CHAPTER

13

Piping Isometrics

WHAT IS AN ISOMETRIC?

An isometric is a type of three-dimensional drawing known as a pictorial. Isometrics, or *isos* as they are commonly called, are developed using the three primary dimensions of an object: height, width, and depth. Unlike orthographic drawings that represent the height, width, and depth dimensions in separate views (see Figure 13.1), the isometric combines the three dimensions of the object into a single view to provide a pictorial representation of the object (see Figure 13.2). To include the height, width, and depth dimensions in a single view, an isometric must be drawn on axes that measure 30° from the horizontal plane, as shown in Figure 13.2.

Like the front, Top, and Right Side views in Figure 13.1, Piping Plans, Sections, and Elevations offer limited visualization of an object, especially when piping components like fittings, flanges, or valves are incorporated. However, by combining the height, width, and depth dimensions found on Plan, Section, or Elevation views, a single pictorial view can result in a drawing that provides greater clarity of the piping configuration. A comparison between the orthographic views shown in Figure 13.3 and the isometric in Figure 13.4 demonstrates that an isometric with piping symbols is obviously clearer and easier to understand than standard orthographic views.

The piping isometric is an important drawing that serves several purposes. It is the primary source for *material take-off* of each pipe configuration in the facility. Material Take-off is the process by which each individual component that makes up a pipe configuration is tabulated for purchase or procurement. This means all piping components (elbows, flanges, nuts, bolts, washers, gaskets, etc.) must be counted so that purchases of those

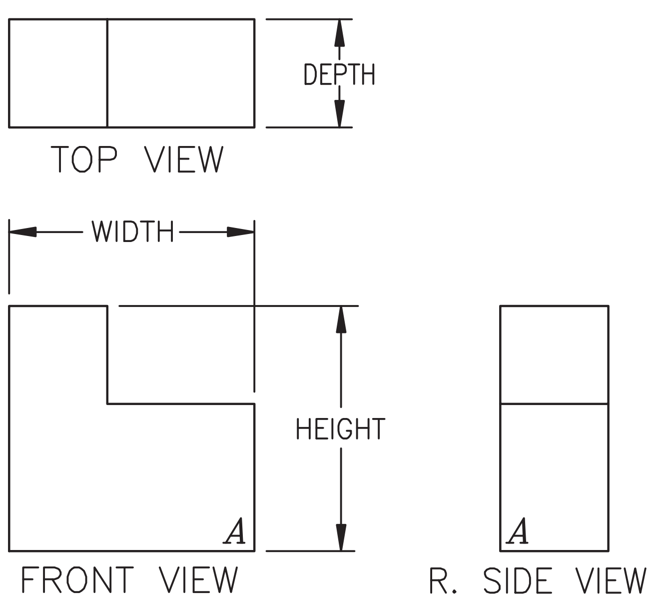


FIGURE 13.1 Orthographic views.

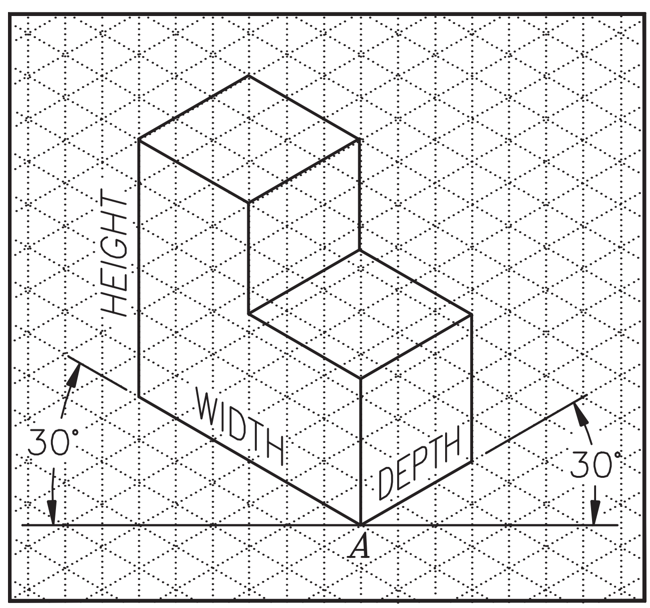


FIGURE 13.2 Isometric view.

© 2012 Elsevier Inc. All rights reserved.

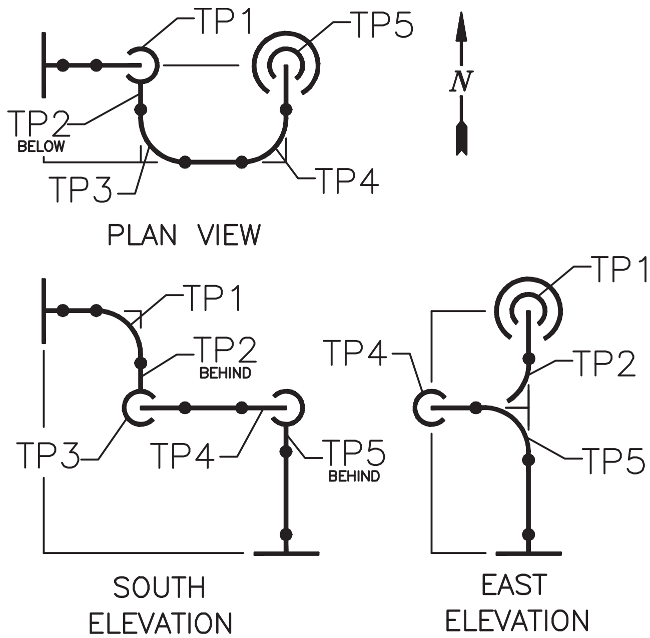


FIGURE 13.3 Piping orthographic views.

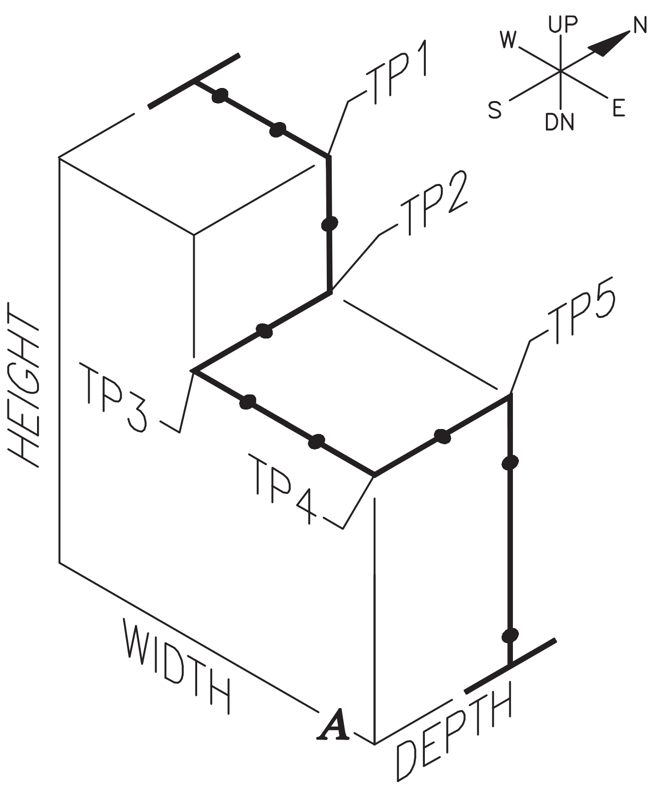


FIGURE 13.4 Piping isometric view.

items can be made. The tabulated results are referred to as the Bill of Materials, or BOM. Isometrics also serve as fabrication drawings. Once drawn and properly dimensioned, isometrics are provided to fabricators who build each piping configuration. Fabricators will use the completed isometrics to build shop spools. *Shop spools* are detailed specifically for pipe welders and fitters with precise cut-lengths and weld symbols, which are not typically shown on isos. After configurations are fabricated, X-rayed, painted, and shipped to the construction site, isometric drawings serve as an aid to the construction and erection of the facility by providing workers with the locations of tie-ins, connections, and routings.

Most engineering and construction companies develop a piping isometric of every piping configuration to be installed in the facility. Piping isometrics are typically created single-line regardless of the pipe's nominal size. Each pipe line is drawn or plotted individually on a sheet of paper with its tabulated BOM. Pipe isometrics are also drawn as a schematic, which means they are not drawn to scale. One common isometric symbol for fittings, flanges, and valves will represent all sizes of pipe. No attempt is made to represent a pipe's actual size or pound rating graphically. This information is conveyed through the use of callouts and notes, particularly the line number, placed on the drawing. Although piping isometrics are not drawn to scale, drafters should make every effort to draw them proportionally. Drawing an iso proportionally simply means one should draw a 10′-0″ run of pipe twice as long as a 5′-0″ length of pipe, when possible.

To be successful in drawing isometrics, the pipe drafter must be able to interpret the information conveyed by the drawing symbols of fittings, flanges, or valves represented on piping arrangement, section, and elevation drawings and transfer that information to the isometric. Note in Figures 13.3 and 13.4 that the elbow symbols differ in the orthographic and isometric views. Piping symbols used on plan, section, or elevation drawings dictate whether a pipe turns left, right, up, or down. When the pipe represented on an orthographic drawing makes a change in direction, that change must also be reflected on the isometric drawing. The point at which the pipe changes direction can be referred to as the *turning point* (TP). To correctly draw the isometric representation of a pipe shown on a plan, section, or elevation view, the pipe drafter must be knowledgeable in the use of piping symbols used in orthographic views and the corresponding symbols used on isometric views.

To make piping isometrics look standardized, companies that hand-draw isometrics use drawing paper that has preprinted isometric grid lines that are used as a drawing aid to establish uniform sizes for fitting, flange, and valve symbols. Remember piping isometrics are not drawn to any particular scale. No matter what size or pound rating the fittings are, they are all drawn the same size. Figure 13.5 shows the size and shape of manually drawn isometric symbols for fittings, flanges, and valves relative to the isometric grid. These symbols are typical of industry applications and should be used as a guide when drawing piping isometrics.

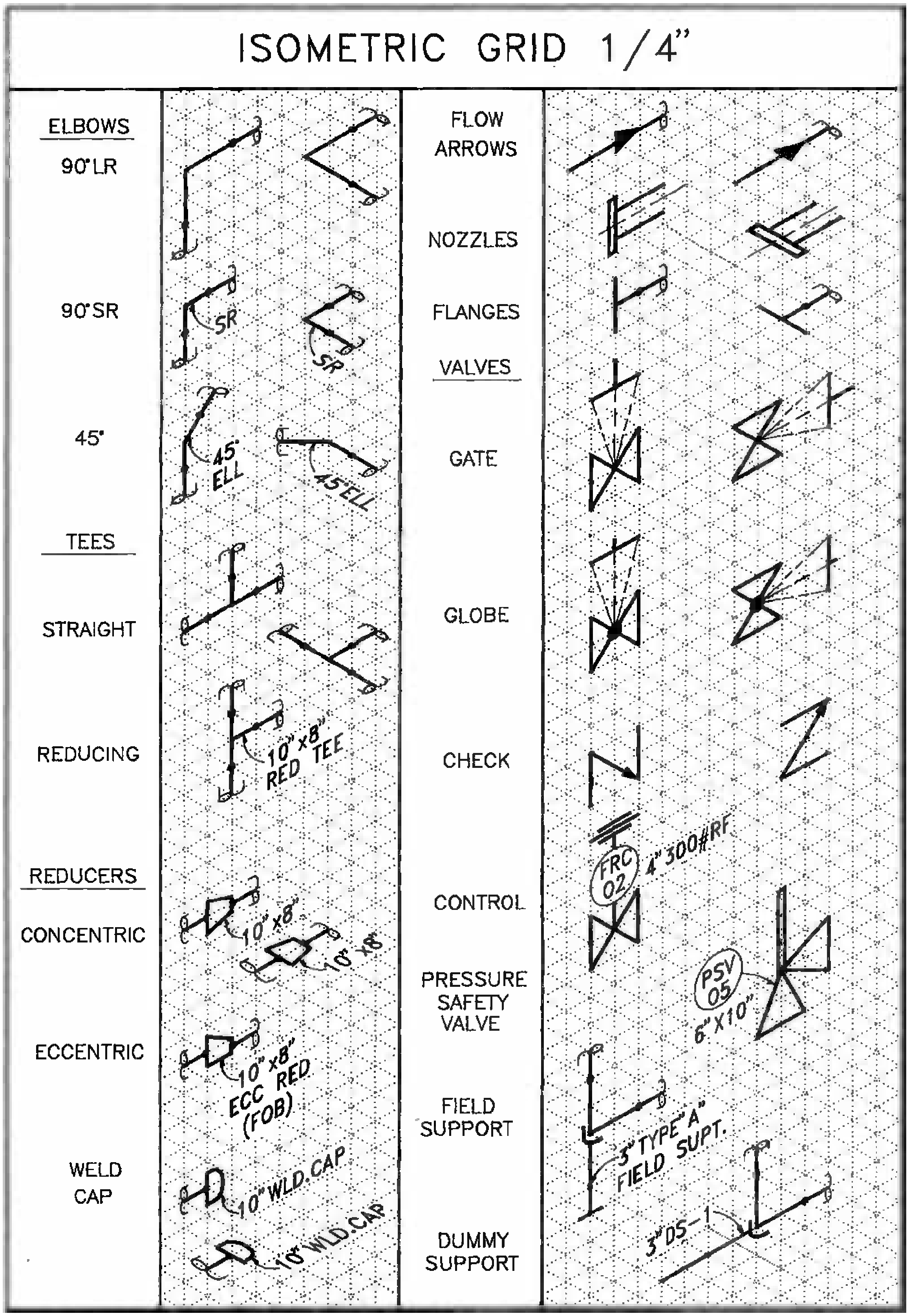


FIGURE 13.5 Isometric piping symbols.

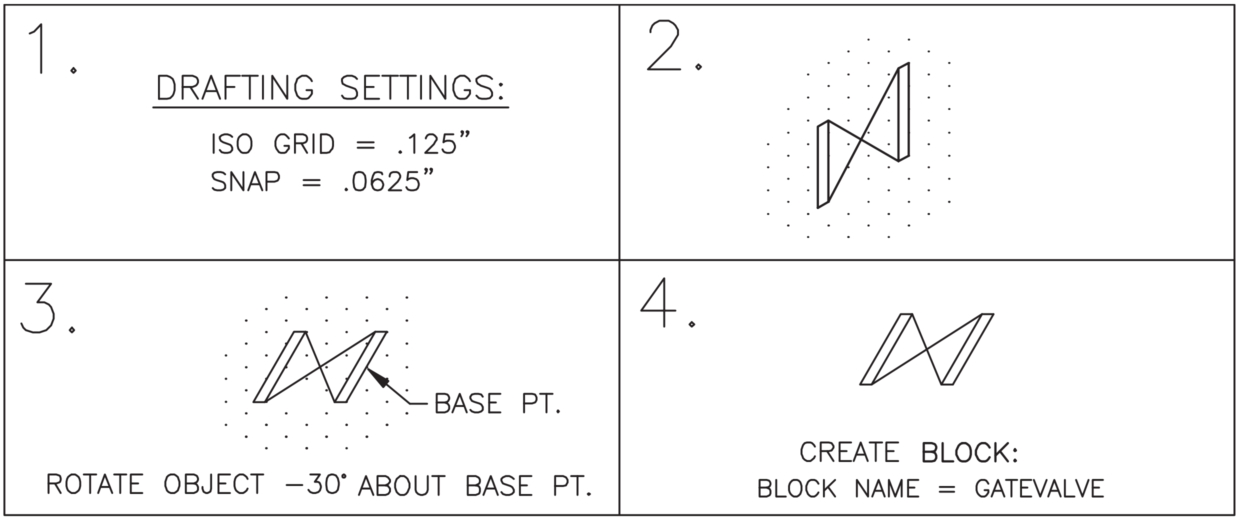


FIGURE 13.6 Creating isometric piping symbols using AutoCAD.

- **Step 1.** Drawing setup. Set the **SNAP** *Style* to *Isometric*. Set the vertical spacing to 0.125″. Set **SNAP** to 0.0625″.
- **Step 2.** Using the isometric grid as a guide draw the desired symbols.
- **Step 3. ROTATE** each symbol –30° about a centralized point (Base Point in Step 3 illustration).
- **Step 4.** Create a **BLOCK** of each symbol. Use a name that accurately describes the component. Select a Base Point that will permit convenient attachment to other components in an isometric.

Isometric symbols drawn with **AutoCAD** can be developed so that a single orientation of the symbol can be used in any of the isometric axes. Isometric symbols can be drawn, rotated, and **BLOCKed** for repeated use in any drawing at any isometric angle. Initially symbols for fittings, flanges, or valves are drawn on the north/south isometric axis, but before they can be used in the other isometric axes, they must be rotated −30° about a *Base Point* placed on the center of the symbol. Use the step-by-step procedures provided below and illustrated in Figure 13.6 to create isometric piping symbols using AutoCAD commands.

Figure 13.7a,b show the size of the symbols relative to the isometric grid in AutoCAD. Companies that use 3D plant modeling software use the software's feature that automatically generates isometrics of the modeled pipes. Isos generated by modeling programs are fully dimensioned, including notes and callouts, and have a completed BOM. It is common however that revisions be made to those isos to reflect client design requirements and drawing enhancements.

ISOMETRIC ORIENTATION

Note in Figures 13.1 and 13.2 how the height, width, and depth dimensions of the L-shaped object in the orthographic views are oriented on the isometric view with ***A*** as a point of reference. By using a point of reference, proper orientation of the isometric can occur by transferring distance and direction from the orthographic view. Similarly, on piping isometrics, establishing a point of reference is imperative. Although the ***A*** can be seen in Figures 13.3 and 13.4, it is not an adequate point of reference. The complexity of piping configurations requires a more descriptive "point of reference" be used to establish orientation between the orthographic and isometric views. In the piping discipline a *north arrow* is used as a "point of reference." Accurate isometric layout is based on the correlation of the orientation of the north arrow on the Piping Arrangement drawing and the north arrow on the piping isometric. Figure 13.8 illustrates the representation of the north arrow on the arrangement drawing and the north arrow on the isometric.

Knowing that the Piping Arrangement drawing is a plan, or top, view drawing, a pipe can be determined to be turning north, south, east, or west when oriented relative to the drawing's North Arrow. So, if a pipe that has been traveling north turns down and then east on the arrangement drawing, it should also be shown to travel north, turn down, and then east on the isometric drawing. Figure 13.9 illustrates the correlation between pipe components shown in a Plan View and those same items in an isometric view. As you may notice, items that can be difficult to visualize on the Plan View drawing become much more evident on the isometric.

Most companies prefer to draw piping isometrics with the north arrow pointing up and to the right. An alternate position is to draw the North Arrow pointing

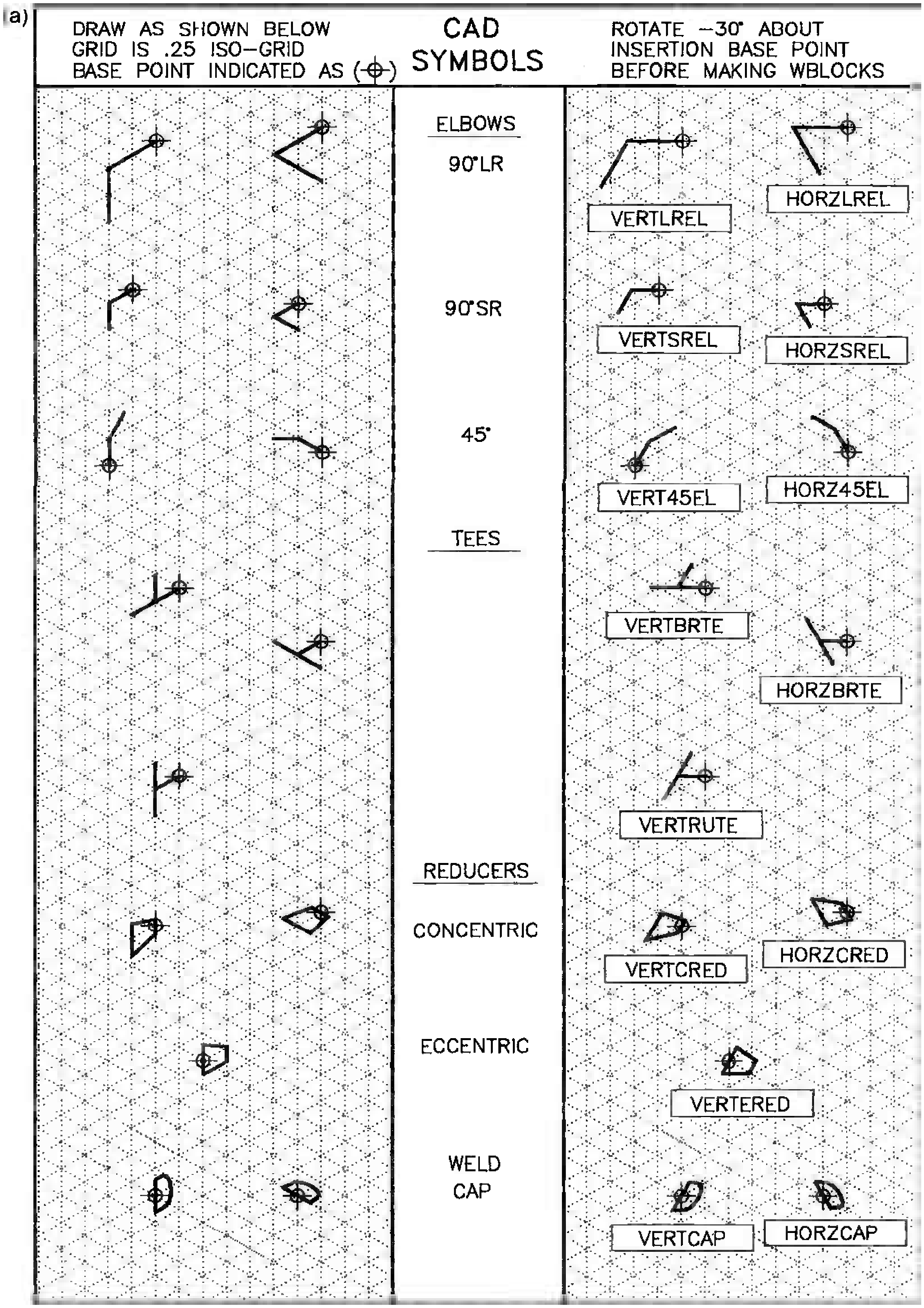


FIGURE 13.7 (a,b) AutoCAD isometric piping symbols.

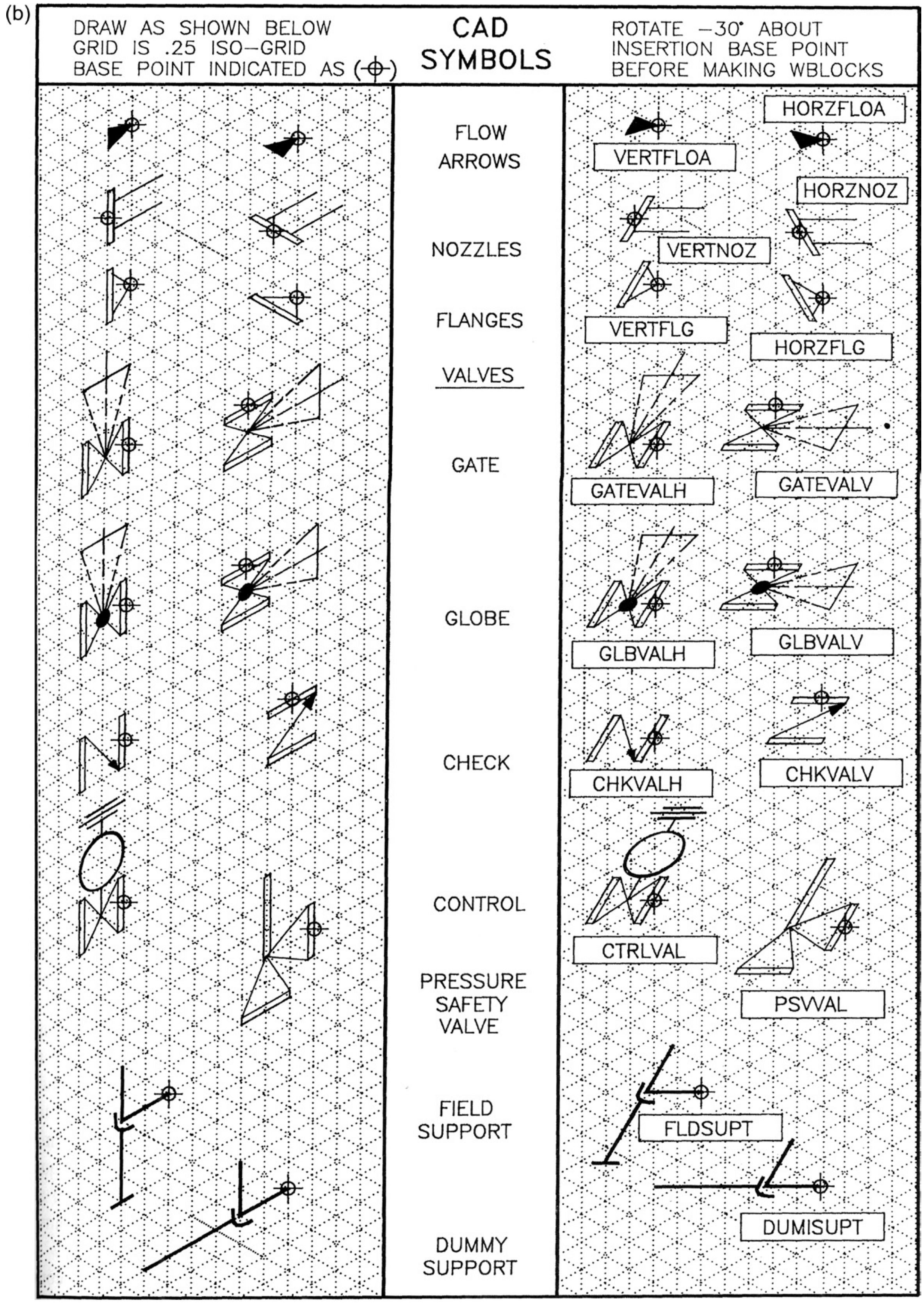


FIGURE 13.7 (*Continued*)

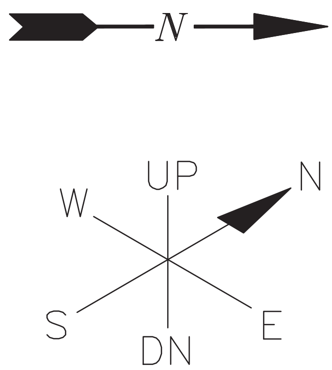


FIGURE 13.8 Orthographic and isometric north arrows.

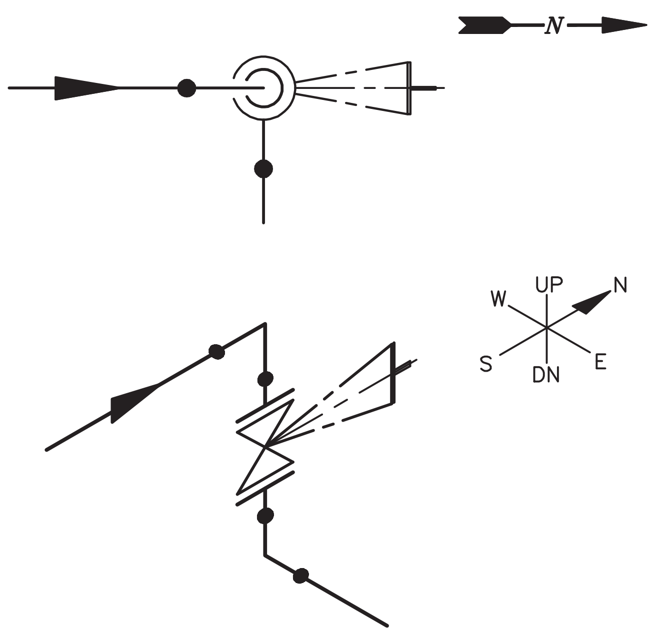


FIGURE 13.9 Isometric orientation.

up and to the left. This is done, however, only in exceptional cases to improve drawing clarity. Figure 13.10 uses the configuration from Figure 13.9 to demonstrate how drawing an isometric with the North Arrow pointing up and to the left will affect the isometric representation. The North Arrow rarely, if ever, points down.

DRAWING PIPING ISOMETRICS

As an isometric for a particular line is developed, constant reference to the Piping Arrangement, Section, or Elevation drawings is essential. Drawing symbols, callouts, coordinates, and elevations provide detailed information of the pipe's configuration and routing as it travels through the facility. By using this information and the isometric symbols that correspond to the various orthographic drawing symbols, the pipe drafter

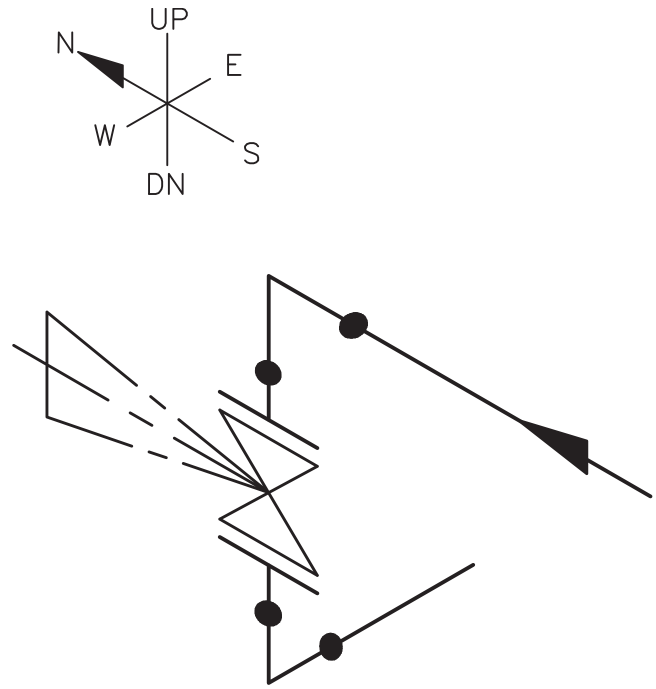


FIGURE 13.10 Alternate isometric orientation.

can develop an isometric describing the pipe's routing. Remember, the isometric must provide a detailed description of the pipe's routing from beginning to end. However, this does not apply to a pipe in a pipe rack. Piping isometrics are generally drawn to represent the configuration up to and including the first fitting in the pipe rack. Use the procedures that follow to develop a piping isometric of line 01-2-C30-10″-IH.

As shown in Figure 13.11, line 01-2-C30-10″-IH is attached to vessel V-101, at nozzle **N1,** and reboiler E-101 at nozzle **C**. The line begins, relative to the flow direction, at nozzle **N1** with a flange and elbow welded together, fitting makeup. The elbow is oriented toward the north, according to the North Arrow. Therefore, as seen in the isometric view in the upper right, if line 01-2-C30-10″-IH turns north on the arrangement drawing, it must also turn north on the iso. To determine the distance a pipe travels in the north direction, or any other horizontal plane, one must use two coordinates. Remember, horizontal dimensions are calculated using coordinates and vertical dimensions are calculated using elevations. So, if there were a need to determine the distance a pipe travels in a vertical plane, a drafter would need one of the following: elevation callouts (found on the plan view drawing) or an elevation drawing that graphically depicts the amount of vertical change. Also, recall elevation changes can be shown on the Piping Arrangement drawing in the form of callouts, but the elevation callouts must be adequate enough to determine the length of the pipe traveling in the vertical plane.

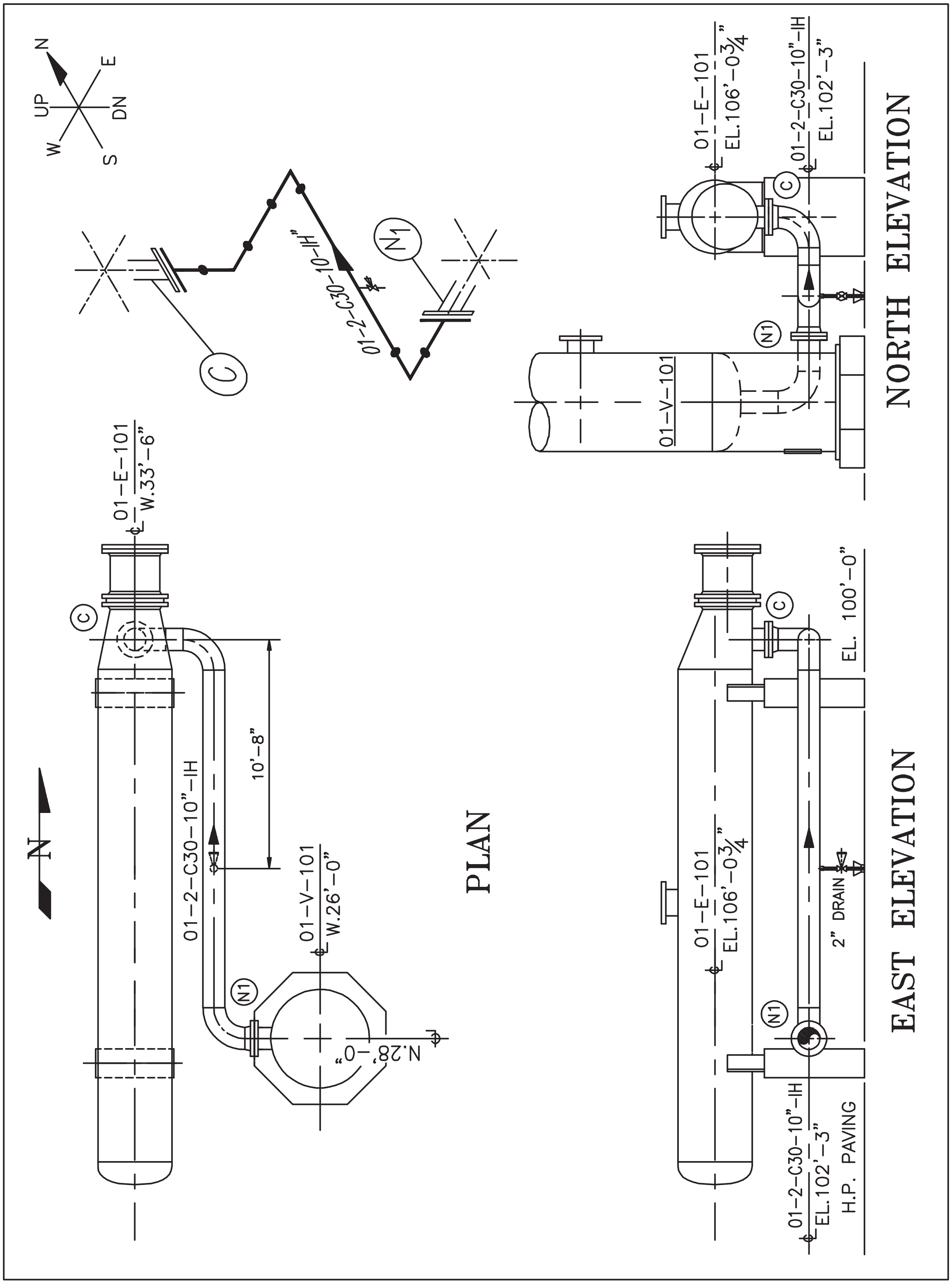


FIGURE 13.11 Line 01-2-C30-10″-IH.

After the north run, an elbow turns west and line 01-2-C30-10″-IH travels below reboiler E-101. Note the elbow is also shown turning west on the iso. When the pipe aligns with the centerline of E-101, another elbow turns the line up and into nozzle **C.** Isometric drawing symbols for 90° and 45° elbows are typically shown with square corners, as opposed to the round corners found on arrangement drawings. However, it is not unusual for some companies and CAD software and 3D modeling packages to draw elbow symbols with round corners. Note also the equipment nozzles are drawn double-line on isos, to distinguish them from flanges and valves. Other important details about line 01-2-C30-10″-IH that must be represented on the iso are shown in Figure 13.12. They include intersecting coordinates for the center of the equipment, nozzle elevation, nozzle number, nozzle projection, and the name/number of the piece of mechanical equipment. In addition to all the information shown, if a nozzle on one end of the configuration happens to be of a different size and pound rating than the rest of the pipe its mating flange is considered to be *out-of-spec*, and that information must also be shown on the isometric, near that particular nozzle.

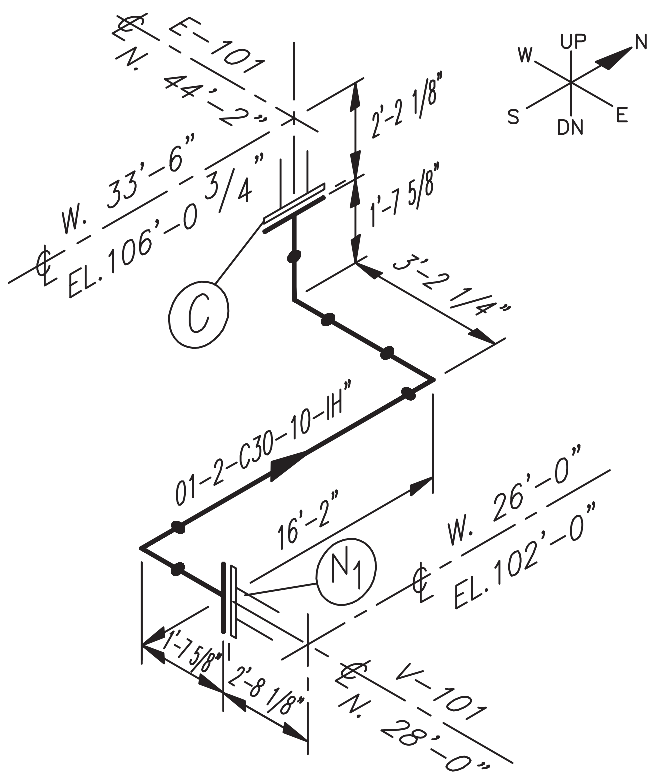


FIGURE 13.12 Line 01-2-C30-10″-IH with dimensions and callouts.

The alignment and orientation of written information (name, coordinates, elevation) about a vessel and/or nozzle on an isometric are sometimes confusing. The four labeling examples in Figure 13.13 indicate that callouts for North and South centerline coordinates are actually written on centerlines running in the east/west direction, while East and West centerline coordinates are labeled on centerlines that run in the north/south direction. To better understand this concept, remember that coordinates measure the distance an object is from the 0′-0″, 0′-0″ origin. So, if a vessel is 30′-0″ east of the 0,0 origin it must have a centerline coordinate indicating its geographic direction and lineal distance. However, proper piping isometric labeling techniques require that it be written along the north/south axis so that it can be read properly. The ***E. 30′-0*″** coordinate indicates a 30′-0″ distance in the east direction, although

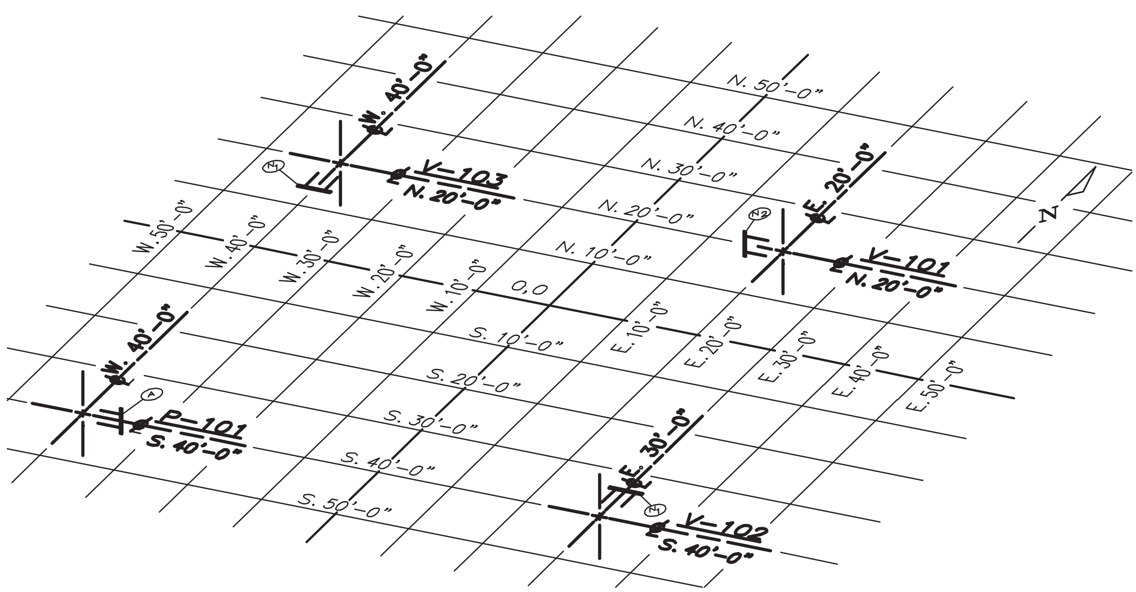


FIGURE 13.13 Isometric orientation and labeling of vessel centerlines.

it's written along the north/south axis. As a reminder, all mechanical equipment, structural columns, foundations, etc. require two intersecting centerline coordinates to locate their exact position.

ISOMETRIC DIMENSIONS, NOTES, AND CALLOUTS

Isometric Dimensions

Length dimensions, in addition to informational notes and callouts, are used on isometrics to define the pipe's exact routing through the facility. Placement of dimensions on the drawing establishes precise lengths between fittings, valves, equipment connections, etc. Numerous pieces of important information from Piping Arrangement drawings, Sections, Elevations and vendor drawings are used to calculate dimensions on a pipe isometric. These include such items as centerline coordinates, nozzle elevation and projection, and pipe size and pound rating. Three types of dimensions exist on an isometric, they are center-to-center, center-to-face, and face-to-face. Figure 13.12 provides dimensions for line 01-2-C30-10″-IH using information found on the Plan and Elevation views shown in Figure 13.11 and the equipment vendor drawings found in Chapter 10, "Piping Arrangement Drawings, Sections, and Elevations."

Placing dimensions on a piping isometric with **AutoCAD** requires the use of the *Aligned* and *Oblique* options within the **DIMENSION** command. Figure 13.14 provides two options for placing dimensions on piping isometrics. Dimensions should be aligned with the routed pipe and "obliqued" as shown in Figure 13.15.

Isometric Notes and Callouts

Dimensions alone cannot provide all the information required to properly describe a piping isometric. Notes and callouts placed on the drawing provide significant information that may impact the purchase, fabrication, and erection of the configuration. Appropriately placed notes are used to denote the size and pound rating of fittings, flanges, and valves, as well as insulation type and thickness, locations for pipe guides, anchors, or supports, and offset angles of pipe. Callouts stipulate instrumentation locations and size, specification breaks, piece marks, and other fabrication details. Any information that is pertinent to a particular pipe must be conveyed on the isometric.

Whether writing dimensions, notes, or any other information on an iso, all written information should remain on one of the isometric axes and be inclined to the right. This task becomes a little more difficult when drawing with AutoCAD. To achieve the proper *obliquing* and rotation angles required on CAD generated isometrics, create the text styles outlined in the following procedures and demonstrated in Figure 13.16.

ISOMETRIC OFFSETS

Isometric offsets are formed when a pipe turns at any angle other than 90°. Angular offsets can be created by rolling a 90° elbow at any angle or replacing 90° elbows with 45° elbows. The result would be pipes that no longer travel north, south, east, west, up, or down. Instead lines would run northwest, northeast, southeast, or southwest. They could also slant upward or downward. Three examples of isometric offsets are shown in Figure 13.17. Dimension lines and callouts are included as a reference. To establish proper visual orientation, the indication of horizontal (H) or vertical (V) angles are included on all isometric offsets. Forty-five degree

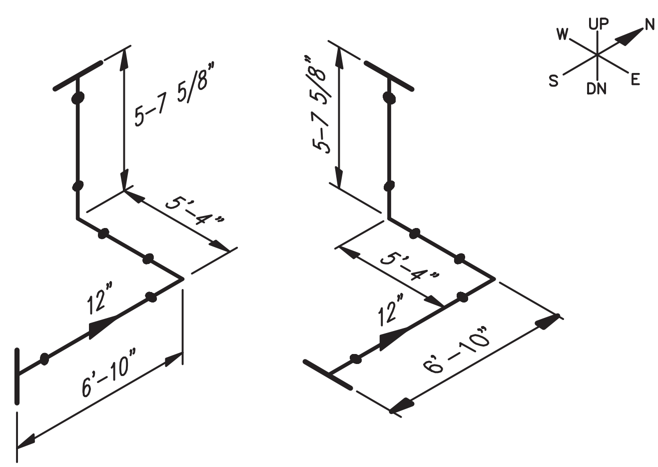


FIGURE 13.14 Dimensioning placement options.

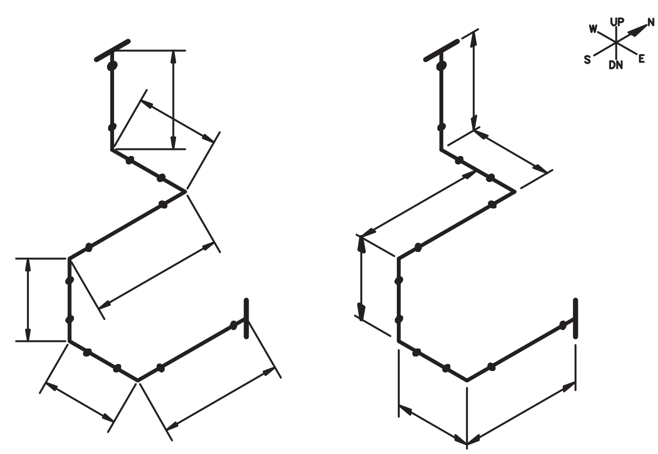


FIGURE 13.15 Aligned and Oblique dimensions.

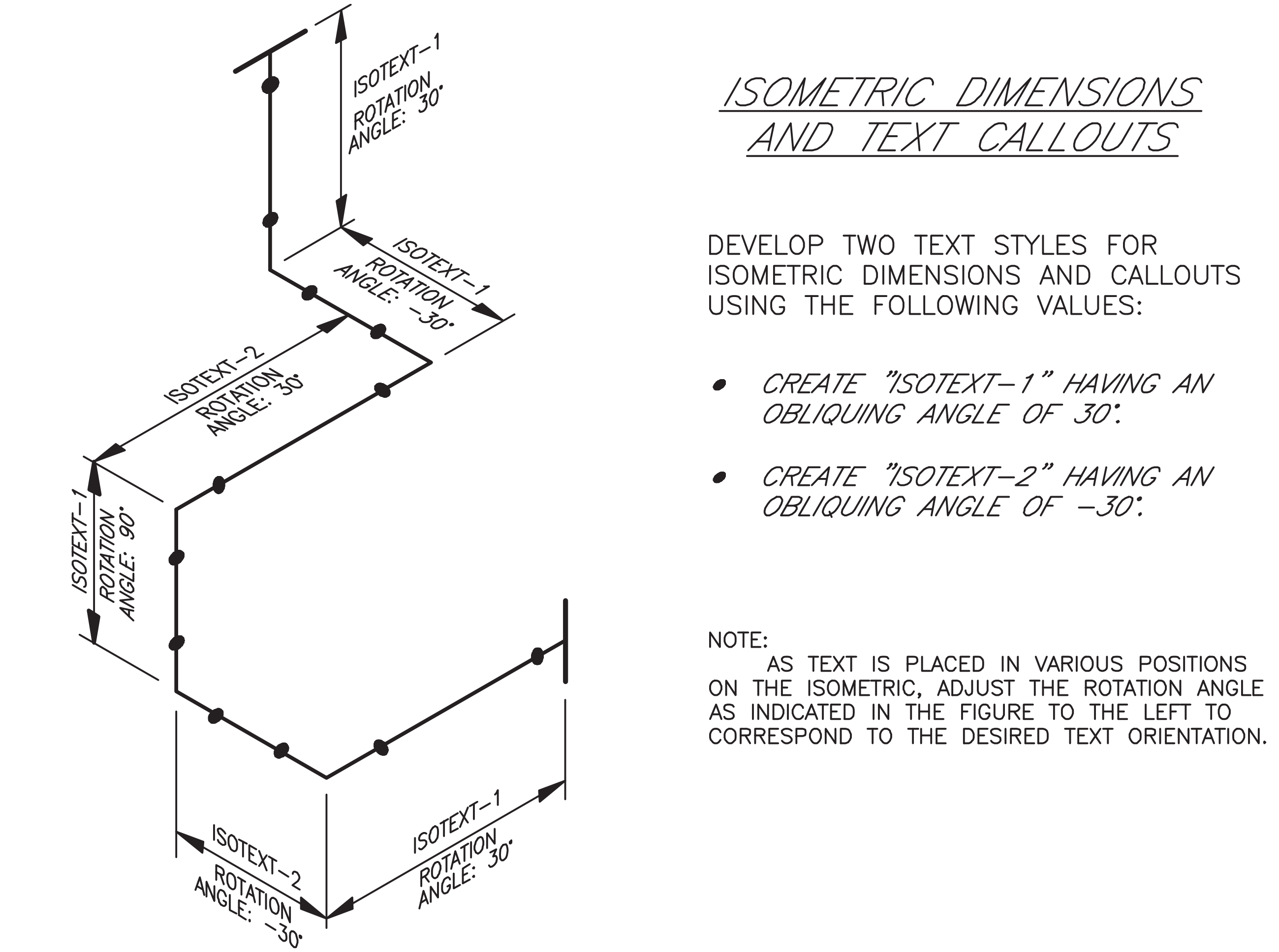


FIGURE 13.16 Creating isometric dimensions and text.

- **Step 1.** Use the **STYLE** command to create two different text styles. Use the style names ISOTEXT-1 and ISOTEXT-2 for easy reference.
- **Step 2.** When creating ISOTEXT-1, set the *obliquing angle* to +30°. For ISOTEXT-2 set the *obliquing angle* to –30°.
- **Step 3.** Depending on the **ISOPLANE** being used, set the *rotation angle* in the **TEXT** command to the appropriate setting as represented in Figure 13.16.

elbows must always be labeled on an iso for material takeoff purposes.

Figure 13.17 represents only three of the many offsets that can be created using 90° and 45° elbows. Example **A** of Figure 13.17 begins with a line traveling north. A 90° elbow is rolled downward and toward the east at a 45° angle, then another 45° elbow is required to return the angular offset back into a due easterly direction. This example is labeled as a vertical offset because a change in elevation occurs when the 90° elbow is turned downward. Example **C** is also a vertical offset, but note there is no change in the geographic direction the pipe travels. Here, two 45° elbows are used to angle the pipe upward while continuing in a northerly direction. Both elbows are 45°, thus the inclusion of the abbreviation **TYP,** meaning "typical" is added to the "45° ELL" callout. Example **B** demonstrates how horizontal offsets are created. As with example **C,** two 45° elbows are used, but rather than turning the elbows upward, they are laid on their side, thus remaining in a horizontal plane. There is no change in elevation.

Dimensioning Offsets

With isometric offsets changing a pipe's routing from one plane to another or from one geographic direction to another, coordinates and elevations no longer provide all the dimensions necessary to describe a pipe's total length. However, the use of 90° and 45° elbows to form the offsets results in a problem that can be easily solved with simple mathematical formulas. The 90° and 45° elbows form right triangles. By using the Pythagorean theorem which states that the sum of the squares of the two sides is equal to the

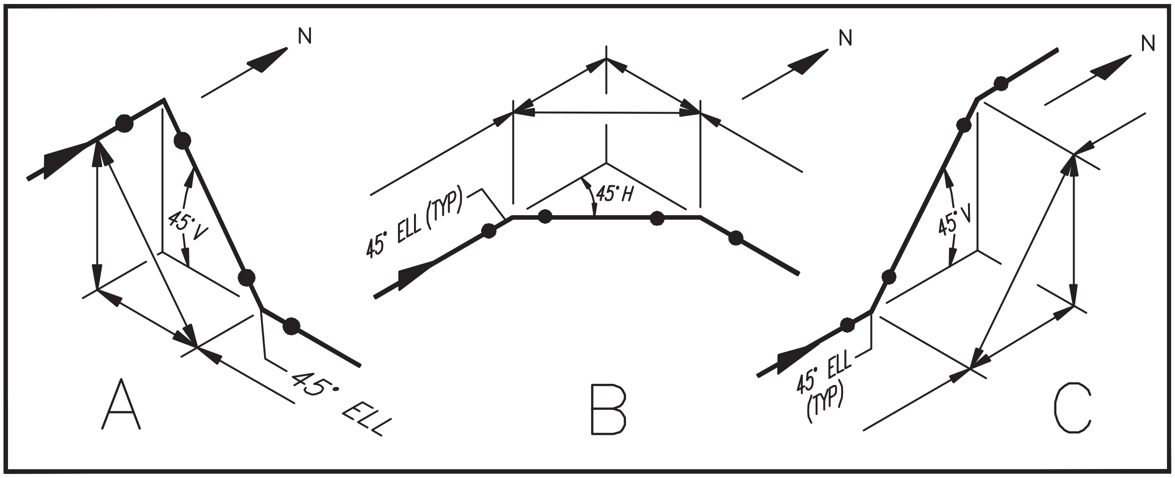
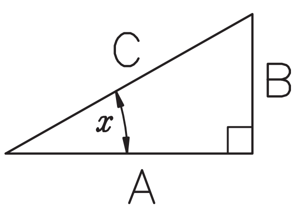


FIGURE 13.17 Isometric offsets.

$$A^2 + B^2 = C^2$$



$$C = \sqrt{A^2 + B^2}$$

$$A = \sqrt{C^2 - B^2}$$

$$B = \sqrt{C^2 - A^2}$$

FIGURE 13.18 Pythagorean theorem formulas.

square of the triangle's hypotenuse, this problem can be solved. Simply stated, $A^2 + B^2 = C^2$. Figure 13.18 identifies the sides and angles of a right triangle and their resulting solution formulas.

These formulas can be used to solve the length of an unknown side when the other two sides are known. They work no matter the degree value of angle ***X.*** Some angles seem to be used repeatedly in pipe drafting. The chart in Figure 13.19 can significantly reduce the amount of time spent calculating unknown sides of right triangles. Use the appropriate decimal value when ***X*** is one of the provided angles.

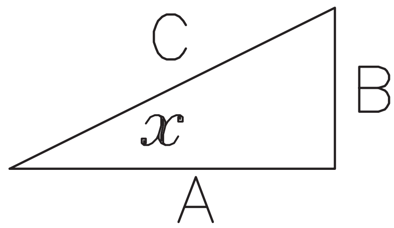
As mentioned previously, 90° elbows can be rolled to form any degree of angular offset. To fabricate such a roll, a pipe fitter should be provided with the lengths of the three sides of the triangle and the degree value of angle ***X.*** Solving for an unknown value of ***X*** requires some additional trigonometric formulas. Use the formulas provided in Figure 13.20 to solve for the unknown value of angle ***X.*** Notice that, relative to ***X,*** side **A** is identified as the Side Adjacent (SA), side **B** is identified as the Side Opposite (SO), and side **C** is identified as the Hypotenuse (HYP).

Multi-angle Offsets

Elbows are not the only piping components installed in angular positions. Because of the arangement and orientation of trays inside a vessel, and obstructions such as ladders, platforms, and cages outside the vessel, nozzles are placed in locations where they can add or extract commodity from the vessel and not hit an obstruction with painstaking accuracy. As a result, nozzles oriented at angles of 10°, 20°, 35°, etc., are not uncommon. When offset or rolled elbows are added, complex math problems often result. Multi-angle configurations, such as the one in Figure 13.21, require additional calculations to determine dimensions for each of its lengths.

We have already seen how unknown lengths can be solved using right-triangle formulas. The key to solving the unknown length dimension in Figure 13.21 is the incorporation of right triangles. Remember, drawing space is limited. Excessive notes, callouts, and dimensions are not practical on Piping Arrangement drawings. As with traditional isometric dimensions, right-triangle dimensions are aligned so their lengths establish center-to-center measurements, that is, center-of-vessel, to center-of-elbow, to center-of-vessel. So, the length of the unknown dimension can only be solved by using the limited information available in Figure 13.21. Figure 13.22 demonstrates the way to position three right triangles to solve for the "unknown" dimension, marked as "**?**" in Figure 13.21.

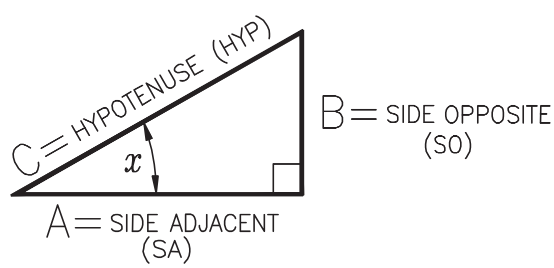
Numbering the triangles will aid in the discussion that follows concerning the solution to the lengths of the sides of each triangle. The "unknown" dimension, "**?**," is equivalent to the hypotenuse of triangle **3.** Begin by determining the known values for each of the triangles from the information provided in Figure 13.21. Figure 13.23 shows the known values of triangles **1, 2,** and **3** placed in their appropriate locations.



RIGHT TRIANGLE MULTIPLICATION FACTORS

TO FIND SIDE	WHEN YOU KNOW SIDE	MULTI-PLY SIDE	WHEN 'x' IS 15°	WHEN 'x' IS 30°	WHEN 'x' IS 45°	WHEN 'x' IS 60°	WHEN 'x' IS 75°
C	A	A x	1.0353	1.1547	1.4142	2.0000	3.8637
C	B	B x	3.8637	2.0000	1.4142	1.1547	1.0353
A	B	B x	3.7320	1.7320	1.0000	.5773	.2680
A	C	C x	.9659	.8660	.7071	.5000	.2588
B	A	A x	.2680	.5773	1.0000	1.7320	3.7320
B	C	C x	.2588	.5000	.7071	.8660	.9659

FIGURE 13.19 Decimal equivalents of common angles.



SA= HYP (COS x)	SO= HYP (SIN x)	HYP= SA (SEC x)
SA= SO (COT x)	SO= SA (TAN x)	HYP= SO (CSC x)
SA= $\frac{\text{SO}}{\text{TAN } x}$	SO= $\frac{\text{SA}}{\text{COT } x}$	HYP= $\frac{\text{SO}}{\text{SIN } x}$
SA= $\frac{\text{HYP}}{\text{SEC } x}$	SO= $\frac{\text{HYP}}{\text{CSC } x}$	HYP= $\frac{\text{SA}}{\text{COS } x}$

$\text{SIN } x = \frac{\text{SO}}{\text{HYP}}$ $\quad$ $\text{COS } x = \frac{\text{SA}}{\text{HYP}}$ $\quad$ $\text{TAN } x = \frac{\text{SO}}{\text{SA}}$ $\quad$ $\text{COT } x = \frac{\text{SA}}{\text{SO}}$

FIGURE 13.20 Right-triangle formulas.

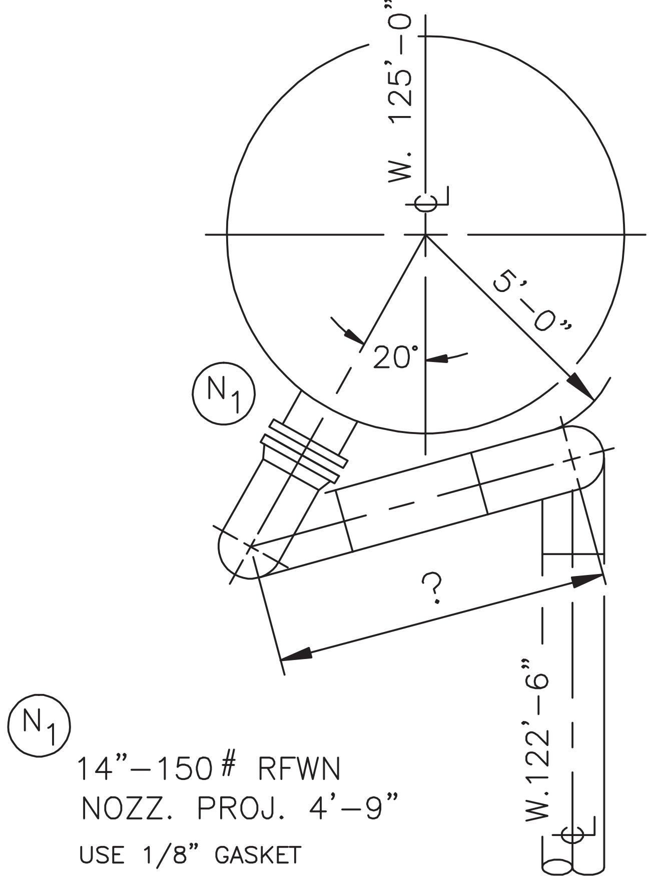


FIGURE 13.21 Multi-angle offsets.

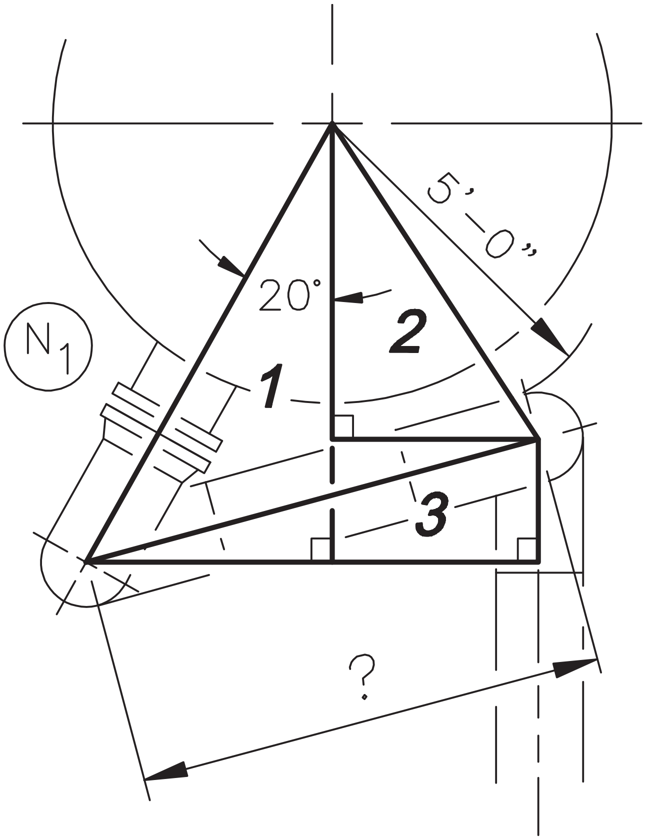


FIGURE 13.22 Locating right triangles.

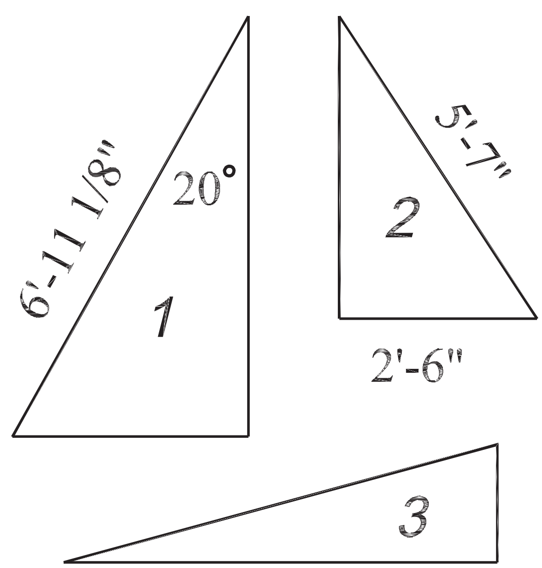


FIGURE 13.23 Known values for triangles **1**, **2**, and **3**.

The **X** angle for triangle **1** is shown to be 20° in Figure 13.21. The 6′-11 1/8″ dimension is the measured length from the center of the vessel to the center of the elbow at Nozzle **N1**. This is determined by adding the nozzle projection for nozzle **N1,** a gasket, one 14″-150# flange, and a 14″ elbow. On triangle **2,** the 2′-6″ measurement is determined by subtracting the West coordinate of W. 122′-6″ from W.125′0″. The 5′-7″ dimension is established by adding ½ of the OD of the 14″ pipe to the 5′-0″ dimension.

Note there are no known dimensions for triangle **3.** However, we must determine the hypotenuse if we are to know the "unknown" dimension. Remember, a minimum of two values must be known in order to solve the three lengths and the angle of a right triangle. By determining the Side Adjacent (SA) and Side Opposite (SO) of triangle **3,** the Pythagorean theorem can be applied to find the Hypotenuse (HYP), the unknown dimension.

Using the available formulas, the missing lengths of triangles **1** and **2** must be solved before the sides of triangle **3** can be determined. Notice that by subtracting the SA of triangle **2** from the SA of triangle **1,** the SO of triangle **3** can be determined. Also, adding the SO of triangle **1** to the SO of triangle **2** (2′-6″) will yield the SA of triangle **3.** The results of these calculations are shown in Figure 13.24. The length of the *unknown*, "**?**," dimension is 5′-1$\frac{3}{16}$″. Angle ***X*** of triangle **3** is also an important value to be determined. This angle establishes the rotation angle for the 90° elbows. In the fabrication shop,

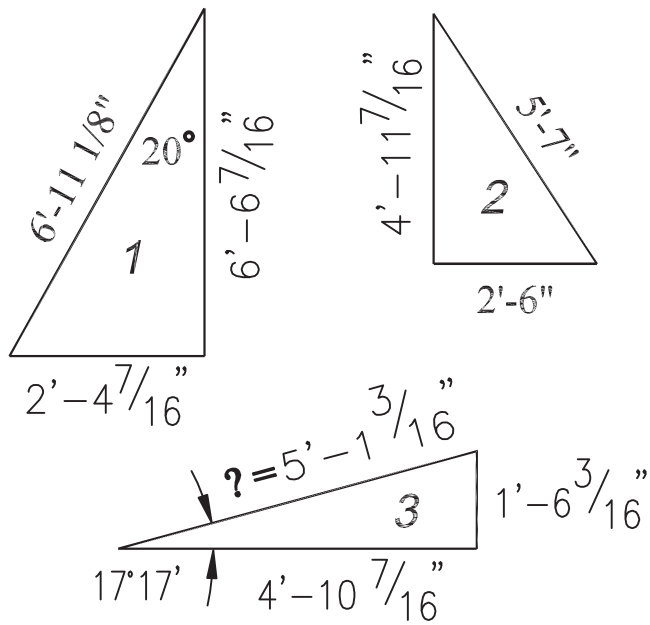


FIGURE 13.24 Solutions for triangles **1**, **2**, and **3**.

the vessel is not available to measure the 5′-0″ dimension. Knowing this horizontal angle is the only way the elbows can be accurately welded during the fabrication process in the shop and later installed precisely in the field.

Rolling Offsets

The culmination of multiple isometric offsets is the rolling offset. The *rolling offset* is a compound offset formed by replacing the two 90° elbows, as shown in Figure 13.21, with two 45° elbows. The result is an offset that changes elevation and direction simultaneously. Figure 13.25 shows the plan and elevation views of a rolling offset.

Because of its complexity, adequate dimensions cannot be placed on the orthographic views that fully describe the rolling offset. An isometric is the best place for representing and dimensioning the rolling offset, because a simple horizontal or vertical triangle with three dimensions is not adequate enough to fabricate a rolling offset. Incorporating the horizontal and vertical triangles into an isometric box is the only way to provide all the necessary dimensions and angles needed by welders to fabricate a rolling offset. Figure 13.26 shows construction of the rolling offset box and its accompanying dimensions and angles.

Combining elevational and directional changes compounds the difficulty in representing the rolling offset on an isometric drawing. Visualizing directional changes in the plan and elevation views simultaneously requires practice and patience. To aid in this visualization process, some helpful notes have been added to the

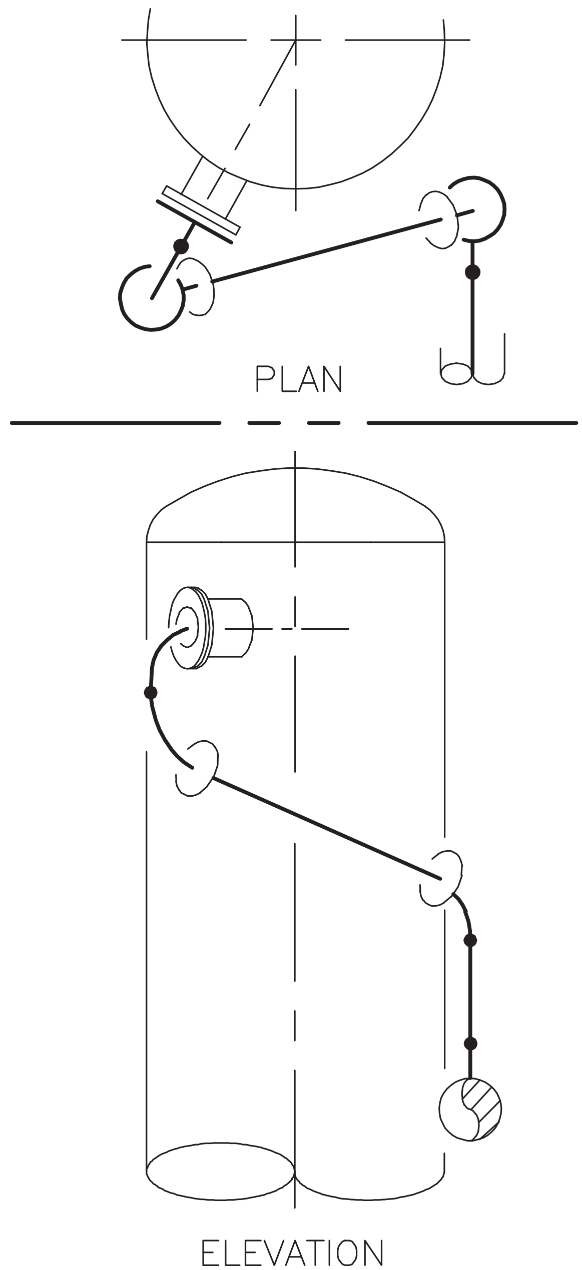


FIGURE 13.25 Plan and Elevation views of a rolling offset.

plan and elevation views of the rolling offset shown in Figure 13.27. In the plan View, a box has been drawn through the centers of the two 45° elbows that form the rolling offset. Its corners have been labeled northeast (NE), southeast (SE), southwest (SW), and northwest (NW). The notes in the elevation view identify upper and lower planes which represent the change in elevation. Remember the Plan view shows north, south, east, west orientations, and the Elevation view depicts vertical changes in elevation.

The Plan view in Figure 13.27 shows that the pipe enters the box from the southwest corner and travels

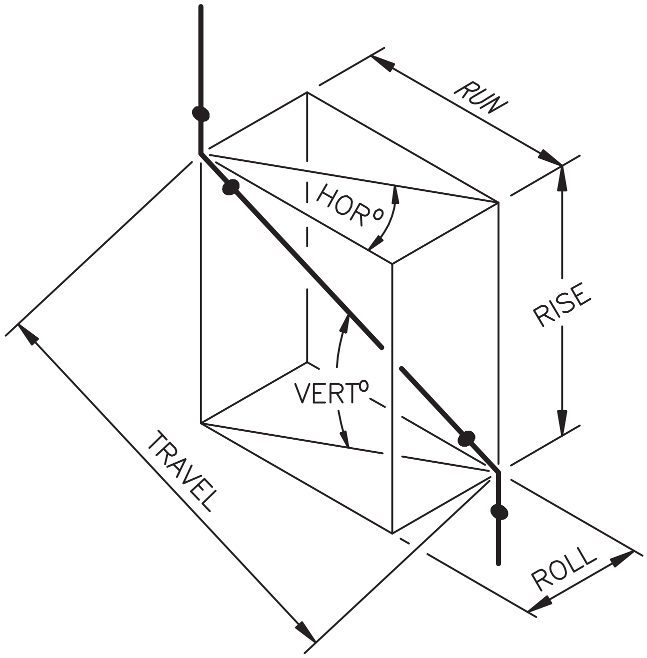


FIGURE 13.26 Rolling offset box.

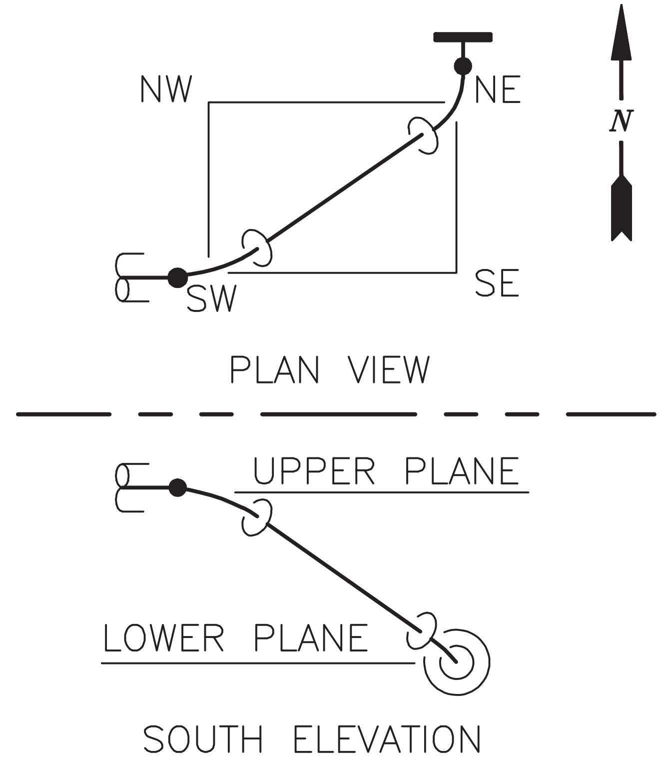


FIGURE 13.27 Visualization aids for rolling offsets.

across to the northeast corner where it ends with a flange. Looking at the South Elevation, we can see the pipe beginning on the upper plane and dropping down to the lower plane. By combining the information from these two views, we know that the pipe begins in the upper southwest corner and travels down to the lower northeast corner. The resulting isometric representation is shown in Figure 13.28.

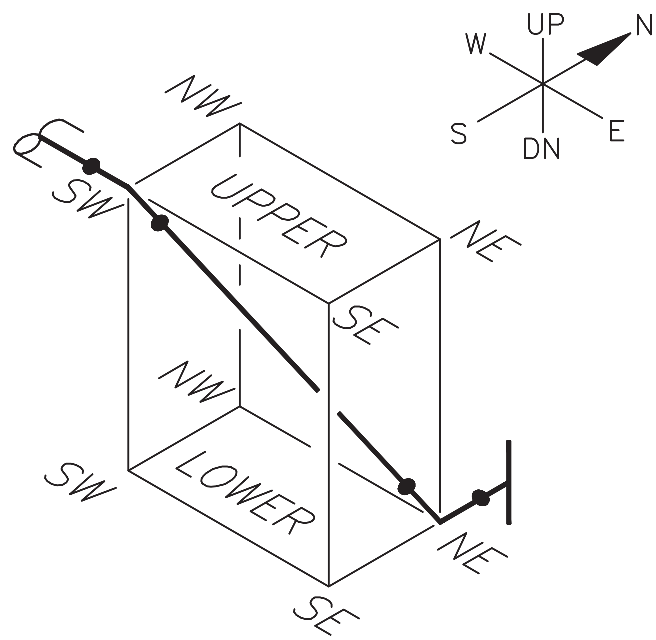


FIGURE 13.28 Isometric of a rolling offset.

Dimensioning Rolling Offsets

Figure 13.26 identifies the six measurements required to dimension a rolling offset. There are four length dimensions and two angular dimensions. When a rolling offset is incorporated into a configuration similar to that shown in Figure 13.29, the lengths of the three sides of triangle **3** are applied to the dimensions of the rolling offset box (see Figure 13.26). Note the SA of triangle **3** in Figure 13.29 is equal to the **RUN** of the rolling offset box, the **ROLL** of the rolling offset box is equal to the SO of triangle **3,** and angle ***X*** of triangle **3** is the same as the horizontal angle (HOR°) of the rolling offset box.

The **RISE** is determined by subtracting the lower plane elevation from the upper plane elevation. These two elevations can be found on a section or elevation drawing of the configuration or depicted in the form of notes on the Piping Arrangement drawing. Rolling offsets are typically fabricated using 45° elbows; therefore, the vertical angle will be 45°. But, 45° to what? Note the dimension labeled **TRAVEL** in Figure 13.26. It establishes the true length of the pipe from the upper southwest corner to lower northeast corner of the rolling offset box. Naturally, this length is the most difficult to calculate. The values used to determine its length depend on how the pipe enters and exits the rolling offset box. Figure 13.30 shows the two examples of how a pipe may enter and exit the rolling offset box. These two examples will help us determine what the pipe is 45° to.

Note in example **A,** the pipe enters and exits the rolling offset box in the vertical plane. Example **B** shows the pipe entering and exiting the box in the horizontal plane. These two methods of entering and exiting the rolling offset box will be used to determine what the TRAVEL is 45° to. When a pipe enters and exits in the vertical direction, Example **A**, a 45° angle is formed between the **TRAVEL** and a dashed line drawn diagonally across the lower plane of the box (hypotenuse of triangle **3).** However, when a pipe enters and exits the rolling offset box in the horizontal direction, Example **B,** a 45° angle is formed between the **TRAVEL** and the **RUN** of the box. Depending on the type, vertical or horizontal, two different 45° right triangles will be formed. The **TRAVEL** of the pipe becomes the hypotenuse for either triangle. Recall that when solving a right triangle whose angle is 45°, the SA and SO will always be equal. Therefore, in Example **A,** the length of the dashed line is equal to the **RISE** of the box, and in Example **B,** the dashed line drawn diagonally across the west end of the rolling offset box is equal to the **RUN** of the box. See Figure 13.31 for a shaded representation of the right triangles formed in Examples **A** and **B**. Once the SA and SO lengths of the 45° right triangle are known, the Pythagorean theorem can be used to easily solve the **TRAVEL** dimension of the pipe. Since 45° is a commonly used angle, Figure 13.19 can be used to make the solution even simpler.

The chart in Figure 13.32 converts inches and fractions of an inch into decimals. Multiplication and division of fractions are simplified using decimal equivalents. This chart is extremely helpful when performing mathematical calculations on a calculator that is limited to decimal input only. To use the chart in Figure 13.32, follow the column below the "inch" value down until it is adjacent to the "fraction" value row. The number at this intersection is the decimal equivalent of the mixed inch and fraction value. For example, to determine the decimal value of 8 5/8″, follow the column below **8**″ down until it is adjacent to **5/8**″ (displayed in the "**Fraction**" column).

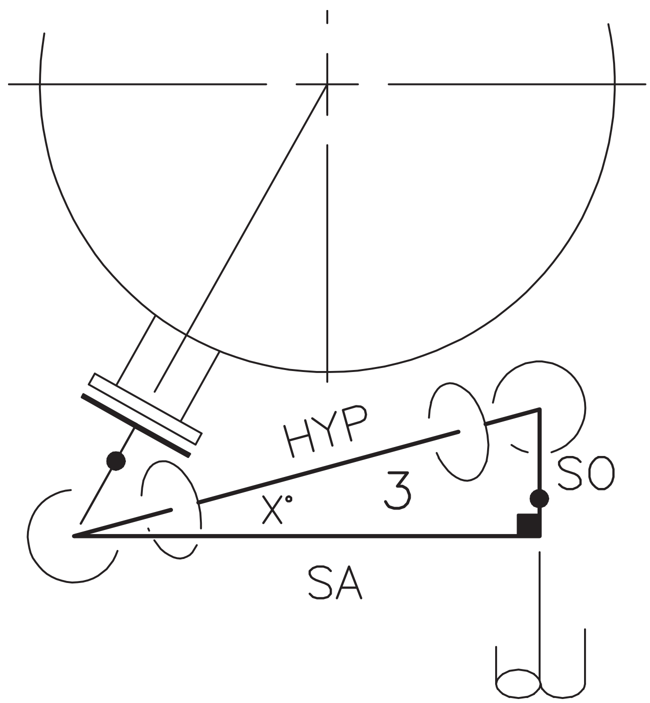


FIGURE 13.29 Rolling offset with right triangle.

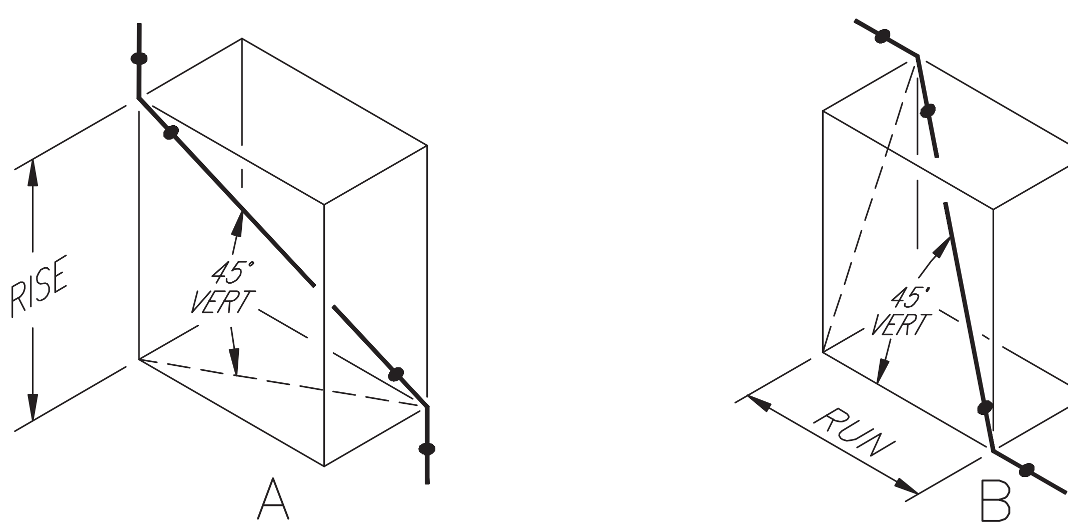


FIGURE 13.30 Vertical and horizontal pipe entering and exiting the rolling offset box.

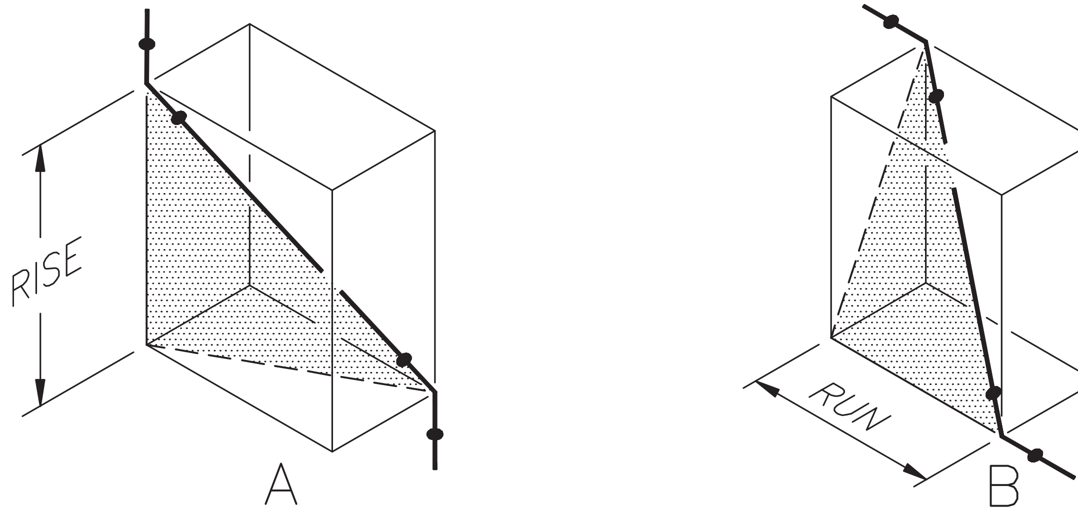


FIGURE 13.31 Right triangles created with **TRAVEL** length as hypotenuse.

FRACTIONS	DECIMALS OF A FOOT													FRACTIONS	DECIMALS OF AN INCH
	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"		
	.0000	.0833	.1667	.2500	.3333	.4176	.5000	.5833	.6667	.7500	.8333	.9167	----		
1/16"	.0052	.0085	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219		1/16"	.0625
1/8"	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271		1/8"	.1250
3/16"	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323		3/16"	.1875
1/4"	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375		1/4"	.2500
5/16"	.0260	.1093	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427		5/16"	.3125
3/8"	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479		3/8"	.3750
7/16"	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531		7/16"	.4375
1/2"	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583		1/2"	.5000
9/16"	.0468	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635		9/16"	.5625
5/8"	.0521	.1354	.2187	.3021	.3854	.4687	.5521	.6354	.7187	.8021	.8854	.9687		5/8"	.6250
11/16"	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740		11/16"	.6875
3/4"	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792		3/4"	.7500
13/16"	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844		13/16"	.8125
7/8"	.0729	.1562	.2396	.3239	.4062	.4896	.5729	.6564	.7396	.8229	.9062	.9896		7/8"	.8750
15/16"	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948		15/16"	.9375

FIGURE 13.32 Inch to decimal conversion chart.

The number at this intersection is 0.7187. Therefore, 0.7187 is the decimal equivalent of 8 5/8″.

Two appendices at the end of the book provide solution examples of the mathematical calculations Figure 13.32 employs. Use these to have an understanding of how to convert inches to decimals and vice-versa when Figure 13.32 is not available.

If a decimal number needs to be converted into inches, use the chart in Figure 13.32 in reverse. Simply locate the decimal number and then follow the column up to locate the whole inch value. Then follow the row to the left or right to determine the fraction value. If the decimal value you are trying to convert does not match a number in the chart precisely, find the decimal value nearest to your number and proceed. The chart provides numbers in 1/16″ increments, which complies with specifications of most of the projects that require dimensions to be given to the nearest 1/16 of an inch.

CHAPTER 13 REVIEW QUIZ

1. What is an isometric?

____

____

2. Which three dimensions found in orthographic views are required when drawing an isometric?

____

____

____

3. What is material take-off?

____

____

4. T F Pipe 14″ and above is drawn double-line on an isometric.

5. T F Multiple pipes are drawn on a single sheet of isometric grid vellum.

6. T F All isometrics are drawn to scale to show exact size and pound rating.

7. T F Lengths of pipe should be drawn proportionally on an isometric.

8. T F Symbols should be drawn different sizes to reflect a change in pipe size.

9. What is the preferred direction to draw the North Arrow on an isometric?

____

____

10. What are placed on isometrics to define the pipe's exact routing through a facility?

____

11. How are isometric offsets formed?

____

____

12. To establish proper visual orientation, the indication of ______________________ or ______________ angles are included on all isometric offsets.

13. State the Pythagorean theorem. ______________

____

14. What are the names of the three sides of a right triangle?

____

____

____

15. Name the six dimensions required on a rolling offset box.

____

____

____

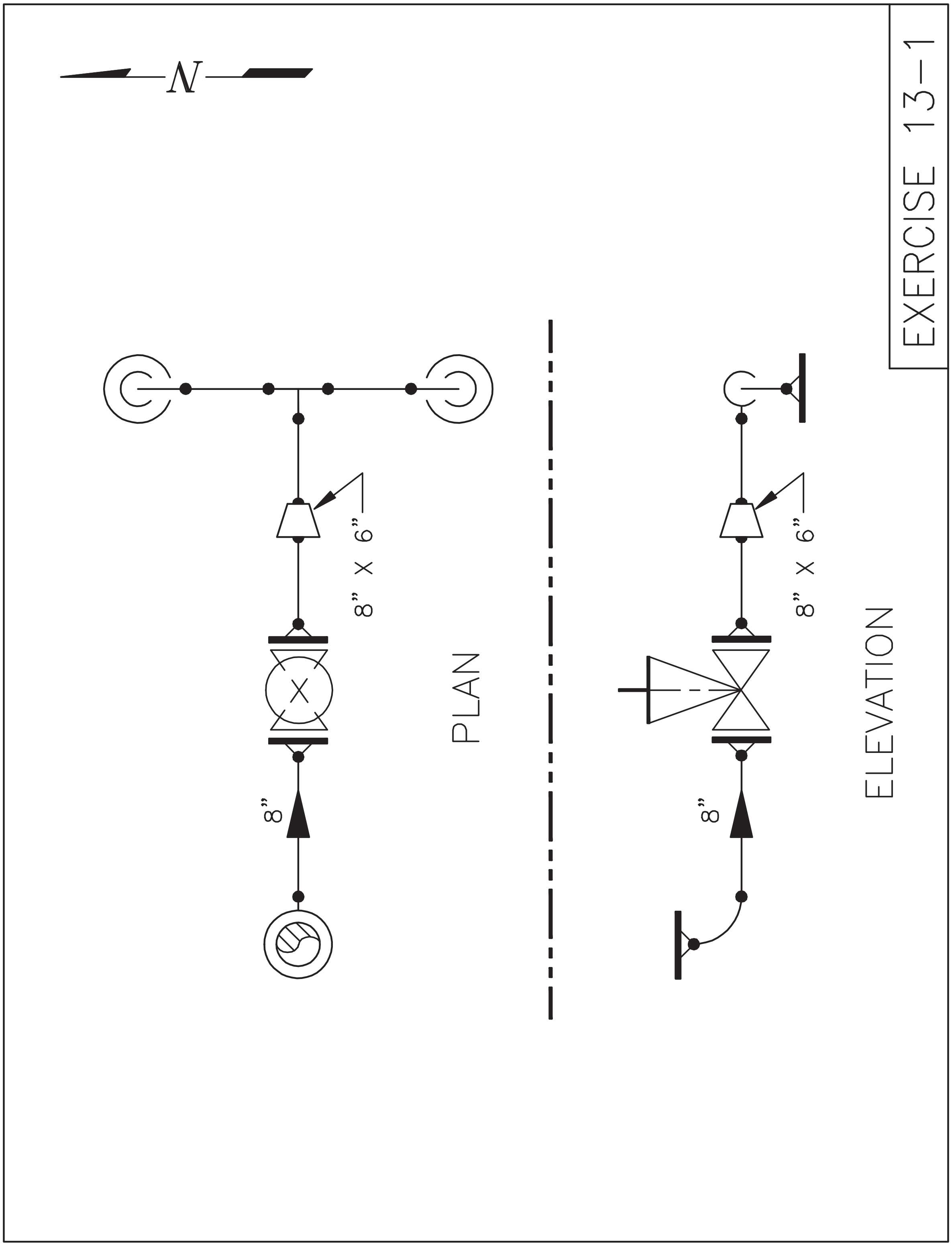
____

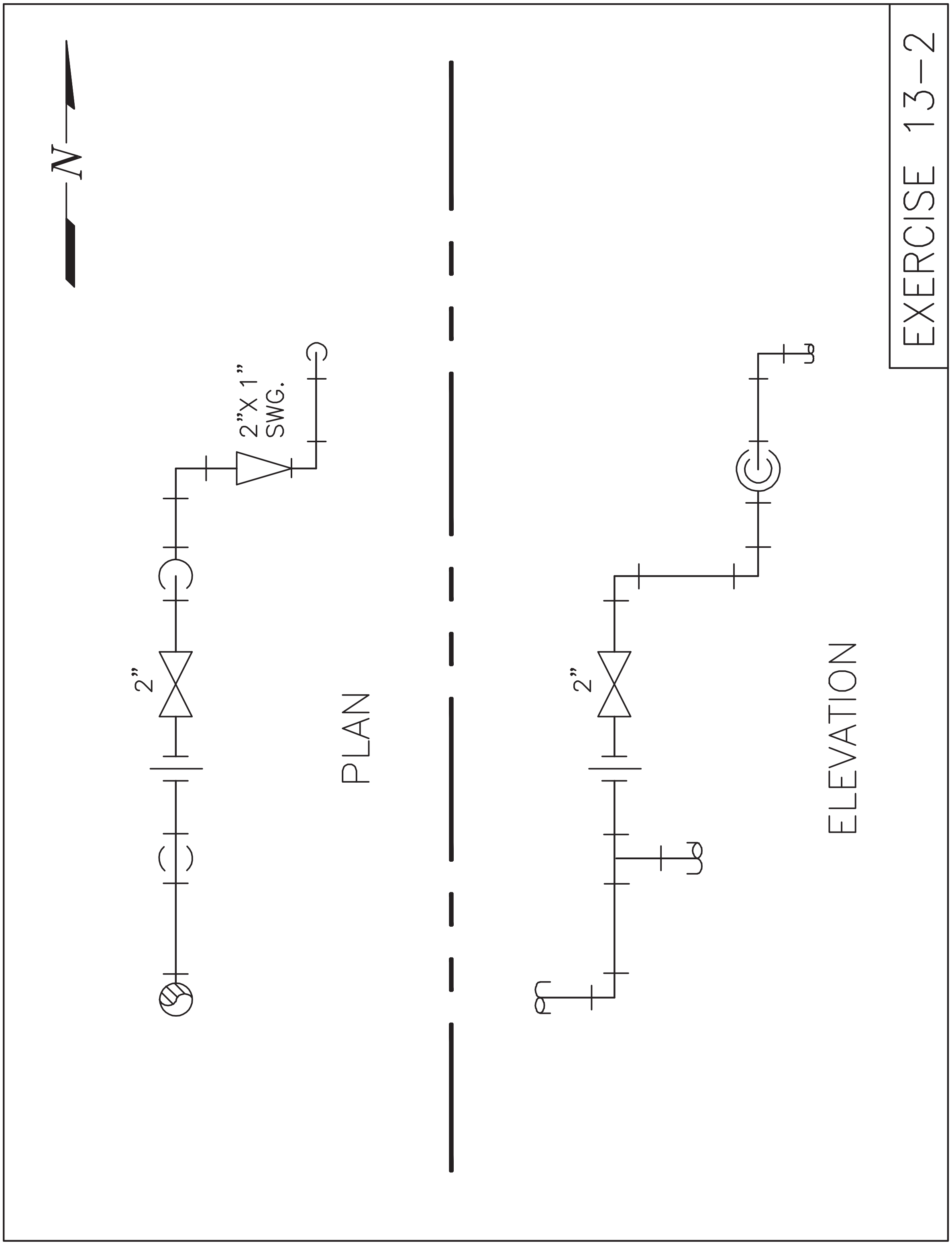
____

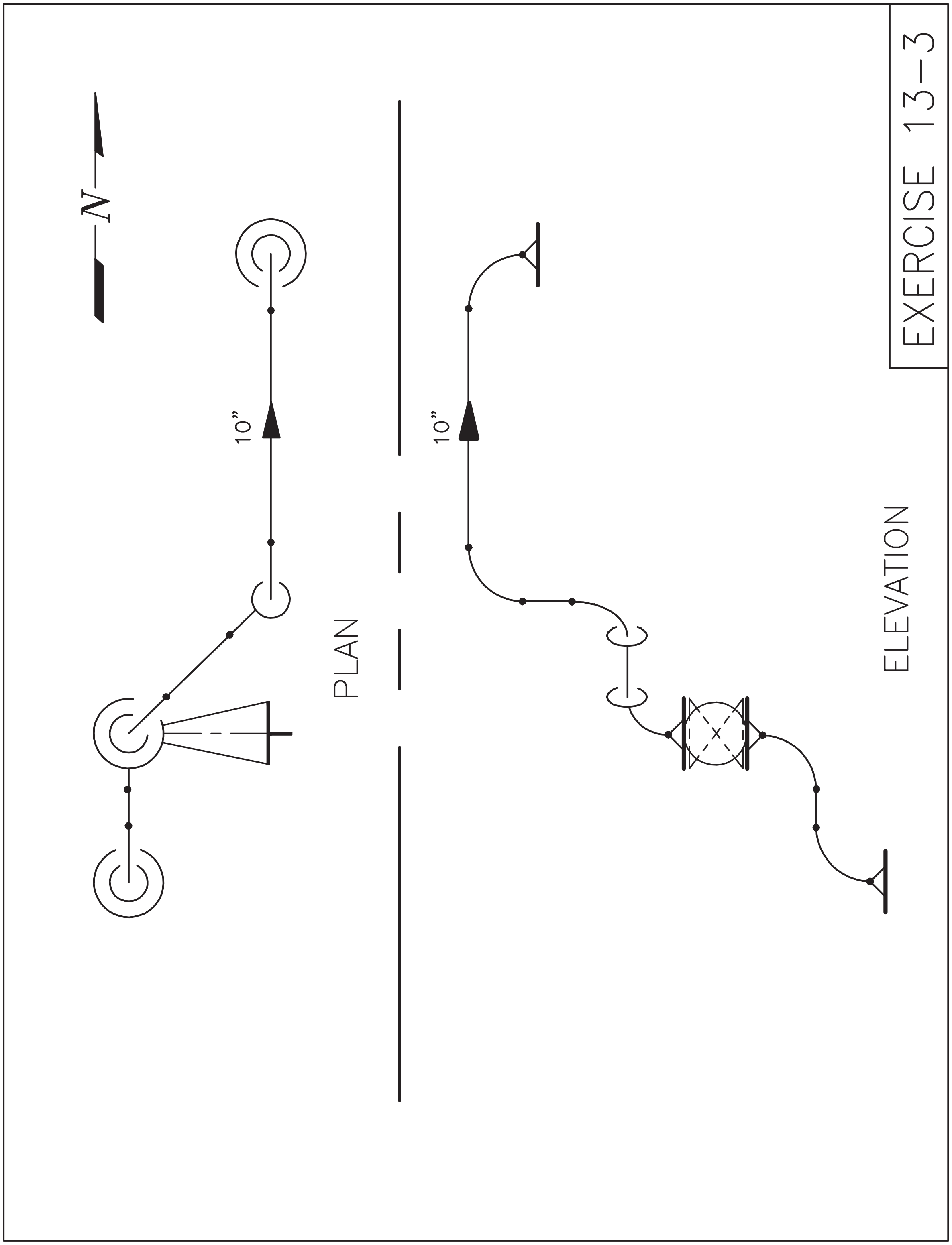
____

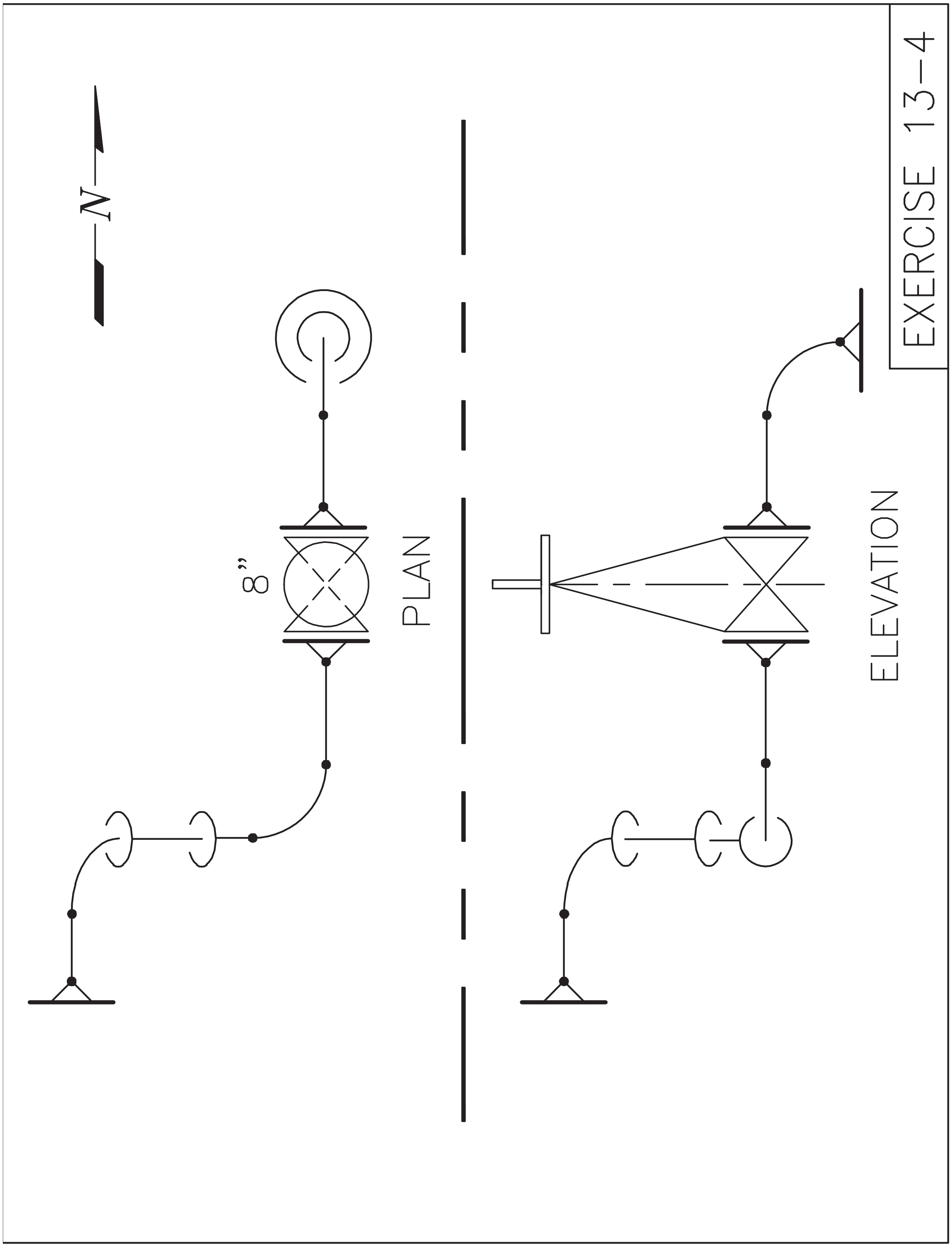
CHAPTER 13 DRAWING EXERCISES

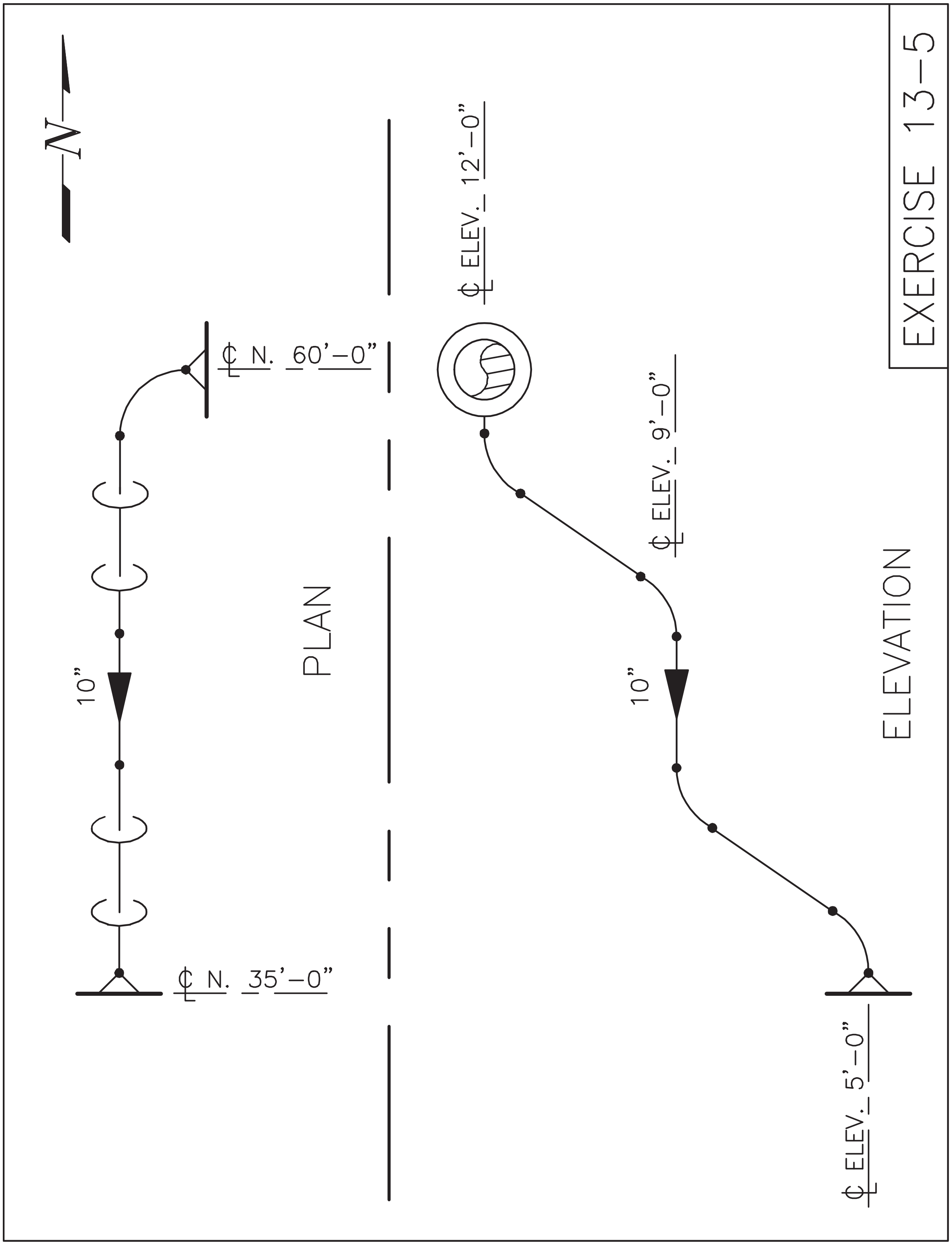
Use the Plan and Elevation views provided to sketch an isometric of the following exercises.



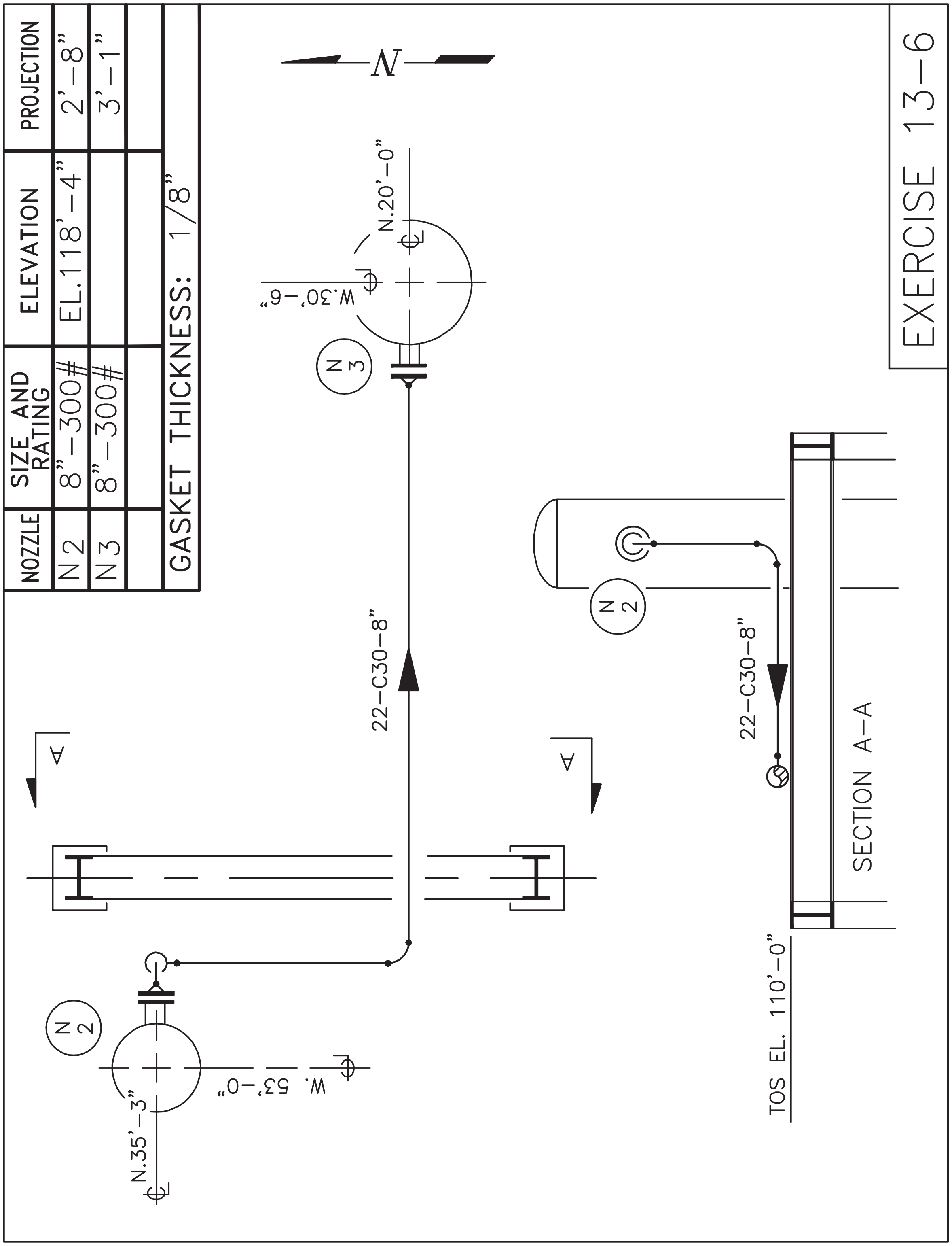

N
2”X 1”
SWG.
2”
PLAN
2”
ELEVATION
EXERCISE 13–2


N
10”
10”
PLAN
ELEVATION
EXERCISE 13–3

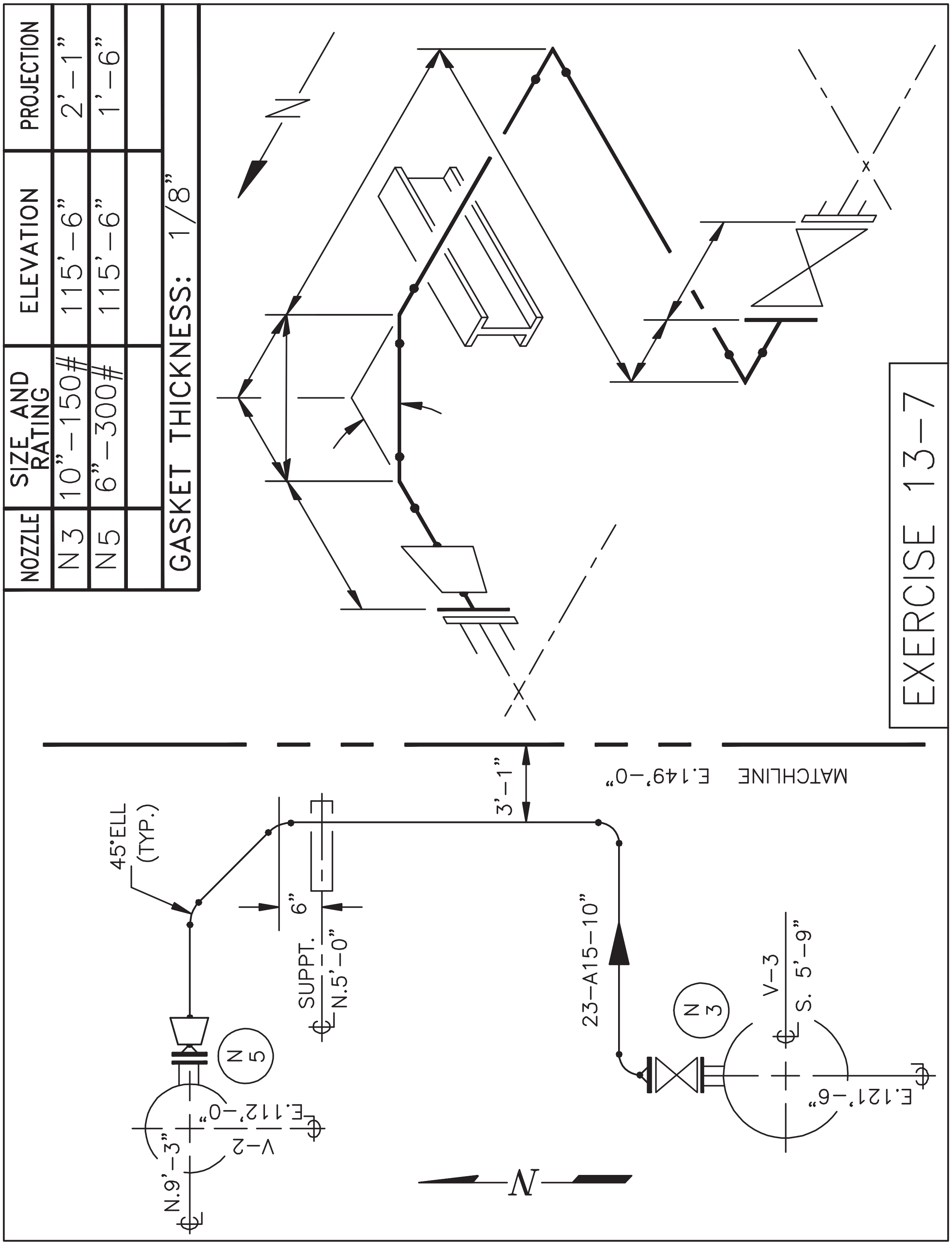

EXERCISE 13–4
N
8"
PLAN
ELEVATION


EXERCISE 13-5
N
PLAN
10"
℄ N. 60'-0"
℄ N. 35'-0"
ELEVATION
10"
℄ ELEV. 12'-0"
℄ ELEV. 9'-0"
℄ ELEV. 5'-0"

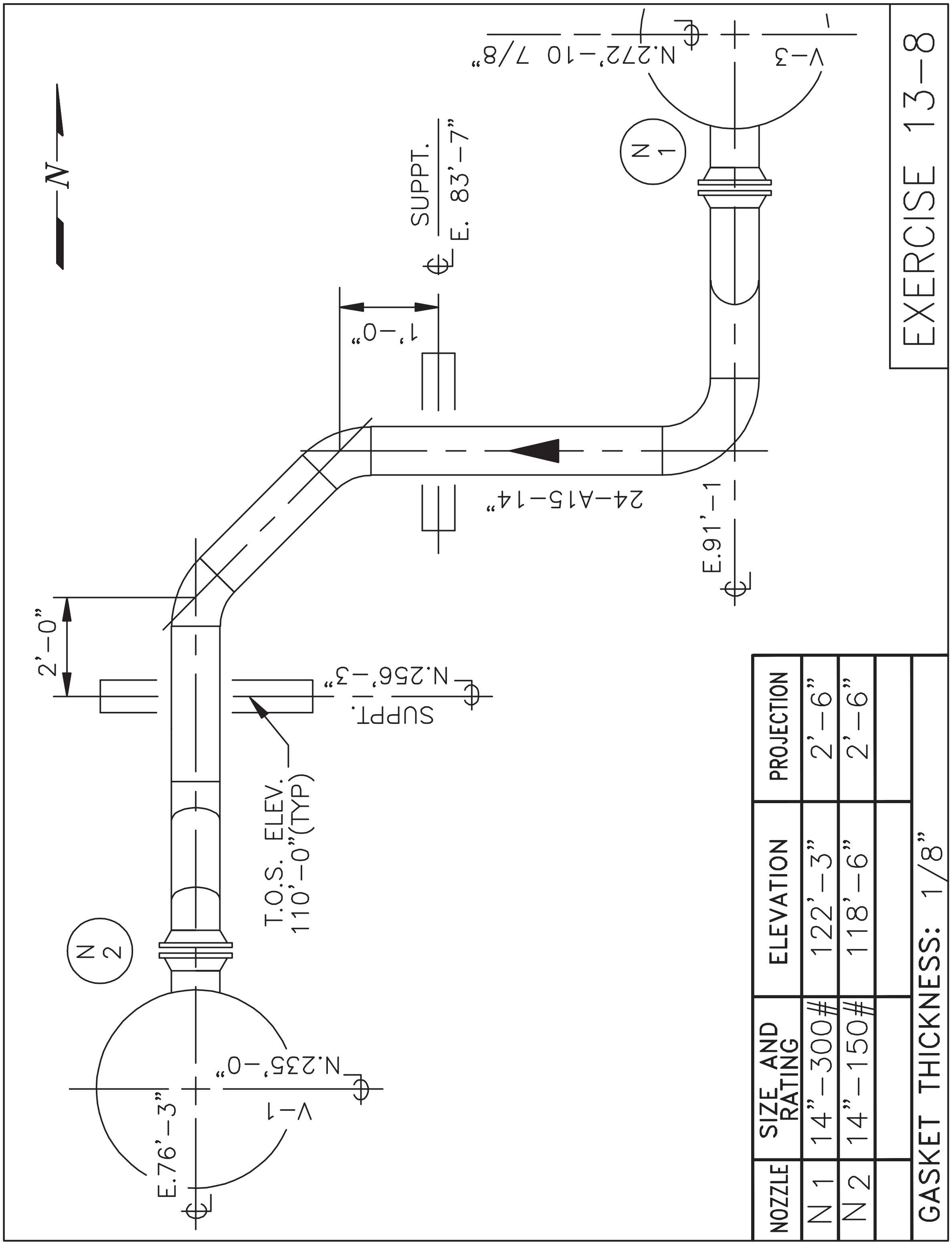
Draw an isometric for the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on the isometric will be up and to the right.



Solve for the missing dimensions on the isometric in the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information.



Draw an isometric for the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on the isometric will be up and to the right.



Solve the conversion problems shown. All feet and inches answers are to be rounded to the nearest ¹⁄₁₆″ value. Decimal answers are to be written to the fourth decimal place.

FRACTION TO DECIMAL & DECIMAL TO FRACTION CONVERSIONS

1 12'-2 7/16" = ________	11 13.8372 = ________
2 1'-11 7/8" = ________	12 2.6525 = ________
3 3'-8 3/4" = ________	13 9.0045 = ________
4 13'-7 1/16" = ________	14 5.2031 = ________
5 9 3/8" = ________	15 4.3021 = ________
6 7'-10 1/2" = ________	16 12.0625 = ________
7 4'-5 3/16" = ________	17 .46875 = ________
8 6'-8 3/8" = ________	18 3.7814 = ________
9 5'-4 7/16" = ________	19 7.3007 = ________
10 8'-3 5/8" = ________	20 11.9875 = ________

EXERCISE 13–9

Solve the conversion problems shown. Answers are to be written in degree, minute, and second values. Decimal answers are to be written to the fourth decimal place.

DEGREE TO DECIMAL & DECIMAL TO DEGREE CONVERSIONS

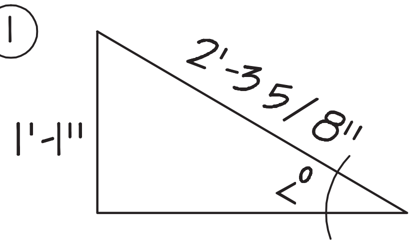
1	32° 9' 45" = ________	11	24.6137° = ________
2	51° 31' 7" = ________	12	12.875° = ________
3	9° 0' 30" = ________	13	38.2113° = ________
4	21°35'42" = ________	14	9.7281° = ________
5	43°33'20" = ________	15	39.465° = ________
6	19°45' = ________	16	43.325° = ________
7	34°10'38" = ________	17	7.9375° = ________
8	6°48'18" = ________	18	28.8167° = ________
9	16°25'44" = ________	19	53.8945° = ________
10	29°10'35" = ________	20	18.4211° = ________

EXERCISE 13–10

Solve for the missing dimensions of the right triangles shown. All dimensions are to be written in Feet and Inches, rounded to the nearest 1⁄16″. Write the angular answers in degree, minute, and second values.

RIGHT TRIANGLE CALCULATIONS

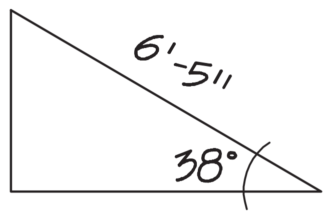
(1)



SA = ________

<° = ________

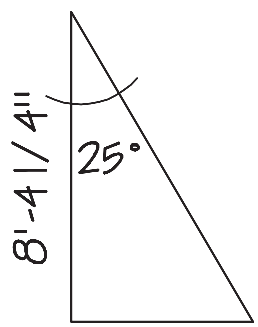
(2)



SA = ________

SO = ________

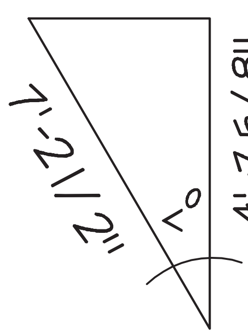
(3)



SO = ________

HYP = ________

(4)

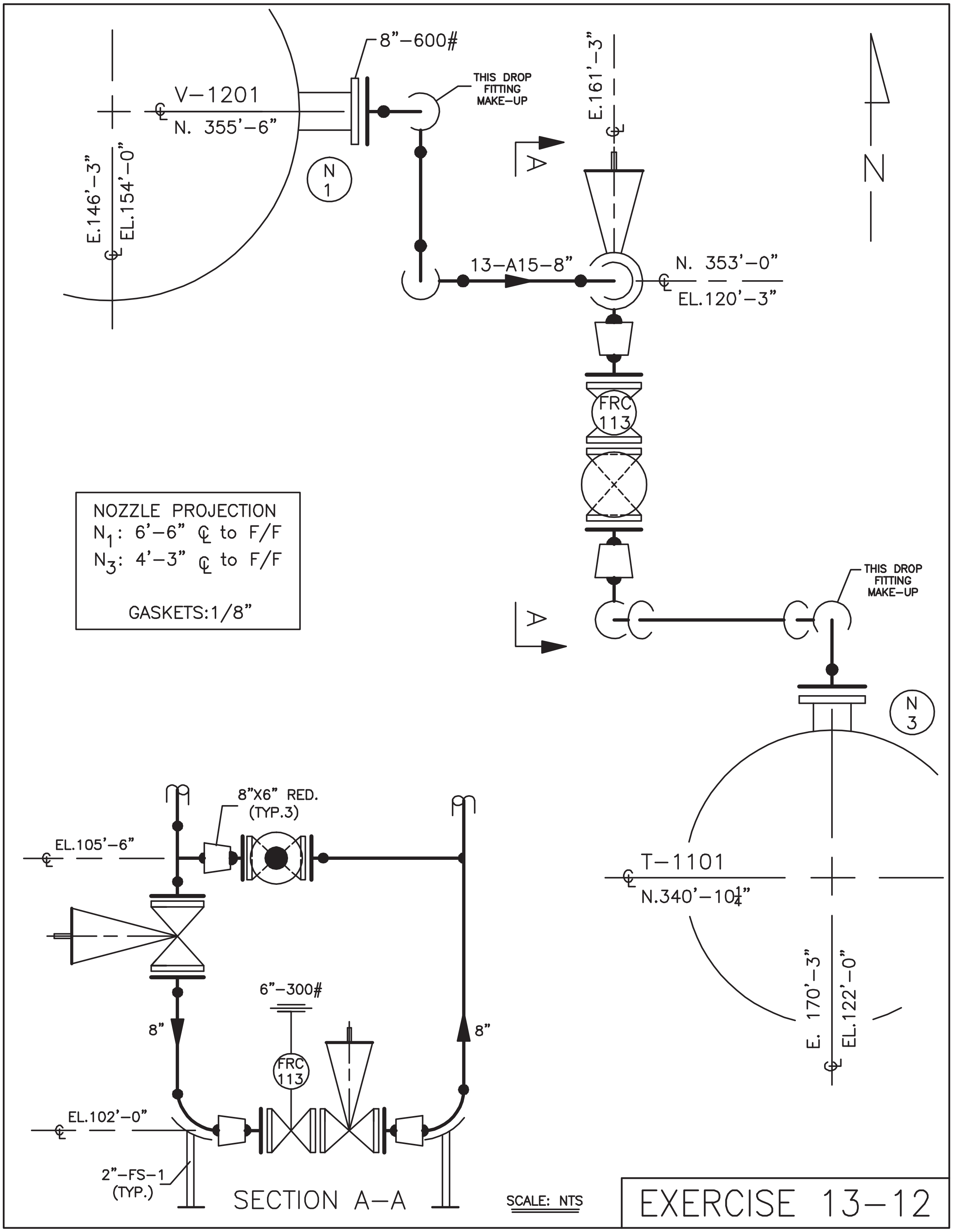


SO = ________

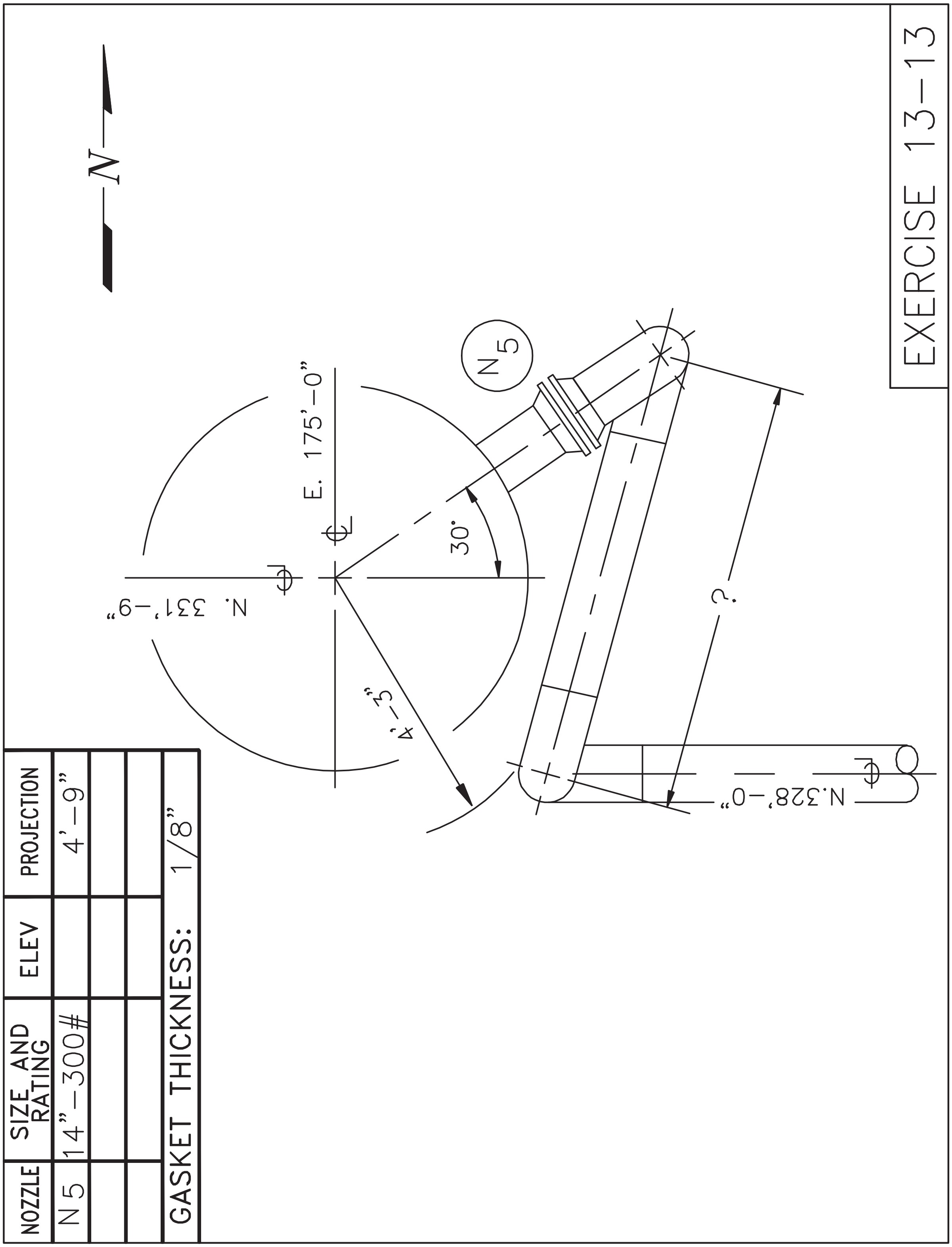
<° = ________

EXERCISE 13–11

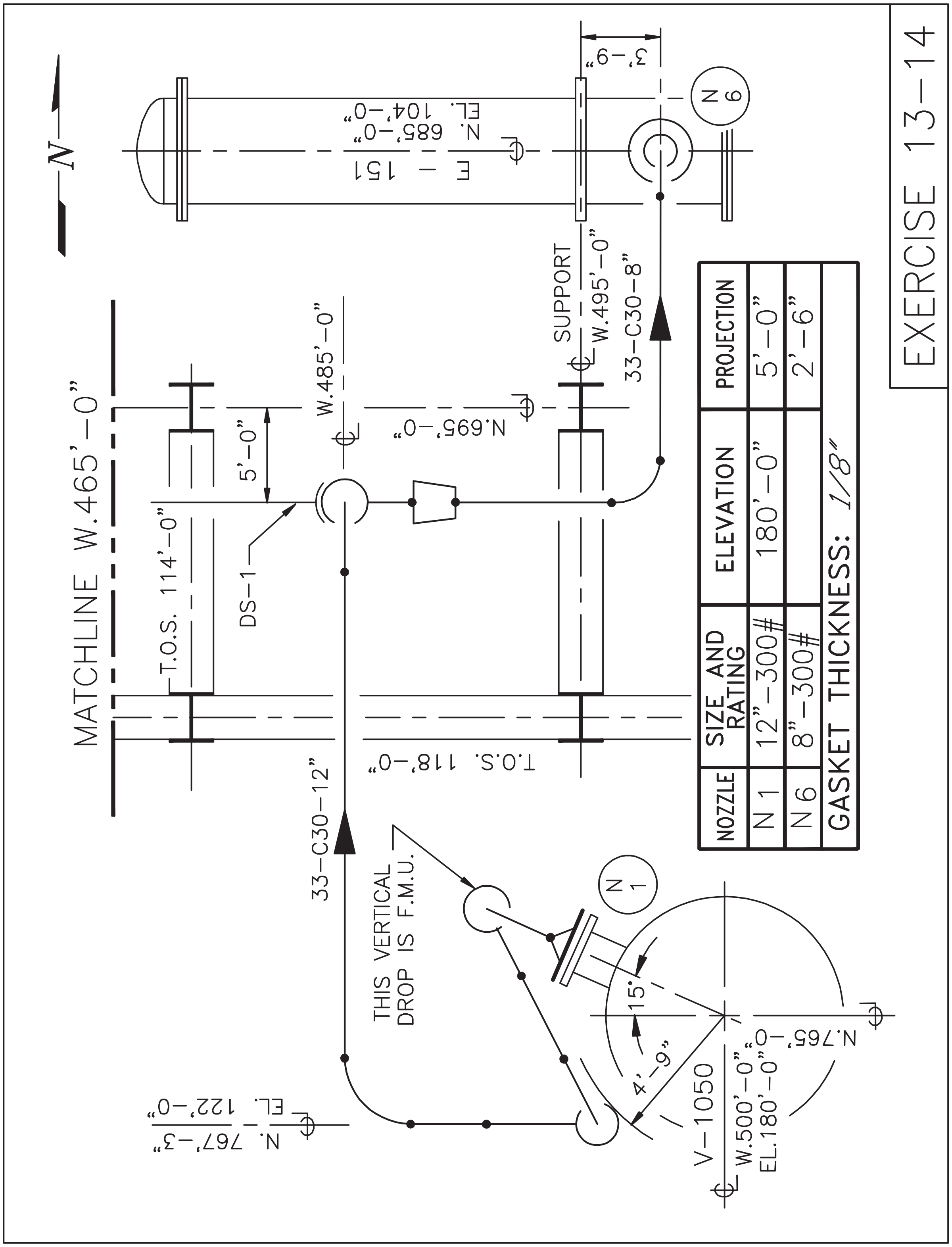
Draw an isometric for the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on the isometric will be up and to the right.

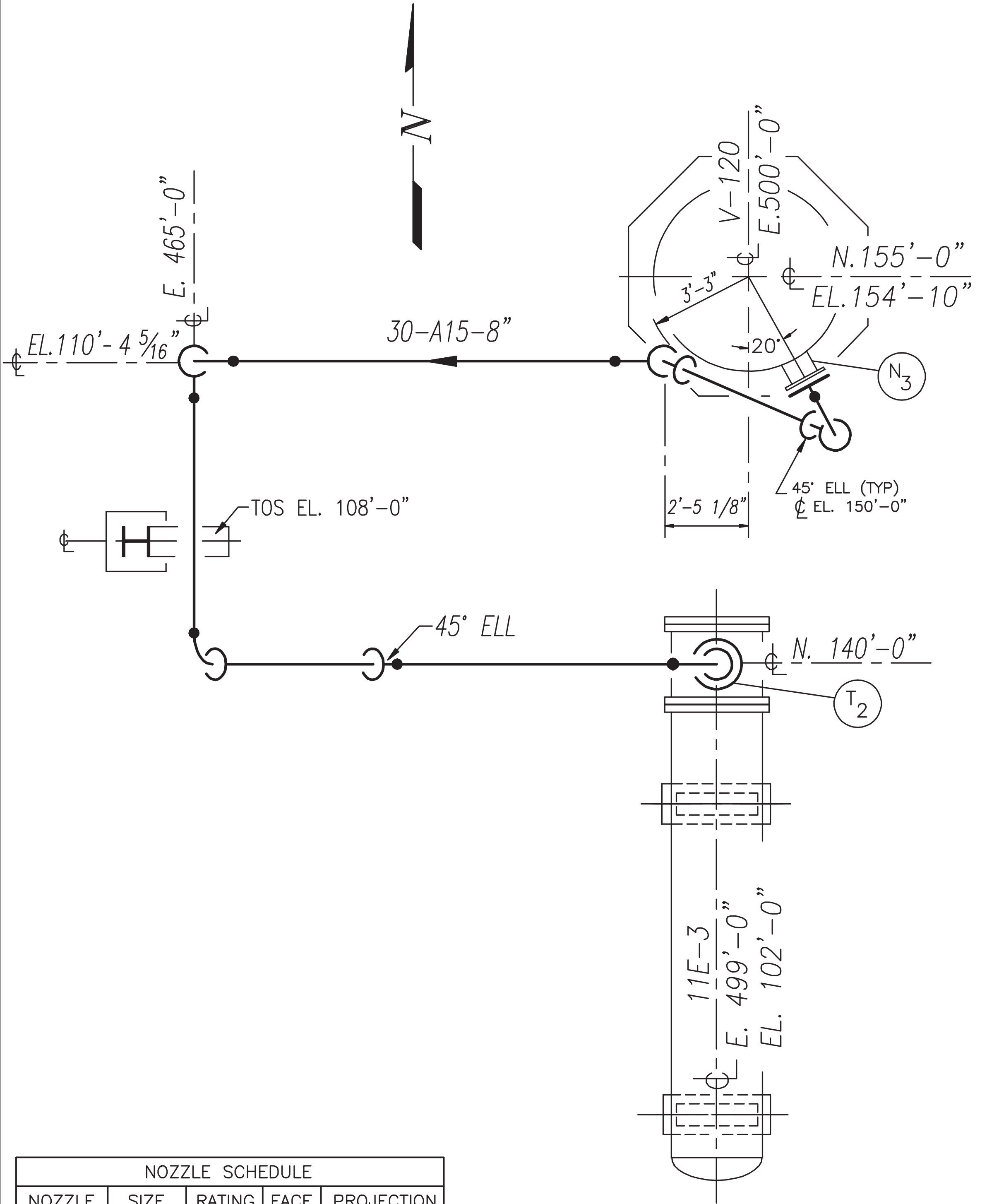


Draw an isometric for the following exercise. Calculate the unknown dimensions and angle for right triangle of the multi-angle offset. North Arrow direction on the isometric will be up and to the right.



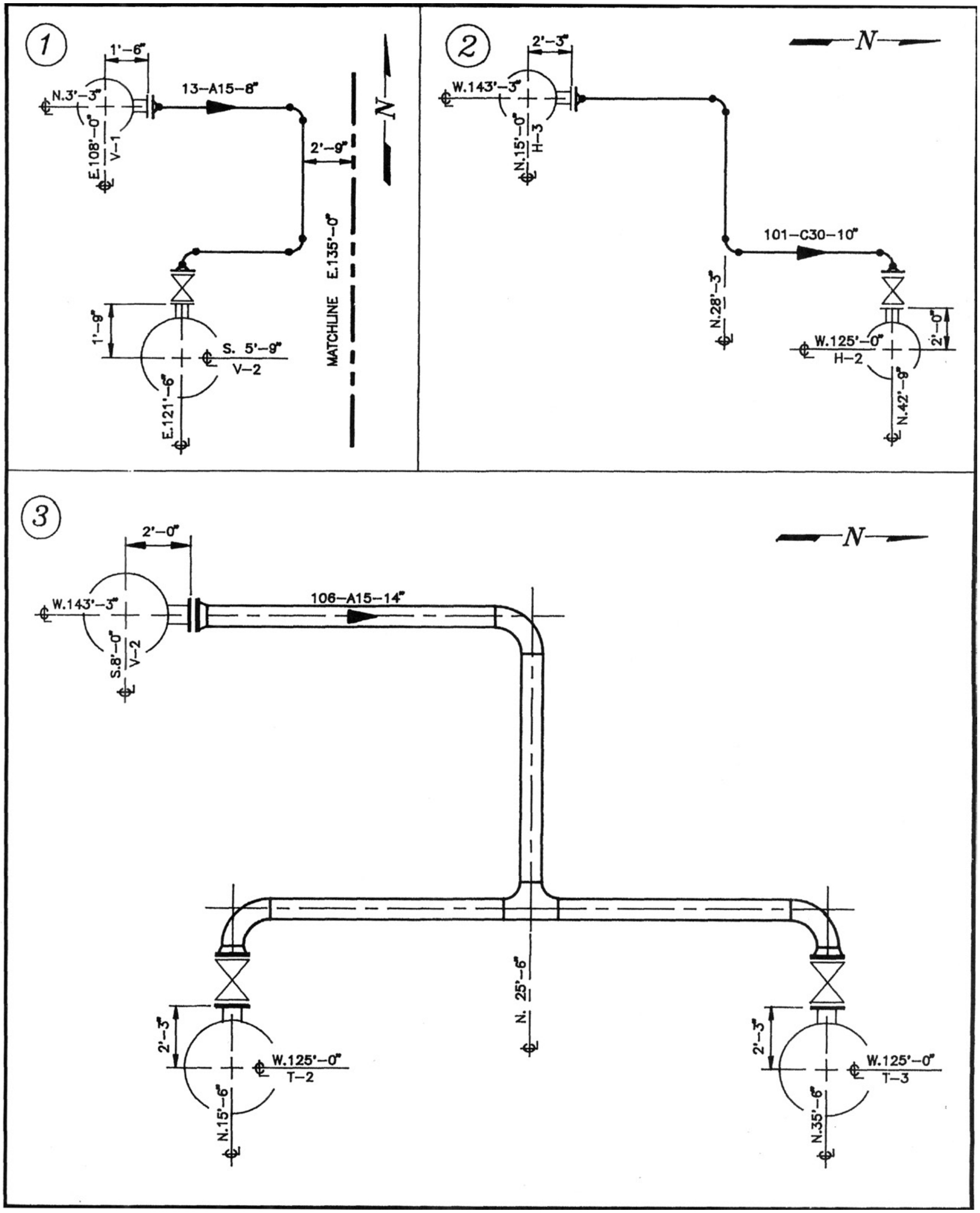
Draw an isometric for the following exercises. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on each isometric will be up and to the right.

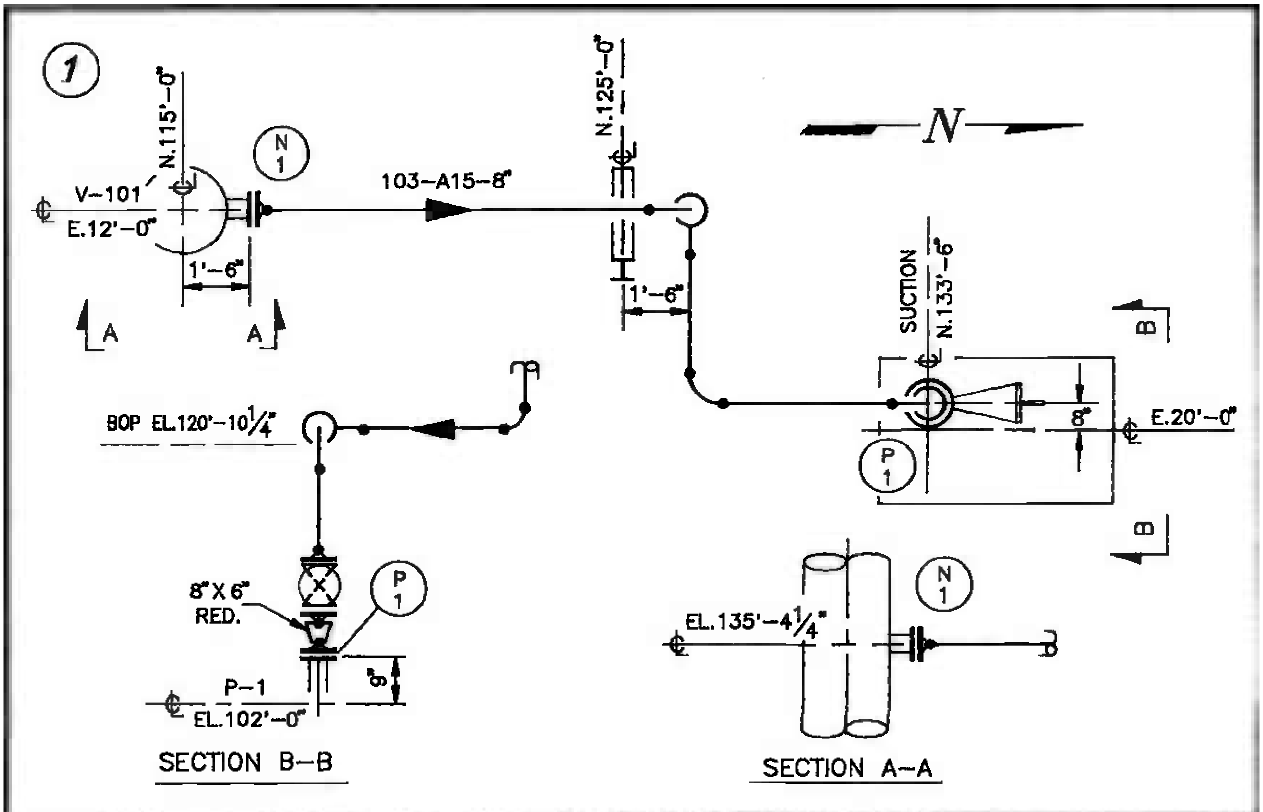


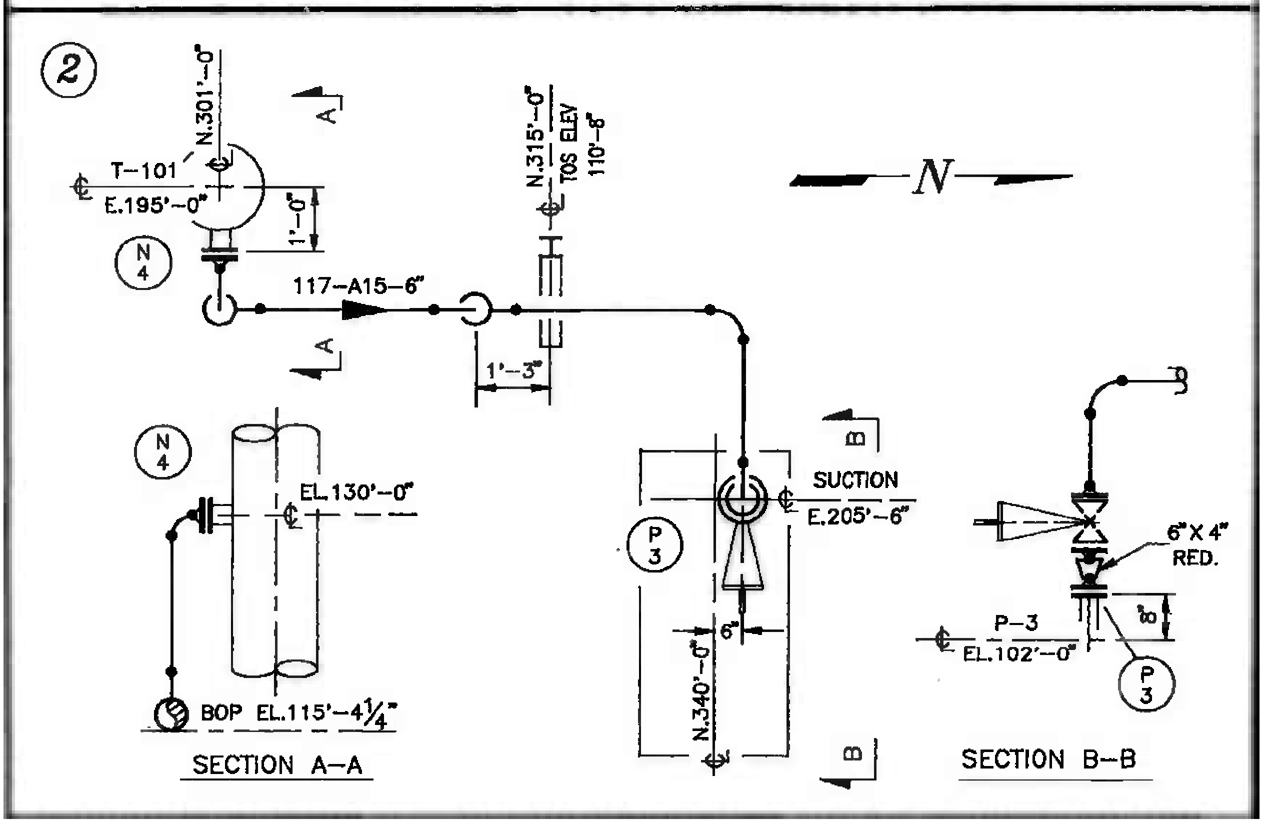


NOZZLE SCHEDULE				
NOZZLE	SIZE	RATING	FACE	PROJECTION
N_3	8"	150#	RF	3'-9"
T_2	8"	150#	RF	1'-6"

EXERCISE 13-15


1
1'-6"
N.3'-3"
13-A15-8"
E.108'-0"
V-1
2'-9"
N
MATCHLINE E.135'-0"
1'-9"
S. 5'-9"
V-2
E.121'-6"
2
2'-3"
N
W.143'-3"
N.15'-0"
H-3
101-C30-10"
N.28'-3"
W.125'-0"
H-2
2'-0"
N.42'-9"
3
2'-0"
N
W.143'-3"
106-A15-14"
S.8'-0"
V-2
N. 25'-6"
2'-3"
W.125'-0"
T-2
N.15'-6"
2'-3"
W.125'-0"
T-3
N.35'-6"


1
N
N.115'–0"
V–101
E.12'–0"
N 1
103–A15–8"
N.125'–0"
1'–6"
1'–6"
A
A
SUCTION N.133'–6"
B
BOP EL.120'–10¼"
8"
E.20'–0"
P 1
B
8" X 6" RED.
P 1
N 1
EL.135'–4¼"
P–1
EL.102'–0"
SECTION B–B
SECTION A–A


2
N.301'–0"
A
N.315'–0" TOS ELEV 110'–8"
T–101
E.195'–0"
1'–0"
N
N 4
117–A15–6"
A
1'–3"
N 4
B
SUCTION
EL.130'–0"
E.205'–6"
P 3
6" X 4" RED.
6"
P–3
EL.102'–0"
8"
N.340'–0"
P 3
BOP EL.115'–4¼"
B
SECTION A–A
SECTION B–B

Solve for the missing dimensions on each of the rolling offset boxes shown. All dimensions are to be written in feet and inches, rounded to the nearest 1/16″.