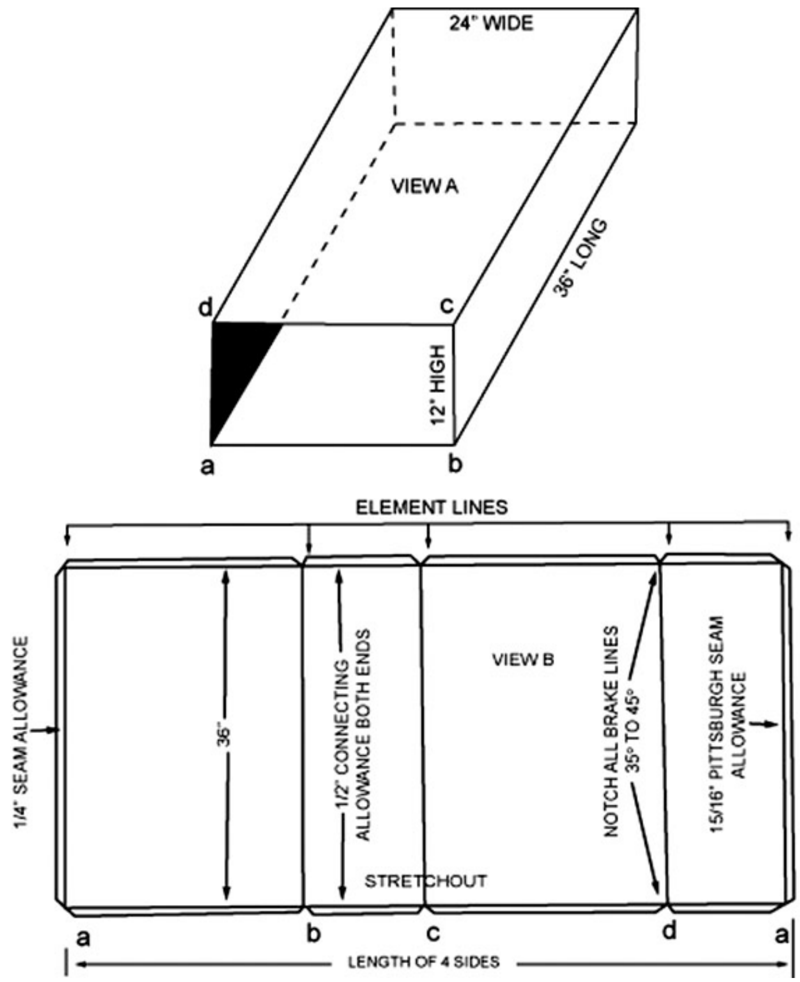


Figure 1–13. Parallel line pattern development for a rectangular duct.

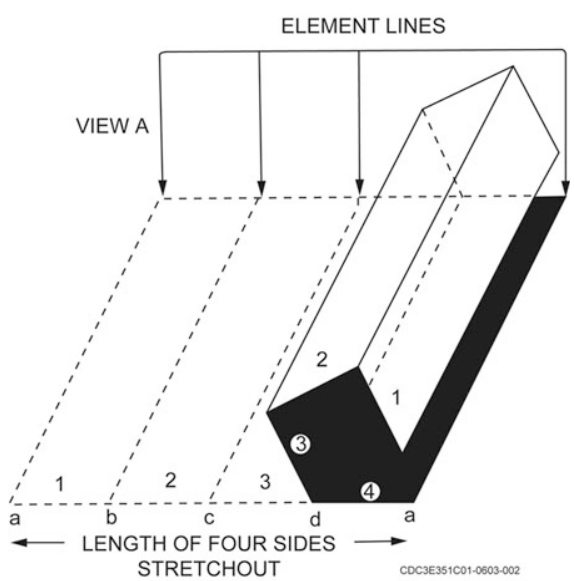


Figure 1–14. Parallel line pattern development for a square duct.

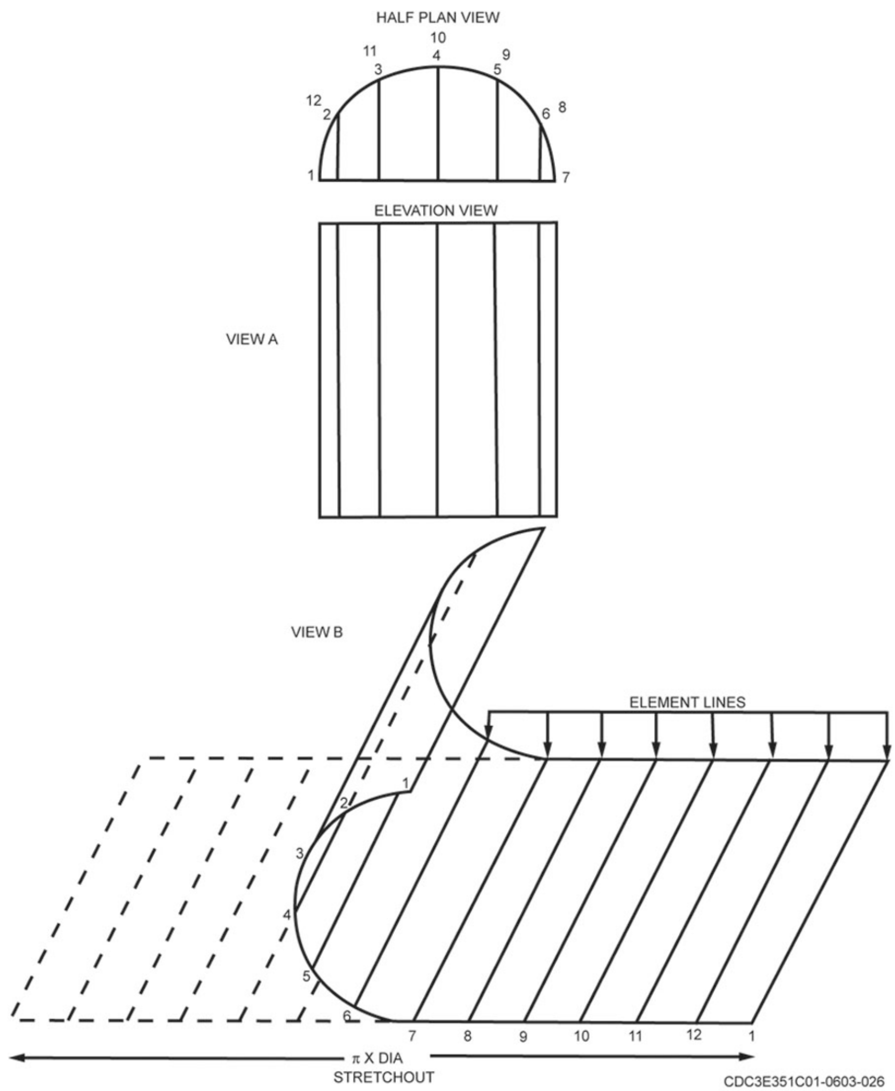


Figure 1–15. Parallel line pattern development for a cylinder.

The three layout methods that you'll use are described in the table below.

Flat Pattern Layout Methods	
Method	**Uses**
Parallel Line	Used to develop patterns for rectangular, round, and square ducts.
Radial Line	Used to develop cone and pyramid shaped components.
Triangulation	Used to develop transitions (e.g., square to round and rectangular to round).

When laying out patterns of straight ducts that are round, square, or rectangular, use a parallel line stretch-out (figs. 1–13, 1-14, and 1–15) to show the duct's shape. However, you cannot use this simple type of stretch-out to develop patterns for round, square, or rectangular objects that are larger on one end than the other. These more complex flat pattern layouts which involve additional layout methods use radial line and triangulation methods.

When using these layout methods, you will use layout tools (e.g., T-square, triangle, divider, compass, and trammel points) that will be covered in volume 2 of this course.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

001. Performing graphic solutions and flat pattern layout

1. Which method is used to bisect a line (divide it into two equal parts)?

2. You need to know how to draw ogee curves to form what types of sheet metal components?

3. When making a sketch of a component, what information should you include?

4. What is the first step in making a flat pattern?

5. List the three layout methods.

002. Parallel line layout

The parallel line layout method is used to develop patterns for components that have parallel sides. The element lines true lengths play an important part in parallel line development. *Element lines*, shown in figures 1–14 and 1–15, are equally spaced lines used for pattern layout. In parallel line development, with a few exceptions, all element lines are parallel or perpendicular to each other. They indicate the length (or true length) of the duct section by the length of the element lines.

NOTE: True length does *not* include the seam allowances.

In this lesson we'll look at using parallel lines to develop various patterns, beginning with simpler patterns and progressing towards more complex ones.

Developing simple patterns using parallel lines

Here we turn our attention to developing some simple patterns using parallel lines. We'll cover patterns for rectangular, square, and round ducts. Then we'll move to a more complex type.

Rectangular ducts

Let's begin by taking a look at view A in figure 1–13. As you can see, sides **ab** and **cd** are the same width, and **bc** and **da** are the same width.

To construct a pattern for view A, you need the length, height, and width of the four sides. In our example we'll use duct measurements of 24-inches wide, 12-inches high, and 36-inches long (24″ x 12″ x 36″ long). With this information we can follow the steps in the table below to construct a pattern for the duct.

Constructing a Duct Pattern (View A)	
Step	**Action**
1	Layout the flat pattern by drawing a straight line (stretch-out) equal to the perimeter of the four sides.
2	On the left, draw element line **a**—which is 36 inches long—perpendicular to the stretch-out line.
3	Draw element line **b** 24 inches from, and parallel to, element line **a**.

Constructing a Duct Pattern (View A)	
Step	**Action**
4	Draw element line **c** 12 inches from, and parallel to, element line **d**. *All the element lines are 36 inches long (the true length of the duct).*
5	Join the element lines across the top to complete the pattern. It is a good practice to check the pattern for correct dimensions and squareness after it has been developed.
6	This pattern can be formed into a rectangular-shaped duct by breaking 90° (bending the metal) at element lines **b**, **c**, and **d**.

Square ducts

Figure 1–14 shows the stretch-out of a square duct. The square duct pattern was developed using the parallel line layout method in the same way as that for rectangular ducts. The *stretch-out length* is the perimeter or the sum of the four sides—1, 2, 3, and 4. You determine the length of the element lines by using the true length of the duct. To form the stretch-out into a square duct, break the element lines **b**, **c**, and **d** at 90° angles.

Round ducts

View A in figure 1–15 includes both the half plan view and the elevation views for a round duct (cylinder). When you develop a pattern for round components, follow the steps described in the table below.

Developing a Pattern for Round Components	
Step	**Action**
1	Draw the half plan and the elevation views on the same centerline. The half plan shows part of the cylinder as you'd see it looking down from the top.
2	Divide the half plan arc into 6 equal parts, resulting in 13 element lines. Notice how the half plan view is used to represent a whole-plan view, and is divided into half the spaces of the whole-plan view. In view B of figure 1–15, which is the pattern for view A, notice that the stretch-out is divided into 12 equal parts and the element lines are parallel to each other. Remember, the element lines are the true length of the duct you are laying out. View B also represents view A as it would look stretched out in a flat pattern.
3	To determine the length of the stretch-out line for view B, use the circumference formula (π x d). Multiply the diameter of the duct by 3.14 (for greater accuracy, use 3.1416 or 3.14159). Divide the stretch-out line into equal parts; in this case we are using 12 parts.
4	Form this pattern by rolling, as shown in view B of figure 1–15.

Developing more complicated patterns

Now that we've looked at developing simple patterns using parallel lines, let's turn our attention to developing parallel line patterns requiring more accuracy and thought. For this example, consider a pattern for a round pipe that has a 30° miter line. The first step is to determine the element lines, then drawing the flat pattern.

NOTE: Mitered round duct sections are exceptions to the rule requiring all components using parallel line layout to have parallel and perpendicular element lines.

Determining element lines

As you recall, you need a plan view and an elevation view to determine the length of the element lines. Line **CD** in view A of figure 1–16 is a miter line that will require element lines of different lengths. When element lines are *not the same length*, you can make a more accurate pattern by drawing additional element lines—the more the better. For this proceed as described in the following table.

Drawing Element Lines	
Step	**Action**
1	Using a T-square on the edge of the drawing board, draw line **AB**, as shown in view A.
2	Using a T-square and a triangle, elevate lines **AC** and **BD** (drawn 90° to line **AB**). To draw line **CD**, draw it with a 30° to 60° triangle. You can find the center of line **AB** in view A with a rule, or by bisecting line **AB** with dividers or a compass.
3	Draw the arc of the half-plan view, using the midpoint of line **AB** as the center.
4	Draw a centerline perpendicular to line **AB** through the midpoint. Draw this perpendicular up to the miter line and down to the half-plan arc. Identify this centerline as element line 4–10.
5	Divide the arc of the half plan into three equal parts on both sides of element line 4–10.
6	After this, element lines 2–12, 3–11, 5–9, and 6–8 are elevated through line **AB** to miter line **CD**.

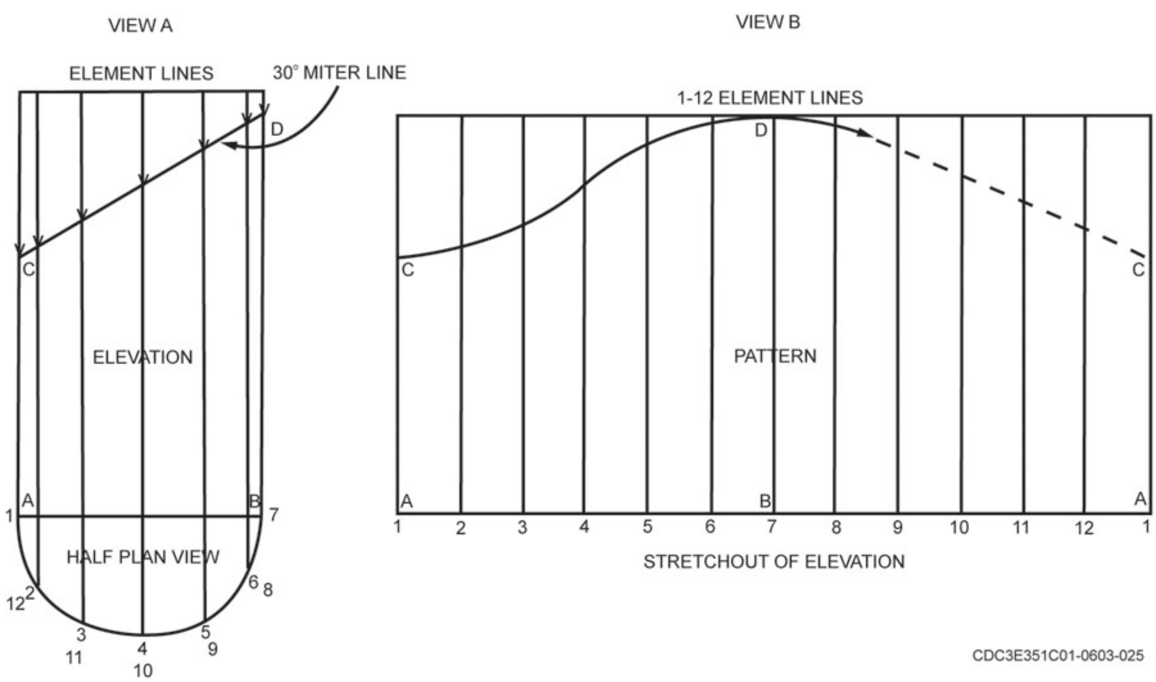


Figure 1–16. 30° miter pattern development.

Drawing the flat pattern

The next step is to lay out the flat pattern (shown in view B of figure 1–16) and described in the following table.

Drawing a Flat Pattern	
Step	**Action**
1	Use the T-square to draw line **ABA**, which is the stretch-out line (equal to the circumference) of the cylinder. If you draw line **ABA** in view B straight across from line **AB** in view A, you can transfer the length of the element lines easily using a T-square.
2	Next, divide line **ABA** in the stretch-out into 12 equal parts by stepping off the distance between the element lines (use the distance between the points on the half plan for reference).
3	After dividing line **ABA** into 12 sections, draw element lines up from each of the points on line **ABA**.
4	Transfer the length of the elevation view element lines to the corresponding numbered lines on the stretch-out. You can transfer the length of the element lines by using a divider, compass, or T-square.
5	After you establish the length of each element line in the stretch-out, connect the points by using an irregular (French) curve.

Now, we have a pattern for a cylinder with a miter line. Notice those element points 1 through 7 represent one-half of the stretch-out; element points 7 through 12, back to 1, represent the other half of the pattern. Point 1 is the seam line, since it is the starting point for numbering. You'll make all seam allowances at point 1, which is line **AC** on either side of the stretch-out. It is a good practice to cut patterns out of paper or stencil board and tape them together to see the finished product before cutting the pattern out of metal.

Elbows

Another important item used extensively in sheet metal work is the multiple-gore round elbow. The elbows are constructed from pieces of metal, called gores, which you can fasten together.

> **NOTE**: The more gores used in the construction of an elbow, the lower the airflow resistance. An elbow with five gores has less air resistance than the three-gore elbow.

Elbows are used to connect straight lengths of pipe running in different directions. For example, suppose you have two lengths of round air duct—one running vertically between the wall studs and the other running horizontally between the floor joists. You'll need an elbow to connect these two ducts, so that the flow of air will pass from one section to the other.

The elevation view of a three-piece 90° elbow is shown in figure 1–17. Study the illustration and learn the parts' names and the symbols' meanings. We'll use the terms: throat, heel, cheek, miter, diameter, and radius, when discussing elbows in this text. You'll use them when you are fabricating elbows in the shop. Notice that uppercase **R** is the *radius of the heel* and that lowercase **r** is the *radius of the throat*. An upper case D represents the diameter. The diameter, number of sections, throat radii, and shape of elbows has no effect on the principle involved in drawing round elbow patterns. An important step necessary before pattern development can begin, is constructing the true miter lines. You can see these miter lines and the various parts of an elbow in figure 1–17.

Developing the pattern

Now, let's use miter lines to develop a pattern. Suppose the drawing or blueprint requires a 90° elbow with a 6-inch diameter and a 3–inch throat radius. To develop the pattern as shown in figure 1–18, follow these steps in the following table.

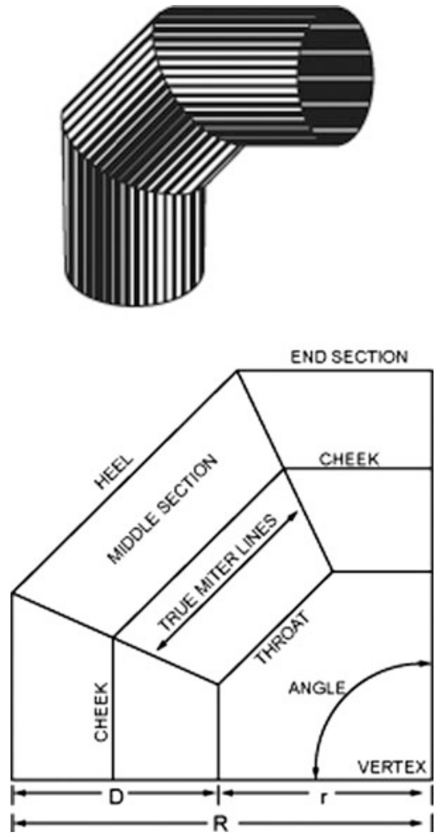


Figure 1–17. Elbow parts.

Developing a Pattern	
Step	**Action**
1	First, draw the elevation view so as to construct a right angle, and then draw heel and throat arcs from the vertex. The *heel radius* for any size elbow is the sum of the elbow diameter added to the throat radius.
2	The miter lines are drawn by connecting the vertex to points stepped off on the heel arc, which divides arc **AC** into eight segments (the dashed lines indicate the divisions when the 90° angle is bisected).
3	Now, draw the dark miter lines to make pieces **I** and **V,** each equal to one-half gore (one segment) on the heel arc, and pieces **II**, **III**, and **IV** equal to one gore (two segments). Drawing these miter lines completes the elevation view.
4	Using the base line **AB** in the elevation view of figure 1–18, construct the half-plan view in the same way shown in figure 1–16.

The greater the number of element lines and spaces you use, the more accurate the pattern will be.

Drawing the pattern layout

To draw the pattern layout shown in figure 1–18 follow these steps.

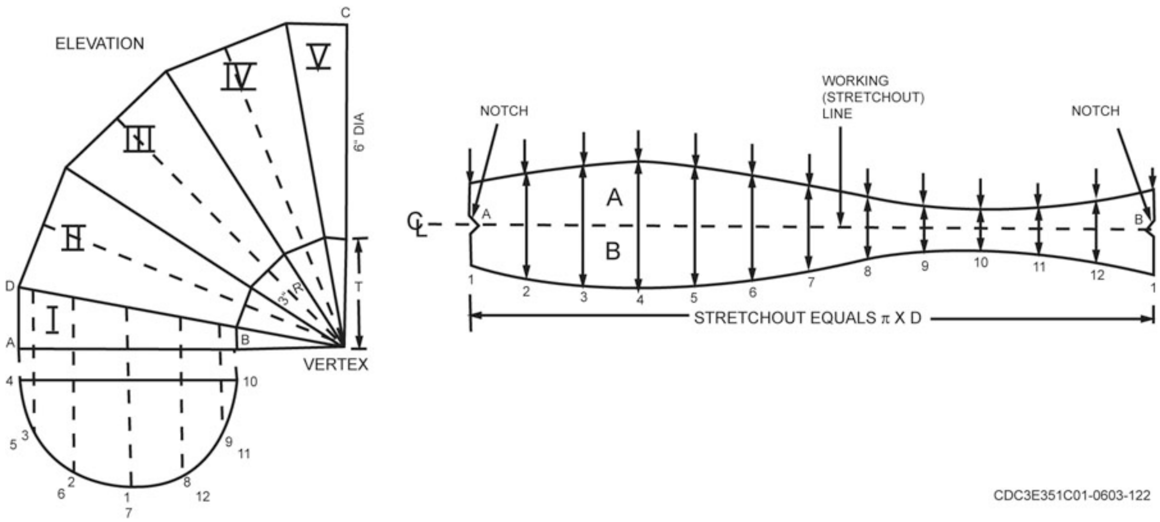


Figure 1–18. Five piece elbow pattern.

Drawing the Pattern Layout	
Step	**Action**
1	First, draw the stretch-out line (base line) equal to the elbow circumference.
2	Then, divide it into the same number of element lines and spaces contained in the half-plan view—12 spaces and 13 element lines.
3	From the 13 points on the stretch-out line, draw element lines on both sides of the line and number, as shown. The beginning and ending numbers in the half plan and stretch-out, designate the seam location in the finished elbow. Generally, the most efficient location for a seam on an elbow is on the cheek.
4	To determine the length of the element lines on each side of the stretch-out line, use a compass to transfer the length of each element line located between line **AB**, and true miter line **D** in the elevation view.
5	Transfer this distance to the stretch-out by placing the sharp point of the compass on the stretch-out line (base line), making two arcs (one above and one below) to indicate the total length of the element line. Make sure the element line numbers correspond. Use an irregular (French) curve to connect these arcs with smooth curved lines.

The stretch-out shown in figure 1–18 is the pattern for one whole piece, or gore, of the elbow shown in the elevation view. You'd use the stretch-out pattern to make pieces **II**, **III**, and **IV**. Side **A** is used to make piece **I**, and side **B** is used to make piece **V.** If you notch the pattern on both ends of the stretch-out line, alignment will be easier when you transfer the pattern to metal. Make elbows of different angles by using various pattern combinations.

Y-branch

The Y-branch shown in figure 1–19 is made in five individual pieces, numbered **I**, **II**, **III**, **IV**, and **V**. When these five pieces are fastened together, the single duct is divided into two identical diameter ducts. You can design Y-branches to connect different sized ducts. The miter lines and the angles at which these pieces meet may vary from job to job. Because of this, you may have to make as many as five different patterns, one for each piece shown in the elevation view.

In Y-branch pattern development, you'll repeat some of the steps used to lay out elbows. From the Y-branch elevation view, you can get the true length of the element lines.

Y-branch Pattern Development	
Step	**Action**
1	Draw the elevation view so that you can determine the shape of the five pieces or gores.
2	Draw the half plan view and divide into an equal number of spaces.
3	From the 13 numbered points, the numbered element lines are projected through each section of the elevation view. This gives you the lengths of the element lines for each piece (gore).
4	Draw stretch-outs for each piece as shown in the illustration.
5	Develop this pattern in the same manner as that for figure 1–18.

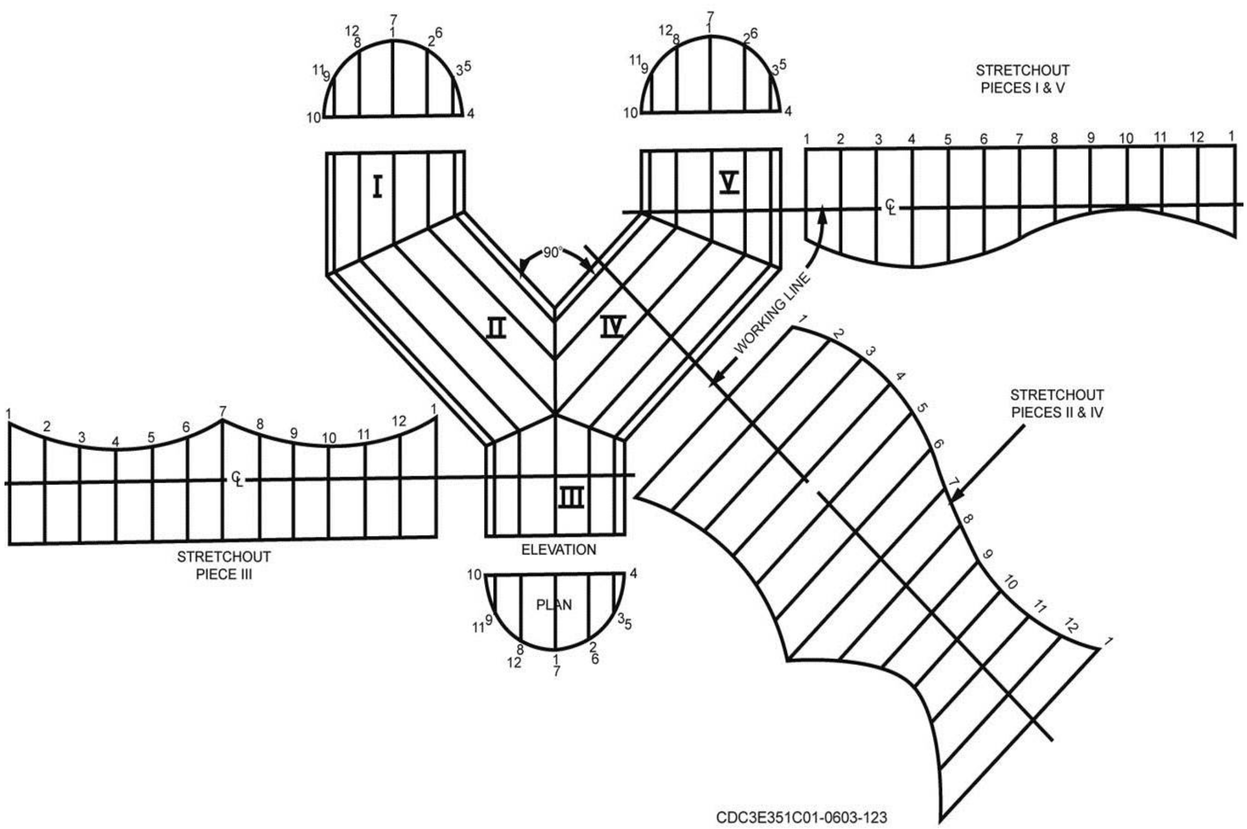


Figure 1–19. Y-branch pattern.

T-joint

You've seen that to develop a stretch-out pattern of round components by the parallel line method, an elevation and plan view must be drawn to complete it. These two views, when constructed, will give you the lengths of all miter and element lines. Figure 1–20 illustrates the two main parts of a T-joint—collar (or branch) and main pipe. The lines where the main pipe and collar meet are called lines of intersection. These lines are also called miter lines.

Drawing stretch-out pattern of round components

Figure 1-20 illustrates the method of constructing miter lines in the elevation view and the projecting of lines from the plan views. Both pipes shown have a diameter of 3 inches.

Drawing Stretch-out Pattern of Round Components	
Step	**Action**
1	Draw elevation view A by using a T-square and a rule.
2	Draw line **AB** 3 inches long. Draw lines **AC** and **BD** perpendicular to line **AB**. Draw line **CD** parallel to line **AB**.
3	Draw the half plan view B directly below the elevation view, and divide half of the arc into three equal spaces.
4	Number and project the dividing points to elevation view A by using the T-square and the triangle to form lines 1 through 7.
5	In this example, the intersecting point for the collar is at the center of the elevation view. At the center of line **BD,** in the elevation view, draw the intersecting collar so that it will extend 2 inches beyond line **BD**.
6	Draw line **EF** 3-inches long, 2 inches to the right of line **BD**. Draw solid lines **4-E** and **10-F**, using a T-square, to both sides.
7	Draw half plan view C and divide the arc into six equal parts and numbers, as shown in figure 1–20.
8	Project the points on the arc with a T-square until each point intersects a line. Notice where the horizontal element lines intersect the vertical element lines in the elevation view.
9	Draw the V-shape miter lines by joining intersecting points **1**, **2**, **3**, **4**, **5**, **6**, and **7**.
10	Miter lines **1–4** and **4–7** are 45° to line **AB**.

Drawing a stretch-out pattern for a collar

To develop a pattern for a collar as shown in the following table, follow the steps in figure 1–20.

Developing a Stretch-out Pattern for a Collar	
Step	**Action**
1	Draw a stretch-out line equal in length to the circumference of the pipe.
2	Divide the stretch-out line into 12 equal spaces and elevate the element lines.
3	Transfer the element line lengths to the stretch-out and join the intersecting points as before.
4	Notice that you'll join the collar on the cheek.

Drawing a stretch-out pattern for a pipe

To develop a stretch-out pattern for a main pipe, make the length of the stretch-out line equal to the circumference of the main pipe and make the height 8 inches. Then follow the steps in the table below.

Developing a Stretch-out Pattern for a Pipe	
Step	**Action**
1	Divide the stretch-out into 12 equal parts and elevate the element lines.
2	Notice that the numbering is somewhat different in this stretch-out. In this case, it is easier to start numbering at the center, since the joining point is line **AC** and the center is line **BD**.

Developing a Stretch-out Pattern for a Pipe	
Step	**Action**
	The cutout is on both sides of the center.
3	If the elevation view and stretch-out are on the same base line, project the length of the cutout lines easily with a T-square from the elevation view. However, *these projection lines are not shown* in figure 1-20.
4	Points **1** through **7** in the elevation view are projected to form the cutout.
5	When connecting the intersecting points in the stretch-out, you have a pattern for the main pipe. Compare the numbering of the element lines in the stretch-out with the numbering of the element lines in the elevation view.

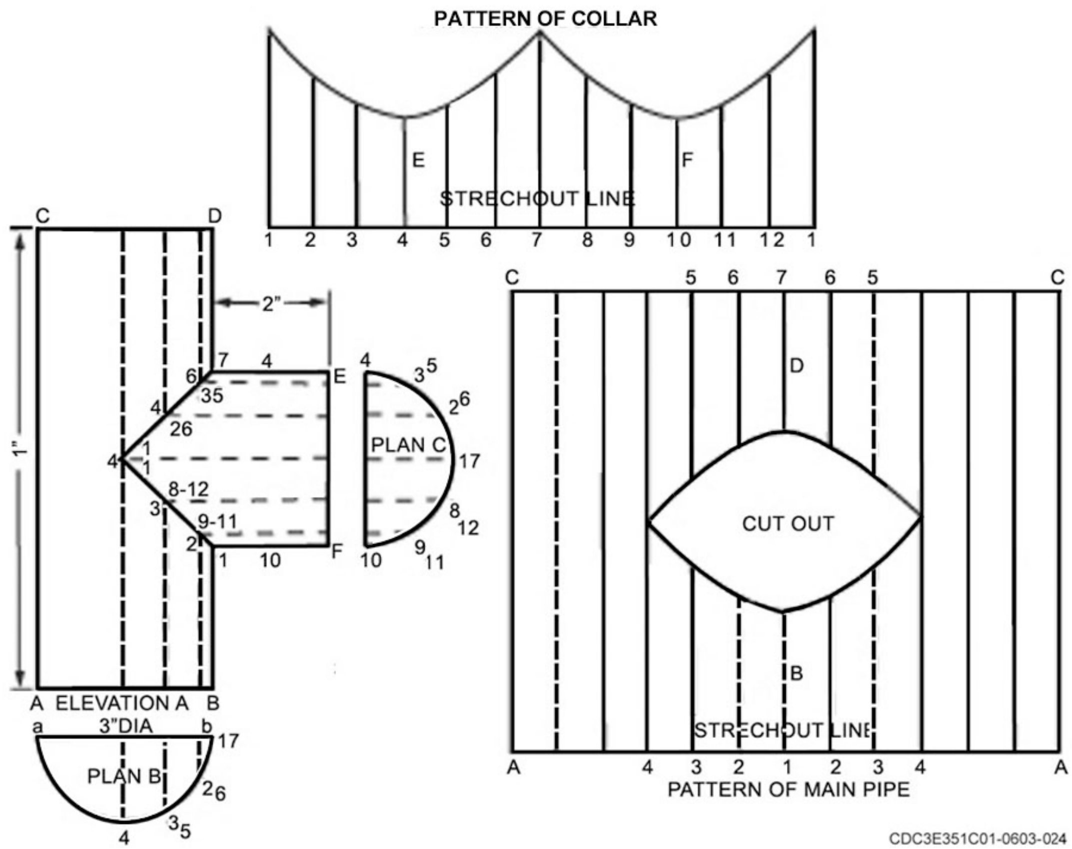


Figure 1-20. T-joint patterns.

This completes our discussion of the parallel line layout method of pattern development. We've shown you how to develop patterns for rectangular duct, elbows, Y-branches, and T-joints. You should have noticed that each round, square, or rectangular duct developed by the parallel line method has not changed in diameter or cross section. The sides and element lines in each pattern have remained parallel. In the following lessons, we'll show you how to use the radial line layout method to develop patterns for components that don't have parallel sides (e.g., cones and pyramids).

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

002. Parallel line layout

1. How do the element lines normally run on an item laid out using the parallel line method?

2. What is stretch-out length of a square or rectangular duct?

3. What two views are required to determine the length of element lines in developing a pattern for a round pipe?

4. What is used in place of a whole-plan view when laying out round components?

5. What length is the stretch-out base line equal to when drawing round components?

6. What are the sections of round elbows called?

7. How is the heel radius of a round elbow found?

8. How do the sizes of the end gores and center gores compare on a round elbow?

9. What are the parts of a T-joint?

003. Radial line layout

The radial line layout method is used to develop patterns for sheet metal components that are cone or pyramid shaped. We'll begin with a look at general patterns for cones and pyramids and then look at patterns for special types such as a right pyramid, a truncated pyramid, and a right cone.

Drawing patterns for cones or pyramids

These cones and pyramids must have a vertex centered over the base. To put it another way, *they must have a centerline (vertical height) that is perpendicular to the base* (e.g., a right cone or a right pyramid). While some development characteristics of the radial line layout method differ from the parallel line layout method, some characteristics, such as drawing the elevation and plan views, are similar. Figures 1–21 and 1–22 illustrate these basic similarities.

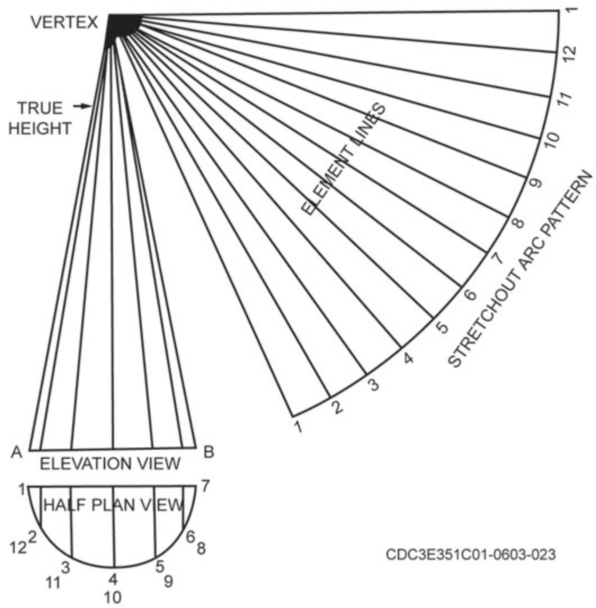


Figure 1–21. Radial line development of a cone.

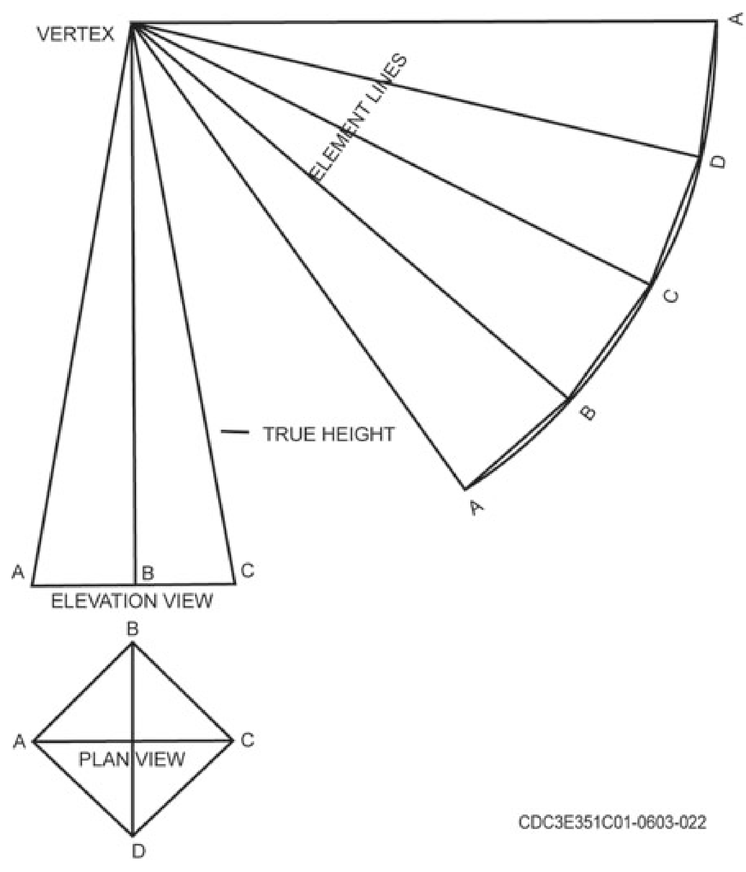


Figure 1–22. Radial line development of a pyramid.

For example: In in each illustration, the elevation view shows the height of the object, and the distance around the circumference of the plan view determines the length of the stretch-out arc. The following table provides more in-depth guidance on drawing stretch-out arcs.

Drawing Stretch-out Arcs	
Step	**Action**
1	After you draw the plan and elevation views, you can draw the stretch-out arc with a radius equal to the true height of the cone (true height of a right cone is the distance from the vertex to the edge of the base).
2	Draw the arc long enough to allow each space in the plan view to be stepped off and lettered or numbered.
3	Connect the vertex to the numbered points on the stretch-out arc to complete the pattern.

All cone and pyramid shaped objects that are to be developed by the radial line method have certain characteristics:

- A circle for their base or a base that can be inscribed in a circle.
- Sides that slant to a common vertex located directly over the center of the base.

Figure 1–23 shows several examples of bases that can be inscribed in a circle.

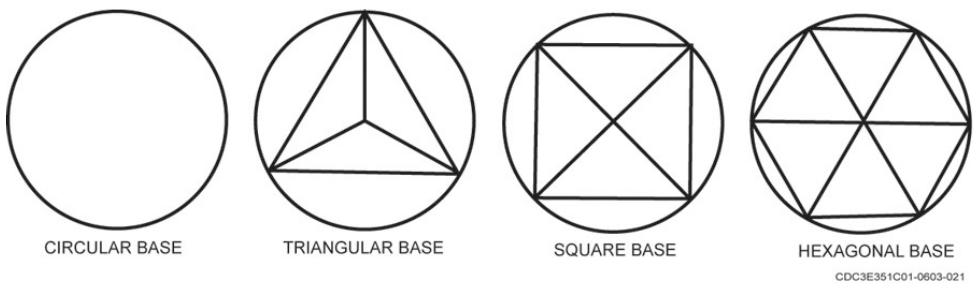


Figure 1–23. Bases inscribed in a circle.

Getting the true height

To understand how to get the true height for a pyramid, study the illustration shown in figure 1–24. Notice the vertical height, **BO**, shown in the elevation view (**ABC**). Then examine the plan view showing the shape of the pyramid base. Observe that the plan view is inscribed inside a circle. To get the true height, you must do the following steps in the table below.

Determining True Height	
Step	**Action**
1	Set the compass equal to the distance **OD** (the distance from the center of the plan view to the corner), using **O** as a center, and swing an arc that strikes the extended base line **AC** at point **Y**.
2	Draw the slant line **BY**, which is the true height of the pyramid, and which will be the true height of the radius of the stretch-out arc. By swinging arc **OD** to point **Y** on line **AC**, you are finding the actual distance from the vertex to the edge of the pyramid base. You cannot find the true height of a pyramid without this step; and, if you omit it, the pyramid will be too short.

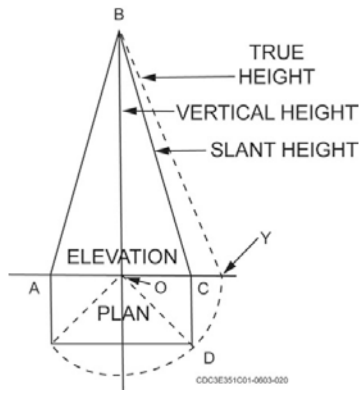


Figure 1–24. Pyramid height.

Arranging a plan view of a pyramid

Figure 1–25 illustrates the reason for drawing the arc from the corner of the plan view to the base line of the elevation view. Figure 1–25, view **B**, is an example where the position of the base in the plan view is arranged so that the slant height (**AC**) in the elevation view is also the true height of the pyramid. Do *not* make the mistake of using the slant height (**AB**), as shown in figure 1–25 view **A,** for the true radius of the stretch-out arc.

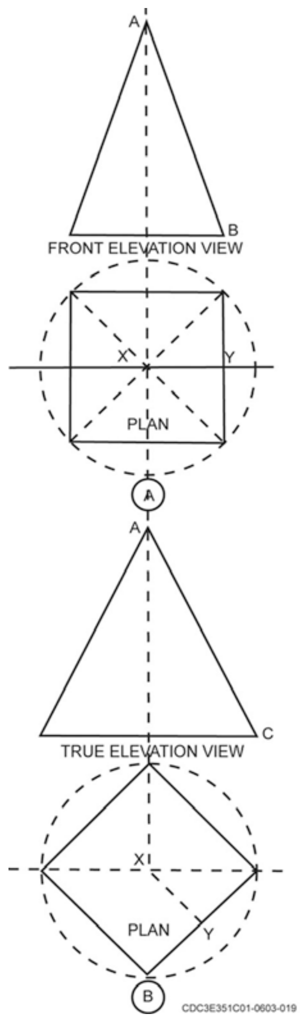


Figure 1–25. Plan view arrangement of a pyramid.

In view **B** of figure 1–25, the elevation view appears larger because the slant line **AC** is the true height for the radius in developing the stretch-out pattern. The appearance of the object depends greatly on the arrangement of the elevation and plan views. This shows how drawing a circle around the plan view provides you with the true height of the item. Compare views **A** and **B** of figure 1–25. You can see by drawing a circle around the plan view in **A**, you get the same distance from the vertex to the edge of the base as you do in view **B**, which has been rotated 90°.

Although there are similarities between radial line development and parallel line development, you've just learned one of the differences. *To determine the true height of a pyramid, it is necessary to draw a circle around the plan view or the pyramid will come out too short.*

Right pyramid

The pattern shape for a right pyramid having six sides can be illustrated by holding its vertex at a definite point and rolling the pyramid view 1 of (fig. 1–26). This shows the outline of each face of the pyramid as imprinted on the surface over which it is rolled. You can see the stretch-out of this pattern in view 2.

To develop a pattern for a six-sided pyramid, follow these steps in the following table.

Developing a Pattern for a Six-Sided Pyramid	
Step	**Action**
1	Draw the plan view, which in this case is a hexagon. The dimensions of this hexagon are the same as those of the base of the pyramid.
2	Number each edge as shown in the illustration.
3	From these numbered points, project vertical lines downward to intersect the base line of the elevation view. This establishes points **1** through **6**. Point **C** is the *vertex*, which you determine by the vertical height of the given pyramid.
4	From the points of intersection on the base line, draw element lines to the vertex. All lines from the vertex **C** represent edges of the pyramid that are equal in length; however, they do not appear so in the elevation view because of the inclined surfaces. Therefore, only the outside lines give the true lengths for use as the radius of the arc in the stretch-out.
5	Draw the arc for the stretch-out and step off points 1 through 5 with spaces equal to the height of any side shown in the plan view. Number these points as shown in view 2.
6	Points located along arc **AB** are each connected and element lines are drawn from each point to the vertex.

This completes the six-sided pyramid pattern. Although the element lines you've just drawn are not absolutely necessary when forming the pyramid, they do clearly show where you can make the folds when forming the object.

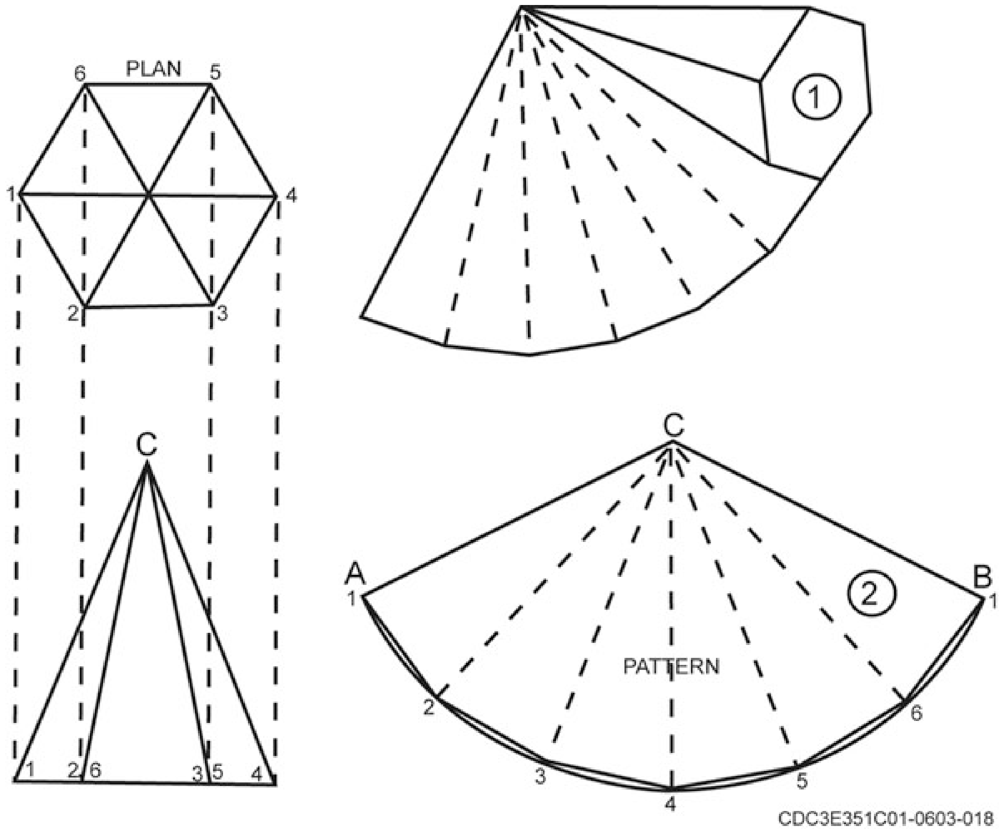


Figure 1–26. Right pyramid.

Truncated pyramid

A pyramid with the top cut off is a truncated pyramid. If the top is cut off *parallel to the base*, it is also called a *regular frustum* of a pyramid. If the *top is cut off at any angle to the base, it is called an irregular frustum*. The elevation view of figure 1–27 shows an example of truncated pyramid that is also an irregular frustum. Develop the pattern for an irregular frustum of a pyramid in a manner similar to that for an entire pyramid except for the element lines, which are no longer the same length. To construct this pattern, follow these steps in the following table.

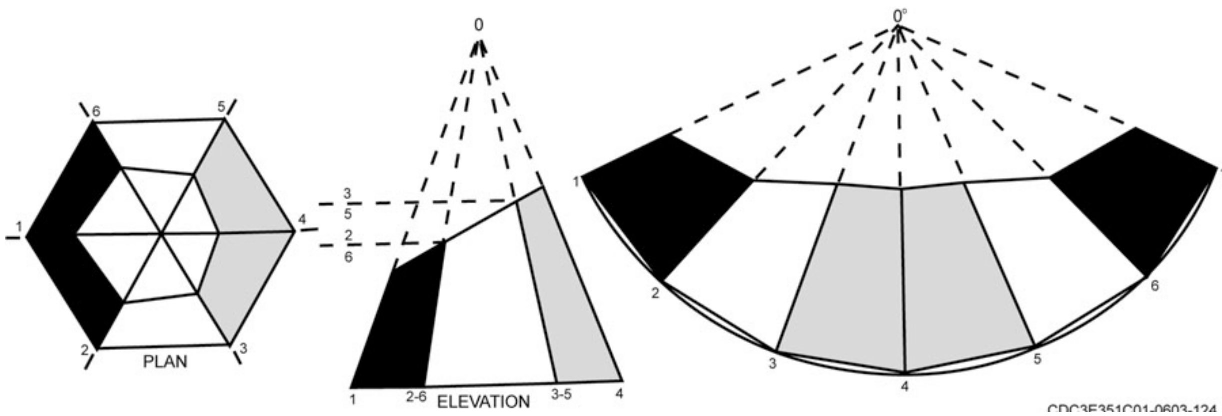


Figure 1–27. Truncated pyramid pattern development.

Constructing a Truncated Pyramid Pattern	
Step	**Action**
1	Draw the plan view and elevation view as described previously. This provides the shape and dimensions of the pyramid. Observe in the elevation view that lines have been constructed to locate the pyramid vertex. This is an essential part of the pattern. The plan view shows the base outline of the pyramid from where you get the side widths.
2	Draw the stretch-out the same as for an entire pyramid, except for the height of the element lines. You are now at the step where the method of getting the true height of the element lines is different because of the truncation.
3	Suppose the pattern begins with the shortest element (line **0–1**). This element line, seen in the elevation view of figure 1–27, is of true length. You can transfer this element line to the stretch-out.
4	Element lines **2**, **6**, **3**, and **5** do *not* show their true height because they're inclined to the plane of projection. This means that, to find their true lengths, you must imagine the pyramid being rotated until the edges concerned come into the position of element line 1, where the true height can be seen. On the elevation view, draw a horizontal projection from the upper end of element lines **2** and **6** until it crosses the extension of element line **1**. The true height of element lines **2** and **6** is the distance from this point of intersection to the base line of the elevation view.
5	Find the true height of element lines **3** and **5** in the same manner.
6	You can see element line **4** in its true length; it does *not* need to be projected. Transfer this true height along line **0–1** to the stretch-out to form the pattern.
7	Connect the points of intersection with a straight line, resulting in a completed pattern for a truncated pyramid.

Right cone

Developing a pattern for a cone is somewhat simpler than for a pyramid because the true height and slant height are the same. You can also use the radial line method of pattern development for whole cones or truncated cones (fig.1–28). A cone with the top cut off (truncated) parallel with the base is called a regular frustum. One with the top cut off at any angle with the base is called an irregular frustum. Generally, the pattern for a cone is fan shaped (fig. 1–29); when the object is unrolled, the stretch-out arc swings (radiates) around the vertex.

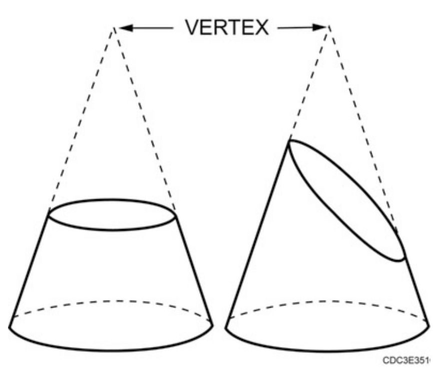


Figure 1–28. Truncated cone.

To develop a pattern for a regular frustum of a cone, you must draw the elevation and half plan views. In figure 1–29, the vertex has the letter **A**, and the base line **BC**. The steps to follow in developing the pattern are described in the table below.

Developing a Pattern for a Regular Frustum of a Cone	
Step	**Action**
1	At any point on the cone, and parallel to line **BC**, construct a line that cuts off the top portion of the cone and letter line **DE**.
2	Draw the half plan view beneath the base of the frustum and divide it into equal sections, as you did in parallel line development.
3	From the numbered points on the half plan view, draw perpendicular lines to the baseline **BC**.
4	From the points at which these lines intersect **BC**, draw lines to the vertex **A**. These element lines that you've just drawn are not absolutely necessary for the construction of the stretch-out pattern. They do show that the element lines in the elevation view converge at the vertex. Since line **BC** represents the widest part of the plan view, lines **AC** and **AB** are true length (true height).
5	Draw the stretch-out arc with vertex **A** as the center and the radius equal to the length of line **AC**.
6	From the same center, draw another arc with a radius equal to line **AE**. Since there are no folds or edges, you do not need to draw element lines. The area enclosed between the arcs and both No. **1** lines are the pattern for the frustum of a cone.
7	After you add allowances for seaming and edging, the stretch-out will be completed.

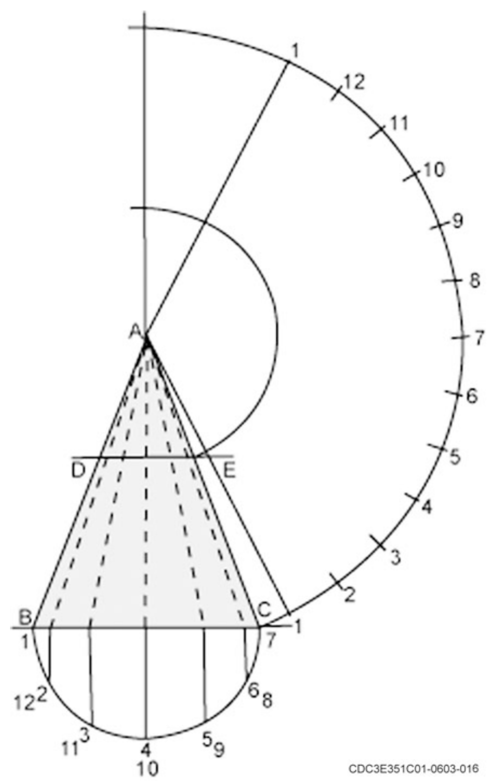


Figure 1–29. Regular frustum pattern development.

Follow the steps described in the table below when developing an irregular frustum of a cone such as that shown in figure 1–30.

Developing a Pattern for an Irregular Frustum of a Cone	
Step	**Action**
1	Draw the truncation line **DE** in the elevation view. This line represents the object's top edge.
2	Divide the circumference of the half plan view into equal sections as done on the previous cone; in this case, it will be from 1 to 12 to 1.
3	From each of these points, draw a perpendicular line to the base of the frustum.
4	From each point of intersection with the base, draw radial lines to the vertex.
5	From each point where the radial lines intersect the truncation line on the elevation, project a horizontal line to line **AC** and number **1** through **12**, as shown.
6	The distance from the vertex along line **AC** to any of these points will give you the true height of the corresponding radial line.

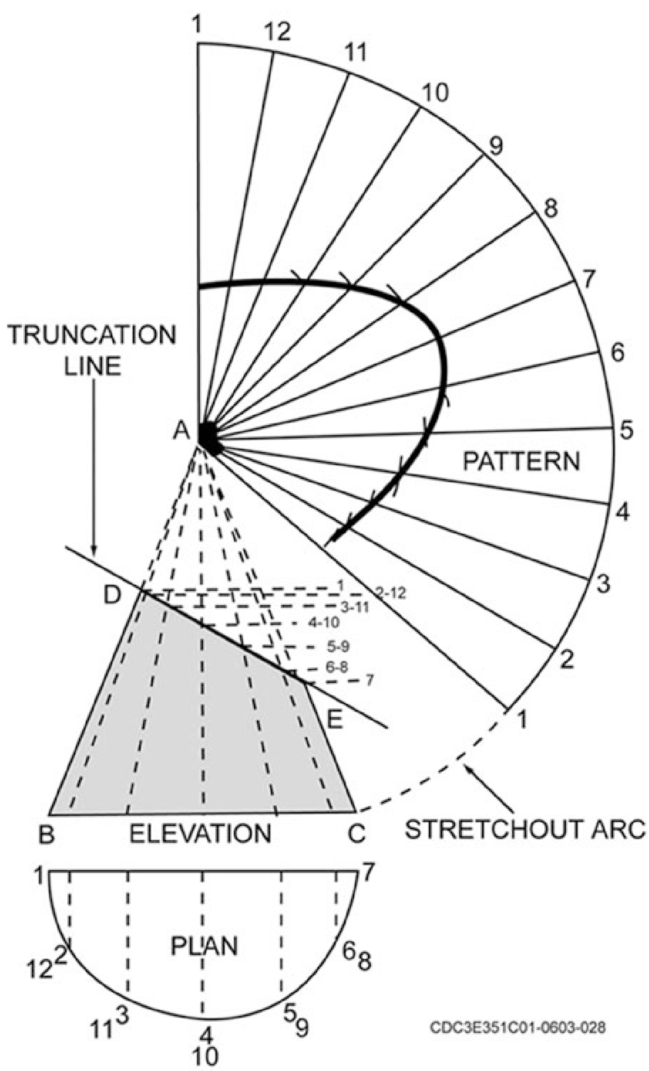


Figure 1–30. Irregular frustum pattern development.

To construct the pattern for an irregular frustum of a cone follow the steps in the table below.

Constructing the Pattern for an Irregular Frustum of a Cone	
Step	**Action**
1	Draw the stretch-out arc with a radius equal to the distance from **A** to **C**, as shown in figure 1-30.
2	Divide the stretch-out into 12 equal spaces and number to correspond with those in the half plan view.
3	From the numbered points on the stretch-out arc, draw element lines to vertex **A**. Constructing these lines is necessary because they're essential in developing the pattern.
4	With the vertex as a center, use a compass and measure the distance between points **A** and **1** along line **AC**.
5	Transfer this measurement to the lines numbered **1** on the stretch-out arc using the vertex as center.
6	Repeat the procedure for each of the numbered horizontal lines in the elevation view.
7	Connect these points with an irregular (French) curve. This curved line determines the top edge of the pattern and the stretch-out arc determines the lower edge.

You may encounter the following job situation. Suppose you are to replace a piece of half-round gutter with a 4-inch downspout outlet that is tapered to 2 inches. As illustrated in the pictorial view of figure 1–31, you can see that this is a *compound truncation*. It has a regular truncation at the bottom to fit the downspout and an irregular truncation at the top to fit the contour of the gutter. To lay out the downspout connection, you'll have to determine which layout method to use. Since the downspout connector is tapered, you'll use the radial line method by following these steps in the following table.

Using Radial Line Layout Method	
Step	**Action**
1	Draw an end view of the gutter 6 inches in diameter, as shown in the illustration.
2	Draw the elevation view and half plan view.
3	Determine and number the divisions on the half plan view, and draw the element lines in the elevation view, project and number the horizontal lines.
4	Draw the stretch-out arc, divide it into 12 equal spaces, and extend the element lines to the vertex.
5	Swing the arc from the vertex to make the 2-inch-diameter regular truncation.
6	Determine the lengths of the individual numbered element lines and transfer them to the pattern.
7	Notice how this pattern, if rolled up so that both No. 1 element lines meet, will fit the contour of the gutter.

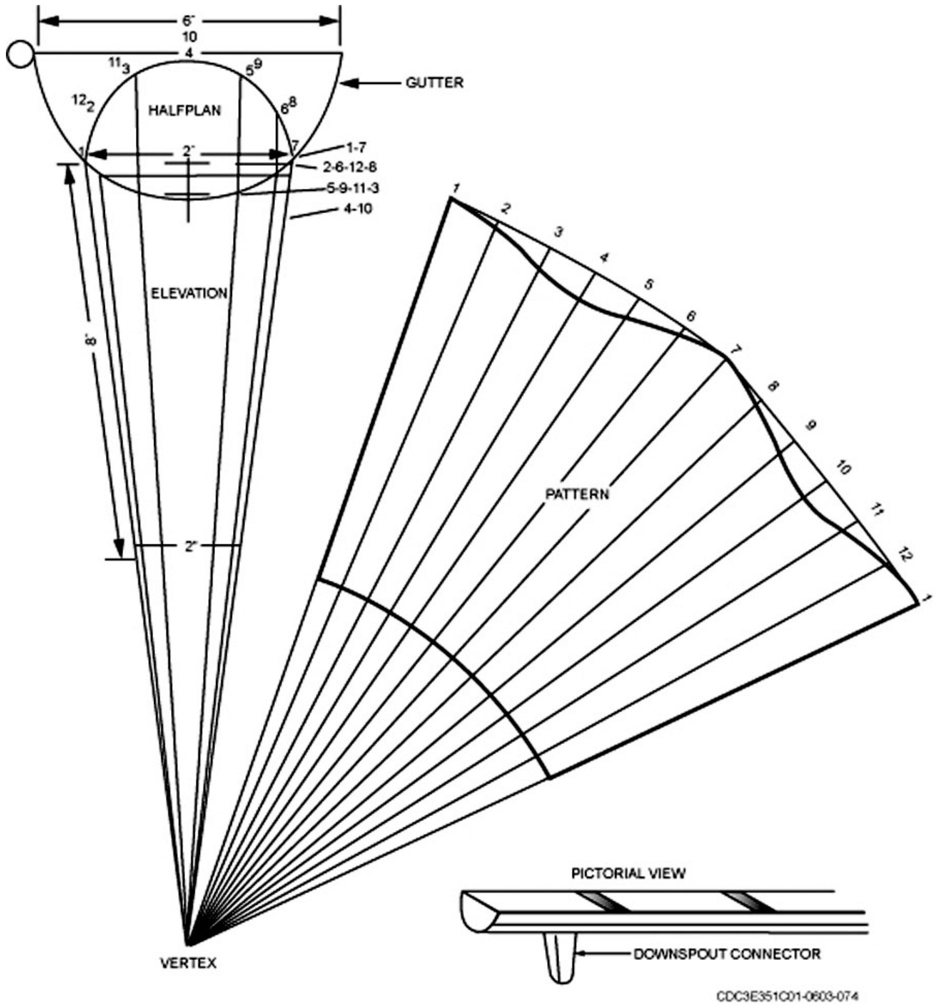


Figure 1–31. Gutter downspout pattern.

To develop the pattern for the frustum of a roof jack, review figure 1–32 in the table below and follow these steps.

Developing a Roof Jack Frustum Pattern	
Step	**Action**
1	Draw the half plan and elevation views as if for a regular frustum.
2	Determine the desired height and draw a line that cuts off the top of the cone (truncated) parallel to the base (regular frustum) and perpendicular to the centerline. *This line must equal the diameter of the vent.*
3	Divide the half plan view into equal sections as done previously.
4	From the numbered points on the half plan view, draw perpendicular lines to the base line of the elevation view.
5	From the point at which these lines intersect the base, draw lines to the vertex.
6	Draw a line from the point where the base and one side intersect to the other side, at an angle equal to the pitch of the roof. Notice that you now have two truncation lines that cut across the elevation view. You'll need both lines.

Developing a Roof Jack Frustum Pattern	
Step	**Action**
7	From each point where the radial lines intersect the lower truncation line, project horizontal lines to the side of the cone. You now have the true height lines for each radial element line.
8	Take the true height measurements from the elevation view and place them on the stretch-out element lines.
9	Connect the points with an irregular curve.
10	Add the elbow edge seam allowance to the top of the frustum stretch-out.
11	Add the groove seam allowance to each edge of the pattern stretch-out

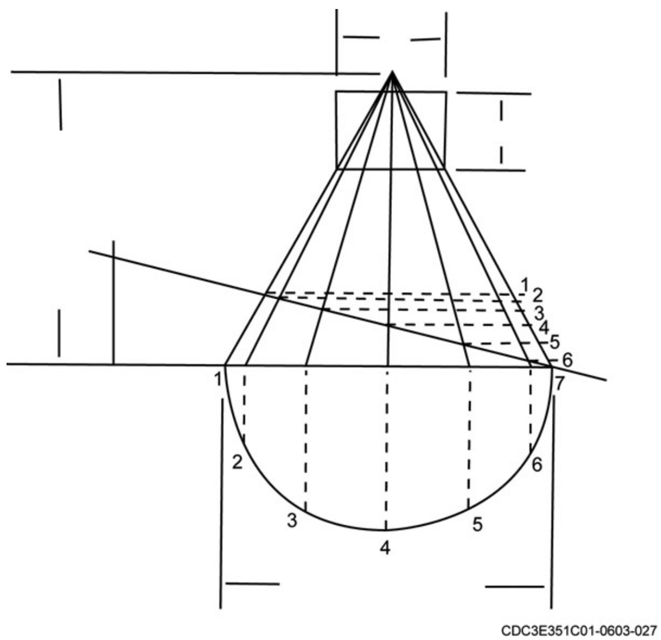


Figure 1–32 Roof jack frustum and collar

Now, you are ready to make the pattern for the roof jack collar. Review figure 1–32 and follow the steps in the following table.

Making the Roof Jack Collar Pattern	
Step	**Action**
1	Determine pipe circumference.
2	Draw a base line equal to the circumference by taking the pipe diameter and multiply by π.
3	Determine the collar height and draw a line parallel to the base line.
4	Add the groove seam allowance to both ends of the pattern.
5	Add one elbow edge seam to the collar pattern. This seam can be added to either the top or bottom of the collar pattern.

This completes our discussion of the radial line layout method of pattern development. You were shown how to develop patterns for tapered components such as pyramids and cones.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

003. Radial line layout

1. Where must the vertex be in relation to the base for items laid out by the radial line method?

2. What is the true height of a right cone?

3. When drawing a radial line layout for a pyramid-shaped object, why must you inscribe the plan view in a circle?

4. When finding the true length of the element lines on a truncated cone, how are the element lines projected to the side element line?

5. What item laid out by the radial line method has a slant height and true height that are the same?

6. How many truncation lines are there in the layout of a roof jack?

004. Triangulation layout

In the following paragraphs, we'll discuss the triangulation layout method of pattern development for components that don't have a common center or parallel sides.

You are probably beginning to realize that, regardless of how complicated the component may be, you can develop a pattern for it by applying the principles in this unit—parallel line, radial line, or triangulation methods. There are many irregular shapes (e.g., transitions and offsets) in sheet metal fabrication that have patterns that you'll not be able to produce by the methods already explained.

Using triangulation layout with transitions

A *transition* is a sheet metal component designed to connect pipes or ducts of different shapes. Transition examples are shown in figure 1–33. Notice that lines drawn on these irregular shapes don't run parallel with each other or meet at a common point. With these figures, you'll need to divide the surface into a series of triangles that slope in many directions. Finding the true lengths of these sloping triangles makes it possible to develop the patterns.

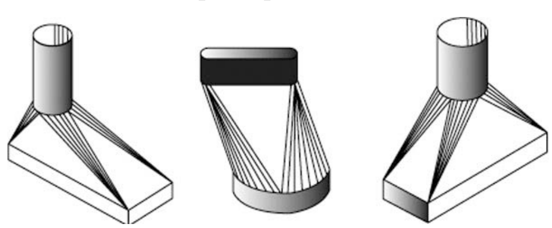


Figure 1–33. Transitions.

In triangulation, the surfaces of the elevation and plan views are divided into a convenient number of triangles where the sides form the element lines. When you look at these element lines in the plan and elevation views, they appear shortened. To make this a little clearer, suppose you take a pencil about 6-inches long and hold it at arm's length, perpendicular to the line of sight, as shown in figure 1–34. Now, as you tilt the top end of the pencil away from you, notice how its length appears to shorten. If you measure the pencil in this position, it will still be 6-inches long, although it appears shorter.

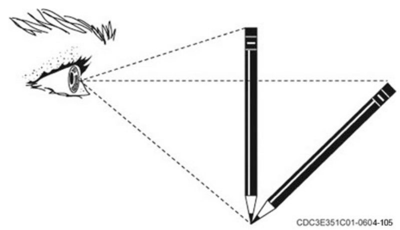


Figure 1–34. Line of sight.

Before the sloping lines of transitions can be transferred to a pattern, you must find their true lengths by making a true-length chart. To find these true lengths you need to show the element lines in two views. The *elevation view* shows the vertical height of the element lines, and the *plan view* shows the horizontal distance covered by the same lines. In Figure 1-35 you can see how these two distances are laid off as the sides of a right triangle with the hypotenuse showing the true length of the element line.

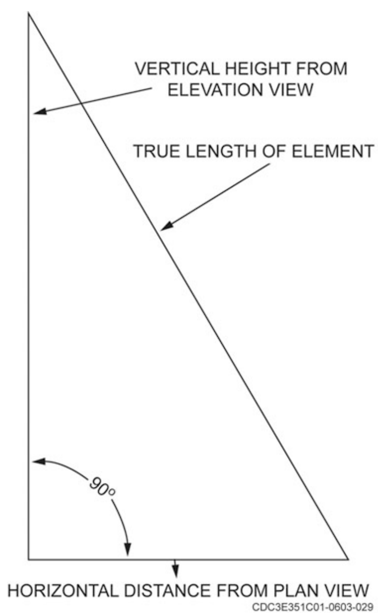


Figure 1-35. True length of an element line.

Square-to-square-twisted

Now let's apply the triangulation principles in the development of an object that has relatively few element lines and will demonstrate true length. Use the following steps in applying these principles to figure 1–36.

Your first action is to construct the plan view and label the points as shown in view **a** of figure 1–36. Notice that the smaller opening is twisted 45° from the larger. Then draw the element lines from all corner points: **1 to A**, **A to 2**, **2 to B**, **B to 3**, and so forth. Next draw the elevation view to show the side and the height of the component (fig. 1–36, view **b**).

These two views give you all the information you need to construct the pattern. The element lines that are between the base and top of the component are *not* true length. To determine the true length of these lines, you must construct a true-length chart (fig. 1–36, view **c)**. First mark the distance on the vertical leg of the chart as taken from the elevation view (fig. 1–36, view **b**).This measurement is equal to the vertical height of the component. Then, you mark the distance on the horizontal leg of the chart as taken from the plan view, which is equal to the horizontal distance each element line travels on the plan view. In this pattern, all the element lines are equal because the small opening is centered on the larger one; therefore, lines **4C**, **4D**, **3B**, **3C**, etc., are all the same length. When components have several element lines the same length, only one true-length chart is required.

Now we are ready to actually develop the pattern using the steps in the following table.

Developing a Square-to-Square-Twisted Pattern	
Step	**Action**
1	To avoid confusion, start with line **1–2**, and draw it equal to the length shown in the plan view (fig. 1-36, view **a**). **NOTE**: Since this line does not slope from the base to the top, it is shown true length on the plan view and is *not* charted on the true-length chart.
2	Using the true length of line **1-A** (from the true-length chart) and **2-A** (also from the true-length chart), complete triangle **1-A–2**. To do this, set a compass to the true length of these lines by using the distance from the vertex of the true-length chart to the numbered point on the base line of the true-length chart.
3	Using points **1** and **2** as centers, draw intersecting arcs to find point **A**.
4	Construct the rest of the triangles in the same sequence as they appear in the plan view. The next triangle is **2-A-B**. First set your compass to distance **A-B** on the plan view.
5	Using point **A** on the pattern as center, draw an arc as shown in Figure 1–36, view **d**.
6	Set the compass to the true length of line **2-B** (from the true-length chart).
7	Use point **2** on the pattern as center and draw an arc to intersect the first one. This locates point **B** and you can now complete triangle **2-A-B**.
8	Continue this procedure for triangles **2-B–3**, **3-B-C**, **3-C–4**, **4-C-D**, **4-D–1**, and **1-D-A**, as shown in Figure 1-36, view **d**.

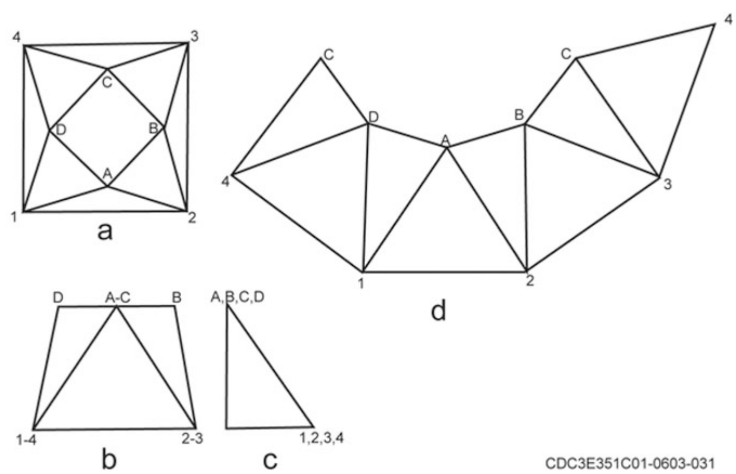


Figure 1–36. Square to square twisted.

Note that you have two **4-C** lines. This will be the seam when the component is formed, and these lines are the same. Now let's apply this same procedure to a component with more element lines.

Square-to-round symmetrical transition

Figure 1–37 is a pictorial view of a rectangular-to-round transition, and figure 1–38 shows the square-to-round development pattern. Both transitions are *symmetrical*—meaning that if cut down the middle, both halves would be the same size and shape. Therefore, pattern development procedures are the same for both. In figure 1–37, the transition is made up of one isosceles triangle where the sections join. In addition, eight parts with curved surfaces form the round opening, and their vertexes meet in corners **A**, **C**, **E**, and **F** (F is *not* shown).

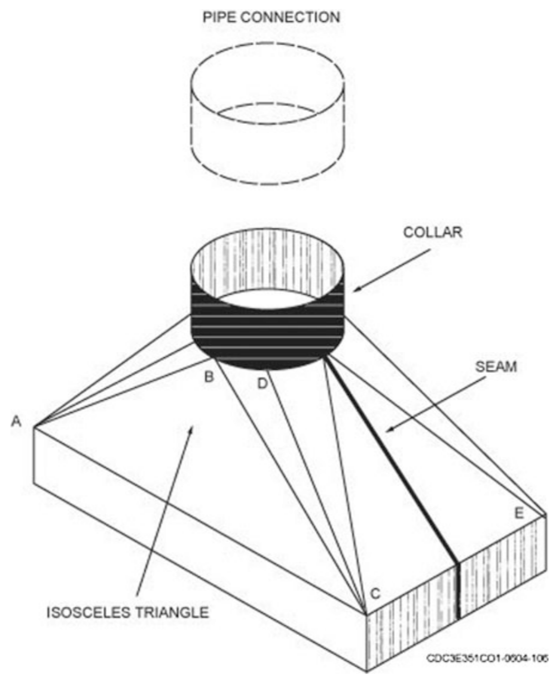


Figure 1–37. Rectangular to round transition.

Only a half pattern of the stretch-out (fig. 1–38) is needed because the transition piece is symmetrical in shape. You'll have to cut two pieces to this pattern in order to complete the transition. Figure 1-38 shows the various steps for developing this pattern. Refer to figure 1–38 as we describe the procedure in the following table.

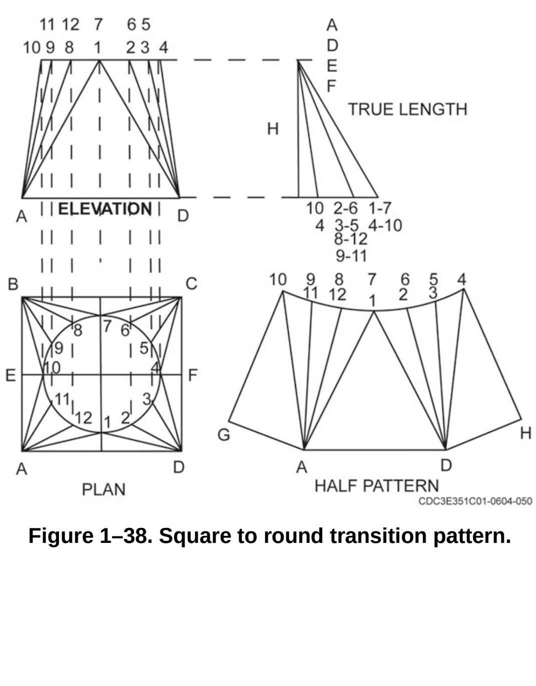


Figure 1–38. Square to round transition pattern.

Developing Symmetrical Transition Patterns

Drawing the Plan View

Draw the plan view as shown, keeping the exact diameter and dimensions of the round and square connectors.

In other words, **ABCD** represents the square end, and the circle represents the round end.

To draw this view, you must:

Step	Action
1	Divide the circle into equal parts and number **1** to **12** and label them from left to right.
2	From the numbered points on the circle, draw straight lines to vertexes **A**, **B**, **C**, and **D** to form triangles.

Drawing the Elevation View

Draw the elevation view to determine the distance between base and top of the transition.

Follow these steps to draw this view:

Step	Action
1	From the numbered points on the plan view, project lines straight up to and intersecting the top of the elevation view.
2	Number these points of intersection to correspond to the numbers in the plan view.
3	Draw element lines from the numbered points to the corners of the base, forming triangles. These are *not* true-length element lines.

Making a True-Length Chart

To determine the true lengths of these element lines, you must set up a true-length chart (fig. 1-38).

The steps to follow are:

Step	Action
1	Draw a right angle with a vertical height equal to the height of the elevation view.
2	Beginning with element line **A–1** in the plan view, use a compass to transfer lines **A–1**, **A–12**, **A–11**, etc., to the base line of the true-length chart, and number each line respectively. From the center of the plan view, you can see that the transition has four identical parts with several element lines of the same length. This is why the true-length chart shows multiple numbers for each true-length line.
3	From the numbered points on the base line, draw straight lines to form a vertex. These straight lines are the *true lengths* of the element lines.

Drawing the Half-Pattern

Use the following steps to draw the half-pattern for the figure shown in Figure 1-38:

Step	Action
1	To start the half-pattern stretch-out for the transition shown in Figure 1-38, draw a horizontal line equal in length to **AD** in the plan view.
2	Set your compass to the true length of element line **A–1**, and using **A** and **D** in the half pattern as centers, swing two arcs so that they intersect. Number the point of intersection **1–7**.
3	Set a compass equal to the distance between points **1** and **2** in the plan view and transfer to each side of point **1–7** in the half pattern. For simplicity, you should leave this compass adjusted to this setting since you'll repeat it.
4	Use another compass to transfer the lengths of the remaining element lines from the true-length chart. (For greater accuracy, make this measurement often by drawing a stretch-out, or straight line of the

Developing Symmetrical Transition Patterns	
	round end of the transition.) The round end shown in the plan view has 12 spaces; therefore, a straight line for this example would be divided into 12 equal spaces. This method is more accurate than other methods because the straight-line distance between two points on an arc is actually the length of a chord between the points, rather than the length of the curved arc between the two points.
5	The compass that is set to the distance between points **1** and **2** in the plan view is used repeatedly to establish the distance between the remaining points to the left and right of point **1–7** on the half pattern.
6	The arcs that have been drawn to each side of point **1–7** (half pattern) are now to be intersected by arcs swung from points **A** and **D**. You can take the radii of these arcs from the true-length chart, line **A–12** (**D–2**). Establish the remaining points to the left and right of the vertex by repeating these steps, using the appropriate true-length lines. After you number each point and draw the element lines, the final steps are to locate points **G** and **H**.
7	To locate **G** and **H**, set the compass to the true length 10–4; and with 10 and 4 as center, scribe arcs at **G** and **H** on the half pattern. Then, set the compass to **DH**, and with **D** and **A** as centers, scribe intersecting arcs at **H** and **G** and draw lines **A-G**, **G–10**, **D-H**, and **H–4**. By connecting all points of intersection with straight or curved lines, you complete the pattern. This final step forms the two right triangles at the extreme ends of the half pattern.

You’ve seen why a transition that is symmetrical requires only a half pattern. However, a transition with a double offset (two end openings that do not share a centerline) will require separate half patterns, since all four sides are different.

Offset rectangle-to-round transition

Develop a pattern for an offset rectangle-to-round transition in much the same way as a square-to-round transition. A half pattern will be sufficient if the offset is only to one side of the center. The rectangle-to-round transition in figure 1–39 with the round section off-center has two equal halves on either side of centerline **EF**.

Draw the plan view and the elevation view with the round section off center. Draw the elevation view to the desired height (8 inches, in this case). The two true-length charts represent the element lines for each quarter part of the half pattern, and are lettered **A** and **B**. You can find the true lengths of the element lines by using the same methods used for square-to-round transitions. Develop the half pattern using the measurements of the rectangular base, the circumference of the round top, and the true-length element lines.

Offset cone

Develop the offset cone pattern in much the same way as the other patterns that we’ve already discussed. You’ll find there are a few additional steps. Notice in Figure 1–40 that there are two circumferences for the frustum that do not share the same center. Connecting the points of each circumference forms the triangles, such as triangle **2–3–4**, which is necessary for pattern construction. Use two true-length charts (one with solid lines and one with dashed lines) to avoid confusion when transferring true lengths to the pattern. Since this particular frustum is symmetrical in shape (two equal halves), only half of the required element lines need to be drawn in the plan view. After you draw the plan and elevation views, divide the circumference in the half plan view into the same number of equal parts. Number these points so that the even numbers are all on one perimeter and the odd numbers are on the other. From the numbered points in the plan view (starting from point **1**), draw a solid line from **1** to **2**, then a broken line from **2** to the odd No. **3**. Continue this process until the plan view resembles the one shown in figure 1–40.

To determine the true length of the element lines, you need to draw two true-length charts (fig. 1-40). Two true-length charts allow you to place the element lines on the charts without stacking them on top of one another.

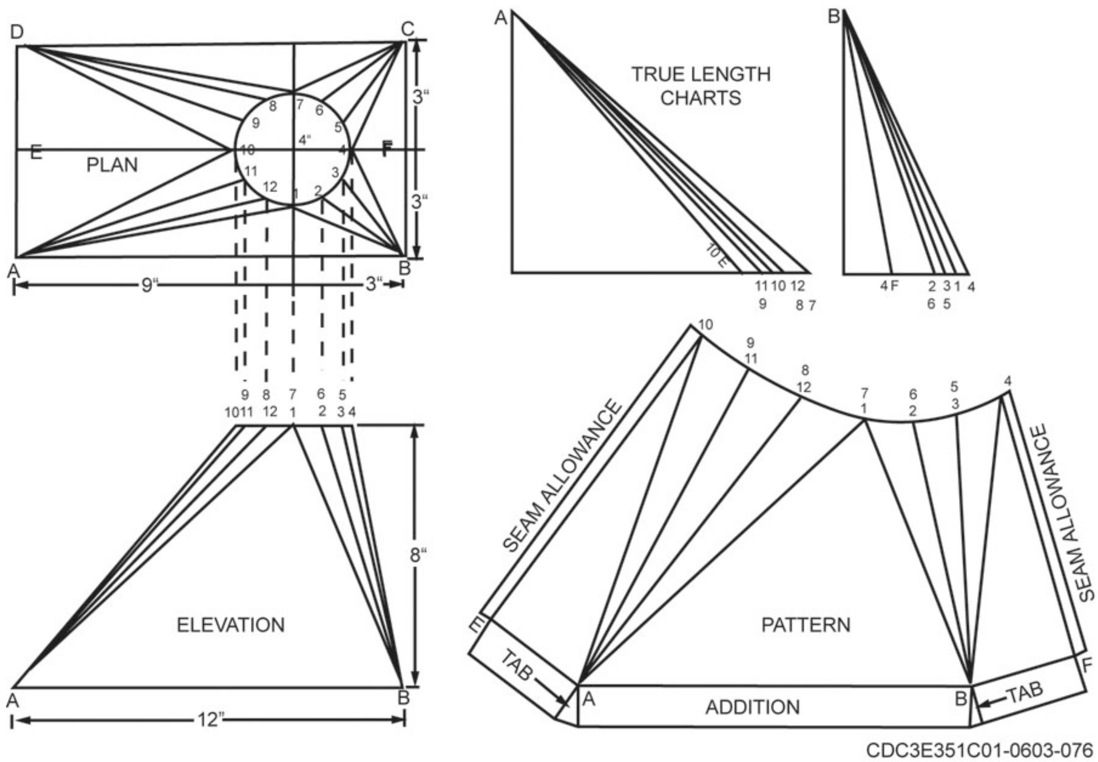


Figure 1.–39. Rectangular to round transition pattern.

To construct the pattern for an offset cone (fig. 1–40), begin the half-pattern stretch-out by drawing line **1–2**, which is obtained from view A of the true-length chart. This is the *reference line for the pattern*; build all future points or lines around it. The distances between the odd-numbered points (**1** through **13**) on the pattern stretch-out are equal and identical to the distances between the same numbers in the plan view. The distances between the even-numbered points (**2** through **14**) of the pattern stretch-out are equal and identical to the distances between the same numbers in the plan view. The sloping element lines (from an even number to an odd number) of the pattern are not equal in length, but they're identical to the lengths of the corresponding numbered lines in the true-length charts. To complete the pattern, except for seam allowances, connect all points of intersection with lines.

Remember, in pattern development, the numbering of element lines begins where the component joins together. And, since patterns made by the triangulation layout method join in the center, the numbering starts at the center of the pattern.

You may develop many items by triangulation. As you look around the base, each sheet metal item you see was developed through one or a combination of the layout methods that we've discussed. This completes our discussion of layout methods. You've studied how the parallel line method, radial line method, and triangulation method are used to develop patterns for sheet metal components. This text has not covered every possible component that you may lay out, but most shops have reference books to use when you come up against really tough layout projects

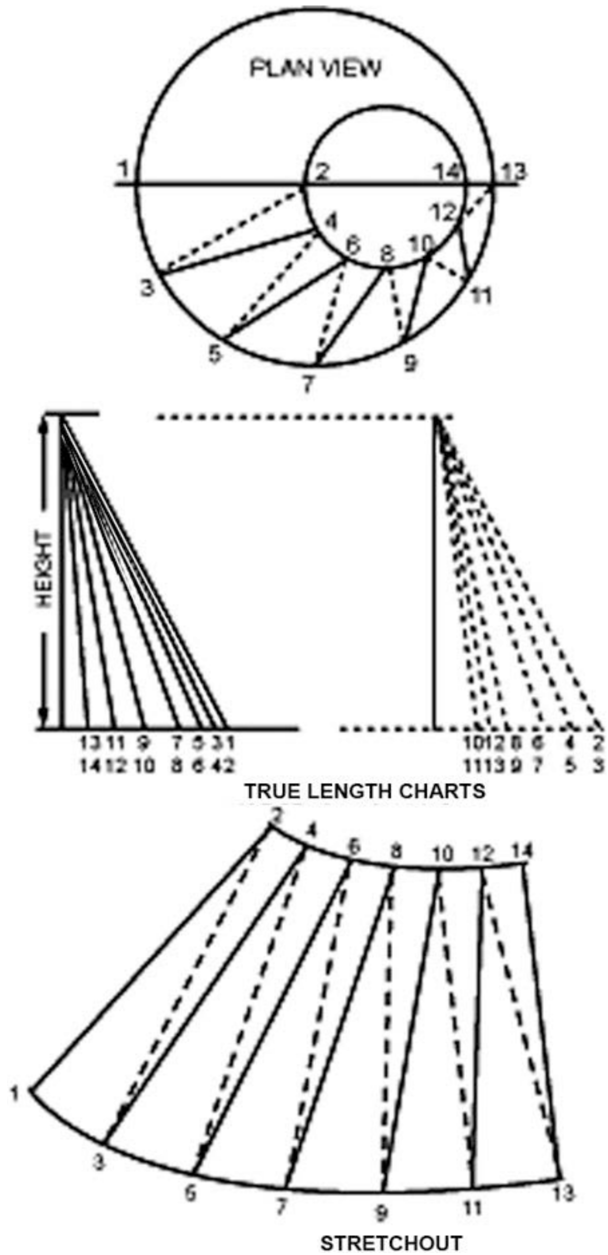


Figure 1–40. Offset cone pattern.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

004. Triangulation layout

1. What are the surfaces of the plan and elevation views divided into when using the triangulation layout method?

2. From where is the height of the true-length chart obtained?

3. Why are two true-length charts helpful when laying out an offset cone?

4. Why are two compasses helpful when using the triangulation method?

5. Where should the numbering on patterns start?

6. What pattern development is needed for an offset cone?

005. Allowances and pattern transfer

To simplify the preceding discussions, we did not consider seam allowances and additions, although in actual practice you'll include them in the pattern development. But now we need to discuss these aspects of pattern development. In the following paragraphs, we'll discuss the seam allowances and additions that you add to the pattern.

Seam allowances

Figure 1–39 shows examples of seam allowances and additions to a pattern for a transition. Sheet metal patterns, such as the two halves of the transition, are assembled with seams. (Later in this course, you'll learn to make and use several types of seams, and various types of lock seams.) When an object has seams you are required to add additional material to the pattern to allow for the seams. Because patterns developed by the parallel line, radial line, or triangulation method do not include allowances for seams, you must determine how much length or width to add. For example, to include ¼-inch grooved seams when assembling the transition shown in figure 1–39 the pattern must allow for a $^{3}/_{8}$-inch extension along both line **F–4** and line **E–10**. (Add the seam allowances along the edges of the pattern where the pieces will be joined.) You must add these seam allowances to the pattern *before you cut it out*.

Additions

Taking another look at figure 1–39 you also see additions to a pattern. You need this additional length for several reasons. For example, if the pattern is for a transition e.g., (fig. 1–37), the additions to each end are probably 2-or-3 inches. However, they can be more or less, depending on how you use the transition. The rectangle-to-round transition has additions at both ends for joint connections (fig. 1–37), where the round addition is needed to fit into a round duct section. Still another use for additions is to extend a component's length a few inches to fill a gap in a duct system. If you connect the rectangular end to a rectangular-shaped duct, you must also add a seam allowance to the addition.

Suppose you need to add 2 inches to the pattern at lines **AB**, **AE**, and **BF** in figure 1–39. You do this by squaring down from line **AB** 2 inches at points **A** and **B** and striking a mark, then repeating that process at points **E** and **F**. Join the marks with straight parallel lines. Notice that the additions have tabs at **A** and **B**. The two tab lines at points **A** and **B** are perpendicular to the base lines of the triangles shown in the pattern. You only cut one of the tab lines at points **A** and **B** so that you can join the corners when the transition is assembled. Secure the tabs by spot welding or riveting when you assemble the pattern. Also notch all element lines that are to be folded so that you can make the connection more easily.

The rectangular duct pattern in figure 1–41 will need a seam allowance to connect the ends (**a**). If you join the duct without making an allowance for seams, it will have two short sides. You determine the seam allowance by the type of seam you use. For the pattern in figure 1–41 you are going to use a Pittsburgh lock seam. To make the Pittsburgh lock seam, you must make allowances on each side of the duct. On one side, you add the *pocket allowance*. The pocket allowance can vary on different Pittsburgh machines, but it is 1 ¼ inches when you form the pocket with a cornice brake. On the opposite side of the pattern, you need ¼ inch for the *Pittsburgh flange* to complete the seam allowance. Since it will be joined to another duct on one or both ends, the length of the duct also need joint allowances. Again, the allowance is determined by the connection you will use. The *connection allowance* for *each S slip* is ½ inch and each *drive slip* is ½ inch. *Remember to add all allowances to your pattern.* In addition, you notch all element lines that you are going to fold (fig. 1–41) so that you can make the connection more easily.

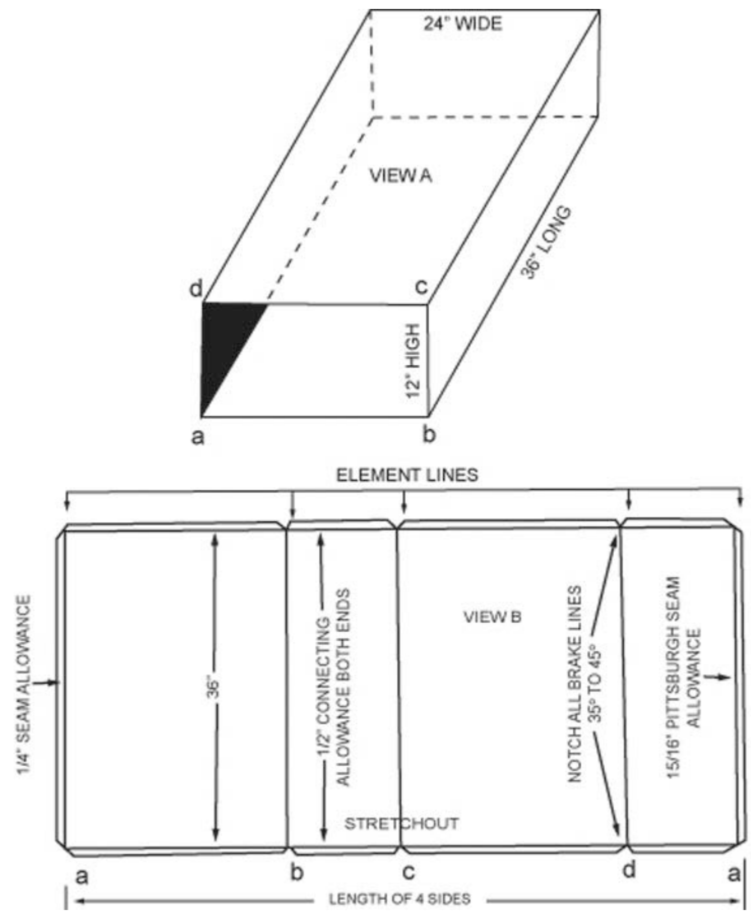


Figure 1–41. Seam allowance for a rectangular duct.

Layout tools useful for drawing seam allowances and additions on paper patterns include the compass, T-square, irregular (French) curve, steel rule, and triangle. The layout tools used to make seam allowances and additions on metal patterns include the framing square, combination set, dividers, and scribe. You will use these tools to measure and make parallel lines when making seam allowances and additions to patterns.

In the following paragraphs, we'll discuss how we transfer patterns. We will discuss transferring patterns to metal and transferring various shapes.

Transferring patterns to metal

In the previous discussions about layout, we suggested drawing the pattern on paper first. Why? There are two reasons for using paper:

- You can see development lines much more easily on paper during the layout process.
- You can save materials when several different patterns are arranged on the sheet metal close to each other.

You transfer paper patterns to metal by duplicating the points at the ends of element lines on the metal. Placing weights on the pattern prevents it from slipping during the transfer. Use a pencil with a sharp point to carefully mark the outside lines, then prick-punch the points and lines on the metal for clarification. (A *prick punch* is a sharp-pointed punch.)

Patterns used repeatedly in the shop are made of metal and called templates or master patterns. Paper patterns, when used repeatedly, soon become worn and inaccurate. If you have to make several identical items, you'll save time by preparing a template. Figure 1–42 shows a prick punch being used to mark the element lines on a metal template of a cylindrical pipe. Notice that weights are holding the template in place while the punch is used. For larger templates than the one in figure 1–42, use clamps to hold the template while scribing the pattern.

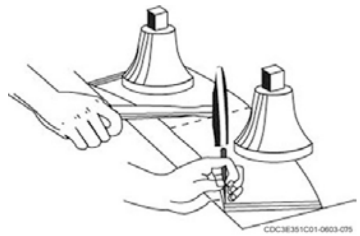


Figure 1-42. Using a template.

Transferring patterns from metal templates to sheet metal is just like transferring paper patterns, except that you use different tools. Use a scribe to mark the edges and the lines and the prick punch to mark points at the end of element lines, just like paper patterns. The template in figure 1–43 is being held in place by hand, but you'll get greater accuracy by using weights or clamps to hold the template.

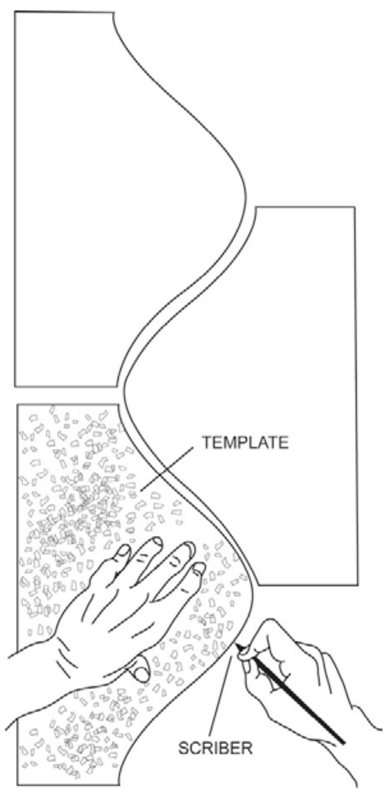


Figure 1-43. Transferring metal patterns.

Transferring patterns for various shapes

While working in your day-to-day job, you will be required to transfer patterns for numerous shapes. In the following table we'll look at transferring some of the more common shapes you will use.

<table>
<tr><th colspan="2">Transferring Patterns for Common Shapes</th></tr>
<tr><th>Shape</th><th>Action</th></tr>
<tr><td>Rectangular duct</td><td>Transferring these patterns is fairly easy.

The pattern as shown in figure 1–41 is transferred to metal by duplicating its shape and using a prick punch to locate the ends of the element lines.

Lines B, C, and D are the break lines when forming the duct.</td></tr>
<tr><td>Round component with a miter</td><td>Transferring the pattern for a round component with a miter (fig. 1-43), is done by simply duplicating the shape of the mitered pattern on the sheet metal.</td></tr>
<tr><td>Elbow</td><td>Transferring elbow patterns requires a different method (refer back to fig. 1-18).

This is a half gore pattern that is sufficient to make five pieces for the elbow. The working line on this pattern is very important when you are transferring the pattern to metal. During the following explanation of the transfer, you'll see why marking the pattern for identification is necessary.

A five-piece elbow requires five gores. Marking gores I and V requires half the pattern (A or B), which is divided at the working line. Make gores II, III, and IV by using the whole pattern (A and B).

If you need to make a 45° elbow, you can use the same elbow pattern, but you will need to transfer two half gores and one full gore. Again, referring back to Figure 1-18, notice in the elevation view that each of the whole gores is divided by broken lines to show whole and half gores.</td></tr>
<tr><td>Y-branch</td><td>Transferring patterns for a round Y-branch (fig. 1–19), is similar to the process for other patterns.

This layout has only three patterns.

Use the pattern for piece III only one time, but patterns for pieces I and II are used twice, since pieces IV and V are duplicates of them.</td></tr>
<tr><td>T-joint</td><td>Figure 1–20 is an example of transferring patterns for a T-joint.

This is done by marking on the outside edges, except for the cutout in the pattern of the main pipe.

Mark the cutout on the inside, so that you can cut the hole out before forming.</td></tr>
<tr><td>Pyramid</td><td>When transferring a pattern for a pyramid (fig. 1–26), make the lines on the outside edge and at the intersecting points.

The intersecting points are the break lines for forming the pattern.</td></tr>
<tr><td>Round offset</td><td>When transferring the pattern for a round offset (fig. 1–40), you'll need two of the pattern halves, since it was laid out in a half pattern.

If you want to make this offset in one piece with one seam, it is necessary to mark one-half of the pattern, roll it end-to-end aligning lines 1–2, and continue marking the other half.</td></tr>
<tr><td>Square-to-round</td><td>The procedures for transferring patterns for square-to-round components (fig. 1–38) are the same as for other patterns.

Mark the outside of the pattern, and the ends of the element lines are prick-punched so that you may see them when you are forming the component.</td></tr>
</table>

We've covered a lot of information on layout procedures. This included the parallel line, radial line, and triangulation methods of pattern development. You've studied about seam allowances, additions, and how patterns are transferred to metal. With this information and practice you can lay out patterns for any component you need.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

005. Seam allowances and pattern transfer

1. Do allowances for seams on pattern layouts increase the size of the pattern?

2. Where are seam allowances placed?

3. For a ¼-inch grooved seam, how much extension must be made on a pattern?

4. When are seam allowances added to patterns?

5. Why are additions made to both ends of a rectangular-to-round transition?

6. What layout tools are used to make seam allowances and additions to metal patterns?

7. Why are patterns drawn on paper before transferring them to metal?

8. What should be placed on the pattern to prevent slippage during pattern transfer?

9. Break lines on a metal pattern are transferred with what tool?

10. What are frequently used metal patterns called?

11. How do you use whole gore elbow patterns to make end gores?

006. Structural steel layout

When working with thin sheet metal, you can estimate (or sometimes even disregard) the thickness of the material. However, when you work with plate or structural steel, neglecting the thickness of the material will cause serious deviations from specified dimensions or a poor fit between components.

When you bend metal to exact dimensions, you must know the amount of material you'll use in forming the bend. The amount of material actually used is known as the *bend allowance*.

Bend allowance terminology and computation

Bending compresses the metal on the inside of the bend and stretches the metal on the outside of the bend. Halfway between these two surfaces or extremes, lies a space that neither shrinks nor stretches, but retains the same length—the *neutral axis* (fig. 1–44, top view). You compute the bend allowance along the neutral axis.

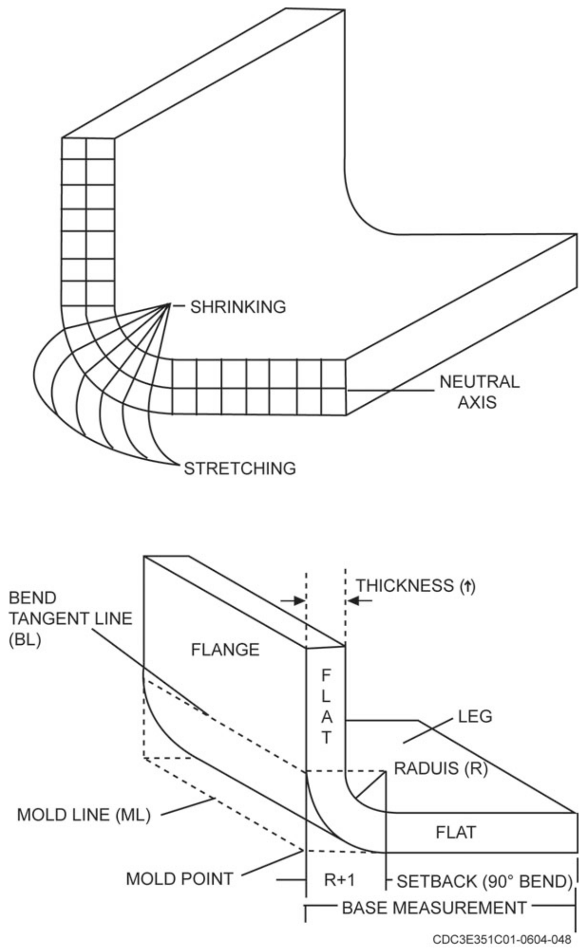


Figure 1–44. Bend allowance terms.

Before we begin discussing structural steel layout you need to have a good understanding of the terminology that is used. The table below along with the bottom view in figure 1–44 is designed to help you master this information.

Bend Allowance Terms	
Term	**Definition**
Leg	The longer part of a formed angle.
Flange	The shorter part of a formed angle. If both parts are the same length, each is known as a leg.
Mold line (ML)	The line formed by extending the outside surfaces of the leg and flange so that they intersect.
Bend tangent line (BL)	The line at which the metal starts to bend.
Bend allowance (BA)	The amount of material consumed in making the bend.
Radius (R)	The radius of the bend. It is always measured from the inside of the bend unless otherwise stated.

Bend Allowance Terms	
Term	**Definition**
Setback (SB)	The amount that the two mold line dimensions overlap when they're bent around the formed part. In a 90° bend, SB = R + t (radius of the bend plus the thickness of the metal).
Bend line (also called brake line or sight line)	The layout line on the metal being formed, which is set even with the nose of the brake and serves as a guide in bending the work. (Before bending, you must decide which end of the material can be most conveniently inserted in the brake.) You then measure and mark the bend line with a soft pencil, from the bend tangent line closest to the end that is placed under the brake. This measurement should be equal to the radius of the bend. You then insert the metal in the brake so that the nose of the brake will fall directly over the bend line.
Flat portion or flat	The flat portion or flat of a plate is that portion *not included in the bend*. It is equal to the *base measurement minus the setback.*
Base measurement (or mold line measurement)	The base measurement is the outside dimension of a formed plate. Base measurement will be given on a blueprint or drawing or may be obtained from the original part.
Closed angle	An angle that is *less than* 90° when measured between legs.
Open angle	An angle that is *more than* 90° when measured between legs.

Bend allowance computation

In order to compute bend allowance, you must know two primary facts—the *radius of the bend* and the *degree of angle* in the bend. Usually, you can determine these factors from the blueprints or drawings from which you are working.

As you study the following examples, refer to figure 1–44 (bottom) to help you understand where and how the mathematical figures are obtained. Remember that you measure bend allowance from the inside of the bend; but you compute bend allowance along the neutral axis of the material being used. Therefore, when calculating bend allowance to determine the radius of the neutral axis, add the bend radius to one-half the thickness of the metal.

Bend allowance is the product of the radius of the neutral axis of the bend multiplied by the size of the bend in radians. The *radian* relates the length of the arc generated to the size of the angle. For the purpose of computing bend allowance, the number of radians per degree of bend is 0.017453.

So, the formula for bend allowance is:

$$ba = r \times \Theta \text{ where}$$

ba = bend allowance

r = Radius of the neutral axis of the bend

Θ = the angle of the bend in radians

Example 1

Using figure 1–45, what is the bend allowance for a 90° bend with a ½-inch bend radius that is to be made in plate that is ½ inch thick?

$$r = 0.50 + 0.250 = 0.750$$

$$\Theta = 0.017453 \times 90 = 1.57 \text{ radians}$$

Therefore,

$$ba = 0.750 \times 1.57 = 1.178 \text{ or } 1.18 \text{ inches}$$

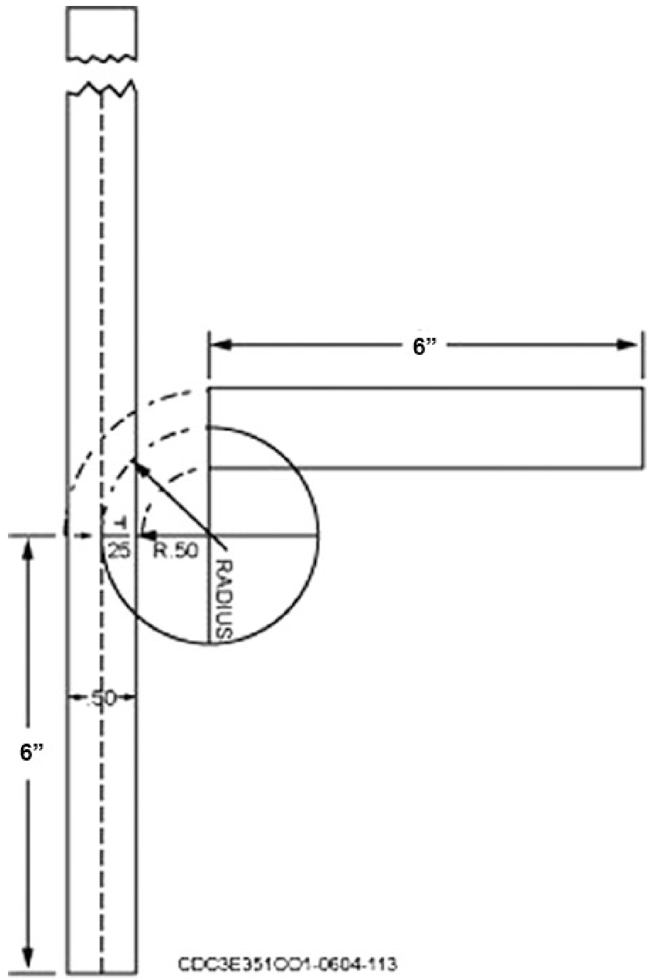


Figure 1–45. Bend allowance and length computation for a 90° bracket.

Example 2

Using figure 1–46, what is the bend allowance for a 180° bend with a 1-inch bend radius that is to be made in a length of ½-inch stock?

$$r = 1.0 + 0.250 = 1.25 \text{ inches}$$

$$\Theta = 0.017453 \times 180 = 3.14 \text{ inches}$$

Therefore,

$$ba = 1.25 \times 3.14 = 3.925 \text{ or } 3.93 \text{ inches}$$

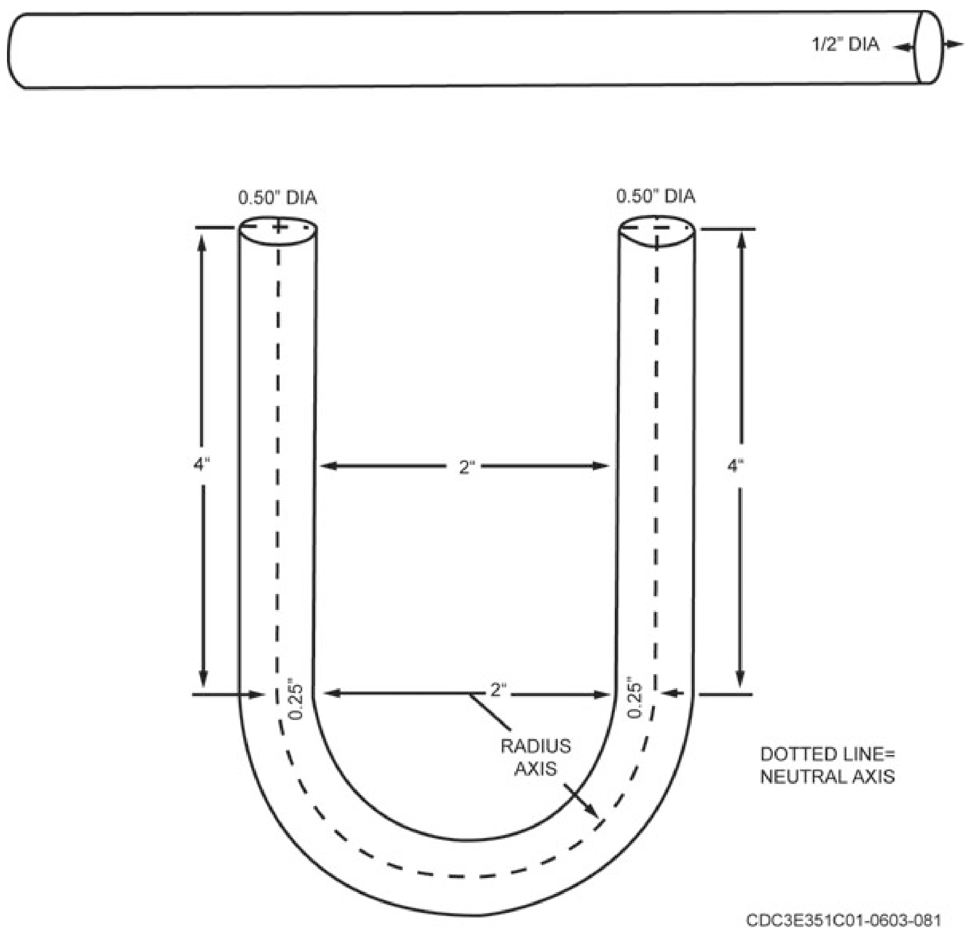


Figure 1–46. U-bolt length.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

006. Structural steel layout

1. Match each term in column B that best matches the definitions in column A. Items in column B may be used once, more than once, or not at all.

Column A	*Column B*
____ (1) Material amount consumed in making the bend.	a. Leg.
____ (2) Line that serves as a guide when bending the work.	b. Flange.
____ (3) Equal to the base measurement minus the setback.	c. Mold line.
____ (4) Angle more than 90° when measured between legs.	d. Bend tangent line.
____ (5) The longer part of a formed angle.	e. Bend allowance.
____ (6) The shorter part of a formed angle.	f. Setback.
____ (7) Mold line overlap when formed around a part.	g. Bend line.
____ (8) The line at which the metal starts to bend.	h. Flat.
	i. Base measurement.
	j. Closed angle.
	k. Open angle.

2. What information must be obtained from a print or drawing before a bend allowance can be computed

3. What number is used to compute the number of radians per degree of bend?

4. What is the formula used to determine bend allowance? What does each symbol of the formula mean?

5. Compute the bend allowance for a ½-inch-thick plate to be bent at a 45° angle with a 1-inch bend radius.

6. Compute the bend allowance for a ¼-inch-thick plate to be bent 180° with a 2-inch bend radius.

Answers to Self-Test Questions

001

1. A perpendicular bisector
2. Rain Gutters, the side pieces for duct offsets, and anywhere sheet metal is formed into an S-Curve
3. All needed descriptive information.
4. Get measurements and a description of the object.
5. (1) Parallel line.
   (2) Radial line.
   (3) Triangulation.

002

1. Parallel or perpendicular to each other.
2. The perimeter or sum of the four sides of the duct.
3. Plan and elevation views.
4. A half plan.
5. The circumference of the cylinder.
6. Gores.
7. By adding the throat radius to the elbow (duct) diameter.
8. The end gores are half the size of the center gores.
9. Collar or branch, and main pipe.

003

1. Centered over the base.
2. The distance from the vertex to edge of the base line
3. In order to get the true height of the pyramid.
4. Horizontally.
5. A right cone.
6. Two.

004

1. A convenient number of triangles.
2. The vertical height of the elevation view.
3. To avoid confusion when transferring element lines.
4. By leaving them set for the distances between equal points, you can save time.
5. In the center of the pattern where the component joins together. Where the seam is to be located.
6. Triangulation.

005

1. Yes.
2. Along the edges of the pattern where the pieces will be joined.
3. $^{3}/_{8}$ inch.
4. Before the pattern is cut out.
5. For joint connections.
6. Framing square, combination set, dividers, and scribe.
7. Development lines can be seen more easily on paper during layout, and materials can be saved when several patterns can be arranged close together on the sheet metal.
8. Weights.
9. Prick punch.
10. Templates.
11. Use one-half of the pattern.

006

1. (1) e.
   (2) g.
   (3) h.
   (4) k.
   (5) a.
   (6) b.
   (7) f.
   (8) d.
2. The radius of the bend and the degree of angle in the bend.
3. 0.017453.
4. $ba = r \times \Theta$; where ba = bend allowance, r = Radius of the neutral axis of the bend, and Θ = the angle of the bend in radians.
5. $ba = r \times \Theta$
   (2) r = 1.0 + 0.250 = 1.25
   (3) Θ = 0.017453 $\times$ 45 = 0.785385 radians
   (4) ba = 1.25 $\times$ 0.785385 = 0.98173125.
6. $ba = r \times \Theta$
   (2) r = 2 + 0.125 = 2.125
   (3) Θ = 0.017453 $\times$ 180 = 3.14154 radians
   (4) ba = 2.125 $\times$ 3.14154 = 6.6757725.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (001) When *making a sketch of a component* what information should be included?
   a. Color, size, and location.
   b. Size, location, and material.
   c. Size, layout method, and location.
   d. All needed descriptive information.

2. (001) Which layout method is used to develop patterns for rectangular, round, and square ducts?
   a. Radial line.
   b. Parallel line.
   c. Perpendicular.
   d. Triangulation.

3. (002) When constructing an elbow how many gores will *reduce air flow resistance the most*?
   a. 1.
   b. 2.
   c. 3.
   d. 5.

4. (002) You can determine the heel radius for a round elbow by
   a. multiplying the *throat radius* by (3.14).
   b. multiplying the *throat stretch-out* by (3.14).
   c. adding the *throat radius* to the elbow diameter.
   d. adding the *throat stretch-out* to the elbow diameter.

5. (002) When drawing round components the stretch-out base line is equal to
   a. the circumference of the cylinder.
   b. the sum of the four sides of the duct.
   c. the height of the elevation and plan view.
   d. half the height of the elevation and plan view.

6. (003) The *height of the true-length chart* is obtained from the
   a. stretch-out or plan view.
   b. width of the base in the plan view.
   c. vertical height of the elevation view.
   d. center of the base to the edge in the plan view.

7. (003) The *true height of a cone* is equal to the distance between which two points?
   a. Vertex to the edge of the base.
   b. Vertex to the center of the base.
   c. One edge of the base to the other edge of the base.
   d. Vertex to a point ½-inch outside of the edge of the base.

8. (003) A pyramid that has the *top cut off* is called a
   a. right pyramid.
   b. bisected pyramid.
   c. modified pyramid.
   d. truncated pyramid.

9. (004) The *triangulation layout method* of pattern development is used for components that
   a. have a common center and parallel sides.
   b. do *not* have a common center or parallel sides.
   c. have a common center and perpendicular sides.
   d. do *not* have a common center or perpendicular sides.

10. (004) In the *triangulation layout method*, the *surfaces of the elevation and plan views* are divided into
   a. cones.
   b. circles.
   c. squares.
   d. triangles.

11. (004) The height of the *true-length chart* is obtained from the
   a. stretch-out or plan view.
   b. width of the base in the plan view.
   c. vertical height of the elevation view.
   d. center of the base to the edge in the plan view.

12. (004) How many *true length charts* are required to lay out a *square-to-square twisted pattern*?
   a. 1.
   b. 2.
   c. 3.
   d. 4.

13. (005) Metal patterns that are used repeatedly in the shop are called
   a. transfer patterns.
   b. element templates.
   c. master copy templates.
   d. templates or master patterns.

14. (005) Component patterns are drawn on paper during the layout process before transferring them to metal because it
   a. takes less time.
   b. uses more material.
   c. is easier to see on paper.
   d. is easier to fold on paper.

15. (005) Which tools do you use when *transferring paper patterns to sheet metal*?
   a. Hammer, scribe, and dividers.
   b. Pencil, weights, and prick punch.
   c. Pencil, weights, and center punch.
   d. Hammer, center punch, and weights.

16. (005) What do you use to *transfer the pattern* from a metal template to a piece of *sheet metal*?
   a. Pencil and prick punch.
   b. Pencil and center punch.
   c. Scribe and prick punch.
   d. Scribe and center punch.

17. (006) The *longer part of a formed angle* is the
    a. leg.
    b. flat.
    c. web.
    d. flange.

18. (006) What number is used to determine the *number of radians per degree of bend*?
    a. 0.0017453.
    b. 0.017453.
    c. 0.17453.
    d. 1.7453.

Please read the unit menu forunit 2 and continue ➔

Unit 2. Folding, Forming, and Seaming Equipment

IN THIS UNIT, you'll study equipment used to fold, form, and seam sheet metal. Straight-line-forming machines include the bar folder, cornice brake, and box-and-pan brake, which all make straight-line folds or bends in sheet metal. Rotary forming equipment includes slip roll forming machines and a variety of rotary machines. The seaming and locking equipment discussed include stakes, seamers and groovers. We'll also touch on safety precautions, maintenance tips, and adjustment and use of folding, forming, and seaming equipment. The most frequently used forming machines in the sheet metal shop include squaring shears, cornice brake, and slip-roll forming machine. The rotary machine, rotary burring machine, turning machine, wiring machine, elbow edging machine, setting-down machine, crimping machine, beading machine, dollies, and form blocks are other types of forming equipment.

You'll want to become highly skilled in the use of this equipment, because the strength and general appearance of a completed job will be greatly affected. For example, suppose you've made a perfect transition layout. The next step is fabrication, which includes cutting, forming, and seaming. To make the component correctly, you'll have to use each machine correctly.

007. Folding and forming equipment

One of the most frequent and common operations in sheet metal work is folding metal, and it's practically impossible to make these folds accurately without the aid of machinery. The folding machines that we will discuss are the bar folder, cornice brake and box-and-pan brake. The bar folder is used when the width of the fold to be made falls within the fold capacity of the machine. However, if the width of the fold is too great for the folder, the cornice brake is used. The box-and-pan brake, as its name implies, is used to fold boxes and pans.

Properly used, these equipment items will greatly aid you in producing quality sheet metal components. In this lesson, we will begin by discussing general safety and maintenance procedures and then cover basic operating procedures so you will be able to properly form sheet metal components to the required specifications. Let's get started.

General safety procedures

General safety procedures for folding, forming, and seaming equipment include keeping hands, fingers, and clothing clear of clamping devices, folding blades, bending leafs, and forming rollers. Make sure materials and personnel don't interfere with operation of the machine's handles and levers. We'll mention specific safety procedures as we discuss the individual machines.

General maintenance requirements

General maintenance requirements for folding, forming, and seaming equipment include keeping machines lubricated, cleaned, and properly adjusted for the gauge of metal to be formed. Don't overload these machines by exceeding the recommended capacity. Like other large machines in the sheet metal shop, each piece of folding, forming, and seaming equipment should have a maintenance record folder that specifies the items to be inspected and serviced, the inspection intervals, and a place to record and initial the completed maintenance.

Bar folder

The bar folder (fig. 2–1) can make bends and folds from 0 to 165° along the edges of sheets up to 43 inches wide. The bar folder in figure 2–1 has a thickness capacity of 20-gauge material. This is the machine generally found in most sheet metal shops. The width of the folds is usually from $^{3}/_{32}$ to 1 inch. The gauge of the material must be considered before selecting and folding because it's what determines how small the fold will be. In other words, *the thinner the gauge, the smaller the fold will* *be*. The *maximum diameter* for wire edged folds is ¼ inch. The bar folder is best suited for forming small double or single hems, right-angle folds, rounded folds, and acute folds less than 90°.

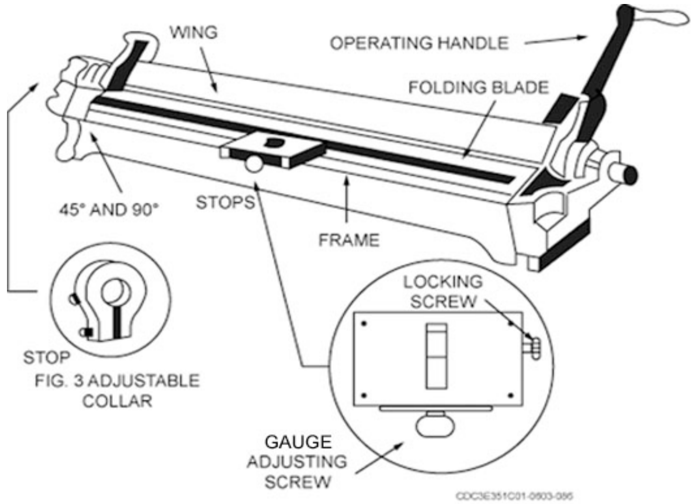


Figure 2–1. Bar folder.

You adjust the bar folder for different material thicknesses by adjusting the wing pressure screws at each end of the folder. These adjustment screws aren't shown in figure 2–1, but each consists of a threaded shaft with an adjusting nut and a locking nut, which are tightened with a wrench to increase or decrease the distance between the wing and folding blade. After the folder has been adjusted, each end of the machine is tested separately by folding a small piece of metal. Do not adjust the bar folder for excessive clamping pressure, because too much pressure can damage the machine. Excessive clamping pressure is easily detected because the machine doesn't operate freely.

The width of the fold is controlled by the gauge adjusting screw (fig. 2–1) which can be turned either clockwise or counterclockwise. This screw moves the slide and gauge bar back and forth for the desired fold. The gauge bar is under the folding blade and isn't visible when you stand in front of the folder. Although the gauge is graduated in fractions of an inch, accurate measurement is achieved by sliding a 6-inch rule between the jaw and blade, and holding it against the gauge bar. After the measurement has been made, lock the gauge in place by tightening the lock screw which is on the right side of the gauge.

It's possible to make both sharp and round folds with this machine. Before adjusting the machine, the wing must be perpendicular to the folding blade. Then adjust the wedge that supports the wing with the wedge-adjusting knob in the center back side of the folding bar. To make a sharp bend, set the wedge so that the wing stays in the same position through a cycle of operation. To make a round fold, adjust the wedge so that the wing falls back when it starts to swing.

There are two positive stops on the bar folder—one is set at a 45° bend and the other at a 90° bend. These stops are small pieces of flat bar that have been cut on the desired angle. To remove the stops, just swing or pivot them out of the way. You can make bends of other degrees by setting the adjustable collar stop (the collar stop is located on one end of the bar folder). To adjust it, loosen the collar stop bolt and rotate the stop to the angle you want and re-tighten the bolt. You can use a small piece of metal to make a test bend. On the other end of the bar folder there is a spring (not illustrated) attached to aid in making the bend. The spring acts as a counterbalance for the wing.

NOTE: When you use the collar stop, pivot both positive stops out of the way.

After adjusting the bar folder, insert the metal between the folding blade and wing. Hold the metal firmly against the gauge and pull the operating handle upward. The wing will automatically raise and hold the metal until the desired bend is made. This safety feature keeps the left hand clear of the folding blade. When the handle returns to its original position, the wing and blade return to their original positions and release the metal.

Cornice brake

The cornice brake (fig. 2–2) is a type of folding machine that has a much greater range than most folders. You can use it for simpler jobs, such as form locks, bends, and complicated jobs, such as forming complex seams and shapes. You can also use it to form square, round, and ogee bends. It can be used for many other jobs, such as forming ducts, gutters, transitions, flashing, and gravel guards, as well as for joints, seams, and locks. For example, you can easily form a Pittsburgh lock with the cornice brake if a Pittsburgh machine isn't available. To get the most out of a cornice brake, you must know how to adjust it for various operations. Knowing these adjustments is important because they save time and improve the quality of work.

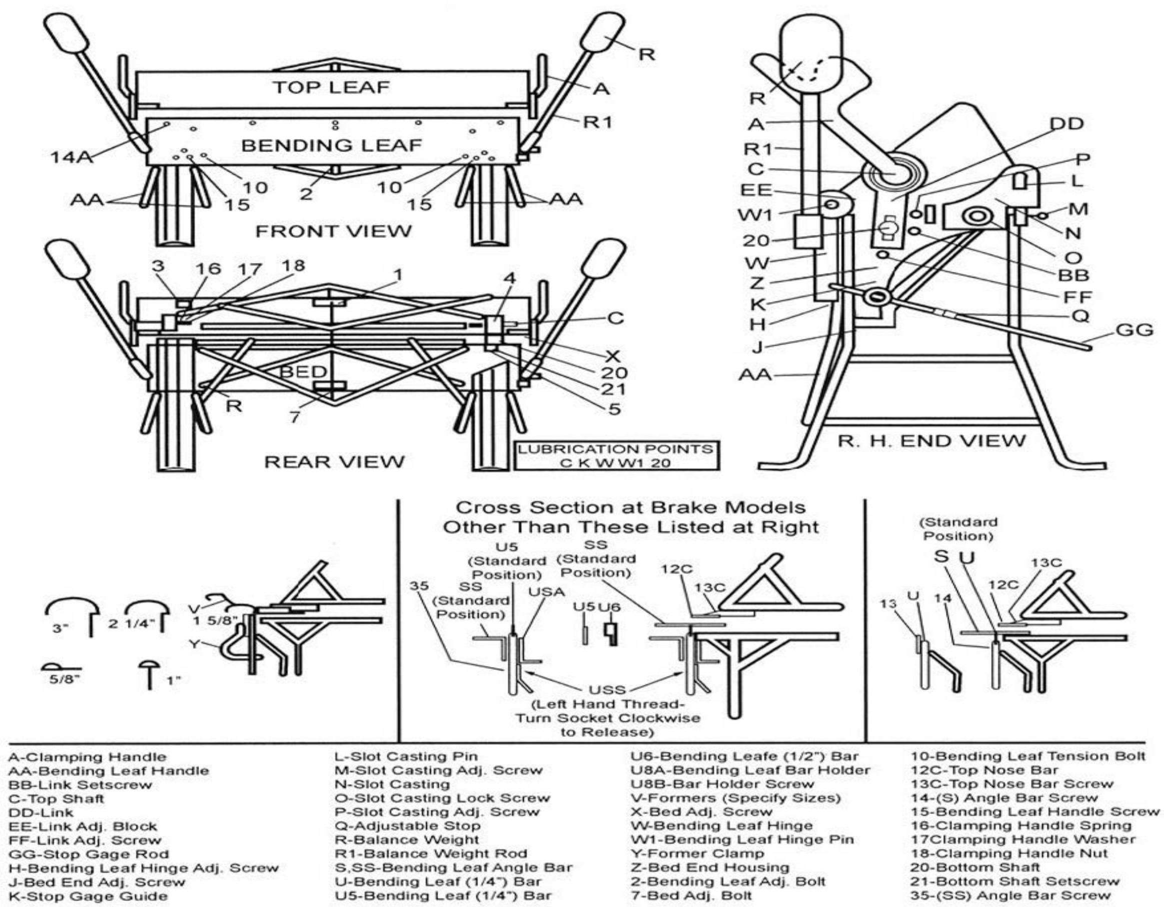


Figure 2–2. Cornice brake.

This completes the six-sided pyramid pattern. Although the element lines you've just drawn are not absolutely necessary when forming the pyramid, they do clearly show where you can make the folds when forming the object.

The cornice brake must be level on the floor to keep the top leaf from creeping when metal is clamped between the top leaf and the bed. If the top leaf creeps, check screws P and O shown in (fig. 2–2). If adjusting them doesn't remedy the creeping, put a wedge of wood or similar material under the rear leg on the side that creeps. The wedge should be forced until the creeping is eliminated. Then replace the wedge with a permanent block of that height.

Next, check the bending leaf in the DOWN position. The edge of this leaf should be $^1/_{64}$ inch below the bed edge at the ends and $^1/_{32}$ inch below the bed edge at the center. To get and maintain this alignment, make these adjustments:

- Adjust leaf ends with screw H (right-hand end view).
- Adjust leaf center with bolt 2 (front view).
- Adjust bed ends with screw J (right-hand end view).
- Adjust bed center with bolt 7 (rear view).

When you bend various thicknesses of metal, the top leaf should be set back two times the thickness of the material being bent. Thus, to make neat sharp bends, *always make sure the set back is correct.* To adjust the set back on the kind of brake shown, adjust the top leaf as follows.

Adjusting the Brake Set Back	
Step	**Action**
1	Loosen screw O (shown on right-hand end view).
2	Move the top leaf forward or backward by adjusting screw M or P (shown in right-hand end view); these screws have right-hand threads.
3	Once the adjustment is made, tighten screw O.

The clamping pressure should be tight enough to hold the metal in place without distorting the metal while the bend is made. You must realize that every gauge of metal has its own adjustment. Remember that the pressure should be equal on both ends of the machine. This clamping pressure can be changed by adjusting the link block, EE in right-hand view of figure 2–2. To do this job takes the following steps.

Adjusting the Link Block	
Step	**Action**
1	Loosen screw BB, which holds link adjustment blocks EE.
2	Adjust blocks EE to the thickness of metal with screw FF.
3	Lock adjustment blocks EE in position with screw BB.
4	Use a test strip to make sure the machine is adjusted correctly.

After the cornice brake has been correctly adjusted, place the metal on the bed beneath the top leaf. Partially lower the top leaf by pulling the clamping handle (fig. 2–2, A) forward. Align the scribed break line on the metal, or prick points, with the nose bar (fig. 2–2,12C) on the top leaf, and then pull the clamping handle until the metal is firmly clamped. To make the fold, pull the bending leaf handle (fig. 2–2,AA) forward and upward, which swings the bending leaf forward and upward as it pivots the bending leaf hinge pin (fig. 2–2,W1). As the bending leaf swings up, the balance weights (fig. 2–2,R) move backward, acting as counterbalance weights for easier manual operation. When the desired angle of bend is reached, lower the bending leaf by the handle or the balance weight. When the clamping pressure is released, remove the metal.

The capacities of machines like the one in figure 2–2 range from 22- to 16-gauge sheet metal, and bending lengths range from 3-to-12 feet. The bending capacity of the cornice brake is determined by the bending edge thickness of the various bending leaf bars (fig. 2–2, S, SS, U, U5, U6). Bending leaf angle bars S and SS permit a smooth 1-inch flange to be made in a piece of material that’s within the capacity of the cornice brake. Some pressure is released on the bending leaf bar identified as U, when the S or SS bar is installed.

In figure 2–2, bending leaf bar U6 is a ½-inch bar for the bending leaf. When U6 is used to make flanges, the capacity of the brake is reduced by 4 gauges. For example, if the cornice brake is rated at 16 gauge, the capacity with a ½-inch U6 bending leaf bar will be 20 gauge.

Suppose you're using the cornice brake to make small offset bends ¼-inch wide. If your brake is like model 316 in figure 2–2, the bending leaf bar identified and U should be removed. If your brake is a model other than those like model 316, the ¼ inch offset can be made by installing bending leaf bar U5. In both of these situations, the rated capacity of the cornice brake is reduced 7 gauges. For example, a cornice brake rated at 16 gauge is reduced to 24-gauge capacity. *Remember this capacity change, because the bending leaf can easily be warped if the rated capacity is exceeded.* Duplicate bends can be made with any of the models of brakes that you may have in your shop by setting the adjustable stop, Q, for the desired angle.

There are times when the material has an uneven bend radius on the cornice brake. This results in material that bends too much or bends further on one end of the brake than on the other. To correct either condition:

1. Loosen screw O (shown in right-hand end view).
2. Readjust the top leaf with screws M and P.
3. Retighten screw O.

If the bending leaf becomes bowed after repeated heavy use, tighten both bolts (10, front view) until the center is brought in line. This line should be straight and should be checked with a straight edge.

Some of the precautions to observe in operating a cornice brake include:

- Always bend short pieces of material in the center of the brake to equalize the strain on the machine.
- Always align SS angle bars with U5 and U6 bars to make narrow offset bends.
- Never bend seams unless you adjust links DD to the clamp the full multiple thickness of the seam, and set the top leaf back for clearance of the same multiple thickness.
- Never bend rod, wire, band iron, or spring-tempered sheets on the cornice brake.
- The counterbalance is very heavy and can cause serious injury to you or other personnel if released improperly. Always return the bending leaf slowly to its proper position after completing a bend.

Box-and-pan brake

The construction of the box-and-pan brake is a great deal like that of the cornice brake except that its clamping leaf is divided into removable sections called fingers or shoes. These fingers (fig. 2–3) vary in width and are interchangeable. This machine is especially designed for making boxes of various sizes and shapes, because it lets you form all sides without distorting any of the finished bends. If the need arises, you can use this brake to do most of the same type of work that can be done on the standard cornice brake. The main advantage a box-and-pan brake has over the cornice brake is that you can form pans or boxes with four sides by using different combinations or arrangements of the fingers.

Since the machine is a great deal like the cornice brake, all adjustments such as radius and thickness can be made the same way as the cornice brake. The steel fingers are secured to the upper beam by thumbscrews. Before using the brake, securely seat the fingers and tighten the thumbscrews.
To remove any of the fingers, raise the clamping bar, loosen the thumbscrews, and pull the fingers forward. To install the fingers, reverse the procedure.

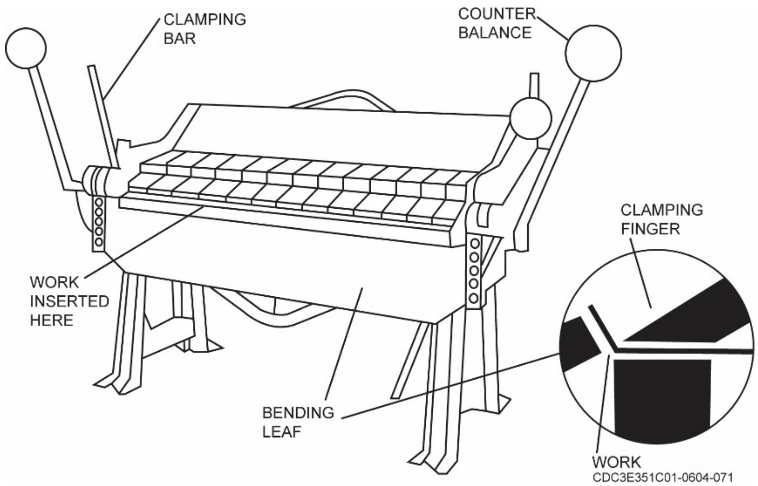


Figure 2–3. Box and pan brake.

Before starting any work on the box-and-pan brake, be sure all adjustments are made and are suitable for the gauge of metal selected. Never bend rod, wire, band iron, or spring tempered sheets on the box-and-pan brake. Operating the box-and-pan brake is similar to operating the cornice brake.

Slip roll forming machine

The slip-roll-forming machine (fig. 2–4) is used to form sheets into cylinders of various diameters. The machine is simply constructed with right- and left-end frames mounting three solid steel rollers in between—two lower rolls and one upper roll. The two lower rolls are connected by gears operated by a hand crank.

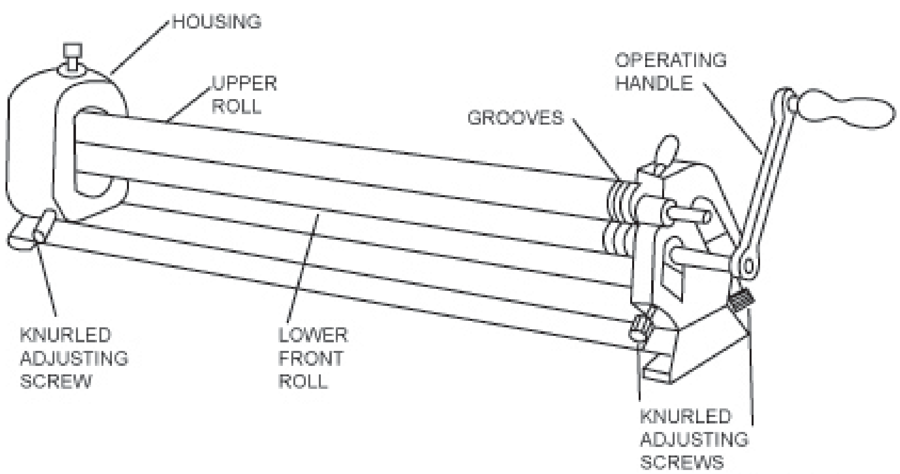


Figure 2–4. Hand-operated slip roll

Hand-operated slip roll forming machine

The lower front roll can be adjusted to the thickness of the metal by the two knurled adjusting screws, one at each end of the roll. Once the metal is started into the machine, it is gripped between the lower front roll and the upper roll and is carried to the lower rear roll, which bends it around the upper roll, thus forming a cylinder. Turning the adjusting screws at each end of the lower rear roll to the right, produces a smaller radius. Turning the screws to the left produces a larger radius.

On most hand-operated slip-roll forming machines, the upper roll can be released at one end to let you remove a formed cylinder without distortion. The rolls are grooved on the right end for forming wire and wired edges. The capacity of slip roll forming machines is determined by the manufacturer and *must not be exceeded*.

Slip roll operation isn't a set procedure, but the general process starts with adjusting the lower front roll so that it, and the upper roll, has a uniform grip on the metal. Once this adjustment has been made, the metal should ride smoothly through the rolls. For a preliminary test, it's best to select a piece of scrap material of the same gauge as the metal you plan to form. Crank the test piece through the gripping rolls until it contacts the lower rear roll. Then use the adjusting screws to set the lower rear roll for the radius. This adjustment must be the same on both ends to form cylinders (unless you want a taper). A truncated cone, or frustum, is formed when the screws have different adjustments. When the rolling is complete, release and raise the upper roll. Remove the test piece and make final adjustments. Place the material square with the rolls, and turn the crank clockwise. The cylinder that is formed should be the finished product.

Power-operated slip roll forming machine

The power-operated slip roll forming machine (fig. 2–5) is a great deal like the hand-operated slip roll machine in that it has two lower rolls and one upper roll. An electric motor supplies the turning power for the rolls, and a reversing switch controls the direction of the rolls.

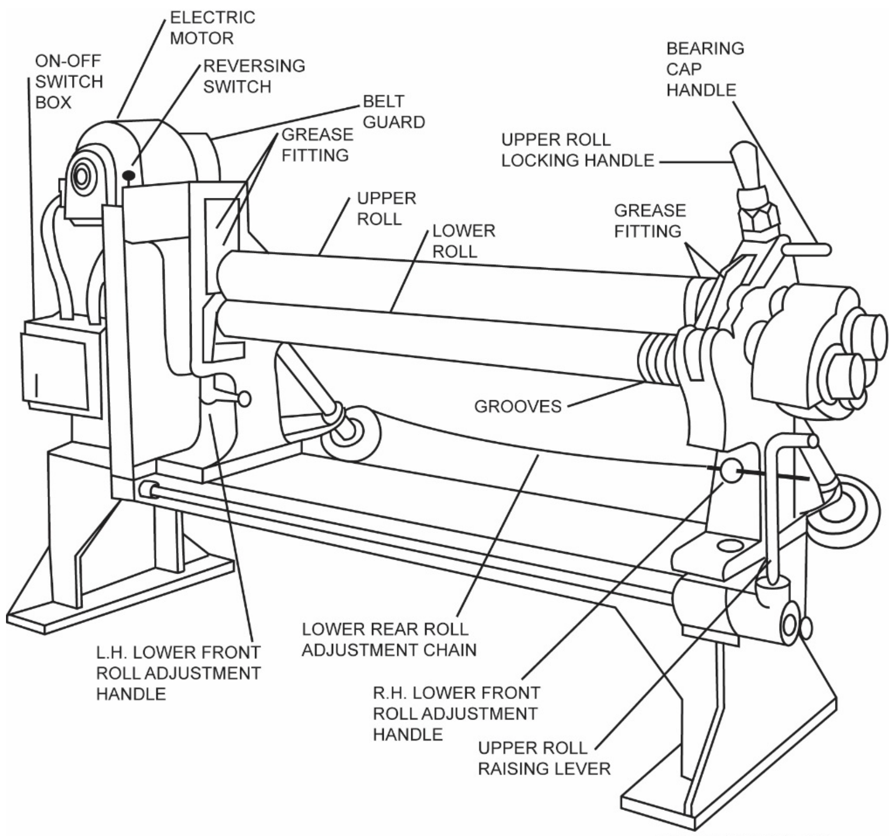


Figure 2–5. Power-operated slip roll

The power-operated slip roll machine, like the hand-operated version, has a limit to the diameter it can produce. When the machine is operating at maximum capacity, thickness and size of the sheet metal and the diameter of the cylinder formed should *not be less than two times the diameter of the upper roll*. If this recommendation isn't followed, the formed cylinder will have flat spots at the seam.

Adjust the front gripping roll's clearance by turning screw handles under the ends of the lower front roll. You adjust the lower rear roll for radius of bend by moving the endless chain (lower rear roll adjustment chain). Use the chain turn adjustment screws at each end of the machine to keep the lower rear roll parallel with the gripping rolls. After the cylinder is formed, remove it by releasing the upper roll locking handle and pressing down the raising lever at the right-hand end of the machine.

To start the electric motor, you must press the ON button of the on-off switch, and then move the reversing switch lever from the OFF position to the FORWARD position. This starts the motor and sets the rolls in motion for normal operation. When you need to reverse the direction of the rolls, move the reverse switch lever to the OFF position until the rolls stop rotating, then move the lever to the REVERSE position. When a job has been completed, stop the rolls and remove power by moving the reverse switch lever to the OFF position and by pressing the OFF button of the on-off switch.

Operating the power slip roll machine is like that of the smaller, hand-operated slip roll except that you can form heavier gauge metal. The heavier gauges must be inserted and rolled for 7 to 9 inches, then backed out, turned around, and rolled from the other end in the regular way. This prevents a flat spot along the seam.

Maintenance for both hand-operated and powerslip roll machine is similar: lubricating the moving parts, keeping the rollers clean, and keeping the machines clear at all times. When the rollers get dirty, clean them with steel wool and a dry rag; and then wipe them with an oiled rag to prevent corrosion.

You should observe safety precautions—such as keeping hands, fingers, and clothing clear of the rollers and drive gears—at all times. Like other machines, handle metal carefully to keep burrs from cutting your hands. Never apply power to the rolls until you're sure the machine is clear. If you're working on large jobs that require help, make sure that you and your assistant are both qualified operators and that you understand which part each of you will do.

Types and functions of rotary machines

Rotary machines figures 2–6 through 2–12 are designed to rotate various shapes of matched roll dies, which press sheet stock into desired shapes. Sheet metal is fed between these rolls much the same as in slip roll machines. Basically, a rotary machine consists of two shafts mounted in a frame.

The rolls are mounted on one end of the shaft, and a pair of mesh gears with a handle, or pulley, are mounted on the other. The distance between the two rolls can be adjusted by a small crank on top of the machine. Rotary machines can be operated by power or by hand, and like many others, have gauges to guide the metal. Such gauges can be set to determine the depth at which a sheet passes between the rolls. Most rotary machines have a head position adjustment and lock screw (fig. 2–6).

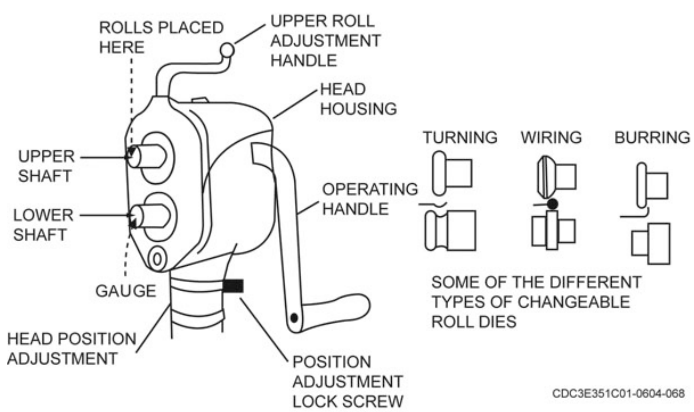


Figure 2–6. Rotary machine.

Because some rotary machines are designed for one specific operation, the operator must be known what each machine can do. This will be easy for you since, in most cases, the name of each rotary machine defines the job that it does. Typical examples are burring, turning, elbow edging, setting down, crimping, and beading machines.

The rotary machine illustrated in figure 2–6 is a combination of several rotary machines, since changing roll dies allow it do several things. This machine has a combination rotary head that will accept turning rolls, burring rolls, and wiring rolls. To change these rolls, loosen the nuts on the end of the shafts, and remove the rolls and replace them with rolls that are needed. Some of the nuts have left-hand threads, so be careful when you change the rolls.

Rotary burring machine

A burring machine (fig. 2–7) is used to turn flanges and edges on circular discs and cylinders. It's also used for turning edges on elbows and for making double seams and single hems when other machines aren't available. An important thing to remember is that it will take considerable time, effort, patience, and practice to turn out a good job.

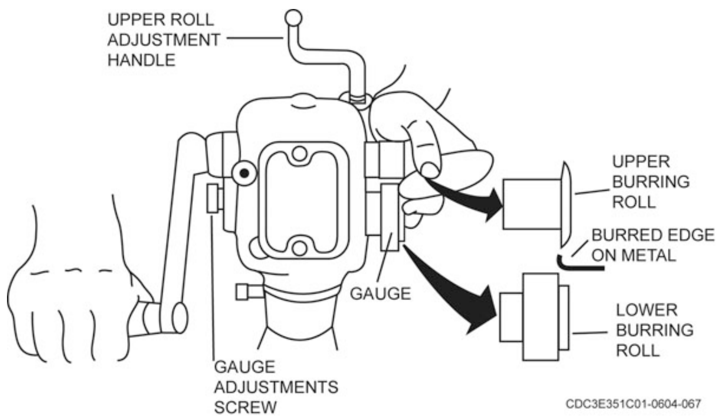


Figure 2–7. Rotary burring machine.

To operate the rotary burring machine, adjust and align it so that the side edge of the top roll protrudes over the shoulder of the bottom roll twice the thickness of the metal. The opening between the rolls should be equal to the thickness of the metal. Be sure these adjustments are correct because if the opening is too small, the top roll will act as a shear and cut the metal. The gauge adjustment screw that controls the amount of metal turned up, or flanged, is on the backside of the machine.
Flange limits are from ⅛ to ¼ inch.

To start forming, place the disc in the machine and lower the top roll with the crank screw until the machine grips the metal and creases it slightly. Turn the crank slowly clockwise while keeping the edge of the disc firmly against the gauge. Use caution to prevent injuring your hand when the disc is rotating between the thumb and forefinger. The first revolution of the rolls should be slow enough for accurate starting of the burred edges. After the first revolution of the disc, you can disregard the gauge and follow the crease as the top pressure increases. Continue turning as before. Raise the disc slightly after each revolution until the full burred edge has been formed.

Turning machine

The turning machine (fig. 2–8) is used to form rounded flanges for wired edges. The rolls of this machine may also be used to turn double seams on elbows when no elbow-edging machine is available.

The turning rolls are removable. Thin turning rolls are for light work and thick rolls for heavy work. First you center the top and bottom rolls, and then you adjust the gauge to allow ample space for the wire. With the gauge set properly, rest the cylinder to be wired on the lower roll and press the edge against the gauge. With the cylinder in place, lower the upper roll by turning the small crank screw on top of the machine until a slight depression is formed in the metal. Turn the crank handle slowly until the cylinder has passed completely through the machine. Be sure to hold the metal firmly against the gauge. After the first crease has been made, lower the upper roll and pass the metal through the machine again with the work tilted upward. Repeat this process several times to get the right groove.

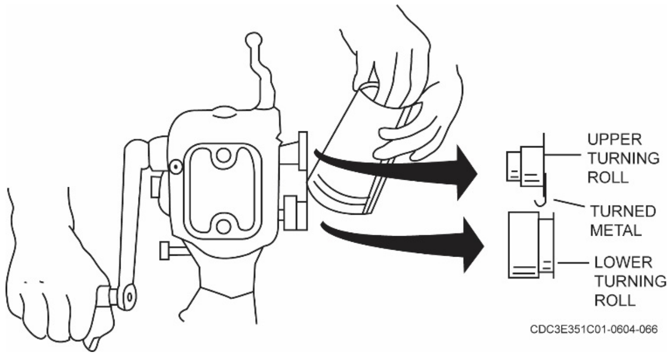


Figure 2–8. Turning machine.

Elbow edging machine

The elbow-edging machine (fig. 2–9) has elbow-edging rolls that fit most standard makes of turning and burring machines. The lower roll of the elbow-edging machine is V-grooved and has a matching upper roll. The rolls are made in three standard types to let you fabricate interlocking edges used in fastening various pieces of elbows together.

For making various types of edges, first, determine what lock seam is best suited for the job; then, screw the guide bar, or gauge, away from the rolls until the desired seam allowance has been made. If using a guide bar isn’t practical, draw or scribe a line around the outside of the elbow section ⅛ inch from the edge to be joined. Make a similar line on the machine section inside the cylinder.

Place the first piece in the elbow-edging machine so that the inside surface of the elbow rests on the lower roll. Keep the edge of the elbow snug against the guide bar, and tighten the top roll until it forms a slight crease in the metal. Turn the handle slowly as you carefully guide the piece through. After one complete revolution of the elbow, tighten the top roll slightly and repeat the process until a deep groove has been made around the edge of the elbow section. Make the second piece the same way, but place the upper roll inside the cylinder. Once the job is complete, the lock should snap together with very little, if any, difficulty. If the flanges are too loose, tighten them with a hammer and stake.

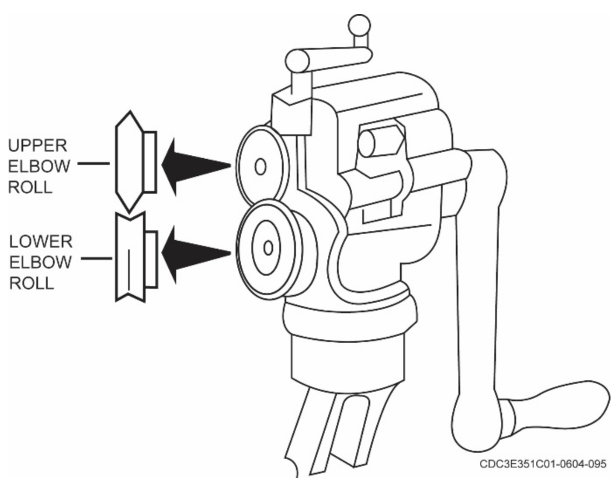


Figure 2–9. Elbow edging machine.

Setting down machine

The setting down machine (fig. 2–10) is used for tightening, or setting down, the edges before double seaming. Two styles are available—one has the upper roll perpendicular to the lower roll, and the other has both rolls sloping toward the machine. When you’re double seaming the bottom of a can or tank, hold the object in any convenient position and run it between the rolls. The crank screw on top of the machine can be adjusted to any pressure necessary to close the seam.

Machine operation consists of placing the object between the upper and lower rolls and lowering the top roll. Medium pressure is desirable for the first revolution around the bottom of the object, and should be continued until all wrinkles are removed. After this seaming down is complete, the seam must be turned up tight against the side with a mallet and stake or a double-seaming machine.

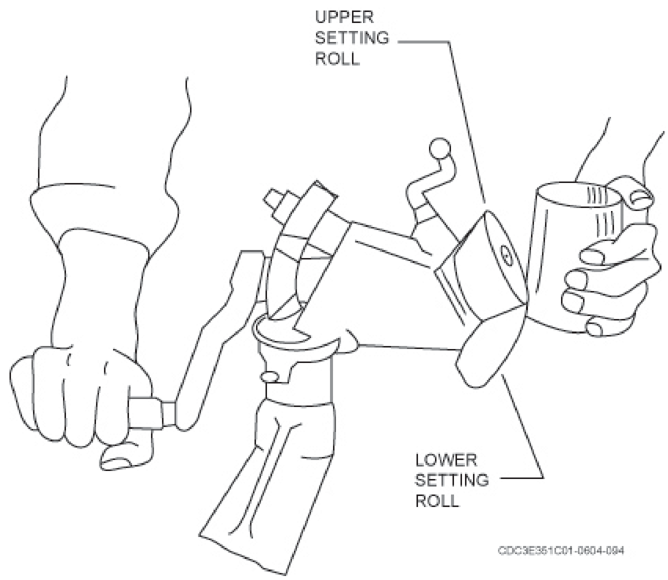


Figure 2–10. Setting down machine.

Crimping machine

The crimping machine (fig. 2–11) makes one end of a pipe joint smaller than the other so that the two sections may be slipped together. Some crimping machines have combination of beading rolls and crimping rolls. The bead serves to reinforce a formed cylinder and to keep the crimped edge from slipping too far into the other cylinder. The mechanism is like that of most rotary machines. For jobs with riveted or grooved seams, the crimp is started near one side of the seam and run around the cylinder to the other side of the seam. *Never crimp the seam itself, because its thickness will damage the rolls and spring the shafts of the machine.* When you crimp a pipe or object, insert it between the rolls, and adjust the gauge to the crimp width you want. Lower the top roll until it makes a slight depression in the cylinder as the operating handle is turned. Repeat this until you get the fit you want.

Beading machine

The beading machine (fig. 2–12) is used for making beads in sheet metal objects such as cans, buckets, and pipes. Beads act as stiffeners and serve as stops for connecting two or more lengths of metal pipe.The beading machine is easy to operate, and with practice, you can turn out high-quality work. It comes with several pairs of rolls—like burring and wiring machine rolls —that can be removed and replaced. The beading machine rolls that are generally used are single rolls, double rolls, triple rolls, and ogee rolls.

To operate the beading machine, place the cylinder between the rolls so that the top roll is on the outside of the cylinder. Place the edge of the cylinder against the adjustable guide, or gauge, and keep it there at all times or the beads won’t meet after the first revolution. The adjustable guide can be set at different locations so that one or more beads can be made at different distances from the edge. Next, lower the rolls with the crank screw until a slight depression is made in the metal. Turn the hand crank with the right hand as the work is guided with the left; as the work revolves around the rolls, an impression is completed. Don’t run the rolls over a seam because that will damage the machine and weaken the seam.

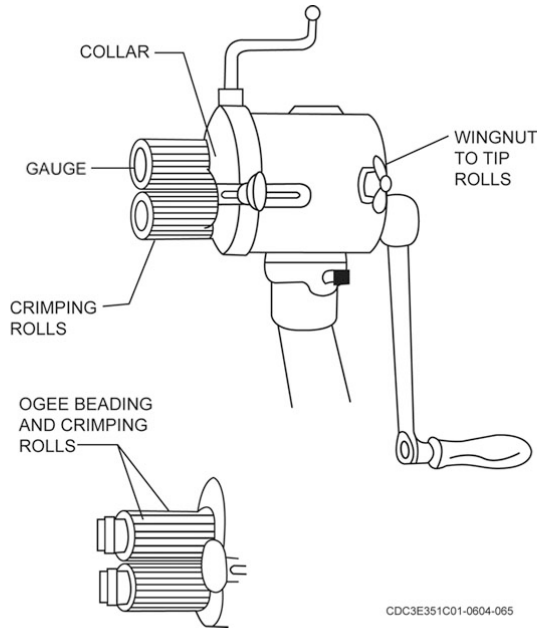


Figure 2–11. Crimping machine

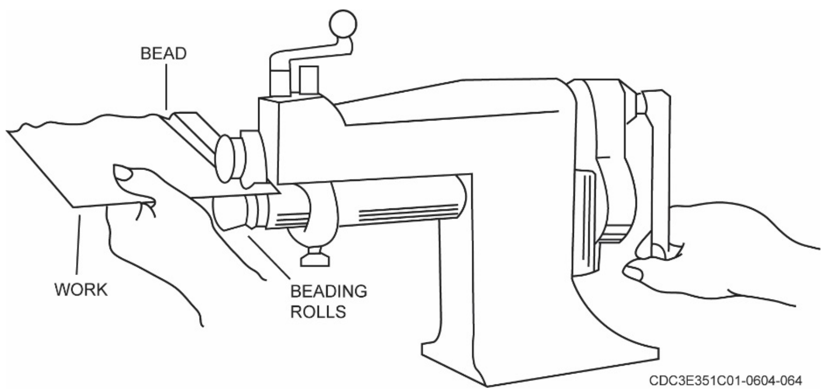


Figure 2–12. Beading machine.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

007. Folding and forming equipment

1. What item is adjusted for the different thicknesses of material?

2. What should you set to make a large number of identical folds?

3. What should you adjust to make a round fold?

4. What screws are adjusted to change the set back?

5. If the bending leaf is too low in the center, what should be adjusted?

6. What feature of a box-and-pan brake distinguishes it from a cornice brake?

7. Which roll is adjusted to produce the desired radius?

8. What controls the direction of the rolls in a power-operated slip roll?

9. Why is an endless chain used on a power slip roll forming machine?

10. When rolling a truncated cone, which direction do you turn the crank?

11. Which two rolls are geared together?

12. What rotary machine is used to turn flanges and edges on circular discs and cylinders?

13. What rotary machine is used to form round flanges for wired edges?

14. What rotary machine is used when cylinders are to be connected together by interlocking grooves?

15. What rotary machine is used to tighten edges before double seaming?

16. Which machine would you use to make one end of a pipe joint smaller than the other?

008. Sheet metal seaming and locking equipment

There are several machines and hand tools you can use to make seams and locks. We've already discussed bar folders and brakes. In this lesson, we'll discuss the Pittsburgh lock-forming machine, hand groovers, hand seamers, bench plates, and stakes for making seams and locks.

We will discuss some of the most common types of power and hand equipment used for seaming and locking. The power equipment discussed is the Pittsburgh lock and snap-lock machines. The hand seaming equipment includes bench plates, stakes, hand seamers, and hand groovers.

Pittsburgh lock-forming machine

The Pittsburgh lock-forming machine (fig. 2–13) is used to form Pittsburgh lock seams for corners of rectangular or square ducts and to form grooved seams for round ducts. Both seams are shown in the illustration. If you change the rollers, you can use the Pittsburgh machine to form other shapes of metal items.

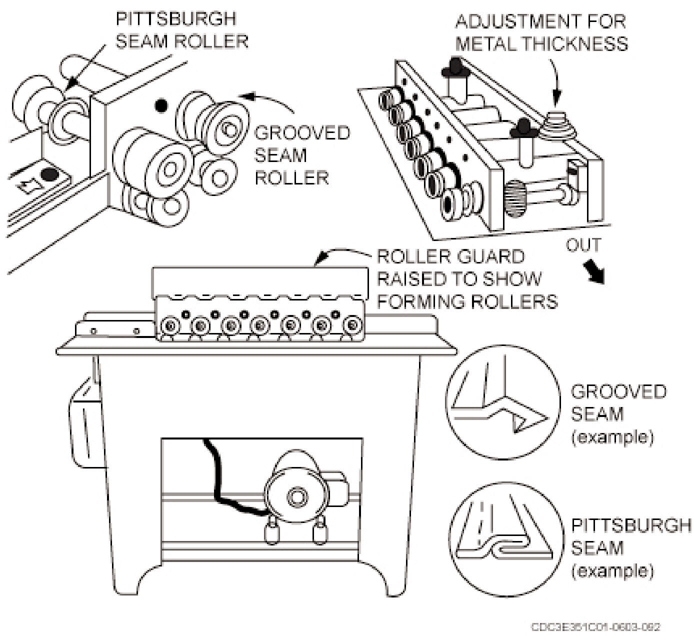


Figure 2–13. Pittsburgh lock-forming machine.

One such item is a drive slip used to connect sections of duct work. Check the manufacturer’s handbook for other forming operations and the roller used for each forming operation. The machine illustrated can form 26 to 18-gauge sheet metal by adjusting for metal thickness. Be careful to set the thickness gauge correctly to prevent damage to the rollers, *and never overload the machine*. The machine has guides to keep the material straight as it is fed into the rollers, and has a protective cover over the rollers. Although figure 2–13 shows this roller guard in the raised position in order to view the rollers, *never operate the machine with the cover open*. When the rollers are being cleaned or changed, remove electrical power from the machine to render the on-off switch inoperative.

Before using the Pittsburgh lock-forming machine, make seam allowances on the pattern and notch the material. Usually, for a Pittsburgh seam the allowance is 1 ¼ inches, 1 inch for the seam side and ¼ inch for the flanged side. The 1-inch seam is formed by the machine (Pittsburgh seam example in (fig. 2–13). The ¼-inch flanged edge is bent 90° on a brake machine, then fitted into the groove of the 1-inch seam (fig. 2–14). Then the metal that extends above the groove is flattened to hold the seam tight.

Allowance for a grooved seam (fig. 2–15) usually requires ½ inch on each side to make the seam, plus an additional ½ inch because the seam will overlap. In figure 2–15, you can see how the grooved seam is secured by flattening the two parts.

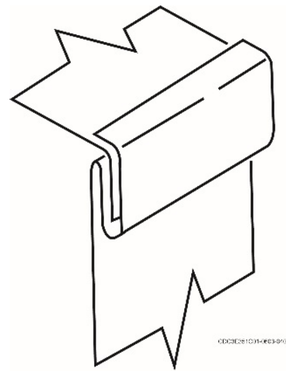


Figure 2–14. Pittsburgh seam.

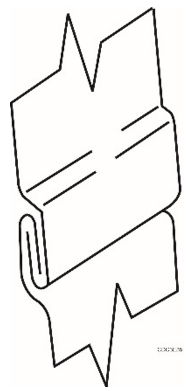


Figure 2–15. Grooved seam.

After setting the thickness gauge on the Pittsburgh lock-forming machine to correspond with the material to be formed, turn the motor on and feed the material into the rollers. Hold the material flush against the guide as it passes through the rollers. It is important to start the material straight because, once it has started through the rollers, the machine will complete the operation whether it is straight or not. Keep hands and fingers away from the rollers during the forming operation.

The Pittsburgh lock-forming machine, like other machines in the sheet metal shop, should have a maintenance record folder which lists items to be inspected and serviced, inspection intervals, and a place to record and initial the completed maintenance. The manufacturer's handbook or the technical manual will specify exactly what parts are to be serviced, including lubrication of the rollers and drive gears. If the motor doesn't have sealed bearings, it will require lubrication. Keep the rollers clean and wipe them with an oiled rag to prevent corrosion.

Snap lock machine

The snap lock is a popular seam used for duct fabrication; but to make this seam you must have a snap lock machine. The snap lock machine is like the Pittsburgh machine because it also has a series of rollers the sheet metal goes through. The machine requires the same maintenance as the Pittsburgh machine, and you should make sure all guards are in place before you use the machine.

Bench plate and stakes

Much of the work done in the sheet metal shop requires some handwork, such as shaping, seaming, and riveting. To do this work, small anvils, referred to as stakes, have been designed to perform many types of shaping and seaming that can't be done by machines. These stakes, which consist of a horn, head, and shank, are fastened either in a vise or to a bench plate. Figure 2–16 shows a bench plate with a set of stakes designed to do almost any sheet metal forming that can be done by hand.

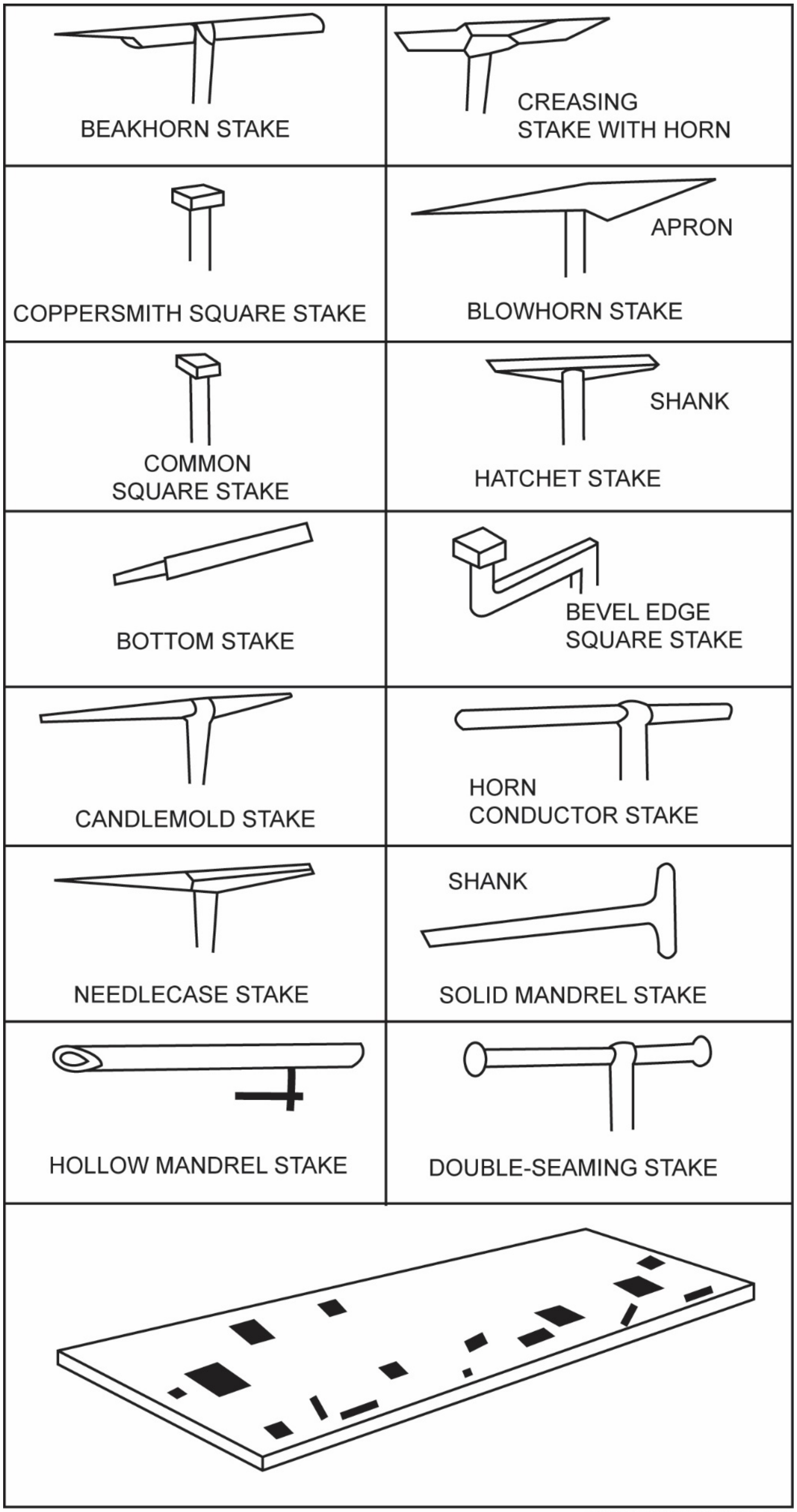
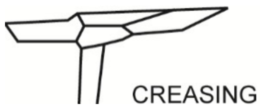
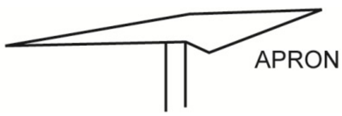
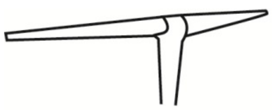
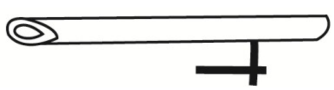
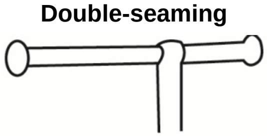


Figure 2–16. Bench plate and stakes.

There are many types of stakes (anvils) that are used in sheet metal shops. The important ones that are not used very often include: the beakhorn, common square, hatchet, conductor, coppersmith square, bottom, bevel edge square, and solid mandrel stakes. The stakes most often used are described in the following table.

Frequently Used Stakes

Type	Description
Creasing 	The creasing stake has a round, tapered horn at one end, and a rectangular shaped horn with grooves on the other. It's used for forming, riveting, or seaming small, tapered articles, for creasing metal, and for bending wire.
Blowhorn 	The blowhorn stake has a short, tapered horn, or apron, at one end and a long, tapered horn at the other. It's used in forming, riveting, or seaming tapered articles such as funnels and pitched covers.
Candlemold 	The candlemold stake has two horns of different tapers for forming, riveting, or seaming long, flaring articles.
Needlecase 	The needlecase stake is used to do very fine handwork. It has a small, tapered horn at one end, and a round beveled edge at the other.
Hollow mandrel 	The hollow mandrel stake has a slot running through its length in which a bolt slides, letting the stake be fastened to the bench at any angle or length. The rounded end is used for riveting and seaming pipes. The rectangular-shaped end is used for forming laps, riveting, and double seaming corners of pans, boxes, and similar sheet metal items.
Double-seaming 	The double-seaming stake has ball-shaped ends for double seaming.

Hand seamers

Hand seamers are used to fold light-gauge metal and to form seams or joints. Figure 2–17 shows two views of a hand seamer with screws on either side of the head. These are adjustable for different width seams. Jamnuts keep the screws from slipping, which might cause an uneven bend in folding the seams. This is also true for bends longer than the width of the hand seamer. The hand seamer is useful in turning edges for seams on small jobs and when the brake or bar folder isn't available.

Hand groovers

The hand groover (fig. 2–18) is used to groove seams after they've been formed. It's useful for small jobs or when a Pittsburgh machine isn't available. Hand groovers in several sizes are issued with your toolkit. The hand groover may be used to form a grooved seam (fig. 2–19). The two edges are turned back 160° with a bar folder, brake, or hand seamer. The two turned-back edges are hooked together and placed over a backing surface; then the hand groover is placed over the lapped edges and struck with a hammer to set down the edges of the seam (fig. 2–19).

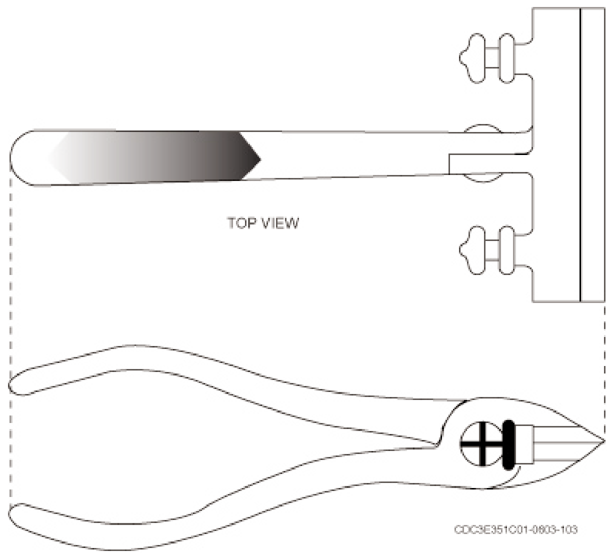


Figure 2–17. Hand seamer.

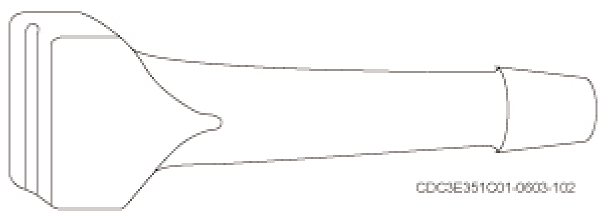


Figure 2–18. Hand groover.

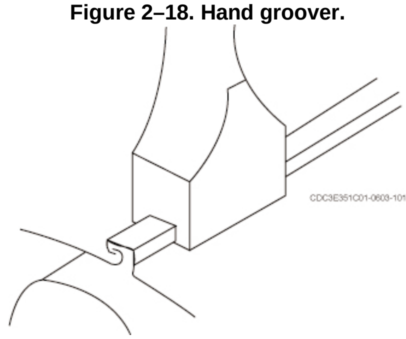


Figure 2–19. Locking a grooved seam with a hand groover

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

008. Seaming and locking equipment

1. What are the products of the Pittsburgh lock-forming machine?

2. What must you do to produce a drive slip on a Pittsburgh lock-forming machine?

3. What allowances must be marked on the material before using the Pittsburgh lock-forming machine?

4. How is the hollow mandrel stake secured to the bench plate?

5. Which stake should you use to install solid rivets in a pitched stack cover?

6. How is the candlemold stake used to form and rivet?

7. What must you adjust to maintain an even seam width with a hand seamer?

8. What tool is used with a hand groover?

Answers to Self-Test Questions

007

1. Wing pressure screws.
2. Adjustable collar stop.
3. Wedge.
4. Adjusting screws P and O.
5. Bending leaf adjusting bolt.
6. Removable, interchangeable fingers.
7. Lower rear roll.
8. Reversing switch.
9. To keep the rear roll parallel with the upper roll.
10. Clockwise.
11. The two lower rolls.
12. Burring machine.
13. Turning machine.
14. Elbow edging machine.
15. Setting down machine.
16. Crimping machine.

008

1. Grooved seams on round ducts and lock seams for corners of rectangular ducts.
2. Change rollers.
3. Seam allowances.
4. With a bolt.
5. Blowhorn.

6. With two horns of differing tapers.
7. Screws with locknuts.
8. Hammer.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

19. (007) What do you set on the bar folder to make many bends of 60°?
    a. Collar stop.
    b. Gage screw.
    c. Wedge knob.
    d. Wing pressure screws.

20. (007) Which *rotary machine* is used to *turn flanges and edges* on circular discs and cylinders?
    a. Burring.
    b. Turning.
    c. Crimping.
    d. Setting down.

21. (007) Which *rotary machine* is used to make one end of a pipe smaller than the other end?
    a. Burring.
    b. Turning.
    c. Crimping.
    d. Setting down.

22. (008) The *normal total allowance* for the seam and flange side of a Pittsburgh seam is
    a. 1 inch.
    b. 1⅛ inch.
    c. 1¼ inch.
    d. 1⅜ inch.

23. (008) What stake is used for forming, riveting, or seaming small, tapered articles and for bending wire?
    a. Creasing.
    b. Candlemold.
    c. Needlecase.
    d. Hollow mandrel.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Seams and Joint Connections

IN THIS UNIT, we will discuss several seam types that are used to assemble sheet metal components. Some of these have been mentioned earlier in this career development course (CDC), so you should already know a seam's basic purpose and are now ready to learn how to make seams and joint connections.

We'll discuss lap seams (e.g., flat lap, offset lap, and corner lap), lock seams (e.g., grooved, double, Pittsburgh, and dovetail), and joint connectors (e.g., S-slips, drive slips, and tapped connections). We will also explain how to include allowances for these seams and joint connections as well as how to notch, form, and assemble them.

Although there are other seam types and joint connections, we've restricted our discussion to the ones you are most likely to encounter on the job. Your knowledge of seams and joint connections will be valuable when you fabricate, install, and repair ducts and other sheet metal components.

009. Lap and lock seams

In this lesson, we'll discuss seams, seam allowances, and seam formations. This information is vital for your job progression.

Lap seam types and designs

A lap seam, as its name implies, is a seam in which one piece of metal partially extends or laps over another. You'll fasten these seams together with rivets, spot welds, bolts, or screws, and may seal them with solder, tape, caulk, or sealing compound.There are three general types: Flat lap seam, offset lap seam, and corner lap seam.

You must allow extra metal in a pattern for the seam—the amount depends on the thickness of the metal and the fastening method. You've already learned how to add seam allowances to patterns and how to space rivets for lap seams. You've also learned how to use handtools and folding and forming machines. Now you'll apply this information to form a seam. While reading the following discussion you will be referred to figure 3–1 where the corresponding seams are referenced by letter and number for example, the flat lap seam, (fig. 3–1, A-1).

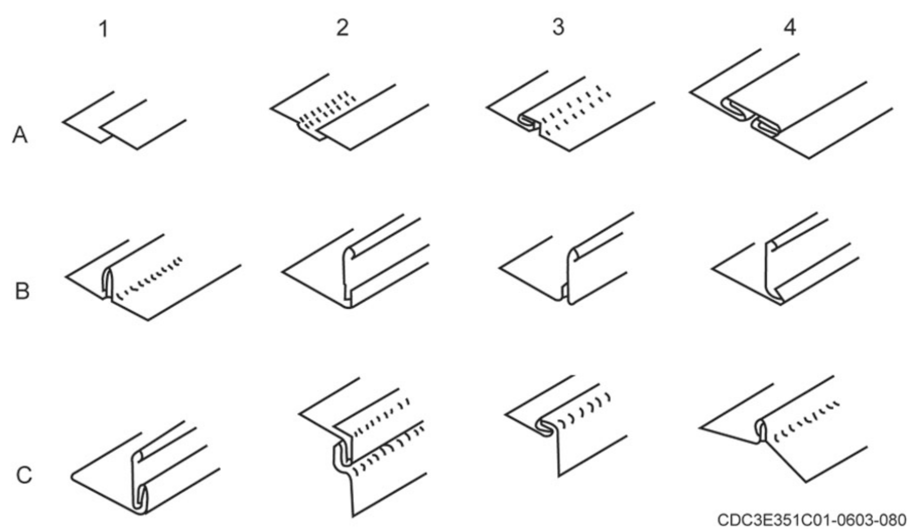


Figure 3–1. Sheet metal seams.

Flat lap seam

You make the flat lap seam (fig. 3–1, A–1) by simply lapping one edge of sheet metal over another edge. You can usually determine the allowance for the lap seam by knowing the thickness of the two sheets and the fastening method needed.

For example, light-gauge sheet metal (e.g., 26 gauge) that is to have a riveted flat lap seam should have a ¼-inch lap. This means that you should make the centerlines for the rivet holes ¼ inch from each edge. The total amount of material allowed for a ¼-inch flat lap seam is ½ inch. In this case, the tinner's rivets should be the 1-pound size and spaced a *maximum* of 2 ½ inches apart, unless otherwise specified by the working drawing.

For medium-gauge sheet metal (e.g., 22 gauge), the flat lap seam should have a ⅜-inch lap and the 2-pound tinner's rivets should be spaced a *maximum* of 2 ¼ inches apart.

When heavy-gauge metal (e.g., 16 gauge) is used, the flat lap seam requires a ½-inch lap and the 4-pound tinner's rivets should be spaced a *maximum* of 3 ½ inches apart.

Offset lap seam

The offset lap seam (fig. 3–1, A–2) is very similar to the flat lap seam, except that one edge is offset so that the surface of one sheet will be flush with the other. Use an offset lap seam where the lap needs to appear as neat as possible. You determine offset lap seam allowances in the same way you do for flat lap seam allowances.

Use the cornice brake to form offset bends (fig. 3–2). In view A, the bending leaf is pulled forward to make a 30° to 35° bend. In view B, a spacer—the same thickness as the desired amount of offset—is placed on the bending leaf and the sheet metal is turned over. In view C, the offset is completed when the top leaf is lowered.

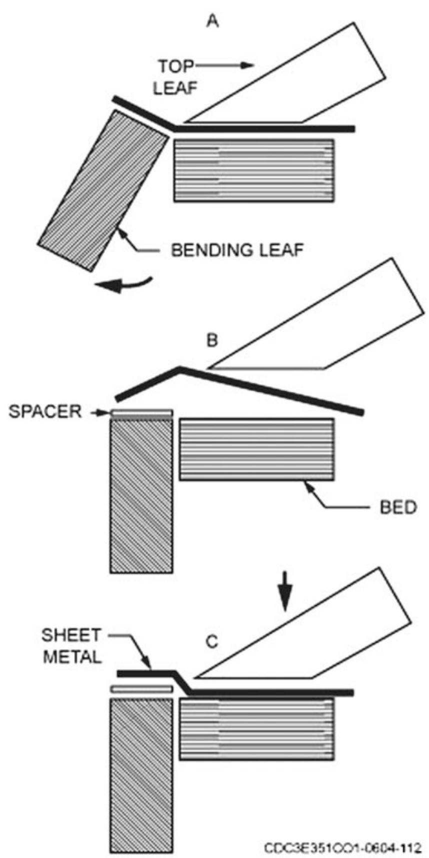


Figure 3–2. Making an offset bend with the cornice brake.

Inside and outside corner lap seams

Inside corner lap seams and outside corner lap seams illustrated in (fig. 3–1, B–2 and B–3) are used on any gauge of metal, especially on heavier gauges of sheet metal. You determine the seam allowances for inside and outside corner lap seams like that for flat lap seams except that you *make the allowance for one edge only*. For example, the seam allowance for 26-gauge metal is ½ inch on the folded side. In this case, the centerline for the rivet holes is ¼ inch from both edges. Use the inside and outside corner lap seams on boxes and pans and other items with square corners.

Seam allowances for lap seams

We've described how various types of lap seams are made and how the seam allowances is determined. The table in figure 3–3 summarizes seam allowance information for your use. It can be used as a handy, quick reference while training as well as when you're on the job.

Type of Seam	Gauge of Metal and Decimal Equivalent	Lap Allowance (Width = W)	Size of Tinner's Rivets	Material Required		
				Formula	Side 1 or Piece 1	Side 2 or Piece 2
Flat Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Offset Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Corner Lap	26 (0.018")	1/4"	1 lb	2 X W	—	1/2"
	24 (0.025")	3/8"	2 lb	2 X W	—	3/4"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	—	3/4"
	20 (0.037")	3/8"	3 lb	2 X W	—	3/4"
	13 (0.062")	1/2"	4 lb	2 X W	—	1"

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Figure 3–3. Seam allowance for lap seams.

Lock seam features and uses

When fabricating sheet metal components, you'll routinely determine how to connect two pieces of sheet metal together. However, the *easiest way is not always the best way*. Factors to consider when choosing the best fastening methods include these questions:

- How big is the item?
- How much does it weigh?
- What load must it hold?
- Is it to be watertight?

Several types of lock seams can be used for connecting two pieces of metal together without rivets, spot welds, bolts, or screws. You'll use lock seams in many places, such as metal roofs, cylinders, cylinder bottoms, and as stiffeners on ducts. In creating a lock seam, you form two pieces of metal in a series of bends, and then interlock them so they cannot come apart. They are designed to hold themselves in place. Many lock seams, such as those on roofs, are waterproof. In the following paragraphs we'll discuss these lock seams:

- Standing seam.
- Grooved seam.
- Double lock seam.
- Pittsburgh lock.
- Snap lock.
- Dovetail.

Standing seam features and uses

When fabricating sheet metal components you can use standing seams in several different ways. Figure 3–1, B–1and C–4 show how the two parts are assembled. In figure 3-1, B–1 shows the seam on a flat surface, and C–4 shows it on an angle (e.g., roof ridge). Although it is primarily used to join two pieces of sheet metal, the standing seam also acts as a stiffener because the metal is folded three times. For this reason standing seams are sometimes used as stiffeners across the top and bottom of large ducts, for connecting joints of rectangular ducts, in installing covers over the ends of ducts, and connecting the corners of exhaust hoods.

Determining seam allowances

The seam allowance for a standing seam is determined by the seam size and the sheet metal thickness. An easy way to remember this is by using the formula shown below.

$$3H + 2T$$

Where:

H is the *height of the seam*.

T is the *thickness of the sheet metal*.

Let's say that you need to make a 1-inch high standing seam out of 16-gauge (0.062-inch) sheet metal. As the formula indicates, the seam allowance must be 3 times the height of the seam, or 3 inches, plus twice the metal thickness. To determine the seam allowance, substitute the measurements in the formula as follows:

$$\begin{aligned}\text{Seam Allowance} &= 3H + 2T \\ &= (3 \times 1 \text{ inch}) + (2 \times 0.062 \text{ inch}) \\ &= 3 \text{ inches} + 0.124 \text{ inch} \\ &= 3.124 \text{ inches}\end{aligned}$$

Remember, *this is the total allowance and includes both sides of the seam*. Converting the decimal 3.124 inch measurement to a fraction equals approximately 3 ⅛ inches—the total allowance for the standing seam in this example. Piece 1 of the seam has 1 inch allowed for the 90° flange, and piece 2 has 2 ⅛ inches allowed for the standing pocket fold. As you can see from the example, more of the allowance is added to one of the seams than the other. When fabricated, the standing seam should have flush surfaces. When joining two sections of duct with a standing seam, bend the piece with the 1-inch flange *out* 90°; the piece with the standing seam pocket gets two bends, one *out* 90°, and one *in* 180°.

NOTE: If the *seam is to be on the inside*, such as when insulating the inside of the duct, then the *direction of the bends is to the inside*.

We’ve described how allowances are determined and how standing seams are fabricated. Now we’ll examine how you can use a standing seam to connect two duct joints.

Connecting two duct joints

A popular way to connect two metal duct joints is to use the cornice brake to make a standing seam. The steps taken to make a 1-inch standing seam are explained in the table below.

Making a 1-inch Standing Seam	
Step	**Action**
1	Bend duct piece 1 up 90° at a brake line, 1- inch from the edge.
2	Bend duct piece 2 up 90° at the brake line, 2 ⅛ inches from the edge.
3	Reposition (turn over) piece 2, and place 1- inch of the previously bent portion in the cornice brake.
4	Make a bend 1-inch from the edge; this bend is to be 160°. Remove the material from the cornice brake, and flatten the bend to 180°.
5	Leave the pocket open just enough to insert the flange of piece 1.

The standing seam makes a tight joint connection but is open at the corners. You may strengthen these corners by using corner clips. You can also use the standing seam across the center of long duct joints, when you use two pieces of metal to make the top or bottom sides. Used this way, the standing seam gives additional bracing and allows the use of smaller pieces. The standing seam, the four Pittsburgh corner seams, and the cross bracing combine to make a very strong duct.

Forming grooved seams

Take a look at a grooved seam in figure 3–1, A–3. Note how it resembles a standing seam that has been bent over and then shaped with a hand groover. One of the main uses of grooved seams in duct construction is joining the edges of round duct joints. Grooved seams are also used for joining metal roofing sheets and for seams not located on the corners of rectangular ducts. In the following paragraphs, we’ll describe how grooved seam allowances are determined, and how the seam can be made with a Pittsburgh lock-forming machine or with a bar folder and handtools.

Figuring seam allowances

The metal allowance for a grooved seam made with a Pittsburgh lock-forming machine is the same as the allowance for a grooved seam made with a bar folder and handtools. Like other seams, you must allow for the seam width and metal thickness. The allowance for a grooved seam is three times the width of the seam (3W) plus the total metal thickness. Sheet metal that is 24 gauge or lighter, requires an allowance of three times its thickness (3T), and sheet metal that is 22 gauge or heavier, requires an allowance of five times its thickness (5T). Therefore, you have two formulas to remember for grooved seam allowance:

Grooved Seam Allowance Formulas	
Formula	**Used For**
3W + 3T	Light gauges, 24 gauge or lighter.
3W + 5T	Heavy gauges, 22 gauge or heavier.

NOTE: This is the total allowance and includes both sides of the seam.

Example: Making the allowance for a ¼-inch grooved seam in 26-gauge sheet metal. First select the appropriate formula for the metal gauge and then substitute your measurements as follows.

$$
\begin{aligned}
\text{Seam Allowance} &= 3W + 3T \\
&= (3 \times \tfrac{1}{4}) + (3 \times 0.018) \\
&= \tfrac{3}{4} + 0.054 \\
&= \tfrac{3}{4} + {}^{1}/_{16} \\
&= {}^{12}/_{16} + {}^{1}/_{16} \\
&= {}^{13}/_{16} \text{ inches}
\end{aligned}
$$

Making a grooved seam with a bar folder

Now that you know how to calculate seam allowances, let's use that and see how to make a grooved seam on a bar folder. (A cornice brake can also be used). To make a ¼-inch grooved seam follow the steps in the table below.

Making a ¼-inch Grooved Seam	
Step	**Action**
1	Set the depth gauge of the bar folder for ¼ - inch.
2	Place the edge of the metal into the bar folder, and pull the wing forward and up to the position shown in figure 3–4, A.
3	After you return the wing to the down position, take the metal out of the folder and turn it over.
4	Pull the wing forward until the folded metal is flattened at 180°, as shown in figure 3–4, B.
5	You use this same procedure for the other half of the seam.

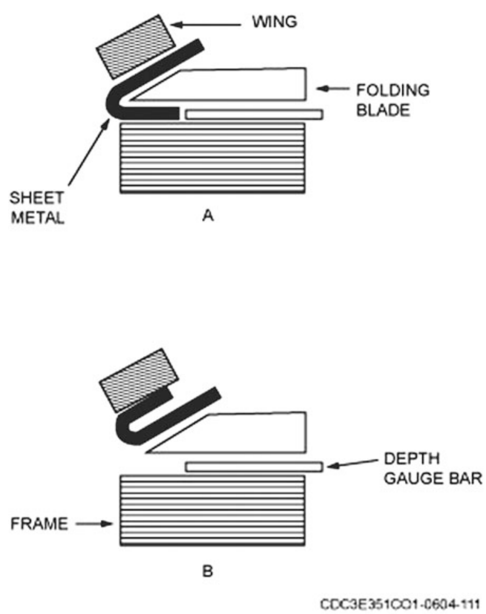


Figure 3–4. Making folded edges with a bar folder.

If you make a grooved seam on round duct or pipe, make the two 180° folds on opposite ends of the same piece of metal, but bend them up at one end and down at the other.

Now look at figure 3–5.

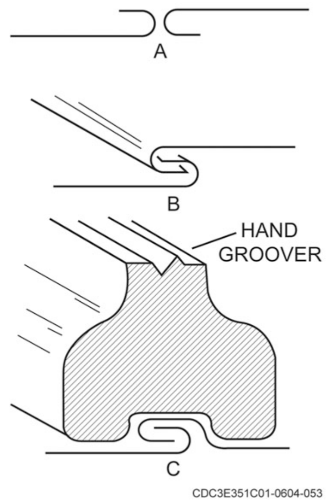


Figure 3–5. Making a grooved seam with handtools.

When grooving the seam, use a suitable backing plate or bench stake. The component shape determines whether a flat plate or a bench stake is used as a backing surface. You must set the groove seam well to prevent slipping. Sometimes it is desirable to make a series of indentations along the seam with a center punch as a further precaution against slipping.

Grooved Seam Construction in Figure 3-5	
View	**Explanation**
A	The two 180° folds that were made on the bar folder.
B	The two folded edges have been hooked together but have not been locked with a hand groover.
C	A hand groover is placed over the seam and struck with a hammer to form the groove and lock the seam together.

Making a grooved seam with a Pittsburgh lock-forming machine

Making a grooved seam with a Pittsburgh lock-forming machine is much easier, and faster than the multi-step hand method. Depending on the make and model of the machine, a Pittsburgh lock-forming machine makes $^{5}/_{16}$-, ⅜ -, or ½-inch grooved seams. Follow these steps when making a grooved seam with a Pittsburgh lock-forming machine.

Making a Grooved Seam with Pittsburgh Lock-Forming Machine	
Step	**Action**
1	Check the allowance for the grooved seam and adjust the thickness gauge on the Pittsburgh lock-forming machine to correspond to the thickness of the sheet metal. • If you set the gauge too loose, the result is a loose seam. • If you set the gauge too tight, the metal may break at the bends. If the adjustment is too tight, you can damage the machine.
2	Turn the machine on.
3	Feed the metal into the rollers and make sure that you hold the metal flush against the guide as it passes through the forming rollers. It is important to keep the metal straight as it starts through the rollers because the machine will complete the operation whether it is straight or not.

Making a Grooved Seam with Pittsburgh Lock-Forming Machine	
Step	**Action**
4	After you run the two pieces through the machine, place them together (fig. 3–6).
5	Set (tighten) the assembled seam with a mallet or hammer and a suitable backing plate or bench stake.

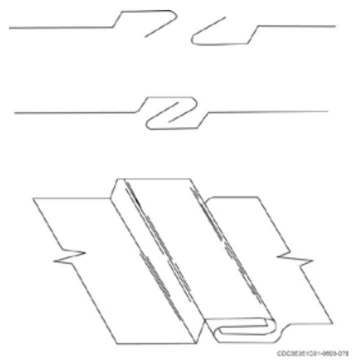


Figure 3–6. Grooved seam made with a Pittsburgh lock-forming machine.

Although a grooved seam made on a Pittsburgh machine is tighter than the handmade seam, you should center punch the seam in several places to prevent slippage.

Forming double lock seams

You will be expected to make two types of double seams:

- The corner double seam (fig. 3–1, C–1 and C–3) that is used to seam the square corners in square and rectangular ducts, pans, boxes, and so forth.
- The bottom double seam that is used to fasten bottoms on cylinders.

Notice that double seams (figs. 3–6, 3–7, and 3–8) are somewhat like grooved seams except that they're located on the corners and edges of components.

Seam allowances for double seam

The seam allowance for a corner or bottom double seam is three times the seam width plus twice the metal thickness (**3W + 2T**). This allowance is slightly less than the allowance for a grooved seam because the *double seam is not offset*. A ¼-inch double seam is often used with 28-to 24-gauge sheet metal, and a ⅜-inch double seam is used with 22-to 18-gauge sheet metal.

Corner double seam

A corner double seam is used to seam square and rectangular ducts. You can partially make a corner double seam on a bar folder or cornice brake, depending on the length of the component. For example, suppose you must make a ¼-inch double seam on a 24-gauge square duct. You must form the two seam parts (fig. 3–7, A and B) before you can form the duct into a square shape. The steps you follow are described in the table below.

Making a Corner Double Seam	
Step	**Action**
1	If the duct joints are 20 inches or less in length, make the bends for the double seam on a bar folder by setting the depth gauge bar for ¼ - inch, bending one edge 90° and bending the opposite edge 180° (fig. 3–7, A and B). Make these bends first because they're difficult to make after the joint is formed into a square.

Making a Corner Double Seam	
Step	**Action**
2	To form the joint into a square, use the cornice brake to bend the metal 90° along each of the three element (brake) lines.
3	After you've made these bends, join the edges (fig. 3–7, C).
4	The next step is to set down the seam (fig. 3–7, D). You can do the setting-down operation with a setting hammer. When using a setting hammer, you must have a backing plate or suitable bench stake.
5	You can see the corner double seam begins to take shape (fig 3–7, E). Bend the seam over with a mallet on the square end of a solid mandrel bench stake.
6	When completely set down, the corner double seam will be like the one shown in figure 3–7, F.
7	Like other lock seams, indentations made with a center punch will keep the seam from slipping.

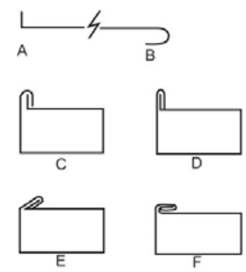


Figure 3–7. Making a corner double seam for components with square corners.

Bottom double seam

Use a bottom double seam (fig. 3–8) to fasten a bottom or end on a cylinder. The illustration shows cutaway views so that you can see the seam shape as it is made. As we've already mentioned, the seam allowance for a bottom double seam is three times the seam width plus twice the metal thickness.

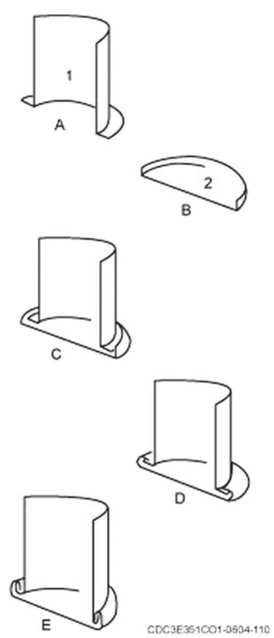


Figure 3–8. Making a bottom double seam for cylindrical shaped components.

Now let's see how we can make the ¼-inch bottom double seam shown in figure 3–8.

Making a ¼-inch Bottom Double Seam	
Step	**Action**
1	Identify the cylinder as piece 1 (fig. 3–8, A) and the bottom as piece 2 (fig. 3–8, B). These two pieces are the starting parts for the seam.
2	Using the formula **3W + 2T**, the seam allowance is ¼ - inch for piece 1, and ½ + either $^{1}/_{16}$, or $^{9}/_{16}$ - inch for piece 2.
3	Use a burring machine to turn ¼-inch 90° flanges on both pieces.
4	Place the bottom on the cylinder (fig. 3–8, C).
5	Turn down the flanged edge of piece 2 (fig. 3–8, D) with a tinner's setting hammer or mallet. You can further tighten this edge with a setting-down machine.
6	To complete the seam (fig. 3–8, E) use a mallet and double seaming stake.

The bottom seam is now complete, unless you must make it liquid tight by soldering.

Forming Pittsburgh lock and snap lock seams

In the following paragraphs you will learn how to form the Pittsburgh lock using the cornice brake and the Pittsburgh lock machine. We will also discuss how to form snap lock seams.

Pittsburgh lock seam

The Pittsburgh lock seam (fig. 3–1, C–2) is most often used along one edge or corner of a rectangular duct and on all four sides of fittings such as transitions and elbows. The Pittsburgh lock seam is made in two parts. You can form the flanged edge usually on a cornice brake, or on a bar folder, if the edge is straight. However, if a radius-shaped offset or elbow is to be joined with a Pittsburgh lock seam, the flanged edge is turned on a rotary burring machine, or by hand with a round bench stake and mallet. Make the pocket side of the seam on a Pittsburgh lock-forming machine or a cornice brake. To join the seam, insert the flanged edge into the pocket and bend the locking edge, which extends above the pocket, 90° until it is locked and looks like figure 3–1, C–2.

Seam allowances for Pittsburgh lock seams

The allowance for a Pittsburgh lock seam made with a cornice brake is different from the allowance for a seam made with a Pittsburgh machine. Pittsburgh lock seams made with a Pittsburgh machine usually require an allowance of $^{15}/_{16}$ inch, 1- inch, or $1^{1}/_{16}$ - inches (depending on the make and model of the machine) for the pocket side of the seam. The flanged edge is usually ¼-inch, though some sheet metal workers prefer a $^{5}/_{16}$-inch flange. The allowance for a ½-inch Pittsburgh lock seam made on a cornice brake is 1¼ inches for the pocket side and ¼- inch for the flanged side.

Making a Pittsburgh lock seam with a cornice brake

To make a Pittsburgh lock seam with a cornice brake, follow the steps in the table below.

Making a Pittsburgh Lock Seam with a Cornice Brake	
Step	**Action**
1	Check the seam allowance for both sides.
2	Form the flange by sliding the metal into the brake until the ¼-inch allowance is even with the outside edge of the clamping leaf, clamp it, and bend it 90°.
3	Form the pocket side of the Pittsburgh seam by marking the metal at ¼ inch.

Making a Pittsburgh Lock Seam with a Cornice Brake	
Step	**Action**
4	Slide the metal into the brake, and line the ¼-inch mark up even with the outside edge of the bending leaf (fig. 3–9, A). Note that ¾ inch will be extending out from the clamping leaf.
5	Bend the pocket to 90° (fig. 3–9, B).
6	Remove the metal from the brake and turn it over to make the next bend in the opposite direction.
7	Slide the metal into the brake until the ¾-inch flange you bent previously touches the bending leaf (fig. 3–9, C).
8	Clamp the metal and bend it as far as the brake will allow (fig. 3–9, D).
9	Before removing your metal, use a mallet to flatten the flange down against the clamping leaf (fig. 3–9, E).
10	Open the brake and slide the pocket under the clamping leaf and flatten it (fig. 3–9, F).
11	To offset the pocket, turn the metal over in the brake with the open side of the pocket up.
12	Slide it into the brake until the fold of the pocket contacts the bed of the brake.
13	Clamp the brake, causing the pocket to rise up (fig. 3–9, G), then flatten it down against the bending leaf with a mallet (fig. 3–9, H).

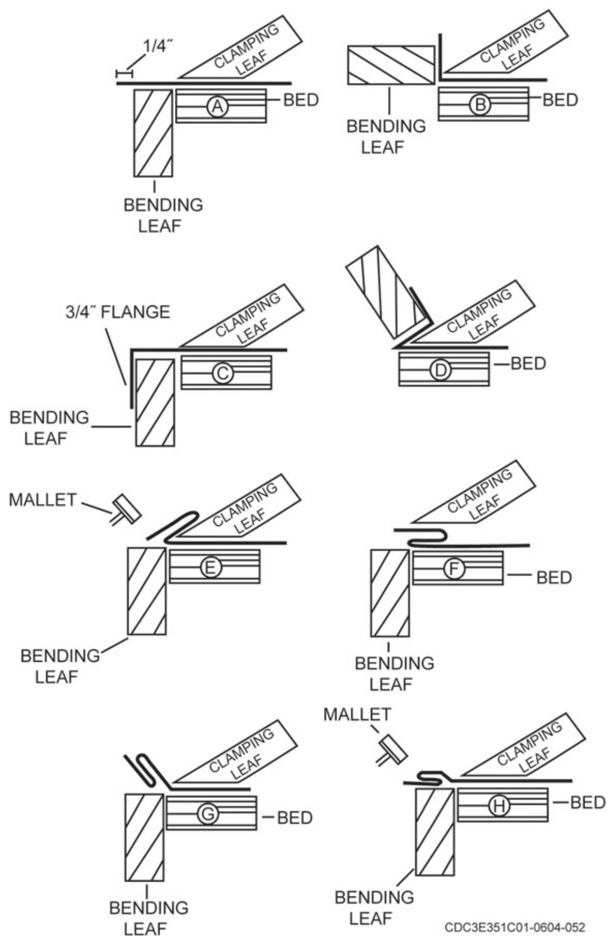


Figure 3–9. Forming a Pittsburgh pocket with a cornice brake.

You should use a mallet when working sheet metal in the brake to keep from damaging the machine surfaces.

Making a Pittsburgh lock seam with a Pittsburgh lock-forming machine

To use a Pittsburgh lock-forming machine to make a Pittsburgh lock seam, set the metal thickness gauge according to the thickness of the metal being formed. If you set the gauge too loose, a loose seam will be made. If you set it too tight, the metal may break at the bends. Also, if the adjustment is too tight, you may damage the machine.

After setting the thickness gauge, turn the motor on and hold the sheet metal flush against the guide as you feed it into the rollers. Be sure to start the material straight, because the machine will form the seam incorrectly if the metal is not started and held straight while it is formed. As this sheet comes out of the Pittsburgh lock-forming machine, the open side of the pocket will be facing up.

Assembling Pittsburgh lock seams

After you form the Pittsburgh seam, you must assemble it. Assemble the seam (lock together) by setting the flange in the pocket, and hammering over the lock edge of the pocket. When setting the flange, use a setting hammer and rivet set to drive the flange solidly into the pocket (fig. 3–10, A). Then use the setting hammer to turn the lock edge down against the top of the duct (fig. 3–10, B).

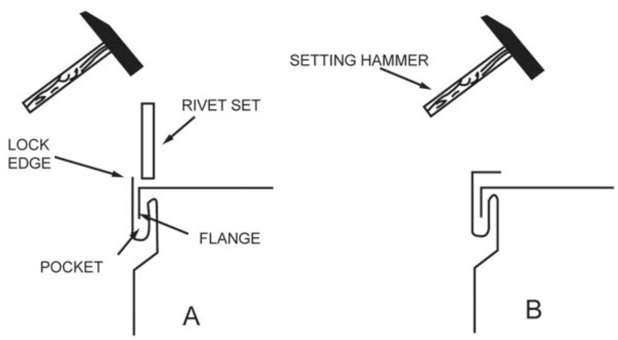


Figure 3–10. Assembling a Pittsburgh lock seam.

Snap lock seam

The snap lock is a popular seam used for duct fabrication; however, to make the seam you must have a snap lock machine. The snap lock machine is similar to the Pittsburgh machine because it also uses a series of rollers to form the sheet metal.

The snap lock seam is a two-part seam (fig. 3–11). The pocket part of the seam is similar to the Pittsburgh pocket, but the edge of the sheet metal is folded inside the pocket, forming a hook. As you form the flange, the machine button-punches it—a process that raises small hooks on the flange. When you assemble the seam, the flange is inserted into the pocket. The hook formed by the edge of the sheet metal inside the pocket and the button-punched hooks on the flange lock together securing the seam. It can normally be assembled quickly, without using tools, by simply pressing the flange into the pocket until it locks.

Figure 3–11. Snap lock seam.

Making dovetail seams

A dovetail seam (fig. 3–12) is often used to connect cylinder-shaped ducts or pipes to flat surfaces (e.g., the base of a roof jack). Figure 3–12, Ashows how ½-inch square tabs have been cut, and every other one is bent down 90° with a tinner's hammer and bench stake. You can also perform this bending operation with a pair of common pliers or vise grips. Cut a hole the size of the cylinder in the flat piece of metal that you'll use as the base. The base is then placed over the cylinder (fig. 3–12, B). The remaining tabs are bent 90°. As you turn down this row of tabs, the blows from the hammer tighten both rows of tabs against the flat base.

Determining seam allowances for a dovetail seam is simple. The flat base does not need an allowance because the hole size is the same as the cylinder that will fit over it. The allowance for the ½-inch dovetail seam for the cylinder is the length of the tabs—normally ½ inch in height. After cutting, each tab should be ½-inch high and ½-inch wide.

If you use a dovetail seam to fasten the base of a roof jack, the best method to make the seam watertight is to solder the seam (tabs) in place. However, the dovetail seam is usually strong enough to hold the base securely without rivets, screws, soldering, or spot welding.

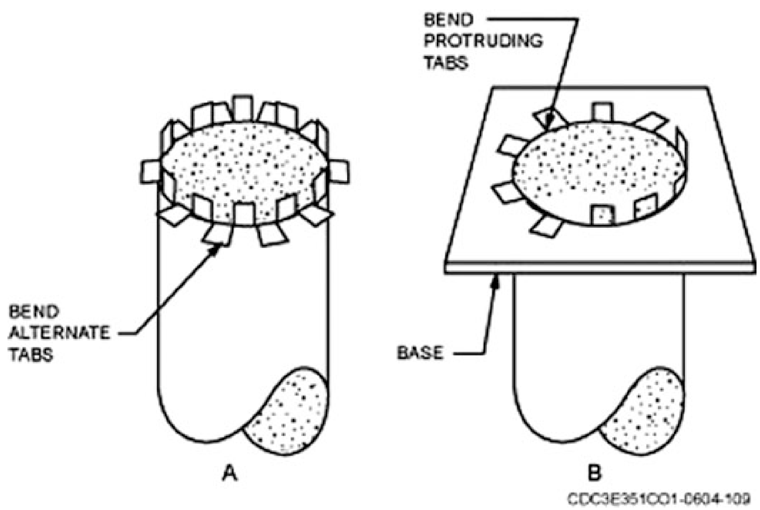


Figure 3–12. Dovetail seam.

In this lesson, we've discussed how various types of lap and lock seams are made and how you determine the seam allowances.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

009. Lap and lock seams

1. List the general lap seam types.

2. What is the seam allowance for a ¼-inch flat lap riveted seam?

3. Where is the offset lap seam used?

4. What seam type is used when a 90° bend is needed?

5. What factors should you consider when choosing the best fastening method?

6. How are lock seams fastened together?

7. List at least three lock seam uses.

8. What are the two uses of the standing seam?

9. What is the formula for determining a standing seam allowance on 16-gauge sheet metal?

10. When joining two sheet metal duct sections with a standing seam, to what angle do you bend the flange section?

11. What is one of the main uses of grooved seams?

12. What is the seam allowance formula for a grooved seam?

13. When forming a grooved seam with a bar folder, how many times is the wing pulled forward for each pocket formed?

14. List three machines that you can use to make a grooved seam.

15. What tools do you need to set a grooved seam that was formed on a Pittsburgh lock-forming machine?

16. What should be done to prevent grooved seams from slipping?

17. What are the two types of double lock seams?

18. What formula is used to determine double seam allowance?

19. What tools and equipment are required to set a corner double seam?

20. Where is the Pittsburgh lock seam most frequently used?

21. What is the seam allowance for a Pittsburgh lock seam made with a Pittsburgh machine?

22. What is the seam allowance for Pittsburgh lock seams formed with a cornice brake?

23. Why should you use a mallet when working seams in the cornice brake?

24. What tools are used to assemble a Pittsburgh lock seam?

25. What holds the snap lock flange in the snap lock pocket?

26. What shape of duct is attached to a flat surface with a dovetail seam?

27. Describe how to make a dovetail seam.

28. When installing a ½-inch dovetail seam, how much allowance is required on the flat surface?

010. Joint Connections

In the first lesson of this unit, you learned how to use seams to join pieces and corners during sheet metal component fabrication. Now, you'll learn about joint connectors—S-slips, drive slips, tapped connections, and slip joints.

Determining joint connection types

Since joint connectors and bracing are often fabricated in the metal shop, you must know how to determine the type of construction that is appropriate for a specific duct system. Because standing S-slips are stronger than flat S-slips, we've included the table below to show the gauges of metal, types of joint connectors, and the type of bracing recommended for various sheet metal duct sizes.

Joint Connectors, Metal Gauges, and Bracing Recommended for Sheet Metal Duct

Aluminum B&S (gauge)	***Galvanized Steel USS (gauge)***	***Width of Duct***	***Types of Joint Connector***	***Bracing***
24	26	Up to 12 inches	Flat S-slips and drive slips, up to 35 inch centers. Standing seam or standing S-slips, up to 7′ 11″ centers.	Cross brake
22	24	13 to 24 inches	Standing S-slips and drive slips, up to 35″ centers.	Cross brake
22	*24	25 to 30 inches	Standing S-slips and drive slips, up to 7′ 11″ centers.	Cross brake and use 1″ x 1″ x ⅛″ angle iron or 1″ standing seams on 4′ centers.

Joint Connectors, Metal Gauges, and Bracing Recommended for Sheet Metal Duct				
Aluminum B&S (gauge)	***Galvanized Steel USS (gauge)***	***Width of Duct***	***Types of Joint Connector***	***Bracing***
22	*24	31 to 40 inches	Standing S-slips and drive slips, up to 7′ 11″ centers.	Cross brake and use 1 ½″ x 1 ½″ x ⅛″ angle iron or 1 ½″ standing seams on 4′ centers.
20	*22	**41 to 60 inches	Standing S-slips (1 ½″ pocket and 1 ½″ standing reinforced edge with 1 3/8″ x ⅛″ bar) and drive slips up to 35″.	Cross brake
20	*22	**41 to 60 inches	Standing S-slips (1 ½″ pocket and 1 ½″ standing reinforced edge with 1 3/8″ x ⅛″ bar) and drive slips up to 7′ 11″ centers.	Cross brake and use 1 ½″ x 1 ½″ x ⅛″ angle iron or 1 ½″ standing seams on 4′ centers.
* For maximum strength, increase metal thickness by two gauges. ** Consider hangers when using ducts this size.				

Notice that the thickness of the aluminum in the chart is measured in B&S (Brown and Sharp) gauge, which is the United States recognized standard in for wire and sheet metal *not made of iron or steel. Galvanized sheet steel* is measured with USS gauge (US Standard). If a coating, such as zinc, is applied to sheet steel to form galvanized sheet metal, the material is approximately 0.004 inch thicker than the gauge shown on the table. The recommendations shown on the chart are suitable for actual use, although your work orders or job specifications may give other instruction.

In the table you can see that as duct width increases, it is necessary to increase the thickness (gauge) of the metal to use for joint connections with additional strength and to use appropriate bracing. For example, 26-gauge galvanized steel (or 24-gauge aluminum) sheet metal is adequate for ducts up to 12 inches wide, if the metal is braced with cross brake bends.

A good way for you to determine the type of joint connector needed is to measure the length of the duct joints. If the joints are *35 inches or less in length*, you may connect them with flat S-slips and drive slips. If the joints are *longer than 35 inches* (up to 7-foot 11-inch centers), you should connect them with standing seams or standing S-slips.

Fabricating S-slip and drive slip connectors

S-slips and drives are an essential component for connecting ductwork. In the following paragraphs we will discuss how to create and install both of them.

S-slips

Use S-slips to join duct sections or fittings during the duct system installation. In figure 3–13, you can see how two sheet metal pieces can be joined with an S-slip. For a rectangle-shaped duct the S-slip is used to connect the two sides that have the greatest width. As the width increases, the need for stiffening and bracing also increases, and variations of the S-slip have been developed to serve this purpose. Figure 3–13 illustrates three types of S-slips:

- Flat S-slip.
- Standing S-slip.
- Reinforced standing S-slip.

Standing S-slips are stronger than flat S-slips, and the reinforced standing S-slip with its enclosed flat bar is the strongest of the three.

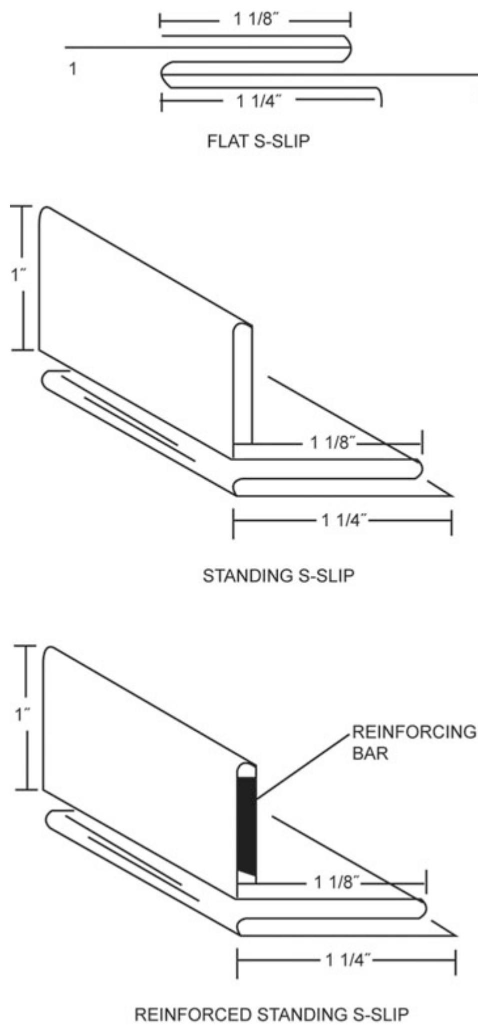


Figure 3–13. Types of S-slips.

Flat S-slip

In figure 3–13, you can see that the flat S-slip is the foundation of all three types. It has two parts, one being 1 ⅛ inch wide, and the other is 1 ¼ inch wide. When you construct an S-slip to these dimensions, it produces a joint with a 1- inch overlap. However, don't let this mislead you about the amount of sheet metal needed when you are figuring the length of the duct joints. When you use a flat S-slip to join ducts, make each duct ½- inch longer at the end that fits into the pocket of the S-slip. Fabricating a flat S-slip is not illustrated here, but it is bent (formed) as indicated in figure 3–14, D, E, and F. To make a flat S-slip, omit the standing edges from the pattern and *do not* perform the steps shown in figure 3–14 B and C. The following paragraphs will clarify this explanation.

Standing S-slip

Because the basic S-slip design is the same, the standing S-slip can be used for the same purposes as a flat S-slip. The difference between the two is the standing edge on the standing S-slip (fig. 3–13). This standing edge is usually 1-inch high but can range from ¾ to 1 ½ inches, depending on the strength required. Standing S-slips, like other S-slips, are used to join the widest sides of a rectangular duct.

Fabricating standing S-slip is not difficult, and is usually done with a cornice brake. To make the S-slip, use the following directions (references in the table correspond to parts of fig. 3–14).

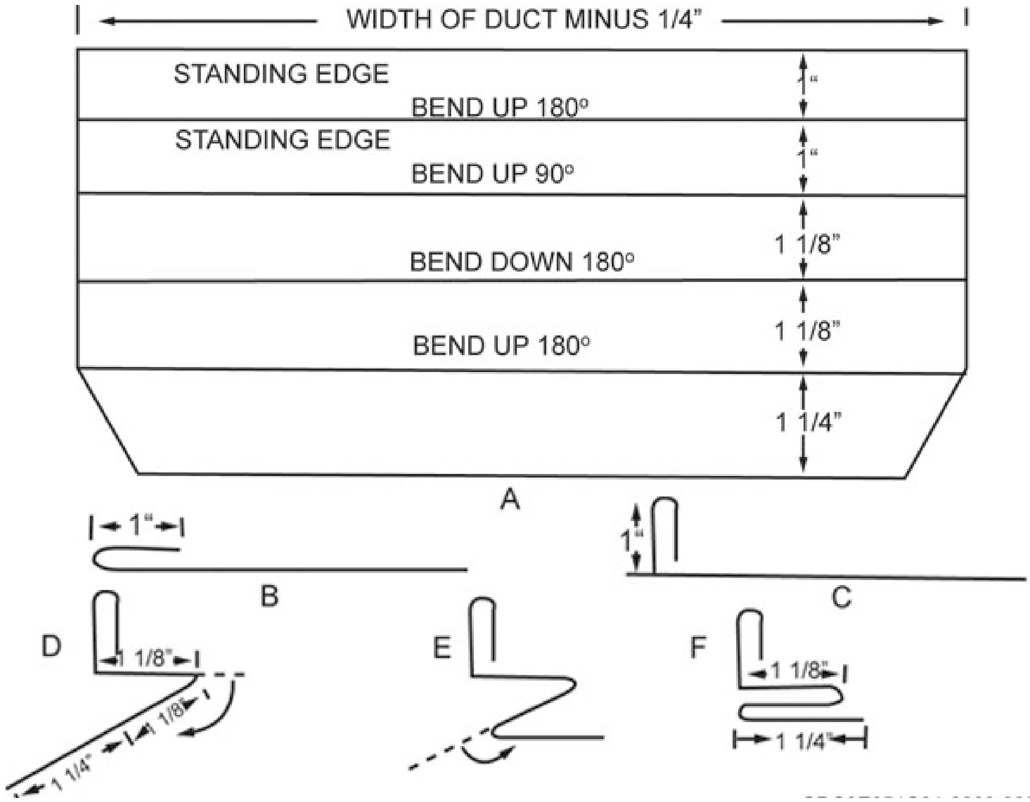


Figure 3–14. Making a standing S-slip.

Fabricating Standing S-slip		
Step	**View**	**Directions**
1	A	Determine the dimensions and lay out the pattern. The pattern should look like view figure 3–14, A, if you are making standing S-slips with 1⅛-inch pockets and a 1-inch standing edge. To give clearance for the corner lock seams, the standing S-slip length should be approximately ¼-inch less than the width of the ducts. Notice how the 1¼-inch portion of the pattern is cut at a 45° angle to make installation easier. For training purposes, we've included the braking instructions on the pattern and figure 3–14 B through F indicates the bend directions.
2	B	Bend the standing edge 180° at the 1-inch line.
3	C	Bend the metal 90° at the second 1-inch line. This bends the standing portion of the S-slip first.
4	D	Turn the metal over in the cornice brake, then bend it approximately 150° at the third line between the two 1⅛-inch measurements.
5	E	Turn the metal over again in the cornice brake and bend approximately 150° at the fourth line between the 1⅛- and 1¼-inch measurement.
6	F	Flatten the two bends with the cornice brake until they're each 180°.

Reinforced standing S-slip

A reinforced standing S-slip (fig. 3–13) is similar to the standing S-slip, but has a flat bar in the standing edge to increase its strength. The procedure for fabricating a reinforced standing S-slip is similar to making a standing S-slip, as explained in the previous paragraphs. The reinforced standing

S-slip (fig. 3–13) has a 1-inch standing edge, which is reinforced with a ¾-inch x ⅛-inch flat bar. Use flat bars of other widths and thickness if the dimensions of the standing edge are increased proportionately.

Drive slip

The drive slip (sometimes called a drive clip or a drive cleat) (fig. 3–15 and fig. 3-1, A–4) is used as a joint connector to secure the narrow side of rectangular duct sections. Notice how the drive slip and the turned-back edges of pieces 1 and 2 form a lock joint. You install the drive slip by striking it lightly with a hammer in the direction indicated by the arrow. Although you can use drive slips to connect flat metal sheets, you'll most often use them, in conjunction with S-slips, to connect duct joints. In discussing S-slips, we said they are used to join the widest sides of the duct. Thus, it is appropriate to use S-slips across the top and bottom of the duct and drive slips on the sides (fig. 3–16). When S-slips and drive slips are combined in this manner, the term *S-and-drive slips* is used.

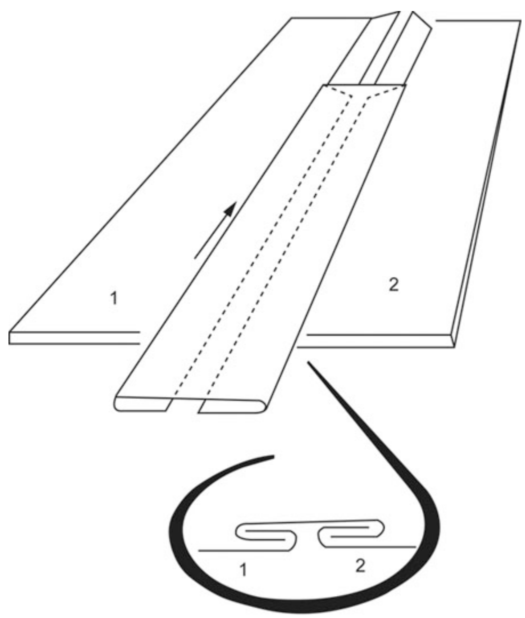


Figure 3–15. Drive slip.

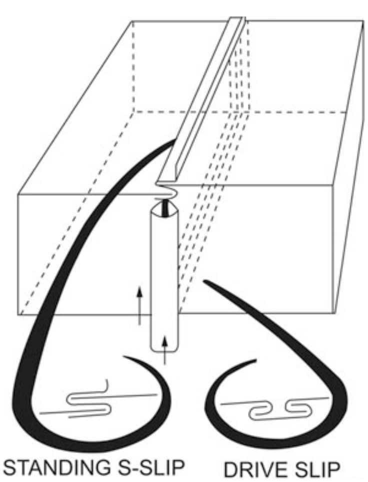


Figure 3–16. Duct joints connected with S-and-drive slips.

Duct joints connected with S-and-drive slips are firmly locked together, although they can be easily removed if the duct needs to be dismantled.

You can determine the material needed to fabricate a drive slip by the width of the drive slip and the dimensions of the duct—usually its height. The views referenced in the following table are to Figure 3–17.

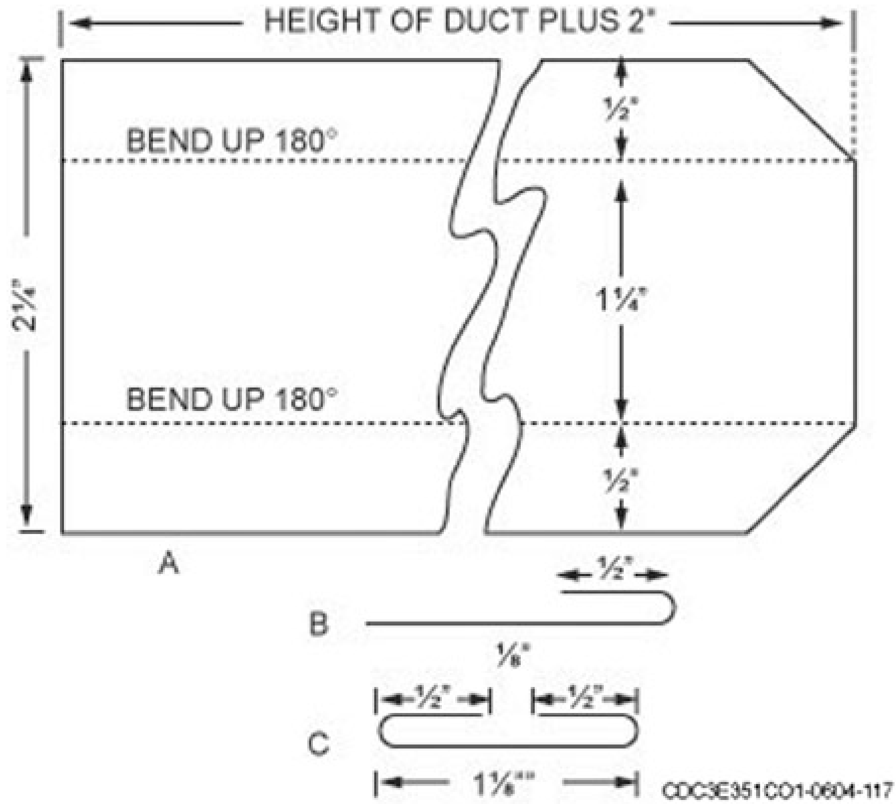


Figure 3–17. Making a drive slip.

Making a Drive Slip		
Step	**View**	**Directions**
1	A	Lay out a drive slip pattern. The figure illustrates the often-used 2 ¼-inch drive slip. Notice that an extra allowance of ⅛ inch is made on the center section to allow easier installation. If you are making a drive slip for a duct that is 18″ wide x 12″ high, make the drive slip 14 inches long so that 1 inch extends past on each end and can be bent down to keep the drive slip in place.
2	B & C	Cut the metal and use the bar folder to turn each edge 180° along the brake lines.
3	C	Cut 45° angles at one end to allow the drive slips to be installed with less effort.

When completed, the 2 ¼-inch drive slip should have the dimensions and appearance shown in step C.

Installing standing S-slip

Figure 3–18 illustrates the complete process of using S-and-drive slips to connect joints of duct.

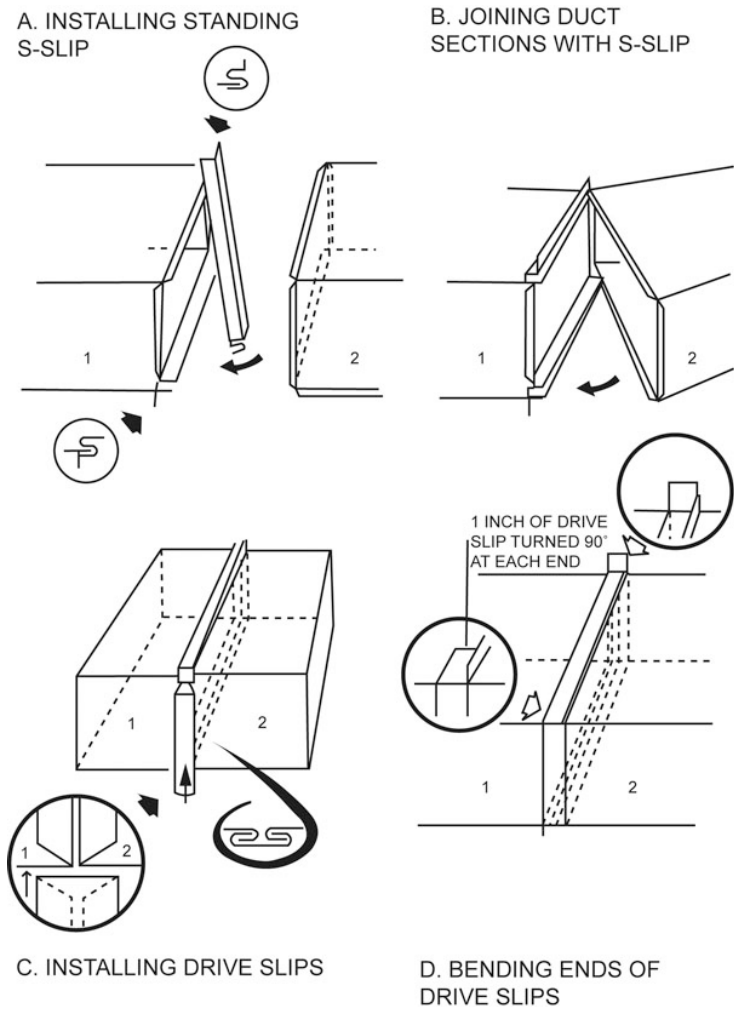


Figure 3–18. Connecting duct joints with S-and-drive slips.

Figure 3–18, A shows standing S-slips being installed on the top and bottom sides of a duct joint. Notice how the top S-slip is started at a 45° angle because the channels are usually tight fitting. After you start the S-slip at one end, you can tap it into place with a hammer or mallet until it is in the same position as the bottom S-slip in the illustration. Notice the position of the standing edges of the top and bottom S-slips. Figure 3–18 also shows the allowance for the overlap of joints 1 and 2. This allowance is ½- inch on each edge when 1 ⅛-inch S-and-drive slips are used. The additions on both joints have been notched at the corners.

Joining duct sections with S-slip

Figure 3–18, B shows how joint 2 is inserted into the S-slip. Start a drive slip on the end just inserted to hold it in place, then move joint 2 firmly in the direction of the arrow until all top and bottom joint additions are inserted into the S-slip's pockets. Now joints 1 and 2 should be in perfect alignment. However, the two S-slips don't lock the joint. The next step is to install the drive slips on the sides of the duct to lock the joints together.

Installing drive slips

Figure 3–18, C shows how you insert a drive slip over the turned-back edges of the two joints. The drive slip should drive on easily with light hammer taps, if the patterns were correctly made and the edges turned properly. When both drive slips are installed, the two joints are firmly held together. There is one last step to ensure that the drive slip does not come off.

Bending ends of drive slips

Figure 3–18, D shows how the extra 1-inch, which was added to each end of the drive slip, is turned down to form a positive lock. This operation completes the connection of two duct joints with S-and-drive slips. This is an excellent connection and has the additional feature of being easy to disconnect, should the duct ever need to be dismantled.

Fabricating and installing tapped connections, takeoff fittings, slip joints, and elbow edges

A tapped connection, like the one shown in figure 3–19, A is used to join rectangular takeoff fittings to rectangular ducts. A takeoff fitting (also called a takeoff) is used to connect a smaller duct or branch line to a larger duct (e.g., trunk line). The elbow edge and slip joints are for connecting round ducts.

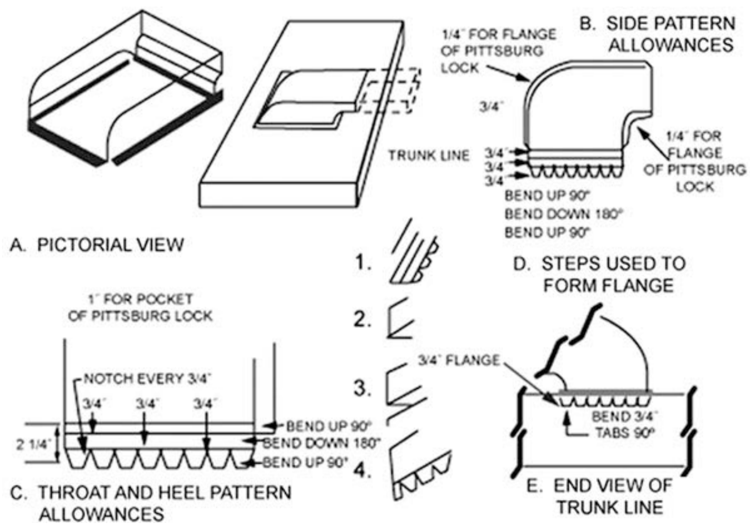


Figure 3–19. Making a tapped connection for a curved takeoff fitting.

Tapped connection

You may find some sheet metal workers using other names for the tapped connection of a takeoff (“Clinch lock,” “P-lock,” and “tap connector” are names often used). In figure 3–19, D, step 4, you can see the flange (sometimes called a frame or collar) that forms a base for the takeoff fitting when you install it in the trunk line opening. After the tabs are inserted in the opening, they’re bent 90° to lock the fitting to the trunk line. A takeoff fitting may be curved, straight, or tapered, making a neat flush fit.

The curved tapped connection illustrated in figure 3–19, is in the form of an elbow. You’ll need four pieces for fabricating it—two sides, a throat, and a heel. Use Pittsburgh lock seams to join all four corners. The material allowance to make this tapped connection is included in each pattern.
Note in figure 3–19, B and C that the *allowance on each pattern* is 2 ¼ inches.

Before you form the tapped connection with a cornice brake, form the flanges and pockets for the Pittsburgh lock seams. Turn the ¼-inch flange on the two side patterns, and form the pocket on the throat and heel patterns. Next, form the ¾-inch flange for the tapped connection, as shown figure 3–19, D, steps 1 through 4. Bending this flange with a cornice brake is the same as the procedure to form a standing seam that was described earlier.

After you’ve formed all four pieces and assembled the elbow, cut a hole in the trunk line, insert the tapped connection in the hole, and bend the tabs outward 90° with a hammer or mallet, using a dolly or bucking bar as a backing surface.

Takeoff fittings

The fabrication procedure for all takeoff fittings is similar and includes making the seams, joint connectors, and tapped connections. We explain making the pattern and allowances, notching, forming, and joining a tapered takeoff fitting. Notice that the example illustrated in figure 3–20 connects a branch line to the side of a trunk line.

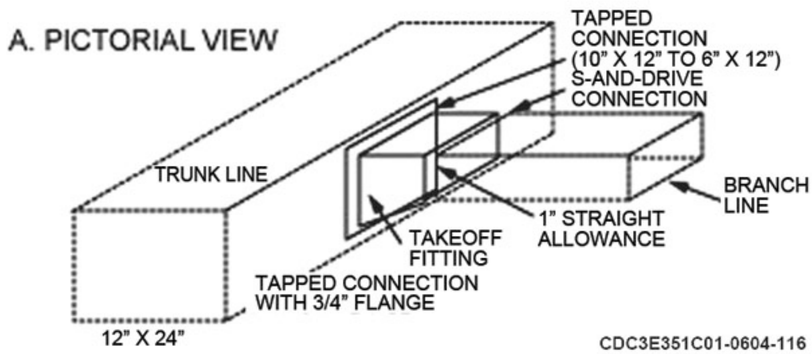


Figure 3–20. Tapped connection on a tapered takeoff.

Making a flat pattern

From the information shown in figure 3–20, it is not difficult to develop the flat patterns A and B shown in figure 3–21.

Making a Flat Pattern	
Step	**Action**
1	Remember from the sheet metal layout unit that the first step in developing a pattern is to draw a plan view with the dimensions (fig. 3–21).
2	From the plan view, develop the pattern (stretch-out) by the parallel line method (except for the slanting sides). The pattern for the top and sides is in one piece because you'll use two Pittsburgh lock seams to join the bottom pieces.
3	Lay out flat pattern A by drawing a straight line (stretch-out) equal to the perimeter of the top and two sides.
4	Next, draw the two perpendicular element lines where you'll fold the corners of the joint. The length of the upper stretch-out line in view A is equal to the perimeter of the 12″ x 6″ opening of the transition.
5	With the ends of the two stretch-out lines connected, you can determine the length of the slanting sides (true length). Flat pattern B for the bottom of the takeoff fitting is the same length as the slant length of the side that it will join.

Making allowances

After you've laid out the flat patterns, the next step is to determine the seam allowances and additions (fig. 3–21). This includes the allowances for the S-and-drive-slip connections, the Pittsburgh lock seams, and the tapped connection. It does not make any difference which allowance you develop first. We've elected to develop the allowances for the S-and-drive slips first. They require a ½-inch allowance on both patterns. You make the allowance for the Pittsburgh lock seams by allowing ¼ inch on each of the slant sides in pattern A, and 1- inch on two sides of pattern B. Make the allowance for the tapped connection on both patterns, and include ¾-inch for each flange and ¾-inch for the tabs—a total of 2 ¼ inches allowed for the tapped connection.

Notching

After you've determined and marked the allowances, cut the notches and slits as indicated on patterns A and B of figure 3–21. In this example, each notch that forms a ¾-inch tab requires two cuts, and is placed 1-inch apart. However, in other patterns, the length of each tab may be less or greater depending on the strength desired, the size of the takeoff fitting, and the effort needed to reach and turn down the tabs after you've joined the fitting to the duct. Notice that each end of the S-and-drive connection allowance is notched with a 45° cut. The ends of the Pittsburgh lock seam pocket allowance in pattern B are notched (cut) at 90° angles.

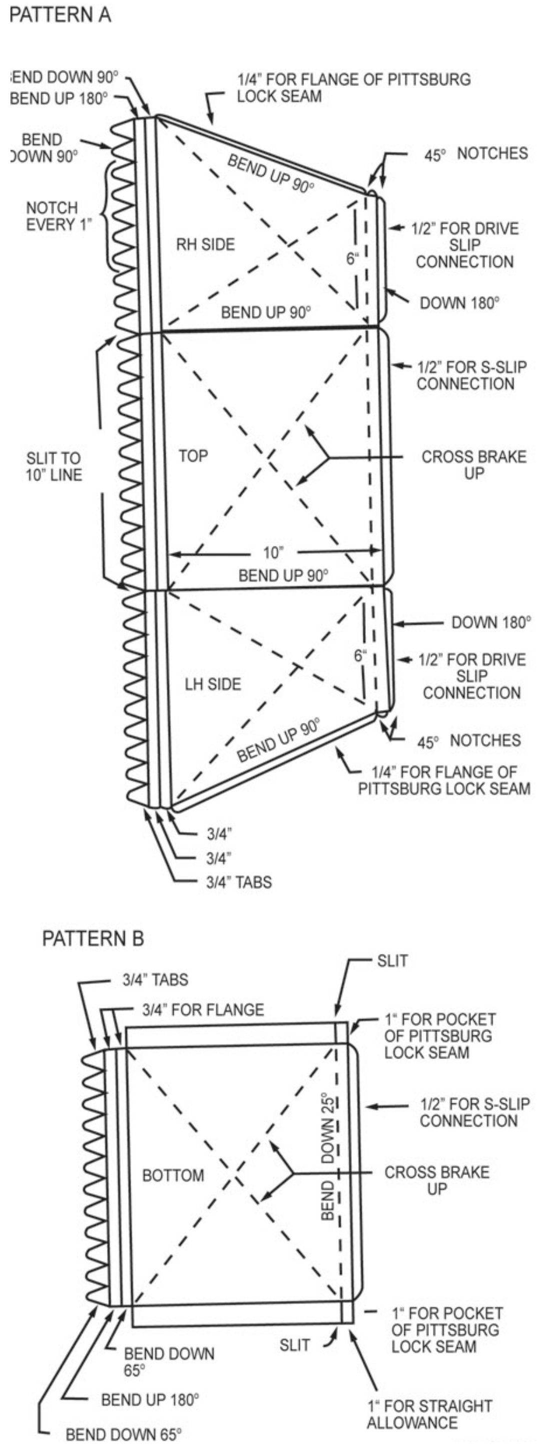


Figure 3–21. Making allowances for S-and-drive slips, Pittsburgh lock seams, and tapped connections.

Forming

You can make all of the bends indicated in figure 3–21 with a cornice brake, a mallet, and a Pittsburgh lock-forming machine. It is important to follow the proper sequence for making the bends so that the top leaf of the cornice brake will not crush the previously made fold. For example, you'll *always make the cross brakes first*, but the sequence of other bends may vary depending on the shape and direction of the bends. A sequence that works in most cases for square or rectangular duct components is identified in the following table.

Making allowances for S-and-drive slips, Pittsburgh lock seams, and tapped connections		
Step	**Procedure**	**Directions**
1	Make the cross brake	To make the bends for the takeoff fitting (fig. 3–21), follow the order of the prescribed cross braking: • Pattern A (piece A) is placed in the cornice brake so that the metal is at a 45° angle to the top leaf. • The metal is clamped with the top leaf and the bending leaf is raised 10° to 15°. • Repeat this procedure along the other cross brake lines.
2	Bend the seam allowances	Continuing with piece A only, bend the ¼-inch flange 90° for the Pittsburgh lock seam. This operation (fig. 3–22) is performed with the cornice brake and mallet. This lets you bend the ¼-inch flange without bending the end of the 1-inch straight and the end of the allowance for the drive-slip connection. After bending the flanges at each side of piece A, you must straighten out each end for about 2 inches so that you can clamp the metal in the cornice brake to make the tapped connection bends.
3	Bend the joint connection allowances	With piece A, make the bends that will be at the two ends of the takeoff fitting. Make the bends for the tapped connections with the cornice brake as shown in figure 3–21. The 180° bends for the drive-slip connection are made as illustrated in figure 3–23. Use the mallet only to fold the bends for the ½-inch allowance on the two sidepieces. (The ½-inch allowance for the S-slip connection on the top and bottom pieces must remain straight.) If desired, you can use a hand seamer to make the bend instead of the cornice brake and mallet. The ¼-inch 90° flange for the Pittsburgh seam, which was temporarily straightened for 2 inches on each end of piece A, is now returned to the 90° angle with a hand seamer.
4	Make the corner bends indicated on the pattern	Continuing with piece A (fig. 3–21), use the cornice brake to make the two 90° corner bends. Make the first corner where the topside and the left side meet, with the pattern positioned at the left end of the cornice brake. This prevents damaging the flange of the tapped connection. Next, bend the 90° corner, where the topside and the right side meet, in the same way. This is the final step for piece A, which should now look like a finished takeoff except for the sloping bottom, not yet in place.

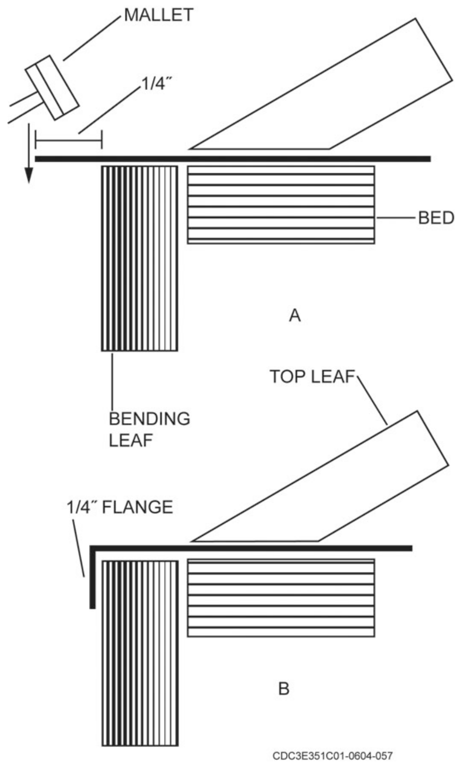


Figure 3–22. Using a cornice brake to bend a ¼″ flange.

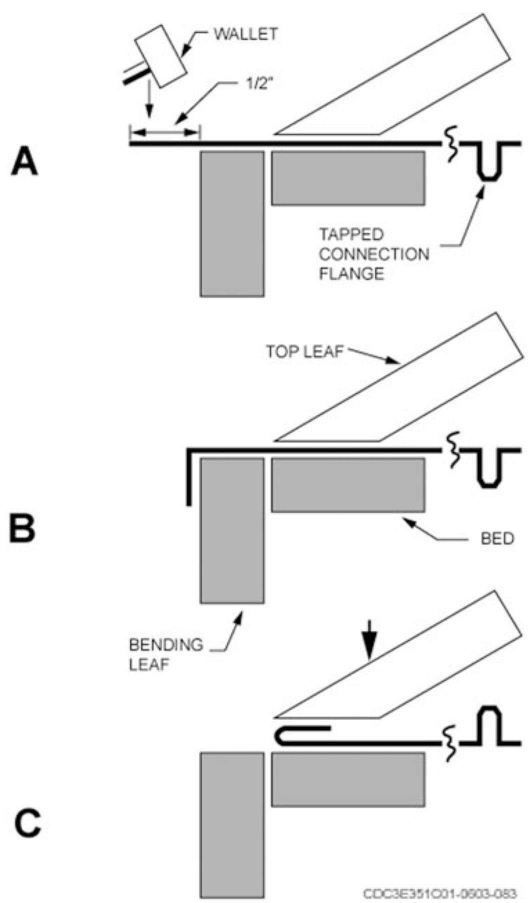


Figure 3–23. Using a cornice brake to bend 180° fold for a drive slip.

Pattern B (piece B), the bottom of the takeoff (fig. 3–21), is formed in a similar sequence.

Making the Bottom of the Takeoff		
Step	**Procedure**	**Directions**
1	Make the cross brake	Cross-brake the pattern along the diagonal lines.
2	Bend the seam allowances	Make the pocket side of the Pittsburgh lock seams on the 1-inch allowance on each side of the bottom piece. Do this with a Pittsburgh lock-forming machine if one is available; if not, do it with a cornice brake.
3	Bend the joint connection allowances	Form the flange for the tapped connection end of the takeoff. You must make a 65° bend downward along the straight allowance line, returning the bottom to the same plane as the duct branch. When you are making this 65° bend, don't use excessive clamping pressure with the top leaf of the cornice brake. Too much pressure can damage the Pittsburgh seams.
4	Make the corner bends indicated on the pattern	*Omit this step in forming the bottom piece.*

Assembly and joining

The takeoff fitting, which we've discussed in the preceding paragraphs, is easy to assemble as described in the following table.

Assembling and Joining the Takeoff Fitting	
Step	
1	Place piece A (fig. 3–21) so that it rests on the top of piece B.
2	Install the bottom piece B so that the ¼-inch flanges of the two sides fit into the pockets of the Pittsburgh seam and the locking edges of the Pittsburgh seam are folded over.
3	This step completes the assembly. Join the takeoff fitting to the hole in the trunk line by inserting the tabs into the hole until the flange rests against the edges of the hole.
4	Bend the tabs 90° outward to make a tight connection.
5	Join the branch duct to the takeoff fitting with S-and-drive slips.

Elbow edge

The elbow edge is a joint used to connect small round duct sections to transition pieces, such as adjustable elbows, diffuser boxes, and register boxes. You can make this connection by following the steps in the table below.

Making an Elbow Edge	
Step	**Action**
1	Make the elbow edge by bending the edges of two same size items so that they will lock together (fig. 3–24).
2	To assemble an elbow edge joint, leave one rivet out of the lap joint to allow the section to be spread and slipped over the edge of the other piece.

Making an Elbow Edge	
Step	**Action**
3	Then push the ends back into place and install the second rivet.
4	Check the joint to ensure everything is properly aligned.

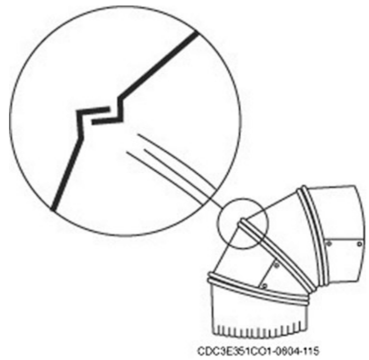


Figure 3–24. Elbow edge joint.

Slip joint

A slip joint connection is somewhat different than a rectangular ducts connection. Slip joints are commonly used to join sections of round duct such as vents, stacks, and branch lines.

Figure 3–25 shows a 1 ½-inch slip joint. The steps for making this joint are explained in the following table.

Making a Slip Joint Connection	
Step	**Action**
1	Crimp one end of each round duct piece with a crimping machine.
2	Make a bead with a beading machine to strengthen the duct and help align the joints during installation.
3	Assemble this connection (slip joint) by slipping the crimped end into the plain end of another joint until the bead is flush with the plain end.
4	Fasten the slip joint together with sheet metal screws or rivets. Remember the airflow must be in the direction indicated in view C.

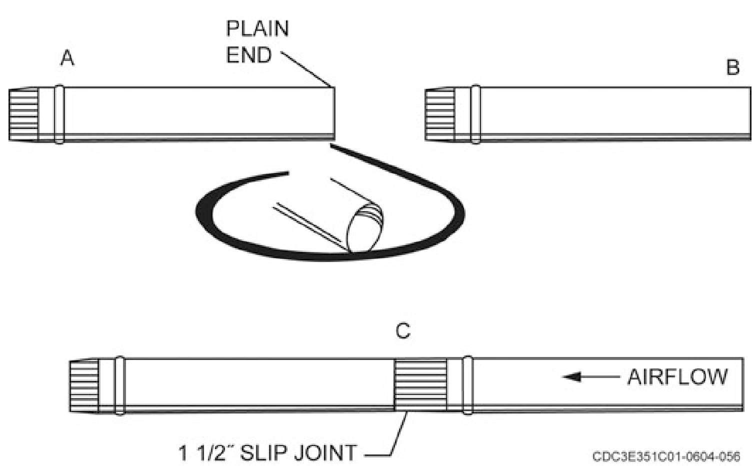


Figure 3–25. Joint connection for round ducts.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

010. Joint connections

1. What type of bracing is recommended for a 24-gauge galvanized steel duct 22-inches wide?

2. For maximum strength, what gauge metal would be used for a duct 58 inches wide and 4-feet long?

3. In duct fabrication, what must be increased as duct width increases?

4. What S-slip is the basis for all S-slips?

5. When forming a 1-inch standing S-slip, the first two bends are used for what?

6. What is the last step in forming a standing S-slip?

7. The standing S-slip is used for what purpose?

8. What are drive slips used with?

9. How long would you make the drive-slip pattern for an 18-inch duct?

10. How can the installation of a drive slip be made with less effort?

11. What is the first step in connecting two duct sections with S-and-drive slips?

12. Why is a drive slip started before the duct is fully in place in the S-slips?

13. Give the last step of an S-and-drive-slip installation.

14. For what purpose are tapped connections used?

15. To fabricate a tapped connection, what step must you complete before you form the parts with a cornice brake?

16. How do you lock a tapped connection in place?

17. When do you use the elbow edge joint?

18. How many parts are there in a slip-joint connection?

19. How are the joints constructed to form a slip joint?

011. Using fasteners

In this lesson, the fasteners discussed are rivets, sheet metal screws, bolts and nuts. We'll not only discuss some of the different types, but you'll learn different uses, installation and removal procedures. We will even discuss the use of taps and dies. There are not many things more frustrating than breaking off the head of a screw or bolt and having to drill and tap the hole. After completing this section, you'll be able to tackle those tough jobs.

Installing and removing rivets

Rivets are used frequently in sheet metal projects. The easiest to use are the blind rivets. In this lesson, you'll learn how to install blind and regular rivets.

Blind rivet gun

To use a blind rivet gun (fig. 3–26), place the rivet stem into the rivet gun and then place the body of the rivet through a predrilled hole. Hold the rivet firmly against the work and squeeze the handle until the stem breaks off. The blind rivet-pulling head (fig. 3–27) shows the internal parts of a pulling head and rivet installed and set. Most pulling heads work on the same principle—the jaws grip the mandrel as they are pulled upward and the upward motion continues until the mandrel breaks in two. Maintenance on the pulling head lies with the jaws; when they get loaded, they slip. So when your rivet gun starts to slip, it's telling you to clean the teeth on the jaws. This can usually be done with a wire brush after disassembling the pulling head.

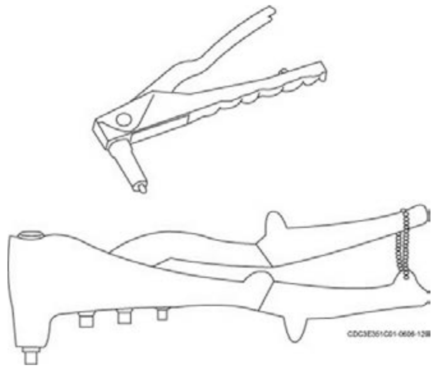


Figure 3–26. Blind rivet guns.

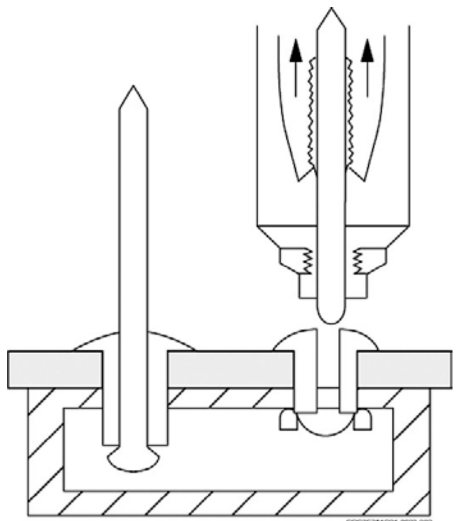


Figure 3–27. Pulling head.

Design of riveted joints

There are two main types of riveted joints—lap joints and butt joints. The *lap joint* is made with two sheets of metal arranged so that one sheet overlaps the other. Butting the plate or sheet ends together makes the *butt joint*. One or more cover plates are then placed over the butt joint and riveted into both sheets of metal to prevent movement. Both types of joints can be single riveted, double riveted, or triple riveted, with one, two, or three rows of rivets. If more than one row of rivets is used and the rivets are directly behind each other, they are said to be *chain riveted*. If they are diagonally behind each other, they are *stagger riveted*. Chain or stagger riveting can be used both in lap and in butt joints when more than one row of rivets is needed.

You can find the rivet spacing for the joint on the drawing or blueprint. If the spacing isn't specified, the type of seam can help you determine whether to set the rivets close together or far apart.
For instance, a joint that must be liquid tight has many more rivets per inch, than a joint that does not need to be liquid-tight. Whatever the rivet spacing, the center of the rivet hole is twice the diameter of the rivet head from the edge of the sheet. Some sheet metal workers prefer to use two and one-half times the shank diameter. The number of rows of rivets in a joint depends on the amount of strength needed in the joint. The distance between rows of the rivets is known as the *transverse pitch*, and the distance between the rivets in the same row is called the *rivet pitch*.

Determining rivet size

The diameter of the rivet is usually determined by the thickness of the plate or sheet stock from which the part is made. Unless otherwise specified, the diameter of the rivet shank is approximately three times the thickness of the sheet metal. The length of the rivet shank is determined by the combined thickness of the sheets to be fastened. The shank should protrude through the metal sheets (fig. 3-28) about one and one-half times the diameter of the rivet to form a well-shaped head and allow maximum holding strength.

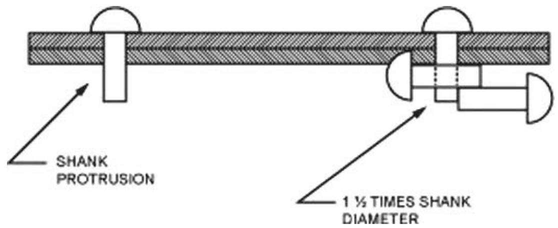


Figure 3–28. Rivet length.

Making a rivet hole

After the rivet size is determined and the layout completed, mark the center of the hole. Mark the hole by placing a sharp-pointed punch on the center and striking it lightly with a hammer, then complete the hole with a rotary action drill or punch. The hole should be slightly larger than the rivet. If the holes are near the edge of the sheet, use the hand lever punch to pierce them. If the holes *aren't* near the edge of the metal, use a rotary action drill for piercing the holes. Regardless of the method you use to make the holes, remember that the edges of the holes must be smooth and the hole slightly larger than the rivet.

When several sheets are to be drilled or punched, use a template to locate the holes. On individual sheets, you can use a pencil, compass, scriber, or dividers. You *should not* use a scriber on aluminum or stainless steel because this scratches the metal and may make the aluminum crack as it's being formed. A soft, pointed pencil is recommended for marking aluminum and stainless steel.

Before driving rivets, remove any burrs and chips to keep from marring the metal and to let the sheets seat tightly against one another. Burrs can be removed by inserting the point of a larger size twist drill in the hole and turning. A countersink may be used the same way.

To align the rivet holes, the sheets must be held in proper relation to one another as the rivets are inserted. A holding device, called a Cleco, is the tool to use for this job. A Cleco in every third or fourth hole along the seam is usually sufficient. Figure 3–29 shows how the Cleco is used.

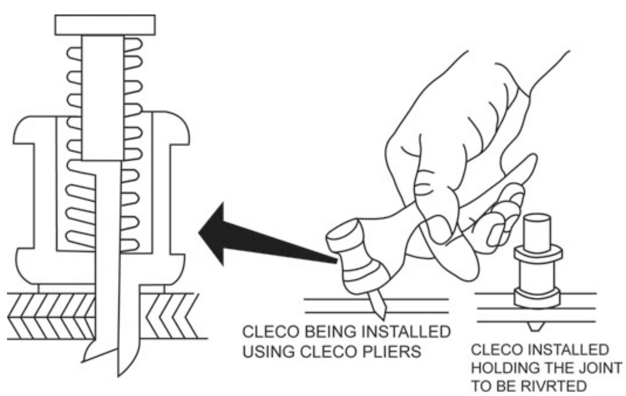


Figure 3–29. Rivet installation

Installing rivets

Rivets are usually installed by placing the manufactured head against a solid surface, such as a backing plate, and following the steps shown in figures 3–30, 3-31, and 3–32. This procedure is used with a hand-riveting set. The steps illustrated are necessary to ensure a strong riveted connection with the proper head size and to keep the joint from being distorted.

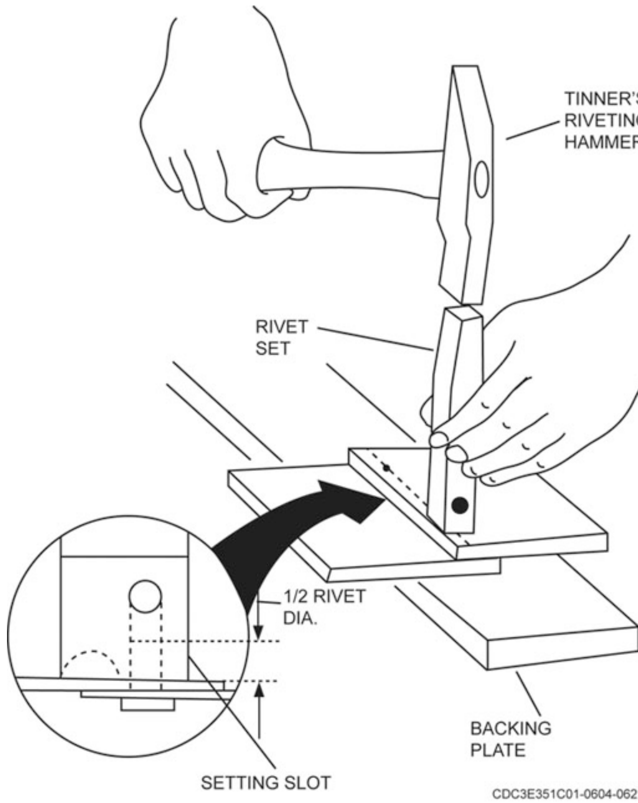


Figure 3–30. Setting rivets.

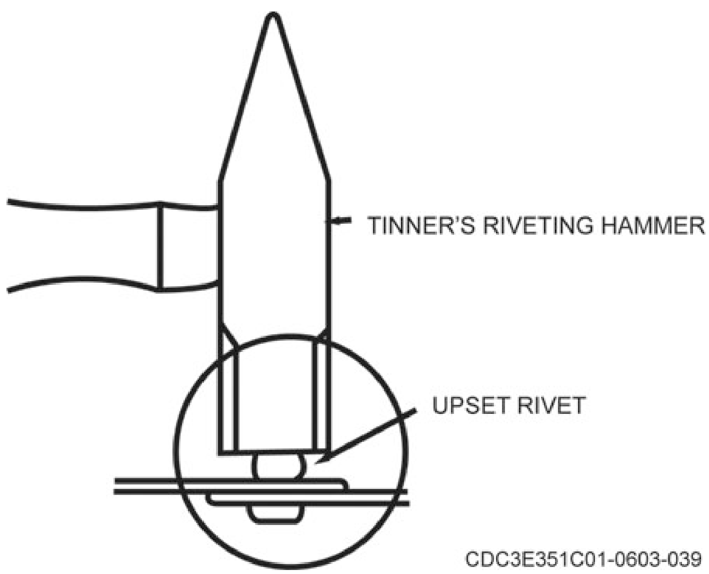


Figure 3–31. Upsetting rivets.

The actual rivet installation begins with the setting step and it is important for you to do it correctly. If the setting step in figure 3–30 isn't done right, the sheets may not seal tightly against each other and may make the rivet swell between the sheets during the upsetting step in figure 3–31. A second problem often appears when the rivet head is not seated up tight against the metal. This causes the rivet to swell below the metal as shown in figure 3–33. Either problem makes the rivet too short to form a proper head, causes the metal around the hole to dimple (bulge), and fails to form a strong joint.

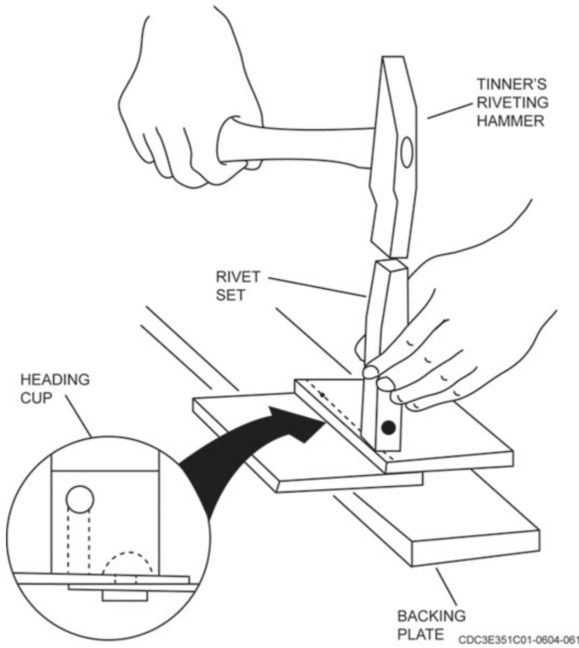


Figure 3–32. Heading rivets.

Upsetting the rivet (fig. 3–32) is also very important, since it's the beginning of the heading process. If the rivet is struck too hard, the rivet shank will be flattened too much to form a good head during the heading step.

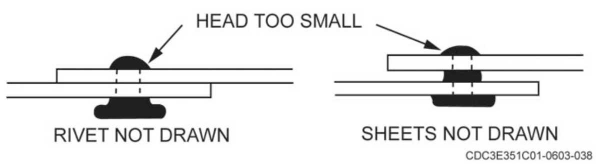


Figure 3–33. Improperly set rivet.

The heading step (fig. 3–33) uses the head-forming depression of the rivet set to form a strong, well-shaped head. Heading the rivet enlarges the head to provide a holding surface all around the hole (fig. 3–34).

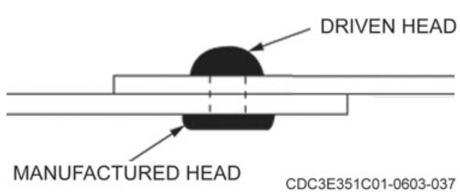


Figure 3–34. Properly set rivet.

The tools needed for hand riveting are a riveting hammer, a rivet set, and a backing surface, such as a backing plate, hand dolly, or bench stake. Rivet sets $^{3}/_{16}$-inch in diameter and under are available in most sheet metal worker toolkits. A rivet set is required to form a good shaped head on the rivet. The size of the set depends on the size of the rivet. The shape and size of the backing plate, hand dolly, or bench stake depends on the size of the rivet, thickness and size of the material, location, and conditions under which the driving is taking place. Therefore, most sheet metal shops have many shapes and sizes of hand dollies and bench stakes available. A piece of square, cold-rolled steel bar of the proper weight can be used as a backing plate when no interference exists. Where riveting is not so simple, hand dollies or bench stakes of various shapes are used. They are designed to overcome the interference and still have enough weight to support setting, upsetting, and heading. Hand dollies are sometimes called bucking bars. When you rivet flat sheets where there's no interference, use a flat steel plate secured to the workbench.

Drawing rivets

Drawing rivets is a process where drilling or punching holes is not necessary. This procedure is used with light-gauge sheet metal, such as 30, 28, and 26 gauges. A solid rivet is placed head down on a bench plate, or stake, then the joint is placed over the rivet. The joint is tapped lightly with a mallet to make an impression of the rivet shank. The set shown in figure 3–30 is placed over the impression in the joint, and the set is tapped with a riveting hammer to draw the rivet through the light sheet metal. This method is useful in making funnels and cylinders and in joining light sheets.

Removing rivets

When you remove a rivet, maintain the original size and shape of the rivet hole so that you don't have to replace it with a larger rivet. If the rivet isn't removed properly, the joint's strength is weakened and replacing other rivets is harder. Drill the rivet's manufactured head, because it's more symmetrical than the shop-made head and there's less chance of damaging the rivet hole or the metal around it. Rivets are removed with hand tools, a power tool, or a combination of both. The round manufactured head of a rivet should be filed flat and center punched for drilling (fig. 3–35). When you're center punching on thin sheet stock, back up the rivet on the upset head to avoid depressing or buckling the metal.

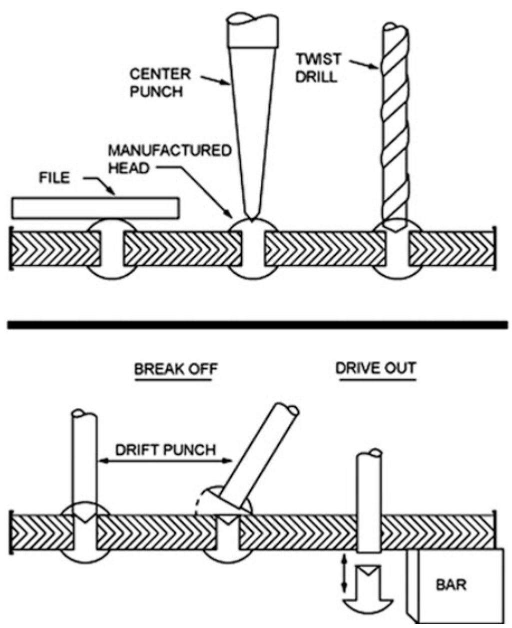


Figure 3–35. Removing a rivet.

Select a twist drill the same size as the rivet shank and drill the rivet head out (fig. 3–35). When you use a portable drill, set the twist drill point on the rivet and rotate the chuck several times by hand before applying the power. (This helps the twist drill cut a starting spot, which eliminates the twist drill possibly slipping off the rivet head and tracking the metal). Apply power and drill the rivet to the depth of the rivet head, holding the drill at a 90° angle to the rivet head. The rivet head usually breaks away and climbs the drill as soon as the head is completely pierced. This is a good signal to stop drilling. Don't drill too deep, as the rivet shank may fail to turn with the drill and cause the metal to tear. If the rivet head fails to come loose on its own, insert a drift punch in the hole (fig. 3–35), and twist slightly to either the left or right until the head comes off the rivet.

The final step is to drive the rivet out with a pin punch slightly smaller than the rivet shank's diameter. Support light-gauge metal with a solid object, such as a bucking bar, when you drive out the shank of the rivet.

Using sheet metal screws, stove bolts, machine screws, and nuts

In this discussion we will look at ways to fasten sheet metal components and assemblies. Some of the fasteners discussed are screws, bolts, and nuts.

Sheet metal screws

Sheet metal screws are often used in locations that make riveting difficult, or are used to fasten sheet metal parts that may later be disassembled. If the hole is drilled or punched to the right size, sheet metal screws are easily installed because they form their own threads in the metal during installation. If the hole is too small, the sheet metal screw, which is hardened, may break, making it difficult to remove. There are three types of sheet metal screws—type A, type Z, and self-tapping (fig. 3–36). Notice that type A and type Z have several different head styles, reading from left to right—roundhead, pan head, stove head, countersunk flathead, and countersunk oval head.

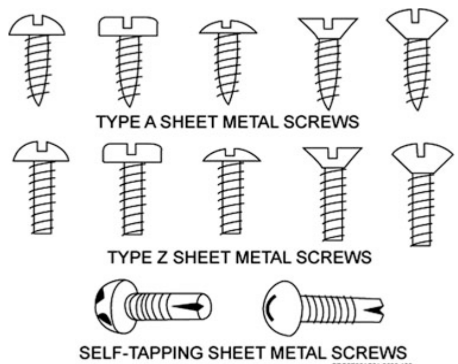


Figure 3–36. Sheet metal screws.

Type A sheet metal screws have a sharp point and resemble a wood screw except that the threads are coarser and extend to the head of the screw. They're recommended for joining and fastening light gauges of sheet metal. *Type Z sheet metal screws* have blunt points and the same threads as type A. They're recommended for joining and fastening light-or heavy-gauge metal. *Self-tapping sheet metal screws* (fig. 3–36) are recommended for heavier gauge sheet metal, since they form threads while being screwed into the proper size hole. This sheet metal screw is also available with a hex head for use with socket wrenches. *Self-drilling sheet metal screws* (fig. 3–37) are designed with a tip that can drill through light-gauge sheet metal and light structural building materials. They normally have a hexagonal head and can be driven with portable electric drills. Self-drilling sheet metal screws work well in light-gauge materials, but they tend to break when driven into heavier materials. You should also note that the self-drilling tip on these is not made of high-speed steel like a twist drill, and is used for drilling only one hole.

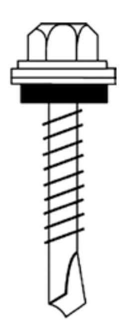


Figure 3–37, Self-drilling screw.

Stove Bolts

Stove bolts (fig. 3–38) were originally developed for use on stoves, as the name suggests. They're small and can be used for many jobs where accuracy, strength, and vibration resistance is not critical. Stove bolts have coarse threads and are normally made of iron. They may be plated with zinc or cadmium to prevent corrosion. You can get stove bolts with round heads, flat heads, or oval heads. When you order or draw stove bolts from supply, you need to know the kind of head, diameter, threads, length, and finish to find the right stock number. For example: bolt, stove, steel, round head, ¼"–20 by 1" cadmium plated.

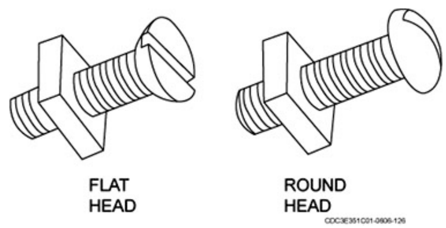


Figure 3–38. Stove bolts and Machine Screws

"Machine screw" is the general term used to designate small screws that may be used in tapped holes or with nuts. Most machine screws have fine threads and are made of steel or brass; they may be plated to prevent corrosion. A variety of diameters, lengths, and head shapes are manufactured, some of which are shown in figure 3–39. When you order or draw machine screws from supply, the kind of head, diameter, threads, length, and finish are required to determine the stock number. For example: screw, machine, round head, 8–32 by 1″, cadmium plated. The following table lists American (National) screw thread sizes and tap drill sizes.

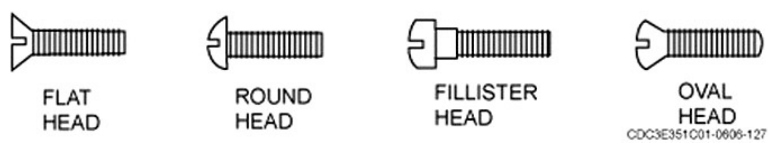


Figure 3–39. Machine screws.

American (National) Screw Thread Series							
National Course Thread Series Medium Fit Class 3 (NC)				**National Fine Thread Series Medium Fit Class 3 (NF)**			
Size and Threads	Dia. of Body for Thread	Tap Drill Pref'd Dia. of Hole	Tap Drill Nearest Stand'd Drill Size	Size and Threads	Dia. of Body for Thread	Tap Drill Pref'd Dia. of Hole	Tap Drill Nearest Stand'd Drill Size
				0–10	.060	.0472	$^{3}/_{64}$
1–64	.073	.0575		1–72	.073	.0591	#53
2–56	.086	.0682	#51	2–64	.086	.0700	##50
3–48	.099	.078	$^{5}/_{64}$	3–56	.099	.0810	#46
4–40	.112	.0866	#44	4–48	.112	.0911	
5–40	.125	.0995	#39	5–44	.125	.1024	#38
6–32	.138	.1063	#36	6–40	.138	.113	#33
8–32	.164	.1324		8–36	.164	.136	#29
10–24	.190	.1472	#26	10–32	.190	.159	#21
12–24	.216	.1732	#17	12–28	.216	.180	#15

American (National) Screw Thread Series							
National Course Thread Series Medium Fit Class 3 (NC)				National Fine Thread Series Medium Fit Class 3 (NF)			
Size and Threads	Dia. of Body for Thread	Tap Drill Pref'd Dia. of Hole	Tap Drill Nearest Stand'd Drill Size	Size and Threads	Dia. of Body for Thread	Tap Drill Pref'd Dia. of Hole	Tap Drill Nearest Stand'd Drill Size
¼–20	.250	.1990	#8	¼–28	.250	.213	#3
5/16–18	.3125	.2559	F	5/16–24	.3125	.2703	I
3/8–16	.375	.3110	5/16″	3/8–24	.375	.332	Q
7/16–14	.4375	.3642		7/16–20	.4375	.386	W
½–13	.500	.4219	27/64″	½–20	.500	.449	7/16″
9/16–12	.5625	.4776		9/16–18	.5625	.506	½″
5/8–11	.625	.5315	17/32″	5/8–18	.625	.568	9/16″
¾–10	.750	.6480	41/64″	¾–16	.750		11/16″
7/8–9	.875		49/64″	7/8–14	.875		51/64″
1–8	1.000		7/8″	1–14	1.000		59/64″

Nuts

When using stove bolts or machine screws to fasten sheet metal parts, use nuts of the same size and thread as the bolts or screws. The size of the nut is determined by the diameter of the bolt or screw it fits. For example, a 3/16-inch nut will fit a 3/16-inch bolt or screw, if the threads are the same. Nuts may be made of brass, steel, or iron, and can be plated the same as a bolt or screw. Nuts are made in several shapes, such as square, hexagon, wing, self-locking, and sheet spring. Many other shapes are available, but these are the most common in sheet metal work.

Square nuts are square, as the name implies, and are tightened with an open-end wrench or adjustable wrench. Stove bolts usually have square nuts.

Hexagon nuts are commonly called hex nuts. They have heads with six sides and are tightened with an open-end wrench, adjustable wrench, box-end wrench, or socket wrench. The box-end and socket wrenches are recommended because they fit tighter and reduce the chance of rounding the corners of the nut. Machine screws normally have hex nuts.

Wing nuts (fig. 3–40) are identified by the wing extending from the two sides of the body of the nut. They are tightened by hand and used when easy or repeated removal is desirable.

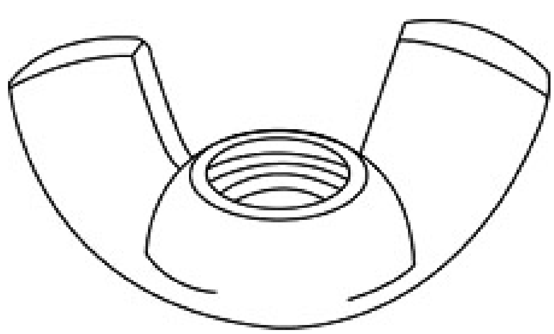


Figure 3–40. Wing nut.

Self-locking nuts differ from the nuts already described, because they have a locking device built in or secured to the nut to act as a binder. They are usually hexagonal and are held in place while the machine screws are installed. Self-locking nuts are used when vibration is a concern.

Sheet spring nuts are manufactured from sheet spring material, usually steel, into varying flat, concave, bent, or curved designs. The hole in the spring nut has internal lugs or prongs that can secure and grip the threads of a screw or bolt. Flat spring nuts must be held in place while a bolt or screw is installed. Other spring nuts are folded like a clip and stay in place while a bolt or screw is installed. Folded spring nuts can be used only near the edges of sheet metal. The metal parts being joined must have a hole drilled or punched to let a bolt or screw pass through.

Using taps and dies

Taps and dies are metal threading tools. Taps make internal threads inside a hole and dies make external threads on a round rod. They are often used for rethreading (cleaning up existing threads).

Taps

A tap is used to cut threads on the inside of a round hole. It's made from a hardened tool steel rod with screw threads and flutes cut into it. The design allows the tap to cut a hole in metal and produce threads for a bolt or screw. A special wrench with the tap, is used to produce the right amount of leverage and balance to maintain accuracy. Common types of hand taps are the taper, plug, and bottoming taps (fig. 3-41). The *taper tap* is tapered at the end 7-to-9 threads, to help start the tap in the hole. It's used when the hole goes all the way through the work. The *plug tap* is also tapered, but for a shorter distance back 2 ½ to 5 threads. After you start the thread with the taper tap, use a plug tap to cut to the maximum length. You may also use a plug tap when one end of the hole is closed. The *bottoming tap* has only one thread on the end that is chamfered or beveled. Use this tap when you need to cut full threads all the way to the bottom of a drilled hole.

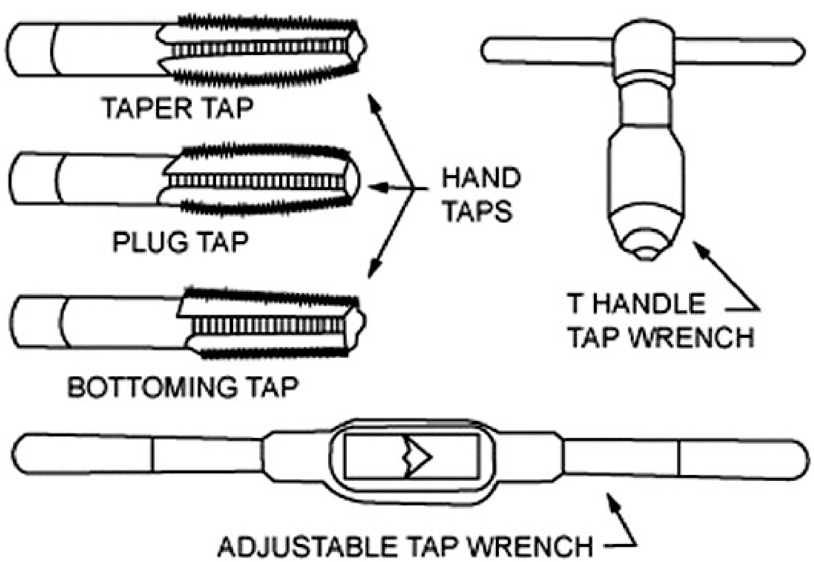


Figure 3–41. Hand taps and tap wrenches.

Before a tap is used, the hole must be drilled to the correct tap drill size. The tap drill size is the size of the drill that should be used to leave the proper amount of material in the hole for the tap to cut a thread. The tap drill, which is always smaller than the tap, leaves enough material in the hole for the tap to produce 75 percent of a full thread. You can get the drill sizes from tables in any machinist handbook (fig. 3–42).

Size	Threads Per Inch	Tap Drill Size	Decimal Equiva-lent
4	40	43	.0890
	48	42	.0935
6	32	36	.1065
	40	33	.1130
8	32	29	.1360
	36	29	.1360
10	24	25	.1495
	32	21	.1590
12	24	16	.1770
	28	14	.1820
1/4	20	7	.2010
	28	3	.2130
5/16	18	F	.2570
	24	I	.2720
3/8	16	5/16	.3125
	24	Q	.3320
7/16	14	U	.3680
	20	25/64	.3906
1/2	13	27/64	.4219
	20	29/64	.4531
9/16	12	31/64	.4844
	18	33/64	.5156
5/8	11	17/32	.5312
	18	37/64	.5781
3/4	10	21/32	.6562
	16	11/16	.6875
7/8	9	49/64	.7656
	14	13/16	.8125
1	8	7/8	.8750
	14	15/16	.9375
1-1/8	7	63/64	.9844
	12	1-3/64	1.0469
1-1/4	7	1-7/64	1.1094
	12	1-11/64	1.1719
1-1/2	6	1-11/32	1.3437
	12	1-27/64	1.4219

Figure 3–42. Tap drill sizes.

When a chart's not available, it's easy to find the tap drill size for any American National thread by applying this simple formula: T.D.S. = D – N where:

T.D.S.	=	Tap drill size
D	=	Major diameter of tap
N	=	Number of threads per inch

Example: Find the tap drill size for a $^5/_8$″–11 N.C. tap.

$$\text{T.D.S.} = {}^5/_8\text{"} - {}^1/_{11}$$
$$= .625 - .091$$
$$= .534$$

The nearest drill size to .534 is .531 ($^{17}/_{32}''$). Therefore, $^{17}/_{32}''$ is the tap drill size for a $^{5}/_{8}''$–11 N.C. tap.

The end of the hole to be tapped should be chamfered to a diameter at least equal to the thread diameter. This assures more accurate alignment and better starting of the tap, and it will keep a large burr from forming. Three methods of starting a tap are shown in figure 3–43. Note that one method involves using a T-handle tap wrench and two of them involve using an adjustable tap wrench. In any case, check the tap for alignment with the hole, as shown in the lower left view. The tap may break if it's not in alignment with the hole. If the tap doesn't enter squarely at the beginning, straighten it by removing it from the hole and restarting it with pressure applied in the direction opposite from which the tap was leaning. Be careful not to exert too much pressure at any one time in the straightening. It's safer to repeat this operation a second or third time, if necessary. When you have properly started and aligned the tap, it will follow and feed itself into the hole as you turn the tap wrench.

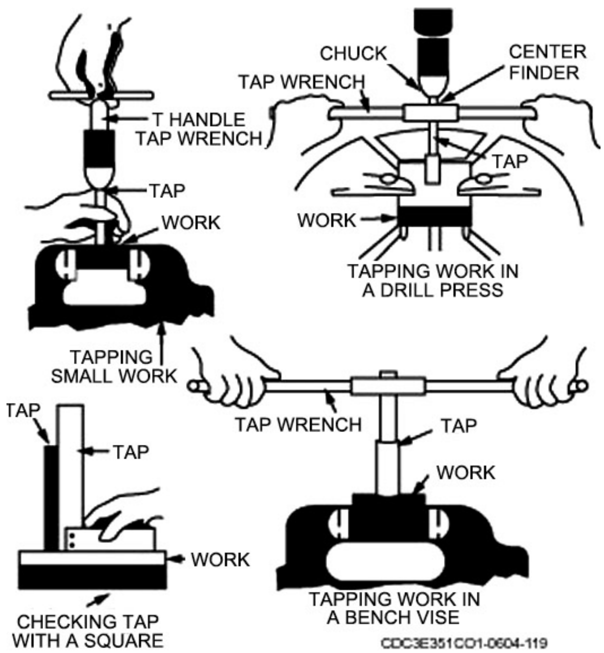


Figure 3–43. Starting a tap.

It's often possible to tap a hole while the work is still mounted in a drill press, immediately after the hole has been drilled and while the work is still aligned under the drill press spindle. This can save time and effort in clamping the work and starting the tap straight. The tap is held in place with a pointed rod mounted in the drill chuck. The point of the rod is placed in the centering hole on the end of the tap, and pressure is applied by using the spindle. The tap can then be turned with a tap wrench or an adjustable wrench.

When you're tapping steel or any tough metal, the best method is to take a partial turn forward, then a partial turn backwards to break the chip. Be careful to do this with a steady motion and turning pressure to avoid breaking the tap. Continue this until the hole has been completely tapped. Break the chips from time to time. Long chips have a tendency to clog the flutes and tear the threads. Always use a cutting lubricant to get best results.

Dies

A die is shaped like a hex head nut and is used to cut external threads on metal rods and to re-thread screws and bolts. Dies are formed in hardened discs of a uniform size that can be clamped in a leverage-producing device called a diestock. Figure 3–44 shows the complete assembly ready for use. Using dies is like tapping.

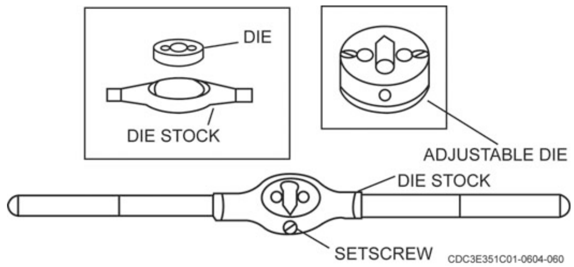


Figure 3-44. Dies and diestock.

Hold the work firmly in a vise and file off any burr on the end of the piece to be threaded. To start the thread, place the large opening of the die over the work and press down firmly while turning clockwise. When the die teeth catch and begin to cut, apply a few drops of cutting oil to the end of the work and continue turning as if tapping—a partial turn forward, followed by a partial turn backward—until the thread is cut to the right length. It's important to lubricate the work frequently. After the die teeth have taken hold, remove the feed pressure and let the threads pull the die onto the work at the proper rate.

Uses of clips, cleats, hangers, and braces

We've been looking at the way rivets, bolts, and screws are used for fastening sheet metal components and assemblies. Now let's look at some clips, cleats, hangers, and braces that fasten sheet metal components and assemblies. These fastening devices are usually made in the sheet metal shop to fit a particular assembly or component. Although we'll glance at only a few of the many variations of these devices, the illustrations will give you a good idea of how the devices are used, and it won't be hard for you to make adaptations for similar sizes, shapes, and uses.

<table>
<tr><th colspan="2">Sheet Metal Fasteners</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Clips</td><td>Clips are used to dress and strengthen corners of sheet metal assemblies that have been notched or damaged.

Figure 3-45 shows a clip used to strengthen the corner of a standing seam.

The size and shape of the corner, joint, or seam being strengthened determines the size and shape of the clip.

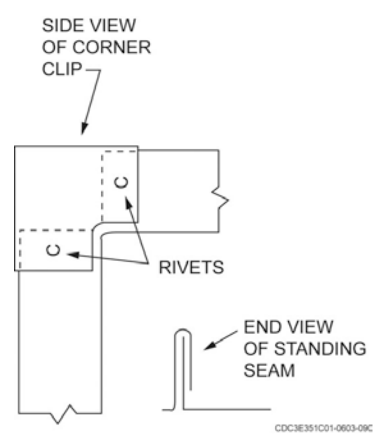
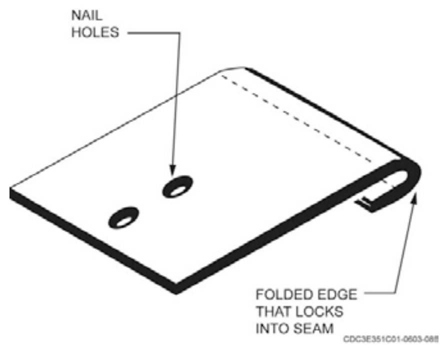


Figure 3–45. Clips</td></tr>
<tr><td>Cleats</td><td>Cleats are fasteners used with roofing nails to secure metal flashing and roofing.

The cleat is nailed at one end to the roof and the remainder is formed into the seams. Cleats may be used with standing or grooved seams. The length of cleats is determined by</td></tr>
</table>

Sheet Metal Fasteners	
Type	**Description**
	the seam being used, but it shouldn't exceed 2-inches. Figure 3–46 shows one type of cleat used with galvanized sheets. Notice the location of the holes. When you install soft copper roofs, the cleats should have nail holes near the end so that ½- inch of the cleat can be folded back over the nail heads; this keeps the nail from backing out and damaging the copper sheet.  **Figure 3–46. Cleat.**
Hangers	Hangers are used, to support and level heating and air conditioning ducts. The size and shape of the hanger depends on the size, weight, and material of the duct it supports. The location and the material of the structure supporting the hanger are other determining factors in selecting the type of hanger.
Braces	Braces are used when ducts are large and the sheet metal needs additional support and strength. The size and shape of the brace depend on the size and shape of the assembly.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

011. Using fasteners

1. What causes the blind rivet-pulling head to slip on the mandrel?

2. What are the three steps of installing tinner's rivets?

3. What procedure should you use to remove a solid rivet?

4. How do you "*draw*" a rivet, and what tools are required?

5. Where are sheet metal screws used?

6. What type sheet metal screw has a point?

7. What factor do you consider in using stove bolts?

8. Where are machine screws used?

9. What are the most common types of nuts used in the metal shop?

10. How do the three common types of hand taps differ?

11. Why should you turn the tap backward occasionally as you tap a hole?

12. Why should the end of the hole be chamfered before tapping?

13. What type of tap is used to tap a blind hole?

14. Why is it important to maintain the alignment of the tap with the hole to be tapped?

15. Where are clips used?

16. Why are clips used?

17. On a flat roof, what keeps the roofing nails from damaging the roof?

18. When are braces used?

19. How are hangers used?

Answers to Self-Test Questions

009

1. Flat, offset, and corner.
2. ½ inch.
3. Where appearance needs to be neat.
4. Corner lap seam.
5. (1) How big the item is; (2) how much it weighs; (3) the size load it must hold; and (4) whether it is to be watertight.
6. Two pieces of metal are formed in a series of bends and interlocked.
7. On cylinders, metal roofs, and stiffeners on ducts.
8. To join two pieces of sheet metal and to act as a stiffener.
9. 3H + 2T or, three times the height of the seam plus twice the thickness of the material.
10. 90 degree.
11. Joining the edges of round duct joints.
12. 3W + 3T for light gauges, and 3W + 5T for heavy gauges.
13. Twice—once to fold the pocket and once to flatten it.
14. Bar folder, cornice brake, and Pittsburgh lock-forming.
15. A backing plate or bench stake and a mallet.
16. The seam should be center-punched in several places.
17. Corner and bottom.
18. 3W + 2T or, three times the seam width plus two times the metal thickness.
19. Setting hammer and backing plate or suitable bench stake.
20. For the corners and edges of square and rectangular ducts, and on transitions and elbows.
21. $^{15}/_{16}$ inch, 1 inch, or 1 $^{1}/_{16}$ inches for the pocket side and ¼ inch for the flanged side.
22. 1 ¼ inches for the pocket and ¼ inch for the flange.
23. To keep from damaging the machine surfaces.
24. Setting hammer and rivet set.
25. The button punched hooks on the flange and the hook inside the pocket lock together.
26. Cylinder or round.
27. Make a cut every ½ inch all around the duct and bend every other tab out 90°. Place unbent tabs through the flat surface and then bend them out 90°.
28. None.

010

1. Cross brake.
2. 20 gauge.
3. Thickness of the sheet metal used.
4. The flat S-slip.
5. Standing edge.
6. To flatten the S portion (last two bends) to form 180°.
7. To connect the long sides of duct sections.
8. S-slips.
9. 20 inches.
10. By cutting the bend allowances at a 45° angle at one end.
11. Attach both S-slips on one piece of duct.
12. To hold the duct sections in place.

13. Bend the ends of the drive slips over the corners of the duct to hold the drives in place.
14. To join rectangular takeoff fittings to rectangular ducts.
15. Form the Pittsburgh seams.
16. By bending the tabs over inside the duct.
17. To connect small sections of round duct to transition pieces.
18. Two.
19. One end of each piece is crimped.

011

1. The jaws are loaded.
2. Set, upset, and head.
3. File a flat spot on the manufactured head, center punch, drill the depth of the head with a drill bit the same diameter as the rivet shank, and drive the rivet out with a pin punch.
4. Place a solid rivet, head down, on a bench plate; place the metal to be joined over the rivet; and tap lightly with a mallet. Use a rivet set and tinner’s hammers to drive the rivet through the metal.
5. In metal parts that may require disassembly.
6. Type A.
7. Vibration.
8. In tapped holes or nuts.
9. Square, hexagon, wing, self-locking, and sheet spring.
10. By the number of threads tapered back from the end.
11. To keep from tearing the threads.
12. To help start the tap.
13. A bottoming tap.
14. To keep from breaking the tap.
15. On the corners of sheet metal assemblies.
16. To dress and strengthen corners.
17. Part of the cleat is bent over the head of the nail.
18. When large ducts need more support and strength.
19. To support and level duct systems.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

24. (009) Which fastening method *cannot* be used to hold sheet metal lap seams together?
    a. Rivets.
    b. Screws.
    c. Butt welds.
    d. Spot welds.

25. (009) What are the three types of *lap seams* used in *duct work*?
    a. Flat, offset, corner.
    b. Half, full, and ship.
    c. Standing, rest, and end.
    d. Vertical, horizontal, and overhead.

26. (009) When choosing the best fastening method you *do not consider*?
    a. the size of the item.
    b. the weight of the item.
    c. the height at which item will be installed.
    d. whether or not the item must be water tight.

27. (009) In duct fabrication, *standing seams* can be used to
    a. provide support for air grilles.
    b. connect joints of rectangular duct.
    c. attach take off fittings for branch lines.
    d. provide a mounting surface for diffusers.

28. (009) What is the *seam allowance* for a 1½-inch standing seam in 16-gauge sheet metal?
    a. 3.00 (3) inches.
    b. 3.50 (3½) inches.
    c. 4.25 (4¼) inches.
    d. 4.62 (4⅝) inches.

29. (009) How is the seam allowance for a *standing seam added to the pattern*?
    a. Equal amounts to each half.
    b. More to one half than the other.
    c. The full seam allowance to each half.
    d. The seam allowance is added to a separate piece of metal.

30. (009) Which type of seam is used on *round duct joints and metal roofs*?
    a. Double.
    b. Standing.
    c. Grooved.
    d. Pittsburgh.

31. (009) When making seam allowances, you *must* consider
    a. type of fastener and thickness of metal.
    b. width of seam and thickness of metal.
    c. width of duct opening.
    d. thickness of the joint.

32. (009) The bottom double seam is used to fasten an end on a *duct that is*
   a. pressurized.
   b. watertight.
   c. rectangular.
   d. cylindrical.

33. (009) What *tools are required* to *set a double seam in sheet metal*?
   a. Mallet and bench stake.
   b. Mallet and hand groover.
   c. Ball peen hammer and dolly.
   d. Ball peen hammer and cold chisel.

34. (009) To avoid damaging the seam what should be done *before using the Pittsburgh machine*?
   a. Adjust it for metal thickness.
   b. Feed your material in at an angle.
   c. Remove power from the machine.
   d. Make sure all guards are installed.

35. (009) How many parts make up a *Pittsburgh lock seam*?
   a. 1.
   b. 2.
   c. 3.
   d. 4.

36. (009) Before removing the sheet metal from the cornice brake, which tool do you use to *flatten the seam flange* for a Pittsburgh lock seam?
   a. Tinner's riveting hammer.
   b. Tinner's setting hammer.
   c. Ball peen hammer.
   d. Mallet.

37. (009) What do you use to *seat a Pittsburgh sheet metal flange in the pocket?*
   a. Bar folder.
   b. Cornice brake.
   c. Hammer and rivet set.
   d. Rawhide mallet and anvil.

38. (010) The recommended joint connection and bracing for a 24-gauge galvanized steel duct, 23-inches wide installed with 35-inch centers, is a drive slip and a
   a. flat S-slip with a cross brake added for strength.
   b. flat S-Slip with a 1 × 1 × ⅛-inch angle iron support.
   c. standing S-slip with a cross brake added for strength.
   d. standing S-slip with 1 × 1 × ⅛-inch angle iron support.

39. (010) For a duct that is 20-inches wide × 15 inches high the *drive slips* should be?
   a. 15-inches long.
   b. 17-inches long.
   c. 20-inches long.
   d. 22-inches long.

40. (010) Drive slips are cut with 45° angles on one end for
   a. easier installation.
   b. joint expansion.
   c. easier bending.
   d. joint clearance.

41. (010) Which seam is used to join *rectangular takeoff fittings to rectangular ducts*?
    a. Tapped.
    b. Double.
    c. Flanged.
    d. Grooved.

42. (010) "Clinch lock," "P-lock," and "tap connector" refer to what type of connections?
    a. Riveted.
    b. Tapped.
    c. Soldered.
    d. Spot welded.

43. (010) Each end of a sheet metal duct section requires how much *allowance* for the S- and drive connections ?
    a. ½ inch.
    b. ¾ inch.
    c. 1⅛ inches.
    d. 1¼ inches.

44. (010) To *form a slip joint* you must
    a. double the seam allowance for the double lock seam.
    b. double the seam allowance for the single lock seam.
    c. crimp both ends of each round duct piece.
    d. crimp one end of each duct piece.

45. (011) What is the *first step* in rivet installation?
    a. Setting.
    b. Backing.
    c. Drawing.
    d. Upsetting.

46. (011) Installing solid rivets in light-gage metal *without first drilling or punching holes* is called
    a. driving rivets.
    b. drawing rivets.
    c. upsetting rivets.
    d. transversing rivets.

47. (011) Which of these is *not* a type of *sheet metal screw*?
    a. Type A.
    b. Type Z.
    c. Wing nut.
    d. Self-tapping.

48. (011) What tool is recommended for tightening a *hex-head nut*?
    a. Pliers.
    b. Vice grips.
    c. Box-end wrench.
    d. Open-end wrench.

49. (011) When the hole goes all the way through the work what *type of tap is used?*
    a. Plug tap.
    b. Taper tap.
    c. Finish tap.
    d. Bottom tap.

50. (011) What is used to cut external threads on metal rods and to re-thread screws and bolts?
    a. Die.
    b. Tap.
    c. Chamfer wrench.
    d. T-handle wrench.

Glossary

Terms

Alloy—A combination of metal and one or more elements mixed together to create specific properties.

Bar folder—A machine that folds metal from 0 to 165 degrees.

Beading machine—Makes beads in sheet metal objects such as cans, buckets, and pipes.

Black iron—Low-carbon steel that is available in various forms such as sheets and angle.

Blueprint—A photographic reproduction that shows drawings in a white on blue background. They are used for architectural and engineering plans for construction.

Box and Pan brake—A machine that has removable fingers to fold metal into various sized pans and boxes.

Braces—Metal strips that are fabricated into a shape that adds strength and support to large sheet metal ducts. A brace can be installed either inside or outside of ducts.

Cleat—A fastener used with roofing nails to secure metal flashing and roofing.

Clip—A fastener used to dress and strengthen sheet metal corner assemblies.

Circle cutters—A tool used with a drill press to cut circular shaped holes in metal.

Condensation—A physical process that involves a liquid being removed from a vapor. It usually occurs in air duct when the air duct is much colder than the room air. This is how water can form and drip from the duct.

Converging—To come together or tend to come together at a point.

Cornice brake—A machine that folds metal and can be used for simple to complicated tasks such ascomplex seams and round bends.

Countersink—A tool used with a hand, battery, or electrically powered drill to bevel the edges of metal for rivets or bolts with countersunk heads for flush to the surface installation.

Crimping machine—Makes one end of a pipe joint smaller than the other end so that the two sections can be slipped together.

Dies—1. Tools that resemble a hex head nut and are used to cut external threads on metal and to rethread screws, and bolts. 2. A form used to form metal in the drawing or extruding process.

Diffusers—A component of an air duct system that diffuses air for even air distribution.

Dollies—Portable, heavy, and thick metal tools that are available in various shapes to form metal and serve as a bucking bar for riveting.

Drawings—The art of representing something by lines and can be done by hand with pencils and paper or can be done on a computer.

Elbow edging machine—Fabricates interlocking edges on metal elbows to join together.

Folding equipment—Machines that folds metal to specific angles.

Forming equipment—Forms distinctive shapes in sheet metal.

Grooved seam—Modified Pittsburgh lock seam that is used to secure two pieces of metal together.

Hand forming equipment—Tools that are used by hand to shape sheet metal.

Hand groover—A hand operated tool used to groove seams after they have been formed.

Hand seamer—A hand operated tool that can be used to form seams, make joints, or produce folds in light gauge metal.

Hanger—A metal component that supports and levels heating and air conditioning ducts.

Height—This term indicates a dimension of an object, or a part of it, that rises above either the surface of the object being described or the one on which it stands.

Lap seam—A seam in which one piece of metal partially extends or laps over another. There are three general types: flat, offset, and corner.

Length—Refers to the greatest dimension of an object or the greatest dimension of any part of the object being described.

Lock seams—A metal allowance which is formed into a series of bends which interlock. Many times lock seams act as stiffeners in sheet metal components.

Metrics—First established in France following the French Revolution the metric system consists of three principal units of measurement—meter, liter, and gram. The metric system is based on units of ten.

Notes—Similar to portions of the specifications and are used to explain the drawing.

Offset—A curve or bend in a metal bar, pipe, and so forth, to permit it to pass an obstruction.

Pittsburgh lock forming machine—Forms Pittsburgh lock seams on corners of rectangular orsquare ducts, and grooved seams for round ducts.

Pittsburgh seam—A locking seam that is used to join two pieces of metal together.

Plans—Also known as blueprints or working drawings. They show lines, dimensions, symbols, specifications and notes. They also convey ideas concerning fabrication, assembly, and installation of structural components.

Punches, hand—Hand operated tools used for marking metal before drilling, for removing pins, for aligning and piercing holes.

Punch, rotary—A machine that has two cylindrical turrets, one mounted over the other and supported by a metal frame. A rotary punch is designed to punch various sized holes in metal.

Radius—Any straight line extending from the center to the periphery of a circle or sphere.

Register—A device that meters or controls airflow in a duct system.

Rivets—A metal fastener with a head on one end. Rivets are placed in holes so that the plain end can be hammered down to join metal or other materials together. If blind rivets are used, a lever action rivet gun is used instead of a hammer.

Rivets, drawing—A process used to install rivets in light gauge metal without drilling or punching a hole first.

Rotary burring machine—Turns flanges and edges on circular discs and cylinders. A rotary burring machine can be used to turn edges on elbows and make double seams or single hems.

Slip roll forming machine—Forms flat metal sheets into various sized cylinders.

Snap lock machine—Fabricates snap lock seams in metal for air ducts.

Snips—Hand operated tools that utilize scissor cutting action to cut flat metal sheets.

Specifications—Indicate clearly the quality and quantity of materials, the methods of construction, the nature of the workmanship, the manner of conducting the work, and the general conditions and agreements. Specifications consist of two types; general and specific.

Stainless steel—A steel alloy that contains nickel, chromium, carbon, manganese and silicon. It is hard and resists scratches and corrosion. It is available in sheets that have a dull or polished finish.

Stakes—Small anvils that are used to shape metal by hand. They can be secured in a bench vise or mounted to a work bench. There are many types available and all of them have a horn, head, and shank.

Stove bolts—Metal fasteners used to secure material where accuracy, strength, and vibration resistance are not important.

Tap—Tool used to cut threads on the inside of a round hole.

Thickness—Refers to the smallest dimension of any part of the object being described. Thickness can apply either to the main part of the object or to some separate part attached to the object being described.

Transition—A passing from one condition, form, stage, activity, place, and so forth, to another.

Turbulence—Full of commotion, violent, irregular motion, or swirling agitation of water, air, gas, and so forth.

Turning machine—Forms rounded flanges for wired edges on sheet metal. A turning machine can also be used to turn double seams on elbows**.**

Ventilator—A device used to bring in fresh air and drive out foul air.

Visual test—A critical look at spot welds for external or internal welding defects.

Water gauge—A measurement in inches that is used to represent the negative air pressure found in air duct systems. Twenty-seven inches of water gauge is equal to one psi.

Width—Usually refers to the dimension of an object from side to side, or in a direction at right angles to the length.

Glossary of Abbreviations and Acronyms

AFOSH	Air Force Occupational Safety and Health
ANSI	American National Standards Institute
BA	bend allowance
BCE	base civil engineer
BTL	bend tangent line
CFM	cubic feet of air per minute
cm	centimeter
dkm	decameter
dm	decimeter
FPM	feet per minute
hm	hectometer
kg	kilogram
km	kilometer
ML	mole line
mm	millimeter
MSDS	material safety data sheet
OC	On center
ppsf	pounds per square foot
psf	per square foot
psi	pounds per square inch
R	radius
RPM	Revolutions per minute
SB	setback

Student Notes

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