Pipe Drafting and Design

Fourth Edition

Roy A. Parisher
Robert A. Rhea

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Roy A. Parisher and Robert A. Rhea

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To Kathy

I am my beloved's, and my beloved is mine. Roy

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Preface

This book provides students with the essential skills and knowledge they need to prepare a variety of piping drawings, solve basic design calculations, and develop 3D models. Its step-by-step approach presents the fundamental information an entry-level student needs to begin a successful career in the pipe drafting discipline. Chapter 1, Overview of Pipe Drafting and Design, is an overview of the many employment opportunities in drafting and design that await those who master the skills presented throughout the book's remaining chapters. Each chapter builds on the concepts presented in the preceding one. It is necessary therefore, to master the concepts in a given chapter before proceeding to the next. Each chapter concludes with exercises and questions designed to help the student review and apply the concepts presented in the chapter. The civil, structural, mechanical, electrical and piping drawings provided in Chapter 10, Piping Arrangement Drawings, Sections, and Elevations, and Chapter 15, Project Coordination and Development, are provided to help the student understand the interaction and required collaboration of all disciplines and their contribution to the successful design, construction and operation of any petro-industrial facility.

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CHAPTER

1

Overview of Pipe Drafting and Design

Project managers, engineers, senior-level designers, and client representatives provide input into the operational design of all industrial and commercial facilities. Their combined input creates the framework from which 3D design models, construction drawings, and project specifications are developed. Using knowledge and experience unique to their specific trade discipline, drafters and designers bound by the framework given them, pool information from various sources to design a facility that meets the client's needs. In addition to client requirements, drafters and designers must work within the constraints of governmental codes and regulations, established safe construction practices, budget limitations, and completion deadlines to generate the 3D models and their associated drawings used by construction and fabrication personnel to build any petro-industrial facility and have it successfully commissioned for service on schedule.

It is generally accepted that the responsibility for the efficient design of a petro-industrial facility falls upon the pipe design group. Input from other design groups such as civil, structural, instrumentation, and electrical is incorporated throughout the design process. Project coordination is essential from all design groups and disciplines. Sharing detailed information in a timely manner is imperative if project completion goals are to be met. As a project progresses through various phases of the design process, job-site visits by members of the pipe design group will become necessary. Site visits may be necessary to field-verify positions, sizes, and locations of completed or existing underground obstructions, structural supports, and mechanical equipment before any pipe routing can begin.

PROJECT TYPES

As a pipe drafter or designer, one can expect to work on a variety of different projects. They may include

- environmentally safe waste disposal sites,
- fertilizer plants,
- food and beverage processing facilities,
- high-rise residential and office buildings,
- hospitals,
- offshore drilling platforms,
- petro-chemical and refining facilities,
- pharmaceutical plants,
- pipeline installations,
- pulp and paper mills,
- power generation plants (fossil and solar fueled),
- ships and barges,
- synthetic fuel plants, and
- water treatment facilities.

Such a wide variety of applications require skills and knowledge unique to that particular specialty. Because of the uniqueness of each project type and the geographic location of the construction site, drafters and designers may find exciting travel opportunities awaiting them.

WHO HIRES PIPE DRAFTERS AND DESIGNERS?

A variety of companies hire pipe drafters and designers. Although their trade has a skill set with common characteristics, drafters and designers must have project-specific knowledge. Therefore companies who hire pipe drafters and designers may require specific skills unique to their project type. Companies that employ pipe drafters and designers include

- architectural firms,
- construction companies,
- engineering companies,
- fabrication shops, and
- plant operators/owners.

ARCHITECTURAL FIRMS

Companies that design commercial, multistory residential/office buildings employ pipe drafters and designers.

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Although typically not found to have the high pressure and high temperature applications of petro-industrial facilities, commercial facilities, such as high-rise apartment and office buildings, hospitals, and shopping malls have boiler rooms, HVAC systems, and roof drainage systems that must be incorporated into their design. The drafter or designer that works for an architectural firm must therefore be able to generate 3D models to extract plot plans, P&IDs, foundation and equipment location drawings, piping arrangement drawings, and isometric fabrication drawings.

Other trade groups or disciplines within an architectural firm that must be able to interpret piping drawings include

- estimators,
- material control,
- material take-off,
- pipe stress,
- project management, and
- purchasing.

CONSTRUCTION COMPANIES

Financial constraints and governmental regulations have brought about the development of companies that exclusively specialize in the construction of the pipe elements of a facility. Working on-site and under the leadership of a construction superintendent, an experienced designer is often on the team that oversees the construction of a facility. As revisions are made to the facility's design, whether by client mandates, initial design flaws, or code variances, the designer and staff of drafters are on hand to incorporate any changes and revisions into the 3D model, drawings, project documentation, and so on with the engineer approval. Upon completion of a project, "as-builts" are developed. "As-builts" are modifications and updates to the 3D model and its accompanying drawings that represent the facility as it actually exists after construction has been completed and commissioned for service.

ENGINEERING COMPANIES

The massive responsibility of designing and engineering a petro-industrial facility falls upon the engineering company. Possibly years in development, the engineering company coordinates client requirements, budget limitations, governmental regulations and permitting, project staffing, and countless other time-sensitive demands to see a facility's concept become a reality. From its beginning with just a few members in a planning meeting, to the staffing for the development of a bid proposal, to the full-blown design team with all the trade disciplines, the engineering company coordinates all aspects of a facility's design. From process flow diagrams to completed 3D models and their associated fabrication drawings, engineering companies generate them all. Whether it is a billion-dollar processing plant, a multilevel deep-water offshore drilling platform, or a small, self-contained pump skid engineering companies are staffed with engineers, designers, and drafters with all levels of experience and expertise. If it is a grass-roots project that requires a full 3D model or a small revamp job to replace a corroded pipe using a couple of 3D scans in an old, existing facility, engineering companies use drafters and designers to complete the job.

FABRICATION COMPANIES

As a facility's concept and design take shape, fabrication, or assembly, become the primary focus. Both under and above-ground pipes require detailed drawings to properly size, spec, route, and install in a facility. Fabrication companies use drawings generated from the 3D model that specify pipe and fitting sizes, dimensions, and routing orientation to fabricators who weld, thread, and bolt pipe configurations together. Software specifically used to generate fabrication drawings called *shop spools* or *spool drawings* provide detailed information to purchasing/estimating personnel, as well as welders and fitters.

Knowing that most pipe configurations are not fabricated at the construction site, accurate fabrication drawings are critical to the proper building, and ultimate assembly, of a pipe. For pipes shipped and delivered to the job site, drawings must specify length, orientation, alignment, and so on to define exactly how a pipe is installed or connected to new or existing equipment. Restricted in size due to the limitations of transportation methods and weld x-ray capabilities, pipe configurations are often fabricated in smaller, shorter segments and assembled at the job site. Fabrication companies must have accurate drawings to make this process efficient and cost-effective.

OPERATING COMPANIES

The "operating" company is typically the generic name that references the client who has contracted the facility's design and construction. Once commissioned and put into active service, the operating company becomes responsible for the day-to-day function of the facility. This means any repairs and/or modifications that may become necessary are facilitated at the owner's expense. To expedite the modifications/repairs and reduce costs, some companies employ a small in-house or contracted staff of drafters and designers. Often this small staff will have knowledge in the various trade disciplines, such as civil, structural, instrumentation, electrical as well as piping. Working knowledge of multiple software programs makes everyone on these small staffs an important member to the team.

PREPARING TO BE A PIPE DRAFTER

As with other disciplines, a solid foundation of basic drafting skills is a must. But, for someone wanting to become a pipe drafter or designer having knowledge of how pipes, fittings, flanges, valves, and mechanical equipment all relate to each other is paramount. Working knowledge of multiple 3D modeling and drafting software programs is extremely beneficial as well. 3D visualization, math, and critical thinking skills are valuable to the pipe drafter who wants to become a designer. Ever-changing advances in technology make it imperative that the pipe drafting student adapt to, and learn, new software programs. The more skills and knowledge a pipe drafter has the more valuable an employee they become.

Generally accepted to be the most challenging, rewarding, and thus well paid, of the drafting disciplines, the piping discipline has a unique appeal. Prospective pipe drafters who want to become a piping designer must become familiar with the standards, procedures, and processes used to design many types of facilities that use pipes, fittings, valves, mechanical equipment, and their many related components. The routine handling of volatile commodities under life-threatening temperatures and pressures makes the safe and efficient design of all piping facilities imperative. Positioning and orientation of pipe, valving, and equipment for safe operation and maintenance are learned skills that grow a drafter into a designer. Welders and pipefitters with years of field experience, laboring in taxing work environments, use their hands-on knowledge to become sought-after drafters by engineering, fabrication, and construction companies.

Because of the value a seasoned drafter has, students entering the piping discipline must display a solid and dependable work ethic to be considered successful. Time deadlines and budget allocations force employers to seek dedicated professionals. Students who demonstrate these mature skills, along with the desire to learn, will always be sought after. Strong math and writing skills are valuable to employers. A student's ability to speak well and demonstrate basic pipe and software knowledge serves themselves well in a job interview. Reliability, a desire to improve one's skills, and a positive team-oriented attitude are essential to becoming a successful pipe designer. All multidiscipline companies work in teams like teams of engineers, teams of designers, teams of drafters, and so on. Companies expect their employees to work together. Promotion and compensation often accompany members of a successful team.

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CHAPTER

2

Steel Pipe

HISTORY OF PIPE

Long ago someone decided carrying water from the nearby stream back to his or her dwelling was time-consuming and laborious. Ingenuity gave birth to the invention, and the *pipe* was born. Using the natural resources available, early humans probably fashioned the first pipe from a hollow, natural resource, such as bamboo. Egyptian and Aztec civilizations made pipe from clay. The first metallic pipes were made by the Greeks and Romans from lead and bronze. The use of iron as a material to manufacture pipe came about with the invention of gun powder. Gun powder, of course, is not used to make the iron, but gun powder necessitated the invention of stronger gun barrels. Iron pipes soon followed. Eventually, exotic metals were developed, and pipe became the highly specialized product it is today.

PIPING MATERIALS

Applied in a general sense, the pipe is a term used to designate a hollow, tubular body used to transport any commodity possessing flow characteristics such as those found in liquids, gases, vapors, liquefied solids, and fine powders.

A comprehensive list of the materials used to manufacture pipe would be quite lengthy. Some of the materials include concrete, glass, lead, brass, copper, plastic, aluminum, cast iron, carbon steel, and steel alloys. With such a broad range of materials available, selecting one to fit a particular need can be confusing. A thorough understanding of the pipe's intended use is essential. Each material has limitations that may make it inappropriate for a given application. Throughout this chapter, we will base our discussion on carbon steel pipe, the most common material used in the piping industry.

MANUFACTURING METHODS

Carbon steel pipes can be manufactured using several different techniques, each of which produces a pipe with certain characteristics. These characteristics include strength, wall thickness, corrosion resistance, and temperature and pressure limitations. For example, pipes having the same wall thickness but manufactured by different methods may vary in strength and pressure limits. The manufacturing methods we will mention include seamless, butt-welded, and spiral-welded pipes.

Seamless pipe is formed by piercing a solid, near-molten, steel rod, called a billet, with a mandrel to produce a pipe that has no seams or joints. Figure 2.1 depicts the manufacturing process of seamless pipe.

Butt-welded pipe is formed by feeding hot steel plate through *shapers* that will roll it into a hollow circular shape. Forcibly squeezing the two ends of the plate together will produce a fused joint or seam. Figure 2.2 shows the steel plate as it begins the process of forming a butt-welded pipe.

The least common of the three methods is **spiral-welded pipe**. The spiral-welded pipe is formed by twisting strips of metal into a spiral shape, similar to a barber's pole, then welding where the edges join one another to form a seam. This type of pipe is restricted to piping systems using low pressures due to its thin walls. Figure 2.3 shows spiral-welded pipe as it appears before welding.

Figure 2.4 shows the three pipes previously described in their final form.

Each of the three methods for producing pipe has its advantages and disadvantages. Butt-welded pipe, for example, is formed from a rolled plate that has a more uniform wall thickness and can be inspected for defects prior to forming and welding. This manufacturing method is particularly useful when thin walls and long lengths are needed. Because of the welded seam, however, there is always the possibility of defects that escape the numerous quality control checks performed during the manufacturing process.

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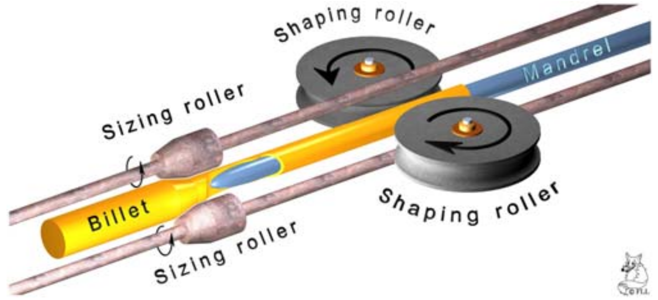


FIGURE 2.1 Sizing seamless pipe.

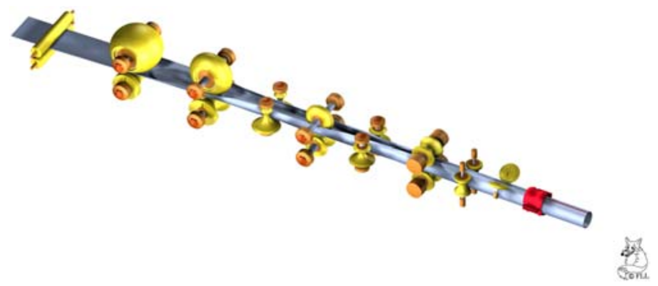


FIGURE 2.2 Shaping butt-weld pipe.

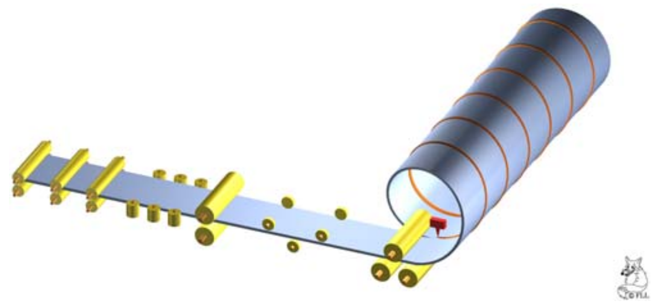


FIGURE 2.3 Forming spiral-welded pipe.

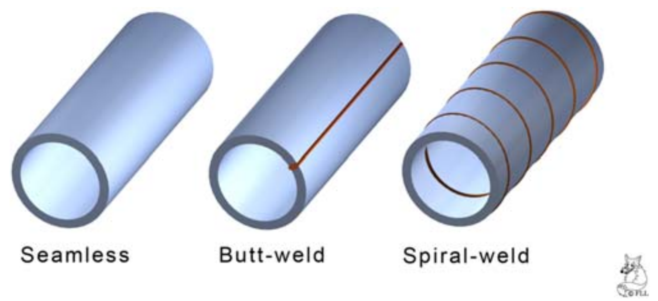


FIGURE 2.4 Manufactured carbon steel pipe.

As a result, The American National Standards Institute (ANSI) developed strict guidelines for the manufacture of pipe. Pressure Piping Code B31 was written to govern the manufacture of pipe. In particular, code B31.1.0 assigns a strength factor of 85% for rolled pipe, 60% for spiral-welded, and 100% efficiency for seamless pipe.

Generally, wider wall thicknesses are produced by the seamless method. However, for the many low-pressure uses of pipe, the continuous welded method is the most economical. Seamless pipe is produced in *single-* and *double-*random lengths. Single-random lengths vary from 16′-0″ to 20′-0″ long. Pipe 2″ and below is found in double-random lengths measuring 35′-0″ to 40′-0″ long.

SIZING OF PIPE

Just as manufacturing methods differ, there are also different ways to categorize the size of a pipe. The pipe is identified by three different size categories: **nominal pipe size**, **outside** diameter, and **inside** diameter (see Figure 2.5).

Nominal pipe size (NPS) is used to describe a pipe by name only. It is essentially a "reference" size and does not translate to an exact diameter measurement of pipe 12″ and smaller. In process piping the term *nominal* simply refers to the name of the pipe, much like a 2″ × 4″ piece of lumber. A 2″ × 4″ board does not actually measure 2″ × 4″, nor does an 8″ pipe actually measure 8″ in diameter. It is just a convenient and easy way to identify pipe and lumber.

Outside diameter (OD) and *inside diameter* (ID), as their names imply, categorize pipes by their true outside and inside measurements.

One of the complexities of pipe design is that different sizes of pipe are manufactured differently. Pipe sizes (NPS) 1/8″ through 12″ have an outside diameter *greater* than its nominal pipe size, whereas pipe sizes 14″ and above have an outside diameter *equal* to its nominal pipe size.

In process piping the aforementioned method of sizing pipe maintains a uniform outside diameter while varying the inside diameter. This method achieves the desired strength necessary for a pipe to perform its intended function while operating under various temperatures and pressures.

WALL THICKNESS

Wall thickness is the term used to describe the measurement of how thick the metal is that a pipe is made from. There are three systems in which a pipe's wall thickness can be categorized; they are the weight system, the schedule system, and the fractional/decimal system. The *weight* system uses three categories to define the thickness of a pipe; they are *standard*, *extra strong*, and *double extra strong*. Limited in number, these three pipe thicknesses restrict a pipe designer's options.

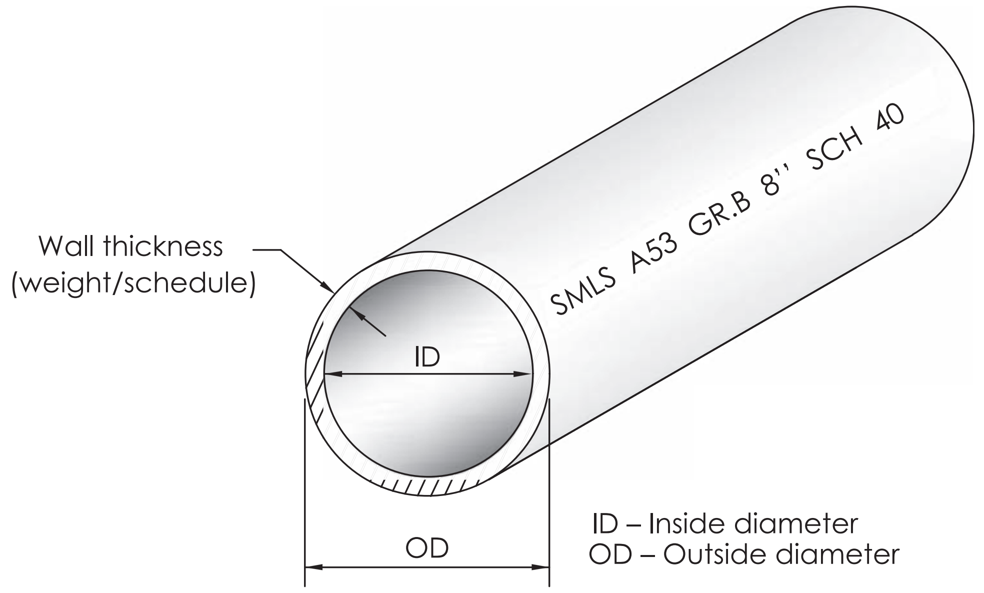


FIGURE 2.5 Pipe measurements.

Over time, pipe selection has increased in complexity. With the development of new chemical processes, the methods of manufacturing pipe have expanded to meet process requirements. Such a wide array of commodity possibilities, with their ever-changing corrosive properties and their extreme range of temperature and pressure variances, has necessitated the manufacture of pipe in additional wall thicknesses. Now called *schedules*, these additional wall thicknesses allow a designer to specify a particular pipe that will meet the exact requirements needed for quality installation and safe operation. Pipe, depending on the diameter, is manufactured in the following schedules: 10, 20, 30, 40, 60, 80, 100, 120, 140, and 160.

The third system of categorizing wall thickness is to simply measure the thickness in either a fractional or decimal value. No matter the method of categorizing a pipe's wall thickness it will not affect the outside diameter of a pipe. OD is a set value that will not change. As wall thickness increases or decreases, it is the inside diameter that adjusts. An example of this variance in wall thickness is shown in Figure 2.6.

Refer to Table 2.1 and notice nominal size is not equal to either the actual OD or the ID for pipe 12″ and smaller. It is simply a convenient method to use when referring to a pipe. As a piping drafter, you should be aware, however, pipe 14″ and larger is identified by its actual outside measurement. The chart in Table 2.1 shows typical pipe diameters and wall thicknesses.

The following formula can be used to calculate a pipe's inside diameter (ID):

$$\text{ID} = \text{OD} - (2 \times \text{Wall Thickness})$$

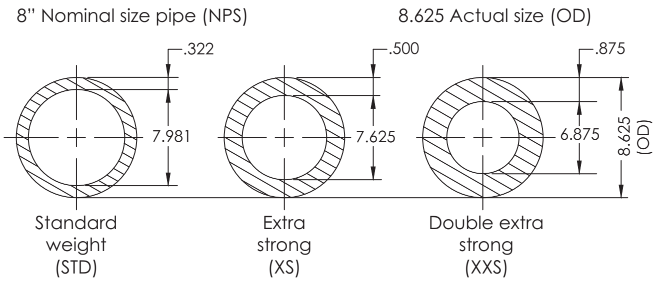


FIGURE 2.6 Pipe thicknesses.

Before selecting a pipe, careful consideration must be given to its material, temperature and pressure allowances, corrosion resistance, and more. The Process engineer will need to pay careful attention to the flow requirements of a pipe used for a particular process. The pressures and temperatures of a commodity in a pipe may dictate its wall thickness. But, with a thick-wall pipe the inside diameter may not permit the required flow rates needed to adequately supply the commodity at its prescribed rate and pressure. Buying and installing the pipe that does not meet the minimum requirements can be dangerous and deadly. Conversely, "over designing" with the pipe that far exceeds what is necessary to do the job can result in unwarranted cost overruns.

METHODS OF JOINING PIPE

There are several methods for joining pipe together. The three methods we will focus on are those most

TABLE 2.1 Carbon Steel Pipe Wall Thickness.

Nominal pipe size		Outside diameter		Standard (STD)		Extra strong (XS)		XX strong (XXS)	
(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)
2	50.8	2.375	60.3	0.154	3.912	0.218	5.53	0.436	11.07
3	76.2	3.5	88.9	0.216	5.486	0.300	7.62	0.552	15.24
4	101.6	4.5	114.3	0.237	6.02	0.337	8.58	0.674	17.12
6	152.4	6.625	168.3	0.280	7.12	0.432	10.97	0.864	21.94
8	203.2	8.625	219	0.322	8.17	0.500	12.70	0.875	22.22
10	254	10.75	273	0.365	9.27	0.500	12.70	1.00	25.4
12	304.8	12.75	323.9	0.375	9.525	0.500	12.70	1.00	25.4
14	355.6	14	355.6	0.375	9.525	0.500	12.70		
16	406.4	16	406.4	0.375	9.525	0.500	12.70		
18	457.2	18	457.2	0.375	9.525	0.500	12.70		

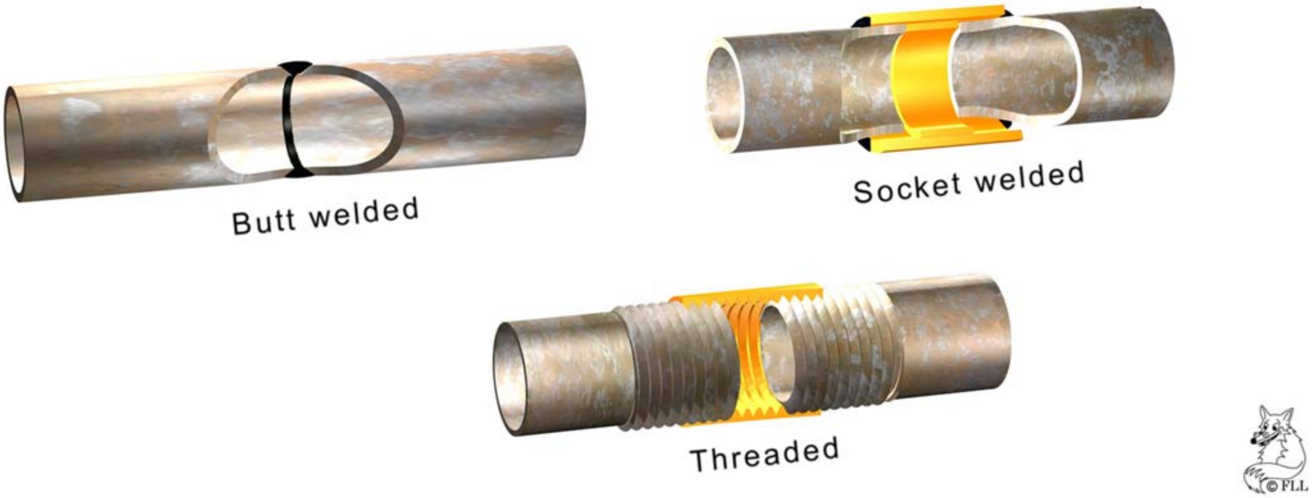


FIGURE 2.7 Pipe joining methods.

widely used in piping systems made of carbon steel, as shown in Figure 2.7. They are butt-welded (BW), screwed (Scrd), and socket-weld (SW). Later in the chapter, cast iron and plastic pipe uses will be discussed.

Butt-Weld Connections

A butt-weld joint is made by welding the beveled ends of pipe together. Beveled ends (BE) indicate that the ends of the pipe are not cut square, but rather are cut or ground to have a tapered edge. In preparation for the welding process, a welder will separate two pieces of pipe by a $\frac{1}{16}''$ space, known as a *root gap*. During the welding process, the two ends are drawn together and the $\frac{1}{16}''$ gap disappears. If two pieces of pipe 3′-0″ long were welded together in this manner, the result would be a total length of 6′-0″.

However, sometimes a *backup ring* is used in critical situations. The backup ring is used when there is a need to prevent the formation of weld icicles inside the pipe. The backup ring creates a gap of $\frac{1}{8}''$ between the two pieces of pipe. In this situation the ring does not allow the ends of the pipe to be drawn together and keeps them separated by $\frac{1}{8}''$.

If two lengths of pipe measuring 3′-0″ each were welded together using a backup ring, the result would be a total length of 6′-0$\frac{1}{8}''$. In this instance the $\frac{1}{8}''$ gap would be shown when dimensioning the pipe. Otherwise, the root gap would not be considered at all. Figure 2.8 shows the $\frac{1}{16}''$ root gap and the resulting butt-weld joint.

Threaded Connections

Another common means of joining pipe is the threaded end (TE) connection. Typically used on pipe 3″ and smaller, threaded connections are often referred to as *screwed* pipe. With tapered grooves cut into the ends of a run of pipe, screwed pipe and screwed fittings can easily be assembled without welding or other permanent means of attachment. Screwed pipe and its mating fittings will have threads that are either male or female. Male threads are cut into the outside of a pipe or fitting, whereas female threads are cut into the inside of the fitting.

As screwed pipe and fittings are assembled, a short length of pipe is drawn into the fitting. This connection length is called a *thread engagement*. When drawing and dimensioning screwed pipe, a piping drafter must be aware of this *lost* length of pipe. As the diameter of the pipe increases, so will the length of the thread engagement. Table 2.2 provides a chart indicating the thread engagements for small bore pipes.

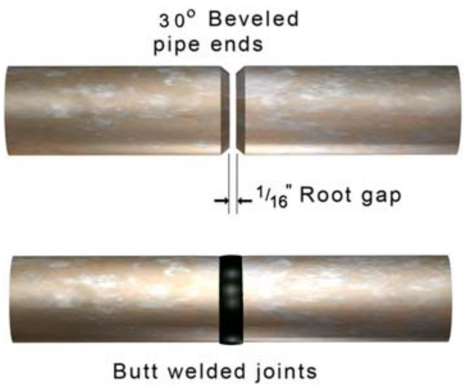


FIGURE 2.8 Butt-weld joints.

Socket-Weld Connections

The third method of joining carbon steel pipe is socket welding. When assembling a pipe with socket-weld fittings, the pipe is inserted into the fitting before welding, unlike a butt-weld connection that has the pipe and fitting placed end-to-end. Inside the socket-weld fitting is a collar that prevents the pipe from being inserted too deeply into the fitting.

As with screwed connections, a short amount of pipe is lost when the socket-weld connections are made. Table 2.3 provides the socket depths for pipe sizes through 3″ in diameter. Before the weld is made, the pipefitter will back the pipe off the collar approximately 1/8″ to allow for heat expansion during the welding procedure. The pipe used for socket-weld connections will be prepared with a plain end. Plain end (PE) means the pipe is cut square, or perpendicular to, the long axis, unlike butt-weld fittings that have beveled ends.

CAST IRON PIPE

Not all piping systems require pipe designed to withstand the extreme conditions found in process piping facilities. Cast iron pipe, which has been in use for centuries, is used primarily in gravity flow applications such as storm and sanitary sewers, and waste and vent piping installations. Residential, commercial, and industrial facilities routinely are built with some form of gravity flow systems. The

TABLE 2.2 American Standard and API Thread Engagement Dimensions.

Dimensions (in inches and millimeters)			
Pipe size		Thread engagement	
(in.)	(mm)	(in.)	(mm)
1/2″	13	1/2″	13
3/4″	20	9/16″	14
1″	25.4	11/16″	18
1 1/2″	38	11/16″	18
2″	50.8	3/4″	20
2 1/2″	63.5	15/16″	24
3″	76.2	1″	25.4

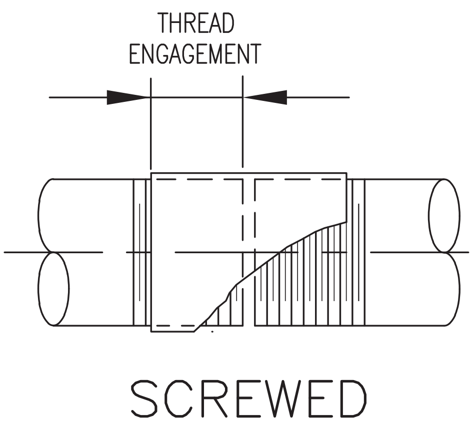
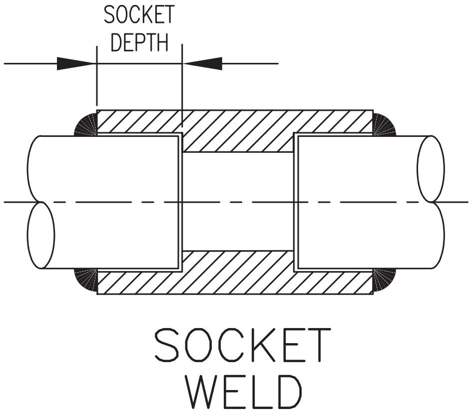


TABLE 2.3 Forged Steel Socket-Weld Fitting Socket Depth Dimensions.



Dimensions (in inches and millimeters)			
(in.)		(mm)	
Pipe size	Thread engagement	Pipe size	Thread engagement
1/2″	1/2″	13	13
3/4″	9/16″	20	14
1″	5/8″	25.4	16
1 1/2″	3/4″	38	20
2″	7/8″	50.8	22
2 1/2″	1 1/8″	63.5	29
3″	1 3/8″	76.2	35

corrosion resistance properties of cast iron pipe make it the ideal product for permanent below-ground gravity flow installations.

The term *cast iron* refers to a large group of ferrous metals. Cast irons are primarily alloys of iron that contain more than 2% carbon and 1% or more silicon. Cast iron, like steel, does corrode. What makes cast iron different is its graphite content. As cast iron corrodes, an insoluble layer of graphite compounds is produced. The density and adherent strength of these compounds form a barrier around the pipe that prevents further corrosion. In steel, this graphite content does not exist, and the compounds created during corrosion cannot bond together. Unable to adhere to the pipe, they flake off and expose an unprotected metal surface that perpetuates the corrosion cycle. In tests of severely corroded cast iron pipe, the graphite compounds have withstood pressures of several hundred pounds per square inch, although corrosion had actually penetrated the pipe wall. Considering the low cost of raw manufacturing materials and the relative ease of manufacture, cast iron is the least expensive of the engineering metals. These benefits make cast iron the choice application in environments that demand good corrosion resistance.

Joining Cast Iron Pipe

Cast iron pipe is grouped into two basic categories: hub and spigot, and hubless.

The hub, or bell, and spigot joint uses pipe with two different end types. The hub end of the pipe has an enlarged diameter, thus resembling a bell. The spigot end of the adjoining pipe has a flat or plain-end shape. The spigot is inserted into the bell to establish a joint. Two methods of preventing leaks on bell and spigot joints are *compression* and *lead and oakum*. The compression joint uses a one-piece rubber gasket to create a leak-proof seal. As shown in Figure 2.9, when the spigot end of the pipe is placed into the hub containing a gasket, the joint is sealed by displacing and compressing the rubber gasket. Unlike welded pipe, this joint can absorb vibration and can be deflected up to 5° without leakage or failure.

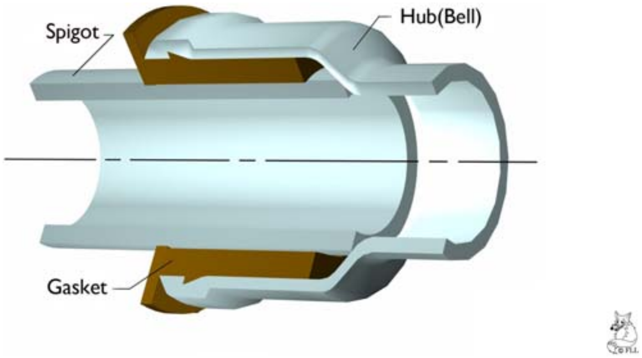


FIGURE 2.9 Cast iron pipe compression joint.

The lead and oakum joint is made with oakum fiber and molten lead to create a strong, yet flexible, leak-proof, and root-proof joint. When the molten lead is poured over the waterproof oakum fiber, which is a loose, oil-laden, hemp-like packing material, the joint becomes completely sealed. Water will not leak out, and when used underground, roots cannot grow through the joints. See Figure 2.10.

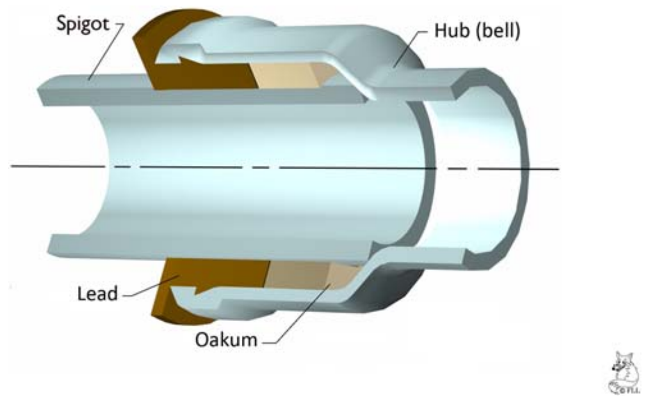


FIGURE 2.10 Cast iron lead and oakum joint.

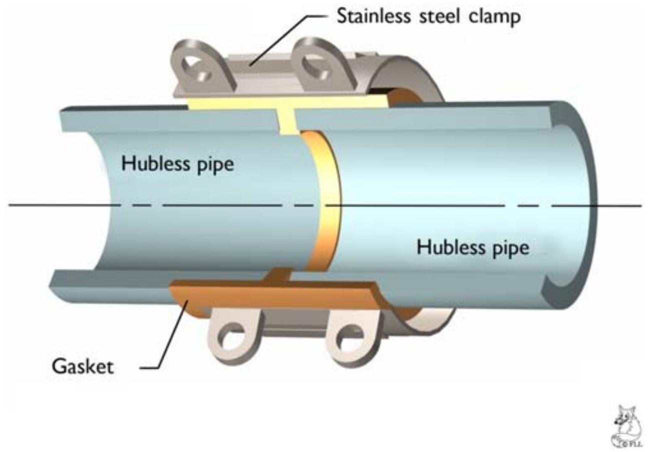


FIGURE 2.11 Cast iron hubless pipe coupling.

Hubless cast iron pipe uses pipe and fittings manufactured without a hub. The method of joining these pipes and fittings uses a hubless coupling that slips over the plain ends of the pipes and fittings and is tightened to seal the ends. Hubless cast iron pipe is made in only one wall thickness and ranges in diameter from 1½″ to 10″. Figure 2.11 depicts the hubless cast iron pipe joint.

PLASTIC PIPE

The latest entry into the materials list for manufacturing pipe is plastic. Not originally thought of as a product capable of performing in the environs of a piping process facility, plastic has emerged as a reliable, safe, and cost-effective alternative material. There is a broad range of plastic compounds being developed today.

For piping systems, two categories are most effective: fluoroplastics and thermoplastics. Fluoroplastics are found in materials like PTFE, PVDF, ECTFE, CTFE, PFA, and FEP. As a group, fluoroplastics perform extremely well in aggressive chemical services at temperatures from −328° to +500°F. Thermoplastics are those that require melting during the manufacturing process. These plastics can be welded or injection molded into shapes for machining into piping system components.

For some piping systems, it is now inconceivable not to use plastics. Pipes made from plastic are replacing traditional, expensive materials like glass or ceramic-lined pipe. Some plastics such as UHMW PE, PVDF, CTFE, and nylon have such excellent wear resistance that they prove in Taber Abrasion Tests to be five to ten times better in this regard than 304 Stainless Steel. The Taber Abrasion Test cycles an abrasive wheel over the face of a plate made of the material being tested. After 1,000 cycles of the wheel, the plate is measured to determine the amount of weight loss. Table 2.4 lists the results.

TABLE 2.4 Tabor Abrasion Test Results.

Abrasion Ring CS-10, load 1 kg	
Nylon 6–10	5 mg/1,000 cycles
UHMWPE	5
PVDF	5–10
PVC (rigid)	12–20
PP	15–20
CPVC	20
CTFE	13
PS	40–50
Steel (304SS)	50
ABS	60–80
PTFE	500–1,000

Joining Plastic Pipe

Plastic pipe can be joined by one of the following methods: threading, solvent cement, or fusion. Threading plastic pipe is not a viable option because it is expensive. Heavy wall thicknesses are required, and leaks from high pressures and expansion and contraction are difficult to control. Joints made with solvent cement have proven more reliable. Although, once hardened, cemented joints cannot be disassembled. They offer good resistance to abrasive chemical and high-pressure commodities and are available in a large selection of fittings without the need of threads. Heat fusion must be performed on some plastic compounds that are resistant to chemical solvents. The pipe can either be butt-joined or socket-joined. Heat fusion can be used with thinner wall thicknesses and are pressure resistant beyond the burst pressure of the pipe.

Socket fittings provide large surface contact between pipe and fittings and are resistant to separation. For this reason, they cannot be disassembled.

Although fabrication with plastic may sound simple, caution must be exercised when using plastic pipe. The effectiveness of a particular grade of plastic must be tested before it is chosen for a particular service. Four important variables must be evaluated: chemical resistance, pressure limitations, temperature limitations, and stress. The various molecular components of plastics make them susceptible to chemical reactions with certain compounds. Hazardous mixtures must be avoided. Pressure and temperature limitations must be established for obvious reasons. Pipe that is overheated or pressurized beyond capacity can rupture, split, or burst. Stress, as applied to pipe, entails physical demands such as length of service, resistance to expansion and contraction, and fluctuations in pressure and temperature. Excessive stresses in the form of restricted expansion and contraction, and frequent or sudden changes in internal pressure and temperature must be avoided.

DRAWING PIPE

Pipe can be represented on drawings as either *single line* or *double line*. Pipe 12″ and smaller is typically drawn *single line*, and pipe 14″ and larger is drawn *double line*. Single-line drawings are used to identify the centerline of the pipe. Double lines are used to represent the pipe's nominal size diameter.

The standard scale used on piping drawings is 3/8″ = 1′-0″. Typically hand-drawn, single-line pipe is drawn with a 0.9 mm or a double-wide 0.7 mm fine-line lead holder. When drawing single-line pipe with CAD software, a line having a width (lineweight) of approximately 9/16″ is used on full-scale drawings. Double-line pipe uses standard or "default" line widths to draw the pipe's nominal size diameter. A centerline is used on all double-line pipe to allow for the placement of dimensions. Figure 2.12 provides several representations of pipe as it may appear on a drawing.

When pipe is represented on a drawing, typically the pipe's nominal size dimension is used to identify pipe size. One would find it difficult to draw a 4″ pipe to its actual outside diameter of 4 1/2″ especially on such a small scale as 3/8″ = 1′-0″.

There are certain applications, however, when the pipe's true outside diameter dimension is used to represent the pipe on a drawing. Drawings created with most software packages are an example. Piping software programs draw with such accuracy that pipe is drawn using the actual outside diameter.

***NOTE**: Pipe created by means other than a piping software program in this text will be drawn using nominal sizes. Be aware that drawings generated by pipe modeling software programs will use actual outside dimensions and will differ slightly from manual and CAD generated drawings.*

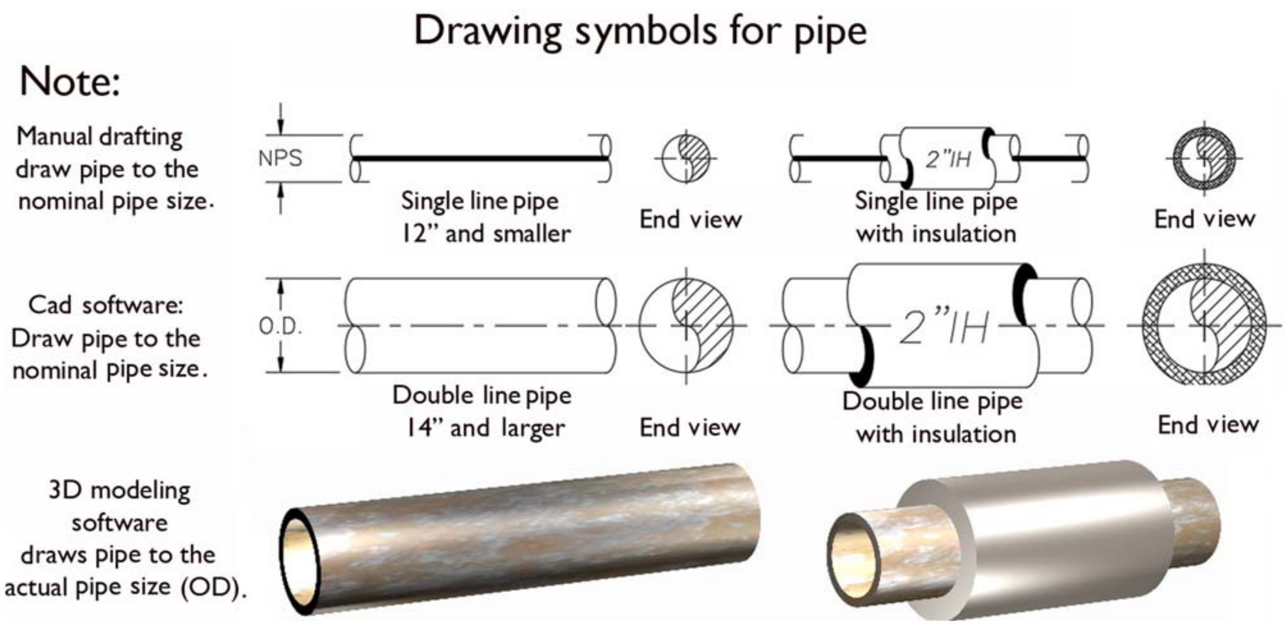


FIGURE 2.12 Drawing representations of pipe.

CHAPTER 2 REVIEW QUIZ

1. Name three methods of manufacturing carbon steel pipe.

____

____

____

2. Name the three most commonly used *end preparations* for joining pipe.

____

____

____

3. What is meant by the term nominal size pipe?

____

4. Which diameter of pipe varies as the wall thickness changes?

____

5. What is the most common material used in the manufacture of pipe used in petrochemical facilities?

____

6. When drawing pipe, which pipe sizes are drawn single-line and which sizes are drawn double-line?
Single-line __________ Double-line ______________

7. How long is the gap between two lengths of pipe when a back-up ring separates them?

____

____

8. What is the name for the amount of pipe "lost" when screwed connections are used?

____

9. What is the standard scale piping drawings are plotted to?

____

10. Name three methods for joining carbon steel and plastic pipe.

____

____

____

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CHAPTER

3

Pipe Fittings

Fittings are fabricated pipe components that are used to perform specific functions throughout the routing of a pipeline. A multitude of various fitting types exist. Among the many purposes fittings have, they are used to make directional changes (elbow), create branches from a main pipe (tee), and reduce the diameter of the pipe (reducer) (see Figure 3.1).

Because fittings are part of the piping system, they must match as closely as possible in specification and rating to the pipe which they are being attached. Fittings, like pipe, are manufactured and classified according to their wall thickness or schedule. There are many more wall thicknesses of pipe however than there are thicknesses of fittings. Fittings are commercially manufactured in standard

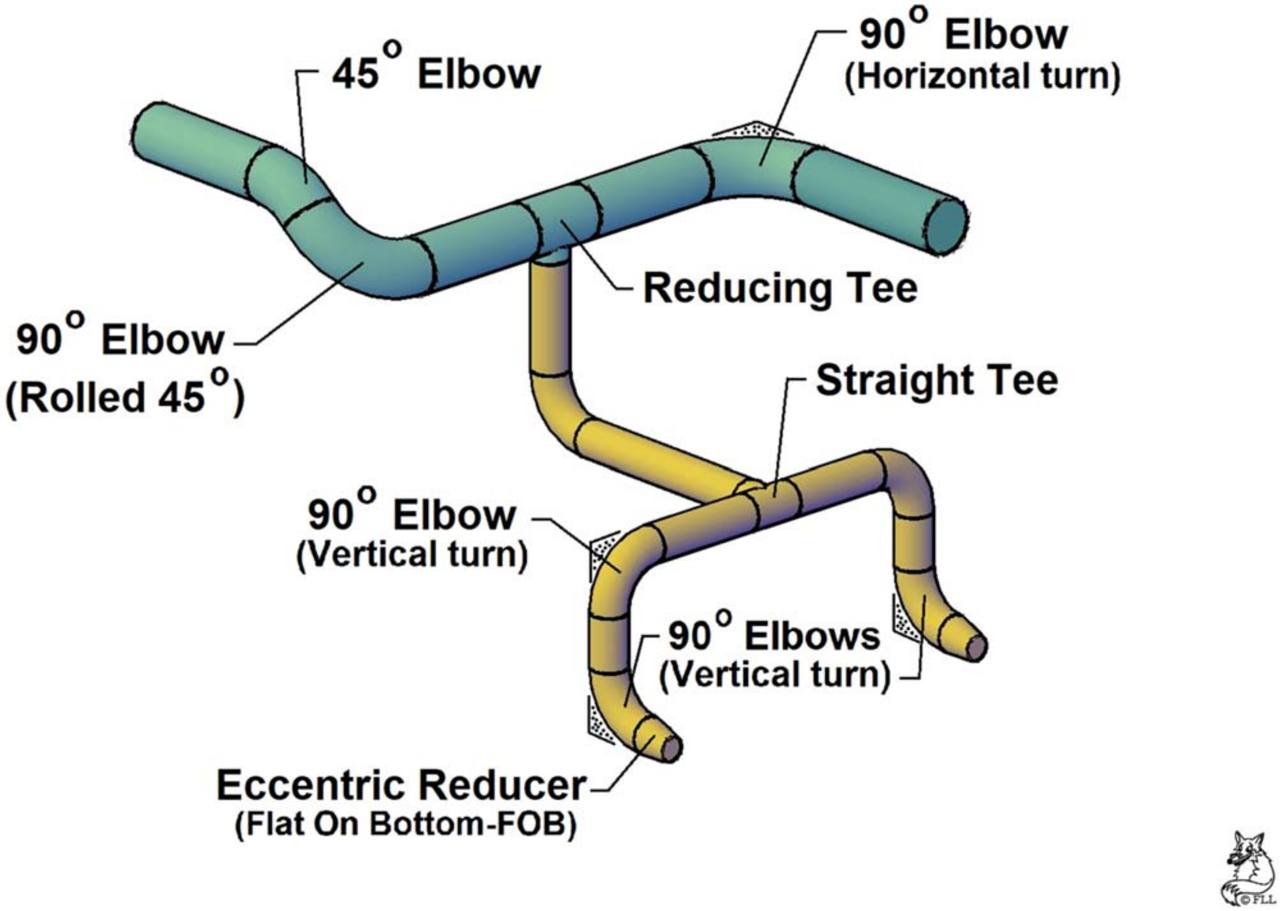


FIGURE 3.1 Fittings.

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00019-4

weight, extra strong, Schedule 160, and double extra strong categories.

In the petro-chemical industry, most companies have guidelines known as *piping specifications* that state pipe 3″ in diameter and larger used in their facility will have butt-welded connections. These specifications, or *specs* as they are more commonly referred, may also require pipe smaller than 3″ in diameter to have threaded or socket-weld connections. For uniformity the previously mentioned specifications will be used throughout this book as a basis for determining pipe connection requirements. However, this is not to say that this is the only spec that can be written. There may be cases where small bore pipe configurations are butt-welded, whereas larger size routings may be threaded or socket-weld.

90° ELBOWS

Of all the fittings, the elbow is the one most often used. Simply put, the elbow, or ell, is used when a pipe changes direction. Elbows can turn up, turn down, turn left, right, or any angle in between (see Figure 3.1). 90° elbows can be classified as one of the following

- long-radius elbow,
- short-radius elbow,
- reducing elbow, and
- mitered elbow.

Of these four types, the long-radius elbow, shown in Figure 3.2, is the one most commonly used.

When one finds it necessary to draw a 90° elbow or calculate how much space it will occupy in a routing configuration, knowing its length becomes essential. An elbow's length is commonly referred to as the *center-to-end* dimension and is measured from the centerpoint of its radius to the end of either opening (see Figure 3.3).

Notice the relationship between the nominal size and the length of the fitting. The 90° elbow's length is equal to the nominal pipe size plus *one-half* of the nominal size. A simple formula that makes calculating this dimension easy to remember is; *Fitting length equals 1½ times NPS (nominal pipe size)*.

Example: The length of an 8″ 90° long-radius elbow is:

$$8'' \times 1^1/_2 = 12''$$

NOTE: *Use this formula for buttweld fittings only.*

Long-Radius Elbow

Dimensional sizes of fittings are typically provided by the manufacturer of the fitting. Manufacturers issue dimensioning charts containing lengths for a particular fitting. The dimensional chart used to establish sizes of fittings discussed in this text are listed on the Welded Fitting-Flanges Chart provided in Appendix A. For brevity, portions of that chart are used throughout this chapter when fitting measurements are needed. Use the 90° elbow portion of the Welded Fitting-Flanges Chart, Figure 3.4, to find the length of the fitting. In the thumbnail sketch on the left end of the chart the ***A*** dimension represents the length or center-to-end dimension of the

FIGURE 3.2 Long-radius elbow.

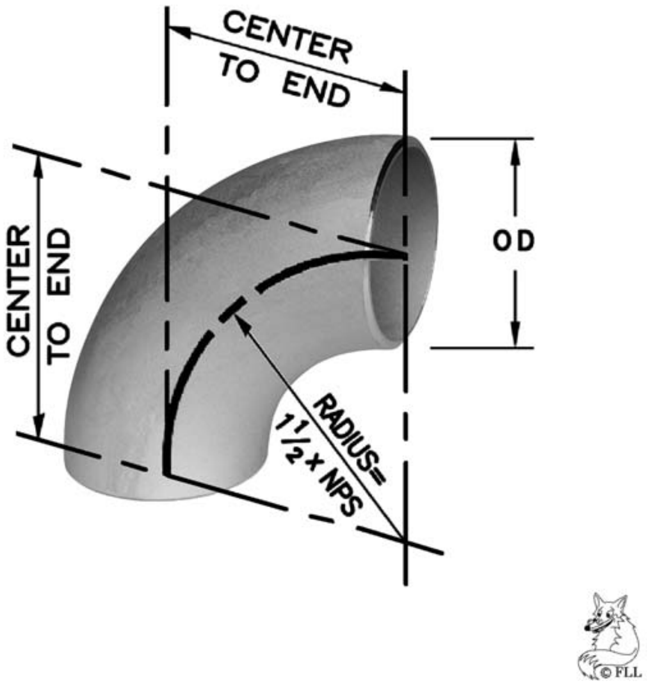
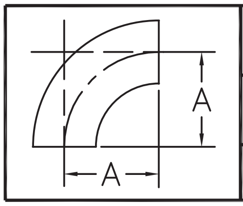


FIGURE 3.3 Center-to-end dimension of a 90° long-radius elbow.



	2"	3"	4"	6"	8"	10"	12"	14"
NOMINAL PIPE SIZE-(INCHES)	2"	3"	4"	6"	8"	10"	12"	14"
PIPE (OUTSIDE DIAMETER)	$2\frac{3}{8}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$6\frac{5}{8}$	$8\frac{5}{8}$	$10\frac{3}{4}$	$12\frac{3}{4}$	14"
Center–to–End 90° ELL A	3	$4\frac{1}{2}$	6	9	12	15	18	21

FIGURE 3.4 Welded fitting-flanges dimensioning chart.

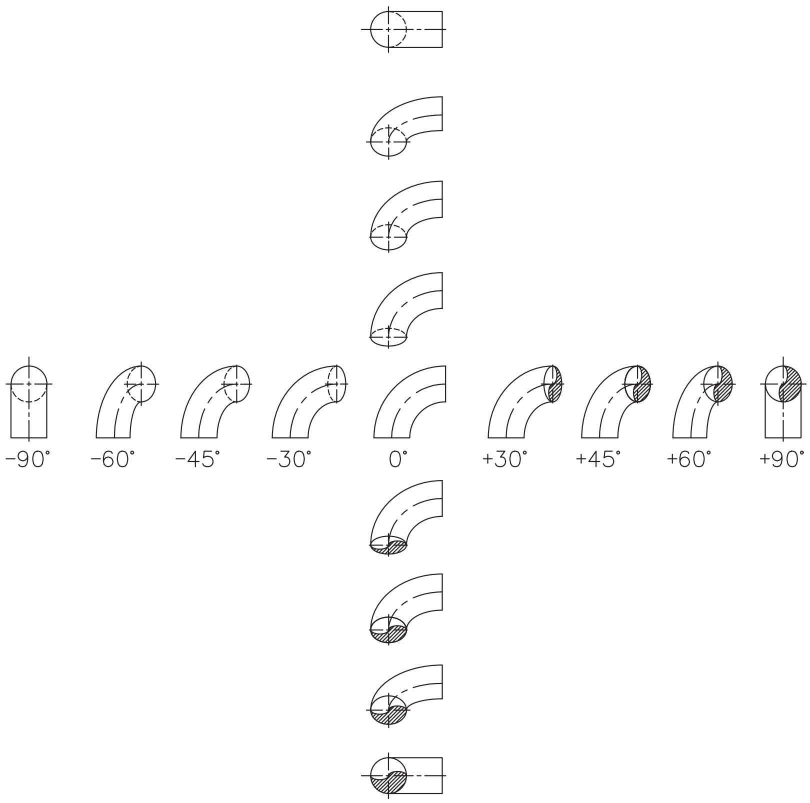


FIGURE 3.5 90° elbow rotations.

elbow. To find the fitting's length, in inches, locate the appropriate pipe size in the row labeled ***Nominal Pipe Size (Inches)***. Below the nominal pipe size, in row ***A***, the center-to-end dimension is shown.

When drawing the elbow, the center-to-end dimension is used as the radius measurement for the elbow's centerline arc. This measurement must be determined before the elbow can be drawn. In time, once the center-to-end dimension formula is memorized, referencing the Welded Fitting-Flanges Chart should no longer be necessary.

Drawing Symbols for the 90° Long-Radius Elbow

As with all drafting disciplines, symbols are used to represent real-world items on drawings. Like door symbols on an architectural floor plan or resistor symbols on an electronic schematic, piping symbols are developed to represent components unique to the piping discipline. What makes the piping discipline so challenging is that all pipe components, whether they will be fittings, flanges, or valves, have multiple symbols for each individual component. So, a single elbow can have multiple representations. Looking at it from the side, the top, or the end will yield different symbol shapes. For example, the 90° long-radius elbow can be rotated in numerous orientations, as shown in Figure 3.5. As one can see, these rotations represent an elbow turning to the right, as well as it rolling toward (right and bottom orthographic views) and rolling away (left and top orthographic views) from the viewer.

The drawing symbols for the 90° long-radius elbow are derived from these rotations. Another drawing technique unique to the piping discipline is that each component, depending on its pipe diameter, can be represented as

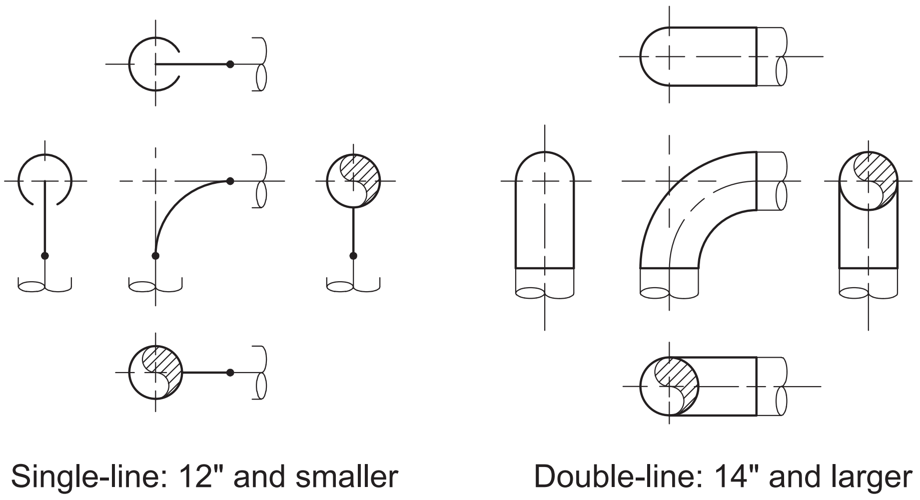


FIGURE 3.6 90° long-radius elbow orthographic drawing symbols.

either a single-line or double-line symbol. As with pipe, fittings that are 12″ and smaller are drawn with single-line symbols and those 14″ and above are drawn with double-line symbols. Figure 3.6 shows the drawing symbols for the various orthographic views of a 90° elbow. To better visualize the long-radius elbow, a short length of pipe has been attached to each end of the elbow. This depicts how the elbow might appear if it were welded to a run of pipe. Remember, only the centerline arc of the elbow is drawn when representing the single-line symbols. The double-line symbol requires one-half of the pipe's OD to be added and subtracted, respectively, from the centerline arc to represent the total pipe diameter. Keep in mind as the front view of the elbow is rotated, so too will the adjacent orthographic views be rotated.

Drawing the 90° Long-Radius Elbow

Two "Step-by-Step" methods will be presented for constructing the 90° long-radius elbow. Figure. 3.7 depicts steps to draw a double-line symbol of a 14″ elbow using AutoCAD commands. Figure 3.8 provides the steps required to draw a single-line 12″ elbow symbol.

***NOTE**: The step-by-step instructional procedures presented using computer-aided drafting techniques presume each student has a comprehensive knowledge of basic AutoCAD commands. These instructional steps provide a simple method to create each fitting. They are not intended to restrict the student to any particular series of commands. Each student is encouraged to experiment with various commands which may achieve the same result in a more efficient manner.*

Short-Radius Elbow

Another elbow that may be used under certain circumstances and with permission from the customer is the 90° short-radius elbow. The 90° short-radius ell makes a much sharper turn than does the long-radius ell (see Figure 3.9). Conversely, the short-radius ell also creates a rather large pressure drop inside the line and does not have the smooth flow characteristics the long-radius ell has. For these reasons the short-radius ell is seldom used.

A simple formula can be used to calculate the center-to-end dimension of a 90° short-radius ell; *Fitting length equals 1 times NPS (nominal pipe size)*. Or, even simpler, fitting length equals nominal pipe size (Figure 3.10).

Example: The length of an 8″ 90° short-radius elbow is:

$$8'' \times 1 = 8''$$

***NOTE**: Use this formula for buttweld fittings only.*

Drawing Symbols for the Short-Radius Elbow

The drawing symbols for a short-radius elbow are shown in Figure 3.11.

***NOTE**: Anytime a short-radius ell is used the abbreviated note **S.R.** must be placed adjacent to the drawing symbol, as shown in Figure 3.11.*

Reducing Elbows

For a relatively short period of time, reducing elbows were experimented with on various piping projects. The development of the reducing elbow come about from the thinking that in a situation where a 90° turn and line-size reduction occurred a single fitting could be implemented. It was thought that a new fitting could be manufactured that combined a 90° long-radius elbow and a pipe reducer

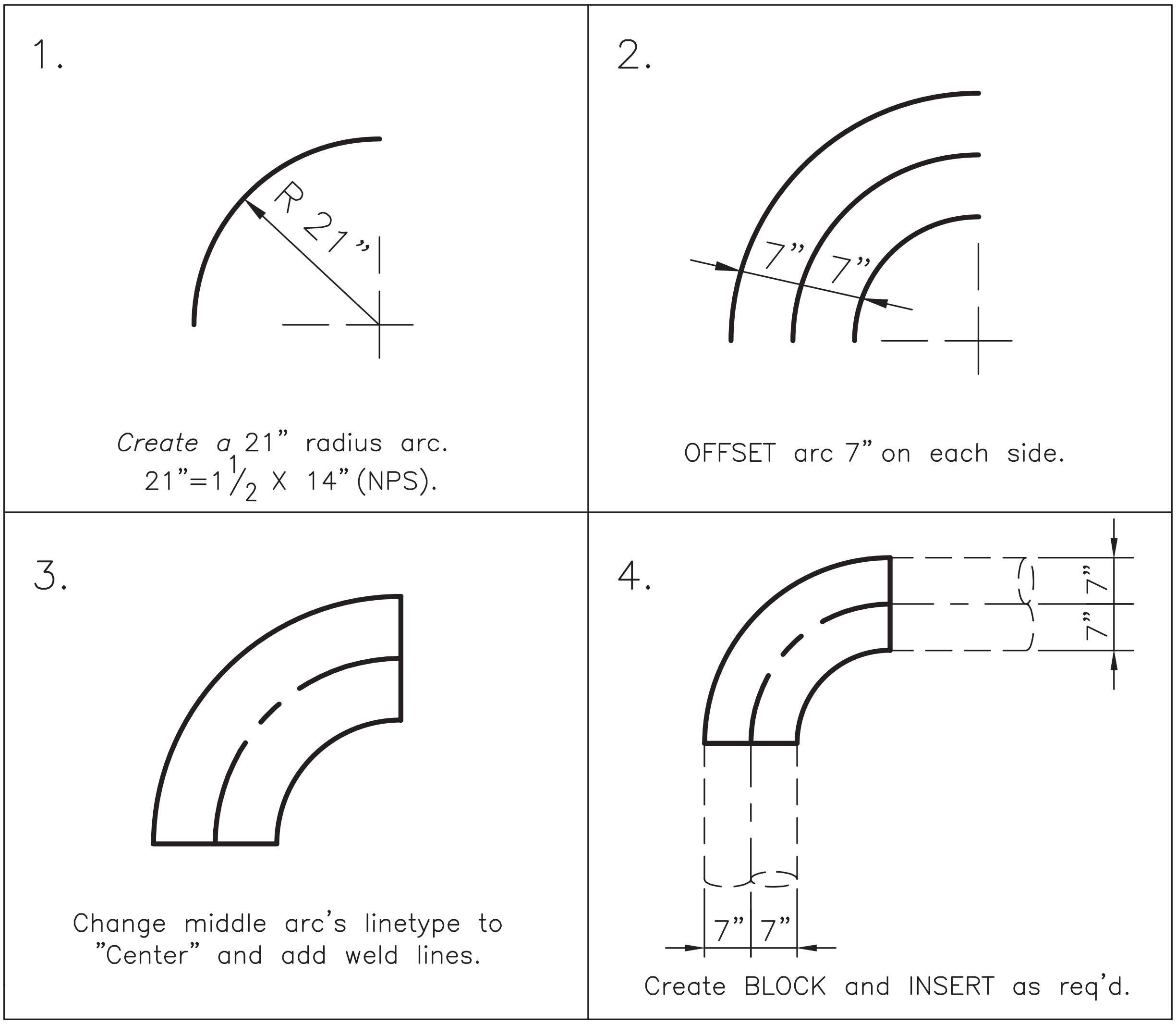


FIGURE 3.7 14″-90° elbow. AutoCAD step-by-step drafting procedure.

Step 1. Create a 21″ radius **ARC** using the Center, Start, End option. (14″ NPS × 1½ = 21″).
Step 2. Develop the elbow by **OFFSET**ing the centerline arc 7″ (one-half the pipe's OD) above and below.
Step 3. Change the middle arc to the "Center" linetype and add the weld lines.
Step 4. Create a **BLOCK** of the elbow. Use the names assigned to the various symbols found in Figure 3.68. **INSERT** the symbol as needed.

to save money and shorten the installation measurement, one fitting as opposed to two. However, although theoretically correct, in the practical application the shortened fitting length made it more difficult to install and remove bolts when it was welded to flanges that were to be bolted to valves or nozzles. The cramped space made it more costly to use in the long run, thus its use has largely been discontinued.

Mitered Elbows

The last 90° elbow to be discussed is the mitered elbow. A mitered elbow is not an actual fitting that is purchased but is instead a field-fabricated bend in the routing of the pipe configuration. Generally used on 24″ and larger pipe sizes, a mitered elbow is much less expensive to fabricate at the job site than to purchase a manufactured elbow and have it shipped to the job site. The miter ell is made by making angular cuts through a straight run of pipe and then welding the pipe back together after the cut sections have been rolled at varying angles (see Figure 3.12).

A 90° mitered ell can be fabricated in two, three, or four welded sections. The number of welded sections used depends on the smoothness of flow required

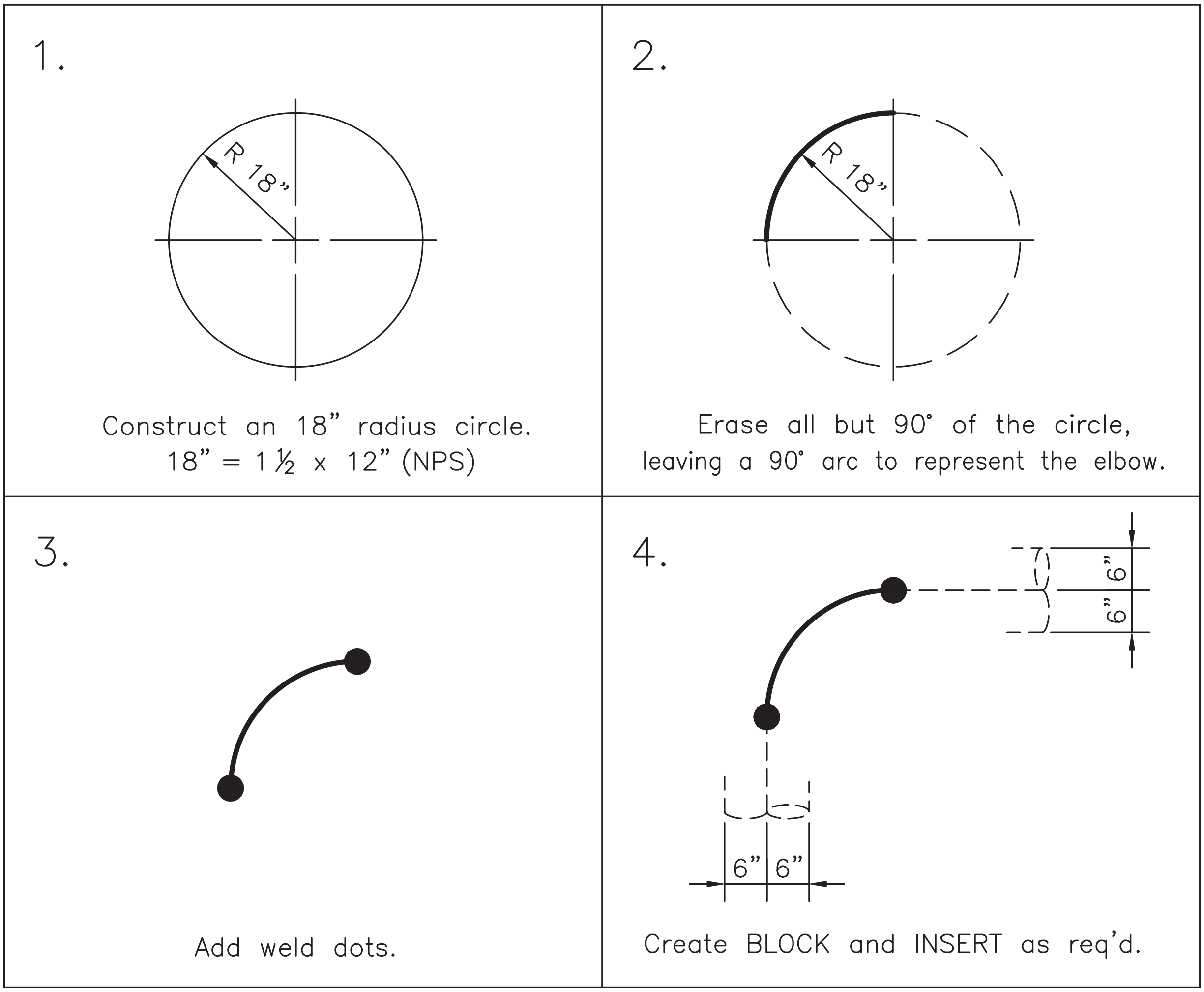


FIGURE 3.8 Single-line 12″-90° elbow. AutoCAD step-by-step drafting procedure.

Step 1. Construct an 18″ radius **CIRCLE** (12″ × 1½ = 18″). Change the circle's lineweight to match the pipe's (0.53 mm).
Step 2. **ERASE**, **BREAK**, or **TRIM** the circle from the top quadrant to the left quadrant. All that should remain is a 90° arc.
Step 3. Add the elbow's weld dots. Create with weld dots with the **DONUT** command. The donut will have an inside radius of 0.0″ and an outside radius of 1.75″.
Step 4. Create a **BLOCK** of the elbow. Use the names assigned to the various symbols found in Figure 3.68. **INSERT** the symbol as needed.

through the turn. A two-weld miter will create more commodity turbulence within the pipe than will a four-weld miter. Although one-weld miters are used, they are rare and typically reserved for 30°, 45°, or 60° turns.

Drawing Symbols for Mitered Elbows

Figure 3.13 depicts the single-line and double-line drawing symbols for mitered elbows. Unlike the previous ells the weld dots and weld lines in the adjacent orthographic views of the mitered elbow are represented by ellipses. Ellipses are used because the welds are not perpendicular to your line of sight. Therefore when projecting from the front view to any of the four orthographic views, the welds must be drawn elliptical in shape.

45° ELBOWS

Another important fitting is the 45° elbow. This elbow is also used to make changes in direction within the piping configuration. The obvious difference between the 90° and 45° elbows is the angle formed by the turn. Because the 45° elbow is one-half of a 90° elbow, as shown in Figure 3.14, it is obviously shorter.

FIGURE 3.9 Long-radius and short-radius elbows.

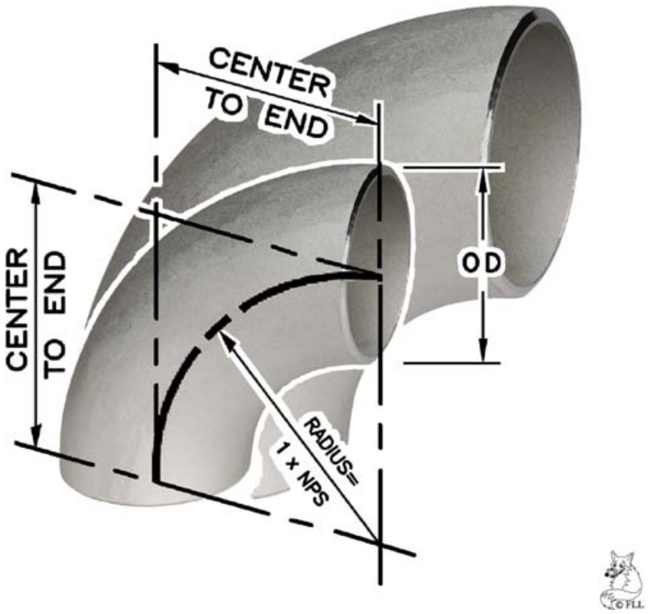


FIGURE 3.10 Center-to-end dimension of a 90° short-radius elbow.

It is logical therefore to assume a design using two 45° elbows to make a directional change, instead of two 90° elbows, would result in considerable savings. Savings not only related to the cost of the fittings themselves, but also savings in the physical space needed to route the pipe. Figure 3.15 shows that two 14″ 90° elbows, when welded together, require 3′-6″ (42″) of space to alter the course of the piping run. This is considerably more than when two 45° elbows are used to make the directional change.

Unlike the 90° elbow, there is not a simple formula that can be applied to establish the center-to-end dimension of all 45° elbows, simply dividing the length of the 90° elbow by two will not work. As depicted in Figure 3.16, one can multiply the nominal pipe size times 0.625 (5/8″) to determine the elbow's length, but that only works for elbows 4″-24″ in size. To avoid confusion, it is recommended to use the Weld Fitting-flanges dimensioning chart to get the length of a 45° elbow (see Figure 3.17).

Drawing Symbols for the 45° Elbow

The drawing symbols for the 45° elbow are shown in Figure 3.18.

Drawing the 45° Elbow

The "Step-by-Step" method presented for constructing the drawing symbols for the 45° elbow is shown in Figure 3.19.

90° Elbows Rolled at 45°

Many times to avoid using two 90° elbows in succession, designers will use one 90° ell and a 45° ell welded together (see Figure 3.20). When a 90° elbow is used without the 45° ell and the elbow is rolled at an angle not perpendicular to your line of sight, the open of the 90° ell will appear as an ellipse. In any view where the open end of the elbow appears at any angle to our line of sight other than 90°, ellipses must be used to represent the fitting. Figure 3.21 shows the orthographic views of 90° elbows rolled at a 45° angle.

Figure 3.22 illustrates the use of 45° ellipses to draw the 14″-90° elbow rolled at a 45° angle. If the 90° elbow is rolled at a 30° or 60°, use the respective degree ellipse to layout and construct the elbows.

WELD TEE

The name of this fitting comes from its resemblance to the letter T. It is a three-outlet fitting used to make perpendicular connections to a pipe (see Figure 3.23).

The two terms used to describe the pipe and its perpendicular connection are *header* and *branch*. The main run of pipe is called the header. While the perpendicular line that connects to the header is known as a branch. Figure 3.24 shows a pipe header with two branch connections. Notice there are two tees installed in Figure 3.24. One is known as a *straight* tee, and the other is a *reducing* tee. On a straight tee, all three outlets are the same nominal pipe size. A reducing tee has

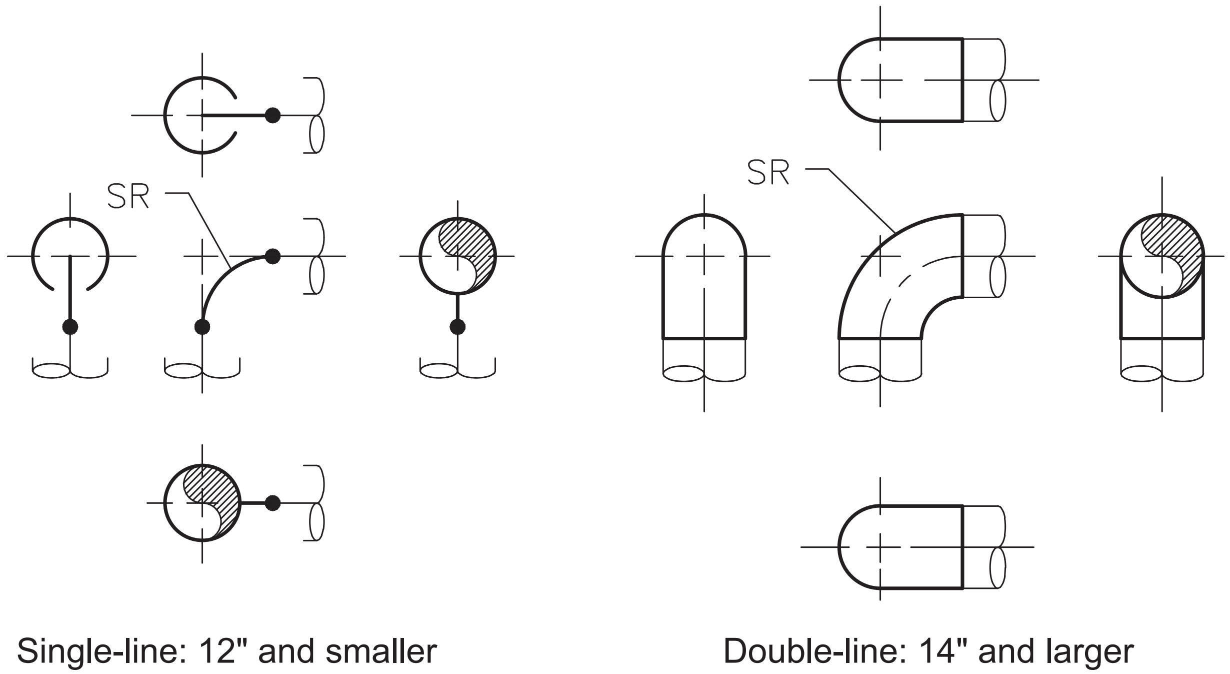


FIGURE 3.11 Short-radius elbow orthographic drawing symbols.

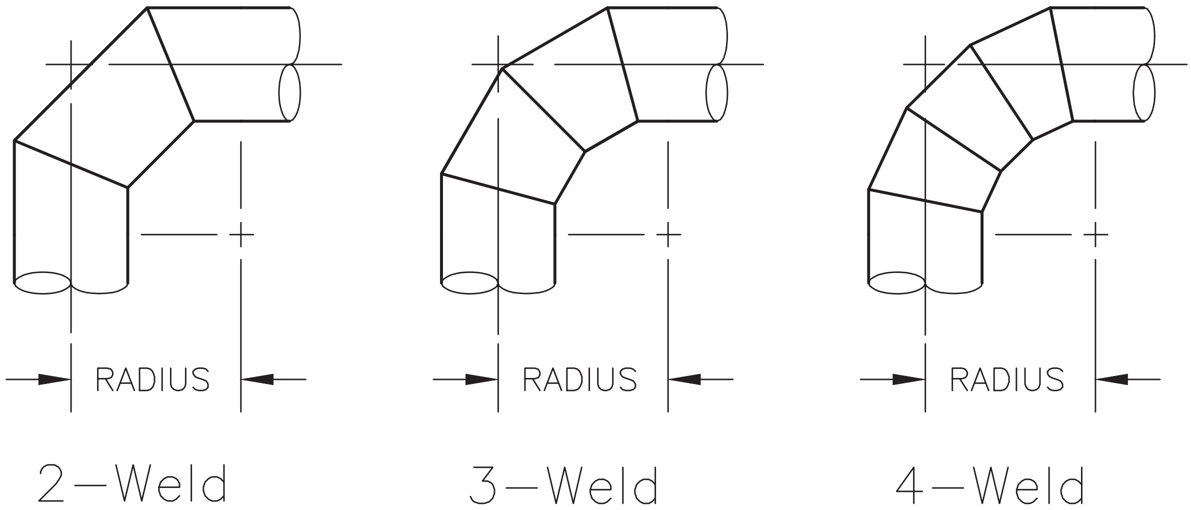


FIGURE 3.12 Mitered elbows.

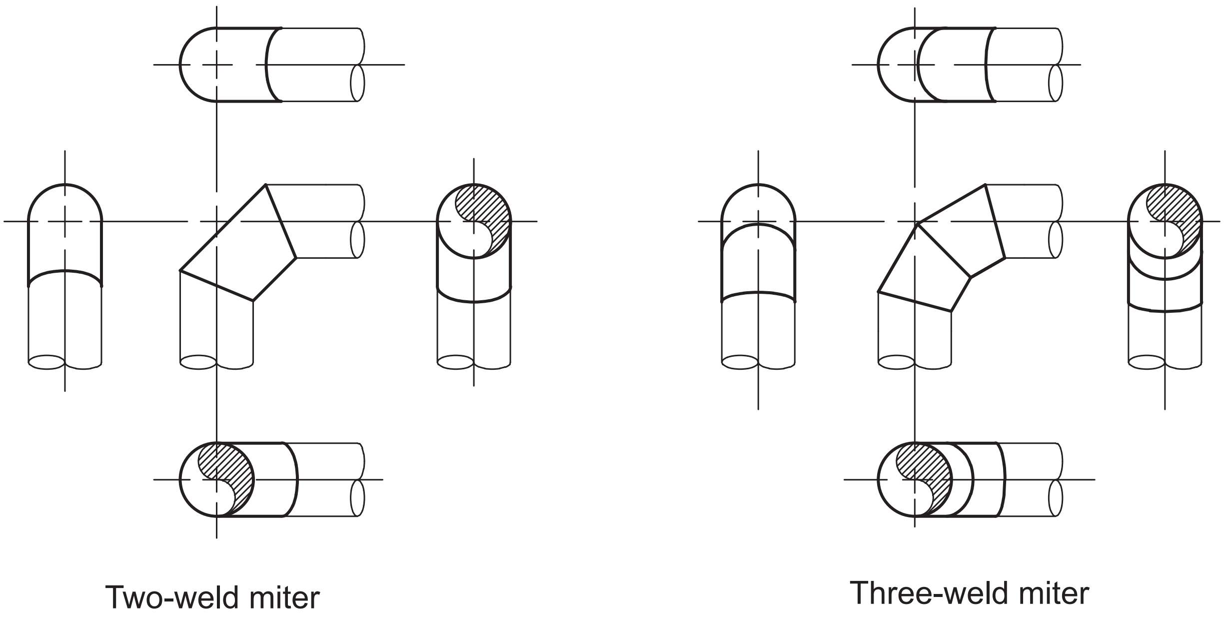


FIGURE 3.13 Mitered elbows drawing symbols.

FIGURE 3.14 45° elbow.

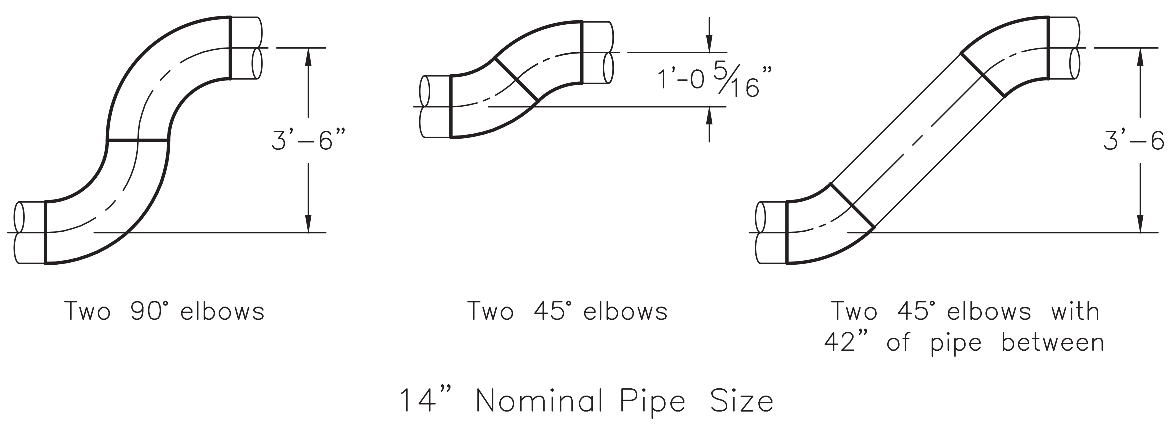


FIGURE 3.15 90° ell versus 45° elbow.

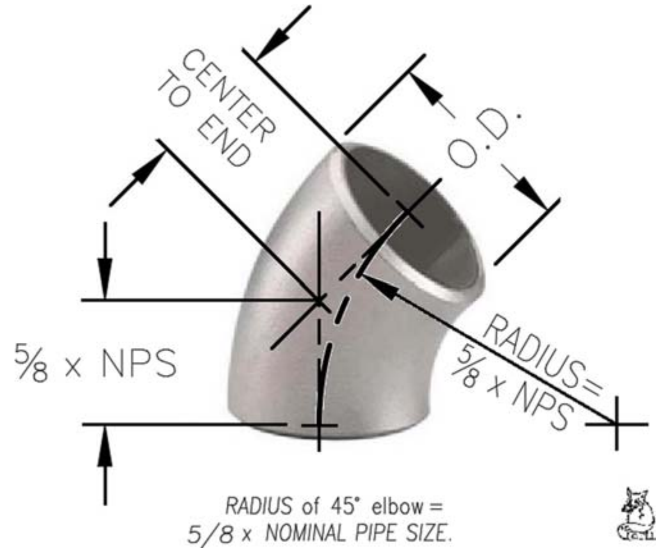
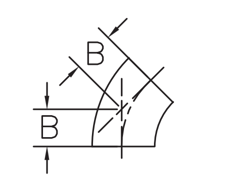


FIGURE 3.16 Center-to-end dimension of a 45° elbow.



NOMINAL PIPE SIZES -(INCHES)	2"	3"	4"	6"	8"	10"	12"	14"
PIPE (OUTSIDE DIAMETER)	2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14
Center-to-End 45° Ell B	1 3/8	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4

FIGURE 3.17 Welded fittings-flanges chart.

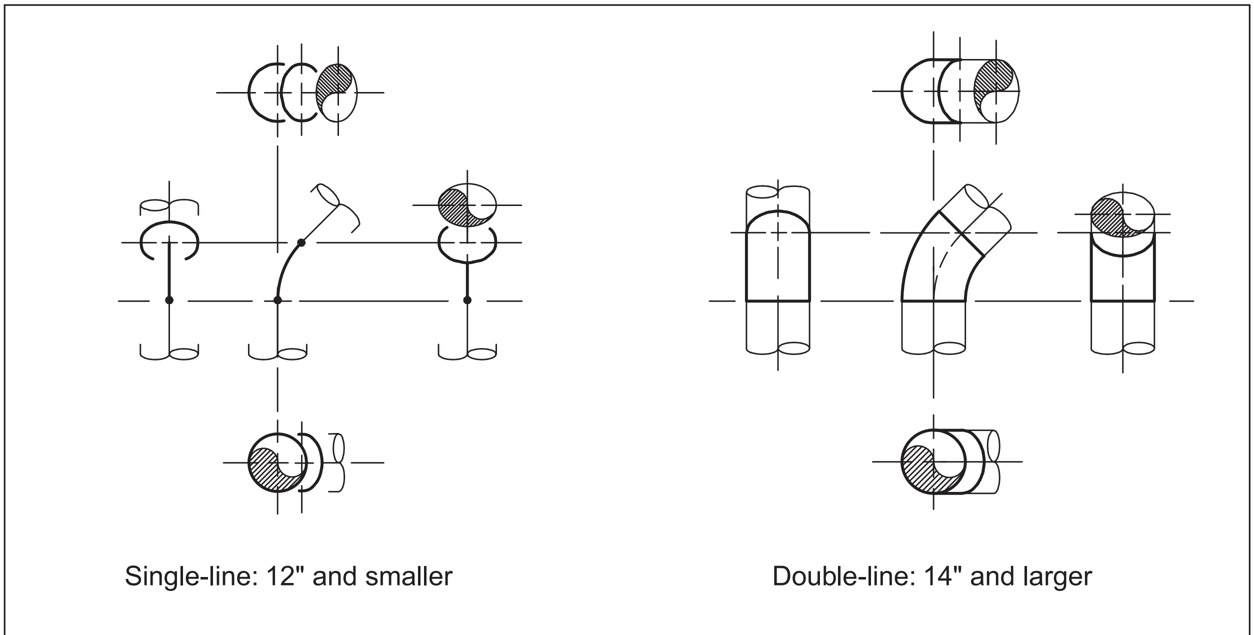


FIGURE 3.18 45° elbow orthographic drawing symbols.

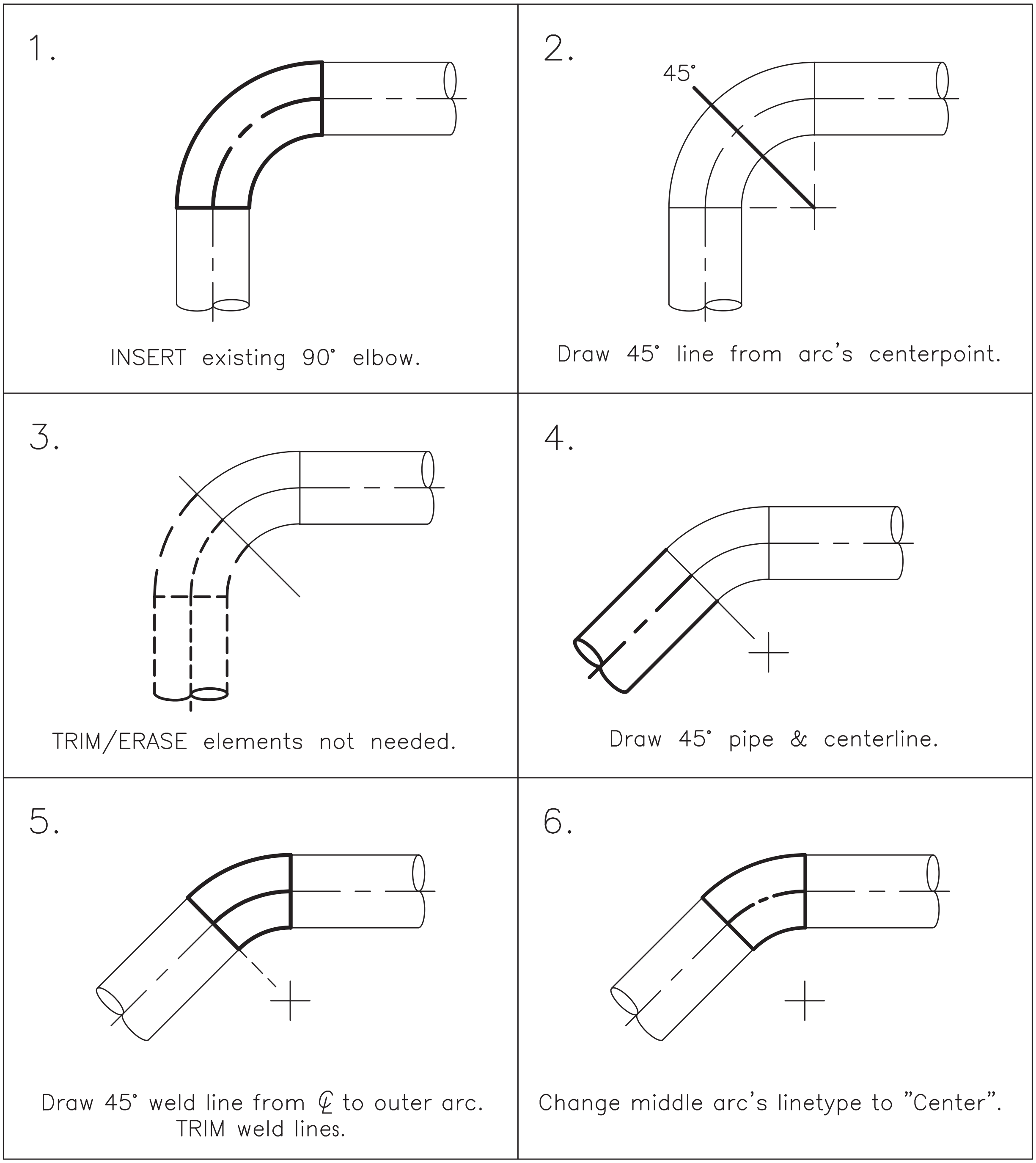


FIGURE 3.19 45° elbow. Step-by-step drafting procedures.

Step 1. **INSERT** the 14−90 elbow create previously.
Step 2. From the common centerpoint of the three arcs, draw a 45° construction **LINE** as shown. Use Polar Tracking set to 45° to simplify this procedure.
Step 3. **TRIM** and **ERASE** the portion of the 90° elbow not needed.
Step 4. Draw the attaching 45° pipe and centerline.
Step 5. Draw the 45° weld **LINE**.
Step 6. Change the middle arc to a "Center" linetype.

a branch that is a smaller line size than the header. Since all pipe lines 12″ and smaller are drawn single line, and therefore are difficult to distinguish pipe diameter sizes, a branch that is 12″ and smaller must be identified with a note that defines the header size and the branch size, 14 × 8, as shown in Figure 3.24. Notice the weld tee requires three welds be made to install the fitting within the header. Pay particular attention to the weld dot used to represent the weld on the 12″ and smaller branch outlet on the reducing tee.

Drawing Symbols for the Weld Tee

The drawing symbols used to represent the tee are developed from the rotations of the tee into the

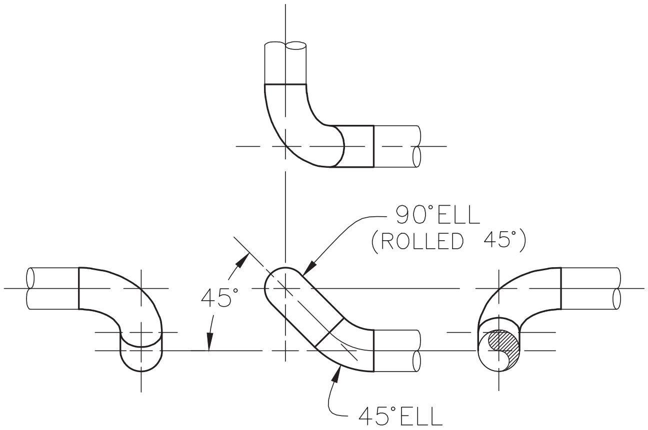


FIGURE 3.20 90° and 45° elbows welded together.

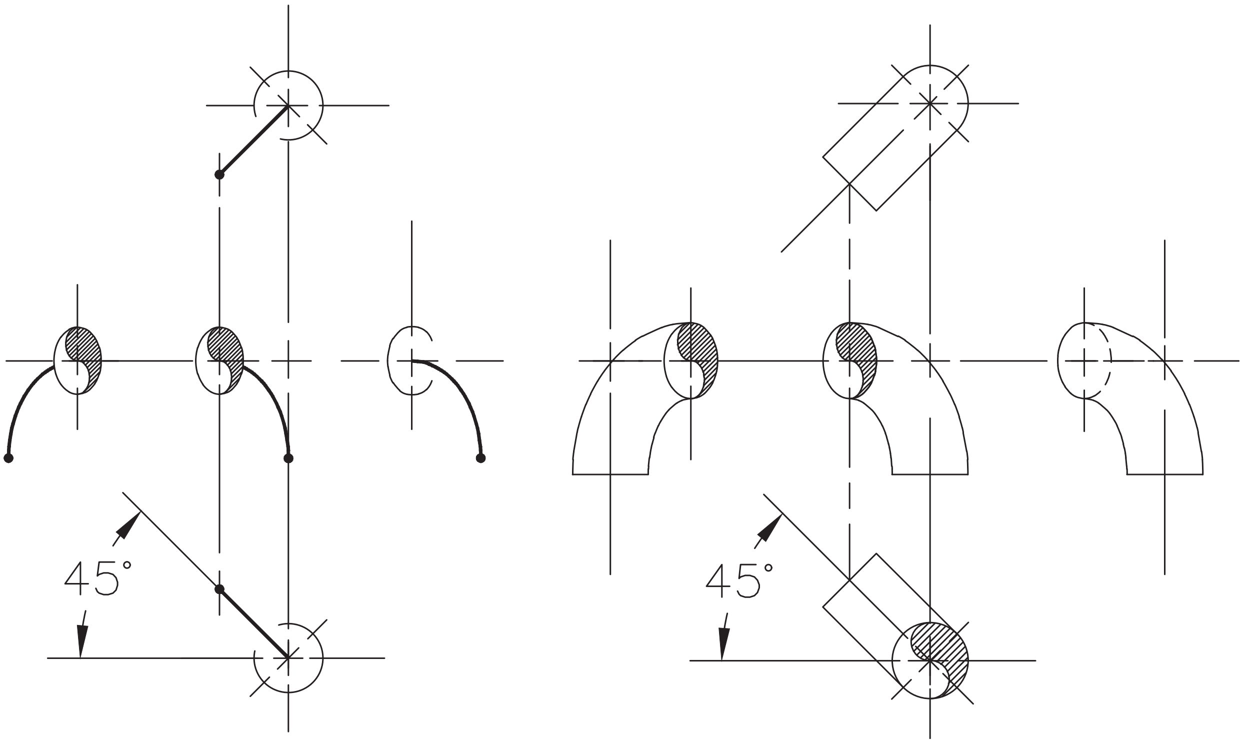


FIGURE 3.21 Orthographic views of 90° rolled at a 45° angle.

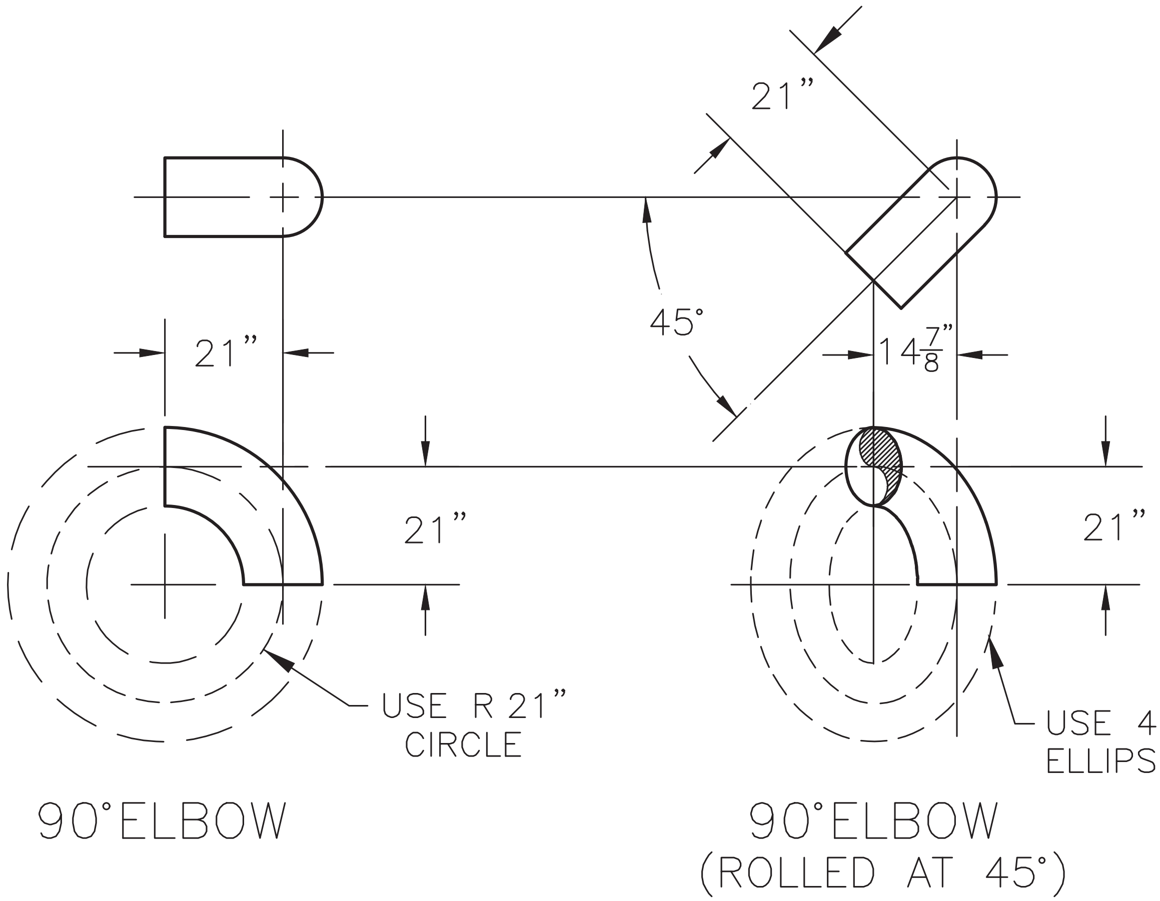


FIGURE 3.22 Constructing the 90° rolled at a 45° angle.

FIGURE 3.23 Weld tee.

various orthographic views. Figure 3.25 depicts the rotations of the tee into the profile and horizontal projection planes.

Figure 3.26 shows the drawing symbols derived from the 90° rotations of a straight and reducing tee. Remember, a callout is required on the reducing tee to identify the header and branch sizes. The header size is always shown first in the note.

Drawing the Weld Tee

Prior to drawing the weld tee, two dimensions must be determined. First, one dimension is required to establish the center-to-end length of the header portion of the tee, and the second is the length of the branch portion of the tee. If a straight tee is to be drawn use the Welded Fittings-Flanges dimensioning chart to find the ***C*** dimension of the tee. The ***C*** dimension is the center-to-end measurement for both the header and branch lengths. Therefore the ***C*** dimension must be doubled to find the total length (end-to-end) of the fitting (see Figure 3.27).

When a reducing tee is drawn, the branch length is slightly shorter than that of a straight tee. Therefore the new branch length must be determined. The ***M*** dimension, as defined on the Taylor Forge Seamless Welding Fittings Chart, establishes the length of the reducing branch. The Taylor Forge Seamless Welding Fittings Chart is found in Appendix A. Figures 3.28 and 3.29 provide the step-by-step procedures for drawing a double-line and single-line tee symbol, respectively.

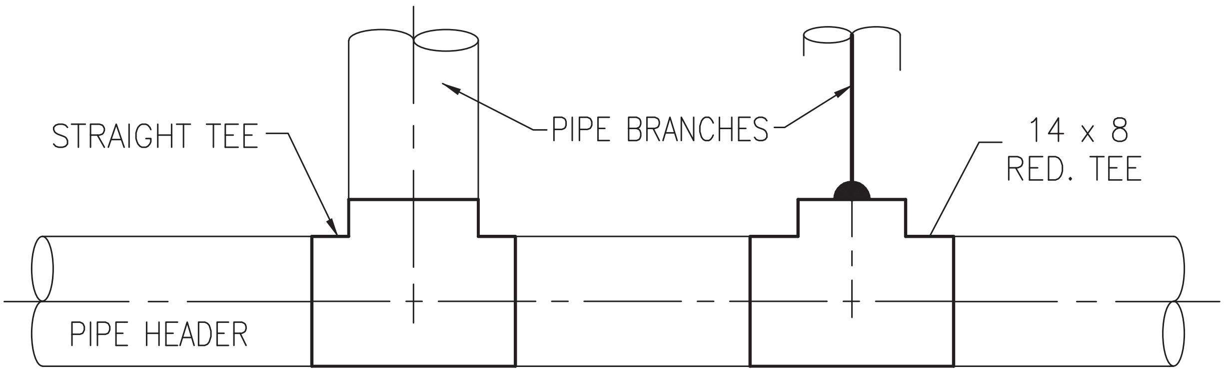


FIGURE 3.24 Header and branch connections.

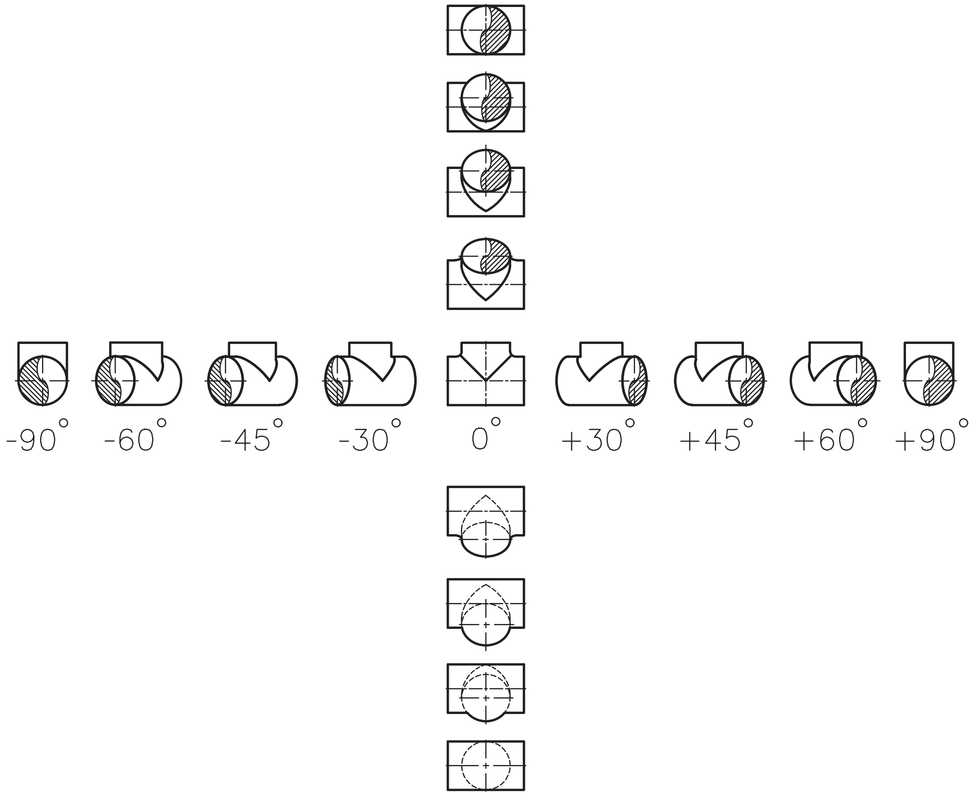


FIGURE 3.25 Weld tee fitting rotations.

THE STUB-IN

Another method of branching a pipe from a header is called a *stub-in*. The stub-in is the most commonly used as an alternative to the reducing tee. The stub-in is not an actual fitting that can be purchased, but rather a description of how the branch connection is fabricated. Quite simply, a hole, either the size of the OD or ID of the desired branch, is bored into the header pipe, and the branch is then stubbed onto it. To create a better fit, the connecting end of the branch pipe is cut, or coped, in such a way as to fit around the hole that has been bored into the header pipe. The two pipes are fitted together and then welded. Although the branch connection can be the same pipe size as the header or smaller, it cannot be larger. Figure 3.30 depicts the attachment of a stub-in.

Figure 3.31 depicts the single-line and double-line drawing symbols for a stub-in connection. Notice only

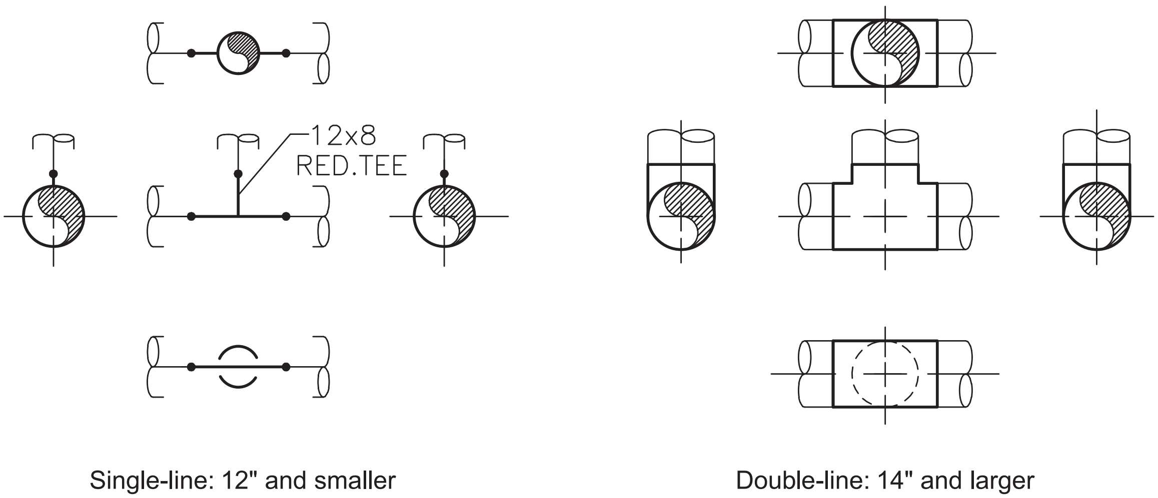
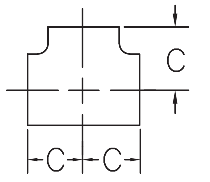


FIGURE 3.26 Weld tee drawing symbols.



NOMINAL PIPE SIZES –(INCHES)		2”	3”	4”	6”	8”	10”	12”	14”
PIPE (OUTSIDE DIAMETER)		$2\frac{3}{8}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$6\frac{5}{8}$	$8\frac{5}{8}$	$10\frac{3}{4}$	$12\frac{3}{4}$	14
Center–to–End HALF TEE	C	$2\frac{1}{2}$	$3\frac{3}{8}$	$4\frac{1}{8}$	$5\frac{5}{8}$	7	$8\frac{1}{2}$	10	11

FIGURE 3.27 Welded fittings-flanges dimensioning chart.

one weld dot is shown on the single-line symbol, and it is placed at the intersection of the header and branch pipe lines. Also, notice that the weld dot is not a complete circular shape. It is semicircular and drawn only on the branching side of the connection.

The proximity to which stub-ins can be placed adjacent to one another is another important consideration. The generally accepted welding practice is to allow a minimum of 3″ between welds or one header pipe diameter, whichever is larger, between welds. This means 18″, in Figure 3.32, is the minimum spacing between the two branches (16″ and 14″) when attached to a common header. This also applies to the placement of branch when welded near a fitting. Figure 3.32 provides the minimum measurements allowed between 16″ and 14″ branches and fittings on an 18″ header.

Stub-in Reinforcements

Even though the use of the stub-in is limited by the pressure, temperature, and commodity within a pipe, its use is becoming increasingly popular. Its chief advantage over the tee is cost. Cost savings are realized not only in the purchase of a fitting but also in the installation. The stub-in requires only one weld, whereas the tee requires three. Although the cost of boring the hole and coping the branch must the factored in, the overall expense of fabricating a stub-in is much less than the purchase and installation of a reducing tee.

When internal conditions such as pressure or temperature of the commodity or external forces such as vibrations or pulsations are placed on a stub-in, special reinforcement may be necessary to prevent the branch from separating from the header. Three reinforcing alternatives are listed below.

- **Reinforcing pad**. The primary intent of the reinforcing pad is to provide strength to the pipe header in the area where the branch hole has been cut. Resembling a round, metal washer that has been bent to conform to the curvature of the pipe, the reinforcing pad is a ring cut from steel plate which has a hole in the center equal to the outside diameter of the branch connection. It is slipped onto the branch pipe before the branch pipe is welded to the header. Once the branch has been welded to the header, the reinforcing pad is slid down the branch to cover the weld connection.

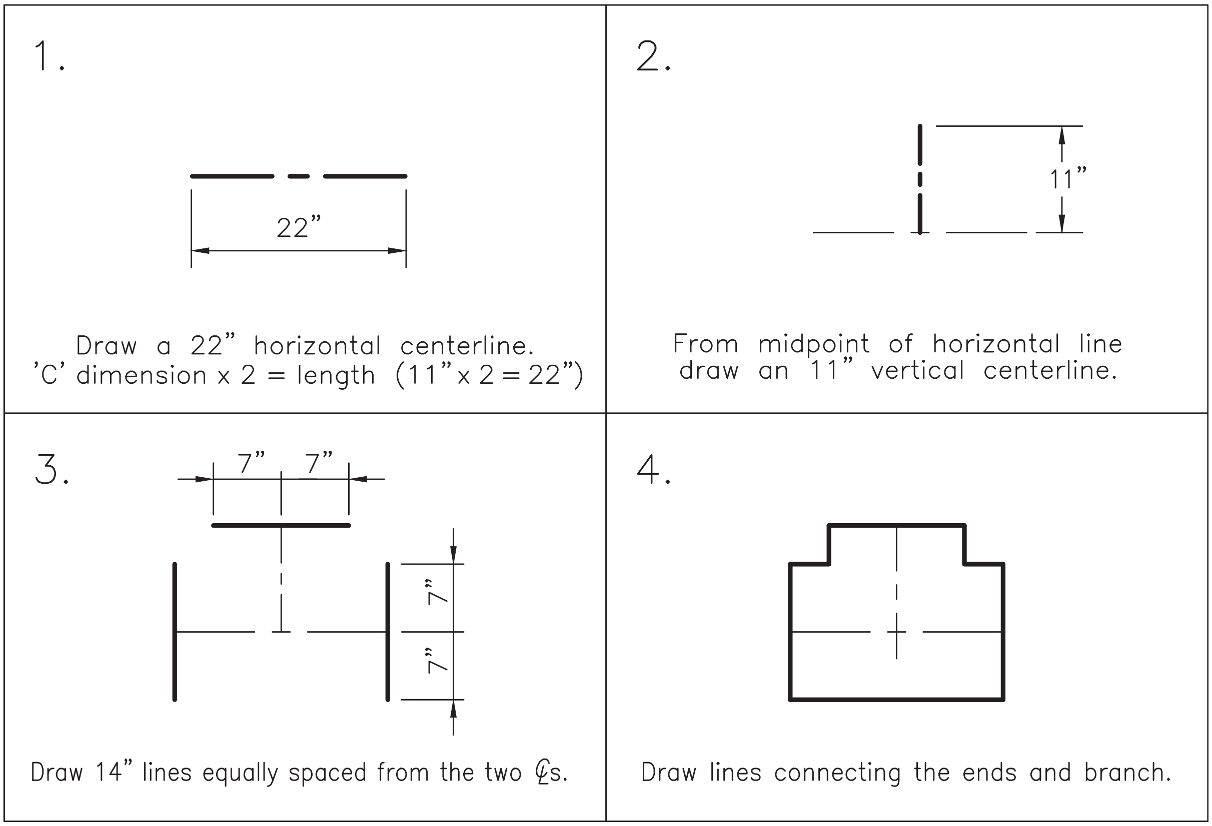


FIGURE 3.28 14″ welded straight tee drawing symbols.

Step 1. Using the 11″ ***C*** dimension found in the 14″ column of the Weld tee section of the Welded Fittings-Flanges dimensioning chart, draw a centerline 22″ long [11″ (1/2 a tee) × 2 = 22″].

Step 2. From the midpoint of the tee’s centerline draw a perpendicular line 11″ long in the direction of the branch.

Step 3. Draw a 7″ (1/2 of the pipe’s nominal pipe size) horizontal line on each side of the branch’s centerline and a 7″ vertical line on each side of the header’s centerline as shown to establish the weld lines of the tee.

Step 4. Add a 14″ vertical weld line on the opposite end of the tee, and then draw two horizontal lines, parallel to the tee’s centerline, that will connect the two vertical weld lines. Add two vertical lines that will connect the horizontal weld line of the branch to the header. Trim the horizontal line as necessary.

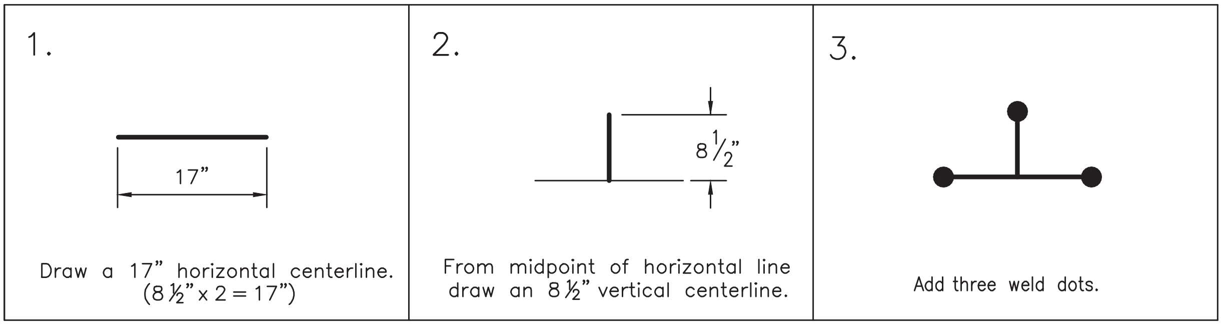


FIGURE 3.29 10″ straight tee. AutoCAD step-by-step drafting procedure.

Step 1. Draw a **LINE** 17″ long, having a 0.53 mm lineweight, to represent the tee’s length (8½″ × 2 = 17″).

Step 2. From the MIDpoint of the tee’s centerline draw an 8½″ perpendicular **LINE** having a 0.53 mm lineweight, the represent the length of the tee’s branch.

Step 3. Add the tee’s weld dots. Create the dots with the **DONUT** command. The **DONUT** will have an inside diameter of 0″ and outside diameter of 1.75″.

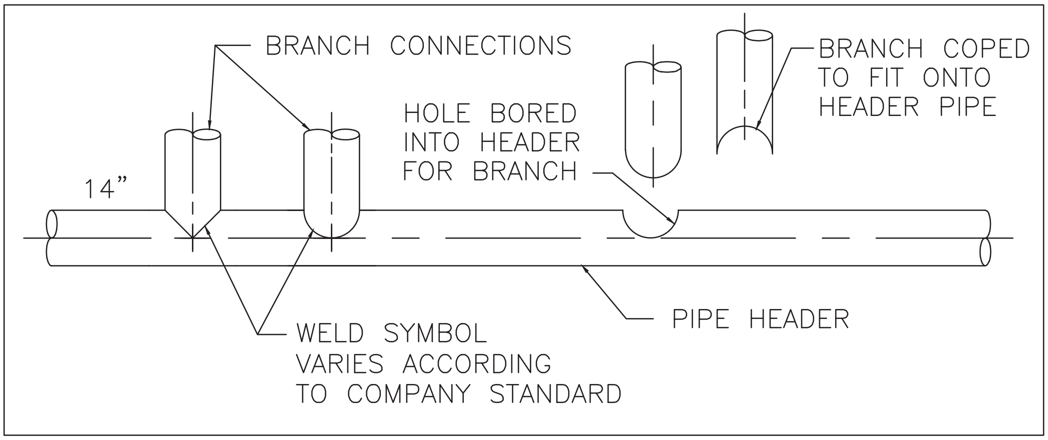


FIGURE 3.30 Stub-in connections.

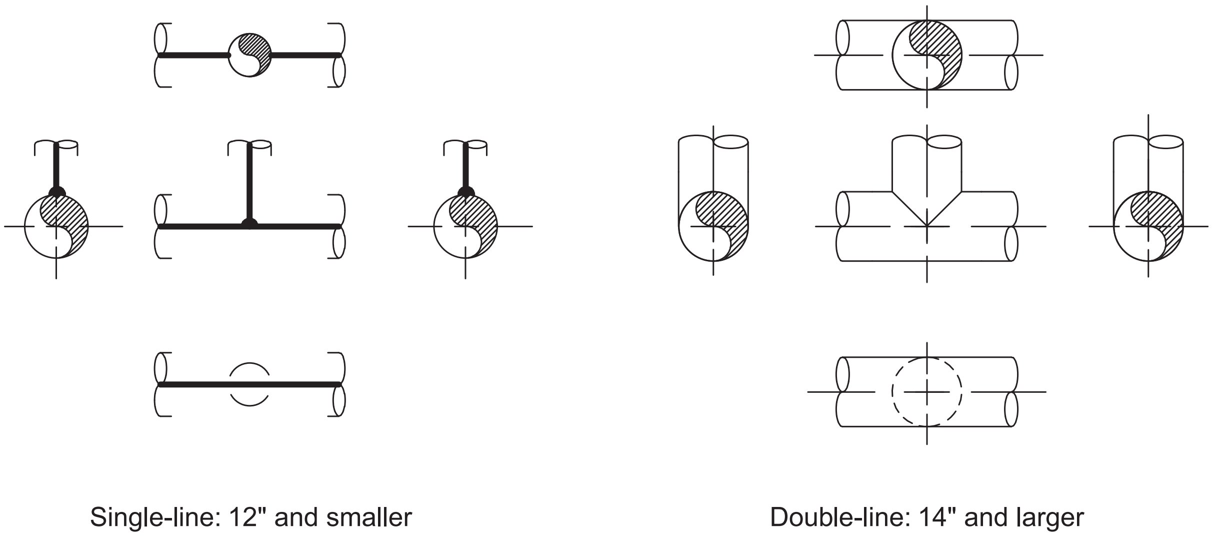


FIGURE 3.31 Stub-in drawing symbols.

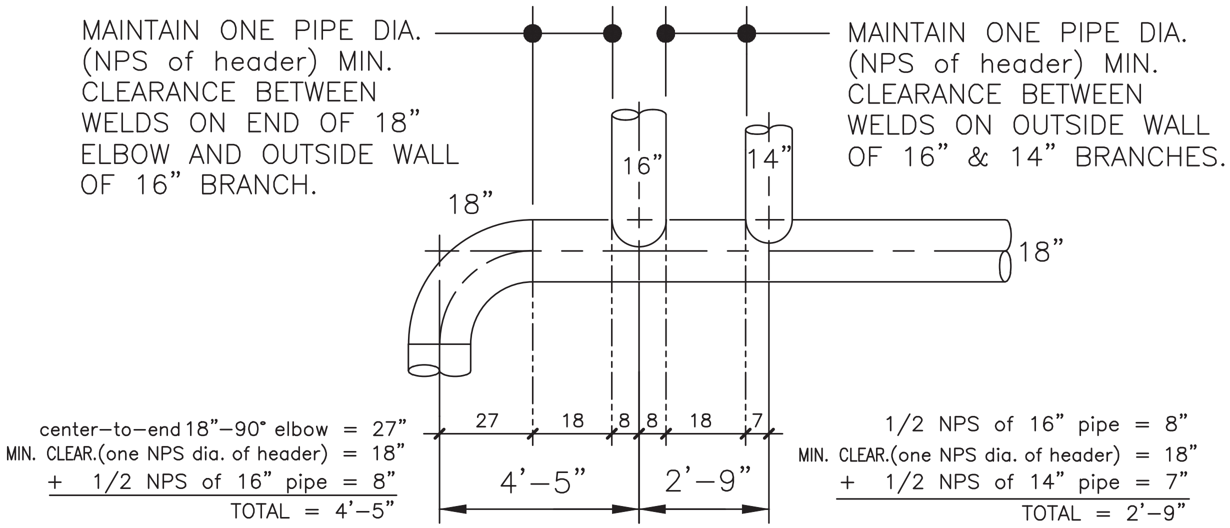


FIGURE 3.32 Spacing minimums for welding stub-ins.

The reinforcing pad is then welded to both the branch and header.

- **Welding saddle**. A precision manufactured reinforcing pad, the welding saddle has a short neck on the branch outlet that is designed to give additional support to the branch connection. Figure 3.33 shows single-line and double-line drawing representations of reinforcing pads and welding saddles.
- **O-lets**. Purchased fittings, o-lets have one end shaped to the contour of the outside diameter of the pipe header and the other end manufactured to accept the type of end connections being used on the branch. O-lets are manufactured for butt-welded, socket-welded, and threaded connections. Weld-o-lets are manufactured for butt-weld fittings. Sock-o-lets are made for socket-weld

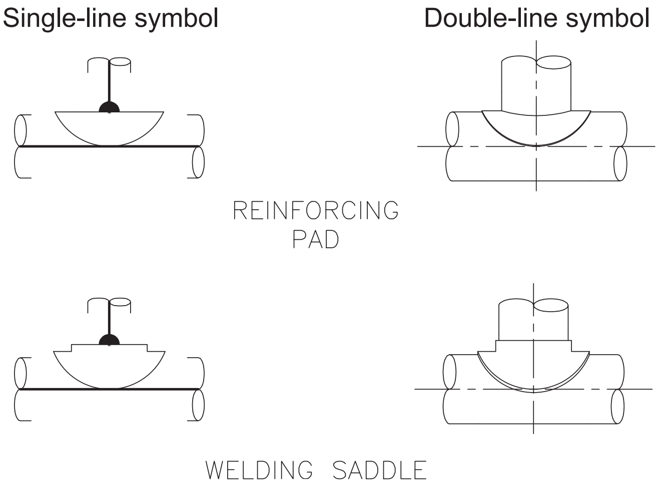


FIGURE 3.33 Reinforcing pads and saddles.

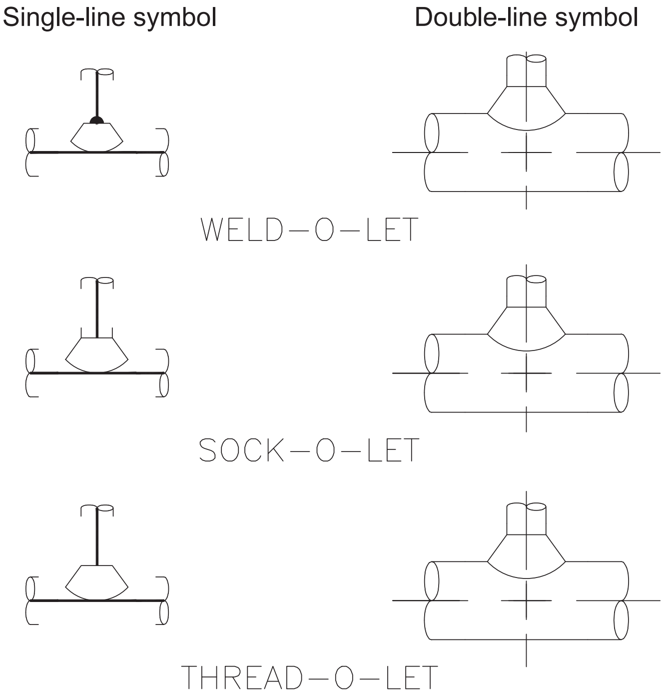


FIGURE 3.35 O-let drawing symbols.

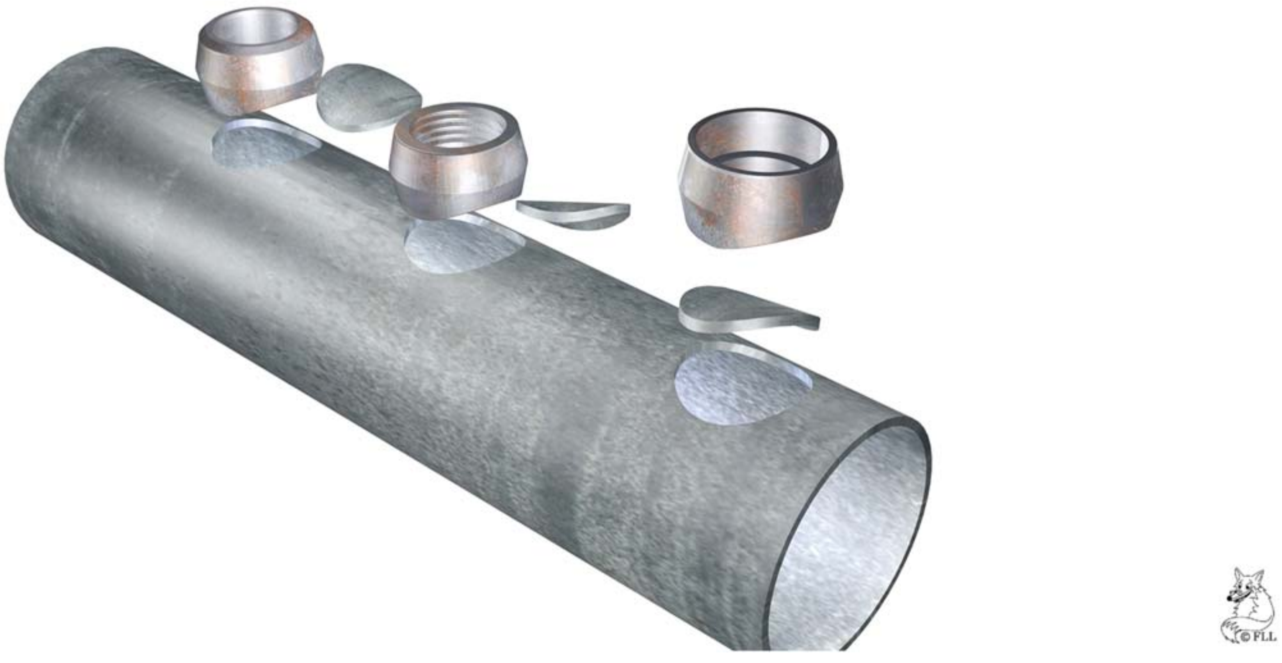


FIGURE 3.34 Thread-o-let.

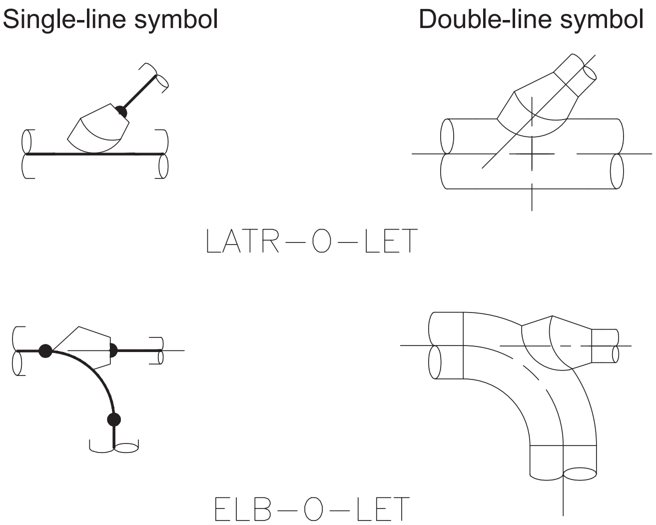


FIGURE 3.36 Latr-o-let and elb-o-let drawing symbols.

fittings. And thread-o-lets are available for threaded fittings. Figure 3.34 shows how a weld-o-let, thread-o-let and sock-o-let sits atop a header pipe before welding. Figure 3.35 provides drawing symbols for weld-o-lets, sock-o-lets, and thread-o-lets.

By design weld-o-lets, sock-o-lets, and thread-o-lets, all form 90° branch connections to the header. For situations where a 45° angular connection may be required other o-lets are available for installation. Specifically, they are the latr-o-let and elb-o-let. Figure 3.36 shows drawing symbols for a latr-o-let and elb-o-let.

COUPLING

Another type of fitting used to make branch connections is the coupling. Used primarily for connecting small-bore threaded or socket-weld pipe to large-bore pipe headers,

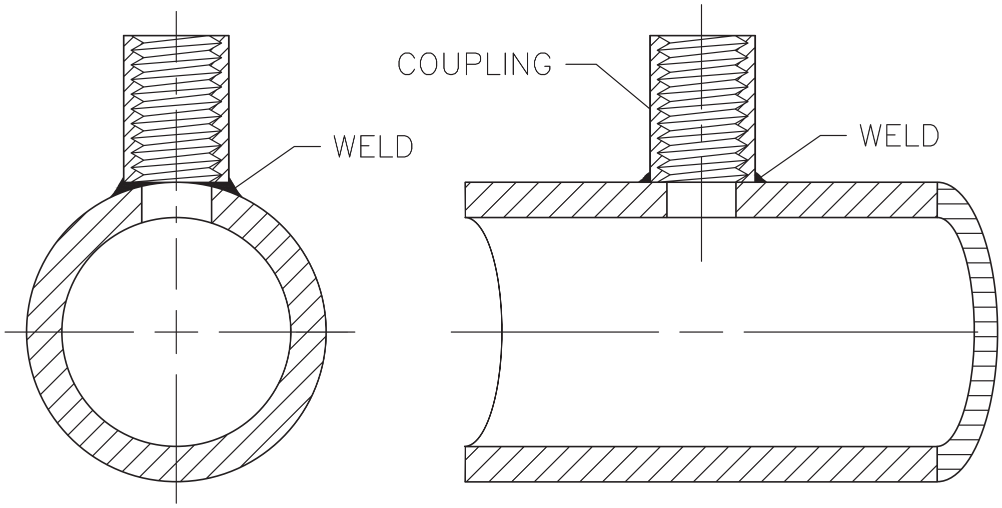


FIGURE 3.37 Welding a coupling onto a pipe header.

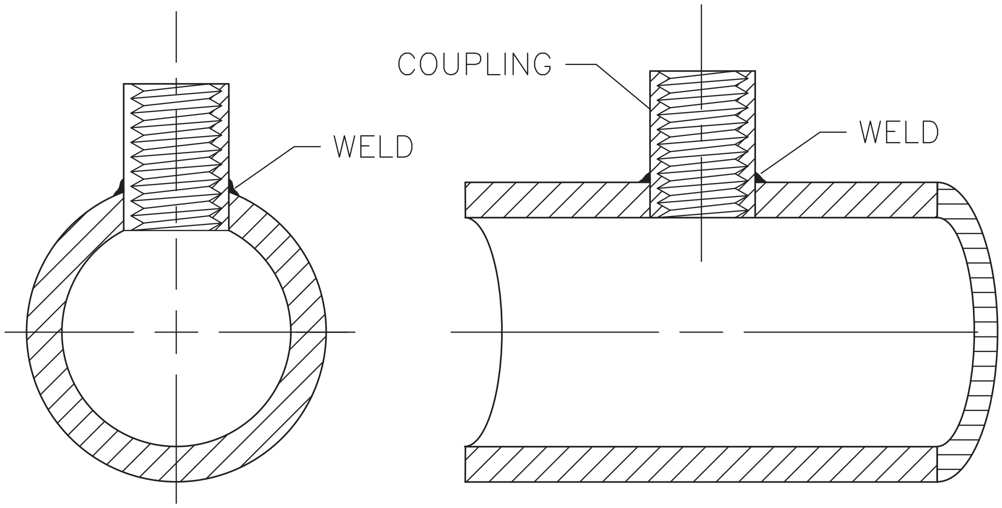


FIGURE 3.38 Inserting a coupling into a pipe header.

the coupling is also used extensively where instrument connections are required. There are two common methods used to make branch connections with couplings:

1. The coupling rests on the external surface of the pipe header and is welded from the outside. See Figure 3.37.
2. A hole is bored into the pipe header large enough to accept the OD of the coupling. The coupling is inserted into the hole and is then welded (see Figure 3.38). Figure 3.39 shows the drawing symbols for a coupling. Being that it is a branch connection, the nominal pipe size and the position of a coupling must be provided on a drawing, typically the isometric fabrication drawing.

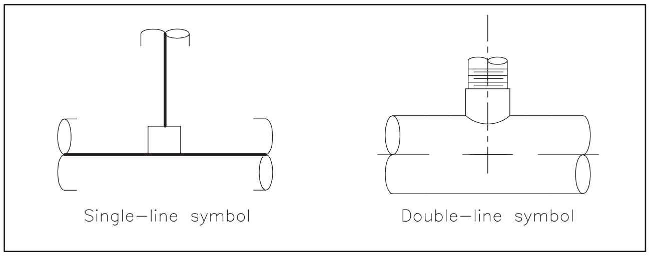


FIGURE 3.39 Couplings as branches.

FIGURE 3.40 Concentric and eccentric reducer.

REDUCERS

When the piping designer wants to reduce the diameter of a straight run of pipe, a reducing fitting must be used. Appropriately named, the *reducer* is available in two styles as shown in Figure 3.40.

Concentric—having a common centerline
Eccentric—having offset centerlines

The differing characteristics of these two reducers are quite noticeable. The concentric reducer maintains the same centerline through both the large and small ends of the fitting. Conversely, the eccentric reducer has offset centerlines that will create a flat surface on either the top or the bottom of the fitting, depending on how the fitting is rolled prior to welding. There are specific situations where the eccentric reducer must be installed with its flat side on the top or the flat side on the bottom of the fitting. For example, when a pipe is routed through a pipe rack, it

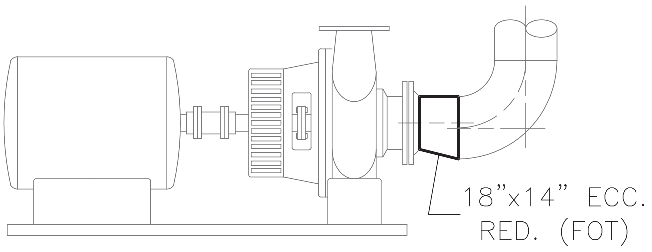


FIGURE 3.42 Eccentric reducer on pump suction nozzle.

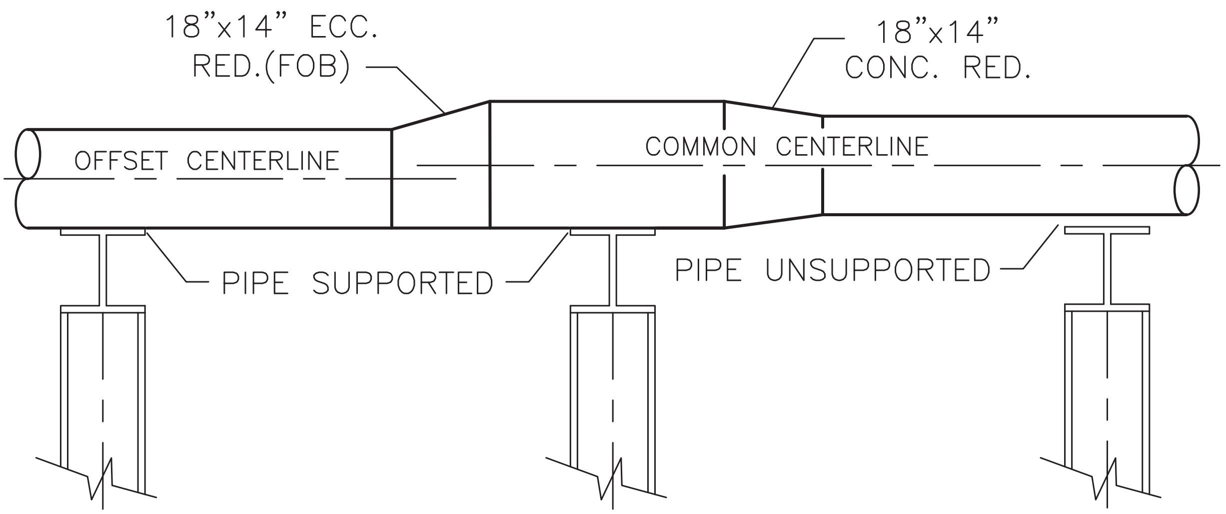


FIGURE 3.41 Reducers in a pipe rack.

naturally will rest on the steel beams and is supported throughout its length. But, if the pipe's size changes as it runs through the pipe rack, it will not rest on all of the steel supports. The small end will not have a diameter large enough to touch the steel supports. Therefore an eccentric reducer is used in pipe racks to maintain a constant *Bottom of Pipe* (BOP) (see Figure 3.41).

Eccentric reducers are also used on pump suction nozzles to keep entrained air from entering the pump. By keeping a *Flat on Top* (FOT) surface, vapor

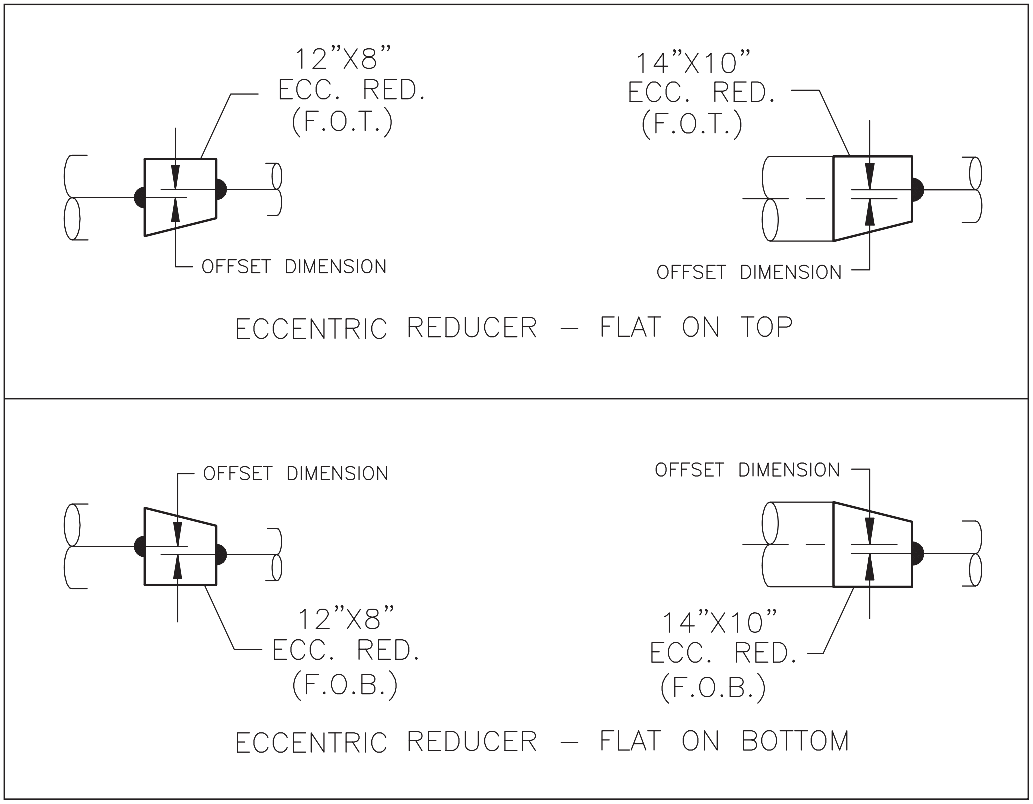


FIGURE 3.43 Offset dimensioning of eccentric reducers.

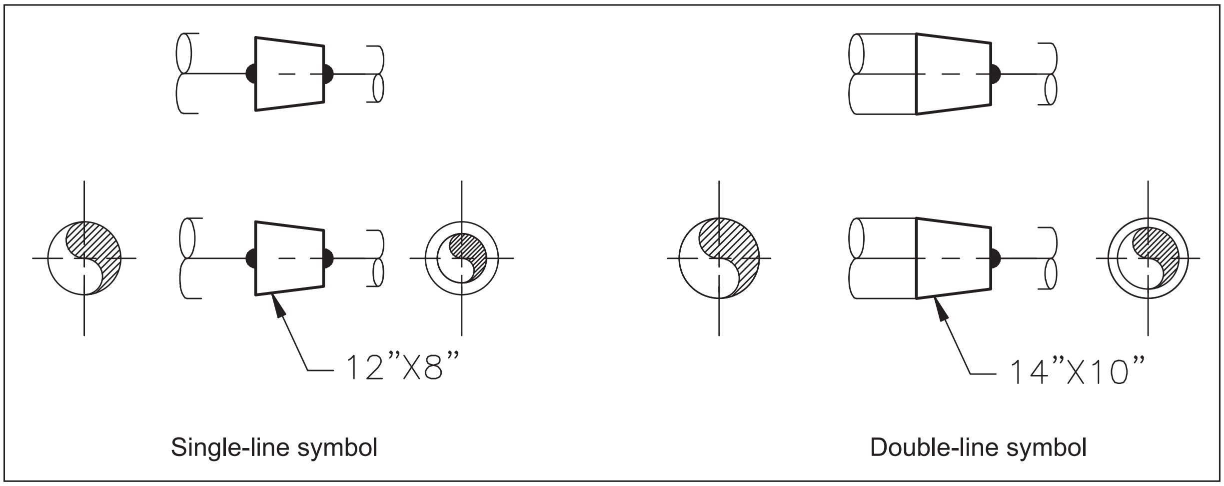


FIGURE 3.44 Drawing symbols for concentric reducer.

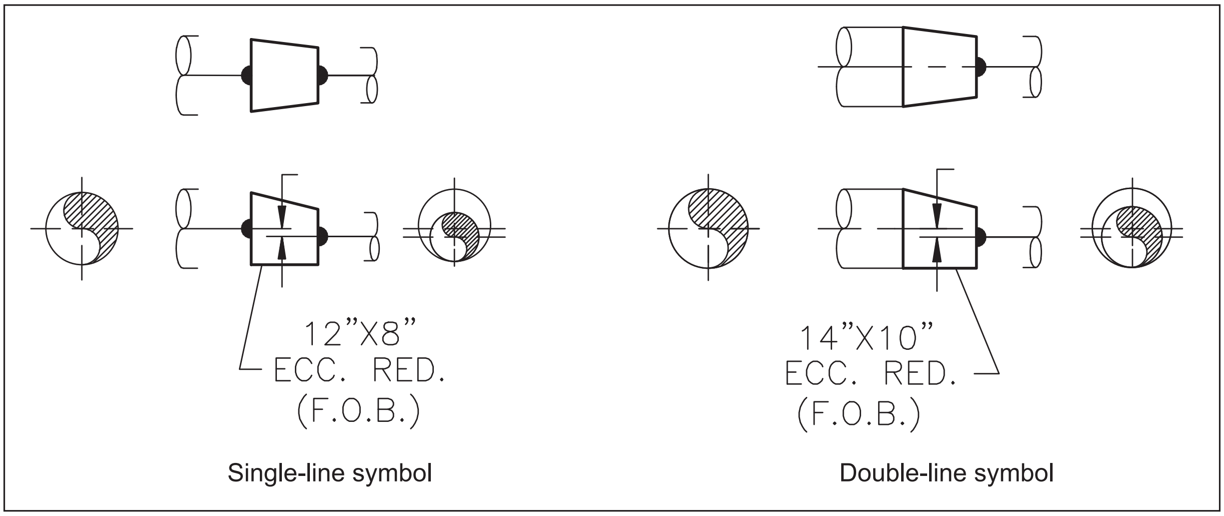
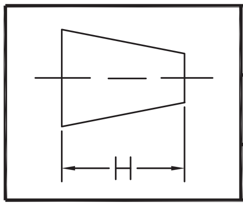


FIGURE 3.45 Drawing symbols for eccentric reducer.



NOMINAL PIPE SIZE-(INCHES)	2"	3"	4"	6"	8"	10"	12"	14"
PIPE (OUTSIDE DIAMETER)	$2\frac{3}{8}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$6\frac{5}{8}$	$8\frac{5}{8}$	$10\frac{3}{4}$	$12\frac{3}{4}$	14"
Length of Reducer H	3	$3\frac{1}{2}$	4	$5\frac{1}{2}$	6	7	8	13

FIGURE 3.46 Welded fittings-flanges dimensioning chart.

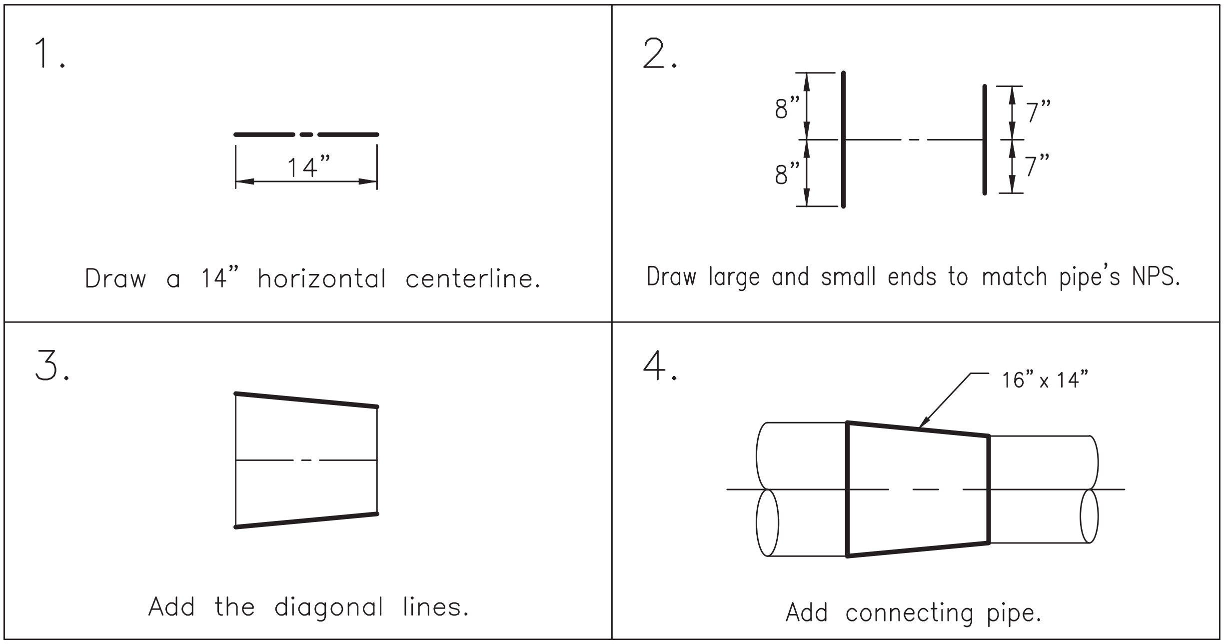


FIGURE 3.47 16″ × 14″ concentric reducer. AutoCAD step-by-step drafting procedures.

Step 1. Using the ***H*** dimension found on the Welded Fittings-Flanges dimensioning chart, draw a centerline 14″ long.
Step 2. Measure 8″ (one-half the 16″ large end size) on each side of the centerline on one end of the centerline and 7″ (one-half the 14″ small end size) on each side of the opposite end of the centerline.
Step 3. Connect the opposing ends of the fitting by drawing lines from endpoint to endpoint.
Step 4. Darken the sides and weld lines of the reducer.

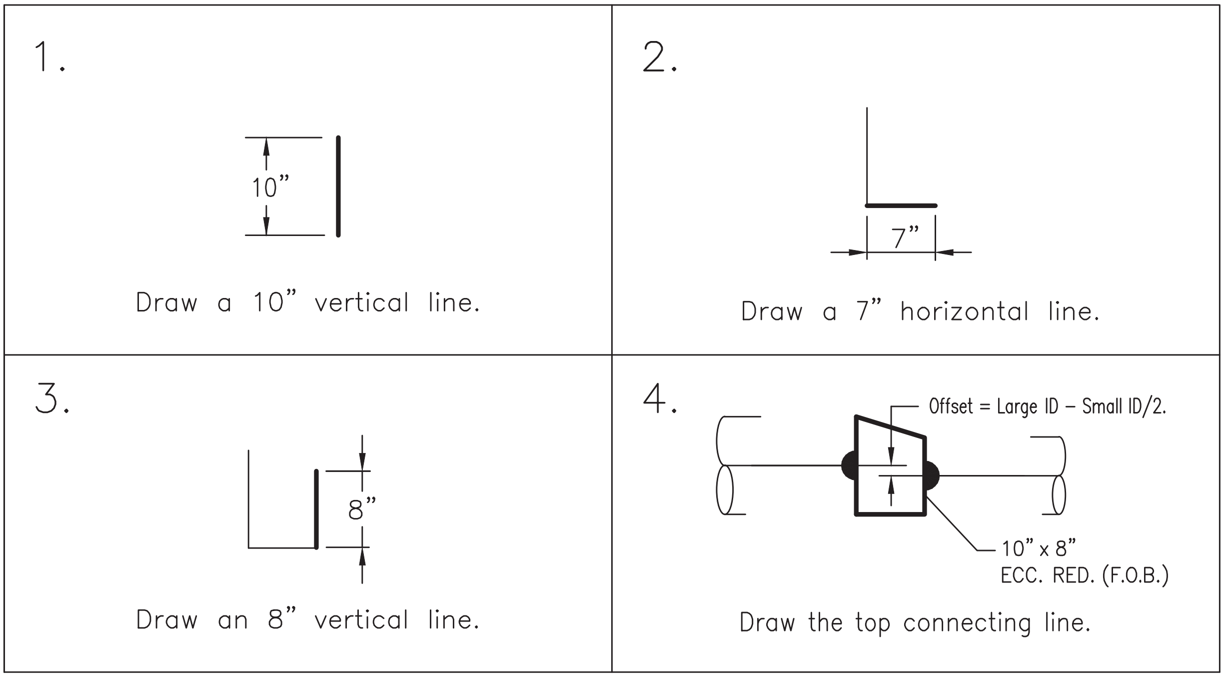


FIGURE 3.48 10″ × 8″ eccentric reducer (FOB). AutoCAD step-by-step drafting procedure.

Step 1. Draw a vertical line 10″ long, having a 0.53 mm lineweight, to represent the large diameter end of the reducer.
Step 2. Draw a similar line perpendicular and to the right measuring 7″, to represent the length of the reducer.
Step 3. Create the small diameter end of the reducer by drawing an 8″ vertical line up from the right end of the reducer.
Step 4. Complete the reducer by drawing a sloping line back to the top of the 10″ line, connecting the two vertical ends.

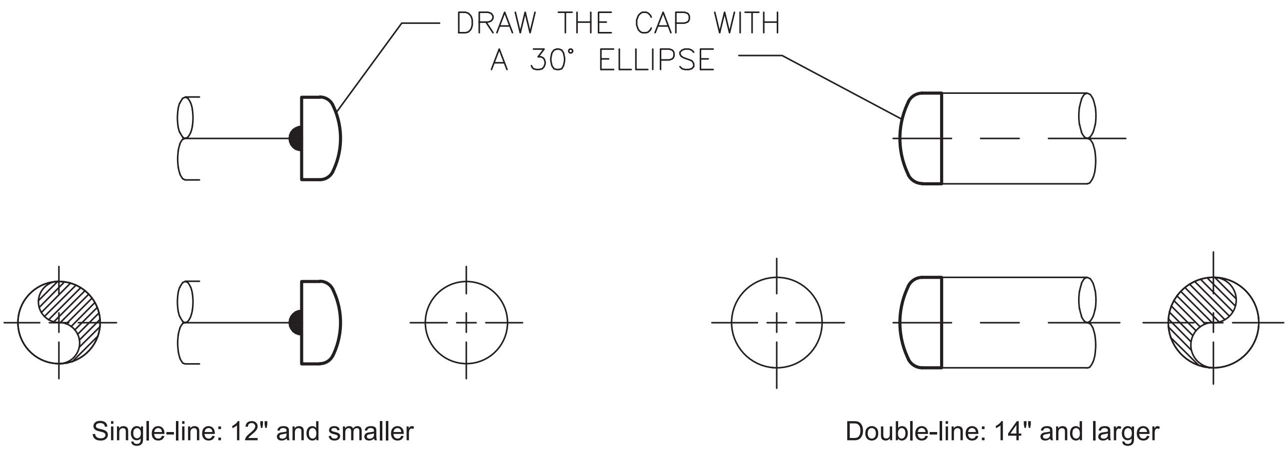


FIGURE 3.49 Weld cap drawing symbols.

pockets can be eliminated. Figure 3.42 depicts the installation of an 18″ × 14″ eccentric reducer installed on a pump suction nozzle with the flat surface installed on top.

It is important a designer not forget to include the dimensional difference between the two centerlines of an eccentric reducer when calculating the elevations of pipe in a pipe rack. The formula for calculating this difference is:

$$\text{Offset} = \frac{\text{Large ID} - \text{small ID}}{2}$$

A quicker, although less accurate method, is to take one-half the difference between the two outside diameters. Figure 3.43 shows the method of dimensioning the offset distance between the centerlines of the eccentric reducer in its FOT and FOB orientations.

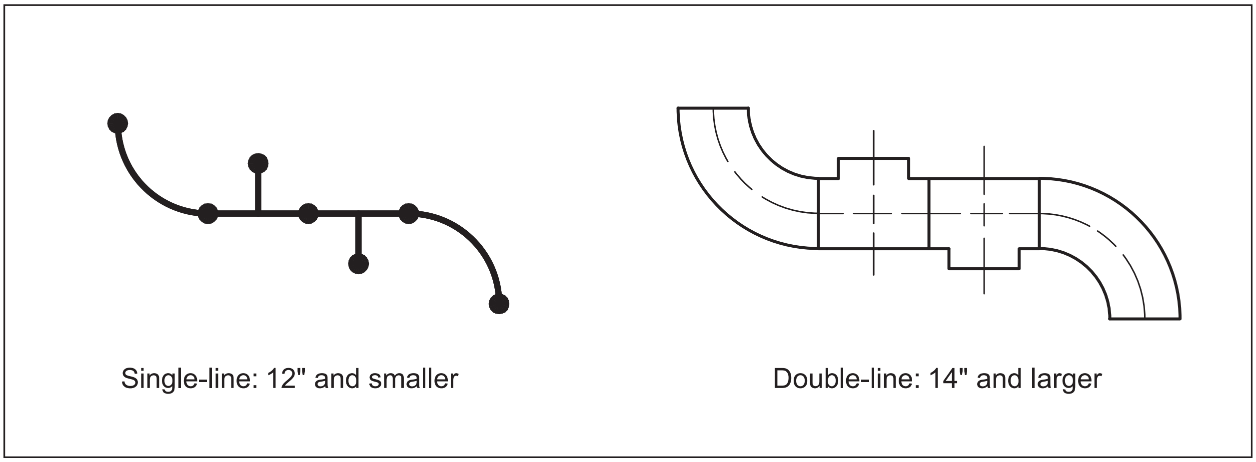


FIGURE 3.50 Fitting make-up.

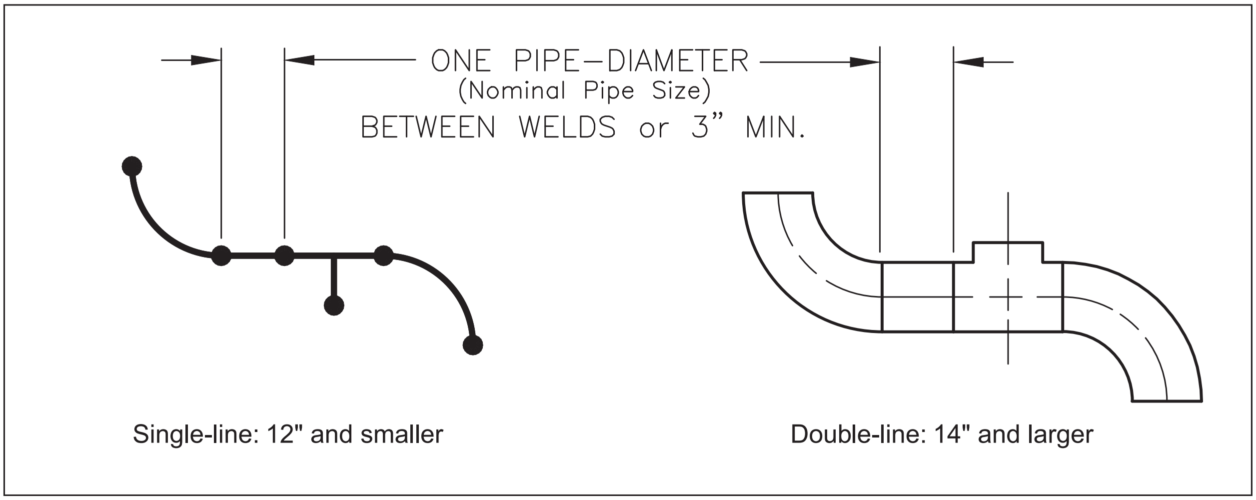


FIGURE 3.51 Minimum pipe cut-lengths.

Drawing Symbols for the Concentric and Eccentric Reducer

The orthographic views for the single-line and double-line representations of the concentric reducer are shown in Figure 3.44. No matter the size of the reducer, it is always drawn as a double-line symbol. Notice the callouts that must be included with the eccentric reducer. The large end is always listed first, no matter the direction of flow, and the flat side must be indicated (Figure 3.45).

Drawing the Reducers

Prior to drawing the reducer, the length of the fitting must be found on the Welded Fittings-Flanges dimensioning chart (see Figure 3.46). The ***H*** dimension will provide the end-to-end length for either the concentric or eccentric reducer.

***NOTE**: Always use the **H** dimension of the large end when determining the fitting length of any reducing fitting.*

Figure 3.47 represents the step-by-step procedures used to draw a 16″ × 14″ concentric reducer. Figure 3.48 shows the step-by-step procedures that a 10″ × 8″ eccentric reducer, flat on bottom, is drawn with.

WELD CAP

Although there are others, the last weld fitting we will discuss is the weld cap. The weld cap is used to seal or "*cap*" the open end of a run of pipe. To dimension the positional location of a weld cap on a drawing, simply

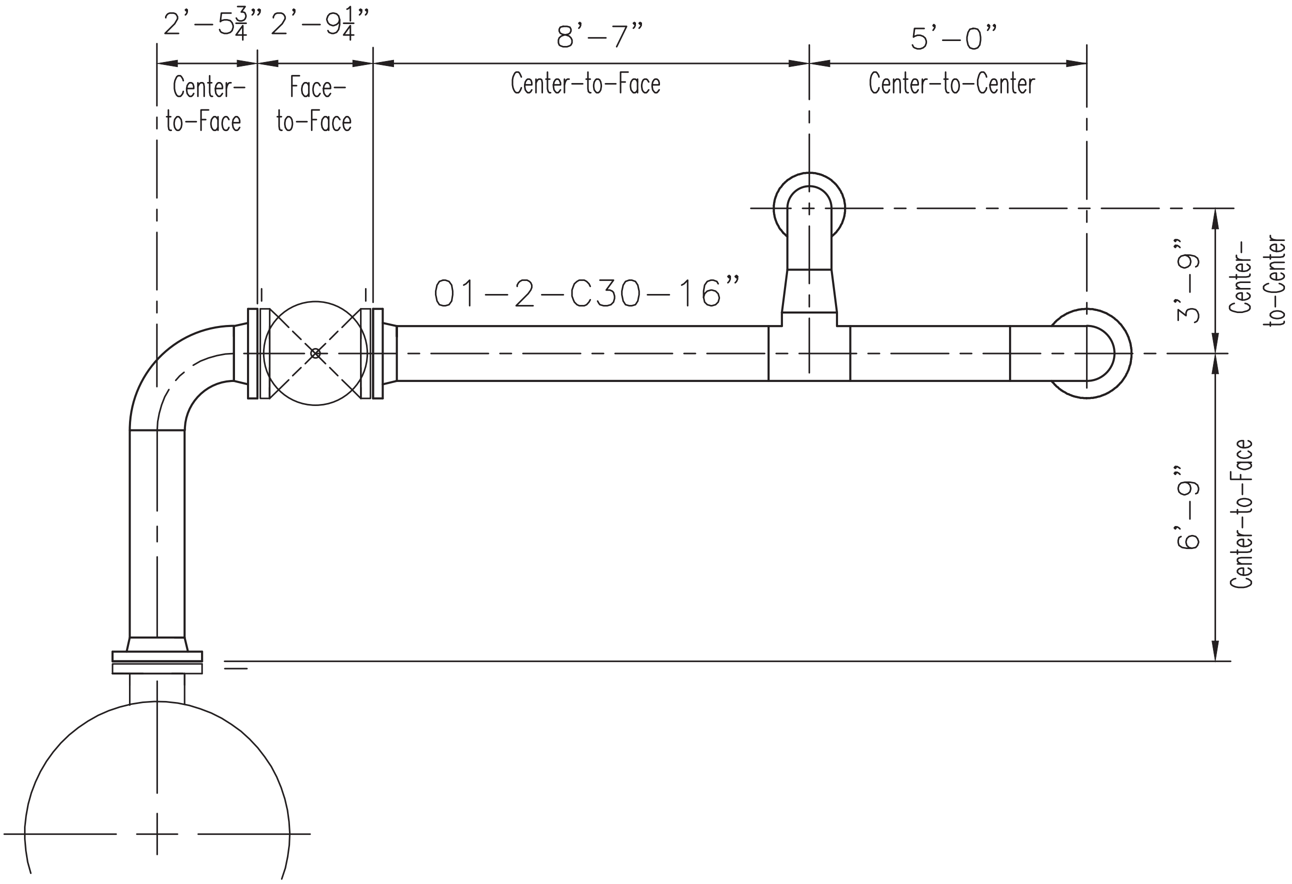


FIGURE 3.52 Placement of dimensions on butt-weld configurations.

dimension the length of the run of pipe. The cap is not included in the length dimension of the pipe. A pipe fitter will know to weld the cap on the end of the pipe.

The weld cap, like the reducer, is another fitting that is drawn as a double-line symbol no matter what the pipe's nominal size is. When representing the cap on a drawing, use an ellipse to construct the round end of the fitting. Figure 3.49 shows the single-line and double-line drawing symbols for a weld cap. Notice the weld dot on the single-line symbol is drawn as a half-circle only.

The length of the fitting is found on the Taylor Forge Seamless Welding Fitting chart in Appendix A.

USE OF FITTINGS

Thus far we have discussed each fitting individually. We will now look at how they relate to other fittings when used in the design of various piping systems. Depending on the given situation, fittings will either be welded to each other or separated by lengths of pipe. Welding one fitting directly to another is called *fitting make-up*. Single-line and double-line representations of fitting make-up are shown in Figure 3.50.

In most situations the erection of the piping system will require the designer to use pipe of various lengths between the fittings. In these cases, pipe is cut to the required length and then beveled in preparation for welding to a fitting. When a pipe configuration is not assembled as fitting make-up, and the fittings are separated by a short section of pipe, most companies stipulate the pipe must be at least one pipe-diameter long or 3″ minimum length whichever is longest. A cut-length of one pipe-diameter means that any section of pipe that is to be placed between two fittings must be at least as long as the nominal pipe size of the fitting used. For example, if 8″ fittings are being used the minimum cut-length of pipe between any two fittings is 8″. For pipe configurations of a 3″ nominal size or smaller, the minimum pipe cut-length is 3″. These short sections of pipe are sometimes referred to as *spool* or *pup* pieces.

It is important to maintain this minimum spacing because once assembled each weld in every piping configuration in the facility must be x-rayed and heat treated.

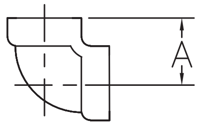
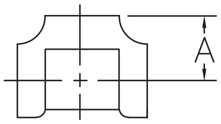
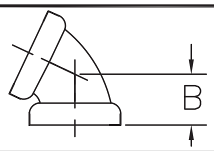
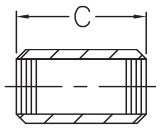
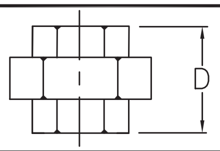
SCREWED FITTINGS										
NOMINAL PIPE SIZE–(INCHES)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	3000 # 90°ELL	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	3000 # HALF TEE	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	3000 # 45°ELL	B	1	1 1/8	1 5/16	1 7/16	1 11/16	2	2 1/16	2 1/2
	6000 #	B	1 1/8	1 5/16	1 11/32	1 11/16	1 23/32	2 1/16	2 1/2	3 1/8
	3000 # COUPLING	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	6000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	3000 # UNION	D	2 3/8	2 7/16	2 3/4	2 15/16	3 3/16	3 7/16	4 1/16	4 1/2
	6000 #	D	2 3/8	3 3/8	3 5/8	3 7/8	4 3/16	4 5/8		
NORMAL THREAD ENGAGEMENT	3000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1
	6000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1

FIGURE 3.53 Threaded fittings dimensioning chart.

X-rays are performed to guarantee the quality of the weld. Once a weld has been completed, if another weld procedure is performed too close to it, the heat from the new weld may have an adverse effect on the first weld. Therefore the one pipe-diameter min spacing allows the pipe to dissipate the heat before it can spoil the first weld. By maintaining a minimum spacing between welds, a pipe can conveniently be cut, beveled, and welded without adverse effects on adjacent welds. Figure 3.51 depicts the one pipe-diameter minimum spacing.

NOTE: *The one pipe-diameter minimum spacing is a standard used throughout the piping industry and will be applied to the drawing exercises and projects used in this text.*

Welds may seem insignificant to the beginning drafter, but it goes without saying a piping facility could not be built without them. So remember, all welds must be shown on drawings in their exact and proper locations. And, use weld *dots* on single-line pipe symbols and weld *lines* on double-line pipe symbols.

Applying Fitting Make-Up Dimensions

The next step in the drawing of pipe is the calculation and placement of dimensions on drawings. At the present time, the only concern is how to position and align dimensions on butt-weld fitting configurations. As a general rule-of-thumb, there are three methods in which dimensions are placed on butt-weld piping configurations. They are:

- Center-to-center. Place dimensions from center of fitting to center of fitting.
- Center-to-face. Place dimensions from center of fitting to face of flange.
- Face-to-face. Place dimensions from face of flange to face of flange.

Figure 3.52 provides some examples for placing dimensions on drawings. Notice although, when a weld cap is installed the dimension needed is a center-to-end of pipe measurement.

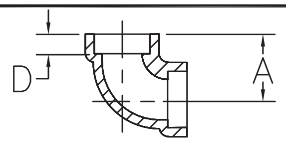
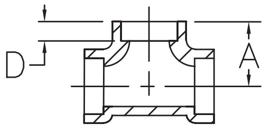
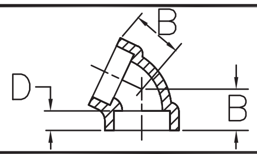
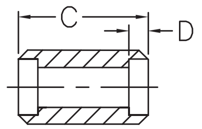
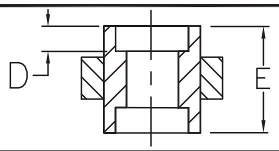
SOCKET-WELD FITTINGS										
NOMINAL PIPE SIZE–(INCHES)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	3000 # 90°ELL	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	3	3 3/8
	6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	3000 # HALF TEE	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	3	3 3/8
	6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	3000 # 45°ELL	B	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	2 1/16	2 1/2
	6000 #	B	1	1 1/8	1 5/16	1 11/32	1 11/16	1 23/32	2 1/16	2 1/2
	3000 # COUPLING	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	6000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	3000 # UNION	E	1 15/16	2 1/4	2 1/2	2 13/16	3 1/16	3 7/16	4	4 5/16
	6000 #	E	2 5/16	2 1/2	2 13/16	2 3/4	2 7/8	3 11/16	3 15/16	4 5/8
SOCKET DEPTH	3000 #	D	1/2	9/16	5/8	11/16	3/4	7/8	1 3/8	1 1/8
	6000 #	D	11/16	3/4	7/8	15/16	1 1/8	1	1 1/2	1 5/8

FIGURE 3.54 Socket-weld fittings dimensioning chart.

THREADED AND SOCKET-WELD FITTINGS

Threaded and socket-weld fittings perform the same basic functions as butt-weld fittings. Like butt-weld fittings, elbows, tees, and reducers are manufactured for threaded and socket-weld applications. There are, however, a few differences that must be examined. Threaded and socket-weld fittings are normally reserved for installations where the nominal pipe size is 3″ and smaller. Threaded and socket-weld fittings are also available in cast iron, malleable iron, or forged steel. While forged steel fittings are used on high pressure and temperature lines; fittings made of cast and malleable iron are typically used on low pressure and temperature lines such as air, water, or condensate.

Pipe lines containing high pressure and temperature commodities, which are subject to substantial amounts of movement and vibration, mandate fittings made of forged steel. For these reasons, forged steel threaded and socket-weld fittings are manufactured in two pressure classes—3000# and 6000#. The sizing charts, shown in Appendix A, provide the dimensional measurements for 3000# and 6000# threaded and socket-weld fittings. Figure 3.53 and Figure 3.54 display a portion of the threaded and socket-weld fitting dimensioning charts found in Appendix A.

Most threaded fittings are manufactured with internal, or *female*, threads as defined by the American Standard and API thread guidelines. As shown in Figure 3.55, of particular, concern to the pipe designer is the amount of pipe length lost during the assembly of threaded fitting configurations. When threaded fittings and threaded pipe are assembled a certain amount of pipe length is lost as a result of the internal and external, or *male*, thread connecting process. Each time a threaded connection, or *engagement*, is made,

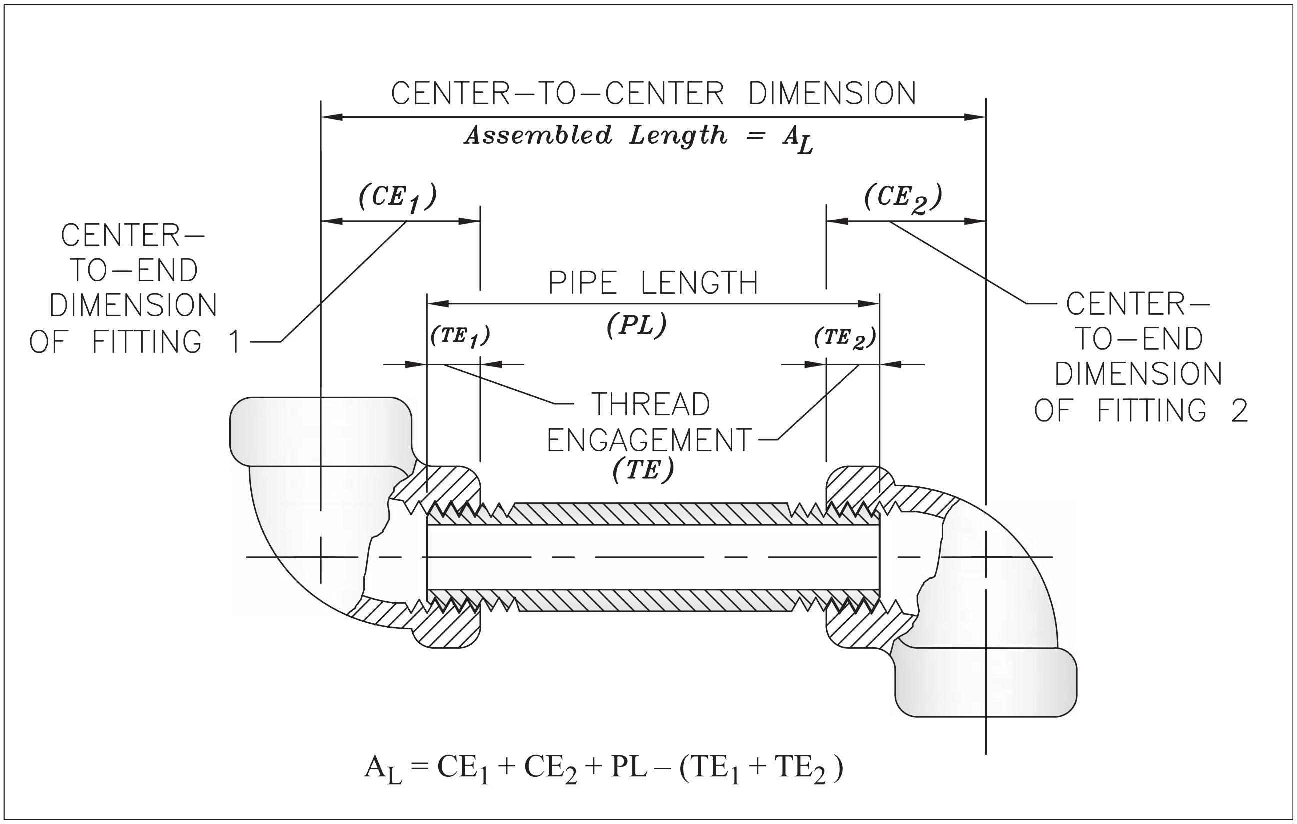


FIGURE 3.55 Internal and external thread engagements.

the configuration gets shorter. The length of this engagement varies depending upon the nominal pipe size and pound rating of the fitting. The procedure to determine the actual center-to-center length of a threaded configuration is to subtract the total length of all the thread engagements from the total unassembled length of pipe and fittings. The *unassembled* length can be thought of as all the pieces, both fittings and pipe, being laid out end-to-end. From this unassembled length the total of all the thread engagements is then subtracted to determine the *total assembled length*. The formula below applies the values shown in Figure 3.55 to calculate the *Assembled Length*.

$$A_L = CE_1 + CE_2 + PL - (TE_1 + TE_2)$$

Some fittings, such as plugs and swages, however, are manufactured with external threads and their assembled lengths are treated differently, as will be explained later.

The socket-weld fitting has become the fitting of choice for many fabricators because it offers greater strength at each point of connection. Even though threaded fittings can be seal-welded if necessary, strength of the fitting is decreased when the threads are cut during the manufacturing process. Socket-weld fittings can be easily fitted and welded without the need of special clamps or tack-welds, which are often required to hold a fitting in place before the final weld is made. Like threaded fitting configurations, during the assembly of socket-weld configurations, there is pipe length loss. This lost length is equal to the depth of the socket, or *socket depth*, and must be accounted for when calculating overall lengths of pipe runs. However, there is a slight difference from threaded pipe assemblies. On socket-weld connections a 1/16″ gap is factored into each socket-weld connection. Figure 3.56 provides a sectional view of two socket-weld elbows and the connecting pipe. Notice two socket depths must be subtracted from the total unassembled length of the two elbows and the piece of pipe, then ⅛″ is added back to account for the two 1/16″ gaps, before an assembled configuration length can be determined. If a formula were applied to calculate the *Assembled*

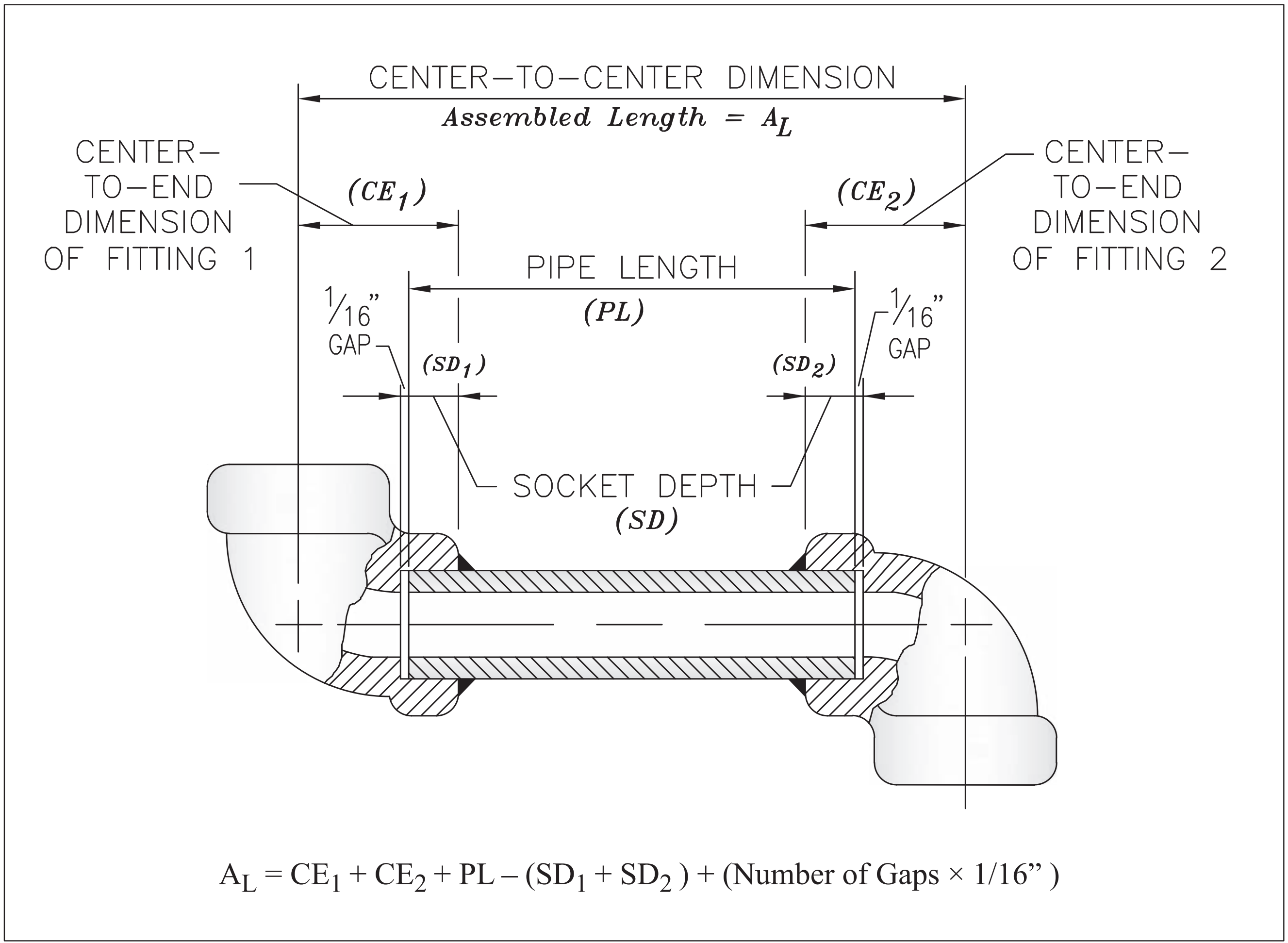


FIGURE 3.56 Socket-weld fitting connections.

Length using the values shown in Figure 3.56, it would look like this;

$$A_L = CE_1 + CE_2 + PL - (SD_1 + SD_2) + (\text{Number of gaps} \times 1/6'')$$

Fittings

Like butt-weld fittings, threaded and socket-weld fittings are used to make similar routings in the piping system, but only in smaller pipe sizes. Threaded and socket-weld fittings differ in size and shape, but they achieve the same purpose as butt-weld fittings. However, there are some differences. 90° elbows are not available as long-radius or short-radius and their center-to-end dimension must be found on a dimensioning chart as there is no formula available for calculating their radius length. Figure 3.57 provides examples of some socket-weld and threaded fittings.

Threaded and socket-weld fittings are represented differently on drawings than their butt-weld counterparts. For example, threaded and socket-weld elbows are drawn with square corners, using short hash marks to represent the connection points of the fitting and its mating pipe. Some engineering companies even draw short *ears* on the hash marks to indicate a difference between threaded and socket-weld symbols (see Figure 3.58).

There are, however, some fittings that are unique to the threaded and socket-weld family of fittings. These fittings do not lend themselves to butt-weld applications and are manufactured solely for use in threaded and socket-weld configurations. A brief discussion of those follows.

Unions

The union, shown in Figure 3.59, is a fitting placed within a piping configuration which will allow the

FIGURE 3.57 Socket-weld and threaded fittings.

assembly to be disassembled for inspection, repair, or replacement. Manufactured for threaded and socket-weld applications, the union is represented on drawings as shown in Figure 3.60. Unions should be positioned in locations that will facilitate the easy removal of critical pieces of equipment. Figure 3.61 shows how unions are placed in a configuration to allow easy removal of a valve.

Plug

The plug, like a cap, is designed to seal the end of a run of pipe. Plugs are manufactured for threaded fittings with male threads and are screwed into the end of a pipe to create a seal. Figure 3.62 shows the drawing symbols for the plug.

Typically, hydrostatic vents and drains are required at all high and low points, respectively. As depicted in Figure 3.63, plugs are used to seal those connections after hydrostatic testing is complete. Even though plugs are threaded components, after the hydrostatic test is completed a seal weld is made to make the threaded connection a permanent one. Also depicted in Figure 3.63 is replacement of the plug with a 4″ pipe nipple and cap on insulated lines.

Coupling

Although this fitting is used in butt welding applications as a branch connection, its primary use is to connect lengths of threaded and socket-weld pipe together. Some clients may stipulate, however, that all socket-weld pipe must be connected with a butt-weld rather than a coupling.

PIPE NIPPLES

By design, threaded and socket-weld fittings cannot be assembled by placing one fitting directly in contact with another fitting. There must be pipe in between. As mentioned previously, threaded fittings are manufactured with threads on the inside of the fitting and socket-weld fittings have an internal socket that prevents fitting make-up assembly like butt-weld fittings. To facilitate the assembly of threaded and socket-weld fittings, short lengths of pipe called *pipe nipples* are placed between the fittings. Pipe nipples can vary in length depending upon the distance required to fabricate the pipe configuration. A *close nipple* is one that allows for the minimum assembly length between two pipe fittings. Remember, threaded and socket-weld

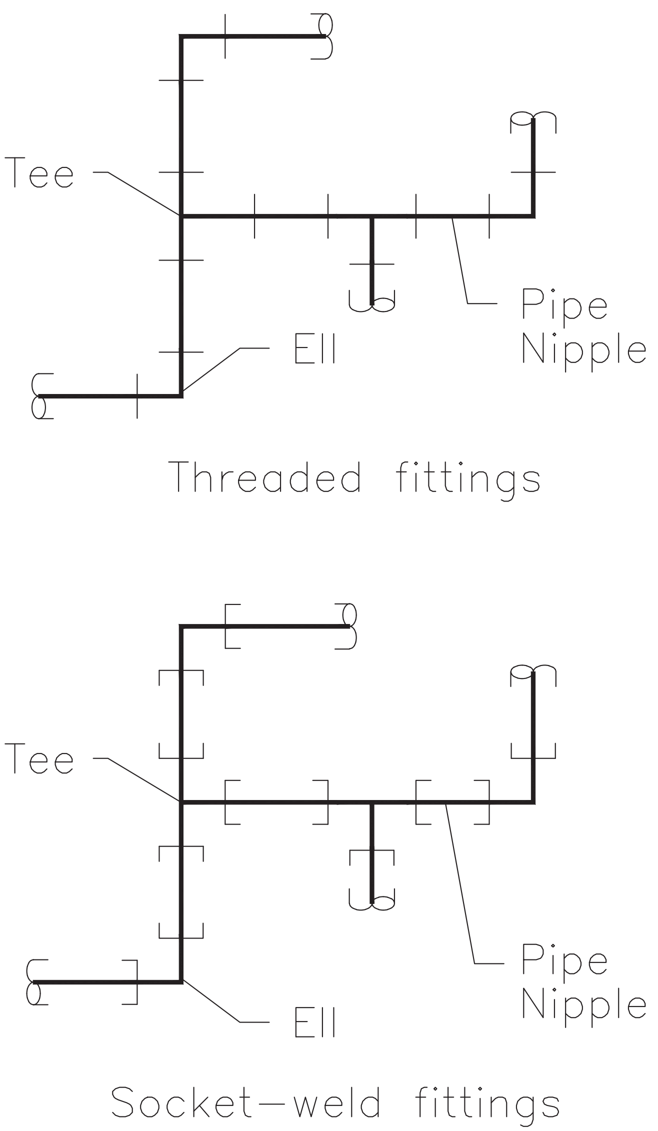


FIGURE 3.58 Threaded and socket-weld drawing symbols.

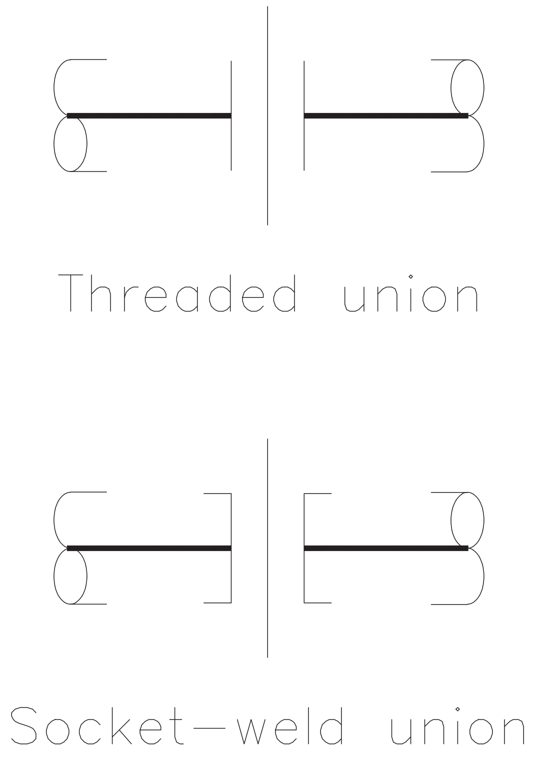


FIGURE 3.60 Union drawing symbols.

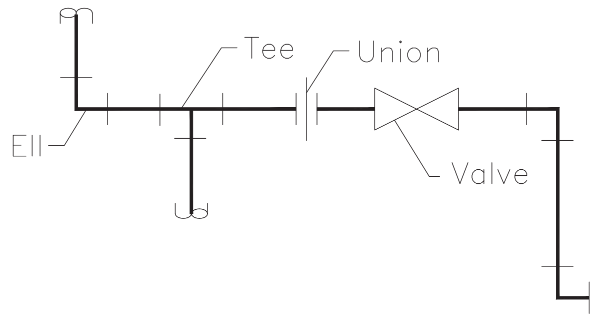


FIGURE 3.61 Positioning of unions.

FIGURE 3.59 Union.

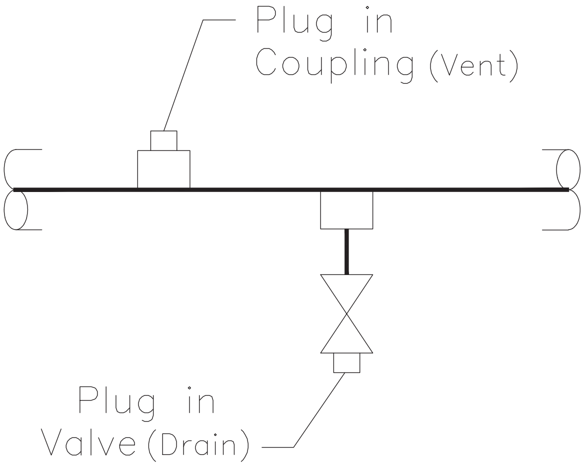


FIGURE 3.62 Plug drawing symbols.

configurations have a certain amount of pipe length loss due to thread engagement and socket depth. Because thread engagement and socket depth varies depending on the pipe's nominal size, each pipe size has a different minimum length for the dimension of a close nipple.

Companies vary between the use of 3″ or 4″ as the standard minimum length of pipe nipples. Either length easily accommodates the amount of pipe length lost on both ends of the fitting as well as provide sufficient wrench clearance during assembly for the larger threaded pipe sizes.

Swage

One exception to the standard 3″ minimum rule is the *swage nipple*. Swages are functionally similar to reducers, in that they are used to make line-size reductions in a straight run of pipe; but, they are specifically designed for threaded and socket-weld pipe. Threaded swages have external (male) threads and are connected directly to other threaded fittings without the need of a pipe nipple. Like reducers, they are available in either a concentric or eccentric shape and are always drawn double-line on a drawing (see Figure 3.66). Figure 3.64 shows varying lengths and sizes of threaded pipe and swage nipples.

Swages are unique in that they can be used in threaded, socket-weld, or buttweld configurations. When used in these configurations, swages will have different end preparations. These end preparations allow the swage to be used in a number of different attachment combinations. In other words, threaded to socket-weld, butt-weld to threaded, or butt-weld to socket-weld. Threaded swages will have threaded ends (TE), socket-weld swages will have plain ends (PE), and butt-weld swages will have beveled ends (BE). Because

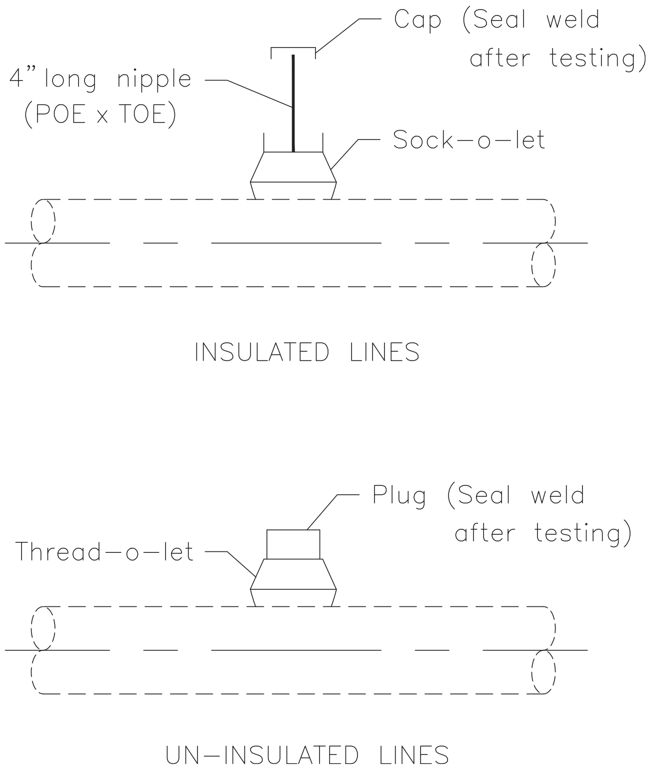


FIGURE 3.63 Plug usage for hydrostatic testing.

socket-weld swages are inserted into mating fittings many companies allow the substitution of beveled end swages. Since the end is inserted into the fitting and the weld is made on the outside of the fitting, it makes little difference how the end cut is made. Swages are also manufactured with different preparations on their opposing ends. When specifying a swage, use the following abbreviations:

BBE	Bevel both ends
TBE	Thread both ends
PBE	Plain both ends
BLE/TSE	Bevel large end/thread small end
PLE/TSE	Plain large end/thread small end

Figure 3.65 depicts four different concentric swage nipples. Notice the end preparation combinations on the examples. Figure 3.66 shows the drawing symbols and accompanying fitting notation for various swages.

The swage section of the *Screwed Fittings* dimensioning chart, shown in Figure 3.67, provides the length or, *S* dimension, of swage fittings. Like reducers, one must always use the large end pipe size to find the length of the swage on the dimensioning chart. Notice the *Outlet* section of the chart. This section simply indicates the range in which the small end pipe size can reduce to. It does not affect the length of the fitting. Remember, all fittings that are attached after the swage

FIGURE 3.64 Pipe and swage nipples.

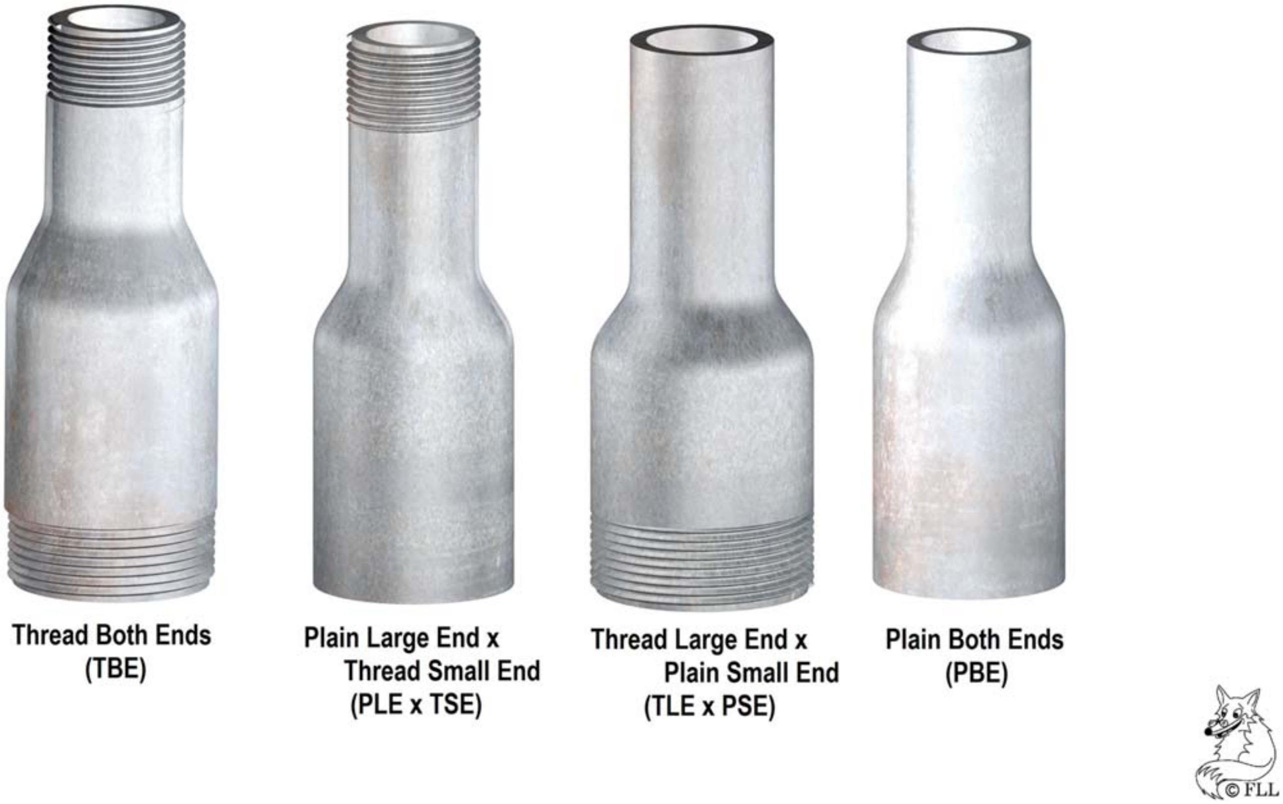


FIGURE 3.65 Concentric swage nipples.

are obviously of a smaller pipe size and therefore will not only be shorter in length, but will also have a shorter thread engagement. Important factors not to overlook when calculating the center-to-center dimensions of threaded or socket-weld configurations.

FLANGED FITTINGS

Flanged fittings perform functions similar to other fittings of the same type. The major difference is their method of connection. The connection joint for flanged fittings is made by bolting two specially designed metal surfaces together. Sandwiched between the two surfaces is a gasket, which prevents leaks. Flange types will be discussed at great length in a following chapter.

CAST IRON FITTINGS

Cast iron fittings are typically designed for use in gravity-flow installations using low-pressure water services. The physical appearance of pipe configurations made of cast iron fittings are quite different from pipe routed with forged steel fittings. The large assortment of available fittings and the method in which these configurations are assembled make their appearance quite distinguishable. Above-ground cast iron configurations often require multiple changes in direction and elevation to avoid obstructions with preexisting installations. Because molten cast iron can be easily manufactured into many unique shapes that cannot be attained with steel, pipe routings that have many varying turns, bends, and branches are quite common.

PLASTIC FITTINGS

Plastic fittings can are also manufactured in many diverse and unique shapes. Therefore they have become the material of choice for many low pressure and low temperature applications, replacing cast iron. All the standard fitting shapes are available, elbows, tees, reducers, couplings, unions, and so on. Plastic fittings are manufactured for either threaded, socket, or butted assembly. Plastic threaded and socket fittings are available in sizes through 4″ in diameter. Butt fittings are manufactured for sizes 6″-10″.

FITTING EXERCISE INSTRUCTIONS AND INFORMATION

The fittings depicted in Figure 3.68 will be used to complete exercise in this chapter along with Chapter 4, Flange Basics; Chapter 5, Valves; and Chapter 10, Piping Arrangement Drawings, Sections, and Elevations. To complete those exercises, draw the symbols below using the following instructions.

- Draw all fitting symbols full size using dimensions found on the Welded Fittings and Flanges dimensioning charts.
- Double-line symbols are drawn with a "default" lineweight. Single-line symbols are drawn with a 0.53 mm lineweight.
- Draw all weld dots with the **DONUT** command have a 0″ inside diameter and a 1.75″ outside diameter.
- Create a **BLOCK** of each symbol. Use a block name that appropriately describes the fitting and its size. (*DO NOT include text with the blocked symbol*).
- **BLOCK** the symbol with the base point placed at an appropriate location using an ENDpoint, MIDpoint, or CENter osnap.
- **SAVE** the file as *Fitting Symbols*.

NOTE: *When drawing the symbol which repsents the back of the elbow, break the arc so that it creates an opening approximately 45° to the pipe.*

SWAGE CALLOUTS

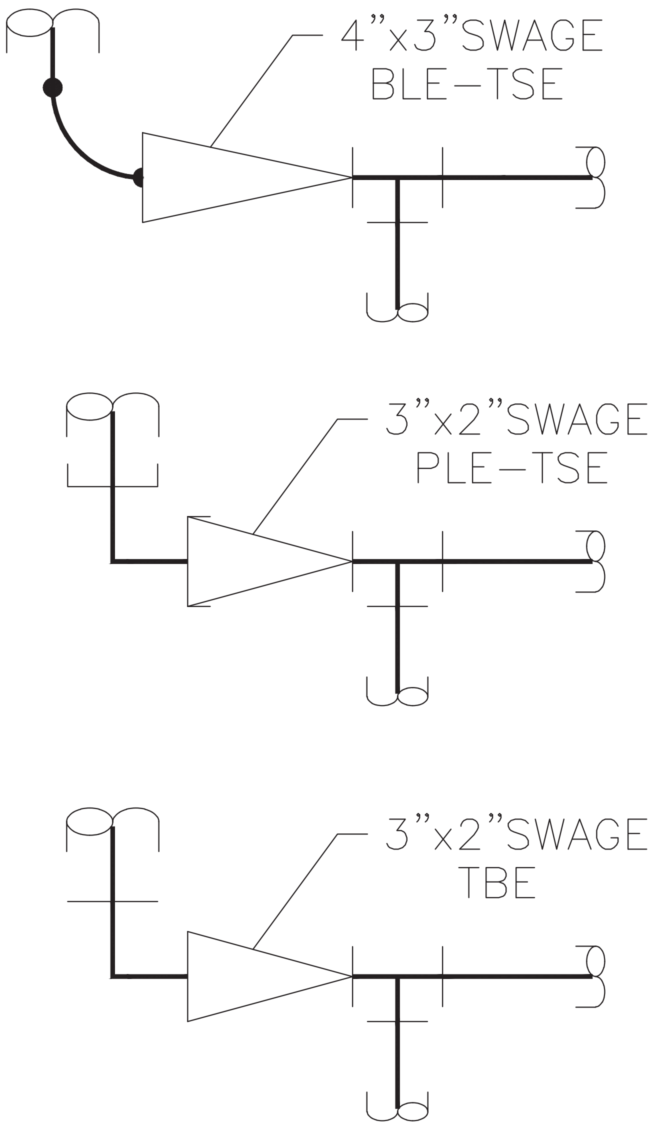


FIGURE 3.66 Swage drawing symbols.

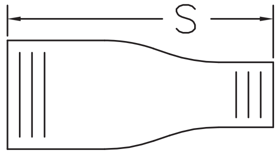
NOMINAL PIPE SIZE–(INCHES)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	SWAGE	OUTLET NPS	1/4 to 3/8	1/4 to 1/2	1/4 to 3/4	1/4 to 1	1/4 to 1 1/4	1/4 to 1 1/2	1/4 to 2 1/4	1/4 to 2 1/2
		S	2 3/4	3	3 1/2	4	4 1/2	6 1/2	7	8

FIGURE 3.67 Swage dimensioning chart.

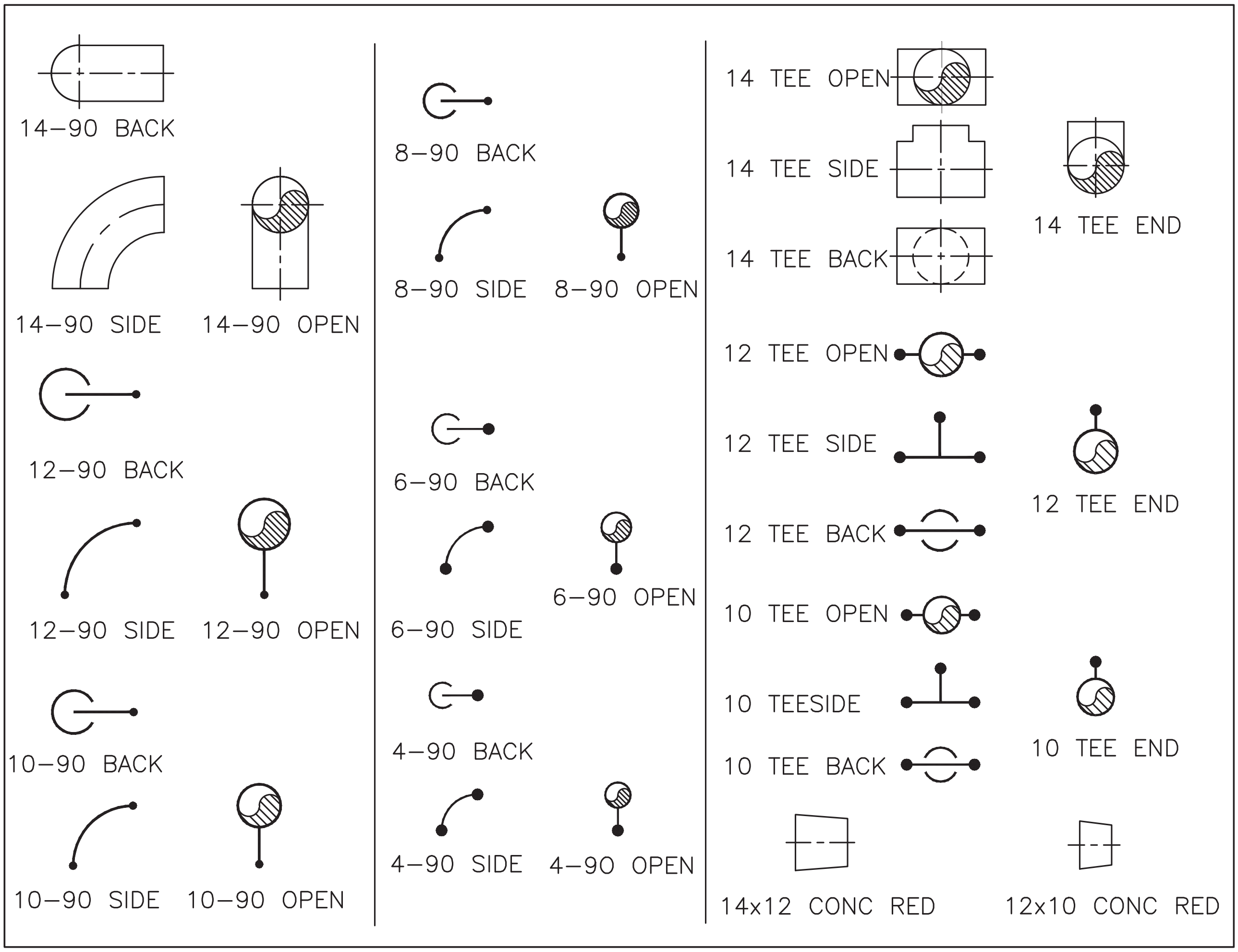
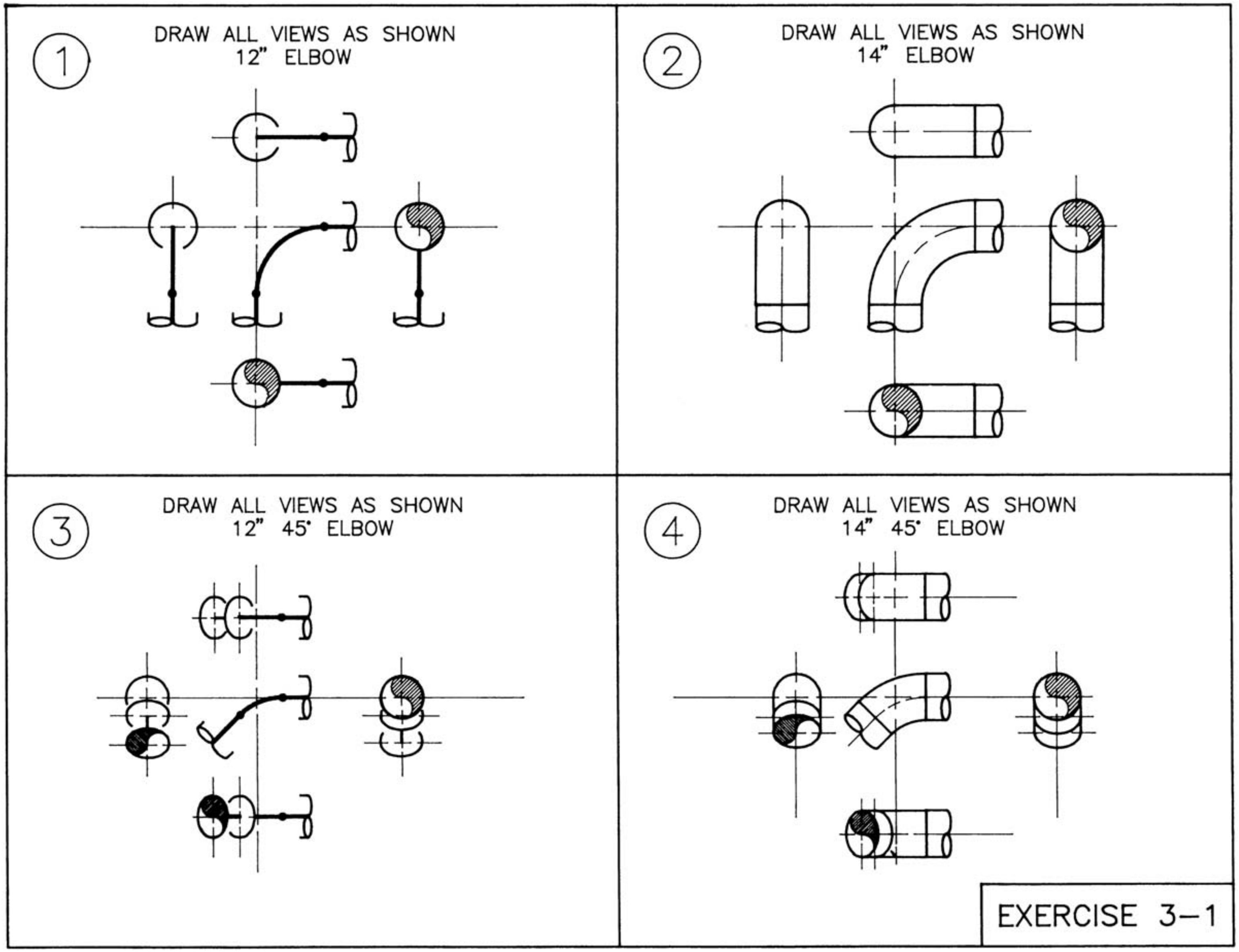
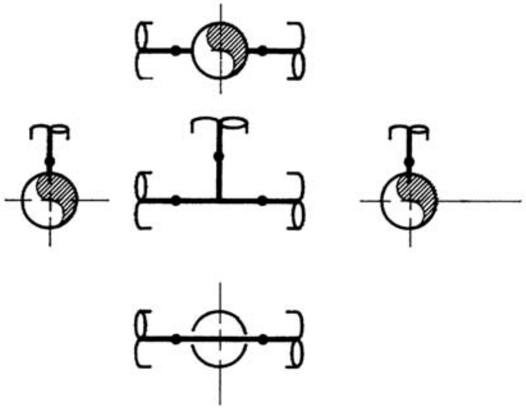


FIGURE 3.68 Fitting drawing symbols with File names.

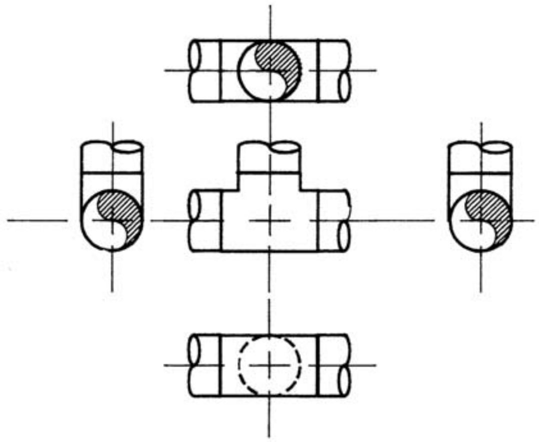
CHAPTER 3 DRAWING EXERCISES



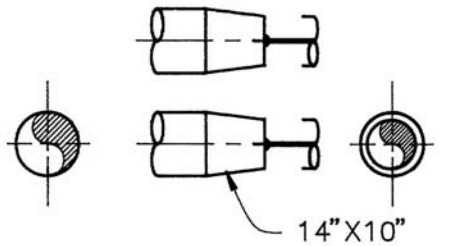
(1) DRAW ALL VIEWS AS SHOWN
12" TEE



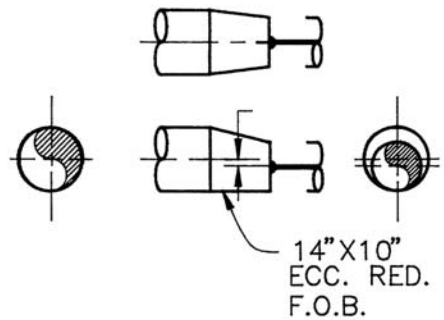
(2) DRAW ALL VIEWS AS SHOWN
14" TEE



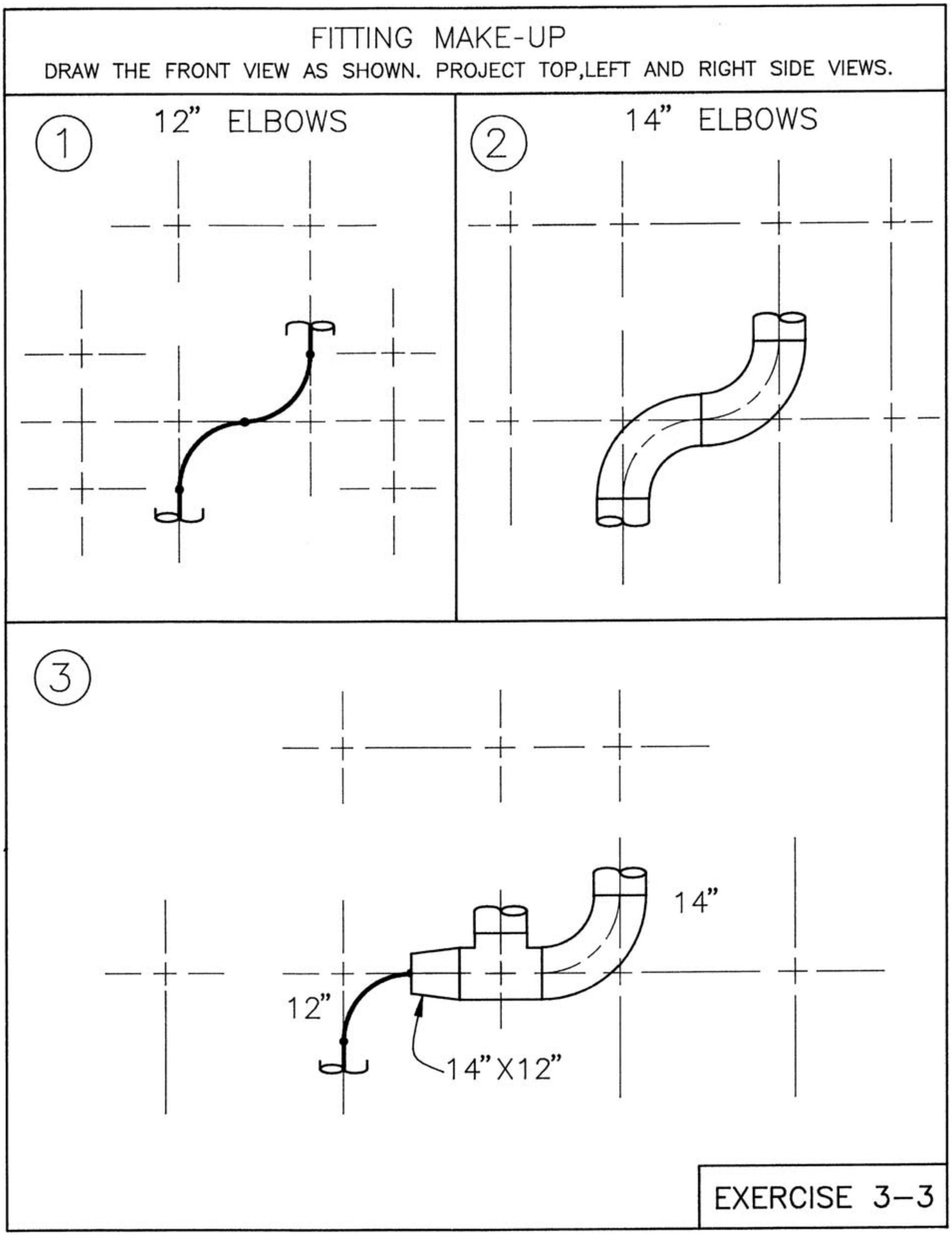
(3) DRAW ALL VIEWS AS SHOWN
14"x10" CONCENTRIC REDUCER



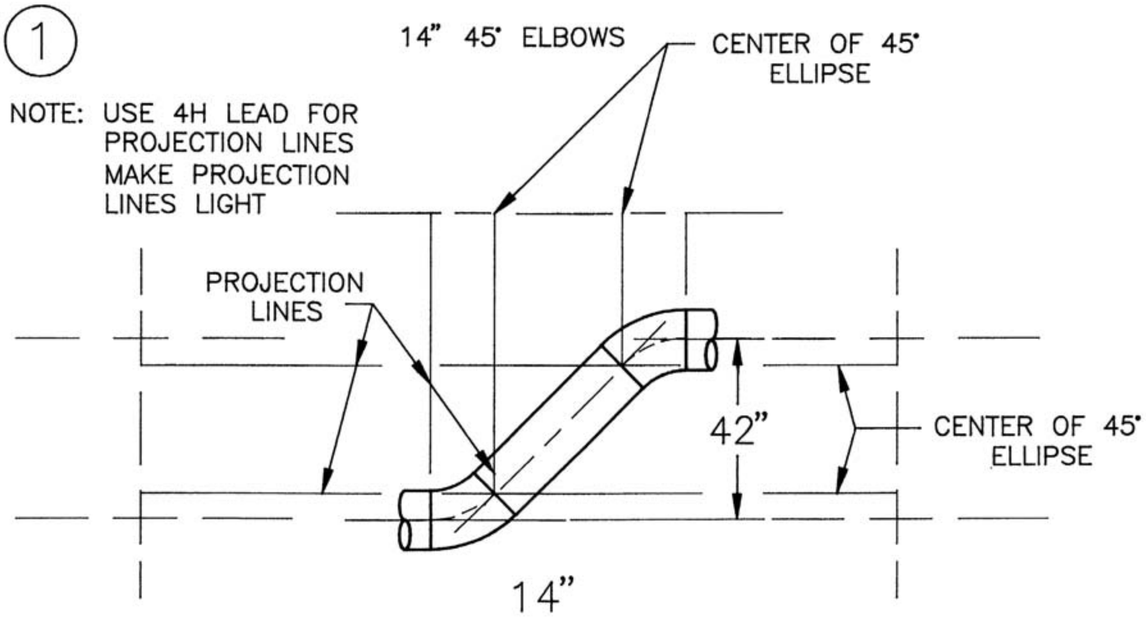
(4) DRAW ALL VIEWS AS SHOWN
14"x10" ECCENTRIC REDUCER



EXERCISE 3–2


FITTING MAKE-UP
DRAW THE FRONT VIEW AS SHOWN. PROJECT TOP,LEFT AND RIGHT SIDE VIEWS.
1
12" ELBOWS
2
14" ELBOWS
3
14"
12"
14"X12"
EXERCISE 3–3

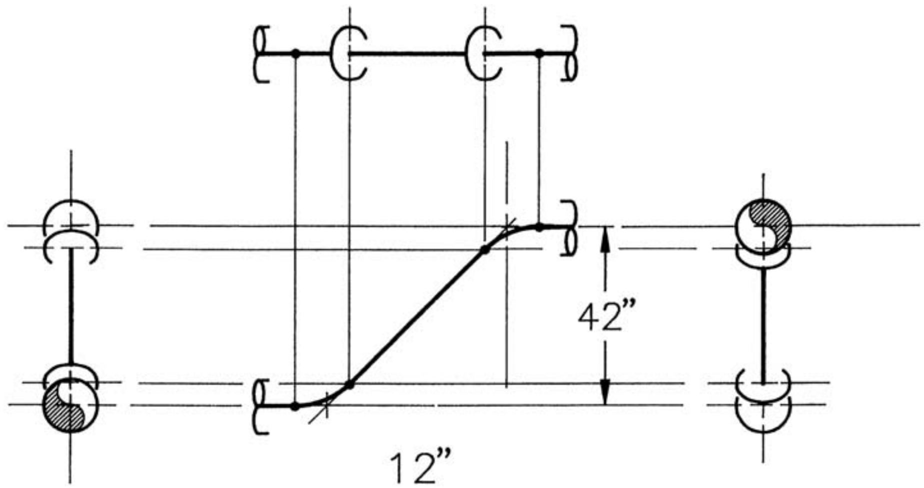
1



DRAW THE FRONT VIEW AS SHOWN. PROJECT TOP, LEFT AND RIGHT SIDE VIEWS.

2

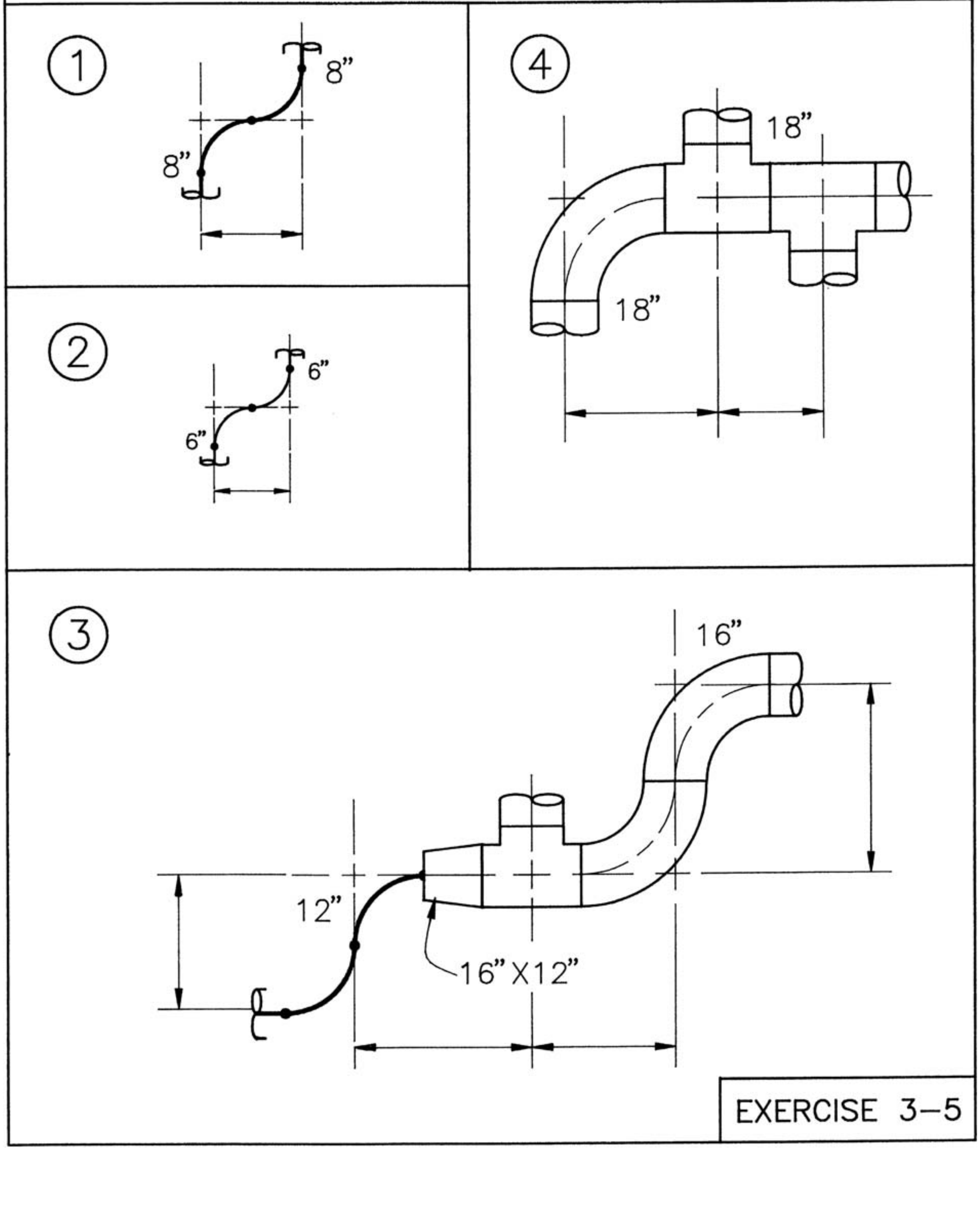
DRAW ALL VIEWS AS SHOWN
12" 45° ELBOWS



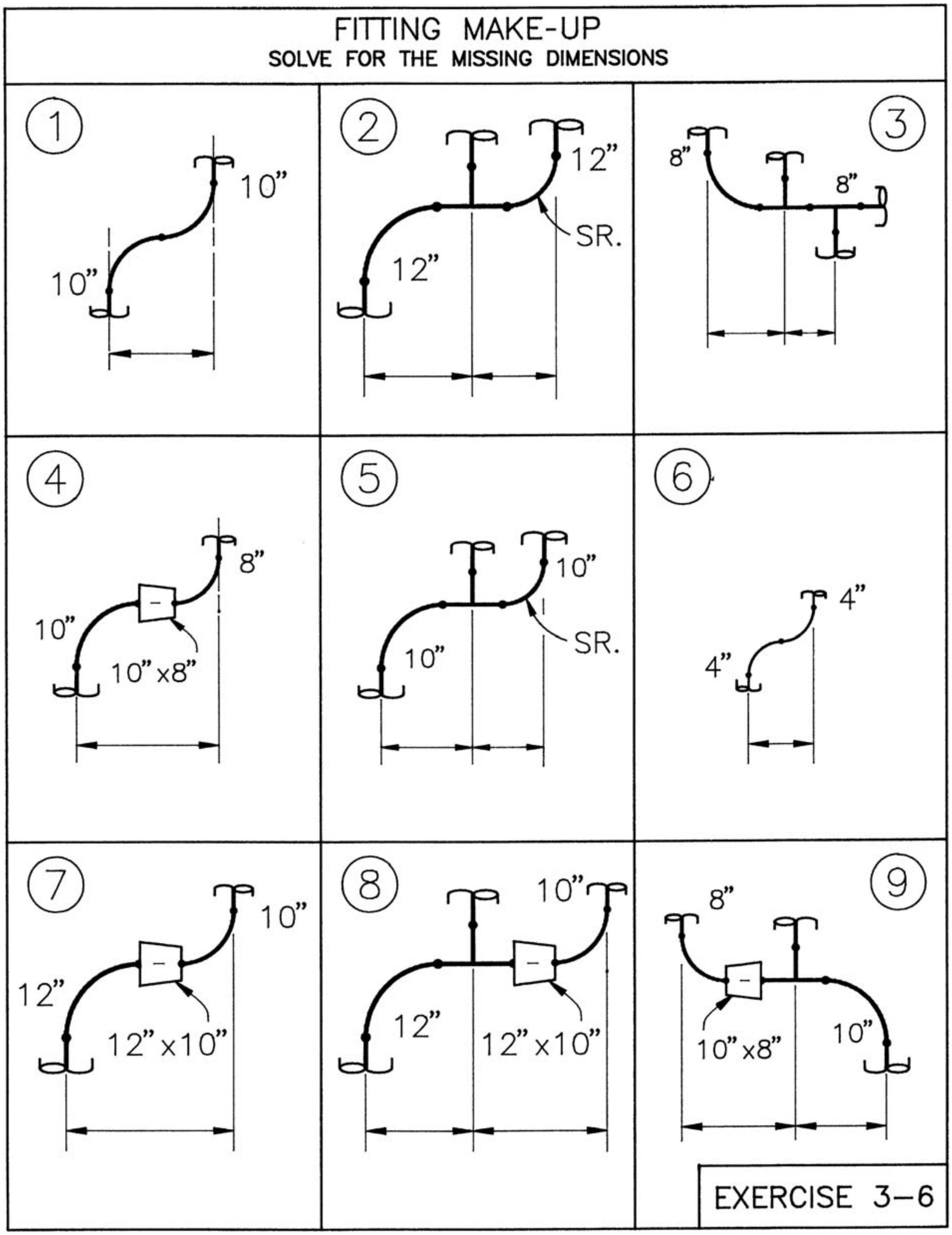
EXERCISE 3–4

FITTING MAKE-UP

SOLVE FOR THE MISSING DIMENSIONS



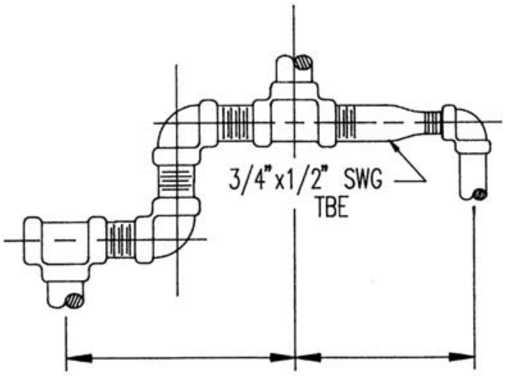
EXERCISE 3–5


FITTING MAKE-UP
SOLVE FOR THE MISSING DIMENSIONS
1
10"
10"
2
12"
12"
SR.
3
8"
8"
4
8"
10"
10"x8"
5
10"
10"
SR.
6
4"
4"
7
10"
12"
12"x10"
8
10"
12"
12"x10"
9
8"
10"x8"
10"
EXERCISE 3–6

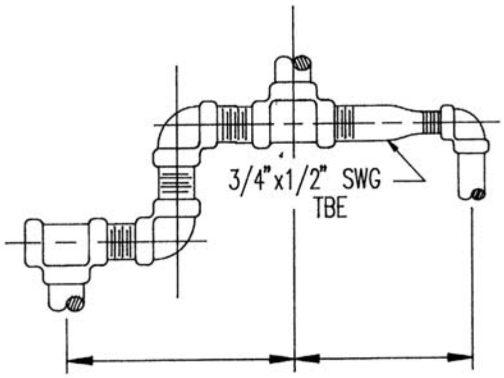
FITTING MAKE-UP

SOLVE FOR THE MISSING DIMENSIONS

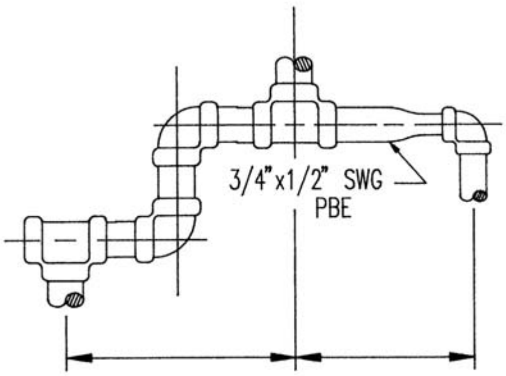
(1) 3000#FS SCREWED
3" LONG NIPPLES



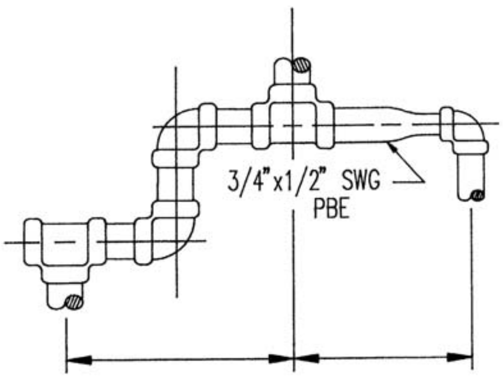
(2) 6000#FS SCREWED
3" LONG NIPPLES



(3) 3000# FS SW
3" LONG NIPPLES



(4) 6000# FS SW
3" LONG NIPPLES

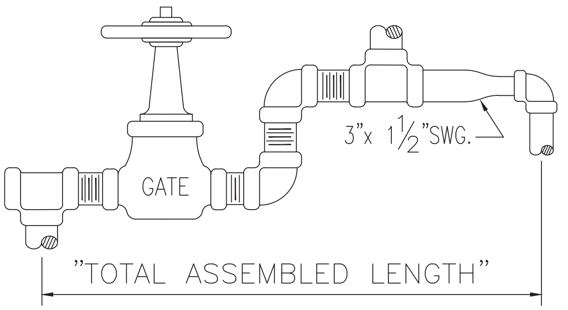


EXERCISE 3–7

FITTING CALCULATIONS

3"–3000# SCRD. FITTINGS

3" LONG PIPE NIPPLES



TOTAL UNASSEMBLED LENGTH: ____________

THREAD ENGAGEMENT LENGTH: ________

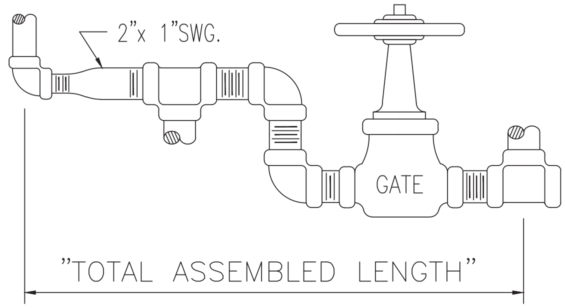
TOTAL ASSEMBLED LENGTH: ____________

EXERCISE 3–8

FITTING CALCULATIONS

2"–6000# SCRD. FITTINGS

3" LONG PIPE NIPPLES



TOTAL UNASSEMBLED LENGTH: ____________

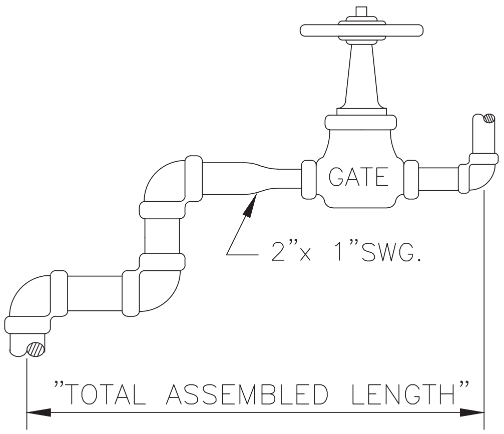
THREAD ENGAGEMENT LENGTH: ____________

TOTAL ASSEMBLED LENGTH: ____________

EXERCISE 3–9

FITTING CALCULATIONS

2"– 3000# S.W. FITTINGS
3" LONG PIPE NIPPLES



TOTAL UNASSEMBLED LENGTH: ____________

SOCKET DEPTH LENGTH: ____________

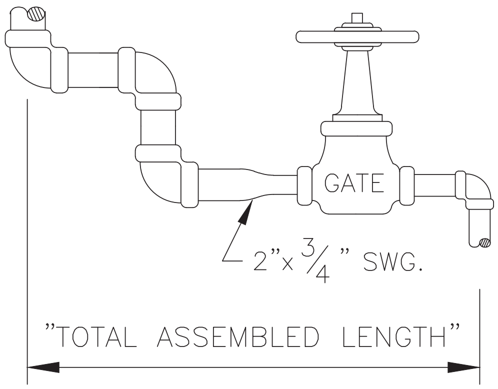
TOTAL WELD GAP SPACING: ____________

TOTAL ASSEMBLED LENGTH: ____________

EXERCISE 3–10

FITTING CALCULATIONS

2"– 3000# S.W. FITTINGS
3" LONG PIPE NIPPLES



TOTAL UNASSEMBLED LENGTH: ____________

SOCKET DEPTH LENGTH: ____________

TOTAL WELD GAP SPACING: ____________

TOTAL ASSEMBLED LENGTH: ____________

EXERCISE 3–11

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CHAPTER

4

Flange Basics

The *flange* is a ring-shaped device that is used as an alternative to welding or threading various piping system components together. Flanged connections, which require bolting, are the preferred alternative to welding because they can be easily assembled, disassembled, then reassembled when needed for shipping, inspection, maintenance, or replacement. Flanged connections are favored over threaded connections because threading large bore pipe is not an economical or reliable operation, as leakage on large bore threaded pipe is difficult to prevent. For these reasons the flange is an important component of any piping system.

Flanges are primarily used where a connecting or dismantling joint is needed. These joints may include attaching pipe to fittings, valves, mechanical equipment, or any other integral component within a piping configuration.

In the typical pipe facility, every piece of mechanical equipment is manufactured with at least one inlet and outlet connection point. The point where the piping configuration is connected to the equipment is called a *nozzle*. From this nozzle-to-flange connection point the piping routing is begun. Figure 4.1 depicts two examples of how pipe components are connected to an exchanger via a nozzle.

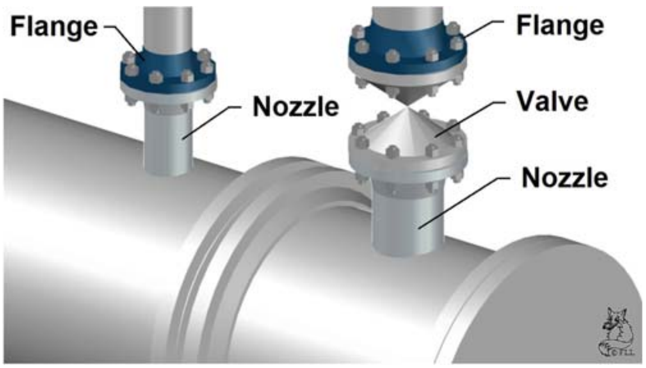

FIGURE 4.1 Nozzles.

RATING FLANGES

Rating, as applied to flanges, may best be defined as the maximum pressure allowed by the Pressure Piping Code for the specific temperature at which the flange will be operating. Flanges and nozzles are sized according to pressure ratings established by the American Society of Mechanical Engineers (ASME). These pressure ratings, often called *pound ratings*, are divided into seven categories for forged steel flanges. They are 150#, 300#, 400#, 600#, 900#, 1500#, and 2500#. Cast iron flanges have pound ratings of 25#, 125#, 250#, and 800#.

Pound ratings, when combined with the temperature of the commodity within the pipe, are used to select the appropriate size, rating, and type of flange. This pressure/temperature relationship will allow any given flange to be used in a number of different applications. For example, a 150# forged steel flange is rated to perform at 150# PSIG at 500°F. If the temperature were decreased to 100°F, this same flange could be used for 275# PSIG. However, if the temperature were increased to 750°F, the flange could only be used for 100# PSIG. As you can see, the pressure/temperature relationship is important. When temperature decreases, the allowable pressure increases and vice versa. Pound ratings are also used to establish the outside diameter and thickness of a flange. Typically, as pound ratings increase, so will the flange's diameter and thickness.

FLANGE FACINGS

The mating surface of a flange, nozzle, or valve is called the *face*. The face is usually machined to create a smooth surface. This smooth surface will help assure a leak-proof seal when two flanges are bolted together with a gasket sandwiched between.

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DOI: https://doi.org/10.1016/B978-0-12-822047-4.00005-4

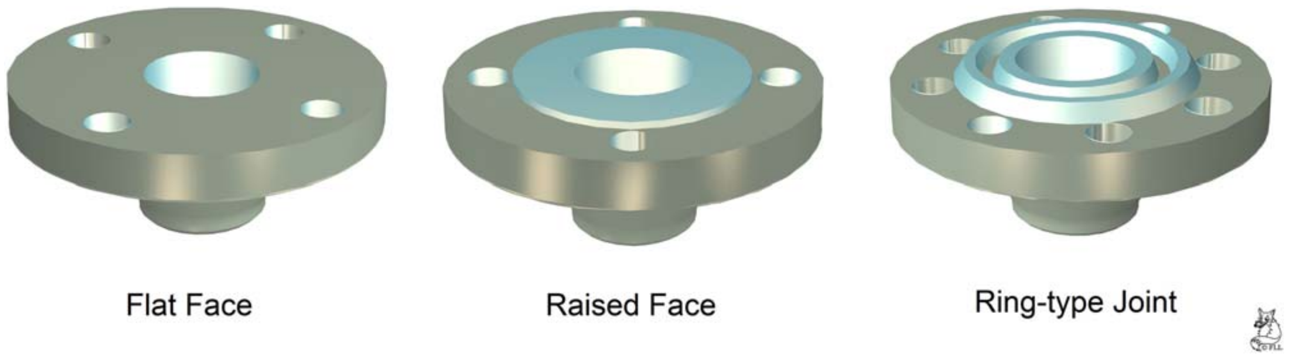


FIGURE 4.2 Flange face types.

FIGURE 4.3 Flat face flange.

Although numerous types of flange faces are produced, we will focus only on the following three (Figure 4.2)

- flat face,
- raised face, and
- ring-type joint.

The two sectional views of a flat face depicted in Figure 4.4 identify the various dimensional features of the flange. These features are of great importance to a pipe drafter/designer and are typically provided on a dimensioning chart.

Flat Face

As the name implies, flanges with flat faces are those that have a flat, level connecting surface (see Figure 4.3). Forged steel flanges with a flat face flange are commonly found in 150# and 300# ratings. Their principal use is to make connections with 125# and 250# cast iron flanges, respectively. Attaching steel pipe to the cast iron flanges found on some valves and mechanical equipment always presents a problem because of the brittle nature of cast iron. Using a flat face flange will assure full surface contact, thereby reducing the possibility of cracking the softer cast iron.

Raised Face

The most common face type in use, the raised face is available in all seven of the aforementioned pound ratings. Appropriately named, this flange face has a prominent raised surface. With shallow grooves etched into the raised surface, this flange face assures a positive grip with the gasket. Flanges rated 150# and 300# have a $^{1}/_{16}''$ raised face, whereas flanges 400# and above have a $^{1}/_{4}''$ raised face (see Figure 4.5). It is important to note that the most dimensioning charts, including the ones provided in this chapter, include the $^{1}/_{16}''$ raised face thickness in the length dimensions for 150# and 300# flanges. However, the $^{1}/_{4}''$ raised face thickness is *not* always included in the length dimensions for 400# and higher pound ratings. To assure accurate dimensioning, always determine if the dimensioning chart being used includes the 1/4″ raised face thickness for the larger pound rating flanges. The 1/4″ raised face thickness *must* be added to the dimensioning chart measurement to obtain the overall flange length if the dimensioning chart indicates it has not been added. Figure 4.6 provides a sectional view of a raised face weld neck flange.

Ring-Type Joint

Also known simply as *ring joint*, the ring-type joint does not use a gasket to form a seal between connecting flanges. Instead a round metallic ring is used that rests in a deep groove cut into the flange face (see Figure 4.7). The donut-shaped ring can be oval or octagonal in design. As the bolts are tightened, the metal ring is compressed, creating a tight seal.

Although it is the most expensive, the ring-type joint is considered to be the most efficient flange used in process piping systems. The ring and groove design actually uses internal pressures to enhance the sealing capacity of the connecting flanges. The superiority of this seal can have its disadvantages, however. When dismantling ring joint connections, the flanges must be forcibly separated to release the ring from the groove. In crowded installations, this could cause major problems. Because of this, the ring joint flange is relegated to applications where space for maintenance and replacement are adequate.

Although available for all pound ratings, flanges with ring-type joint faces are normally used in piping

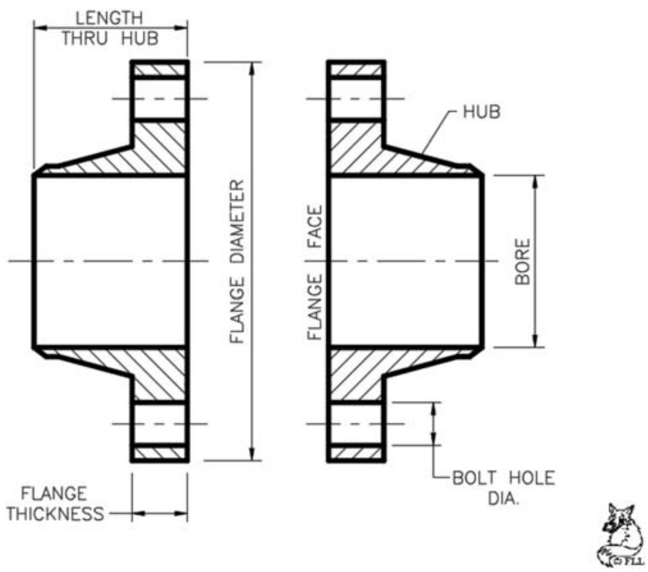


FIGURE 4.4 Sectional view of flat face flange.

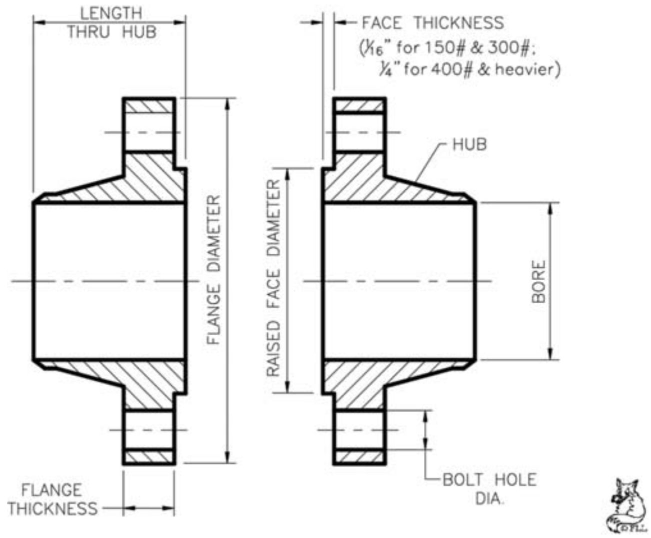


FIGURE 4.6 Sectional view of raised face welding neck flange.

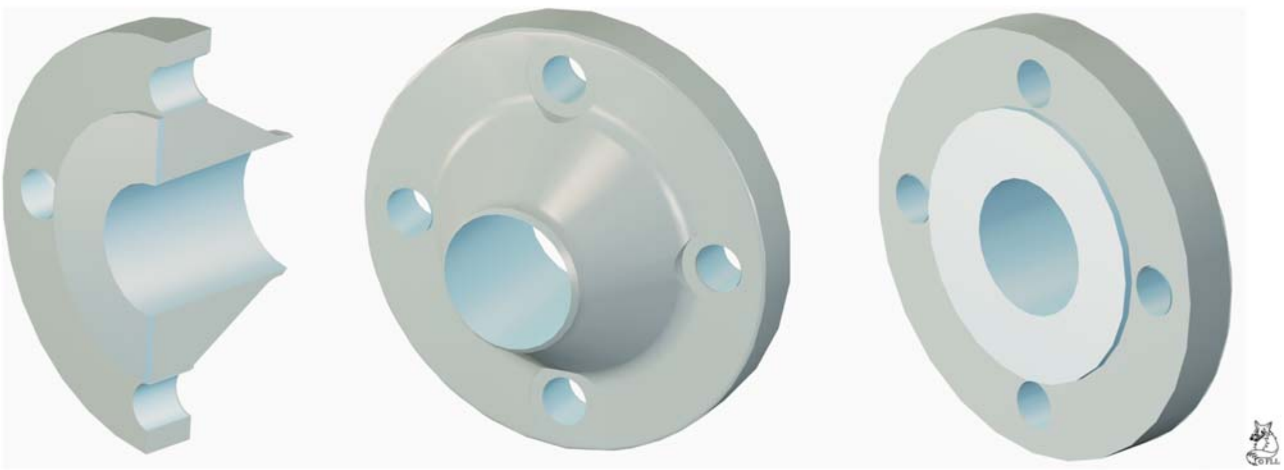


FIGURE 4.5 Raised face flange.

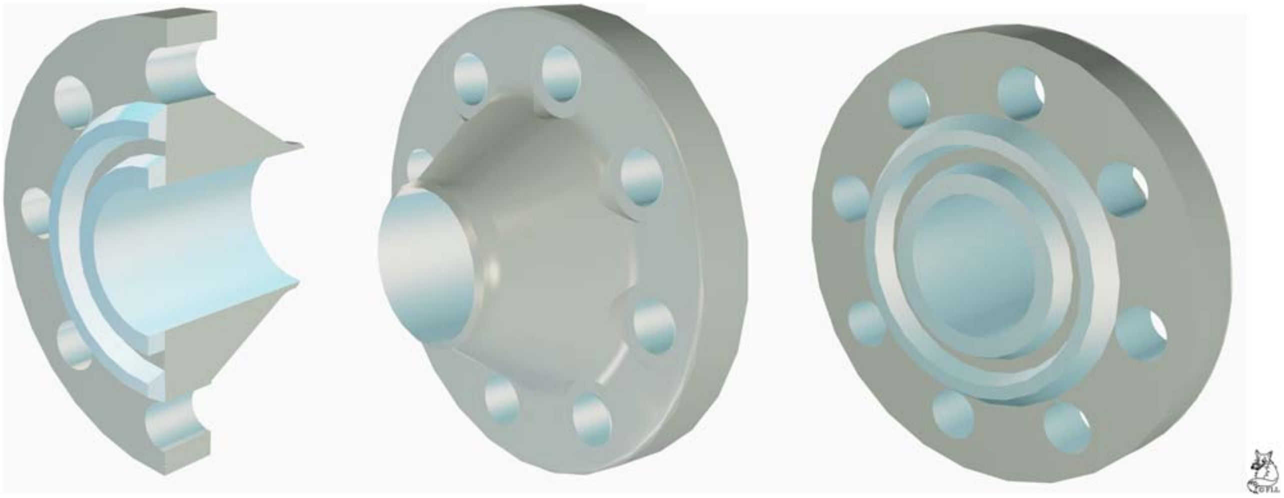


FIGURE 4.7 Ring-type joint flange.

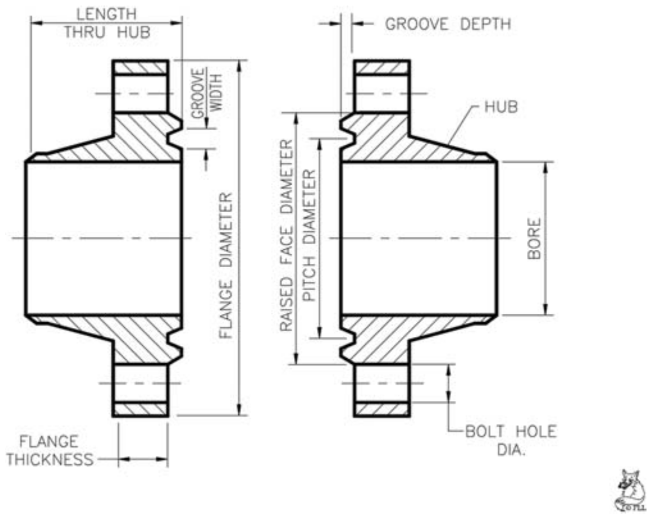


FIGURE 4.8 Sectional view of ring-type joint welding neck flange.

systems rated 400# and higher. See Figure 4.8 for the sectional view of a flange with a ring-type joint face.

FLANGE TYPES

Flanges have been designed and developed to be used in a myriad of applications. Each one has its own special characteristics and should be carefully selected to meet specific function requirements. The following flanges will be discussed in this chapter:

- weld neck,
- threaded,
- socket-weld,
- slip-on,
- lap-joint,

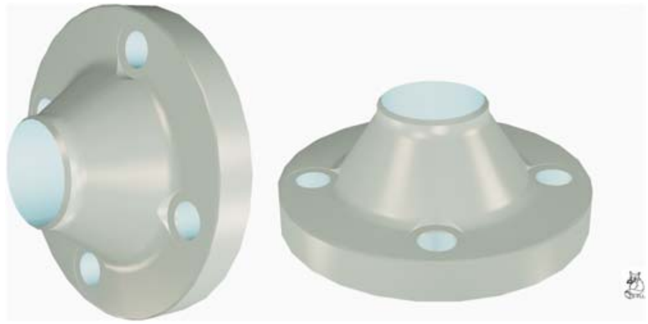


FIGURE 4.9 Weld neck flange.

- reducing,
- blind, and
- orifice.

NOTE*: A photograph and short description accompanies each flange, as well as symbols to depict the flange as it would appear on a drawing. Because all flange symbols are somewhat typical, only the step-by-step drawing techniques used to create the orthographic drawing symbols for a weld neck flange will be shown. The drawing symbols for the remaining flanges can be created in a similar fashion with only a few minor alterations.*

Weld Neck Flange

The *weld neck flange* shown in Figure 4.9 is occasionally referred to as the "high-hub" flange. It is designed to reduce high-stress concentrations at the base of the flange by transferring stress to the adjoining pipe. Although expensive, the weld neck flange is the best-designed butt weld flange available because of its inherent structural value and ease of assembly.

Known for its strength and resistance to dishing, the weld neck flange is manufactured with a long tapered

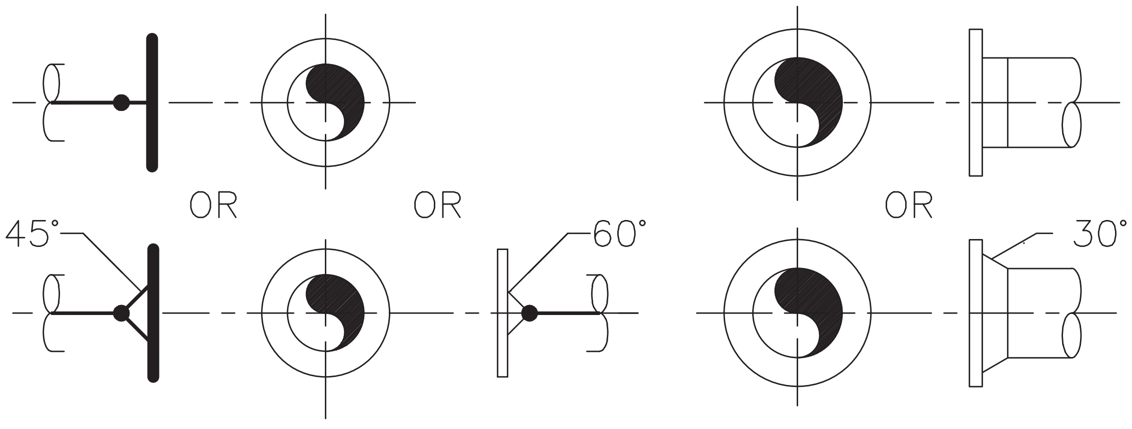
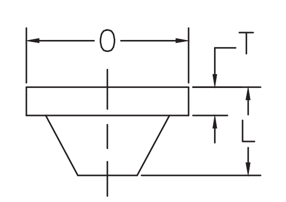


FIGURE 4.10 Weld neck flange drawing symbols.



NOMINAL PIPE SIZES –(INCHES)		2”	2½”	3”	4”	6”	8”	10”	12”	14”	16”	18”
PIPE (OUTSIDE DIAMETER)		2 3/8	2 7/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
RFWN FLANGES	O	6 1/2	7 1/2	8 1/4	10	12 1/2	15	17 1/2	20 1/2	23	25 1/2	28
	L	2 3/4	3	3 1/8	3 3/8	3 7/8	4 3/8	4 5/8	5 1/8	5 5/8	5 3/4	6 1/4
	T	7/8	1	1 1/8	1 1/4	1 7/16	1 5/8	1 7/8	2	2 1/8	2 1/4	2 3/8
	1/16” RAISED FACE INCLUDED ON ’L’ & ’T’ DIMENSIONS											

FIGURE 4.11 Welded Fittings-Flanges dimensioning chart.

hub. The tapered hub is created by the gradual increase in metal thickness from the weld joint to the flange facing. The symmetrical taper transition is extremely beneficial under conditions of repeated bending caused by line expansion, contraction, or other external forces. See Figure 4.10, for weld neck flange drawing symbols.

Weld neck flanges are normally used in severe service applications involving high pressures, high temperatures, or subzero conditions.

The hole in a weld neck flange is bored to match the ID of the adjoining pipe. In other words the thinner the wall thickness of the pipe, the larger the bore (hole) through the flange. Conversely, the thicker the wall thickness of the pipe, the smaller the bore through the flange. Because the pipe and the flange have matching inside diameters, there is little restriction to the flow. Turbulence and erosion are therefore eliminated.

Drawing the Weld Neck Flange

Prior to constructing the orthographic drawing symbols, three important dimensions must be determined. These dimensions can be found on the Welded Fittings-Flanges dimensioning chart, shown partially in Figure 4.11. The thumbnail image in this chart represents the raised face weld neck (RFWN) flange and the position of its three dimensions in the chart.

The three dimensions needed to draw the flange are ***O***, ***T***, and ***L***. ***Note: Other flange dimensioning charts will use different letters to identify the various features of the flange. Carefully, note the difference before using each dimensioning chart*. The ***O*** dimension represents the flange's outside diameter. The ***T*** defines the flange's face thickness, and the ***L*** provides the flange's length or *length-thru-hub* dimension (some charts may show this as the ***Y*** dimension). These three dimensions vary for each pipe size and pound rating and must be determined prior to constructing the drawing symbols of each flange.

To find the numerical values for these dimensions of a particular flange, select the appropriate pound rating chart, which is, *150#*, *300#*, 400#, and so on. Next, find the proper size pipe in the *Nominal Pipe Size* row. Follow the *pipe size* column down, through the chart, to determine the ***O***, ***T***, and ***L*** dimensions. For demonstration purposes, the procedures to draw double-line

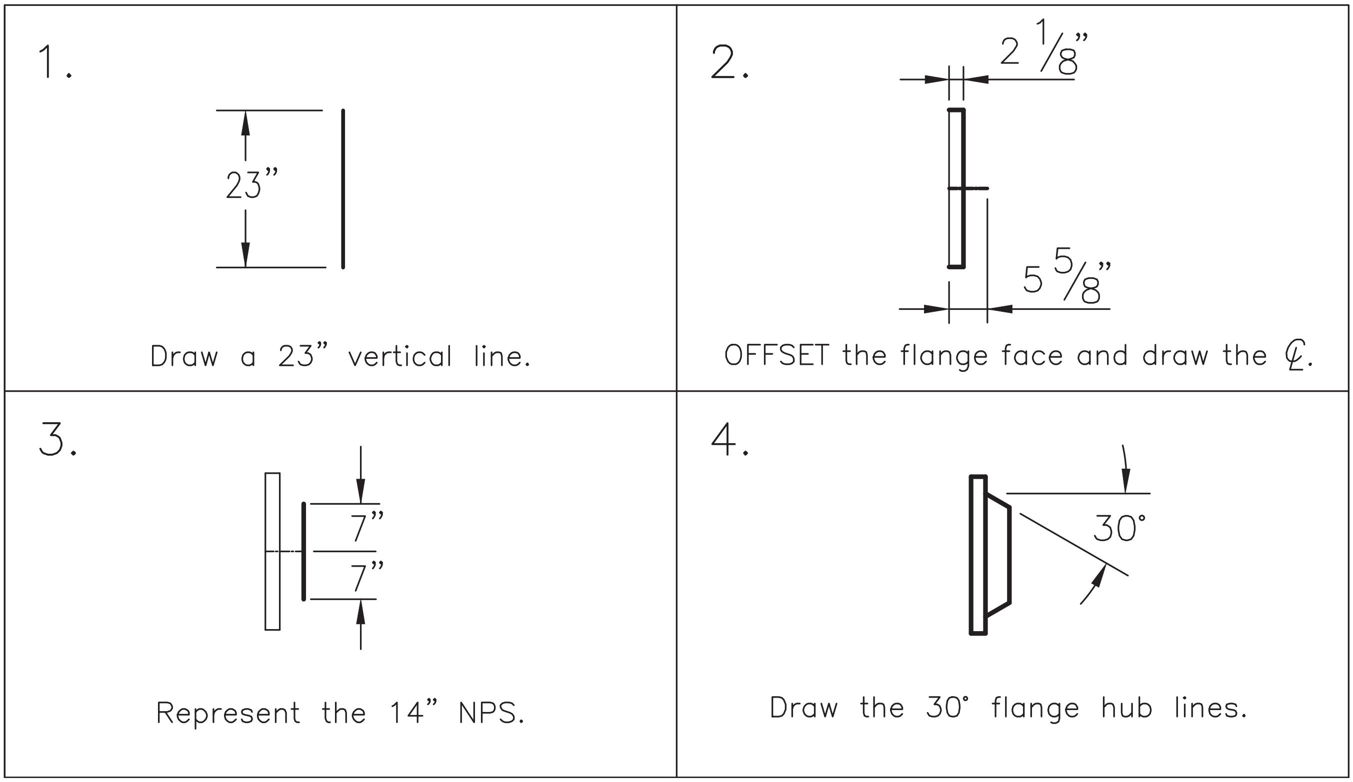


FIGURE 4.12 Drawing procedures for a 14″-300# RFWN flange.

Step 1. Using Architectural units, draw a vertical line 23″ tall. This line will represent the flange's face diameter.
Step 2. **OFFSET** a line 2[1]/8″ to the right to represent the flange face thickness. Draw a horizontal line across the ends of the two vertical lines to cap the flange face. From the MIDpoint of the flange's face (left line) draw a centerline 5[5]/8″ to the right to represent the flange length (length thru hub).
Step 3. From the right end if the centerline draw vertical a line 7″ upward and downward to represent the pipe's 14″ NPS.
Step 4. From the vertical ends draw 30° lines to the flange face to represent the hub. (45° lines are used when constructing single-line symbols.)

drawing symbols for a *14″-300# raised face, weld neck* (*RFWN*) flange and a single-line 12″-150# RFWN flange will be presented. You should find the ***O***, ***T***, and ***L*** measurements for these flanges to be 23″ (O), 2 1/8″ (T), and 5 5/8″ (L) and 19″ (O), 1 1/4″ (T), and 4 1/2″ (L), respectively.

Use Figure 4.12 and the step-by-step procedures that follow to construct the drawing symbols for a 14″-300# raised face, weld neck flange Figure 4.13 depicts the step-by-step procedures to construct the drawing symbols for a 12″–150# raised face, weld neck flange.

Slip-on Flange

The *slip-on flange* shown in Figure 4.14 has a low hub that allows the pipe to be inserted into the flange prior to welding. Available with a flat (FFSO) or raised face (RFSO) and shorter in length than a weld neck flange, the slip-on flange is used in areas where short tie-ins are necessary or space limitations necessitate its use and in replacement operations when connecting preexisting equipment. The slip-on flange does have two significant disadvantages; however, the requirement of two fillet welds, one internal and one external, to provide sufficient strength and prevent leakage, and a life span about one-third that of the weld neck flange. They are preferred over welding neck flanges by many users because of their lower initial cost. However, the total cost after installation is not much less than the welding neck because of the additional welding involved. See the Taylor Forge Seamless Fittings Dimensioning Chart in Appendix A for dimensions of the slip-on flange. The drawing symbols for the slip-on flange are shown in Figure 4.15.

Lap-joint Flange

The *lap-joint flange* in Figure 4.16 is primarily used on carbon or low alloy steel piping systems. Attachment of the lap-joint flange to the piping system requires a lap-joint stub end. The lap-joint flange and stub-end assembly are used mainly in piping systems that necessitate frequent dismantling for inspection or routine maintenance. It is also used in the erection of large diameter or hard-to-adjust piping configurations

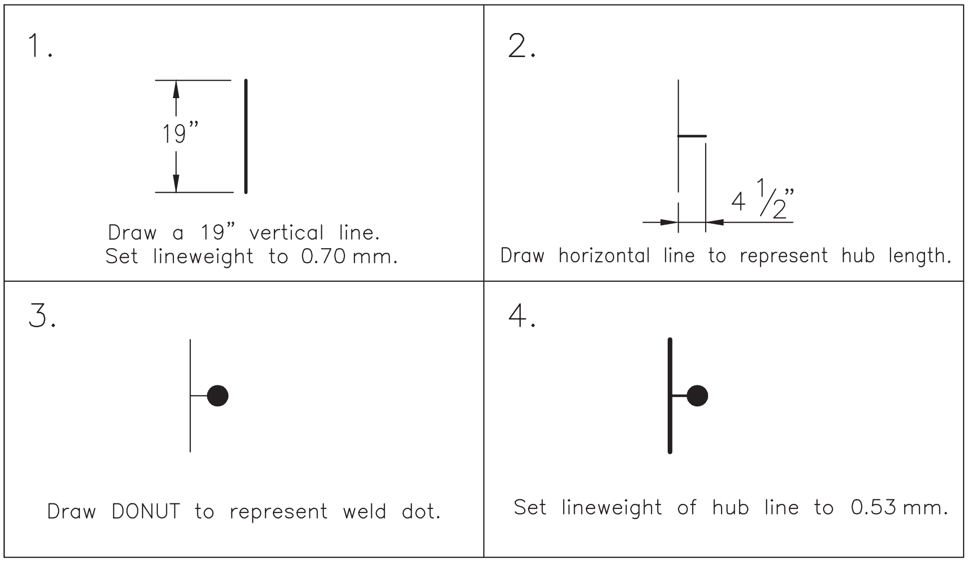


FIGURE 4.13 Drawing procedures for a 12″-150# RFWN flange.

Step 1. Using Architectural units, draw a vertical line 19″ tall. Give the line a 0.70 mm lineweight. This line will represent the flange's face diameter.
Step 2. From the MIDpoint of the flange's face draw a horizontal line 4½″ to the right to represent the flange's length (length thru hub).
Step 3. On the right end of the horizontal line draw a DONUT having a 0.0″ inside diameter and a 1.75″ outside diameter to represent the weld dot.
Step 4. Change the lineweight of the horizontal line (hub) to 0.53 mm. This will match the lineweight of the pipe when the symbol is attached to it.

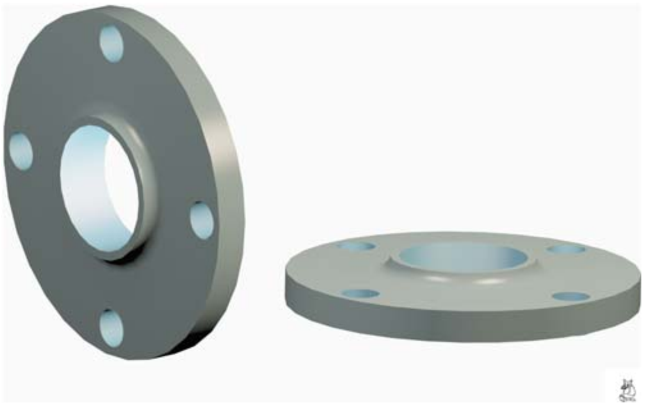


FIGURE 4.14 Slip-on flange.

because of its quick bolt hole alignment. Figure 4.17 depicts the drawing symbols for the lap-joint flange.

Threaded Flange

The *threaded flange* depicted in Figure 4.18 similar to the slip-on flange, but the bore is threaded. Its principal value is that it can be assembled without welding. This feature makes the threaded flange well-suited to extreme pressure services that operate at normal atmospheric temperatures and in highly explosive areas where welding may create a hazard.

Threaded flanges are not suited, however, for conditions involving temperatures or bending stresses of any significance, particularly when cyclic conditions exist, which may cause leakage through the threads. After just a relatively few cycles of expansion and contraction or movement caused by stress, the threaded flange no longer performs adequately.

A *seal weld* is sometimes applied around the threaded joint to reduce the possibility of leakage. This technique, however, cannot be considered as entirely satisfactory nor is it always possible. Figure 4.19 represents the single-line threaded flange drawing symbol.

Socket-Weld Flange

The *socket-weld flange* shown in Figure 4.20 is also similar to the slip-on flange. It was originally developed for use on small diameter (½″ through 4″) high-pressure piping systems. Like socket-weld fittings, pipe is inserted into the socket then welded. An internal weld is often employed for added strength. By grinding the internal weld smooth, turbulence and flow restriction are kept to a minimum. The single-line drawing symbol for the socket-weld flange is shown in Figure 4.21.

Reducing Flange

Like the reducer fitting, the *reducing flange* in Figure 4.22 is used to make a reduction in the diameter of the pipe. A reducing flange is most frequently used

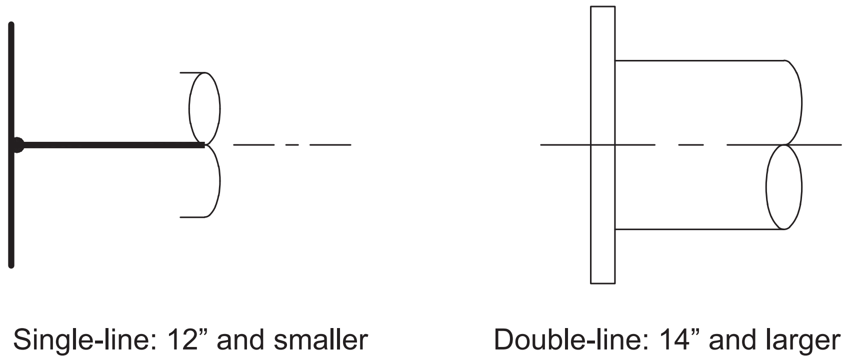


FIGURE 4.15 Slip-on flange drawing symbols.

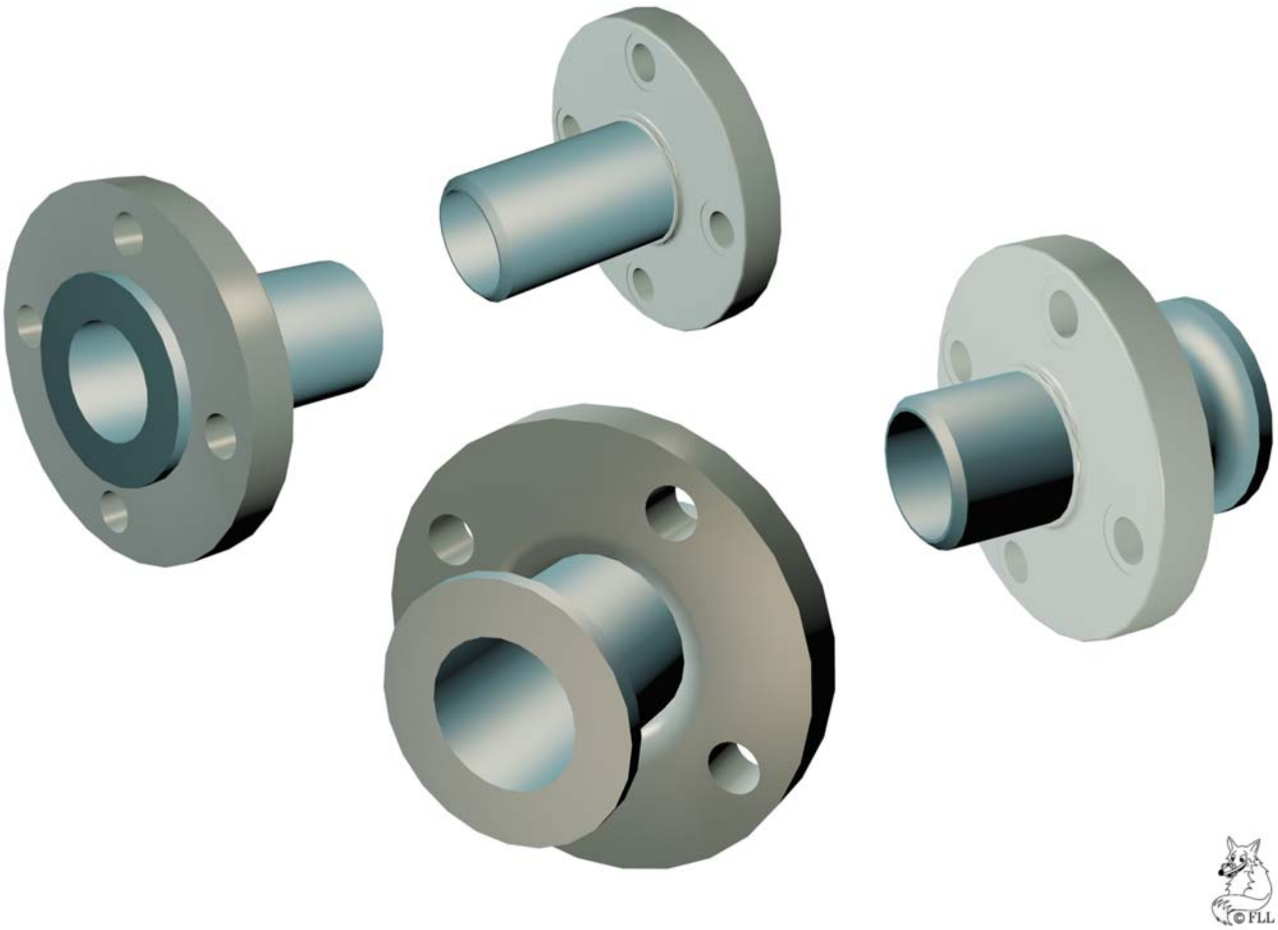


FIGURE 4.16 Lap-joint flange.

in installations with limited space. Crowded situations may necessitate the use of the reducing flange because it has a shorter overall length when compared to a weld neck flange and reducer-fitting configuration. Be advised however, the flow should travel from the smaller size to the larger. If the flow were reversed, severe turbulence could develop.

Callouts are placed on drawings to describe the reducing flange in the same manner as those used on the reducer fitting: large end first, small end second. One additional note is needed, however. The pound rating and flange type is included in the callout.

The reducing flange maintains all the dimensional characteristics of the larger end size. One exception

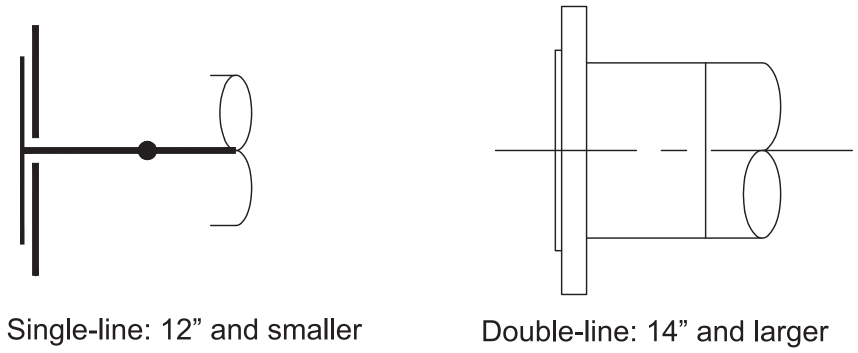


FIGURE 4.17 Lap-joint flange drawing symbols.

FIGURE 4.18 Threaded flange.

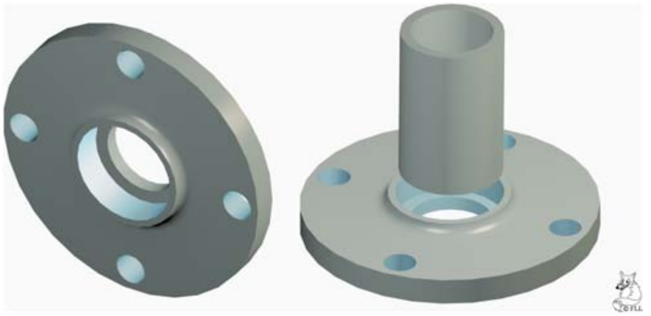


FIGURE 4.20 Socket-weld flange.

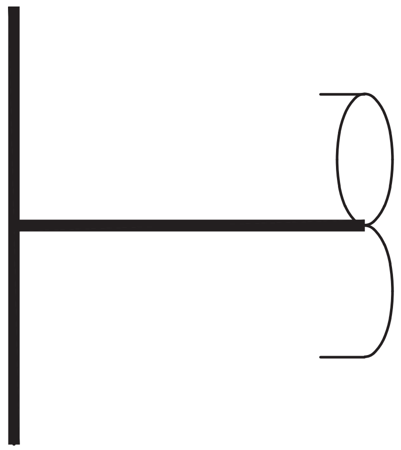


FIGURE 4.19 Single-line threaded flange drawing symbol.

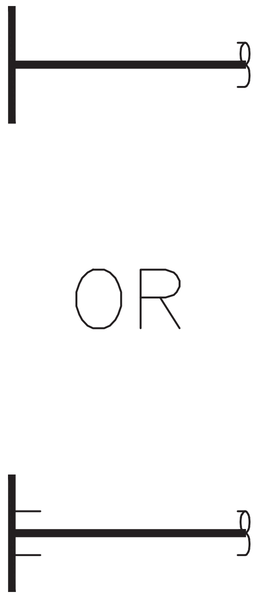


FIGURE 4.21 Socket-weld flange drawing symbols.

however is the internal bore. The internal bore is manufactured to match that of the smaller pipe size. Figure 4.23 shows a 12″ × 10″-300# Raised Face Slip-On flange. Notice the use of abbreviations to keep the size of the callout to a minimum.

Reducing flanges are manufactured as weld neck, slip-on, or threaded flange types.

Blind Flange

The *blind flange* depicted in Figure 4.24 serves a function similar to that of a plug or cap. It is used to terminate the end of a piping system. The blind flange

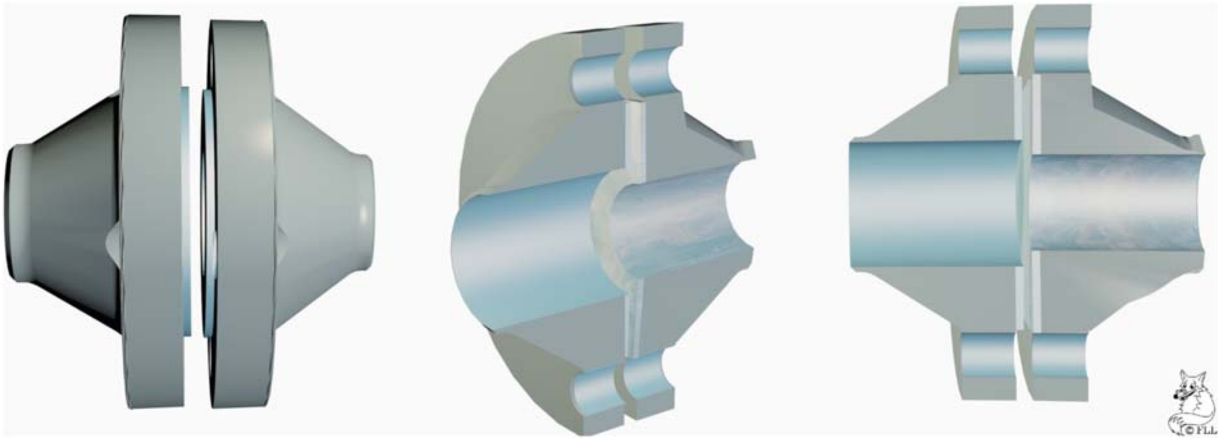


FIGURE 4.22 Reducing flange.

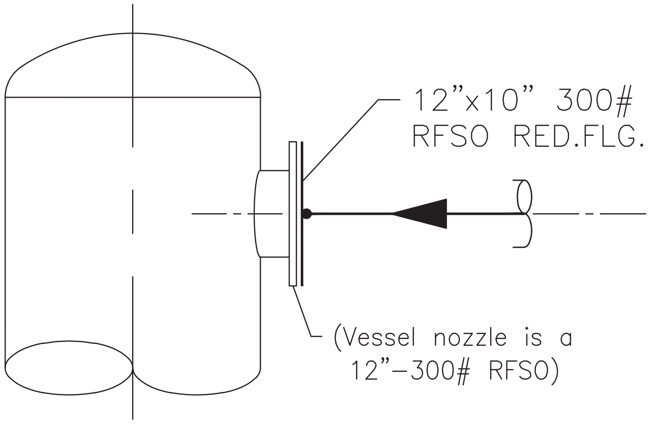


FIGURE 4.23 Reducing flange drawing symbol with callout.

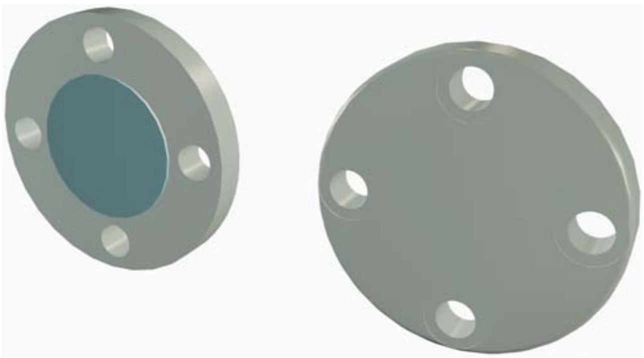


FIGURE 4.24 Blind flange.

is basically a flange that does not have a hub or a bored center. Blind flanges have the face thickness of a flange, a matching face type, and similar bolting pattern. Blind flanges can also be used to seal a nozzle opening on a pressure vessel. Because it is bolted, the blind flange provides easy access to the interior of a vessel or pipe, unlike a cap that is welded. Figure 4.25 represents the drawing symbol for the blind flange.

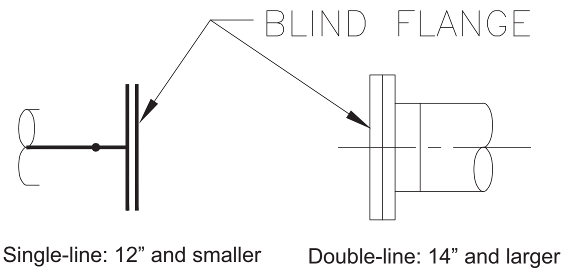


FIGURE 4.25 Blind flange drawing symbols.

Orifice Flange

Of the flanges discussed, the *orifice flange* is the only one that actually performs a function. The function of the orifice flange is to measure the rate of the flow of the commodity through the piping system. Orifice flanges are easy to recognize because they have a hole drilled through the face of the flange perpendicular to the pipe. They also have an additional set of bolts called *jack screws*. These screws are used to help separate the flanges so inspection and/or replacement of the orifice plate can be performed. The orifice flange is a single component of the *orifice flange union* assembly (Figure 4.26). The orifice flange union is composed of two orifice flanges, an orifice plate, bolts, nuts, jack screws, and two gaskets. A representation of an unbolted and separated orifice flange union assembly is depicted in Figure 4.27.

The orifice flange union is used to measure, or meter, the amount of pressure drop through the orifice plate. The length of pipe within the piping system where orifice flanges are installed and where these measurements are recorded is known as a *meter run*. Figure 4.28 shows the orifice flange union assembly

FIGURE 4.26 Orifice flange.

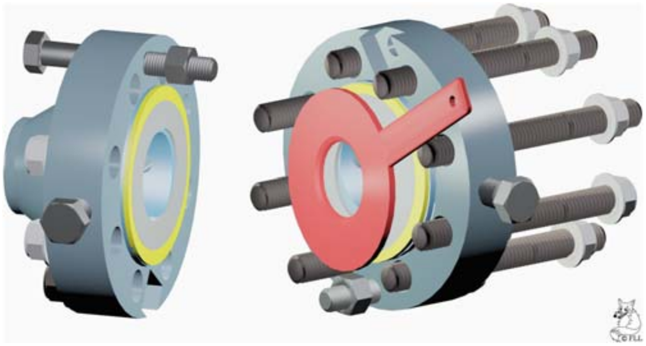


FIGURE 4.27 Unbolted orifice flange union assembly.

installed in a meter run. The broken-out section shown in Figure 4.29 shows the internal view of a meter run.

The orifice plate, which is not typically furnished with the orifice union assembly package, looks similar to a large ring washer with a handle attached. When fully assembled, the orifice plate is sandwiched between the orifice flanges. Valve taps are inserted into pressure holes that allow for the attachment of field monitoring equipment so accurate measurements can be recorded.

Orifice flanges can be either weld neck, slip-on, or threaded. The weld neck and threaded orifice flanges are manufactured in 300# and larger pound ratings. However, the slip-on orifice flange is only available as a 300# raised face flange. The single-line and double-line drawing symbols for the orifice flange are shown in Figure 4.30.

BOLTS

To complete any flanged assembly, two additional items are required: bolts and gaskets. Bolts obviously hold mating flanges, nozzles, or valves together. The pressure rating of a flange will

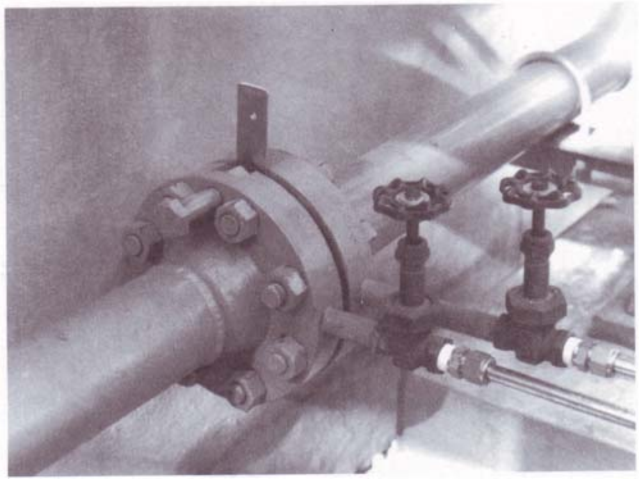


FIGURE 4.28 Orifice flange union assembly. *Courtesy of Nisseki Chemical Texas Inc., Bayport, Texas.*

determine the size, spacing, and number of bolts required. As the nominal pipe size and pressure ratings change so will the diameter, spacing, and number of bolts.

Flanges are designed to match the bolt circle and bolt hole dimensions of other flanges that are of the same diameter and pressure rating. Bolt hole arrangements may seem inconsequential; but, when one considers the fact that components of a piping system may be fabricated in one country then shipped to another country for assembly, bolt alignments become increasingly important. It is critical that drawings convey the exact orientation of flanges to the fabricator. Otherwise, bolt holes may not align properly. ANSI standards require all flanges straddle the horizontal, vertical, or north-south centerlines of pipe and equipment, as shown in Figure 4.31, unless otherwise noted on a drawing.

To assure that bolt holes on flanges, nozzles, or valves align properly, holes are equally spaced around the flange. One column on the Taylor Forge Forged Steel Flanges Dimensioning Chart found in Appendix A indicates the number and diameter of the bolt holes on flanges. Notice bolts are found in quantities of four, that is, 4, 8, 12, 16, etc. The following formula makes bolt hole location and alignment quick and simple.

Formula: $360^\circ/\#\text{of holes} = \text{angular location}$
Example: $360\ /8(\text{holes}) = 45^\circ$

Using this formula shows holes on an eight-hole flange to be spaced 45° apart. By straddling the centerline, holes will be positioned $22^1/_2{}^\circ$ on each side of the centerline (see Figure 4.32).

Bolts are available in two types, *machine* or *stud*. Machine bolts have a "head" on one end and threads

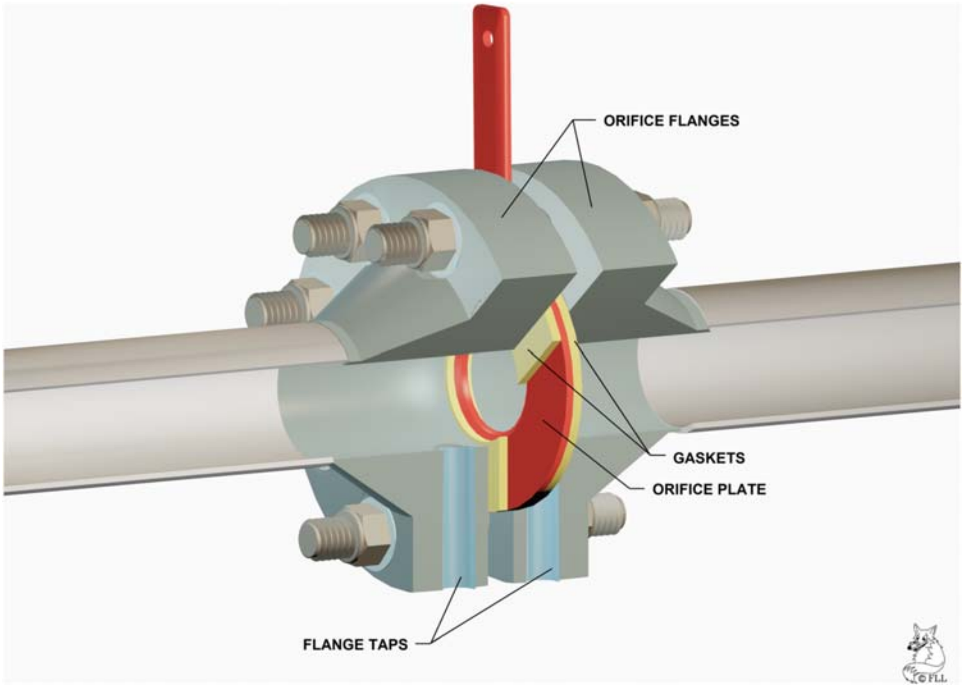


FIGURE 4.29 Broken-out section of meter run.

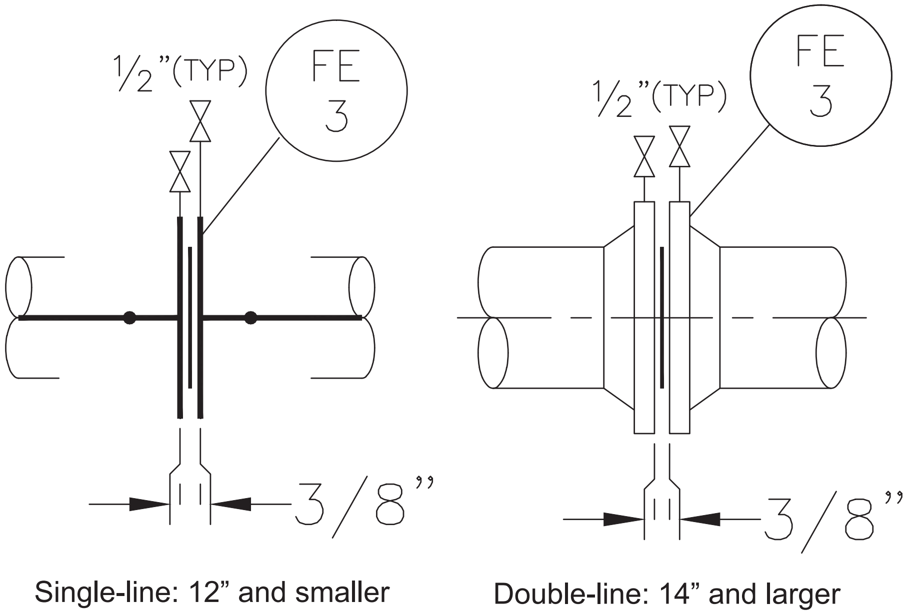


FIGURE 4.30 Orifice flange drawing symbols.

on the other. Stud bolts have threads throughout their entire length and require the use of two nuts (see Figure 4.33). Stud bolts are the most commonly used type and are available in two grades, A-193-B7 and A-193-B16. B7 grade bolts are used for temperatures to 1,000°F. B16 bolts are used when temperatures exceed 1,000°F. Figure 4.34 depicts a sectional view of two flanges being mated around a gasket and secured with stud (upper) and machine (lower) bolts.

GASKETS

The primary purpose of any flanged assembly is to connect piping systems in such a manner as to produce

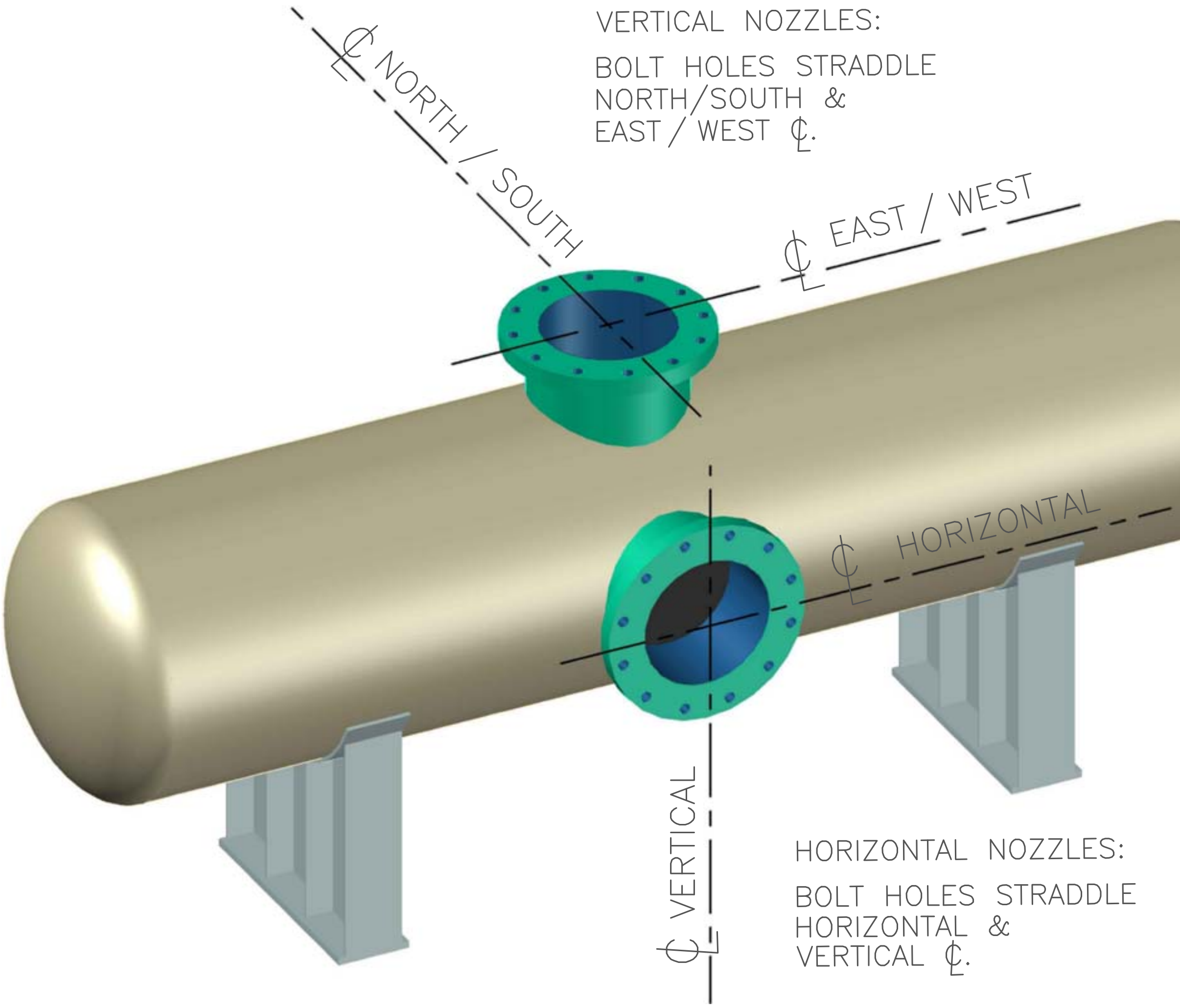


FIGURE 4.31 Bolt hole orientation.

a leak-free environment. Hazardous and combustible materials and extreme pressures and temperatures require the utmost in safety precaution. Creating a leak-proof seal between two connecting metal surfaces in an industrial setting is almost impossible. Therefore gaskets perform a vital function in plant safety.

Using a gasket material softer than two adjoining flanges is an excellent way to eliminate the possibility of a fluid escape. Gaskets can be made of materials such as asbestos, rubber, neoprene, Teflon, lead, or copper. When bolts are tightened, and flange faces are drawn together, the gasket material will conform to any imperfections in the flange faces to create a uniform seal.

Figure 4.35 depicts the three types of gaskets that can be found in piping systems. They are full face, flat ring, and metal ring. Full face gaskets (Figure 4.36) are used on flat face flanges. Flat ring gaskets (Figure 4.37) are used on raised face flanges. Metal rings (Figure 4.38) are used on ring-type joint flanges.

A gasket's thickness must be accounted for when dimensioning the piping system. The typical gasket has a thickness of 1/8″ (3.175 mm). At every occurrence of a flange bolting to a nozzle, two flanges joining one another, two valves joining one another, or a flange connecting to a valve, a gasket thickness must be added to the length of the pipe components. Figures 4.39 and 4.40 show that a flat ring gasket does occupy space. Although it is only 1/8″ thick, a gasket cannot be ignored.

Figure 4.41 shows an open set of ring-type flanges and the oval ring that separates them seated in the groove of the left flange. The ring-type flange section of the Welded Fittings-Flanges Dimensioning Chart identifies the gap measurement between two bolted ring-type flanges as the **G** dimension. This dimension will vary depending on the size and pound rating of the flange. Figure 4.42 depicts the gap between ring-type joint flanges after they are bolted together. This is an important consideration to keep in mind when

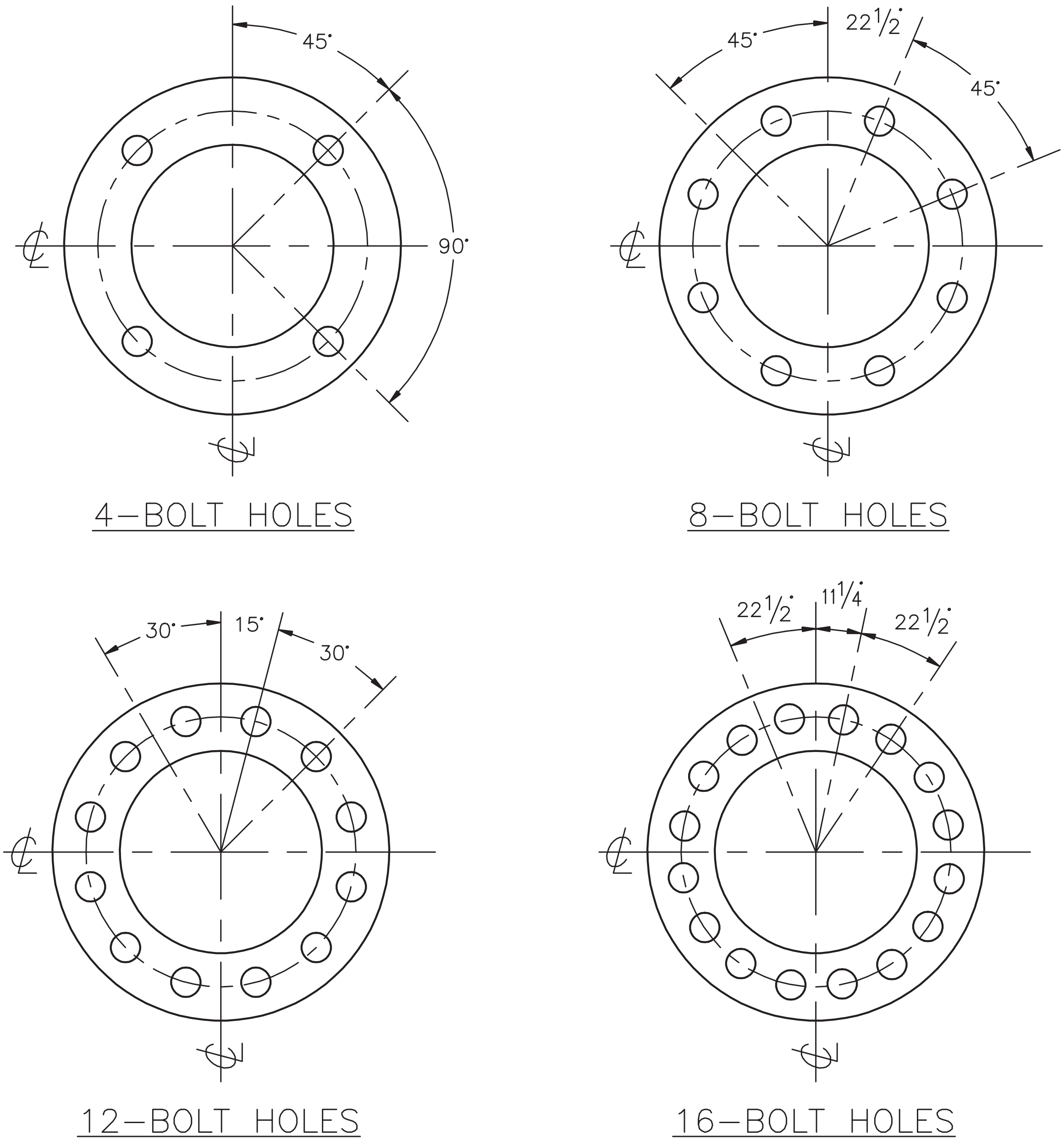


FIGURE 4.32 Bolt hole spacing.

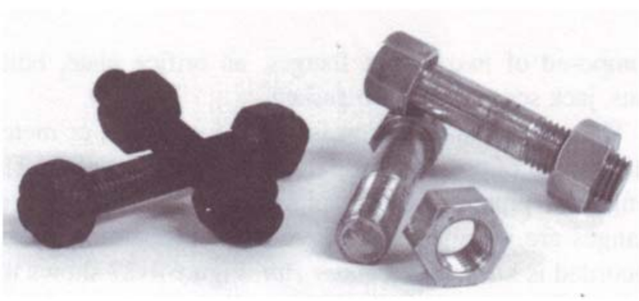


FIGURE 4.33 Stud and machine bolts.

dimensioning piping runs that have ring-type joint connections.

For each instance of a gasket or ring, gap spacing must be reflected in the dimensions shown on a piping drawing. *Tick* marks are used to indicate each location where a gasket or ring gap has been included in the dimensioning of the piping configuration. Tick marks are drawn approximately 1/8″ long and are placed on piping drawings near the location where a gasket or ring is to be installed. Figure 4.43 depicts two tick marks, one on each end of a

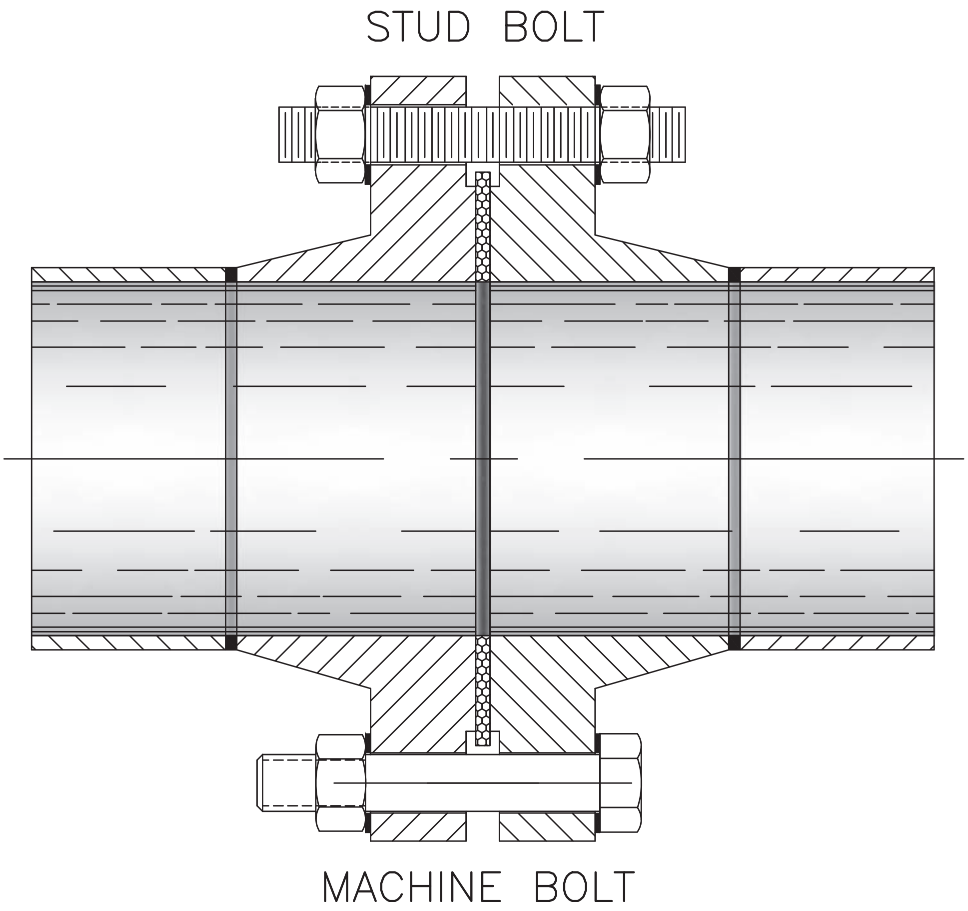


FIGURE 4.34 Drawing representation of stud and machine bolts.

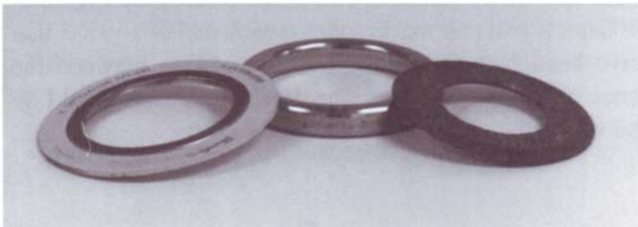


FIGURE 4.35 Gaskets. *Courtesy of Flexitallic, Inc.*

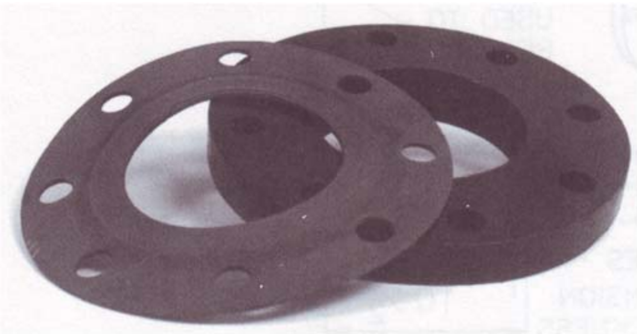


FIGURE 4.36 Full face gaskets.

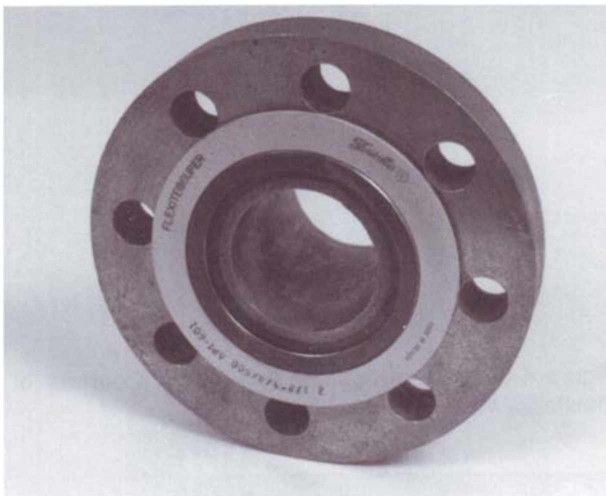


FIGURE 4.37 Flat ring gaskets. *Courtesy of Flexitallic, Inc.*

valve, that have been included in the total dimension between the faces of the two flanges. The dimension would be the sum total of one valve and two gaskets.

FIGURE 4.38 Metal rings for ring-type joint flanges. *Courtesy of Flexitallic, Inc.*

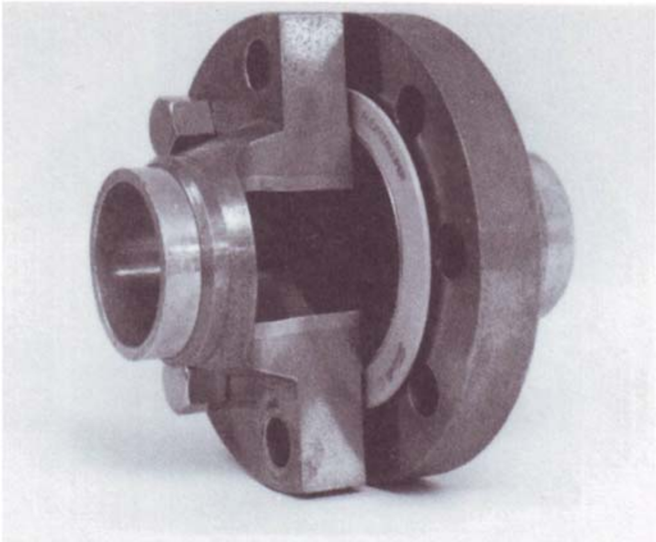


FIGURE 4.39 Flat ring gasket and flange. *Courtesy of Flexitallic, Inc.*

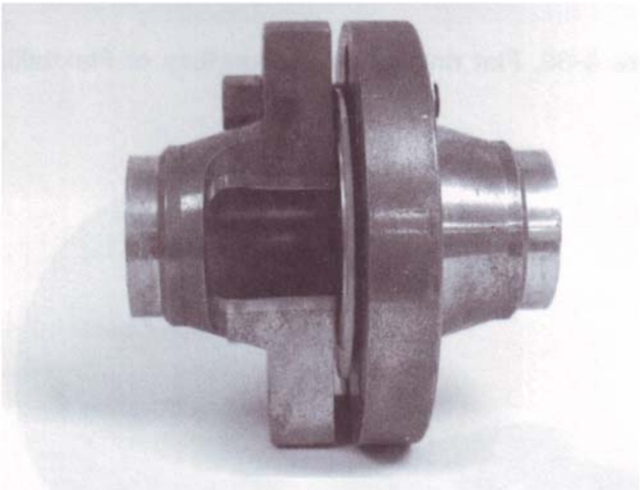


FIGURE 4.40 Flat ring gasket between flanges. *Courtesy of Flexitallic, Inc.*

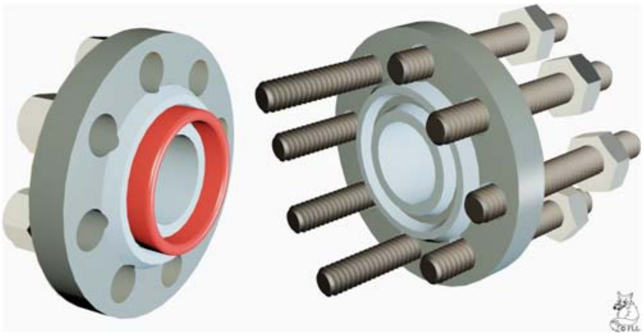


FIGURE 4.41 Ring-type flanges and oval ring.

CHAPTER 4 REVIEW QUIZ

1. Name the seven forged steel flange pound ratings.

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2. Name the four pressure classes for cast iron flanges.

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____

3. What are the three flange face types discussed in this chapter?

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____

4. What is the thickness of the raised face on a 600# raised-face flange?

____

5. Briefly describe five types of flanges depicted in this chapter.

____

____

____

____

____

6. Give O, T, and L dimensions of the following flanges.

SIZE/RATING	O	T	L
4″—150# R.F.W.N.	________	________	________
6″—300# R.F.W.N.	________	________	________
10″—400# R.F.W.N.	________	________	________
16″—600# R.F.W.N.	________	________	________
8″—600# R.F.W.N.	________	________	________

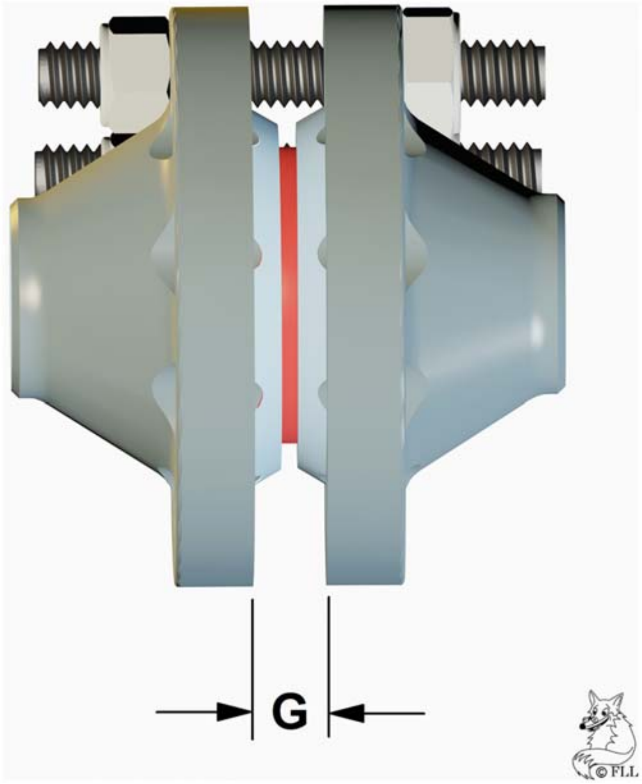

FIGURE 4.42 Ring-type joint gap spacing.

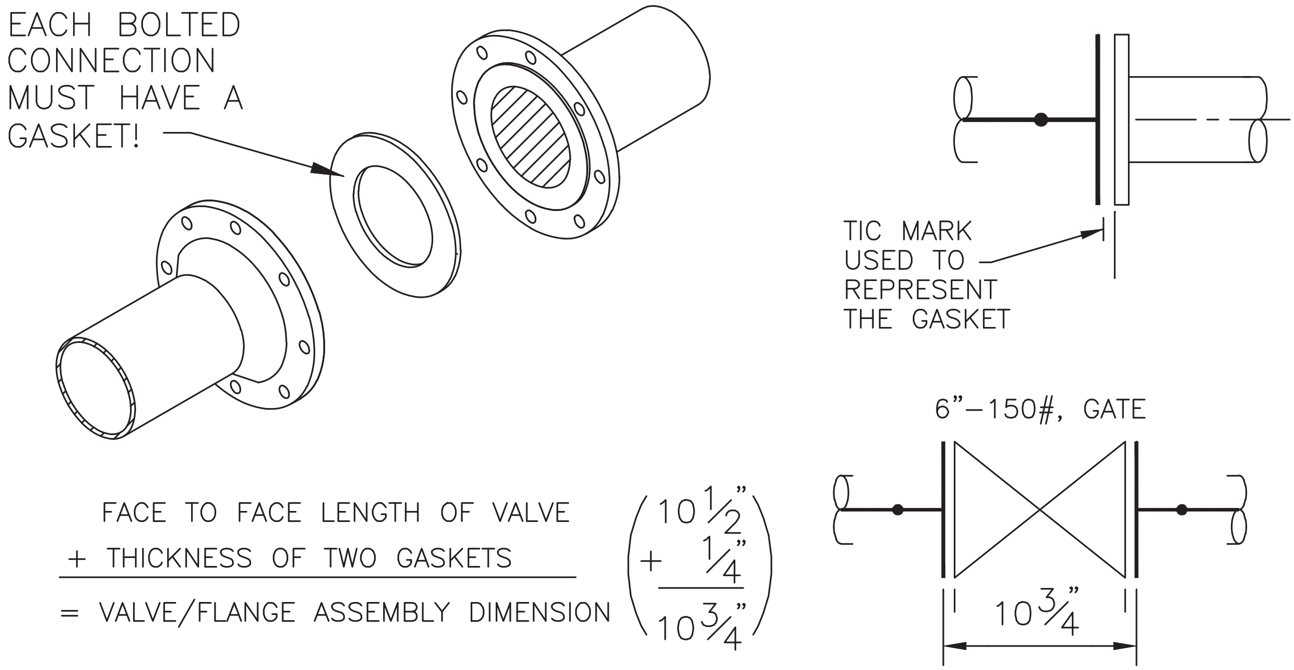

FIGURE 4.43 Gasket thickness.

7. What is the purpose of an orifice flange union assembly?

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____
____
____
____

8. Name the two types of bolts used to assemble flanges.

____
____

9. According to ANSI standards, which centerlines should flanges straddle on pipe and equipment?

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____
____
____
____

10. List four materials used to manufacture gaskets.

____
____
____
____

EXERCISE INFORMATION

The flanges depicted in Figure 4.44 will be used to complete the exercises in this chapter along with Chapter 5, Valves, and Chapter 10, Piping Arrangement Drawings, Sections, and Elevations. To complete the exercises draw, the symbols shown using the following guidelines.

- Draw all flange symbols full size using dimensions found on the Welded Fittings-Flanges dimensioning charts.
- Items in Figure 4.44 that are represented with a "Phantom" linetype are for reference only and are not to be drawn. They will *not* be part of the finished symbol.
- Double-line symbols are drawn with a "default" lineweight. Single-line symbols are drawn with a 0.53 mm lineweight.
- Draw all weld dots with the **DONUT** command having a 0″ inside diameter and a 1.75″ outside diameter.
- Create a **BLOCK** of each symbol. Use a block name that appropriately describes the flange and its size and pound rating. (*DO NOT include text with the blocked symbol*).
- **BLOCK** the symbol with the base point placed at an appropriate location using an ENDpoint, MIDpoint, or CENter osnap.

SAVE the file as *Flange Symbols.dwg*.

CHAPTER 4 DRAWING EXERCISES

Drawing Flanges

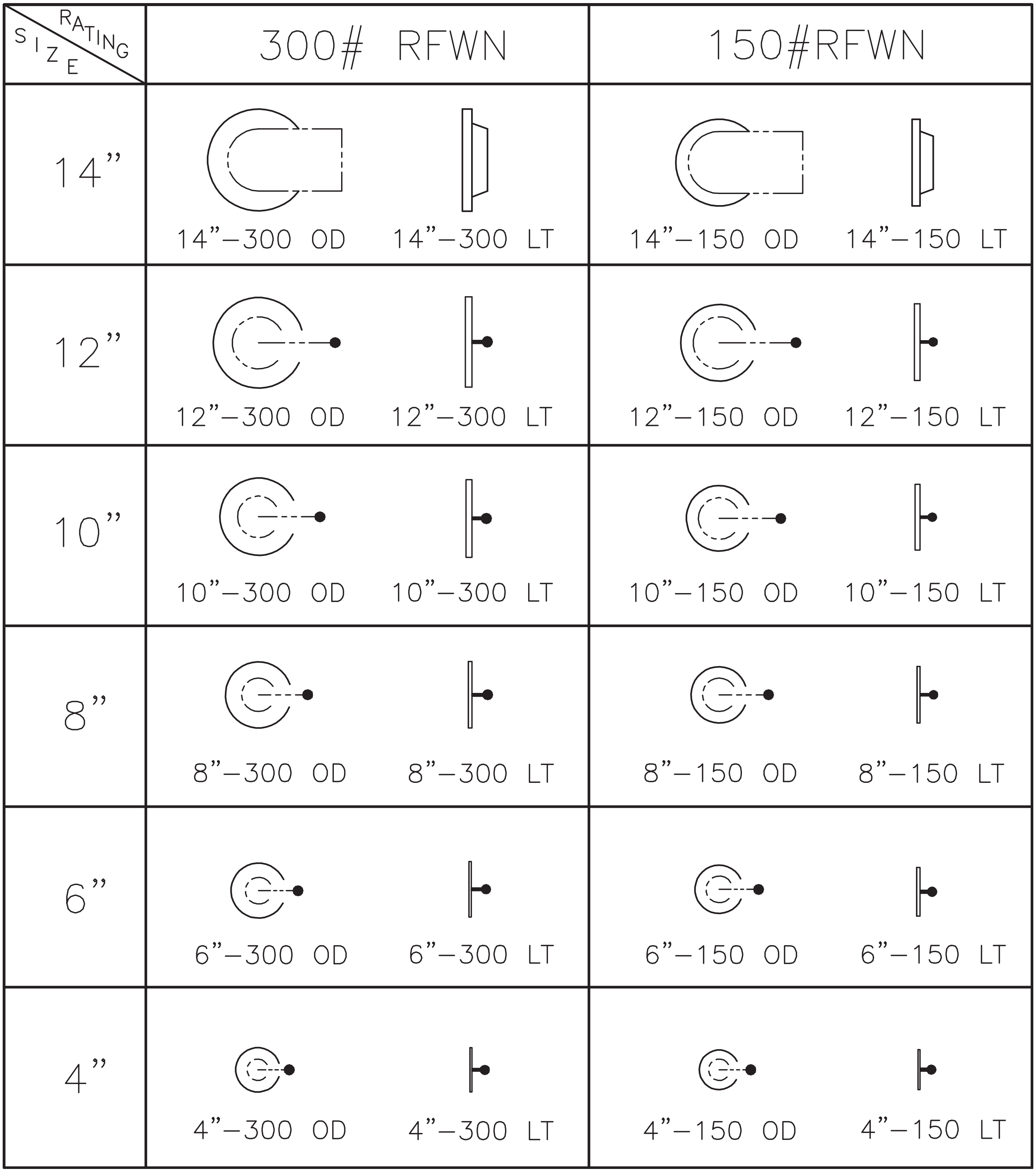
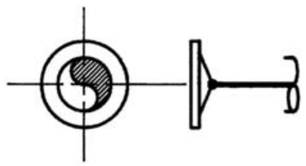
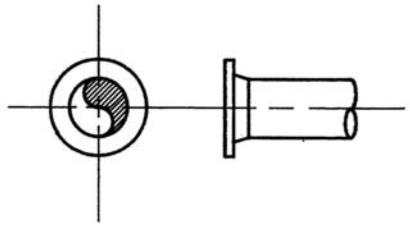


FIGURE 4.44 Flange drawing symbols.

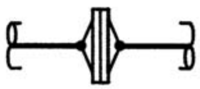
(1) DRAW ALL VIEWS AS SHOWN
12"–300# RFWN



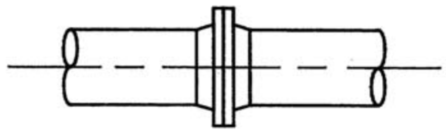
(2) DRAW ALL VIEWS AS SHOWN
14"–300# RFWN



(3) DRAW ALL VIEWS AS SHOWN
10"–300# RFWN



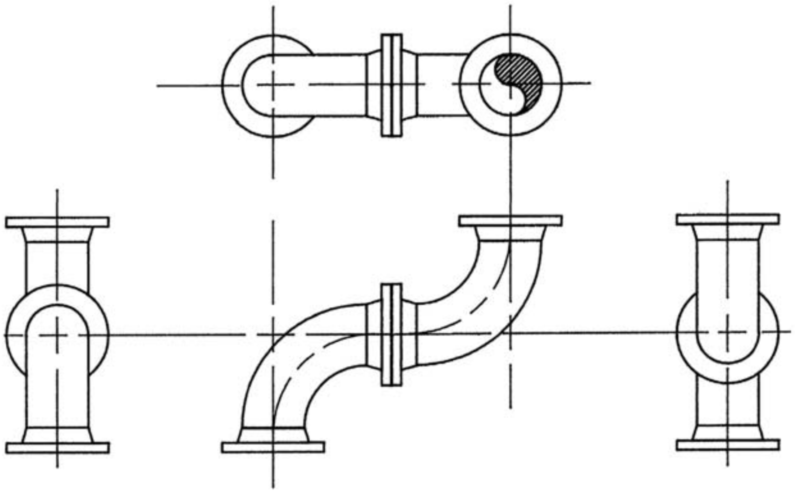
(4) DRAW ALL VIEWS AS SHOWN
18"–300# RFWN



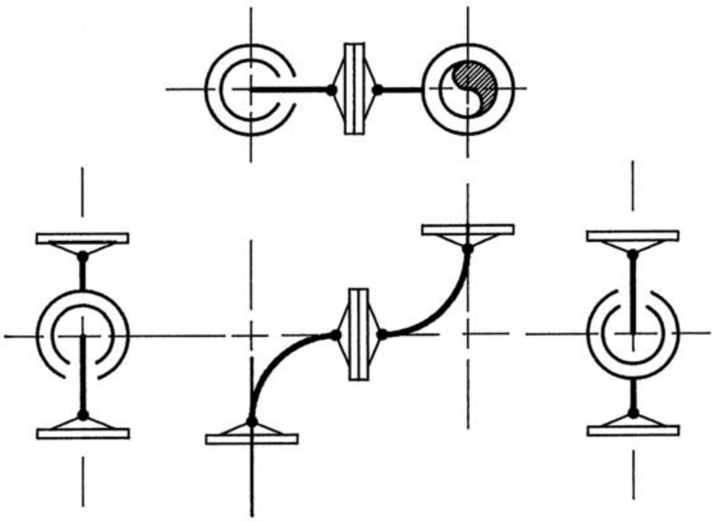
EXERCISE 4–1

FITTING MAKE-UP

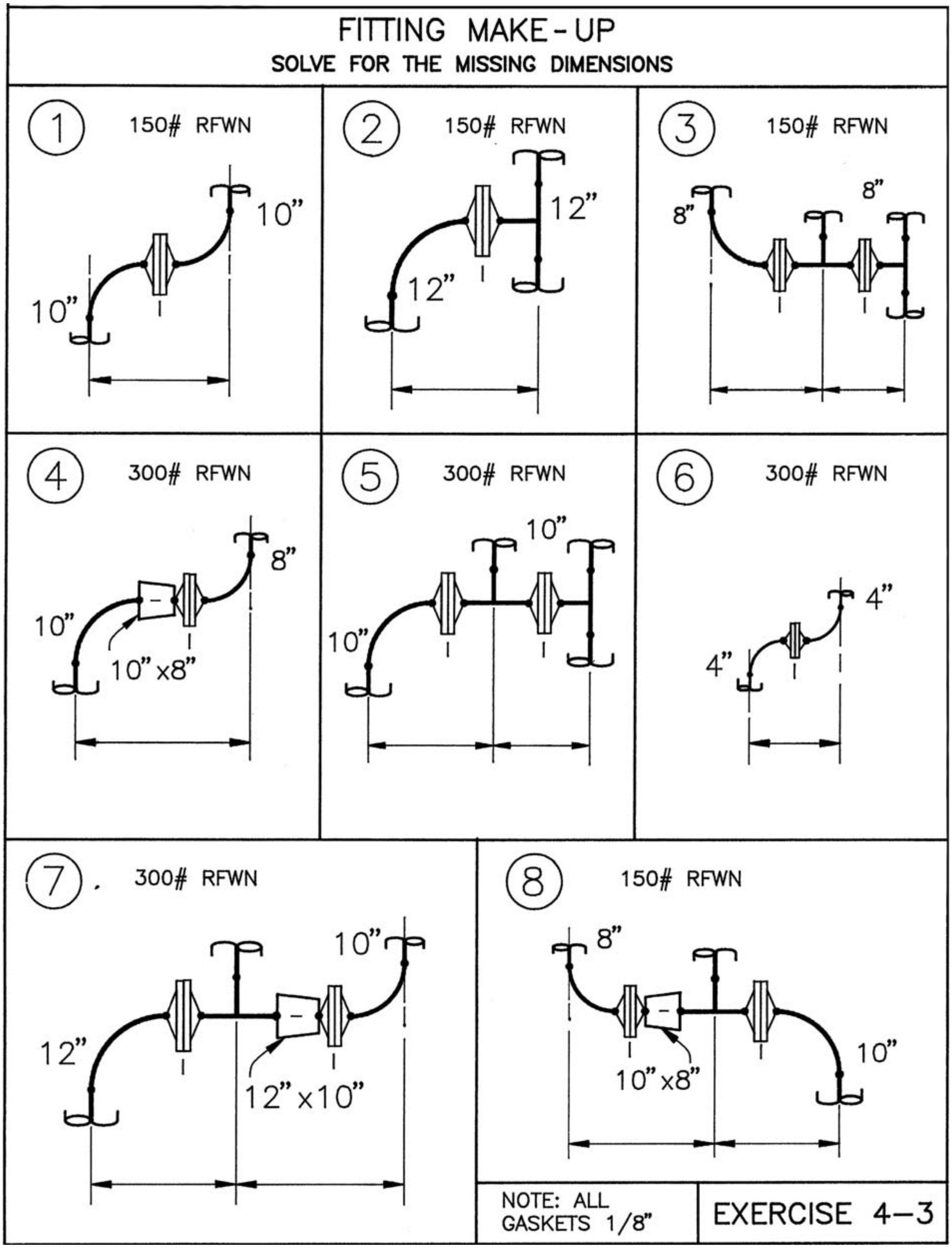
DRAW ALL VIEWS AS SHOWN
14"–300# RFWN



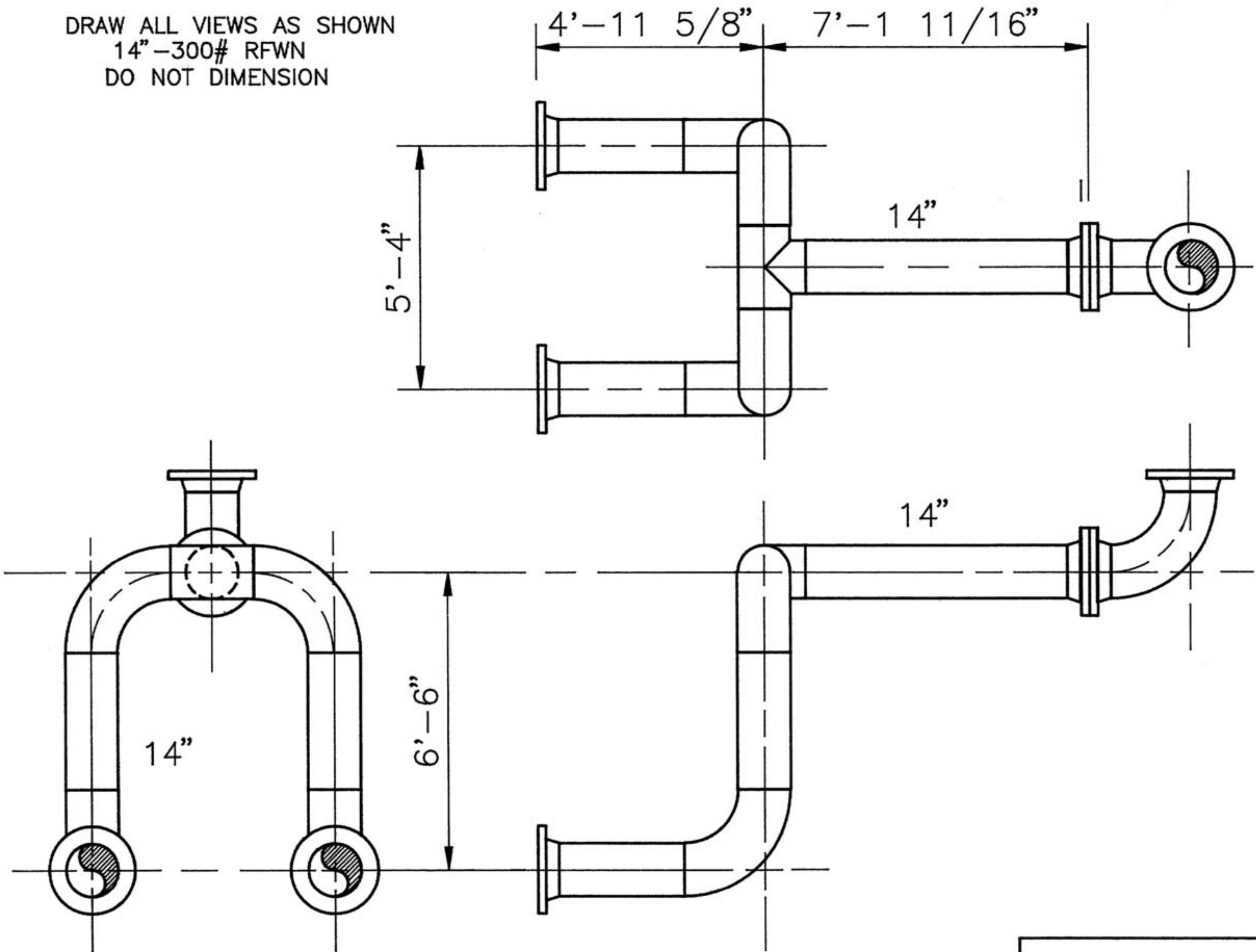
DRAW ALL VIEWS AS SHOWN
12"–300# RFWN



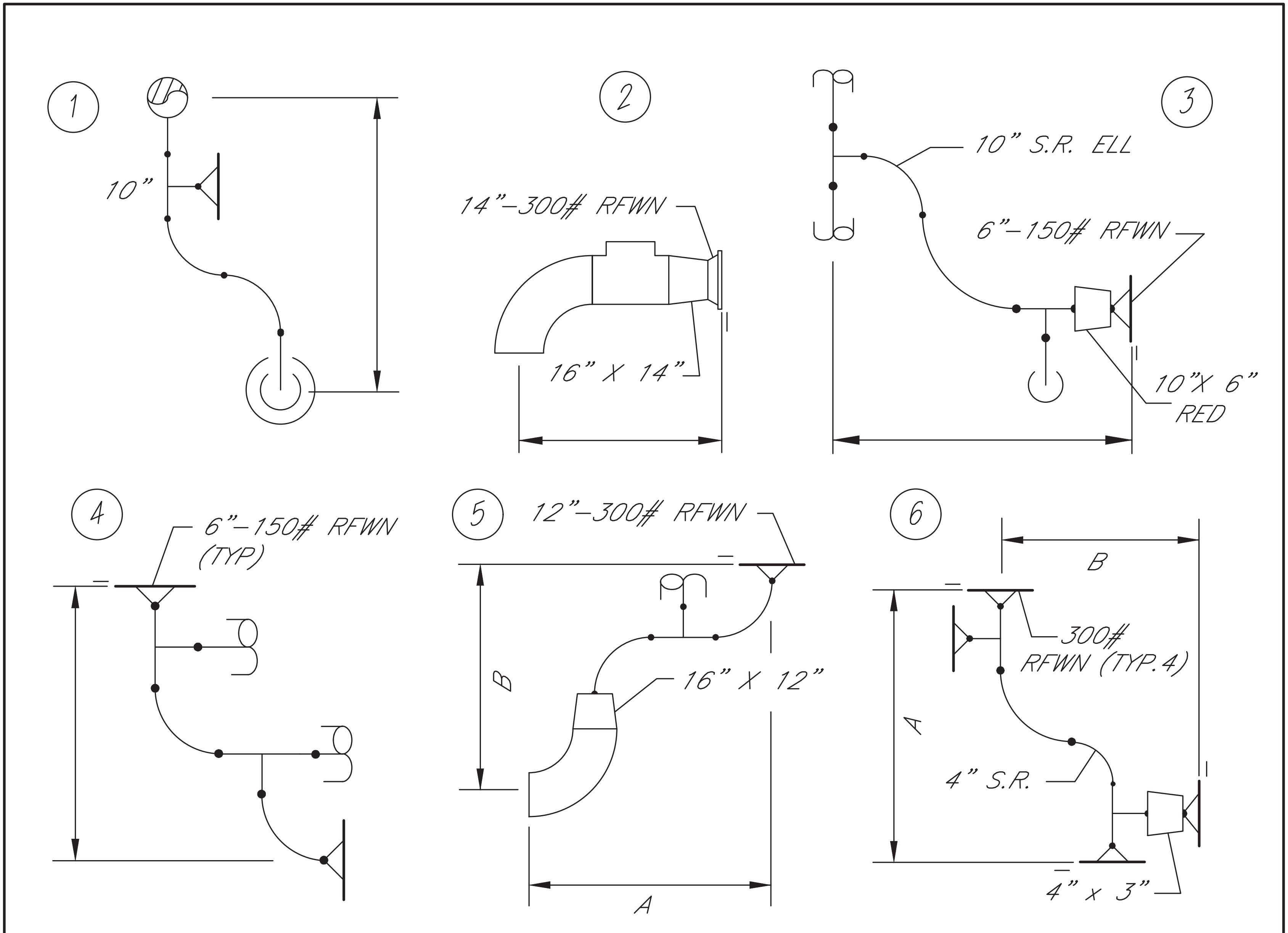
EXERCISE 4–2


FITTING MAKE-UP
SOLVE FOR THE MISSING DIMENSIONS
1
150# RFWN
10"
10"
2
150# RFWN
12"
12"
3
150# RFWN
8"
8"
4
300# RFWN
8"
10"
10"x8"
5
300# RFWN
10"
10"
6
300# RFWN
4"
4"
7
300# RFWN
10"
12"
12"x10"
8
150# RFWN
8"
10"
10"x8"
NOTE: ALL GASKETS 1/8"
EXERCISE 4–3

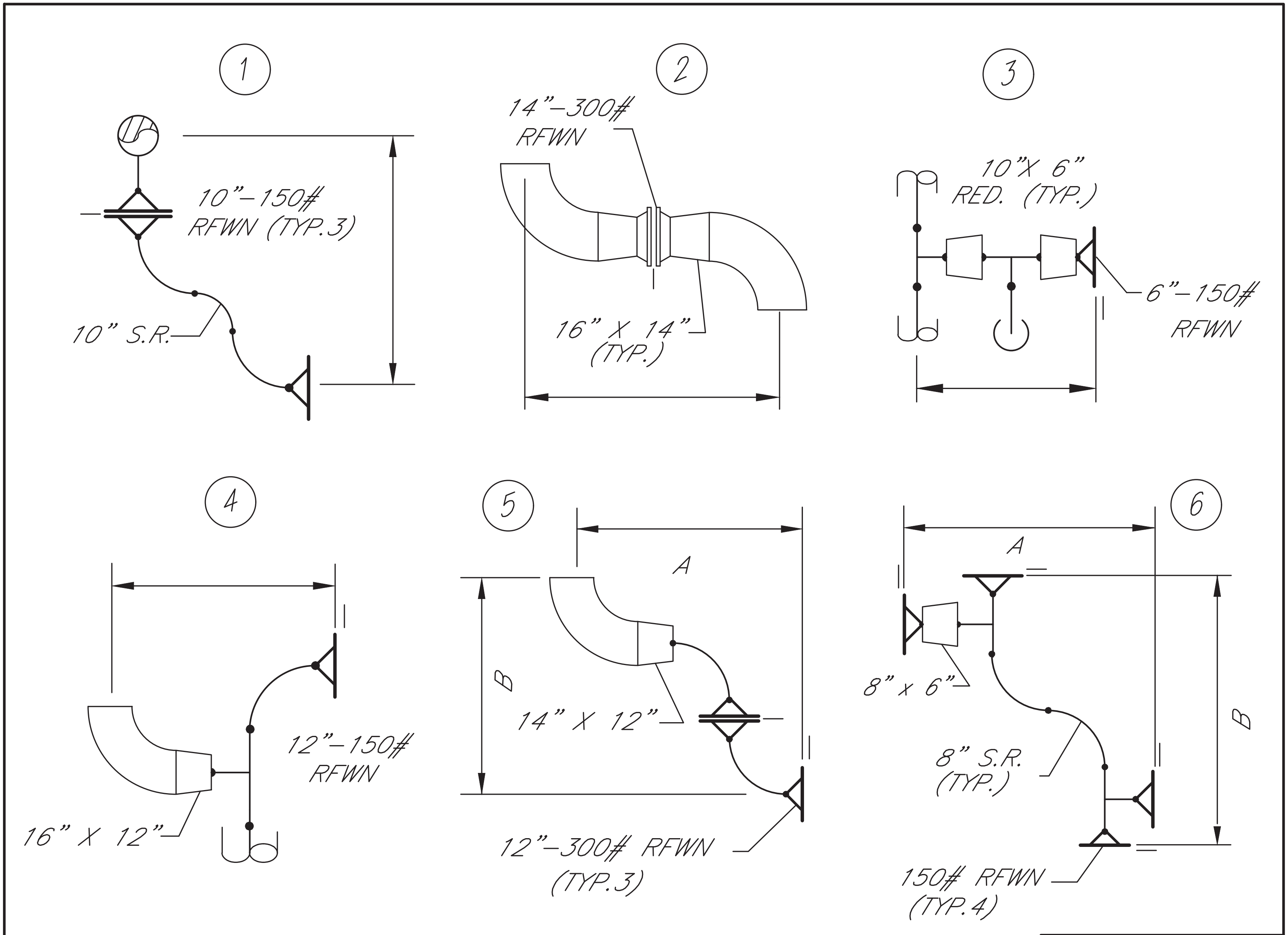
DRAW ALL VIEWS AS SHOWN
14"-300# RFWN
DO NOT DIMENSION



EXERCISE 4-4


1
10"
2
14"-300# RFWN
16" X 14"
3
10" S.R. ELL
6"-150# RFWN
10"X 6"
RED
4
6"-150# RFWN
(TYP)
5
12"-300# RFWN
16" X 12"
B
A
6
B
300#
RFWN (TYP.4)
A
4" S.R.
4" x 3"

EXERCISE 4-5


1
10"–150# RFWN (TYP.3)
10" S.R.
2
14"–300# RFWN
16" X 14" (TYP.)
3
10"X 6" RED. (TYP.)
6"–150# RFWN
4
12"–150# RFWN
16" X 12"
5
A
B
14" X 12"
12"–300# RFWN (TYP.3)
6
A
B
8" x 6"
8" S.R. (TYP.)
150# RFWN (TYP.4)

EXERCISE 4–6

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CHAPTER

5

Valves

WHAT IS A VALVE?[1]

A valve is a product rarely noticed by the average person, yet it plays an important role in the quality of our lives. Each time you turn on a water faucet, use your dishwasher, turn on a gas range, or step on the accelerator in your car you operate a valve. Without modern valve systems, there would be no fresh, pure water in your home, no modern appliances, and no gasoline waiting at the corner service station.

One of the most widely observed, but least recognized, type of valve is the fire hydrant. Fire hydrants are connected to municipal water supply systems. They are specialized in that they are underground valves that can be opened and closed from an aboveground location when needed in emergency situations.

By definition, a valve is a device that controls the flow of a fluid. But today's valves can control not only the flow but also the rate, the volume, the pressure, and the direction of a fluid within a pipe. Valves are not limited to fluids. They can control liquids, gases, vapors, slurries, or dry materials. Valves can turn on or off, regulate, modulate, or isolate. They can range in size from a fraction of an inch to as large as 30 ft in diameter and can vary in complexity from a simple brass valve, available at the local hardware store, to a precision-designed, highly sophisticated coolant system control valve made of exotic metal alloy used in a nuclear reactor. Valves also can control the flow of all types of commodities. From the thinnest gas to highly corrosive chemicals, from superheated steam to toxic gases, from abrasive slurries to radioactive materials, valves can be designed to service them all. They can handle temperatures from the cryogenic region to molten metal exceeding 1,500°F, and valves can contain pressures ranging from severe vacuum to 20,000 pounds per square inch.

The valve is one of the most basic and indispensable components of our modern technological society. As long as industries continue to devise new reasons to control gases, liquids, and even solids, valve design will continue to meet the demand.

COMMON VALVE TYPES

Valves are manufactured in numerous sizes, body styles, and pound ratings to meet a wide variety of application needs. Valves are also manufactured with varying types of end preparations that allow them to be readily mated to flanges or pipe of the same size and rating. Valve end preparations can be screwed, socket-weld, beveled, or flanged. Flanged valves are manufactured to have raised, flat, or ring-type joint faces.

Gate Valves

The *gate valve* is perhaps the most frequently used valve in piping systems. It is a general service valve that is used primarily for on-off, nonthrottling applications. When fully opened, the gate valve creates minimal obstruction to the flow. With less obstruction to the commodity's rate of flow through the valve's body, there is less turbulence, resulting in minimal drop in commodity pressure. Gate valves control the commodity flowing through the pipe with a flat, vertical wedge, or gate, that slides up or down as the valve's handwheel is turned. As the handwheel is rotated, the wedge will slide through the valve body to block or release the flow.

Designed to be either fully opened or closed, the gate valve should not be operated in a partially opened/closed position. A partially opened gate valve will hasten erosion caused by the commodity within the pipe and will ruin the valve seat in a short period of time. Turbulence from the commodity will also

[1]"What is a Valve?" Courtesy of VMA (Valve Manufacturers Association).

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00007-8

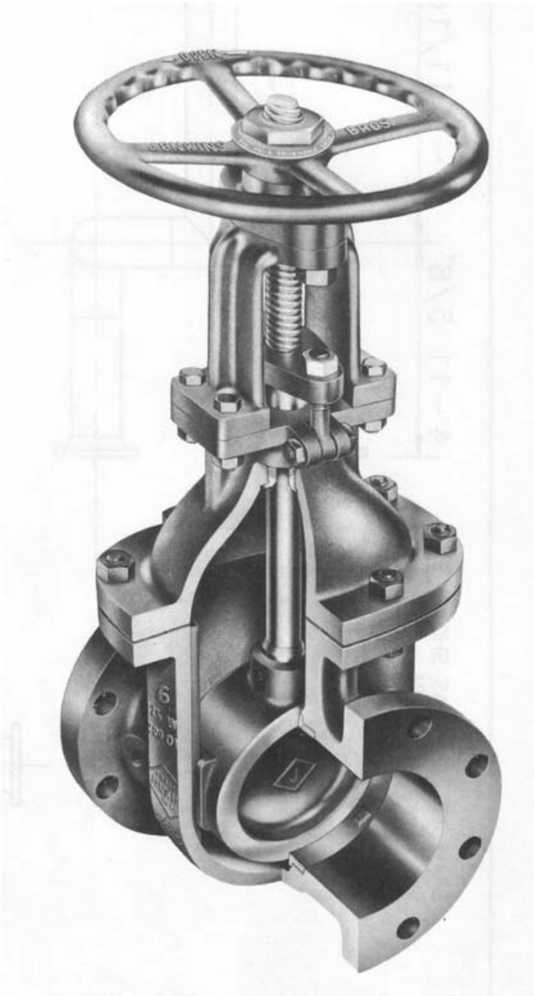


FIGURE 5.1 Gate valve. *Courtesy of Jenkins Bros.*

cause the wedge to vibrate creating a "chattering" noise when the valve is partially opened. Figure 5.1 depicts the external and internal views of a typical gate valve.

As with pipe, fittings, and flanges, valves are represented by symbols on piping drawings. These symbols are developed in such a manner as to describe the valve's body style, end type, and handwheel orientation. Symbol sizes are established from dimensions provided in manufacturers' catalogs or data sheets. Three dimensions are crucial when drawing a valve symbol: face-to-face, handwheel height, and handwheel diameter (see Figure 5.2).

The length of a valve is represented on most dimensioning charts as the *face-to-face* dimension. The face-to-face dimension is a length that is standard among valve manufacturers and defines the length of a valve from one end to the other. Also important is the height and diameter of a valve's handwheel. These measurements are necessary to establish operational clearances and worker accessibility around the valve. Of particular importance is the valve's *open* handwheel height. This dimension defines the maximum height of the valve when it is in the full-open position. The open handwheel height is measured from the centerline of the valve body to the tip of the valve *stem*.

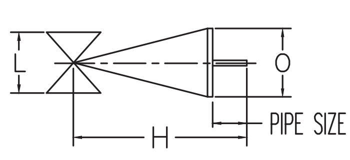
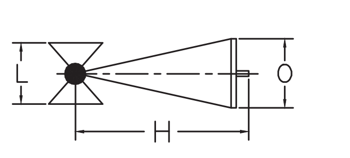
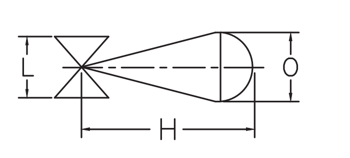
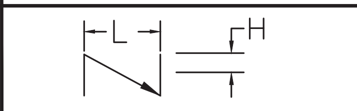
The valve stem is a threaded rod that connects the valve's wedge or gate to the handwheel. Valve stems fall into one of two categories: rising or nonrising. A rising stem is one in which the stem raises and lowers as the handwheel is rotated. The handwheel remains in a stationary position as the stem passes through it. On valves having a nonrising stem, the handwheel is attached to the end of the stem and moves up and down with the stem as the valve is opened or closed.

The length of a rising stem must be determined before the handwheel is represented on a drawing. When the valve is fully opened, the stem is at its highest point. The maximum distance the stem will extend above the handwheel is approximately equal to the nominal size of the pipe. Knowing the length of the stem allows a piping designer to draw the valve symbol with the handwheel located the proper distance from the end of the stem and also to determine when interference problems may occur.

Another important dimension is the diameter of the flanged faces on flanged valves. When representing flanged valves, the diameter of the valve's flanges must be drawn to match the size and pound rating of the flange or nozzle to which the valve is being bolted. Because most valve dimensioning charts do not provide this information, a drafter must refer to the flange dimensioning chart to find the proper flange OD measurements.

Valve symbols vary from company to company and client to client. It is therefore imperative that a drafter be familiar with the symbols being used on a project before work begins on that new project. The symbols shown in this chapter are typical of those found on many piping drawings. They should not be considered standard for all applications, however. The symbols shown in Figure 5.3 represent screwed, socket-weld, and flanged gate valves. Notice also the two methods of representing handwheels.

The valve rotations represented in Figure 5.4 depicts the possible rotations in which valves may appear on drawings. Bolt-hole orientations of nozzles on vessels, pumps, or other equipment may not always straddle the preferred north-south or east-west centerlines. Also, accessibility may not always allow for vertical or horizontal positioning of handwheels. Therefore angular rotation of valves becomes imperative and the rotations shown in Figure 5.4 indicate how those valve rotations would appear on piping drawings.

VALVES		150#									
NOMINAL PIPE SIZES –(INCHES)		2	3	4	6	8	10	12	14	16	18
PIPE (OUTSIDE DIAMETER)		2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
VALVES – GATE 	L	7	8	9	10 1/2	11 1/2	13	14	15	16	17
	H	15 3/4	20 3/4	25 3/4	35 1/4	44	52 1/2	60 1/2	70 1/2	79 3/4	89
	O	8	9	10	14	16	18	18	22	24	27
VALVES – GLOBE 	L	8	9 1/2	11 1/2	16	19 1/2	*	*	*	*	*
	H	13 3/4	16 1/2	19 3/4	24 1/2	26	*	*	*	*	*
	O	8	9	10	12	16	*	*	*	*	*
VALVES – CONTROL 	L	10	11 3/4	13 7/8	17 3/4	21 3/8	26 1/2	*	*	*	*
	H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
	O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
VALVES – CHECK 	L	8	9 1/2	11 1/2	14	19 1/2	24 1/2	27 1/2	35	39	*
	H	5	6	7	9	10 1/4	12 1/8	13 3/4	18	20 1/2	*

NOTE: ALL DIMENSIONS ARE IN INCHES
* REFER TO VENDOR'S CATALOG

150# RF

FIGURE 5.2 Flanged valve dimensioning chart.

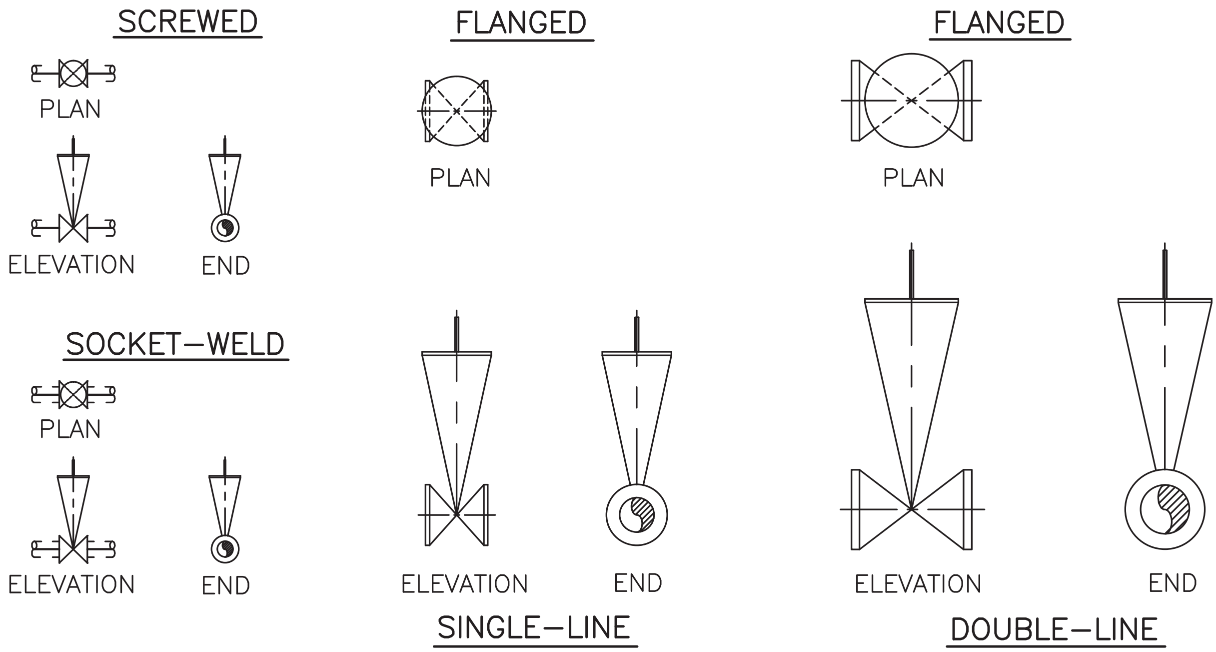


FIGURE 5.3 Gate valve drawing symbols.

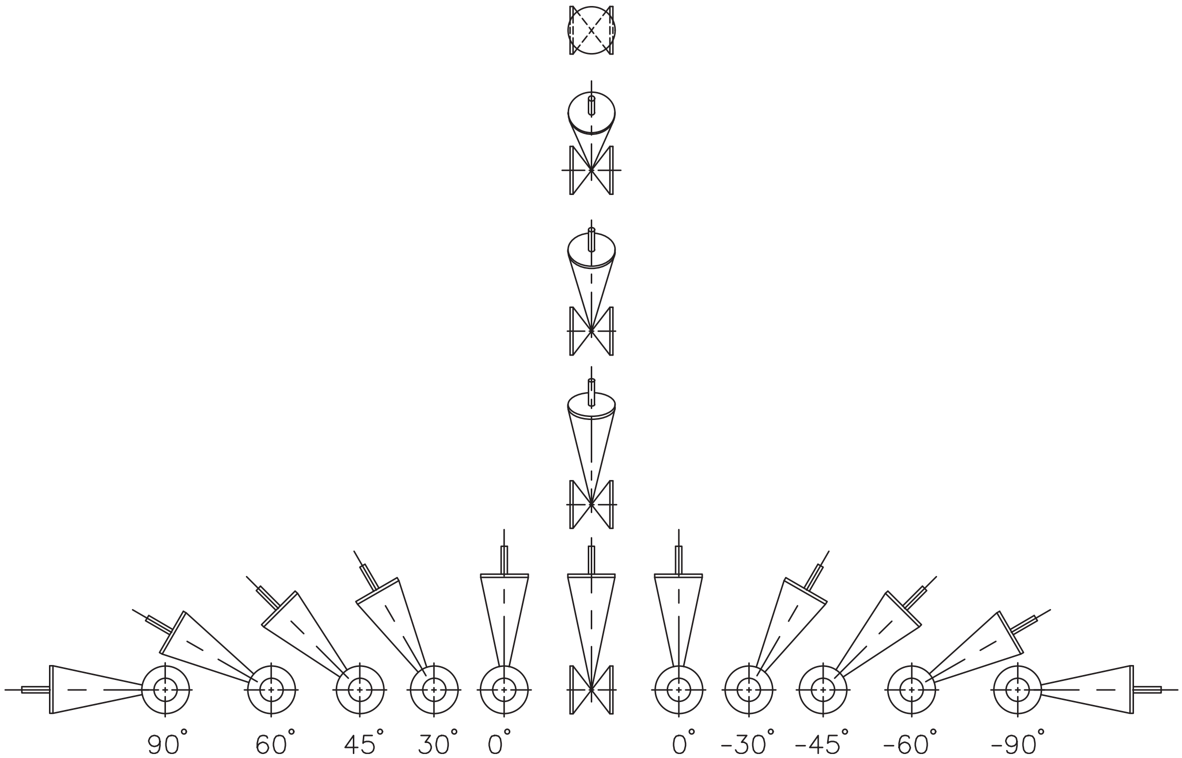


FIGURE 5.4 Gate valve rotation drawing symbols.

Drawing the Gate Valve

Figure 5.5 is a pictorial representation of the step-by-step procedures used to draw a 10″-300# RF gate valve using **AutoCAD**. Symbols depicting other valve types are developed using similar step-by-step procedures but with minor changes or alterations which would reflect the representation of that particular valve.

Globe Valves

Globe valves are used primarily in situations where throttling of the commodity is required. By simply rotating the handwheel, the rate at which the commodity flows through the valve can be adjusted to any desired level. Having the valve seat parallel to the line of flow is an important feature of the globe valve. This feature makes the globe valve efficient when throttling commodities as well as yielding minimal disc and seat erosion. This s-shaped configuration, however, creates a large amount of resistance within the valve. The design of the globe valve body forces the flow of the commodity to change direction within the valve itself. This change in direction creates substantial pressure drop and turbulence. The globe valve is therefore not recommended when flow resistance and pressure drop are to be avoided. In most installations the commodity is routed into the valve's body from below the valve seat and disc. This flow direction uses the pressure of the commodity to aid in the opening operation of the valve. It also reduces wear on the valve seats and disc. One exception however is when high temperature steam is routed through the valve. The extreme temperature of the steam contacting the valve seat from below creates a significant temperature difference from the top of the seat and disc. This temperature difference across the valve's seats and disc causes the metal of the disc to contract which results in leakage. Therefore when high temperature steam is routed through a globe valve, it is routed into the valve from the top of the disc, opposite of normal commodity flow direction. Figure 5.6 depicts the internal view of a globe valve.

Drawing symbols of the globe valve are similar to those of the gate valve. Measurements used to draw the valve are found on manufacturers' dimensioning charts. One noticeable difference is the use of a darkened circle positioned at the intersection of the diagonal lines in the valve's body. One other difference, although not quite as noticeable, is the use of a nonrising stem on globe valves. Drawing symbols for globe valves are shown in Figure 5.7.

Angle Valves

The *angle valve*, like the globe valve, is used for throttling. As shown in Figure 5.8, the flow entering

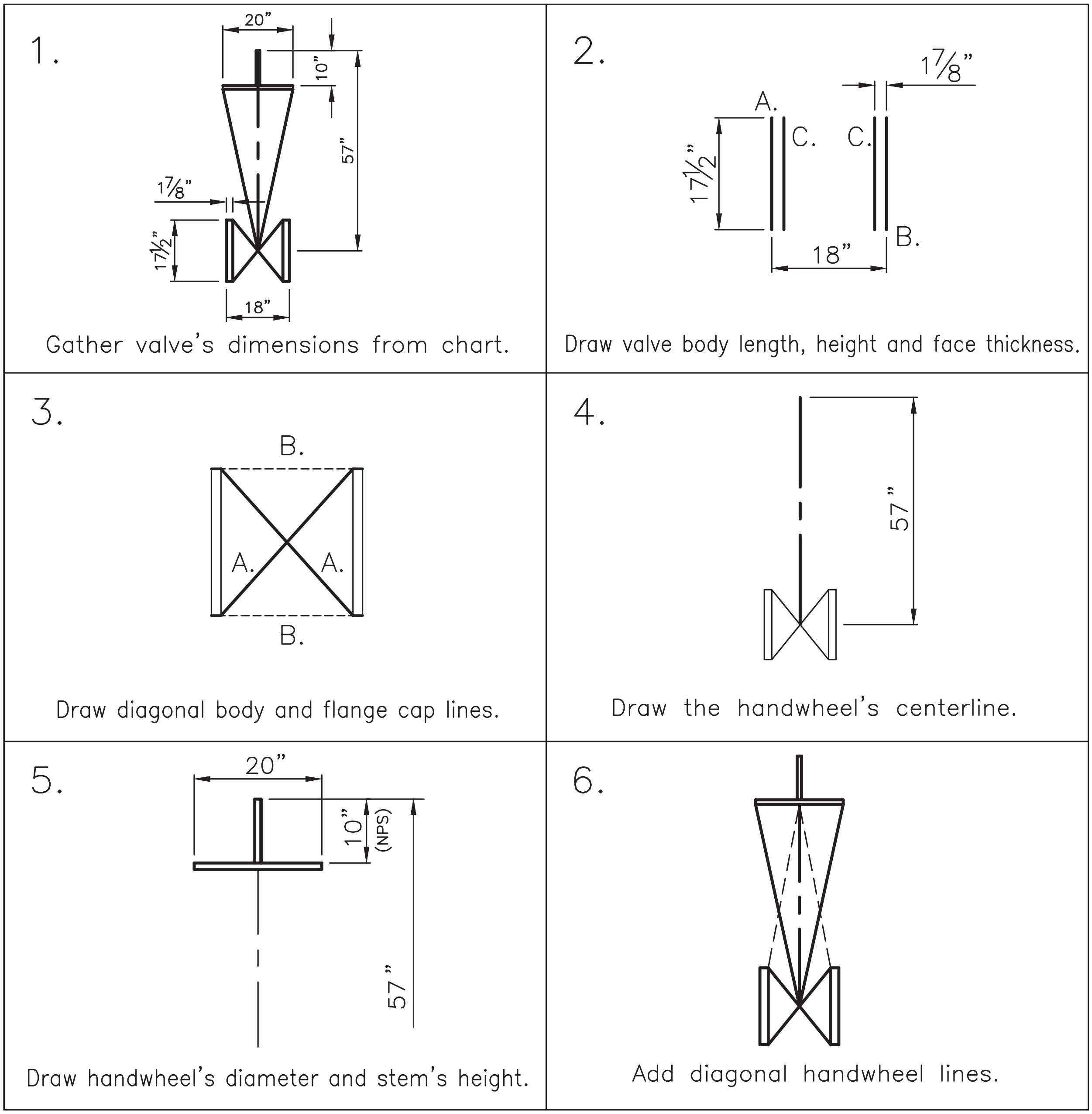


FIGURE 5.5 Gate valve. Step-by-step drawing procedures.

Step 1. Use the appropriate vendor's catalog to determine the overall dimensions of a 10″-300# RF gate valve. Find the valve's length (face-to-face); ***L*** (18″), handwheel height; ***H*** (57″) handwheel diameter; (handwheel ***O***) (20″), flange diameter; (flange ***O***) (17$^1/_2$″**)**, and flange thickness; (flange ***T***) (1$^7/_8$″).

Step 2.

A. Draw a vertical **LINE** 17$^1/_2$″ long to represent the flange diameter of the valve's face.
B. **OFFSET** the vertical line 18″ (face-to-face dimension) to the right to establish to valve's length.
C. From each end of the valve **OFFSET**, toward the center, the valve's flange face thickness (1$^7/_8$″).

Step 3.

A. Draw horizontal **LINE**s (A) to "cap" the ends of the valve's flange face.
B. Draw intersecting, diagonal **LINE**s (B) from the ends of the vertical lines to create the valve body.

Step 4. Draw a vertical centerline from the center of the valve's body 57″ long to represent the handwheel's "open" dimension.

Step 5. Draw a 20″ (handwheel's diameter) horizontal **LINE**, equally centered on the valve's centerline, 10″ (distance equal to NPS) from the top end of the valve's centerline. Give the valve's handwheel and stem a 0.3 mm lineweight.

Step 6. To complete the handwheel representation, draw a **LINE** from each end of the handwheel down to the center of the valve body. Lines drawn in the opposite direction can also be used as an alternative.

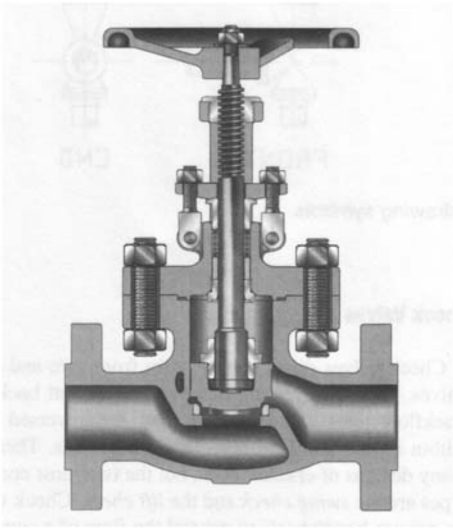


FIGURE 5.6 Globe valve. *Courtesy of VELAN.*

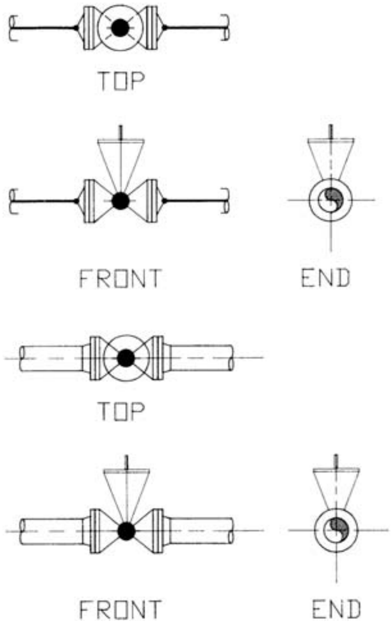


FIGURE 5.7 Globe valve drawing symbols.

the valve and the flow leaving the valve form a 90° angle. In the event a pipe is making a 90° turn, the angle valve is used to eliminate the need for a 90° elbow and additional fittings.

As mentioned above, like globe valves, angle valves are typically installed so a commodity will flow in an upward direction through the valve body. This upward flow direction will keep pressure under the disc seat. Pressure from below the seat promotes easier operation and reduces the erosive action on the seat and disc. For high temperature commodities however, such as superheated steam, the flow direction is reversed. When the valve is closed, temperature on the

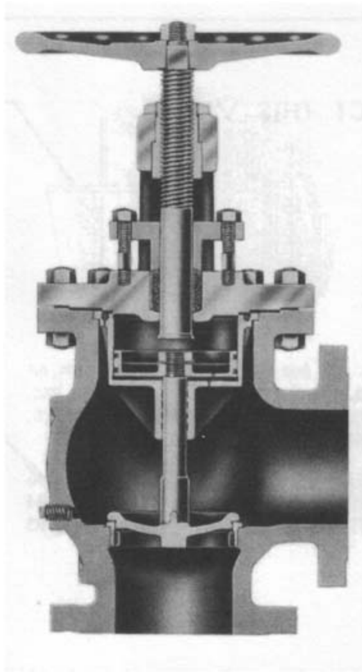


FIGURE 5.8 Angle valve. *Courtesy of Jenkins Bros.*

lower side of the disc is significantly higher than that on the upper side. Because the valve's stem is on the upper side of the disc, it will be cooler. This temperature differential causes the valve stem to contract, lifting the disc off the seat. This lifting action will result in the seat and disc faces being scored. To avoid this problem, valve manufacturers recommend installing globe and angle valves so high temperature commodities flow into the valve from the upper side. This flow direction will keep pressure above the disc, forcing it into the seat and creating a tighter seal. Figure 5.9 depicts the drawing symbols for the angle valve.

Check Valves

Check valves differ significantly from gate and globe valves. *Check valves* are designed to prevent backflow. Backflow simply means flow that has reversed itself within a pipe and begins to flow backwards. There are many designs of check valves, but the two most common types are the *swing check* and the *lift check*. Check valves do not use handwheels to control the flow of a commodity, instead they utilize gravity and the pressure of the commodity to operate the valve (see Figure 5.10).

The swing check valve is installed as a companion valve to the gate valve. As the name implies, this valve has a swinging gate that is hinged at the top and opens as a commodity flows through the valve. When the valve disc is in the open position, a clear flow path is created through the valve. This clear path creates

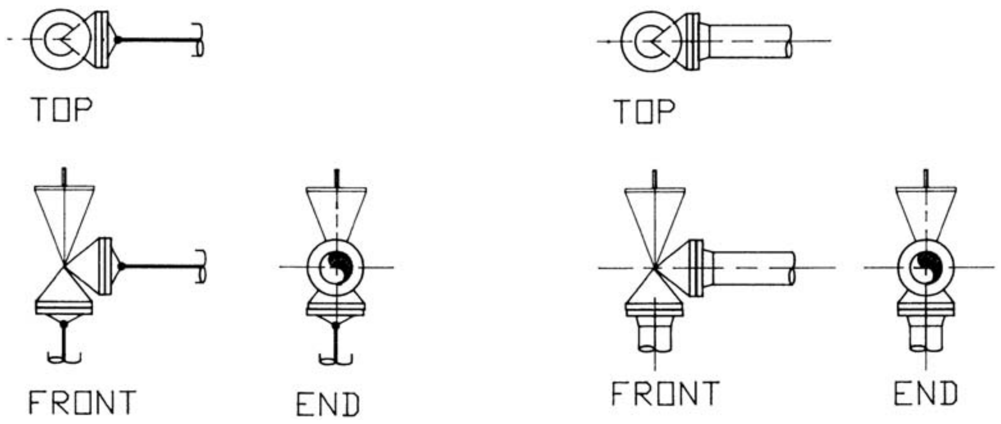


FIGURE 5.9 Angle valve drawing symbols.

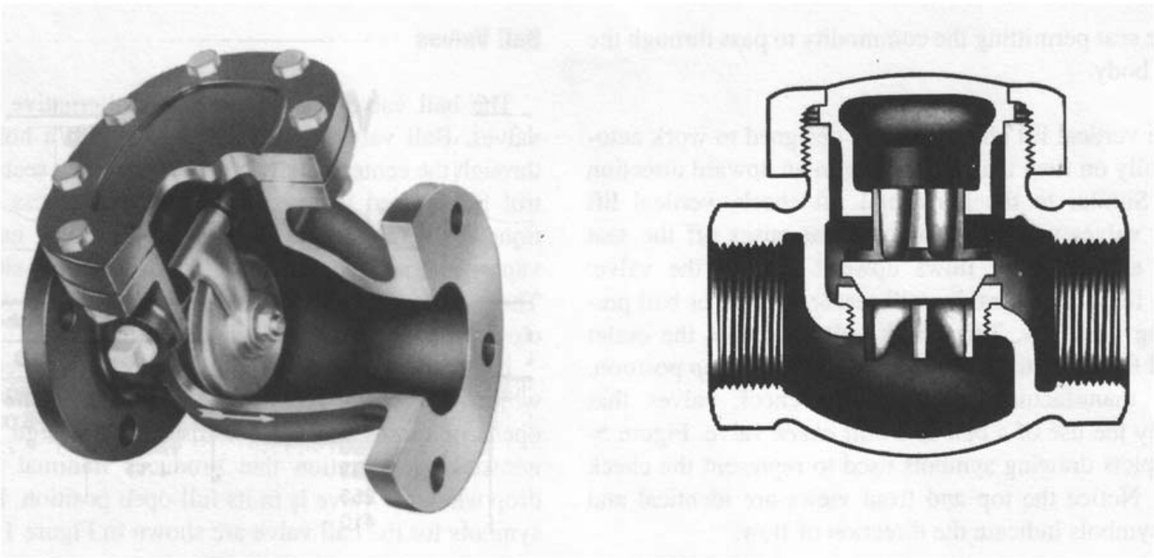


FIGURE 5.10 Swing and lift check valves. *Courtesy of Crane Co.*

minimal turbulence and pressure drop within the valve. Pressure must always be under the disc for the valve to function properly. When flow reverses, the pressure and weight of the commodity against the disc will force the disc against the seat, stopping all backflow. Check valves are often regarded as safety or precautionary equipment.

The lift check valve is often bolted directly to a globe valve. Notice in Figure 5.10 how the lift check valve has a body style similar to that of a globe valve. As flow enters the valve, the disc is lifted up off the seat to allow flow to pass. As with the globe valve, there is significant turbulence and pressure drop.

There are two types of lift check valves: *horizontal* and *vertical*. Both of these valves use either a disc or ball and the force of gravity to close the valve in the event of reverse flow. The horizontal lift check valve has a seat that lies parallel to the flow. The result is an S-shaped body style that mandates the valve be installed in the horizontal position only and has flow that enters from below the seat. Flow entering the valve raises the disc or ball off the seat permitting the commodity to pass through the valve body.

The vertical lift check valve is designed to work automatically on flow that is traveling in an upward direction only. Similar to the horizontal lift check, vertical lift check valves use a disc or ball that raises off the seat when a commodity flows upward through the valve. When flow stops, gravity will reseat the disc or ball preventing backflow. This check valve requires the outlet end of the valve to always be installed in the *up* position. Some manufacturers refer to lift check valves that employ the use of a ball as a *ball check* valve. Figure 5.11 depicts drawing symbols used to represent the check valve. Notice the top and front views are identical and both symbols indicate the direction of flow.

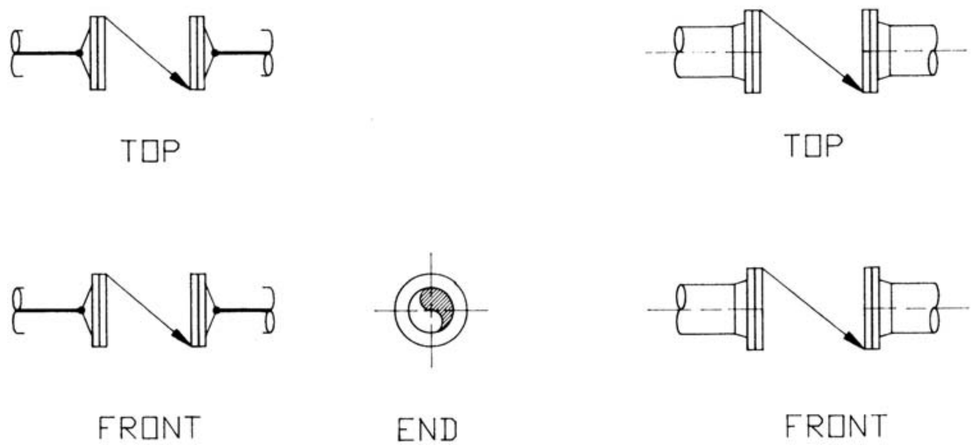


FIGURE 5.11 Check valve drawing symbols.

FIGURE 5.12 Ball valve. *Courtesy of Jenkins Bros.*

Ball Valve

The ball valve is an inexpensive alternative to other valves. *Ball valves* use a metal ball with a hole bored through the center, sandwiched between two seats to control flow. Used in many hydrocarbon process applications, ball valves are capable of throttling gases and vapors and are especially useful for low flow situations. These valves are quick opening and provide a very tight closure on hard to hold fluids (see Figure 5.12).

Ball valves do not use a handwheel, but instead use a wrench to control the flow. A 90° turn of the wrench opens or closes the valve. This simple design yields a nonstick operation that produces minimal pressure drop when the valve is in its full-open position. Drawing symbols for the ball valve are shown in Figure 5.13.

Plug Valve

Unlike other valves, the *plug valve* uses either a handwheel or wrench to operate the valve. Plug valves provide a tight seal against hard to hold commodities and requires a minimum amount of space for installation. Unlike the ball valve, the plug valve uses a tapered wedge rather than a ball to create a seal. This wedge, or plug, has an elongated opening, which when placed in the *open* position, allows the commodity to pass through the valve. The plug is the only movable part of the valve and its tapered shape assures positive seating (see Figure 5.14).

Plug valves are designed with etched grooves along the tapered plug to permit a lubricant to seal and lubricate the internal surfaces as well as to provide a hydraulic jacking force to lift the plug within the body, thus permitting easy operation. The clear and open passageway through the valve body provides little opportunity for scale or sediment to collect. In fact the plug seats so well that as the plug is rotated, foreign debris is wiped from the plug's external surfaces. These valves, however, do require constant lubrication to maintain a tight seal between plug and body. Figure 5.15 depicts drawing symbols used to represent the plug valve.

Butterfly Valve

The *butterfly valve* has a unique body style unlike the other valves we have discussed. The butterfly uses a circular plate or wafer operated by a wrench to control flow. A 90° turn of the wrench moves the wafer from a fully open position to a fully closed position. The wafer remains in the stream of flow and rotates around a shaft connected to the wrench. As the valve is being closed, the wafer rotates to become perpendicular to the direction of flow and acts as a dam to reduce or stop the flow. When the wrench is rotated back to the original position, the wafer aligns itself with the direction of flow and allows the commodity to pass through the valve (see Figure 5.16).

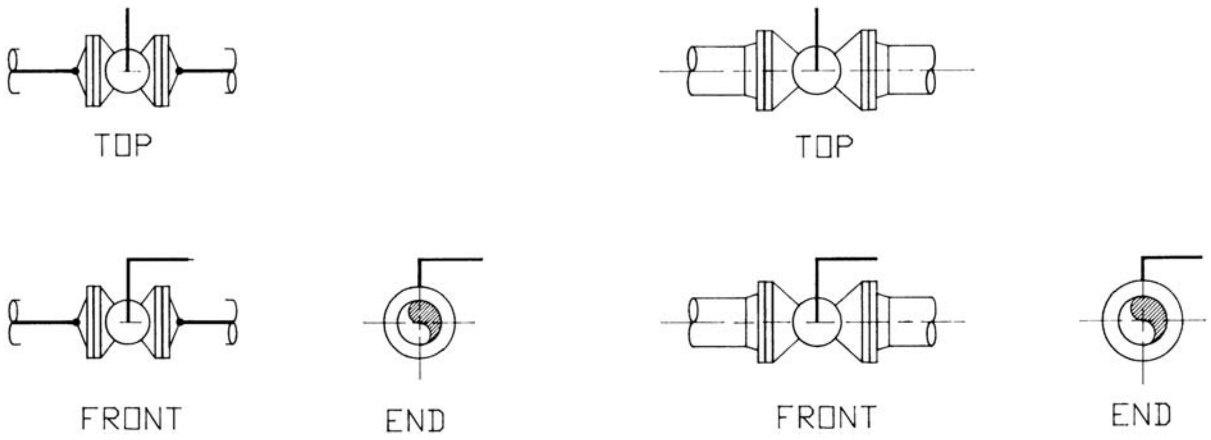


FIGURE 5.13 Ball valve drawing symbols.

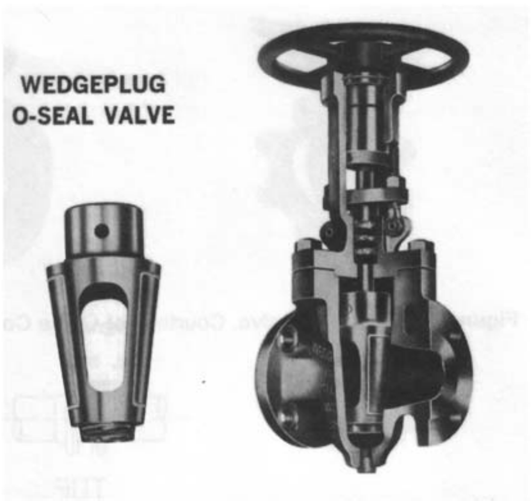


FIGURE 5.14 Plug valve. *Courtesy of Stockham Valves.*

Butterfly valves have minimal turbulence and pressure drop. They are good for on-off and throttling service and perform well when controlling large flow amounts of liquids and gases. However, these valves do not normally create a tight seal and must be used in low-pressure situations or where some leakage is permissible. Drawing symbols for the butterfly valve are shown in Figure 5.17. A dimensioning chart for the butterfly valve is included in the Appendix.

Relief Valves

Relief valves have a purpose quite different from the previous valves. They are designed to release excessive pressure that builds up in equipment and piping systems. To prevent major damage to equipment, and more importantly, injury to workers, relief valves can release elevated pressures before they become extreme.

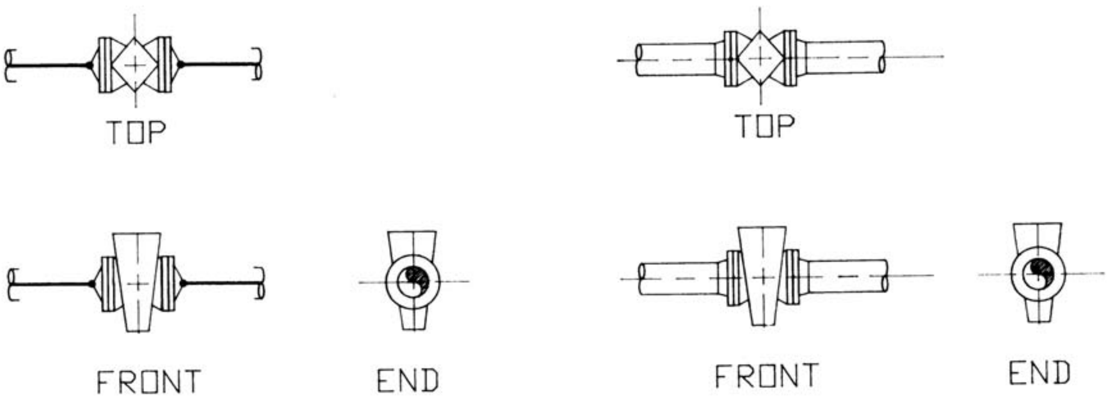


FIGURE 5.15 Plug valve drawing symbols.

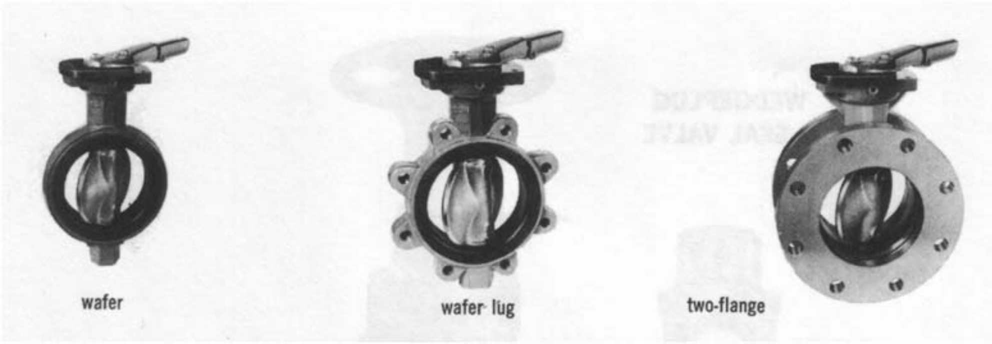


FIGURE 5.16 Butterfly valve. *Courtesy of Crane Co.*

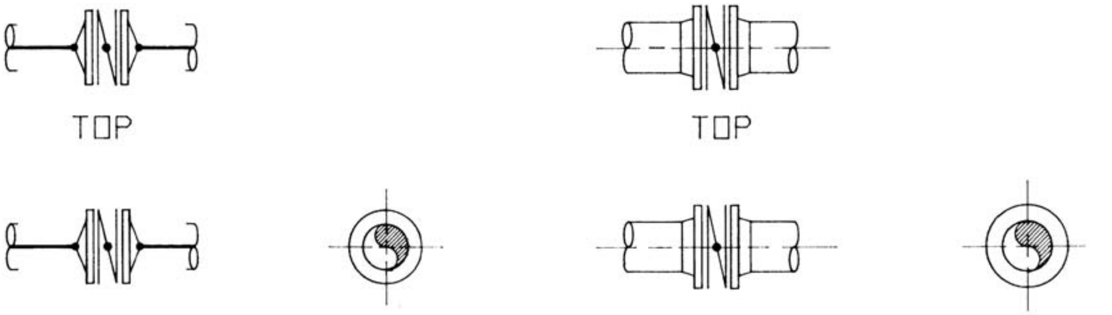


FIGURE 5.17 Butterfly valve drawing symbols.

Relief valves use a steel spring as a means to automatically open when pressures reach unsafe levels. These valves can be adjusted and regulated to *pop off* when internal pressures exceed predetermined settings. Once internal pressures return to operational levels, the relief valve closes. Figure 5.18 shows the internal mechanism of a relief valve.

Another valve that performs the same basic function as the relief valve is the *pressure safety valve*. Although similar in design and appearance, the two valves operate differently. Relief valves are used in piping systems that service liquid commodities and are designed to open proportionally, that is, as pressure from the commodity increases so does the opening of the valve. The higher the pressure, the larger the opening. The pressure safety valve, however, is used with higher pressure commodities such as steam and gas. Pressure safety valves are designed to open completely when internal pressures exceed the setting for which the internal spring has been set. As with the relief valve, once internal pressures return to operational levels the valve will close itself. Figure 5.19 provides drawing symbols used to represent the relief valve and pressure safety valve.

Control Valve

The flow, level, pressure, and temperature of all commodities being processed must be monitored, adjusted, and regulated to maintain a safe, efficient, and profitable facility. Pressures and temperatures that are allowed to elevate unchecked to extreme levels can become deadly. Commodity flow rates and product storage levels that are insufficient may lead to less production. Therefore the *control valve*, which is a remotely operated valve that can make precise adjustments to regulate and monitor any commodity flowing through a piping system, is widely used. The most common valve body style used as a control valve is the globe valve. Ball, butterfly, and plug valves can also be used as control valve body types. Control valves receive a signal from instruments positioned throughout the piping system to automatically make adjustments that regulate the commodity within the piping system. Control valves can perform many routine and repetitive operations or they can be designed for one specific task. Figure 5.20 shows the drawing symbols for a control valve.

Control valves are positioned throughout a piping facility, often in remote locations where access by plant personnel is problematic. However, when operational procedures require there be continuous functionality, a backup to the control valve must be incorporated. To achieve this, *control valve manifolds* are configured. Control valve manifolds, also known as manifold control stations, use a combination of gate, globe, and control valves, uniquely arranged, to make continuous operational control of the commodity feasible. Control

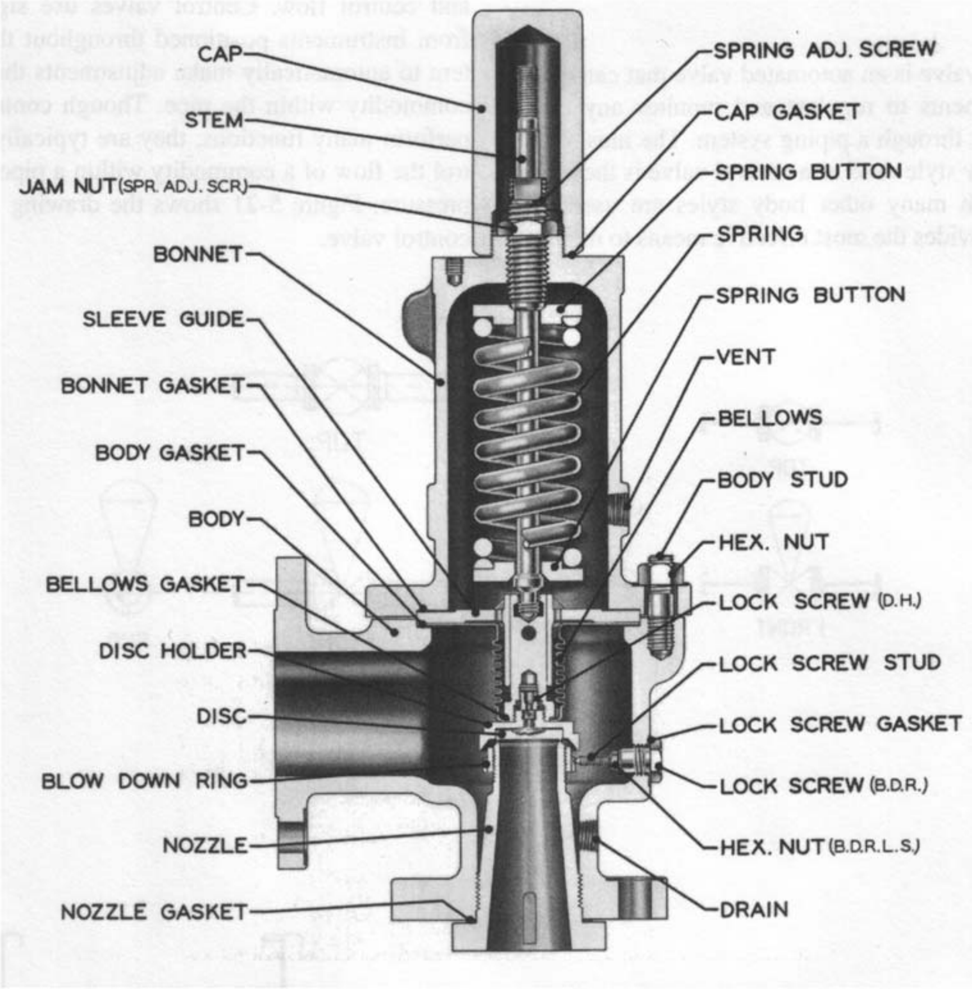


FIGURE 5.18 Relief valve. *Courtesy of Farris Safety-Relief Valves.*

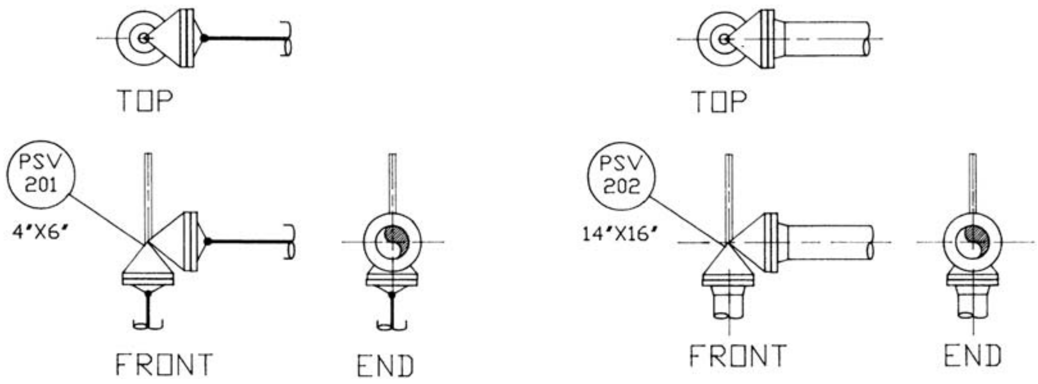


FIGURE 5.19 Relief and pressure safety valve drawing symbols.

valve manifolds are discussed in greater detail in Chapter 12: Piping Systems. Figure 5.21 depicts the Plan and Section A-A views a typical control valve manifold.

Depending upon the space available for the installation of a manifold control station, different configurations can be employed. Figure 5.22 shows two possible installations of a control valve manifold.

VALVE OPERATORS

A *valve operator* is a mechanism that causes a valve to perform its function. Operators can be *manual* or *automatic*. Manual operators employ levers, gears, or wheels to facilitate movement within a valve. A designer/drafter has freedom and responsibility to determine the

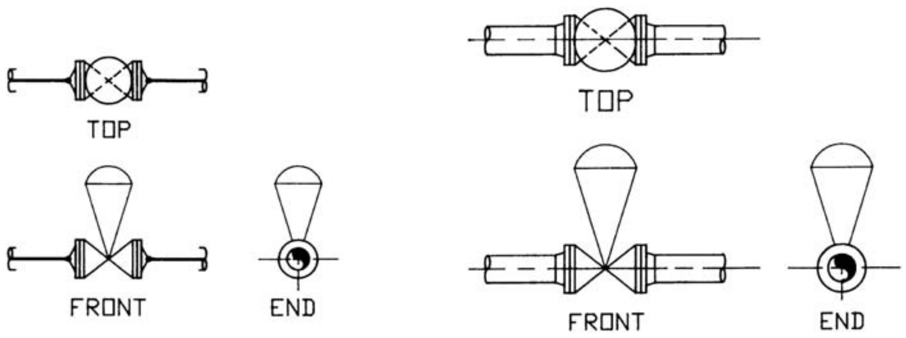


FIGURE 5.20 Control valve.

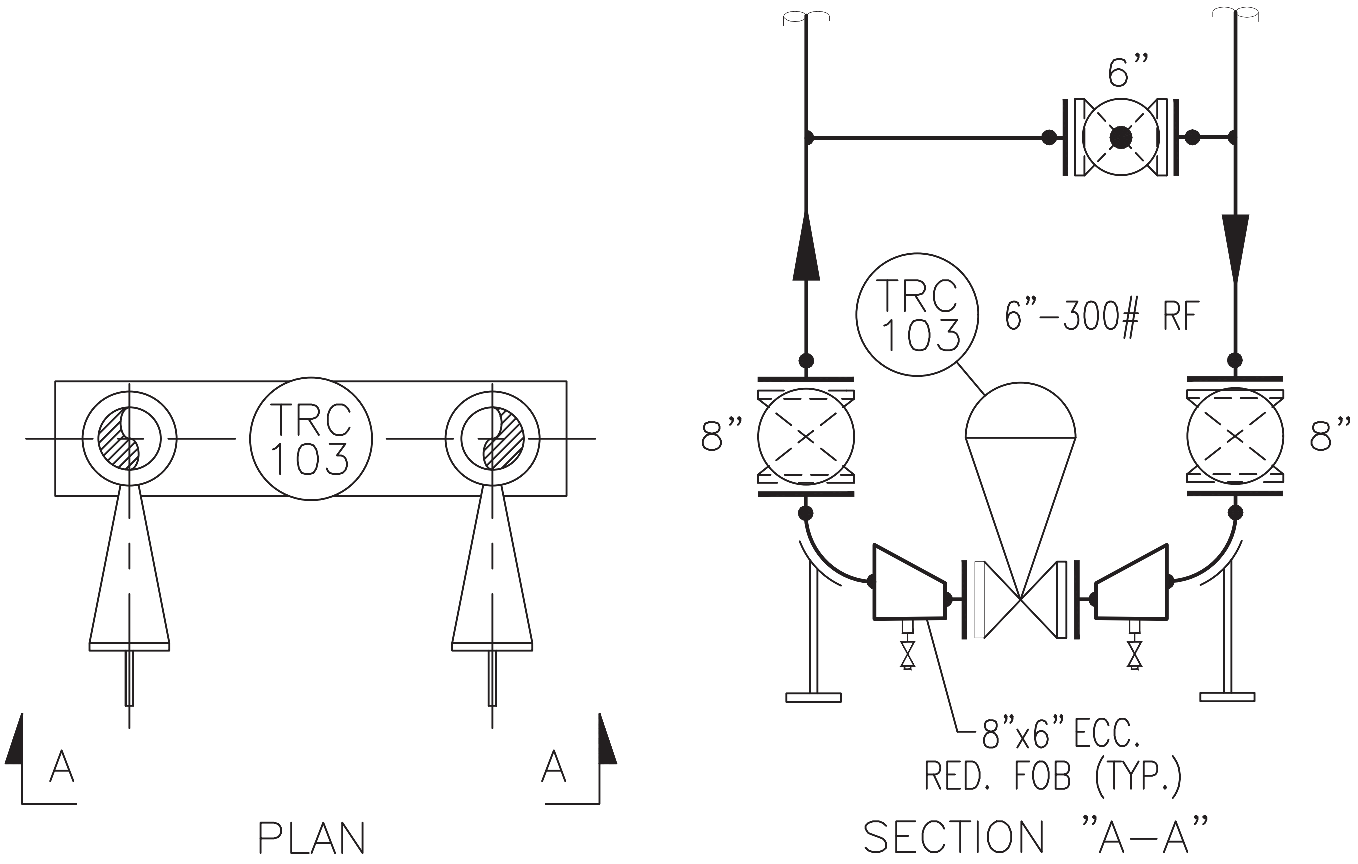


FIGURE 5.21 Control valve manifold.

positional location and orientation of valves. Not only must consideration be given to making valve operation convenient and practical but also safe for facility personnel. When locating a valve, the diameter and length of its handwheel, and it possible "clash" or interference with other components, must be addressed. Therefore the placement and orientation of handwheels must follow some specific guidelines. Figure 5.23 provides the location preferences for operating, emergency, and isolating valves when their stems are installed horizontally. Notice, specific "hazard" zones are shown for the head and lower leg area that must be avoided. Figure 5.24 shows similar guidelines for orienting valves when they are installed vertically. Notice that once a valve handwheel reaches its maximum installed height of 4′-6″ the valve is then rotated and bolted at such an angle so that it will eventually become horizontal in orientation.

In situations where the standard handwheel is insufficient to operate the valve, gears are commonly used to enhance a handwheel's effectiveness. Bevel, spur, and worm gears supply the handwheel with a greater mechanical advantage to open, close, or throttle the commodity within the pipe.

If a valve is installed at a height that is out of a worker's reach, a *chain operator* is often used. The chain operator is a sprocket-like attachment bolted to a

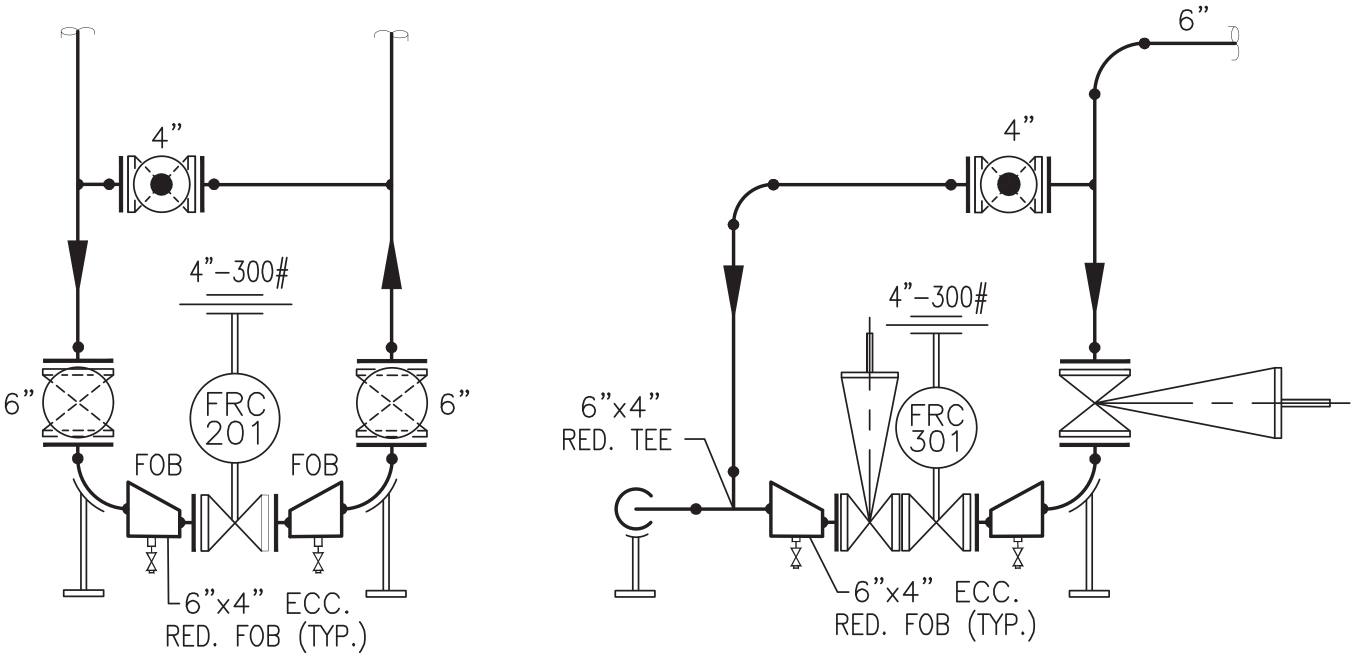


FIGURE 5.22 Control valve manifold configurations.

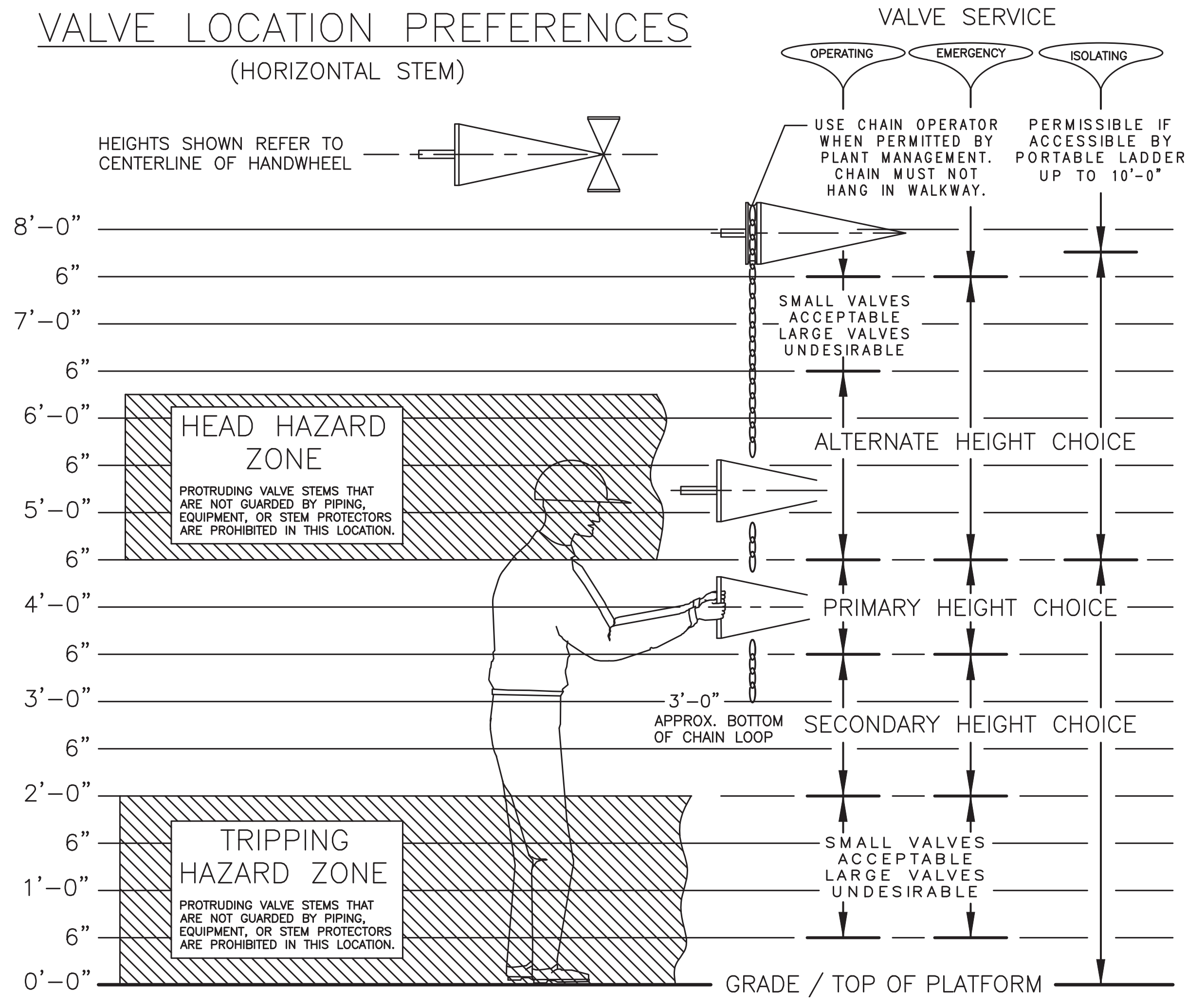


FIGURE 5.23 Valve location preferences with horizontal stem.

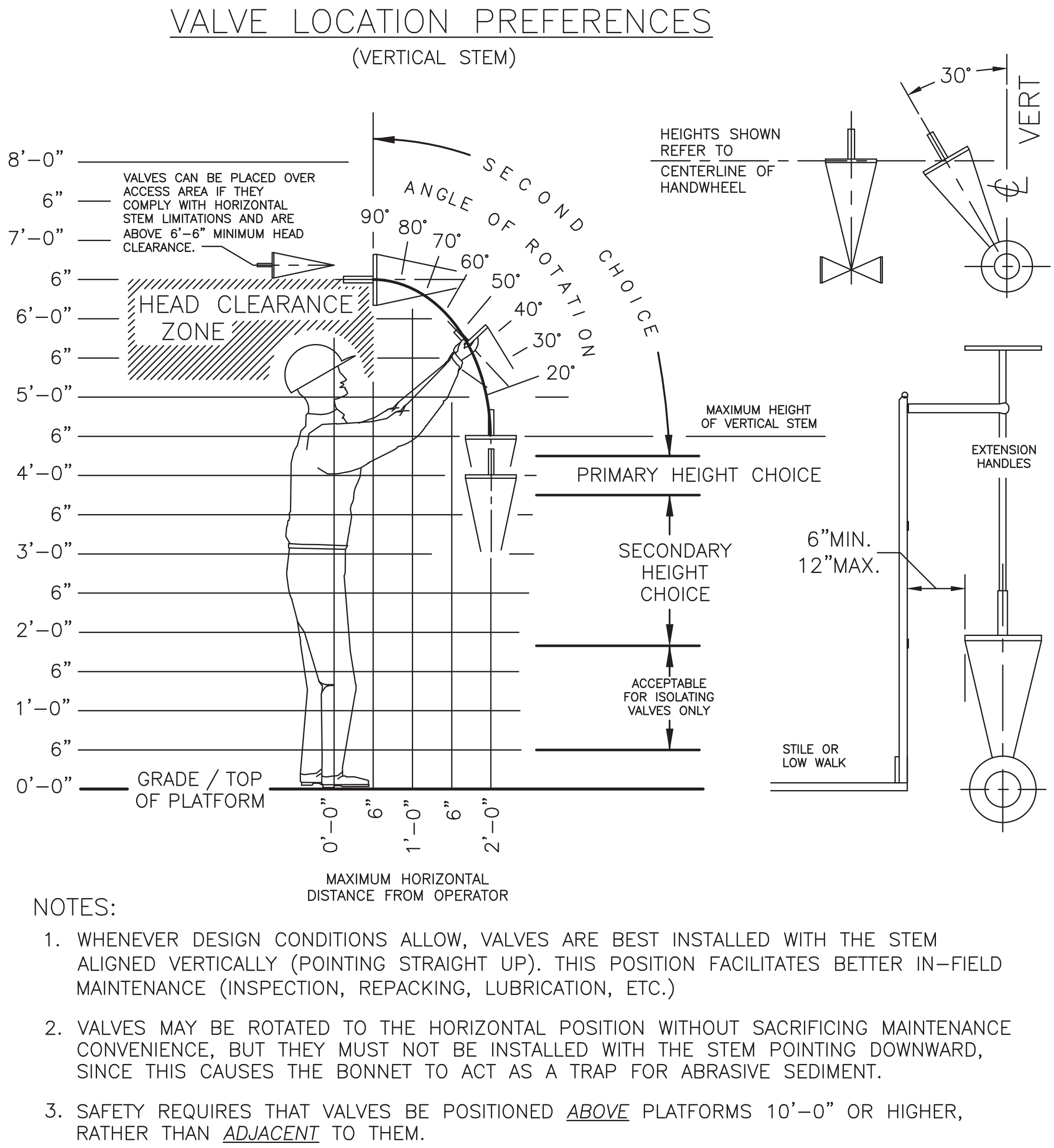


FIGURE 5.24 Valve location preferences with vertical stem.

valve's handwheel. A looped chain is passed through the sprocket and is hung down to a height that is accessible by a worker. This allows a worker to operate the valve without the aid of a ladder or moveable scaffold. Figure 5.25 shows a typical chain operator.

Actuators

Automatic operators known as *actuators* use an external power supply to provide the necessary force required to operate valves. Automatic actuators use hydraulic, pneumatic, or electrical power as their source for operating valves. Hydraulic and pneumatic actuators use fluid or air pressure, respectively, to operate valves needing linear or quarter-turn movements. Electric actuators have motor drives that operate valves requiring multiple turn movements.

Automatic actuators are often provided on control valves that require frequent throttling or those found in remote and inaccessible locations within a piping facility.

FIGURE 5.25 Valve chain operator.

Another common application for automatic actuators is on control valves of large diameter pipe. These valves are often so large that a worker simply cannot provide the torque required to operate the valve. Also, in an effort to protect workers, control valves located in extremely toxic or hostile environments are outfitted with automatic actuators. Additionally, in emergency situations, valves that must be immediately shut down are operated automatically. Figure 5.26 shows a diaphragm-style valve actuator. Notice it is attached to a double-port, globe valve body, which makes throttling possible.

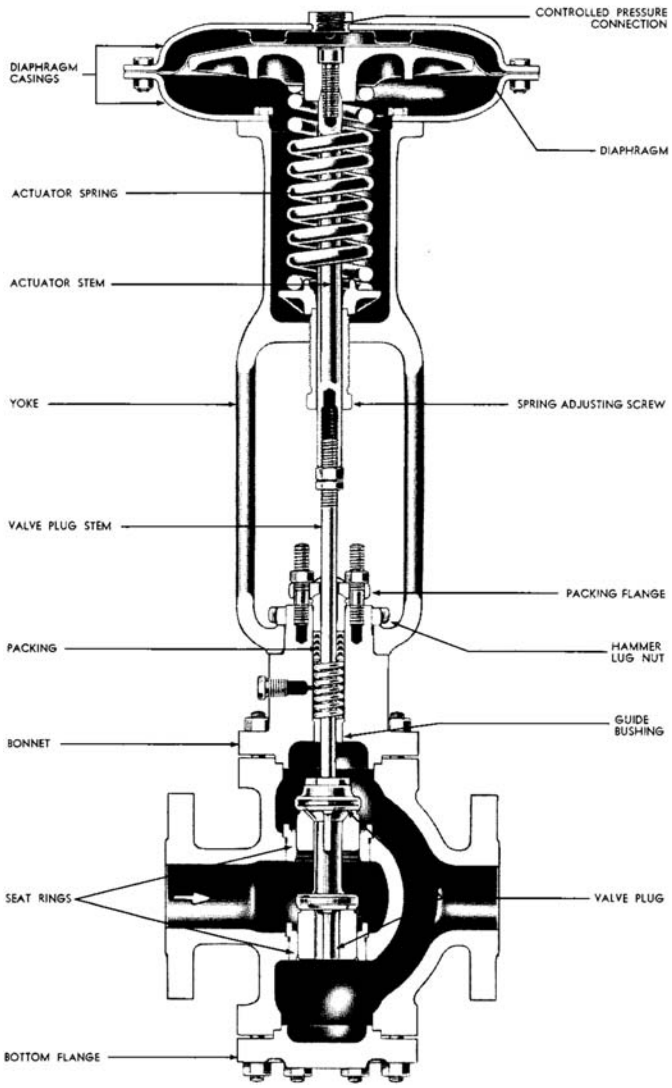


FIGURE 5.26 Valve actuator. *Courtesy of Fisher Controls.*

CHAPTER 5 REVIEW QUIZ

1. What is a valve?

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____

2. Name four end preparations for manufactured valves.

____

____

____

____

3. What is the primary application for gate valves?

____

4. What phrase describes a valve's length measurement?

____

5. What can be used to approximate the distance a stem will rise above a handwheel?

____

6. Globe valves are used for what service situation?

____

7. When using angle valves, in which direction must the flow be traveling when it enters the valve?

____

8. What is the purpose of a check valve?

____

9. Which valve prevents excessive pressure on gas and vapor service line?

____

10. What type of device is used to operate valves installed in remote locations of a piping facility?

____

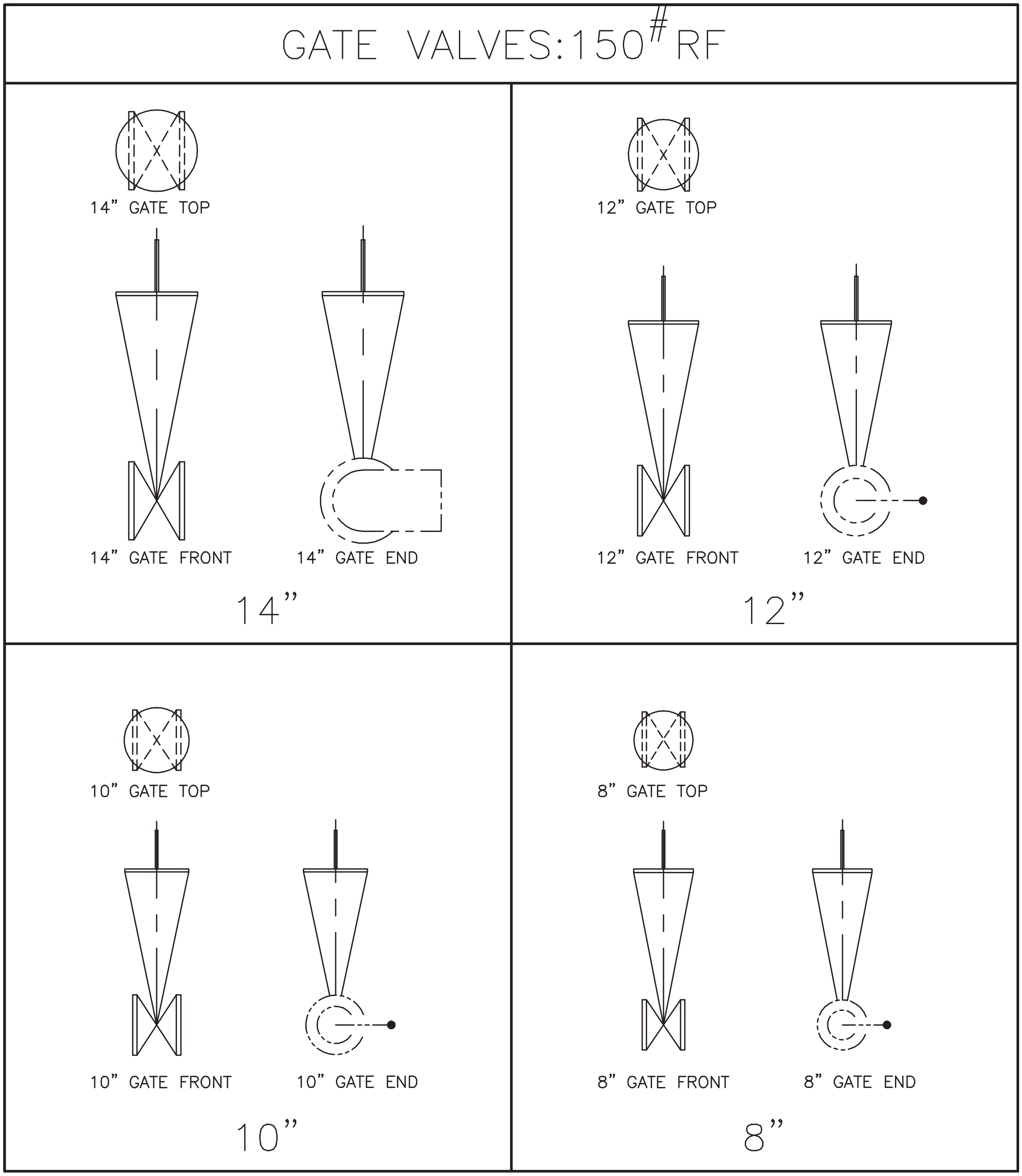
EXERCISE INFORMATION

The valves depicted in Figure 5.27a and b will be used to complete the exercises in this chapter and Chapter 10, Piping Arrangement Drawings, Sections, and Elevations. Draw the valve symbols using the following guidelines.

- Draw all valve symbols full size using dimensions from the Welded Fittings-Flanges and Valves dimensioning chart.
- Draw the valve's body, centerline and handwheel bonnet with "default" lineweights.
- Create a BLOCK of each symbol. Use a block name that appropriately describes the valve and its size and pound rating. (DO NOT include text with the blocked symbol)
- Place a *base point* on either end of the *"bowtie-shape"* symbols and in the center of *"end-view"* symbols using either *MIDpoint* or *CENter* **OSNAP** options.
- **SAVE** the file as "*VALVE SYMBOLS.dwg*."

After the symbols have been created and the drawing saved, begin a **NEW** drawing and use *AutoCAD Design Center* or the **INSERT** command to place the required valve symbols in their appropriate locations to reproduce Exercises 5.1, 5.2, and 5.4.

Solve for the missing dimensions using the required dimensioning charts to complete



(a)

FIGURE 5.27 (a and b) Valve drawing symbols.

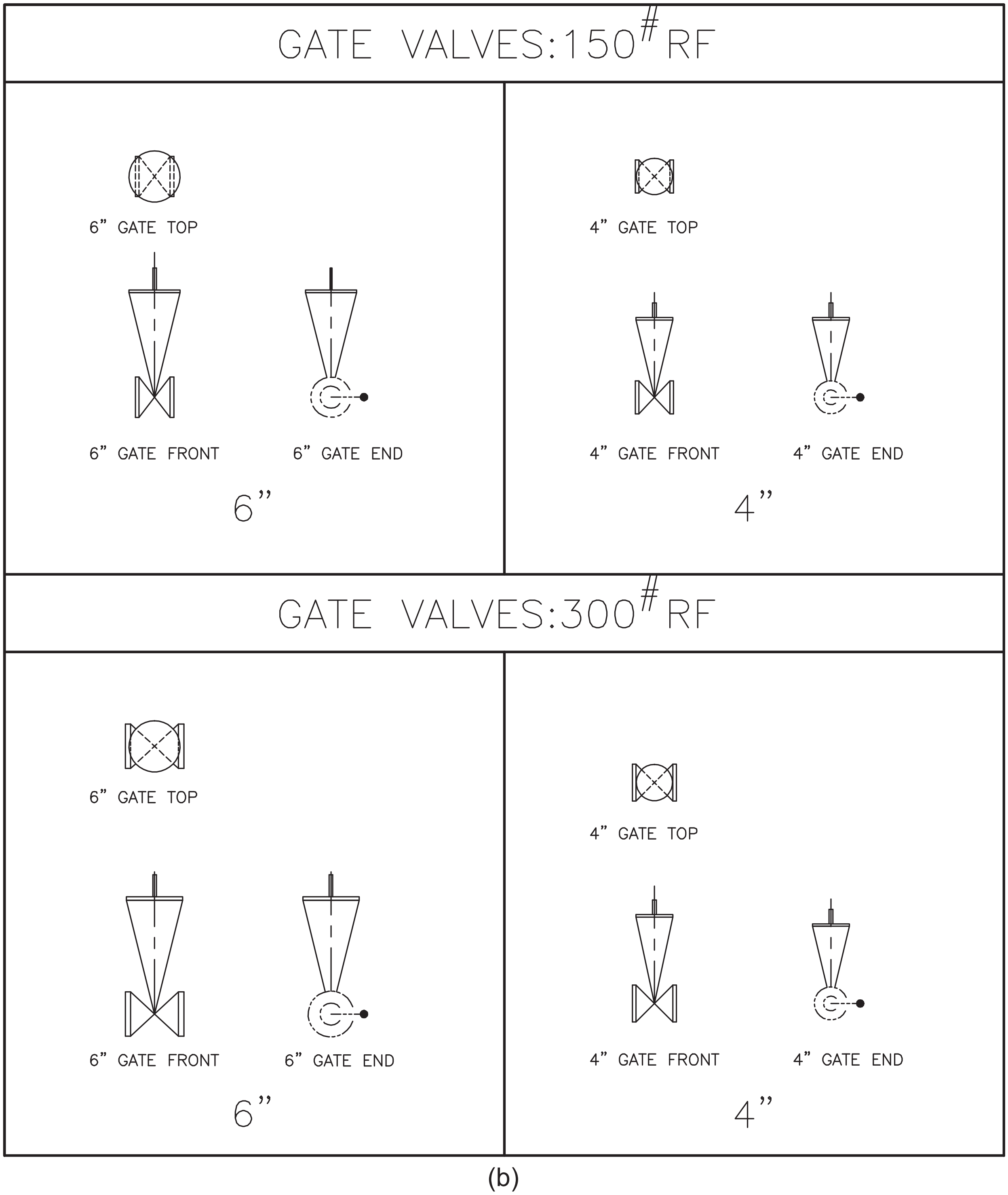
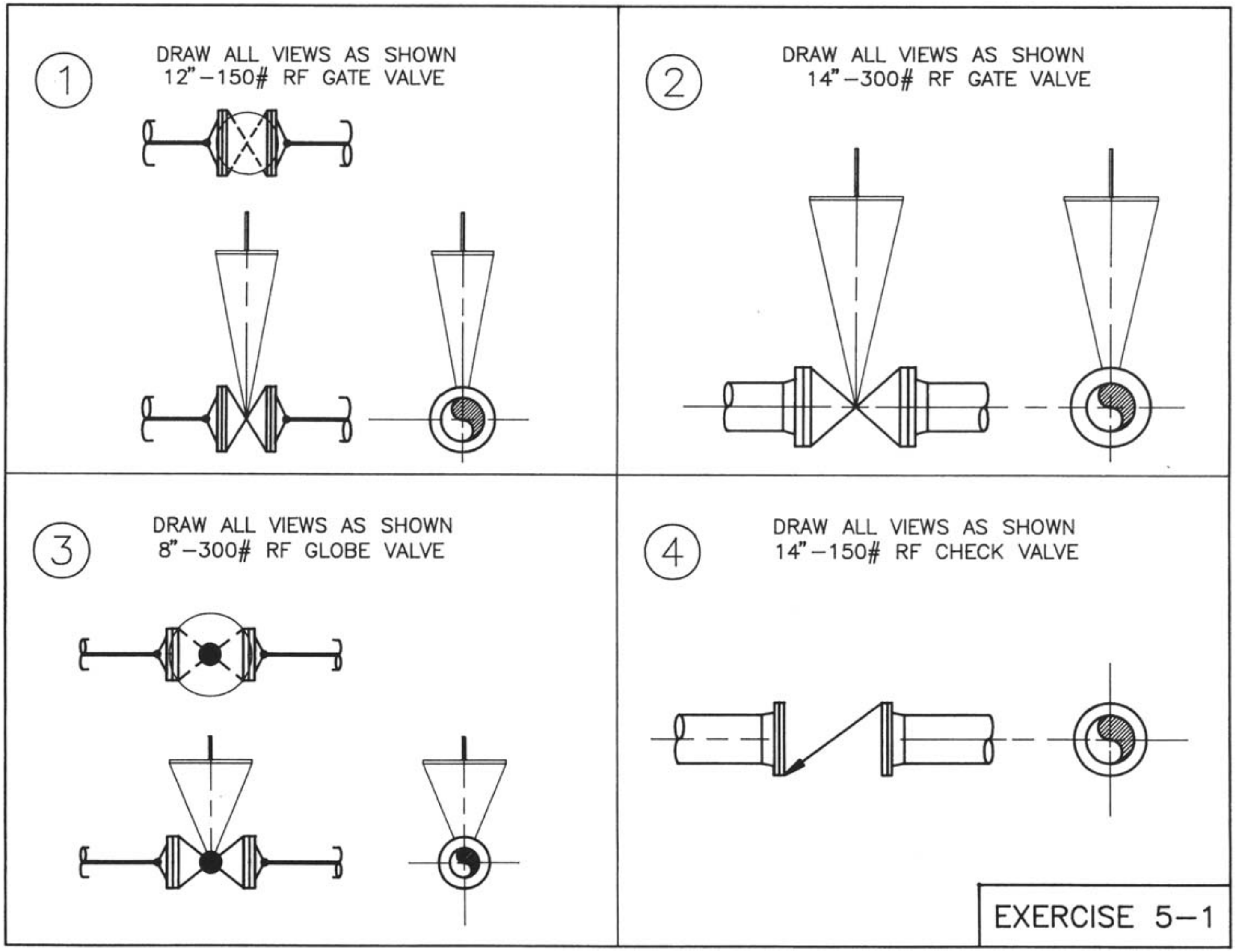


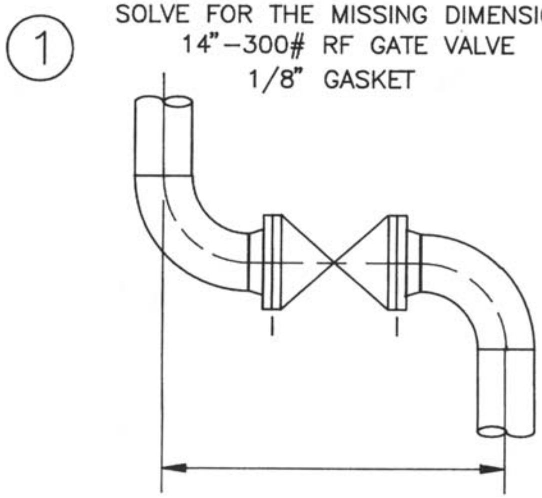
FIGURE 5.27 *(Continued)*

CHAPTER 5 DRAWING EXERCISES

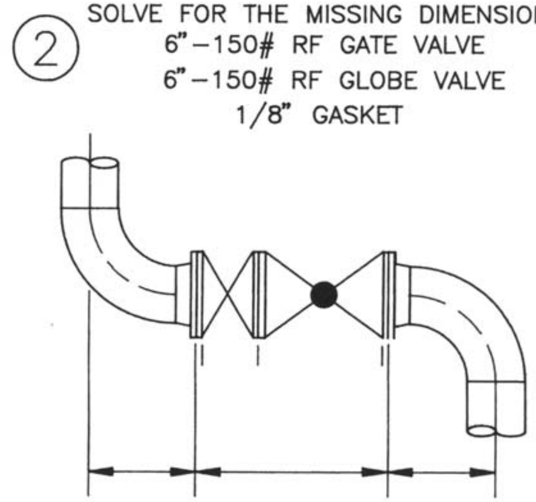
Drawing Valves



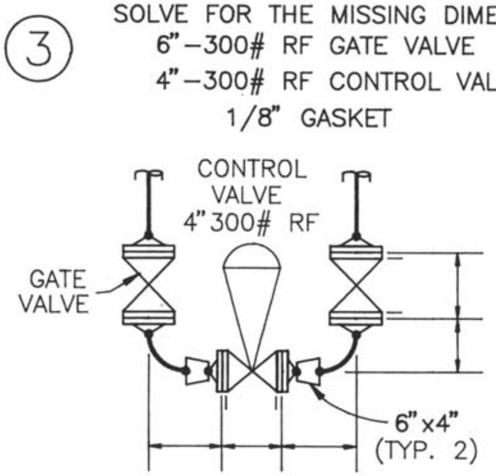
SOLVE FOR THE MISSING DIMENSIONS
14"-300# RF GATE VALVE
1/8" GASKET



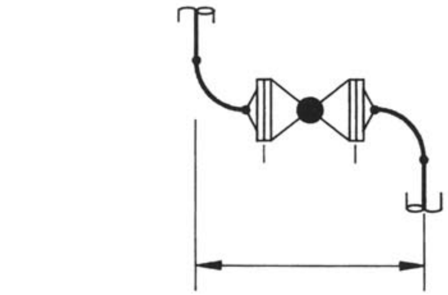
SOLVE FOR THE MISSING DIMENSIONS
6"-150# RF GATE VALVE
6"-150# RF GLOBE VALVE
1/8" GASKET



SOLVE FOR THE MISSING DIMENSIONS
6"-300# RF GATE VALVE
4"-300# RF CONTROL VALVE
1/8" GASKET



SOLVE FOR THE MISSING DIMENSIONS
8"-300# RF GLOBE VALVE
1/8" GASKET

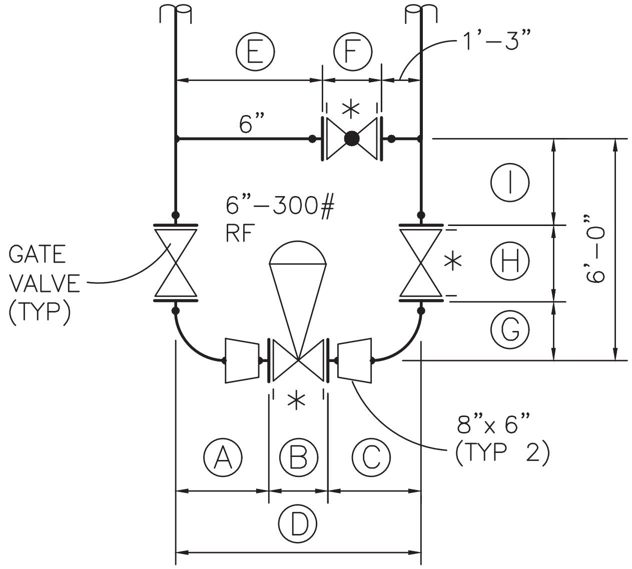


EXERCISE 5-2

① Solve for the missing dimensions

- 8"–150# GATE (BLOCK) VALVE RF
- 6"–150# GLOBE (BYPASS) VALVE RF
- 6"–300# CONTROL VALVE RF

* All gaskets 1/8" thick.



A= ?

B= ?

C= ?

D= ?

E= ?

F= ?

G= ?

H= ?

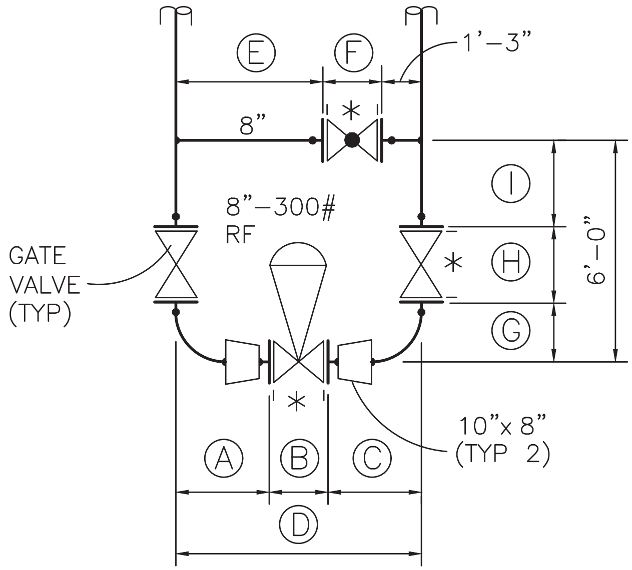
I= ?

E=(D)–(F+1'–3")

I=(6'–0")–(G+H)

② Solve for the missing dimensions

- 10"–150# GATE (BLOCK) VALVE RF
- 8"–150# GLOBE (BYPASS) VALVE RF
- 8"–300# CONTROL VALVE RF



A= ?

B= ?

C= ?

D= ?

E= ?

F= ?

G= ?

H= ?

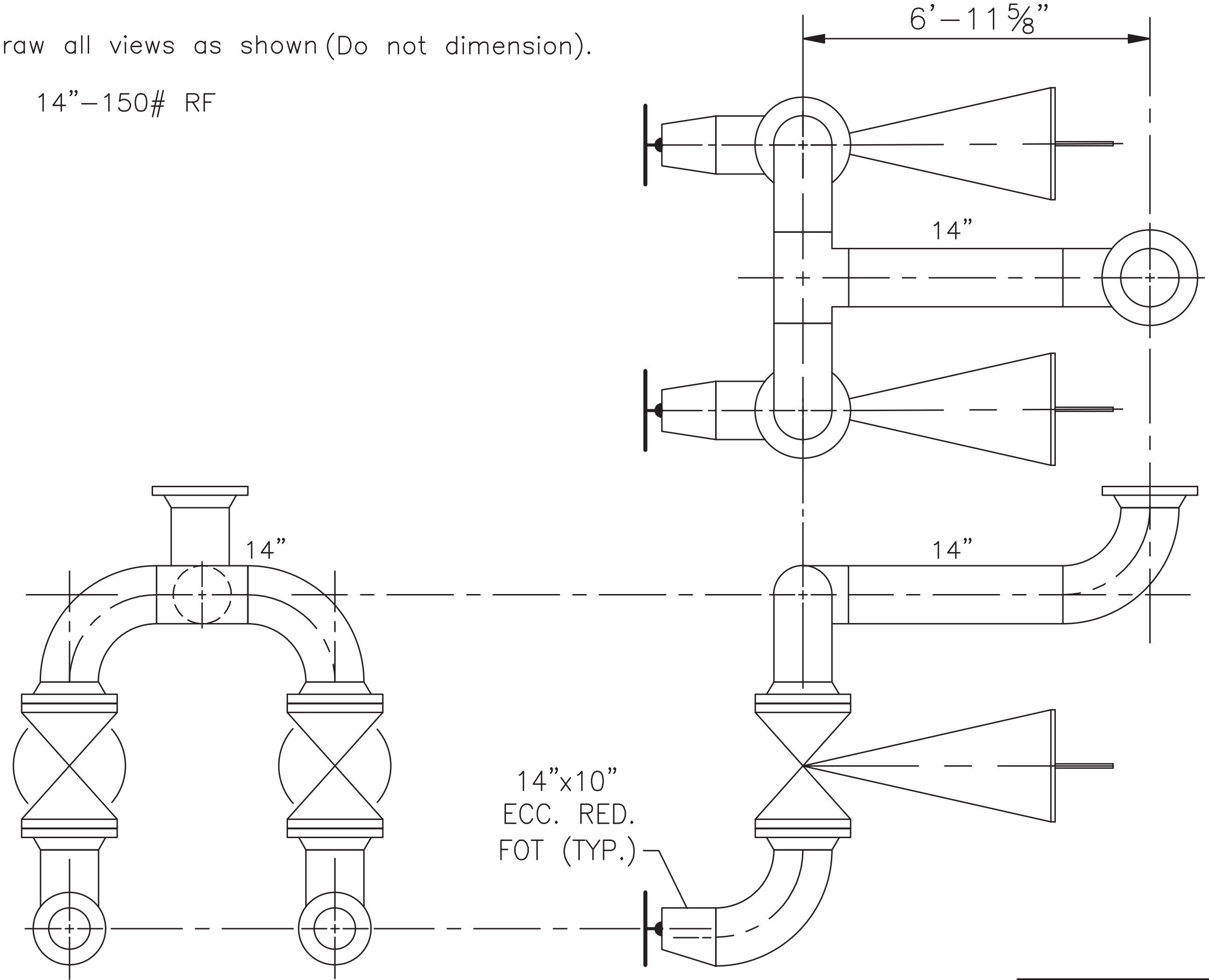
I= ?

E=(D)–(F+1'–3")

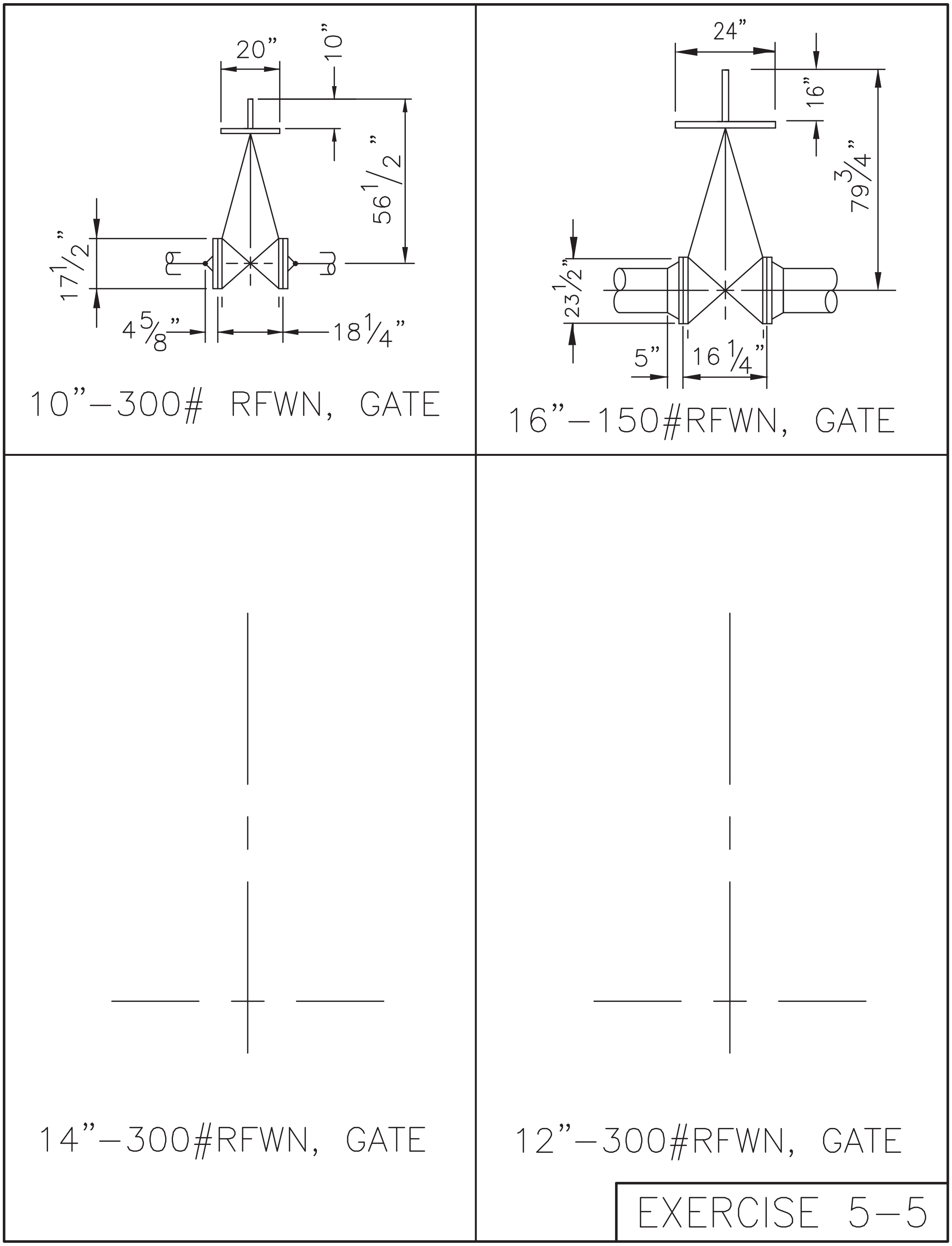
I=(6'–0")–(G+H)

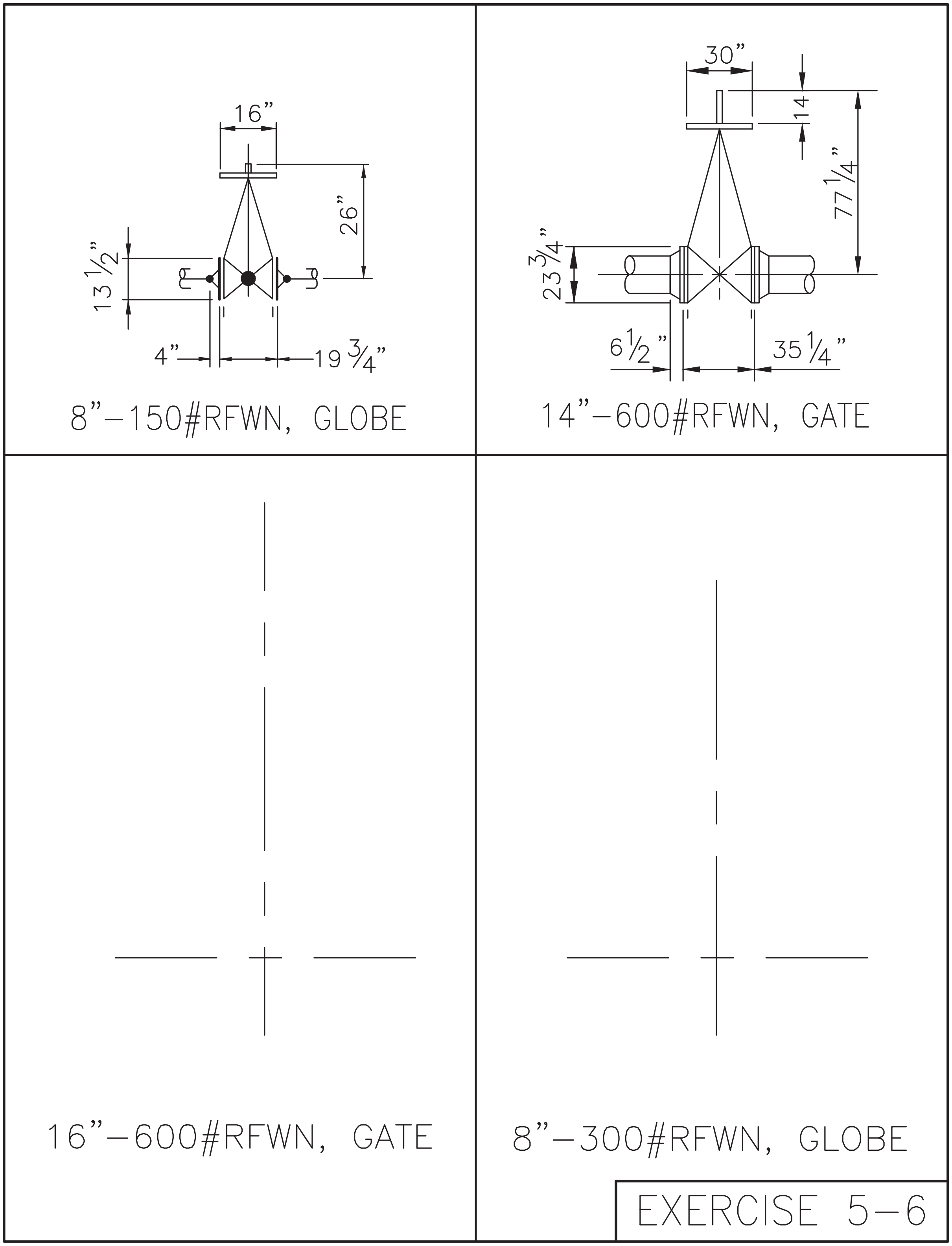
Draw all views as shown (Do not dimension).

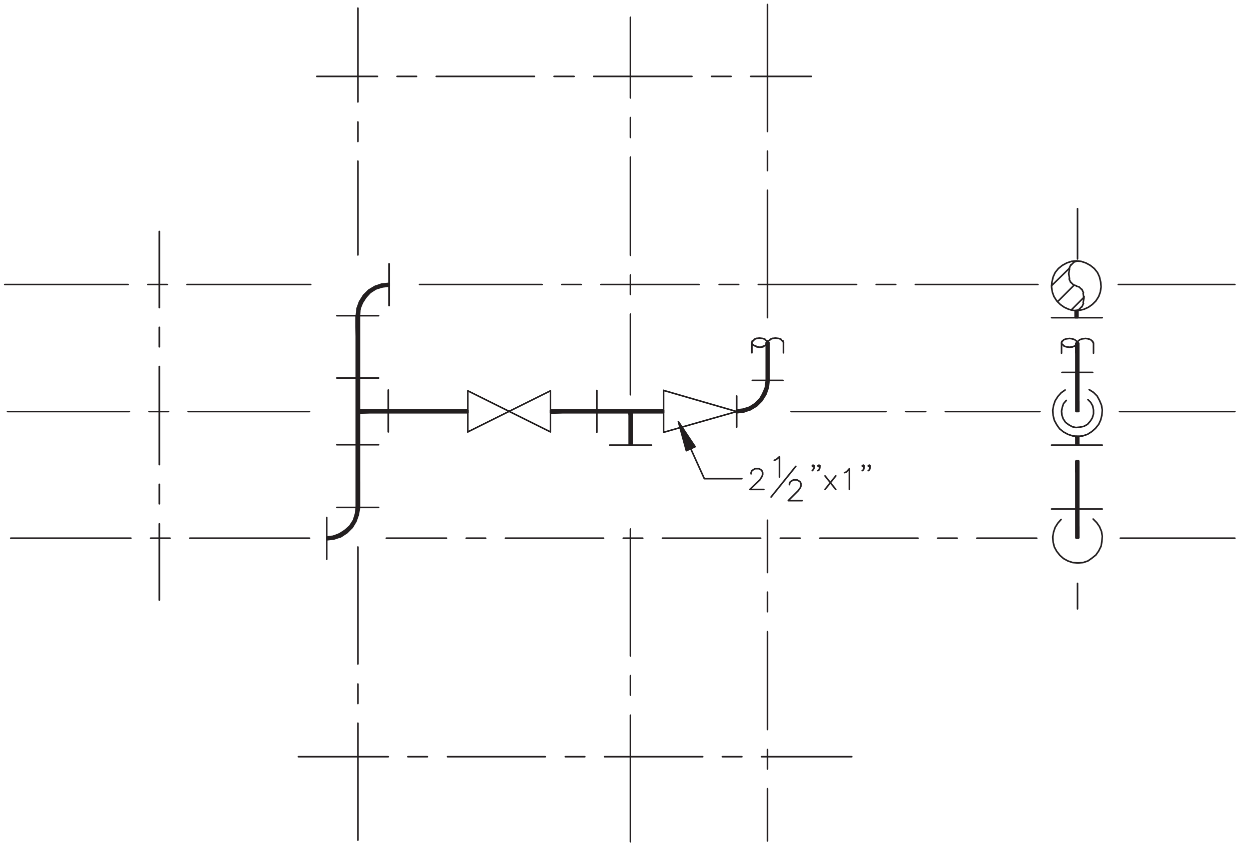
- 14"–150# RF



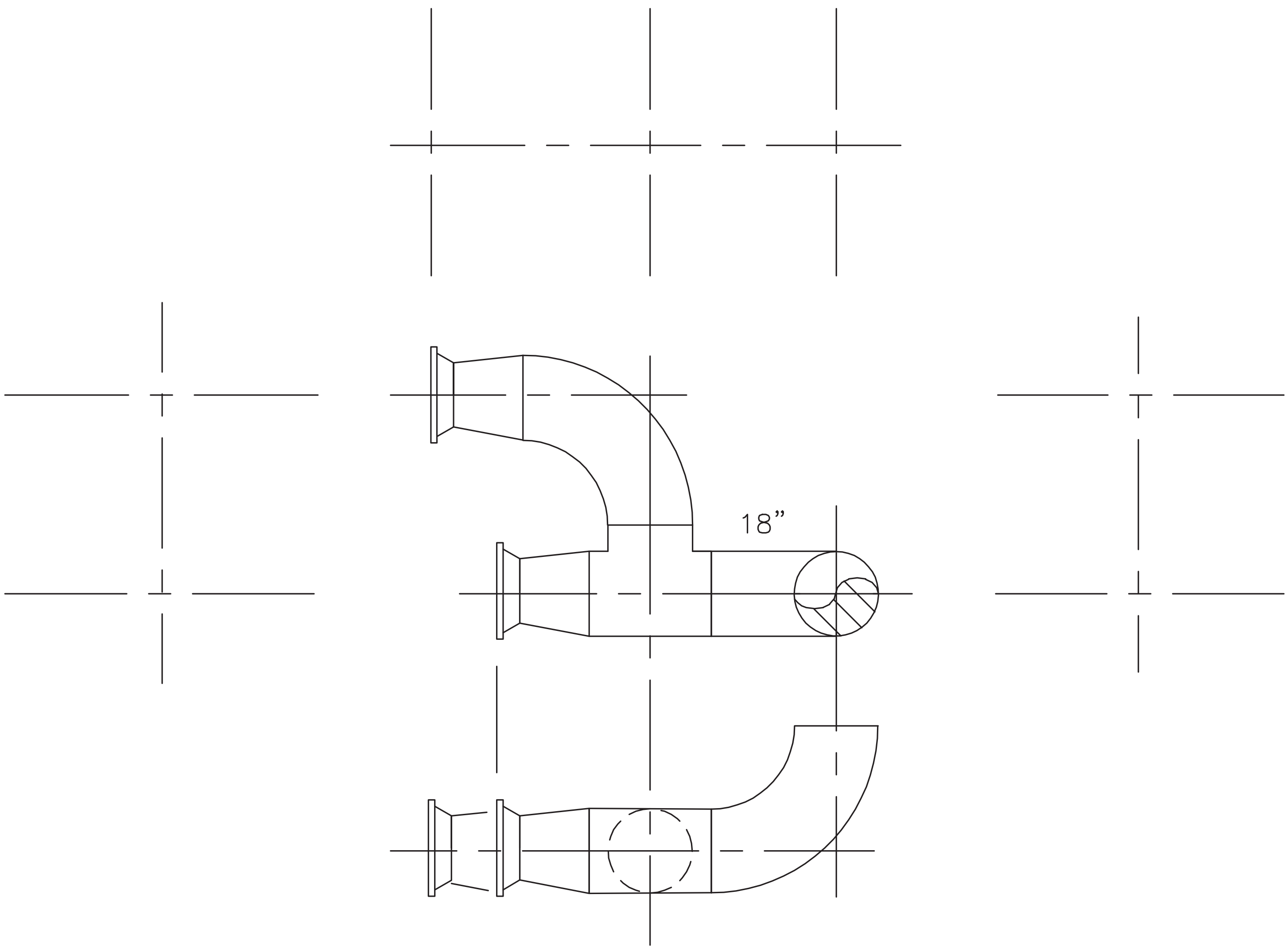
EXERCISE 5–4


20"
10"
56 1/2"
17 1/2"
4 5/8"
18 1/4"
10"–300# RFWN, GATE
24"
16"
79 3/4"
23 1/2"
5"
16 1/4"
16"–150#RFWN, GATE
14"–300#RFWN, GATE
12"–300#RFWN, GATE
EXERCISE 5–5

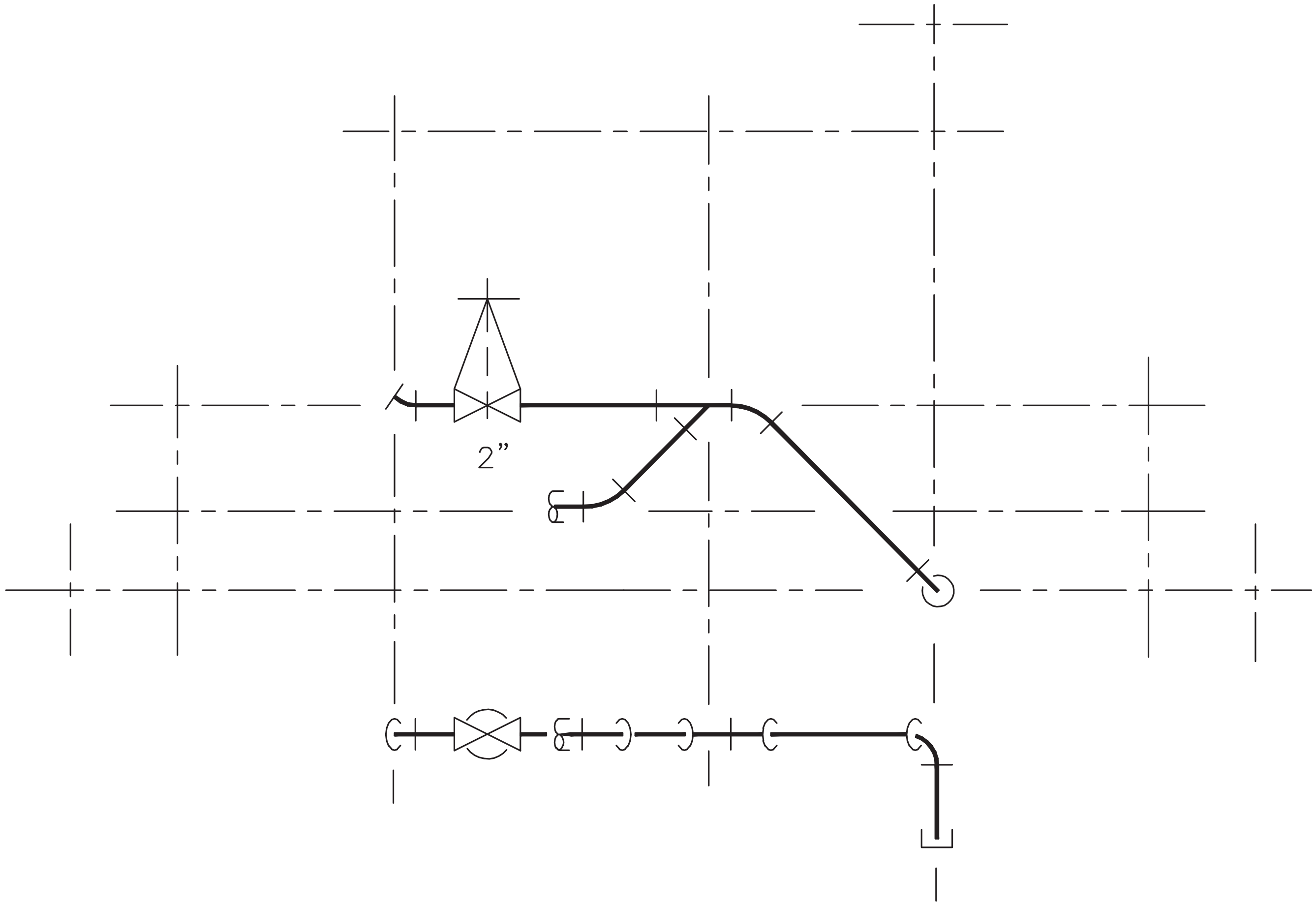

16"
26"
13 1/2"
4"
19 3/4"
8"–150#RFWN, GLOBE
30"
14
77 1/4"
23 3/4"
6 1/2"
35 1/4"
14"–600#RFWN, GATE
16"–600#RFWN, GATE
8"–300#RFWN, GLOBE
EXERCISE 5–6



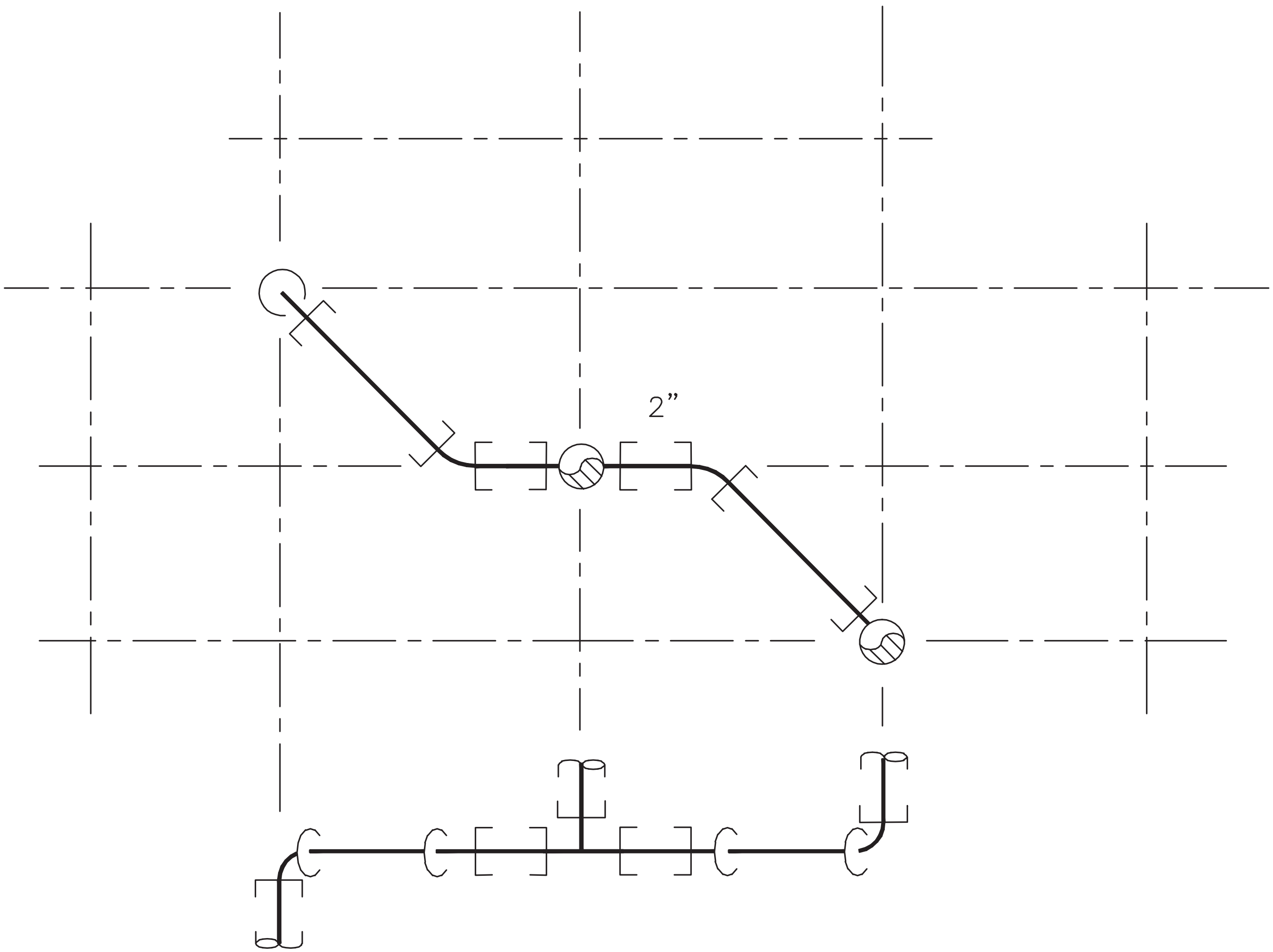
EXERCISE 5-7



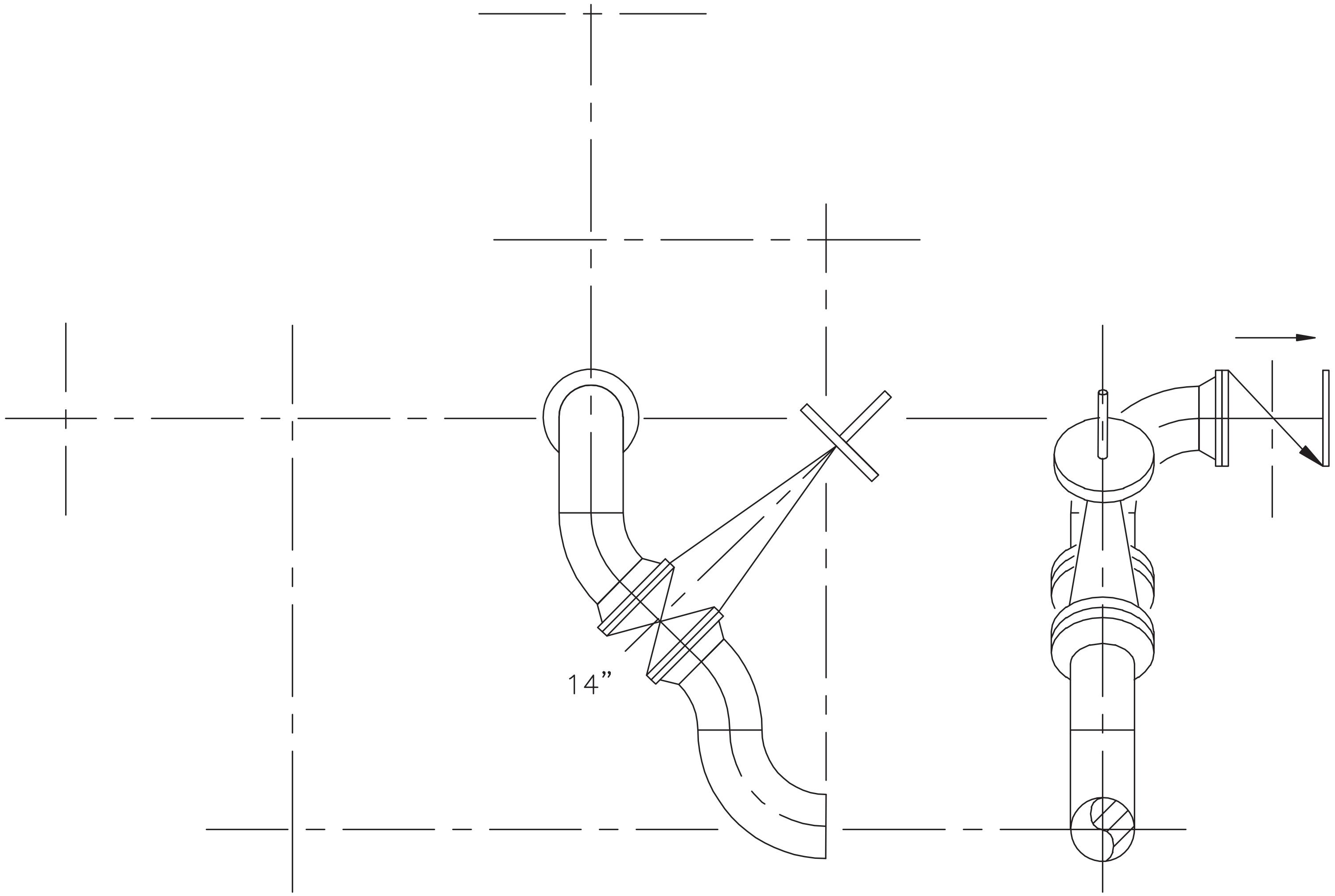
EXERCISE 5-8



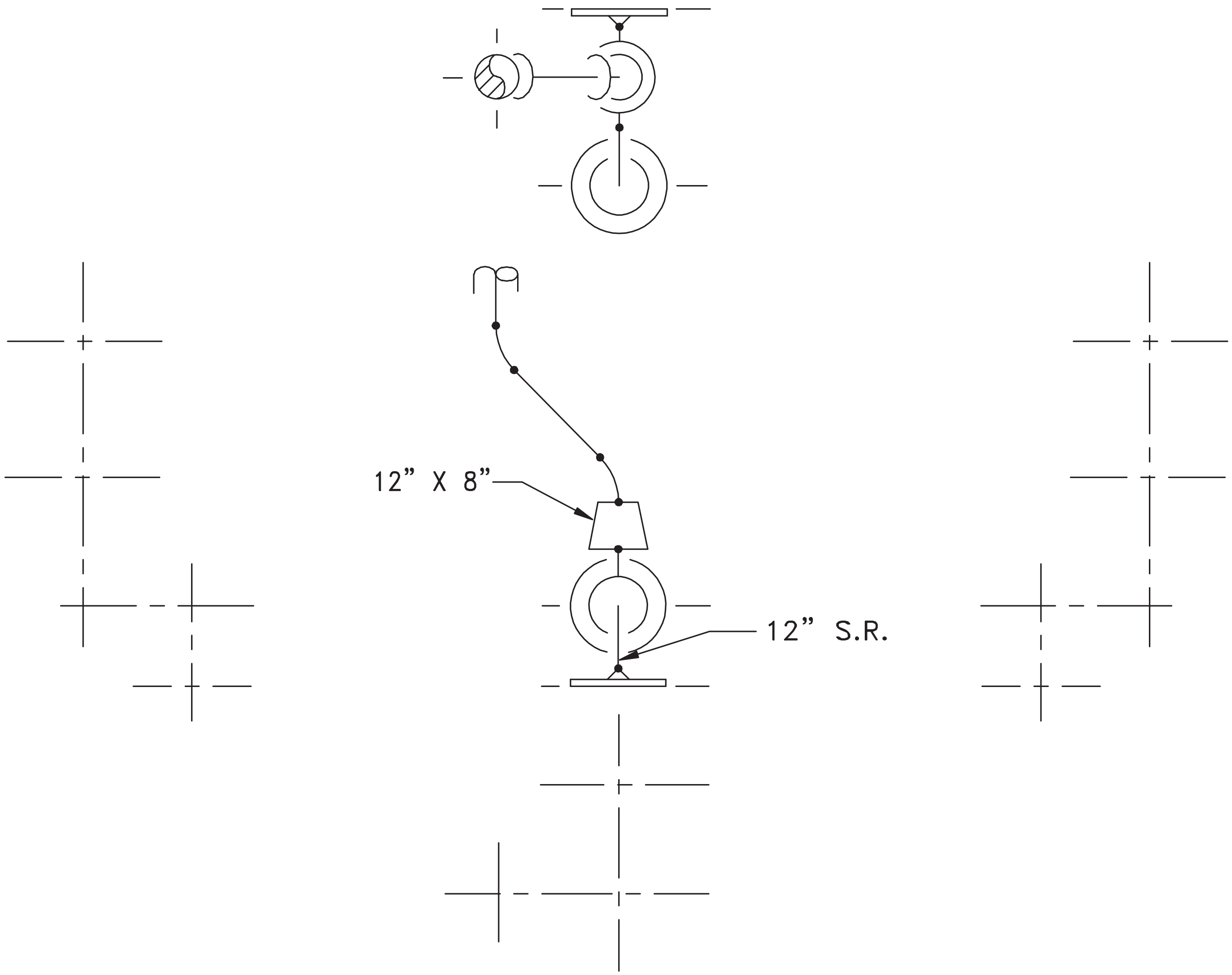
EXERCISE 5–9



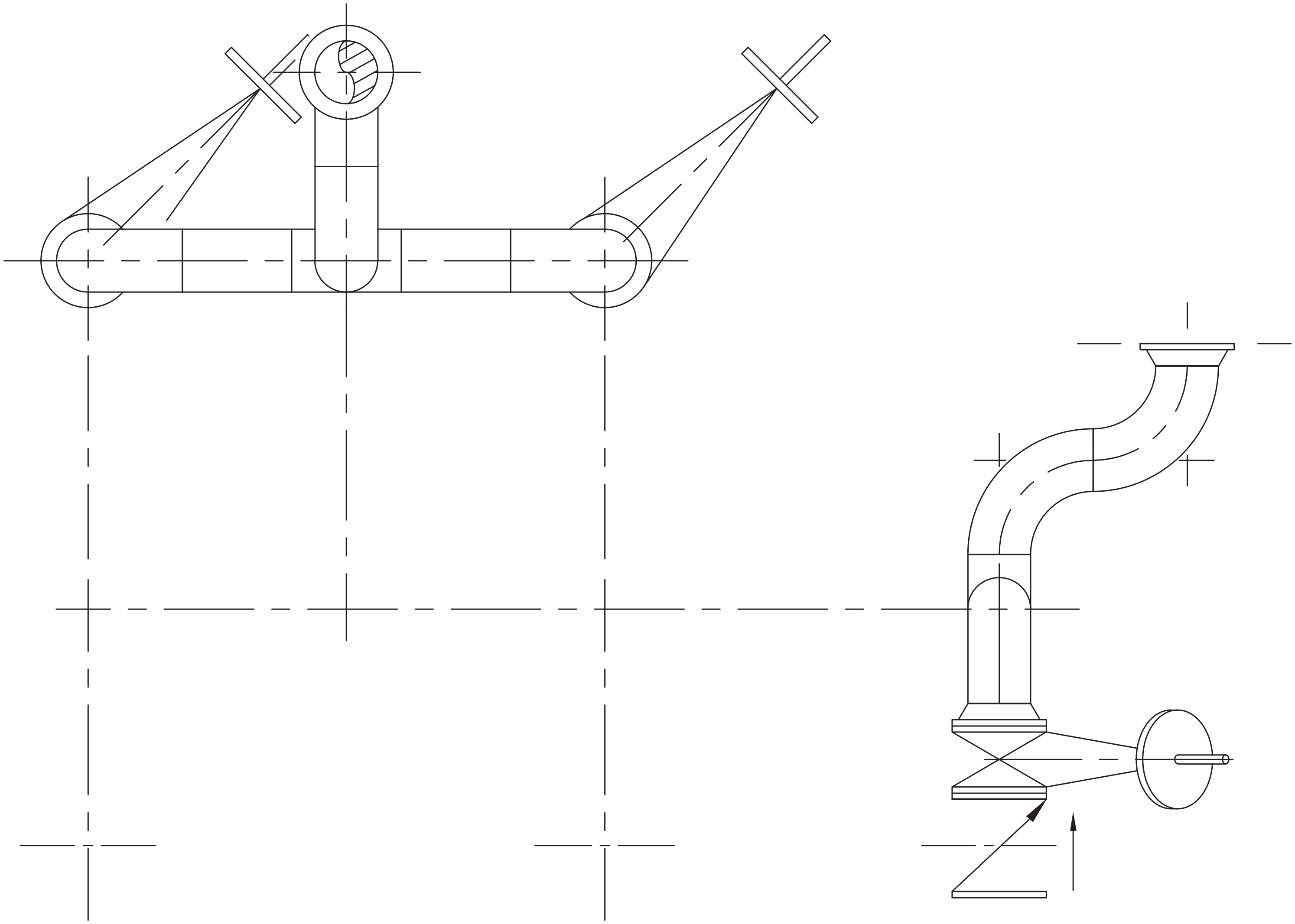
EXERCISE 5–10



EXERCISE 5–11



EXERCISE 5–12



EXERCISE 5–13

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CHAPTER

6

Mechanical Equipment

TYPES OF EQUIPMENT

Although piping components such as fittings, flanges, and valves are important and indispensable in a process facility, they play a minor role in the actual manufacturing of a salable product. More specialized, and sometimes proprietary, components of a piping facility actually perform the tasks for which the facility is being built. Collectively, those specialized components are known as *mechanical equipment*.

Mechanical equipment can be used to start, stop, heat, cool, liquefy, purify, distill, refine, vaporize, transfer, store, mix, or separate the commodity flowing through the piping system. The discussion in this chapter will concentrate on the common pieces of equipment used in a majority of all chemical and refining facilities.

Vessels

Horizontal Vessels/Accumulators

The horizontal vessel, similar to the one shown in Figure 6.1, is a cylindrical-shaped storage tank that is installed in a facility with its long axis parallel to the horizon. Also known as an *accumulator*, it is used primarily as a receiving and collecting container for liquids and/or gaseous vapors and therefore has no internal moving parts. Accumulators can be located at Grade level or placed high in an equipment structure. Support saddles, which are U-shaped supports, are welded on the underside to secure and stabilize the vessel as it rests on two concrete foundations, which are located near each end of the vessel. A nozzle on the top of the vessel allows liquids to enter and fill the vessel. Another nozzle, coming off the bottom, allows the liquids to be drawn out. Smaller nozzles are positioned that are used for venting, draining, and instrumentation attachment. To be discussed in Chapter 7, Flow Diagrams and Instrumentation, specialized monitoring instruments are needed to measure the level and pressure of the commodity within the vessel. Lastly, a large diameter nozzle, typically 18″ ID, called a *manway or manhole*, provides an entrance into the vessel for a worker who must perform internal inspection and/or maintenance. The rendering in Figure 6.2 represents a view into the interior of a horizontal vessel.

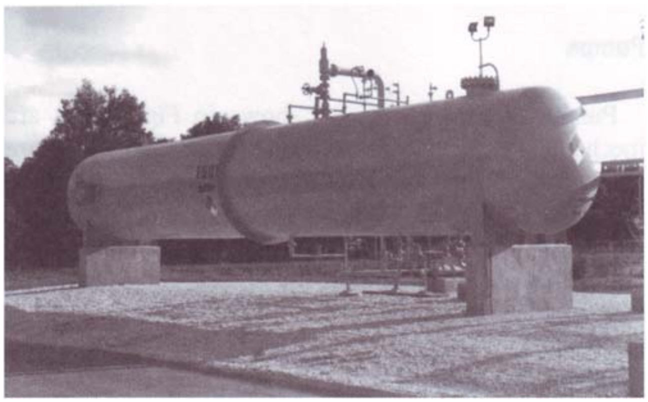


FIGURE 6.1 Horizontal vessel. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

In Figure 6.3 the symbols for the Plan and Elevation views of a typical horizontal vessel, as it would appear on piping drawings, are shown. Figure 6.4 provides a partial view of the Unit-01 Piping Arrangement drawing. For clarity purposes only the horizontal vessel in highlighted with a heavier lineweight.

Vertical Vessels/Fractionation Columns/Reactors

The vertical vessel is a cylindrical vessel whose long axis is perpendicular to the horizon (see Figure 6.5). Easily one of the most visible pieces of equipment, some vertical vessels can exceed 200 ft in height. Configured as a *Fractionation column*, these vertical vessels have internal plates called *trays* which aid in the

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00011-X

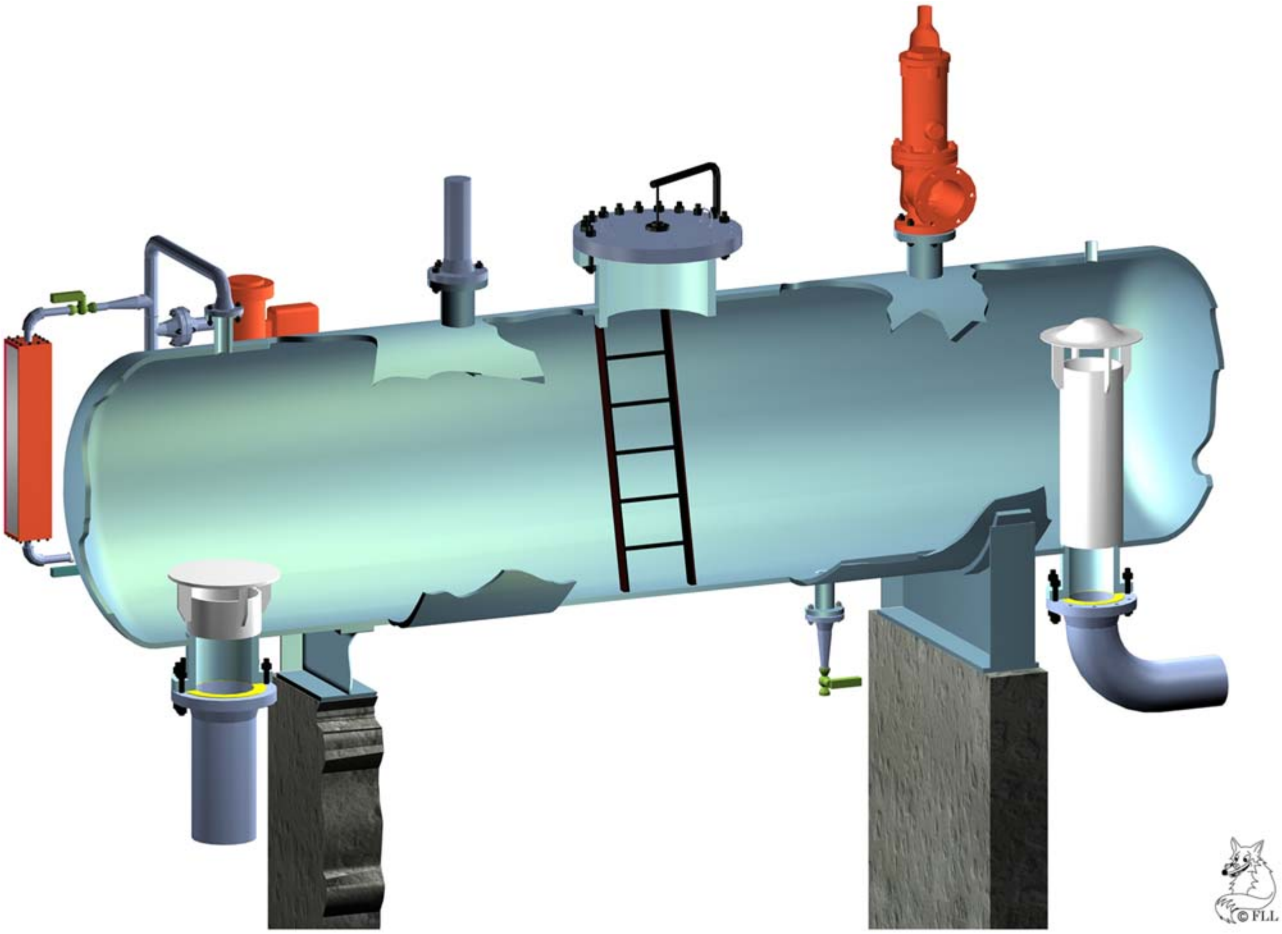


FIGURE 6.2 Interior view of a horizontal vessel.

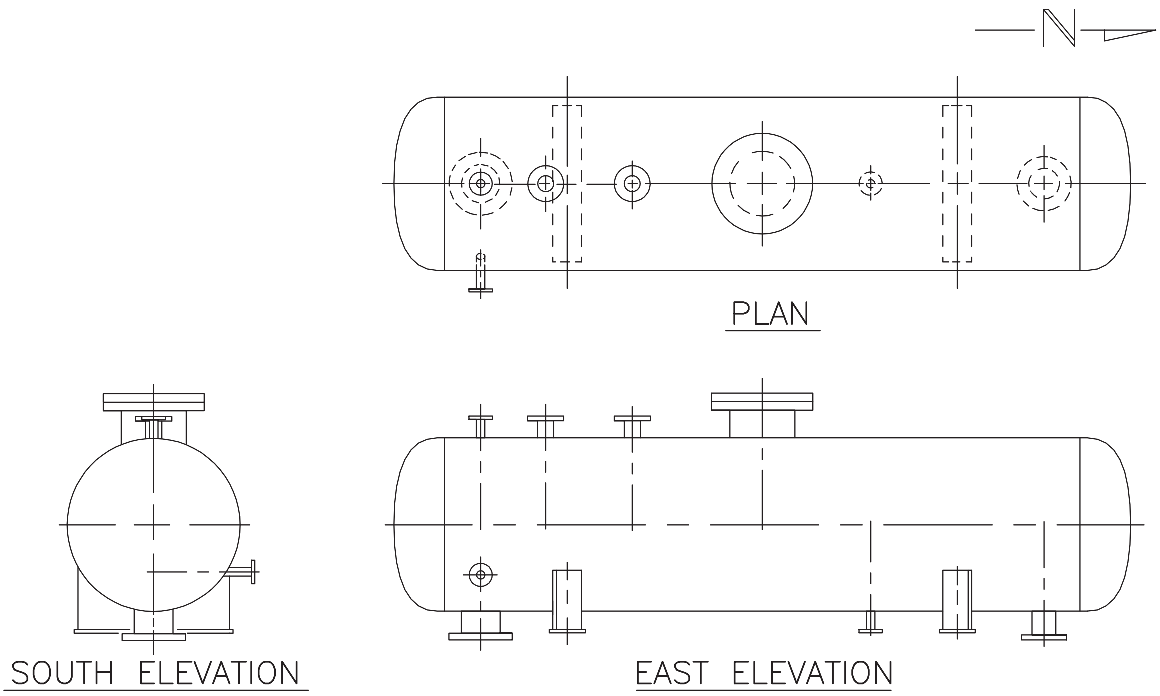


FIGURE 6.3 Plan and elevation views of a horizontal vessel.

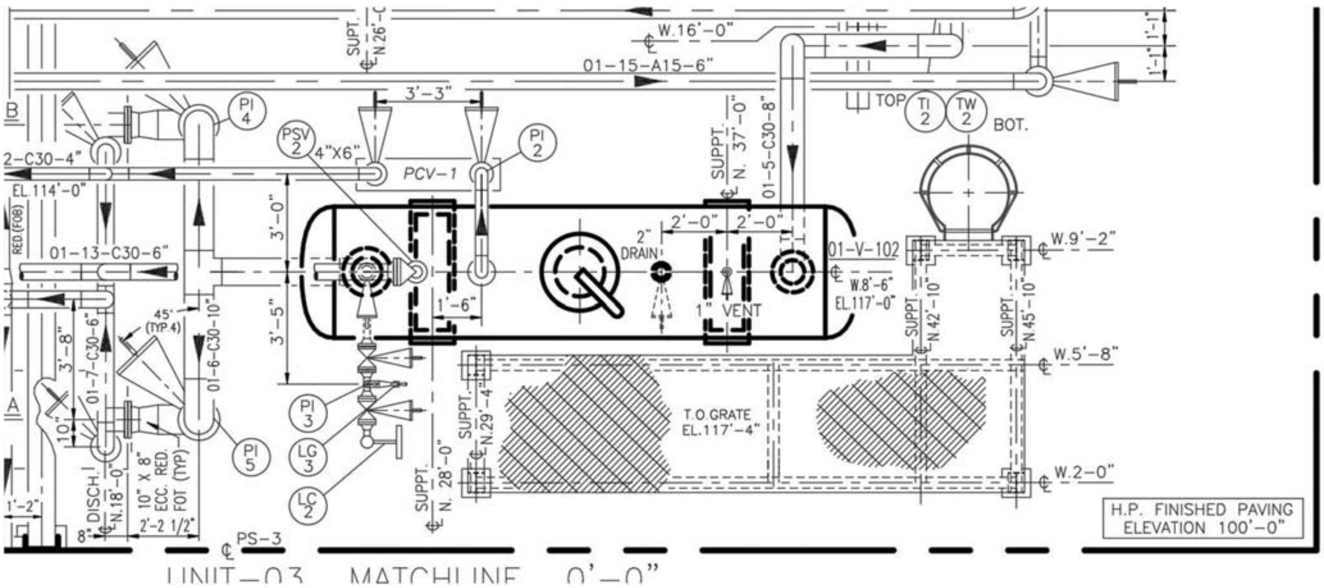


FIGURE 6.4 Highlighted plan-view representation of a horizontal vessel.

FIGURE 6.5 Vertical vessel. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

refining and collection of the various molecular compounds of a feed stock. The process of refining, more precisely, the breaking down of a feed stock into its various molecular compounds is called *fractional distillation*. Distillation elicits only a physical change in a commodity, not a chemical one. After further refinement and processing, these compounds will become salable commodities such as fuels, plastics, and many other essential products. A detailed explanation of the fractional distillation process will be presented later in this chapter.

Reactors, through the introduction of a reagent or catalyst, change the chemical composition of a commodity. Typically, much larger in size than a fractionation column, reactors can be housed in large, steel frame-work structures. Being the primary piece of equipment in a more volatile process, reactors are more closely monitored than fractionation columns because of the higher temperatures and pressures they operate under.

In Figure 6.6 the symbols for the Plan and Elevation views of a typical vertical vessel, as it would appear on piping drawings, are shown. Figure 6.7 provides a partial view of the Unit-01 Piping Arrangement drawing with the vertical vessel highlighted with a heavier lineweight, for clarity purposes. In the example shown the vertical vessel is so tall it requires a secondary view (to the right, identified as Upper Plan) be included. The Upper Plan represents the appearance of the vertical vessel above 135′-0″.

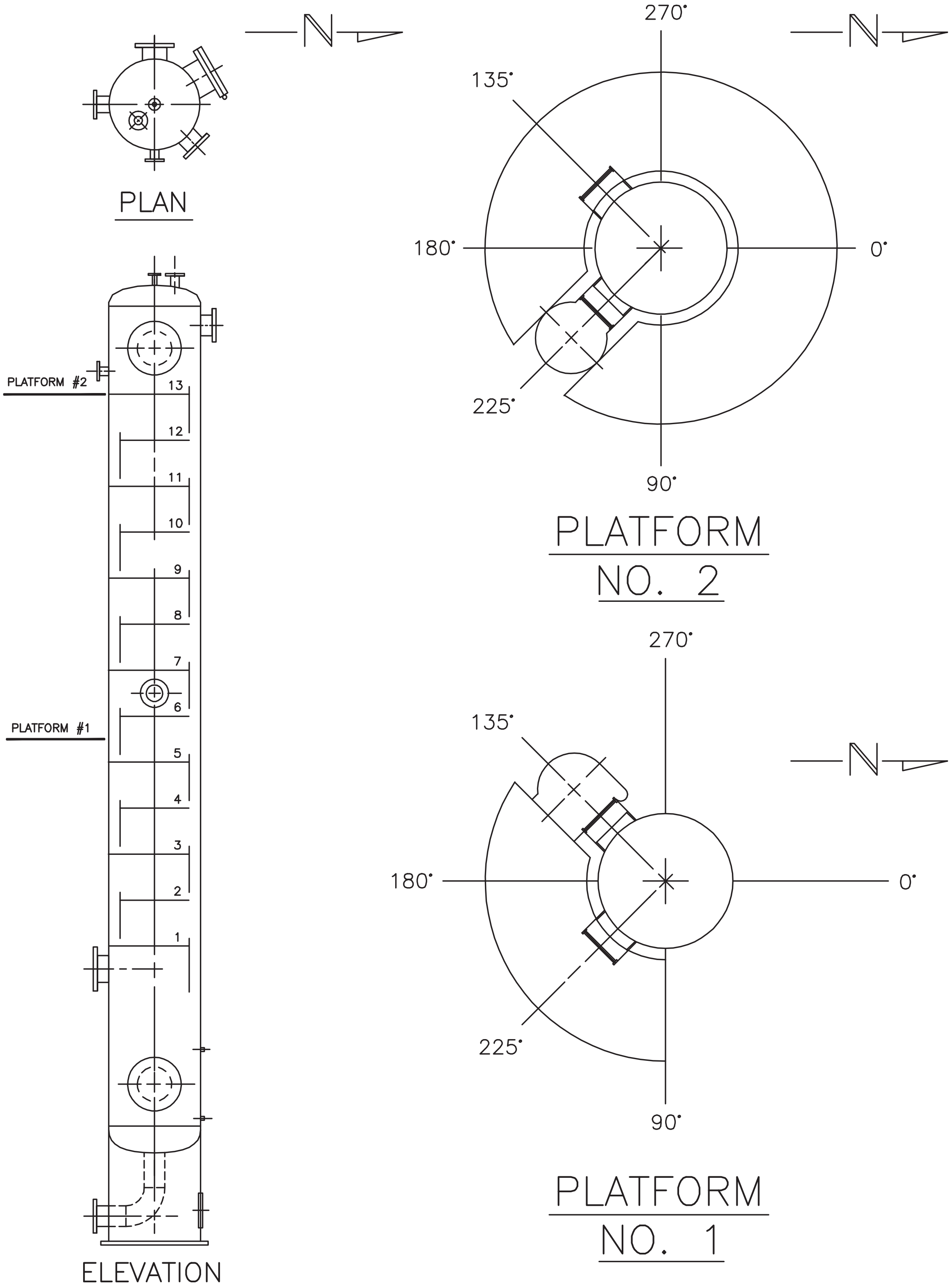


FIGURE 6.6 Plan and elevation views of a vertical vessel with platform orientations.

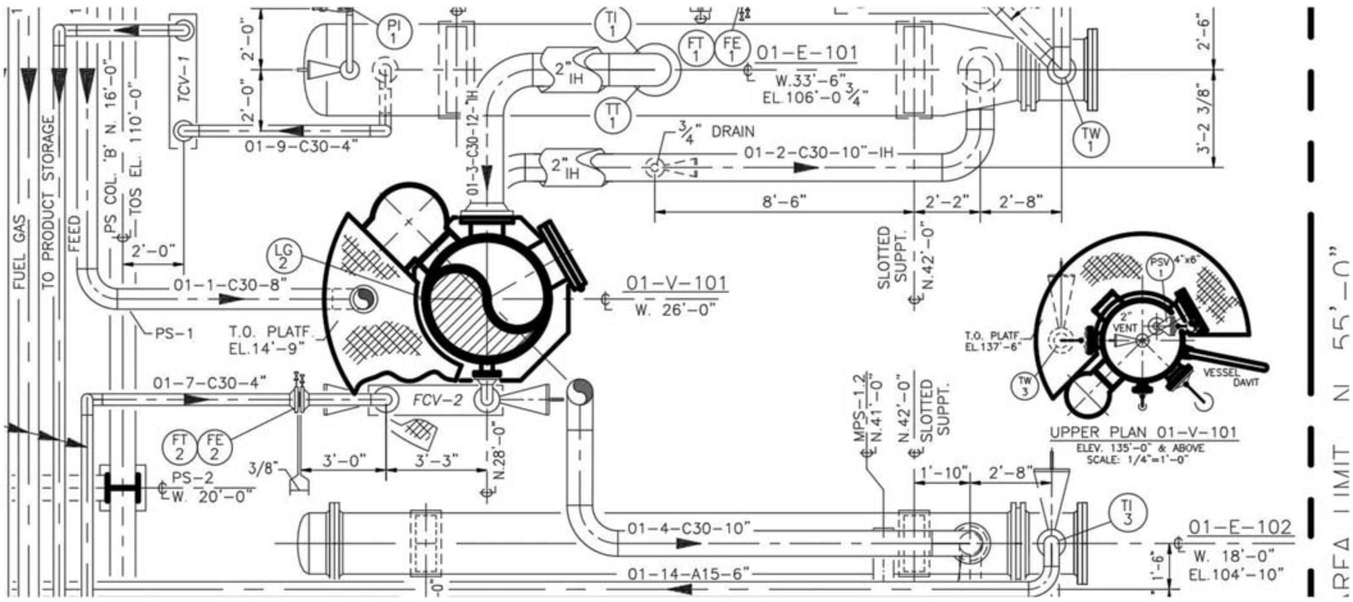


FIGURE 6.7 Highlighted plan-view representation of a vertical vessel.

Ladders, Cages, and Platforms

Many vessels and other pieces of equipment are built to such heights they are only accessible by ladders. *Ladders* allow workers to access the higher elevations of equipment for routine inspection and maintenance. Ladders are made of steel round and flat bar which are then welded or bolted to the exterior of a vessel.

Cages are designed to enclose a ladder and prevent a worker from falling. Made of steel plate, cages provide the worker with a sense of security when scaling tall structures.

Platforms are like elevated walkways installed around the outside of a vessel or between pieces of equipment. Platforms can be manufactured to meet any required shape but are typically either circular or rectangular (Figure 6.8). Having a minimum width of 3′-0″, they have a floor made of steel grating or "diamond" plate. With handrails that measure 42″ high above their floor and a 4″ tall toe plate, workers can safely operate, inspect, and maintain a vessel. Platforms are spaced so ladders will not have a vertical run of more than 30′-0″ but are not spaced closer than 8′-0″ to provide adequate headroom clearance. Larger platforms can actually become large multilevel structures that provide flooring for equipment needed at higher elevations, as seen in the lower half of Figure 6.5. A typical ladder and cage are shown in Figure 6.9 attached to the side of a vertical storage tank. Platform walkways are also depicted spanning between storage tanks in Figure 6.9.

Pumps

Pumps, similar to the one shown in Figure 6.10, are mechanical devices used to move fluids under pressure from one location to another. Pumps accelerate the speed at which a commodity travels within a pipe, thereby increasing its rate of flow. Pumps used in piping facilities typically will be one of the following classifications: centrifugal, reciprocating, or rotary.

Centrifugal Pumps

The centrifugal force created by the high-speed impellers of a centrifugal pump creates a smooth nonpulsating rate of flow. With a fast spinning impeller creating a low-pressure center point, any commodity entering the pump will naturally seek the center of the impeller only to be spun out at a high rate of speed. The efficient operation of the centrifugal pump makes it the standard of most piping facilities.

Reciprocating Pumps

The reciprocating pump creates pressure with a piston or plunger that alternately move back and forth. With each stroke of the piston, pressure is increased forcing the commodity out of the pump. The reciprocating pump is installed in piping systems where extremely high pressures are required.

Rotary Pumps

The rotary pump is similar to the reciprocating pump in that it is a positive displacement type. Rotary pumps

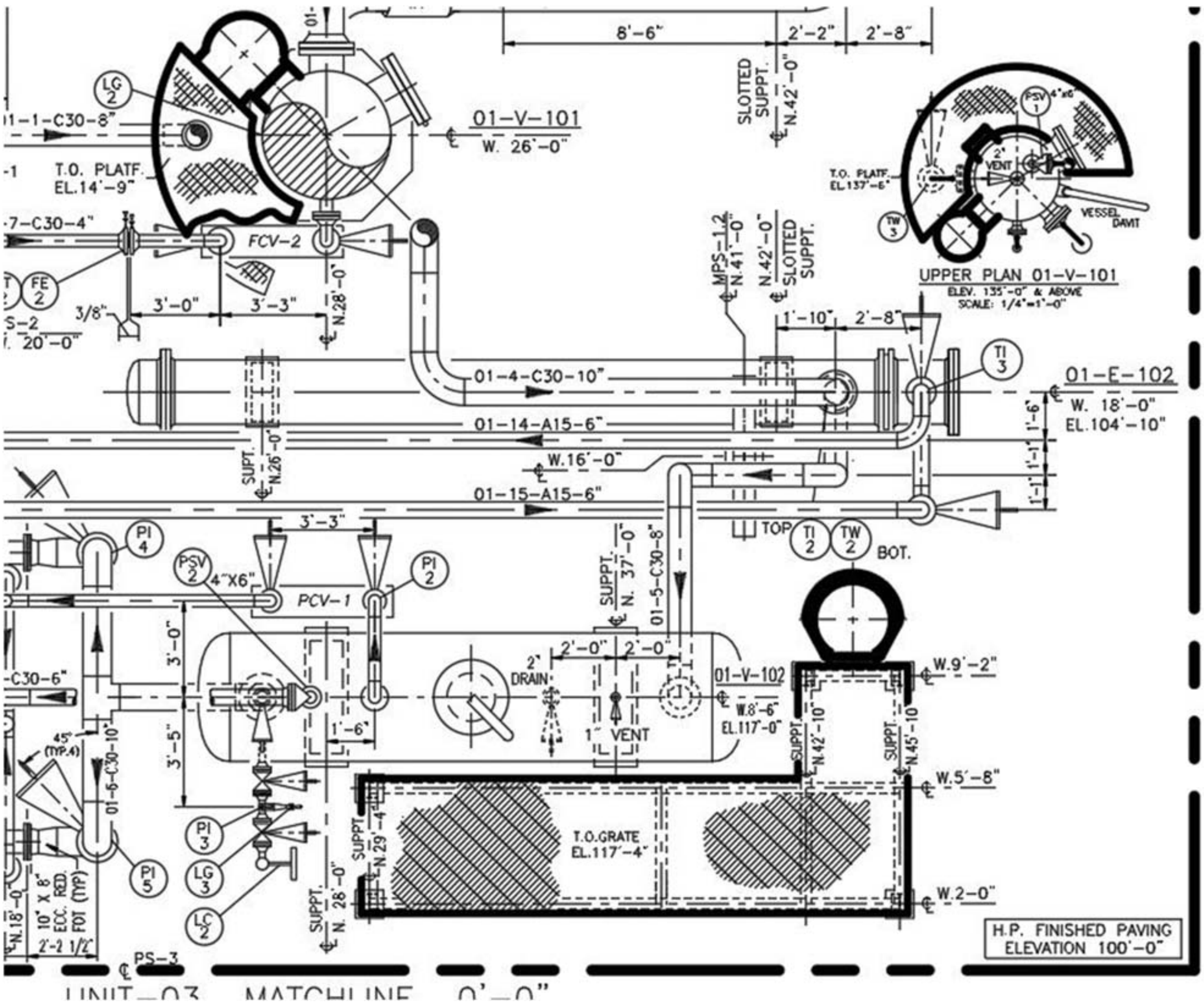


FIGURE 6.8 Highlighted plan-view representation of circular and rectangular platforms.

use mechanical devices such as pistons, gears, or screws to discharge a commodity at a smooth, continuous rate of flow. It performs without creating the extreme pressure surges often associated with the reciprocating pump.

Nozzle Arrangements

To effectively locate a pump within a piping facility, one must be especially concerned with the suction and discharge nozzles. The *suction* nozzle is where the commodity is drawn into the pump. The *discharge* nozzle is where the commodity is propelled from the pump. The positioning of the nozzles on the pump is called *pump nozzle arrangement*. Depending upon the type, pumps typically are available in five different nozzle arrangements. The chart in Table 6.1 shows the arrangements of pump nozzles.

Of primary concern to pumps, especially centrifugal ones, is NPSH. *Net Positive Suction Head* is, in simplified terms, the minimum amount of pressure (*head*) needed by the commodity flowing into the pump that will keep the pump primed, or pumping. NPSH, mathematically, is the sum of the resident pressure on the commodity in the pipe, at the pump's suction nozzle, plus the pressure caused by gravity's effect on the commodity minus the amount of friction on the commodity flowing through the pipe. More simply stated NPSH is head pressure plus gravity pressure minus friction. To achieve maximum efficiency, most pumps are installed with its suction line entering the pump from a vertical orientation to maximize head pressure.

Figure 6.11 depicts the Plan and Elevation views of a typical pump. Notice only two nozzles are represented in detail. A pipe drafter's primary concern is the location, size, and rating of these nozzles. The type of pump driver is secondary, unless it is a steam turbine, in which case the turbine's steam supply and return nozzles must be represented on the Piping Arrangement drawing.

FIGURE 6.9 Ladder, cage, and platforms. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

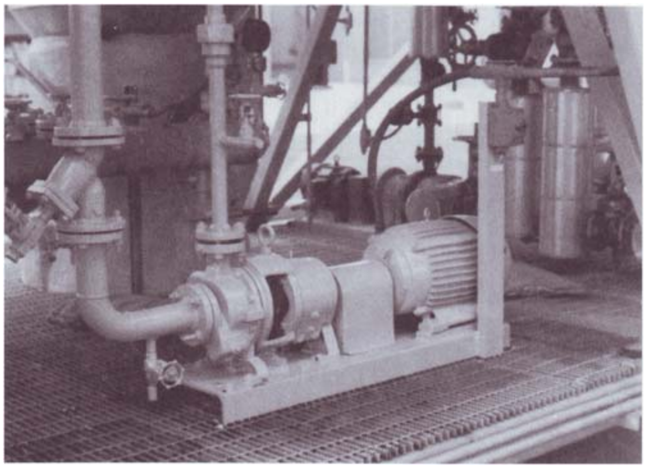
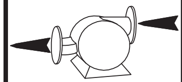
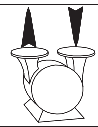
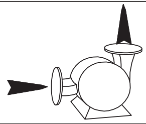
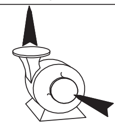
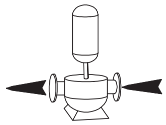


FIGURE 6.10 Pump. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

Figure 6.12 provides a partial view of the Unit-01 Piping Arrangement drawing with two matching end-suction/top-discharge centrifugal pumps highlighted for clarity. In the example shown the pumps are so

TABLE 6.1 Pump Nozzle Arrangements.

NOZZLE ARRANGEMENTS

	SUCTION	DISCHARGE	POSITION
1	SIDE	SIDE	
2	TOP	TOP	
3	SIDE	TOP	
4	END	TOP	
5	END	END (IN-LINE)	

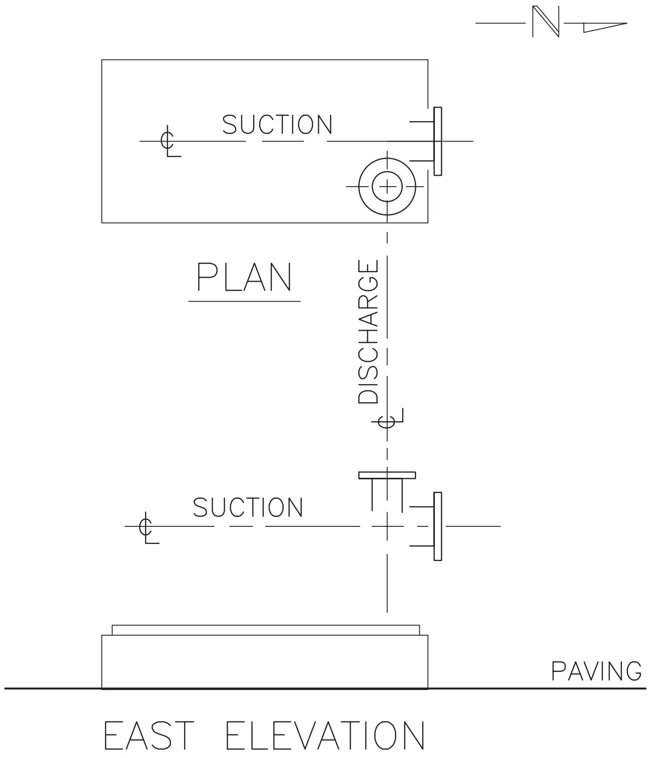


FIGURE 6.11 Pump plan and elevation views.

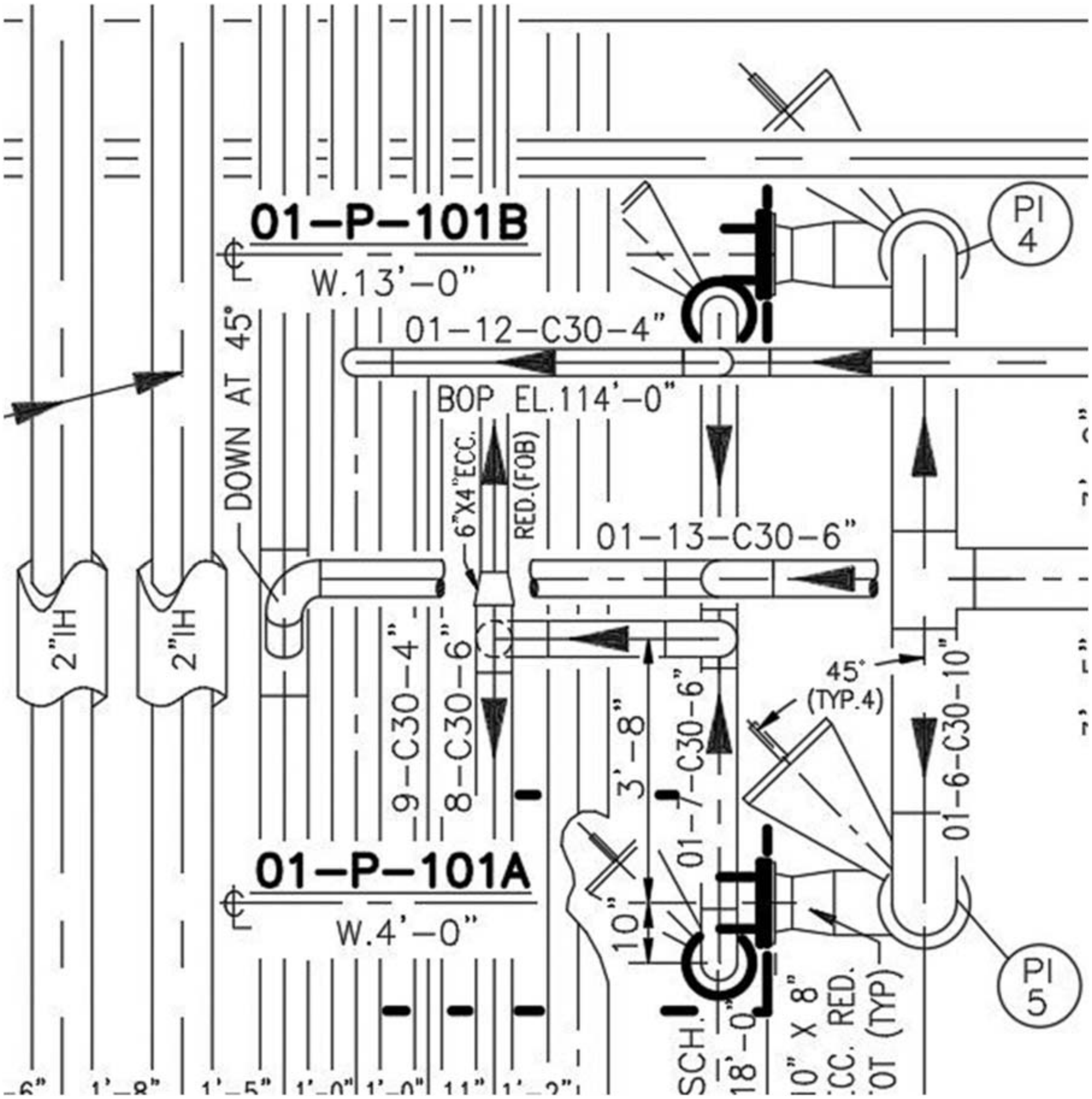


FIGURE 6.12 Highlighted plan-view representation of end-suction/top-discharge pumps.

obscured by other components in the facility, and they must be clearly labeled as 01-P-101A and 01-P-101B. Barely noticeable is the pump skid's shape. Only the suction and discharge nozzles are evident. Although they have larger nozzle pipe sizes, the nozzle orientation of the pumps represented in Figure 6.12 are similar to the nozzle orientation of the pump pictured in Figure 6.10.

Pump Drivers

All pumps require a starting device to function. These devices are known as *drivers*. The driver is connected to the pump via a rotating shaft and coupling. The shaft turns the impellers, gears, and screws or moves the pistons to initiate the "pumping" action. An electric motor is the most commonly used driver. As an alternative to electricity and as a backup to the electric motor, a steam turbine is often employed. The steam turbine can operate during power outages or when a motor is being repaired or replaced. Steam turbines are also chosen over electric motors for use in areas where explosive gases may be present. The electric current, which is required to power the motor, is a possible ignition source to flammable gases that may have leaked and collected near the motor. The turbine, driven by steam, obviously reduces the possibility of an explosion. Figure 6.13 shows an electric motor driver.

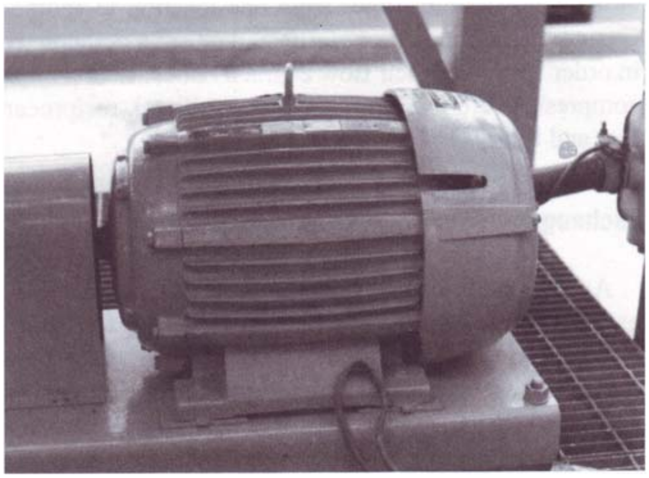


FIGURE 6.13 Electric motor. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

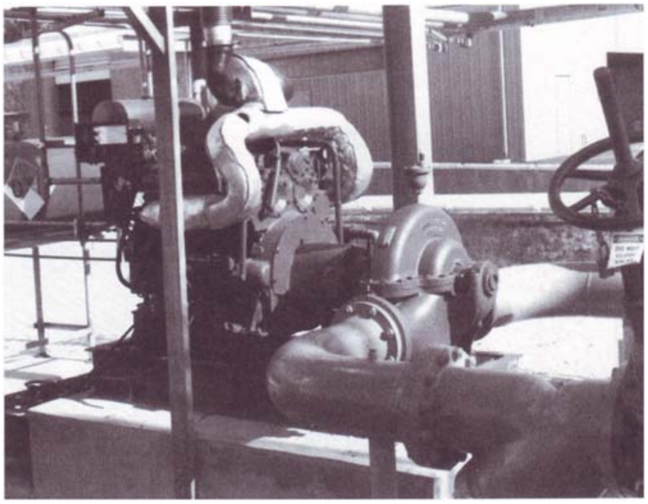


FIGURE 6.14 Diesel engine. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

A diesel engine is used during times of emergency. When piping systems have been damaged and shut down because of an explosion or a fire, diesel engines provide power to the pumps that provide water to fire monitors, hoses, and other firewater systems in a facility. Turbines can also provide electrical power to other essential plant services. Limited to outdoor service only, diesel engines can be used when conditions render electric motors and steam turbines useless. Figure 6.14 shows a typical diesel engine driver.

Compressors

The compressor is similar to the pump but is designed to move air, gases, or vapors rather than liquids. The compressor is used to increase the rate at which a gaseous commodity flows from one location to another. Gases, unlike liquids, are elastic and must be compressed to increase flow rate. Liquids obviously cannot be compressed, unless you are building a hydraulic application. Like pumps, compressors are manufactured in centrifugal, reciprocating, and rotary configurations.

Exchangers

Another common piece of mechanical equipment is the exchanger. The exchanger's primary function in a piping facility is to transfer heat from one commodity to another. Whether the objective is to heat a liquid to a desired temperature or cool a product for final storage, the exchanger can accomplish both. The most important feature of the exchanger is that commodities are not mixed with another agent to heat it up or cool it down. A substantial amount of time and money has been invested to purify the commodity so mixing anything with it, just to heat it up or cool it down would be counterproductive. Exchangers simply transfer heat through contact with a metal surface of different temperatures. An exchanger most people are familiar with is the common household water heater whereby cold water flows around a heated element to warm the water. A number of exchanger types are available; they include the shell and tube, double pipe, reboiler, and air fan.

Shell and Tube Exchanger

The shell and tube exchanger accomplishes its cooling task by circulating a hot liquid around tubes which contain a cooler liquid. The hot liquid circulates in an enclosed area called the shell. Tubes containing the cooler liquid are looped through the shell. Hot liquid in the shell warms the cooler liquid in the tubes, whereas the cooler liquid in the tubes cools the warm liquid in the shell. Figure 6.15 provides a look into the shell and tube exchanger to identify its various components. Contact between the cool and hot liquids will naturally exchange heat from the hotter to the colder. Depending on the process being performed, inlet and outlet orientation of the channel-end and shell-end nozzles can be swapped (see Figure 6.16).

In Figure 6.17 the symbols for the Plan and Elevation views of a typical shell and tube exchanger, as it would appear on piping drawings, are shown. Figure 6.18 provides a partial view of the Unit-01 Piping Arrangement drawing with the shell and tube exchanger highlighted.

Double-Pipe Exchanger

Also known as the *G-Fin* or H*airpin* exchanger, double-pipe exchangers are manufactured with a

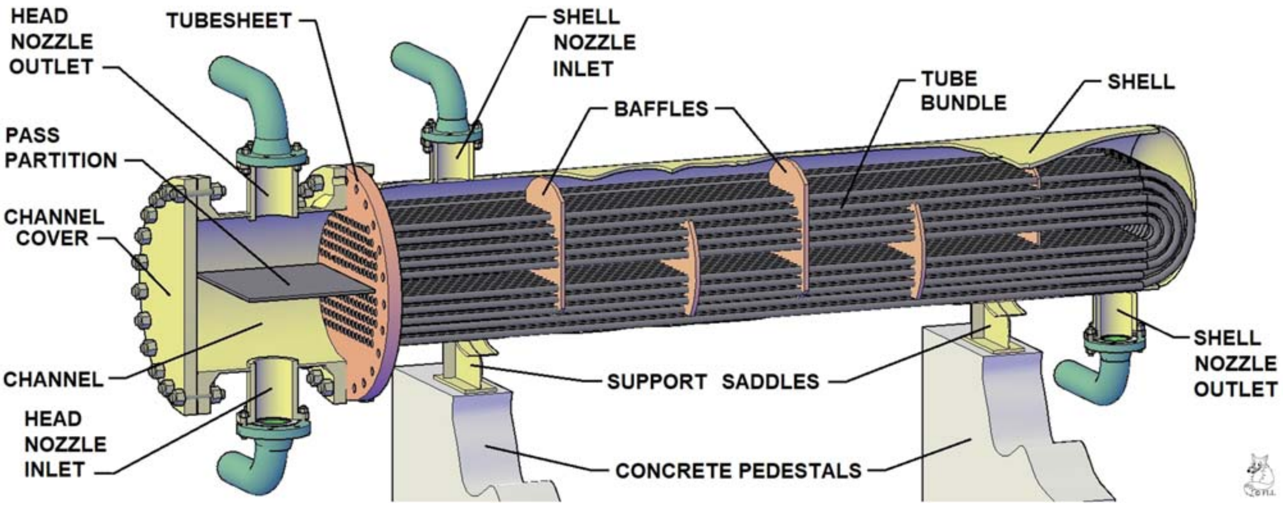


FIGURE 6.15 Shell and tube exchanger components.

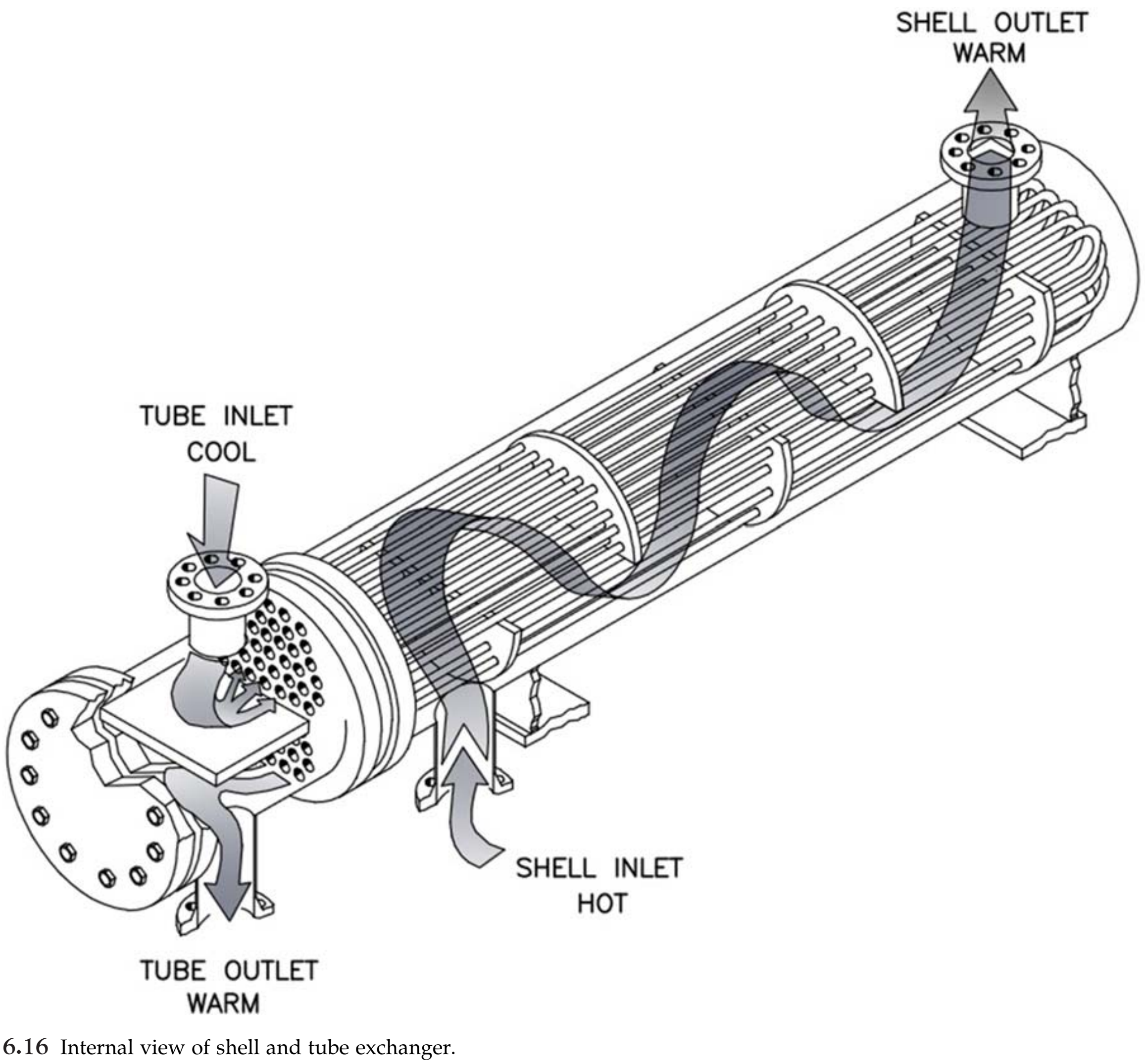


FIGURE 6.16 Internal view of shell and tube exchanger.

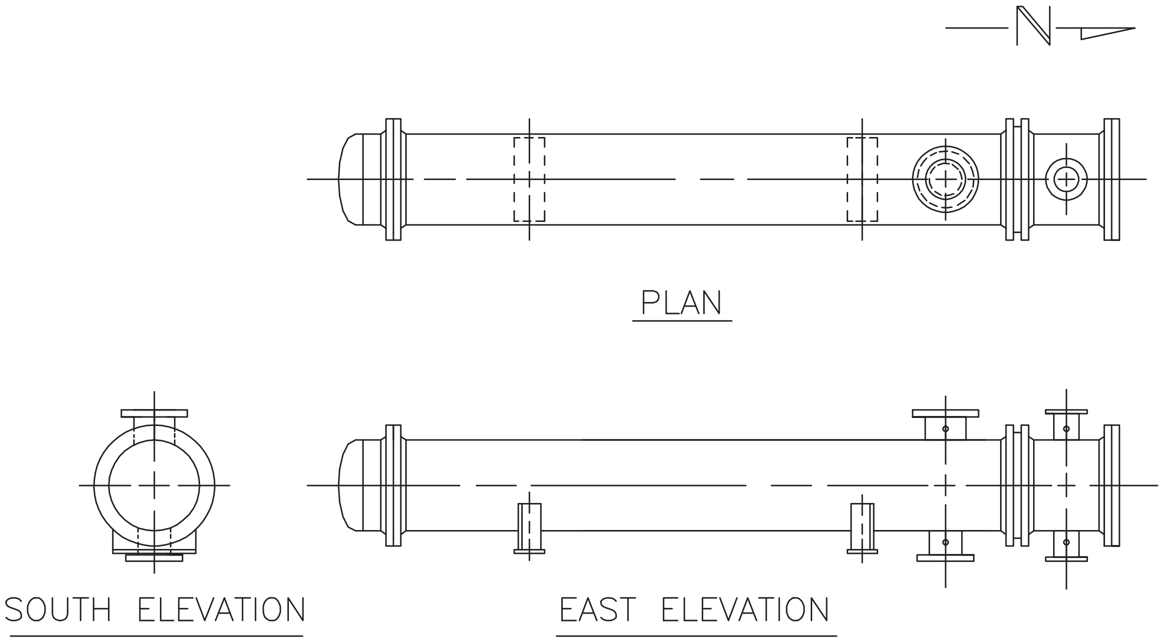


FIGURE 6.17 Shell and tube exchanger Plan and Elevation views.

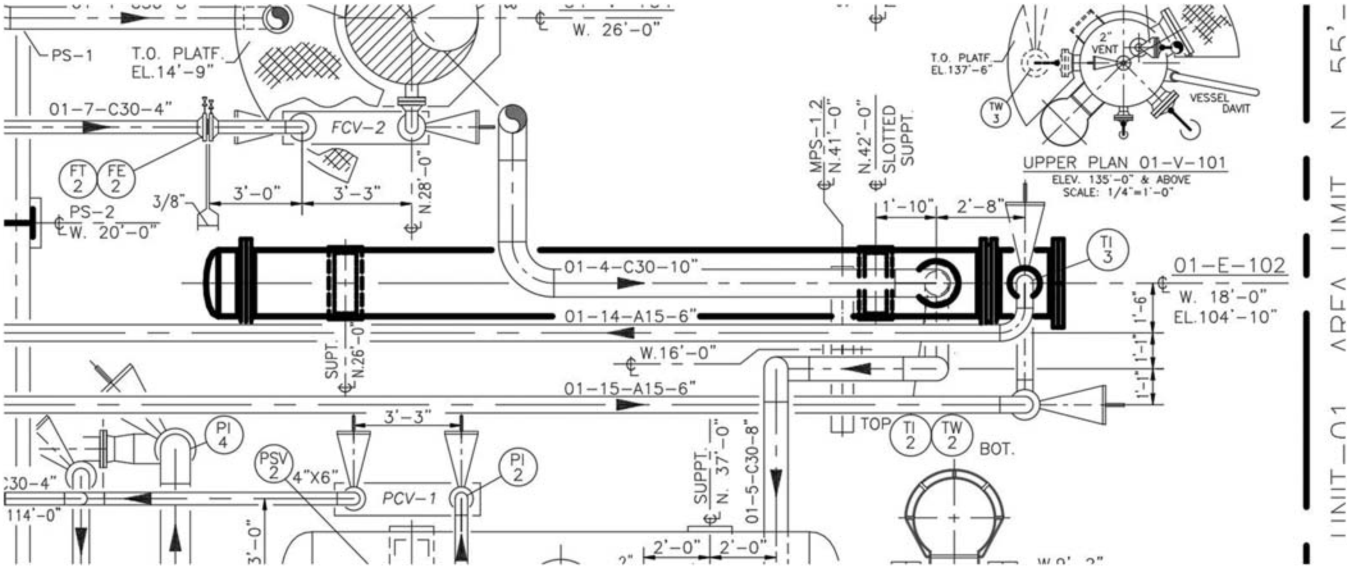


FIGURE 6.18 Highlighted plan-view representation of shell and tube exchanger.

single, small diameter pipe inserted into a larger diameter pipe. The two pipes contain commodities of different temperatures similar to the shell and tube exchanger. Figure 6.19 is a photograph of two double-pipe exchangers stacked atop one another. The upper is shown without protective insulation, whereas the lower one is with insulation. Figure 6.20 is an internal view looking inside a pair of stacked double-pipe exchangers.

To prevent the two pipes of the exchanger from coming in contact with one another, thin-metal plates called *fins* are welded to the outside of the smaller pipe. These fins also aid in the transfer of heat from one commodity to the other. Figure 6.21 depicts the fins within a double-pipe exchanger. Fins are not the only method used to increase the amount of surface area of the internal component of the double-pipe exchanger. Another option is to use multiple coils of tubing rather than a single pipe with fins. Figure 6.22 depicts how a single tube may appear inside the outer pipe.

Figure 6.23 provides the Plan and Elevation views of the double-pipe exchanger as it would be represented on piping drawings.

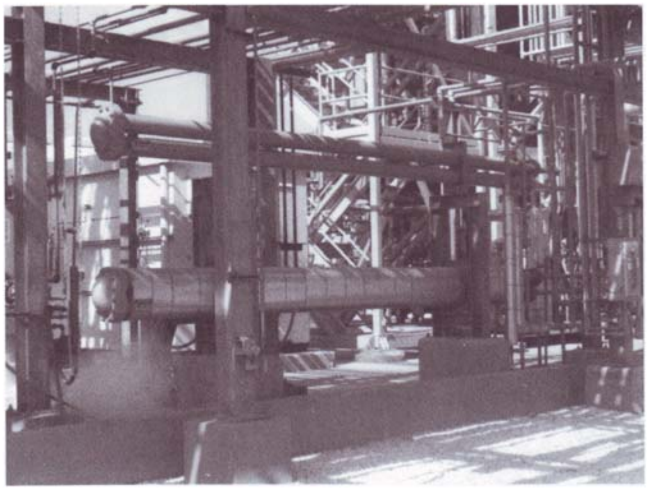


FIGURE 6.19 Double-pipe exchanger. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

Reboiler

The reboiler, as the name implies, is a device used to replenish the heat lost by a process commodity. It is natural that during the refining process commodities will lose heat. In many cases, lower temperature means less efficiency and productivity. Therefore it becomes necessary to reheat certain commodities after a period it time. Two types of reboilers are available for use; the kettle-type and the thermosyphon. A kettle-type reboiler is similar in design and appearance to the shell and tube exchanger. The commodity to be heated is routed, via pipe, to and from the heater and fractionation column. The thermosyphon reboiler however is attached

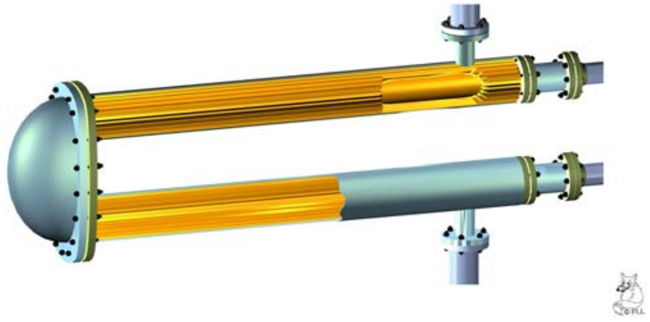


FIGURE 6.21 Fins of a double-pipe exchanger.

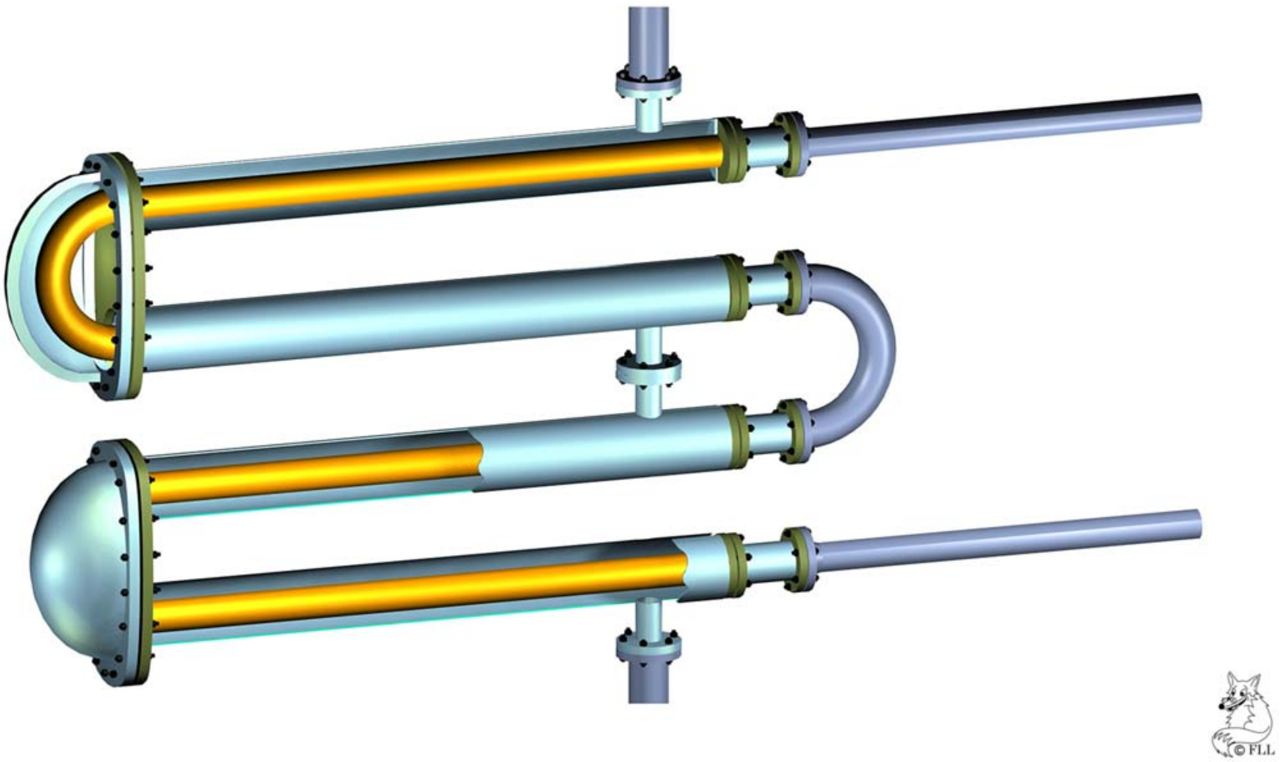


FIGURE 6.20 Internal view of double-pipe exchanger.

directly to a fractionating column via its nozzles. The inlet and outlet nozzles of a reboiler are bolted directly to two nozzles on the fractionating column. Figure 6.24 represents an exploded view of a kettle-type reboiler to help identify its internal components.

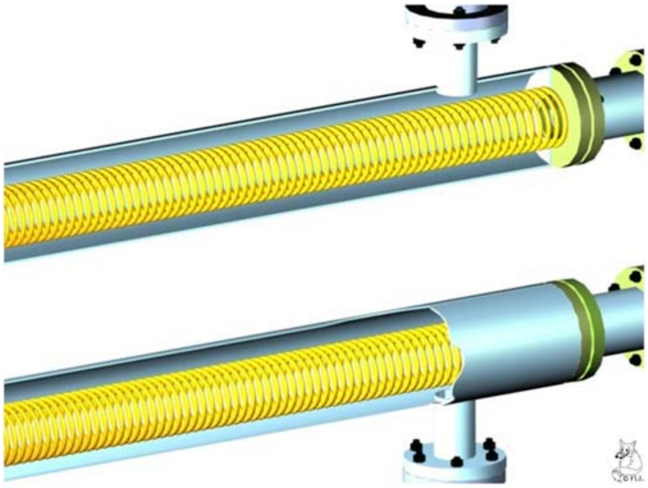


FIGURE 6.22 Double-pipe exchanger with coil tube.

Reboilers are used to keep process commodities circulating through a fractionation column at their minimal operating temperature. Figure 6.25 identifies how the process commodity enters the reboiler in a liquid state, is heated by either superheated steam or another hot liquid, and is returned in a vaporous state to an area in the fractionation column called the *flash zone*. Figure 6.26 depicts the process position and use of a reboiler between the fractionation column and heater. As is discussed in more detail later in this chapter, the flash zone is crucial to the distillation process. In Figure 6.27 the symbols for the Plan and Elevation views of a typical kettle-type reboiler, as it would appear on piping drawings, are shown. Figure 6.28 provides a partial view of the Unit-01 Piping Arrangement drawing with the kettle-type reboiler highlighted.

Air Fan

Air fans are large fan-type coolers placed above or below a pipe rack that draw air across pipes to cool them. Air fans operate on the same principle as an automobile's radiator, only on a much larger scale. A main pipe containing a heated commodity is routed

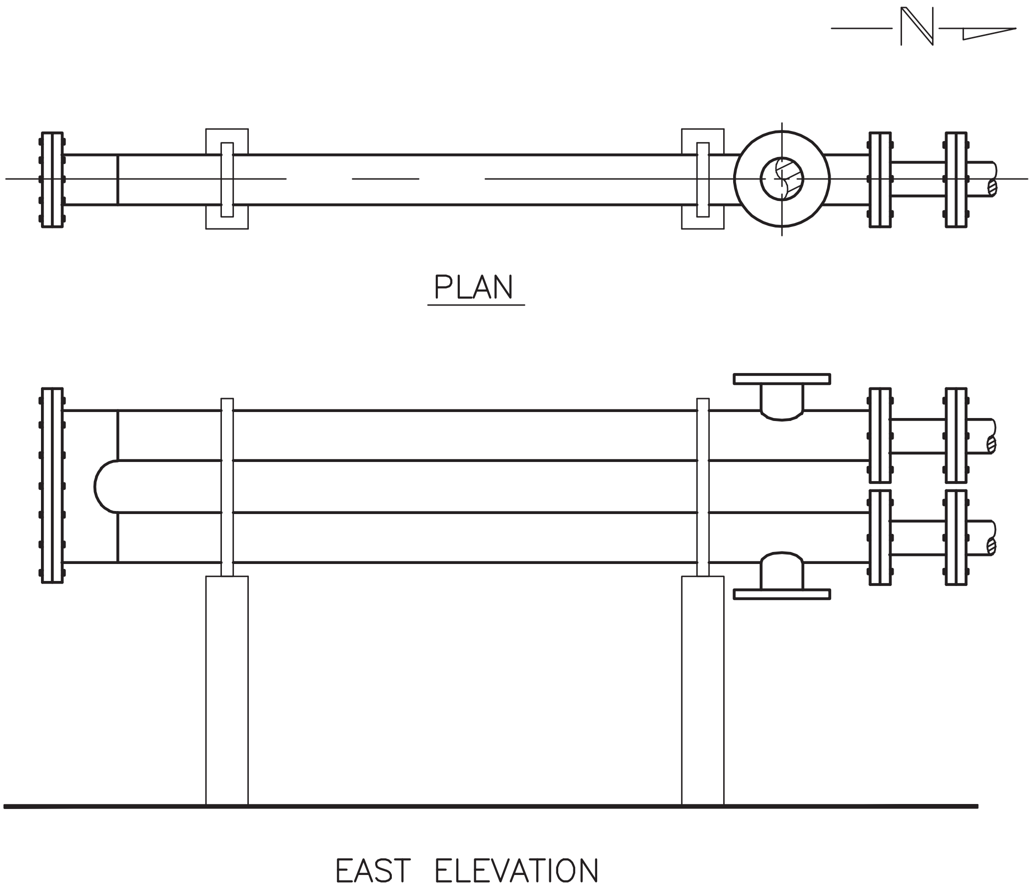


FIGURE 6.23 Double-pipe exchanger Plan and Elevation views.

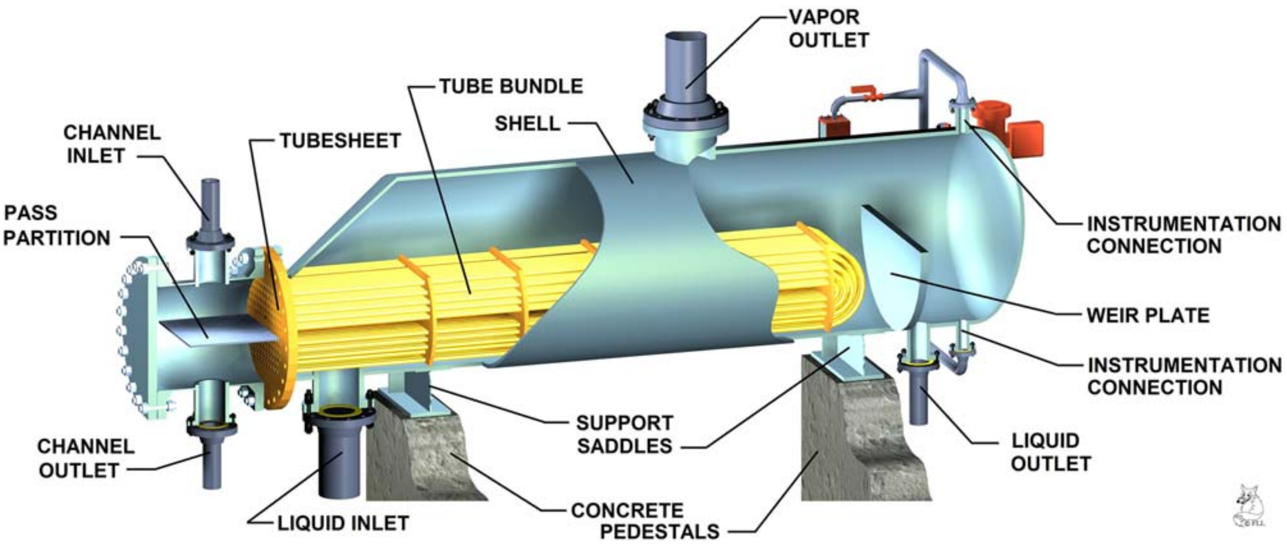


FIGURE 6.24 Kettle-type reboiler components.

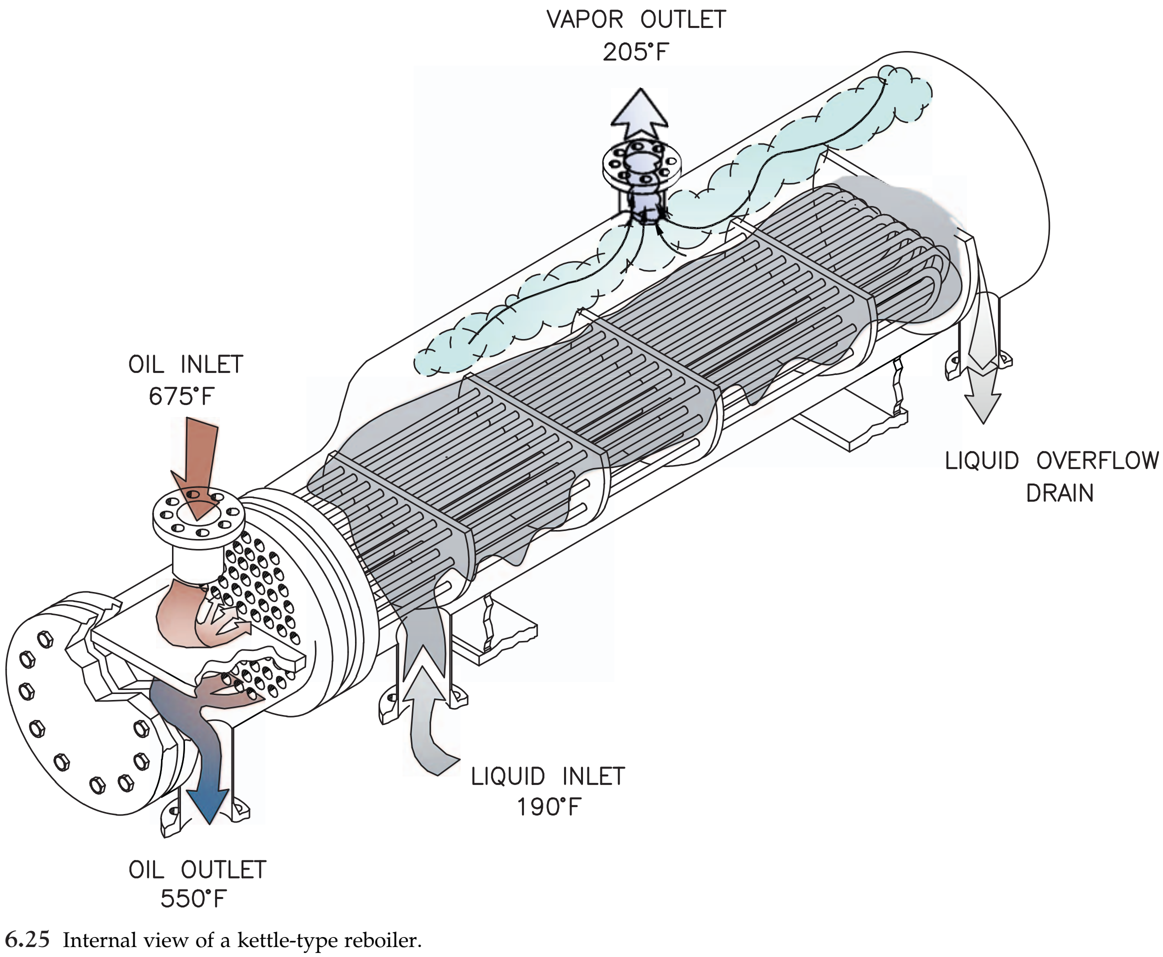


FIGURE 6.25 Internal view of a kettle-type reboiler.

into a pipe header where it is diverted many smaller diameter pipes which span either above or below a large diameter fan. The rapid moving air is drawn across the pipes and cools the commodity inside. Diverting the commodity into smaller diameter pipes increases the amount of surface area which the air comes in contact with. Air fans can be as large as 20′-0″ wide and 30′-0″ long. If linked together, air fans

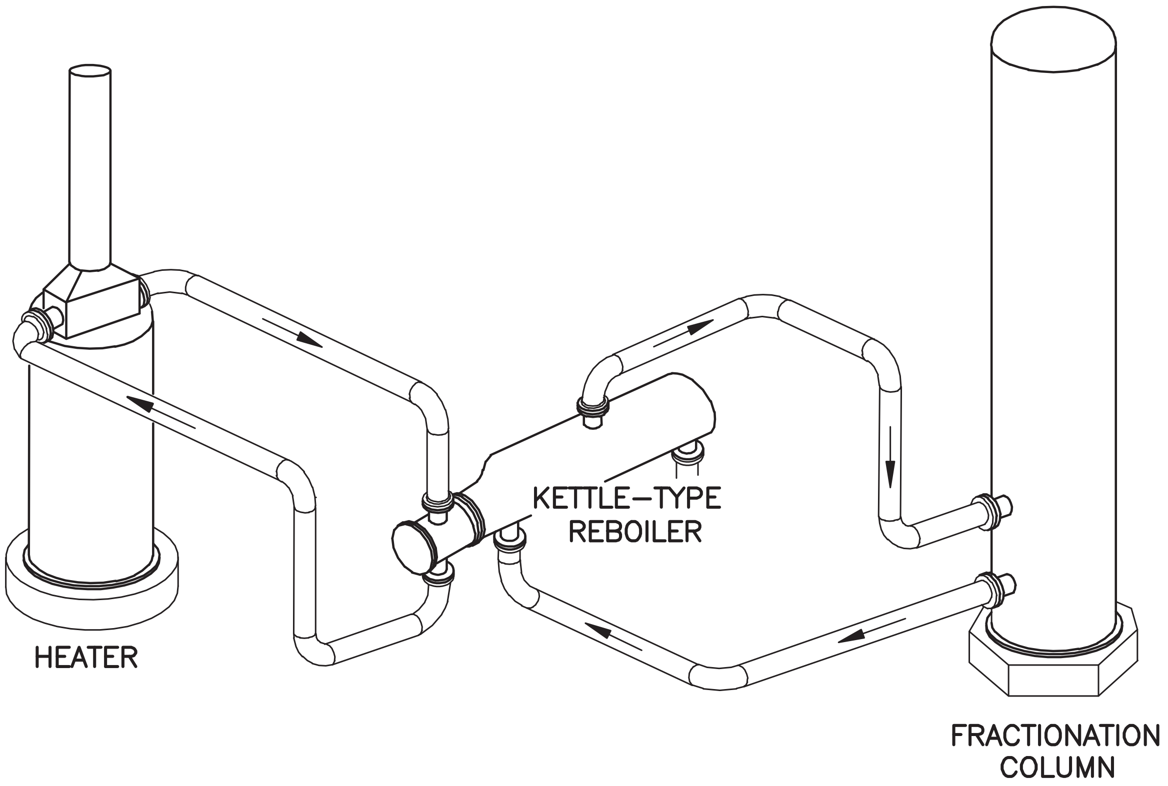


FIGURE 6.26 Kettle-type reboiler in use.

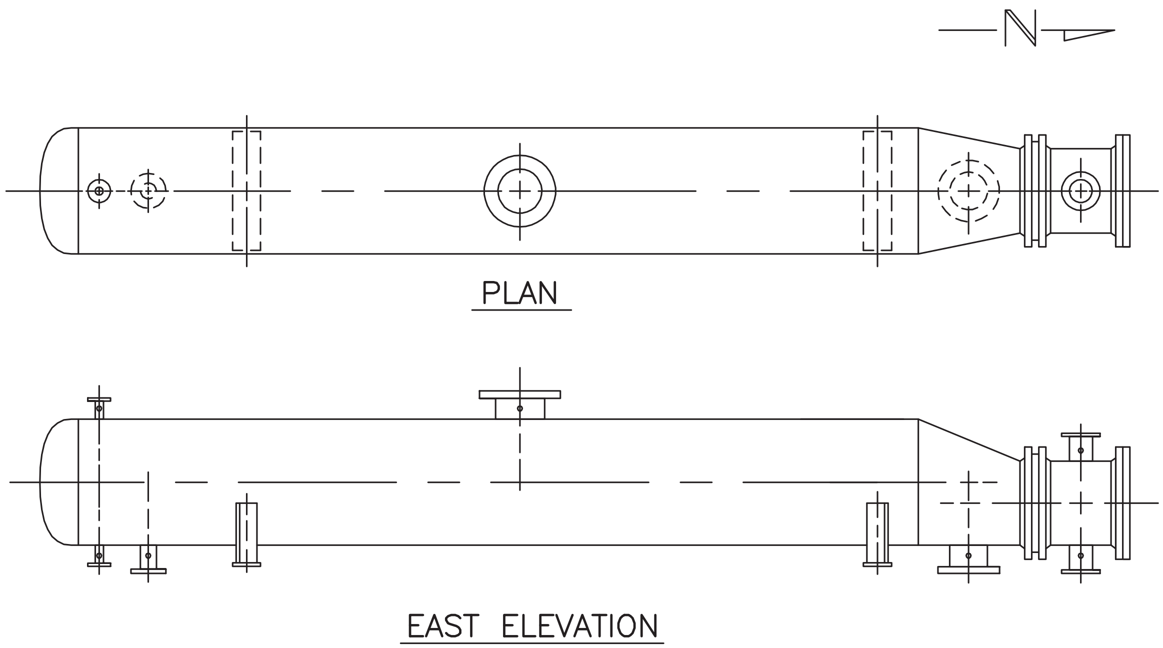


FIGURE 6.27 Kettle-type reboiler Plan and Elevation views.

can span up to 500 ft or more, running the entire length of a pipe rack. At the opposite end of the air fan, all of the smaller pipes connect to another pipe header and are routed back into a large diameter pipe at a much cooler temperature (Figure 6.29).

Cooling Towers

After circulating through equipment such as exchangers and condensers, cooling water will have accumulated substantial heat gain. Without dissipating

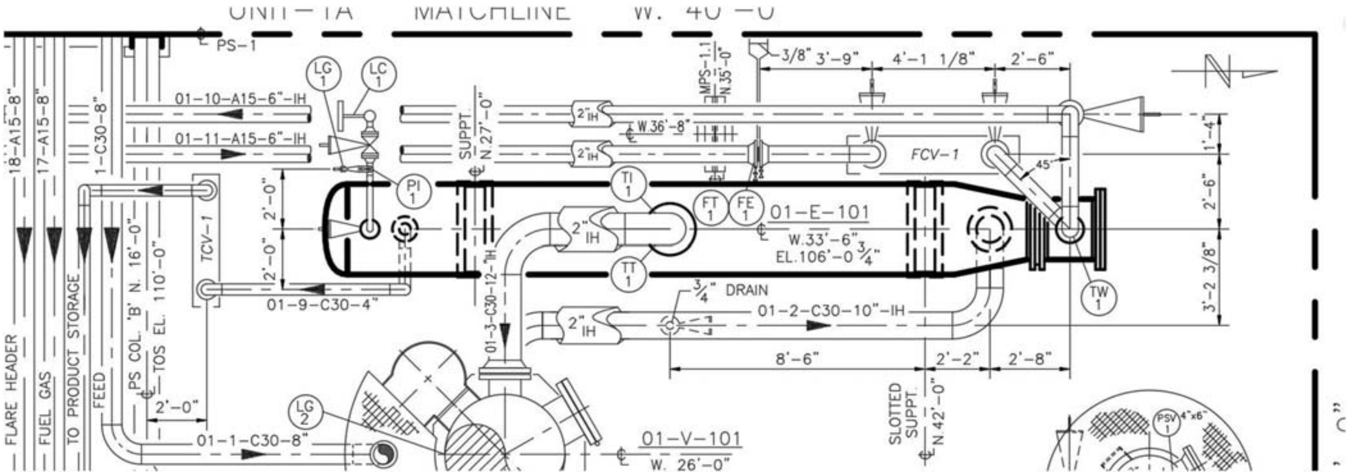


FIGURE 6.28 Highlighted plan-view representation of kettle-type reboiler.

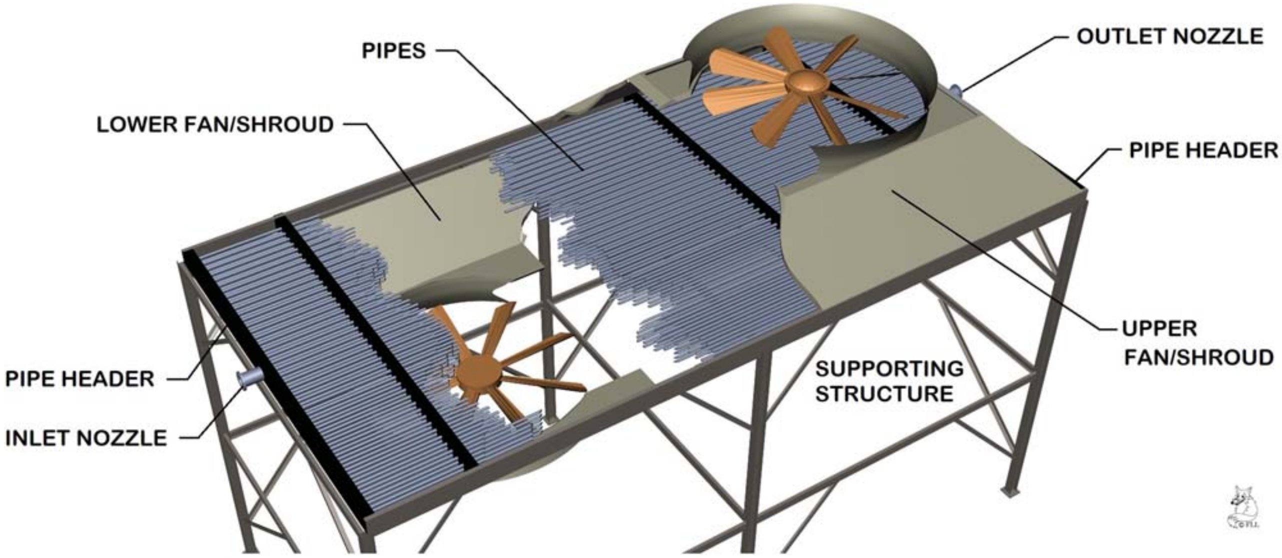


FIGURE 6.29 Air fan components.

the heat gain, cooling water will lose its cooling effectiveness and become less efficient. A cooling tower is a mechanical device that will lower the temperature of cooling water. Cooling towers are uniquely designed to dissipate heat gain by evaporating large amounts of aerated water that is circulated through an air-induced tower. Large fans sit atop a honey-combed chamber and draw through cascading sheets of water. As the air passes through the falling water, it extracts heat. Although there is a significant amount of *drift* (the amount of water lost during the aerating and evaporation sequence), cooling towers are extremely efficient and are widely used. Older cooling towers are easily recognizable because they are constructed of wood and have horizontal slats resembling louvers with water cascading down the walls. Figure 6.30 represents a typical cooling tower.

FIGURE 6.30 Cooling tower. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

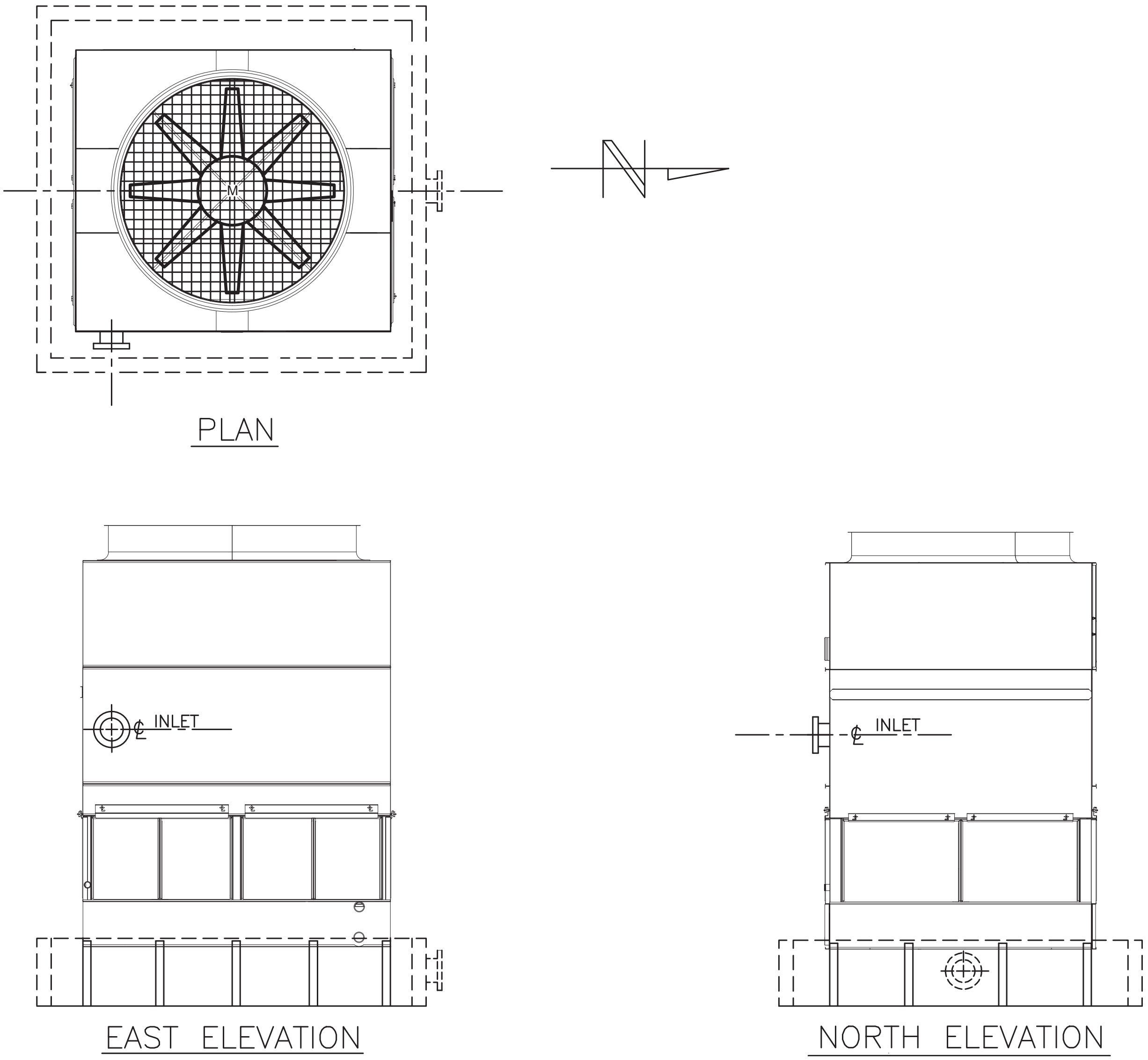


FIGURE 6.31 Cooling tower Plan and Elevation views.

In Figure 6.31 the symbols for the Plan and Elevation views of a cooling tower, as it would appear on piping drawings, are shown. Figure 6.32 provides a partial view of the Unit-04 Piping Arrangement drawing with the cooling tower highlighted.

Heaters/Boilers

Heaters, or furnaces as they are also known (see Figure 6.33), are used to raise the temperature of a feed stock to the point where it can be used in a process facility. Some feeds, like crude oil, must be heated to approximately 700°F before it can be piped into a fractionation column where it refining process begins. Fire brick lines the interior walls of a heater to retain heat. Open-flame burners, fueled with oil or gas, are used to generate the extreme temperatures inside the heater's fire box. Depending on their orientation, the pipes carrying the commodity being heated traverse back and forth in a continuous *S* or *U* pattern. Heaters are designed to be either vertical or horizontal in orientation. Vertical heaters are often cylindrical in shape and have internal piping traveling in a vertical direction (see Figure 6.34). Horizontal or *box* heaters are rectangular in shape and have pipes routed in the horizontal plane. Both the *S* and *U* pattern heaters have similar characteristics that include brick-lined heating chambers, flaming burners, and baffled venting stacks (see Figure 6.35).

Boilers employ the same heating principle as a heater. They are used primarily to generate superheated steam or stripping steam. Constructed similar

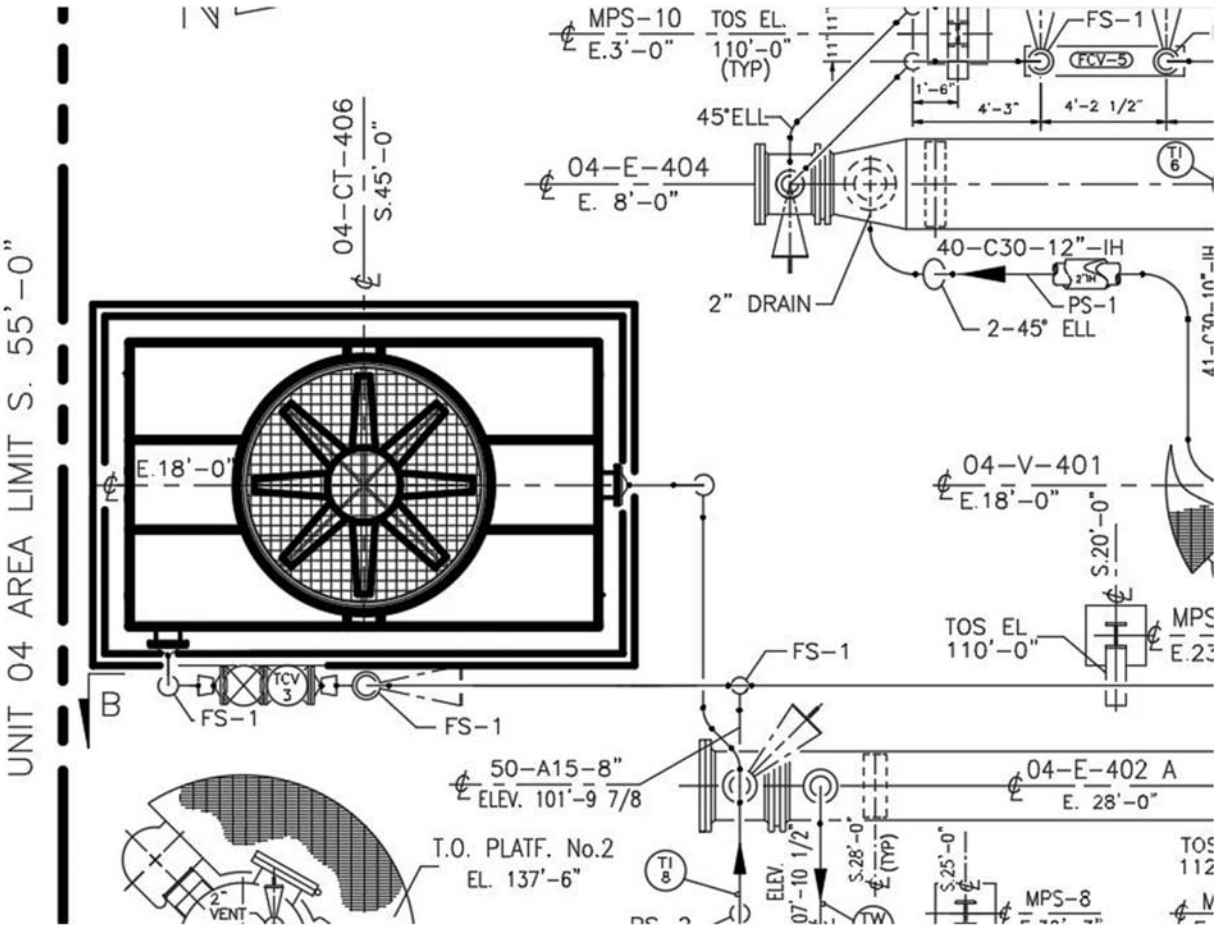


FIGURE 6.32 Highlighted plan-view representation of a cooling tower.

to a heater, boilers can raise the temperature of water or condensate to 1,000°F or more.

In Figure 6.36 the symbols for the Plan and Elevation views of a box heater, as it would appear on piping drawings, are shown. Figure 6.37 provides a partial view of the Unit-04 Piping Arrangement drawing with the box heater highlighted.

Storage Tanks

From the name, it should not be difficult to determine what this piece of equipment is used for. Storage tanks are used in several phases of the refining process. They can be used to store crude oil prior to its use in the facility, as holding tanks for a partially refined product awaiting further processing, or to collect a finished product prior to its delivery or pick-up by a customer.

Usually placed within a common area of a facility known as a *tank farm*, storage tanks come in various shapes and sizes. Some are shaped similar to horizontal vessels, and some are spherical, like a ball. The majority of storage tanks, however, are huge, ground-supported vessels, as much as 200 ft in diameter and up to 60 ft tall. Spherical tanks are used primarily for storing liquefied petroleum gases like butane, methane, or propane. The expanding nature of gaseous commodities requires that a spherical shape be used. As gases expand equally in all directions, it becomes necessary to store them in a vessel that distributes load stresses equally to its walls. The larger tanks, used for storing liquid product, may have a conical, elliptical, geodesic dome, floating, or open roof. Floating roofs raise and lower to automatically adjust to the level of the commodity in the tank. Floating roof tanks use "pontoons" to create a seal against the tank's wall to help reduce evaporation and prevent the buildup of dangerous gases that often occur with flammable liquids.

As a preventative measure, containment *dikes* are erected to contain major leaks or spills. Should a storage tank rupture or suffer severe damage, the dike will prevent major contamination to surrounding areas. Dikes can be earthen dams or concrete retaining walls built around the perimeter the entire storage facility,

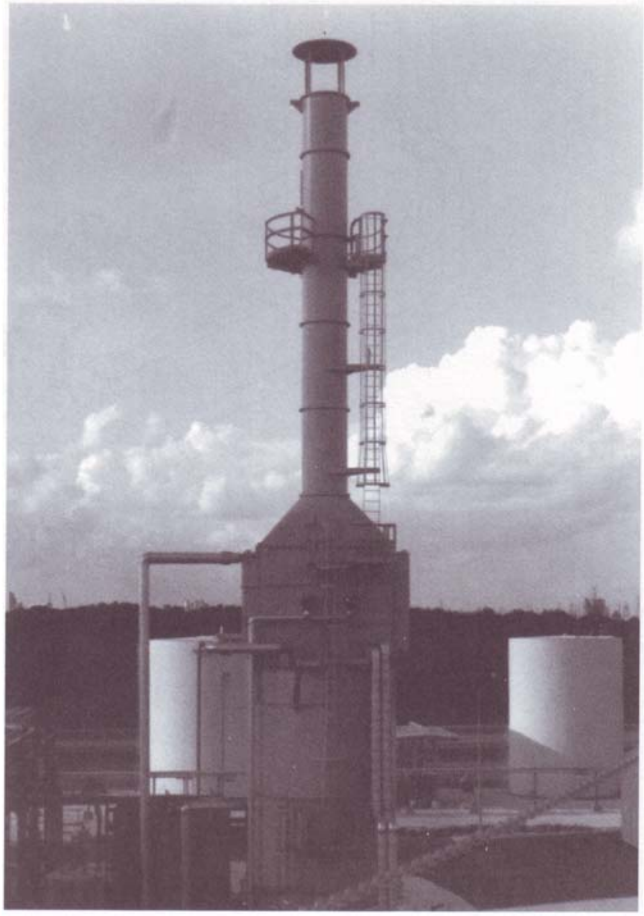


FIGURE 6.33 Vertical heater. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

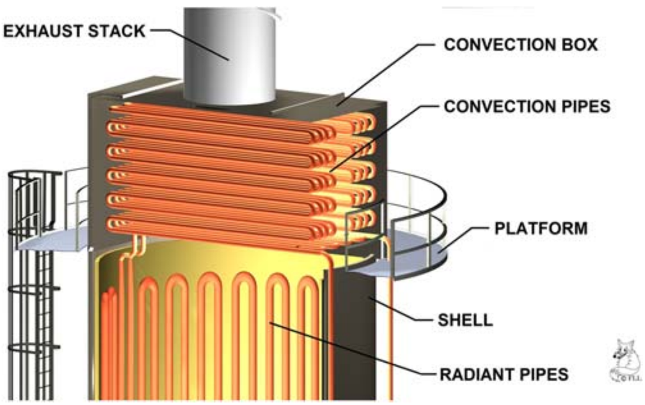


FIGURE 6.34 Vertical heater internal piping.

or a single tank, at a height that would hold the contents of a storage tank, should a spill occur. Figure 6.38 depicts typical storage tanks and surrounding concrete retaining wall.

TYPES OF MECHANICAL EQUIPMENT

There are numerous pieces of mechanical equipment used in process facilities. Below is a list and description of some of them.

- ***Accumulator***—a horizontal-axis vessel having no internal parts used to collect product as it circulates through the refining process.
- ***Air coolers***—(air fan and fin-fan) rectangular device having small diameter pips or tubes winding back and forth, side-to-side, similar to that of an automobile radiator. Sometimes mounted above a piperack, it uses large fans to draw air across the tubes for cooling.
- ***Chiller***—one of the many types of exchangers used to reduce the temperature of a process commodity.
- ***Column***—see *fractionation column*.
- ***Compressor***—mechanical device used to increase the flow pressure of a gaseous or vaporous commodity.
- ***Cooling tower***—uses a large fan to remove the latent heat from cooling water by drawing air across cascading water.
- ***Debutanizer***—a distillation column that receives the bottoms residue from a depropanizer whose overhead product is a mixture of normal and iso-butane. Its bottoms residue is a C_5+ mixture (pentane).
- ***Deethanizer***—the first in a series of three distillation columns whereby heavier gaseous molecule hydrocarbons, or NGL (Natural Gas Liquids) are fractionated. The deethanizer distillation column's overhead product is ethane gas. Its bottoms residue is routed to a depropanizer for further processing.
- ***Deiso-butanizer***—a distillation column that fractionates butane. Iso-butane is a refrigerant that is used to replace ozone layer-depleting gases.
- ***Demethanizer***—a fractionating column in a cryogenic low-temperature distillation process whereby lighter gaseous molecule hydrocarbons (methane) are fractionated from raw natural gas.
- ***Depropanizer***—a distillation column that receives the bottoms residue from a deethanizer whose overhead product is propane. Its bottom residue is routed to a debutanizer.
- ***Distillation column***—see *fractionation column*.
- ***Exchanger***—(shell and tube, g-fin) any, from a family of devices, used to transfer heat from one commodity to another, specifically designed to prevent the two commodities from mixing.
- ***Flare stack***—a vertical-axis tower which uses an open flare to burn waste or contaminated product.

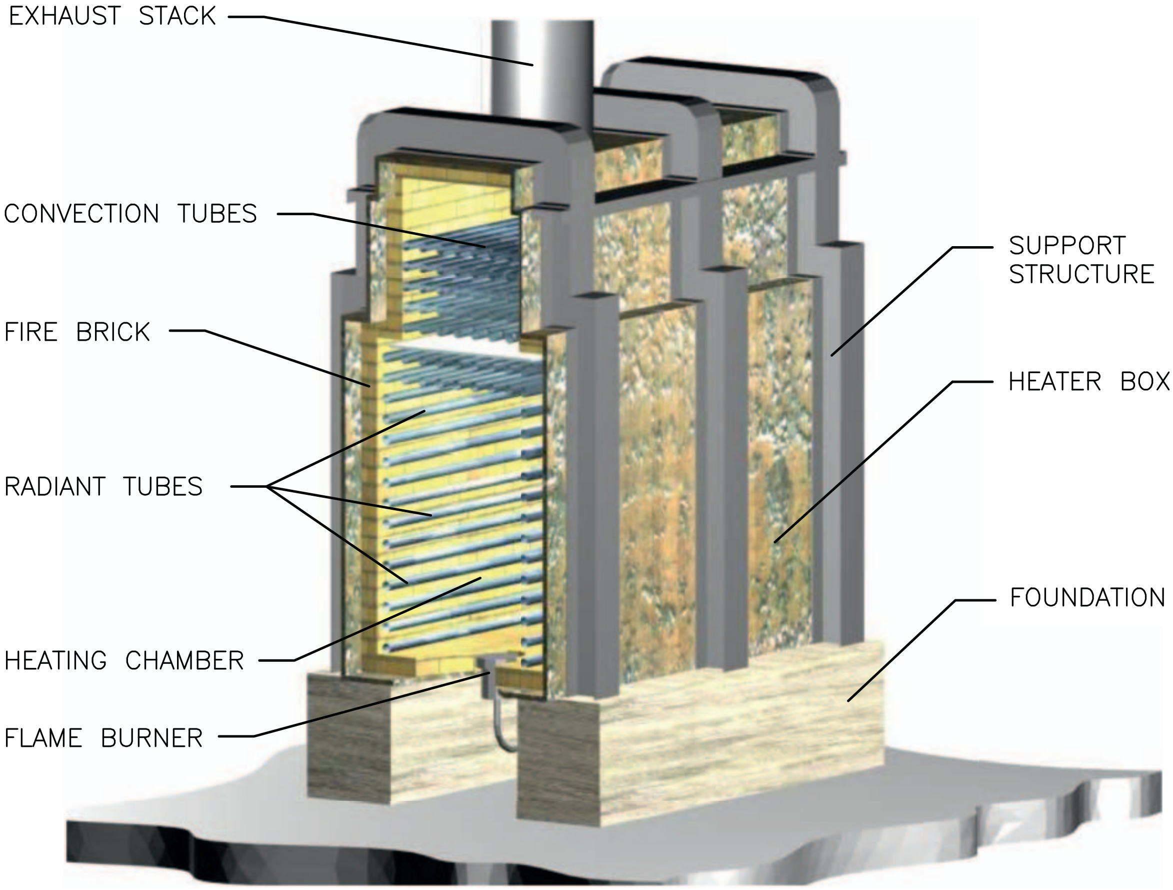


FIGURE 6.35 Box/horizontal heater internal piping.

- ***Fractionation column***—any number of vertical-axis, separating devices having internal trays, plates, or other packing materials which are used to separate, or fractionate a feed stock into various component by-products (fractions) by refining it (distilling, fractionating) at the molecular level.
- ***Heater***—horizontal or vertical axis device used to heat a commodity by circulating it through pipes which run through an open-flame firebox.
- ***Knock-out drum***—used to collect any liquids present in the waste stream prior to entering a flare system, especially important if substantial cooling of heavy liquids is necessary.
- ***Mixer***—device used to combine liquid, semiliquid, or bulk materials needed in the refining process.
- ***Pump***—mechanical device used to increase the flow pressure of a liquid commodity.
- ***Reactor***—a vertical-axis vessel which introduces a reagent or catalyst into a feed stock to induce a chemical reaction that will yield a uniquely different product.
- ***Reboiler***—used to superheat or vaporize the liquid feed before entering a distillation column. Kettle-type (horizontal) and thermosyphon (vertical) reboilers use steam or hot oil to vaporize the feed before it enters the distillation column.
- ***Separator***—any collection-type vessel used to separate liquids from gases or other liquids during the refining process.
- ***Scrubber***—used to separate contaminants from gases during the refining process.
- ***Storage tank***—containment vessel used to store gases or liquids before, during, or after the refining process.

EQUIPMENT IN USE

Now that we have discussed the major pieces of equipment, let us look at how they are integrated and function in a typical piping facility. The description to follow will be an abbreviated sequence of steps necessary to transform raw crude oil into its various by-product components.

Crude oil and its derivatives are the most common supply product used in petro-chemical facilities.

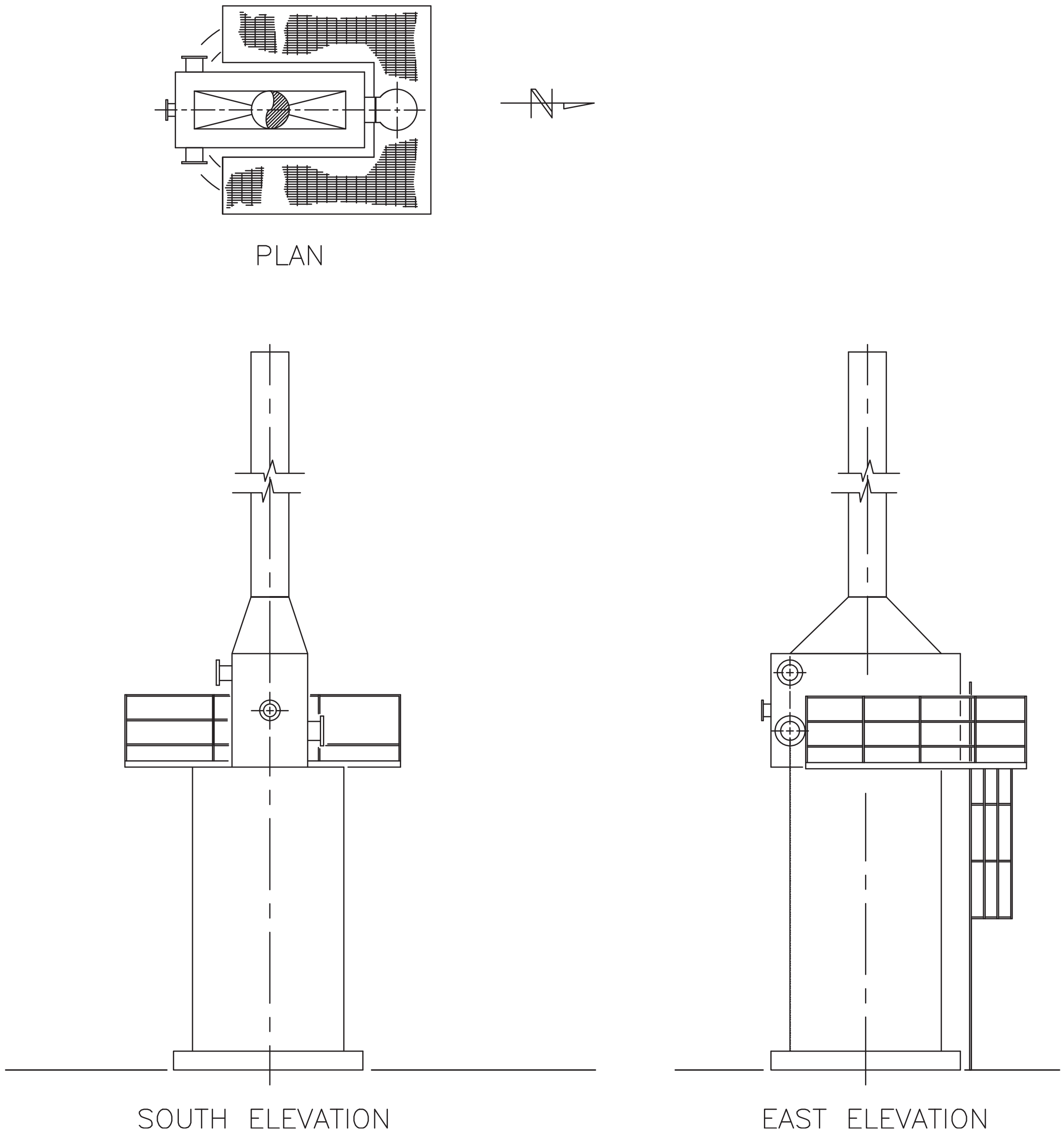


FIGURE 6.36 Box heater Plan and Elevation views.

Known as *feed*, crude oil is made up of molecules formed by thousands of different hydrogen and carbon atom combinations. Because the molecules are different, each crude oil molecule will boil at different temperatures. But, because they are comparatively similar in molecular structure, groups of molecules often boil within a narrow range of each other. These groups are called *fractions*. The process that will separate these fractions into their various groups; therefore they may be collected for further processing, is called *fractional distillation*. Figure 6.39 depicts the by-products refine from crude oil feed.

A closer look at the fractional distillation schematic will allow us to examine how each piece of equipment has a unique and distinct role in the refining process.

From the storage facility, crude oil feed is pumped through preheat exchangers. These exchangers are the first stage of the heating process. From the preheat exchangers the crude is sent to a heater or furnace. Once inside the heater, the feed is circulated through a series of pipes and is heated to a temperature of approximately 700°F. The boiling feed is then piped to the fractionating column. This area of the column is

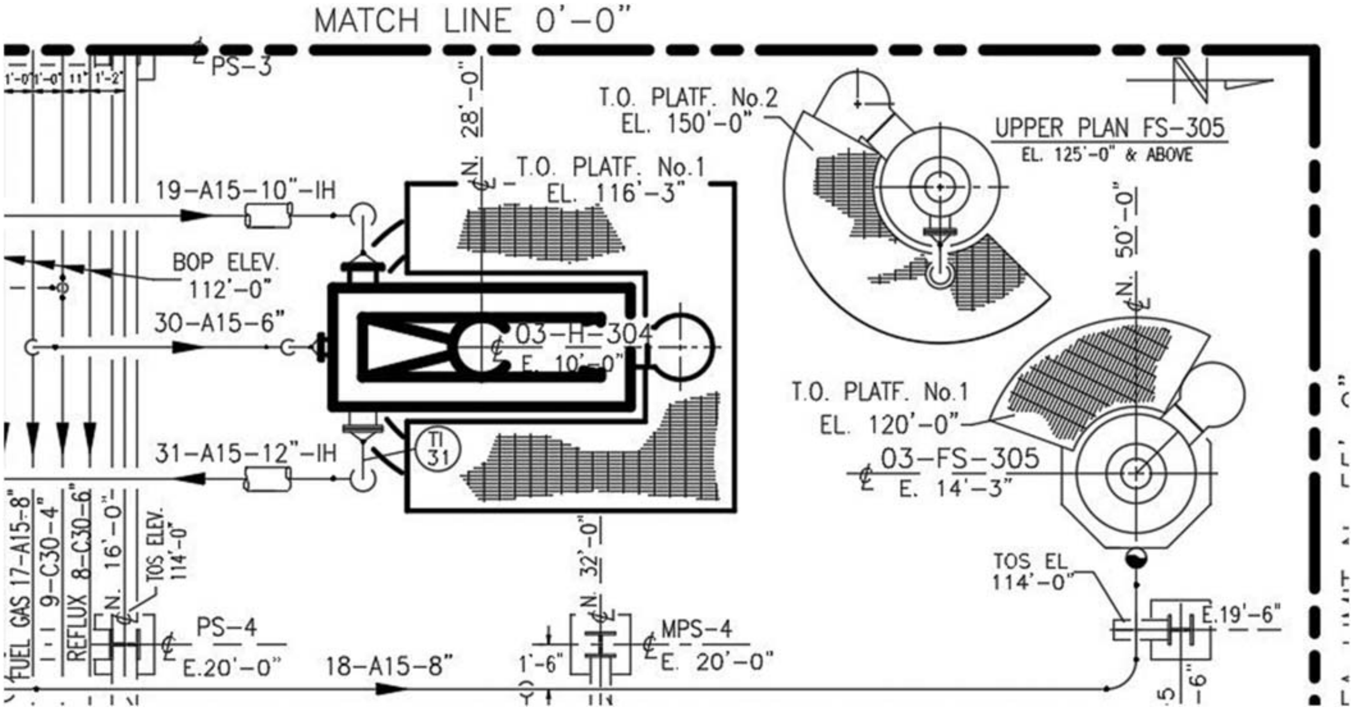


FIGURE 6.37 Highlighted plan-view representation of a box heater.

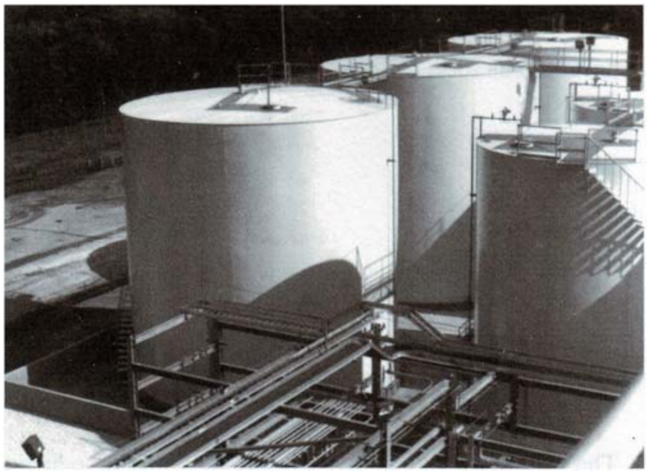


FIGURE 6.38 Storage tanks. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

known as the *flash zone*. The flash zone is the position in the fractionating column where the incoming feed, when infused with stripping steam, separates into vapor and liquid states. *Stripping steam* is superheated, dry steam that enhances the molecular breakdown of the crude feed.

Inside the column the heated crude oil molecules will begin to group together according to their weights. The natural tendency of lighter weight molecules to rise causes the light fractions, those with a low-temperature boiling point, to vaporize and rise to the top of the column. Heavy fractions, the heavier molecules with a high-temperature boiling point, remain in a liquid state and settle to the bottom of the column. Horizontal trays, spaced 18″−24″ apart inside the column, perform a progression of filtering procedures to isolate and collect fractions of the same molecular structure at specific levels throughout the height of the column.

As vapors rise through the column, they begin to cool. At one specific and unique height in the column, when the vapors cool to a precise temperature, the fractions condense. The condensing fractions, now liquid, collect on a tray that has been placed in the column at that exact height based on temperatures calculated by a process engineer. Trapping the liquid is a short, vertical plate, known as a *weir*, which acts as a dam to contain the liquid on the tray. The weir is of such a height that liquid by-product will collect and be drawn off by pipe attached to a nozzle. The liquid fraction, now a by-product of the feed, is routed to other areas of the facility for additional refinement and processing. If an excess amount of liquid collects on the tray, it will overflow the weir and fall down through an area known as a *downcomer* to a lower section of the column. There it is once again heated to the point of vaporization. The vapors will begin to rise and start the process over again. Depending on precise fractionation requirements, a number of tray types exist, each performing a unique task for which they are specifically designed. Tray types include bubble cap, sieve,

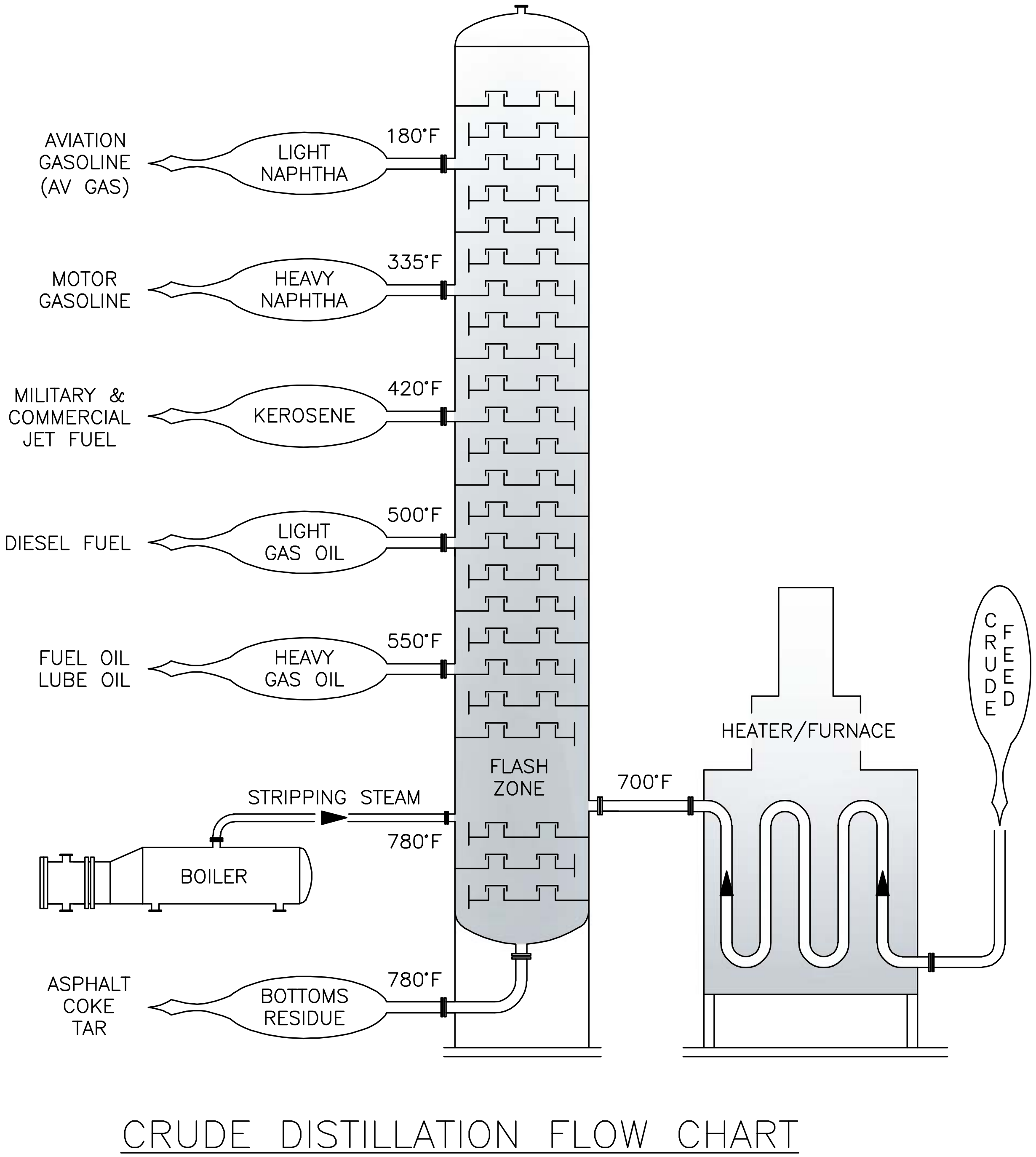


FIGURE 6.39 Crude feed by-products.

and valve. Valve trays can have either fixed or floating valves. The sample trays in Figure 6.40 depict how bubble caps are spread across the surface of the tray, the height of the weir controls the depth of the fluid on the tray's surface and how the downcomer returns excess fluid that spills over the weir back to the tray below. Figure 6.41a–c provides a closer look at three bubble cap designs. The Sieve tray, shown in Figure 6.42, is nothing more than a series of holes perforated through the tray plate. The diameter of the holes can range in size from 0.1875″ (3/16″) through 1″. The pressure of the rising vapors rising up through the holes prevents liquified fractions from seeping back down through the holes. Liquid commodity will then collect on the tray, spilling over the weir, and into the downcomer. Fixed-valve trays (Figure 6.43) typically

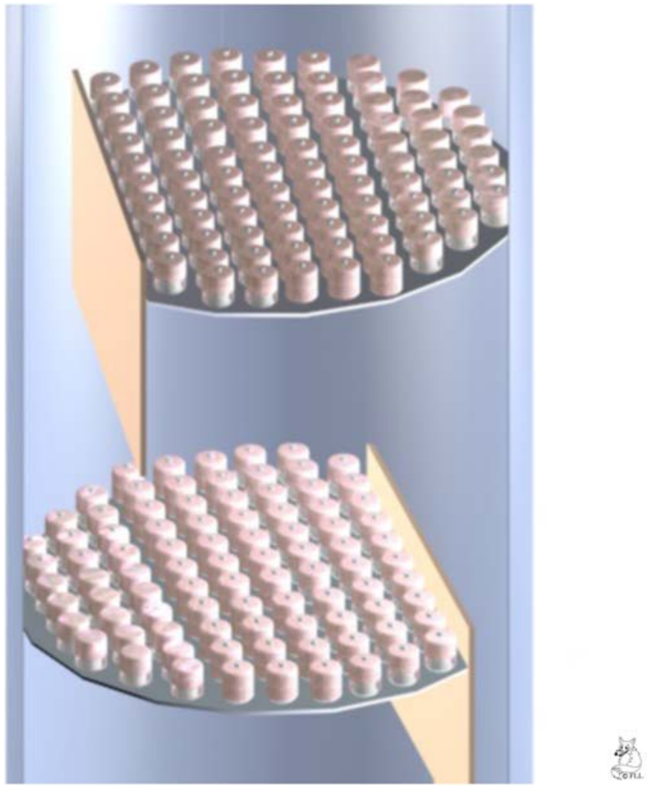


FIGURE 6.40 Fractionation column trays.

have the lowest pressure drop of the tray options. The opening where vapors pass through the tray are punched from the tray plate material. Therefore the fixed-valve tray has no moving parts. The Floating-valve tray is perhaps the type most traditionally associated with distilling/fractionating columns. Floating-valves are either circular or rectangular in shape. The four legs, stamped into the domed-shaped valve during the manufacturing process, shown in Figure 6.44, have short "feet" bent at a 90° angle which prevents the valve from disengaging from the tray. Another manufacturing method used to keep the valve in position is to build a cage around the floating valve. A caged Floating-valve is depicted in Figure 6.45.

Inside each column/tower trays can have multiple configurations and orientations. Figure 6.46 provides a representation of a "single-pass" and "double-pass" configuration of a sieve tray.

Figure 6.47 demonstrates the flow of rising vapors and falling liquids throughout the height of the fractionation column on "single-pass" and "double-pass" sieve trays.

Figure 6.48 illustrates an expanded schematic flow chart of a fractionating column and the by-products extracted for its crude oil feed. As you look at this

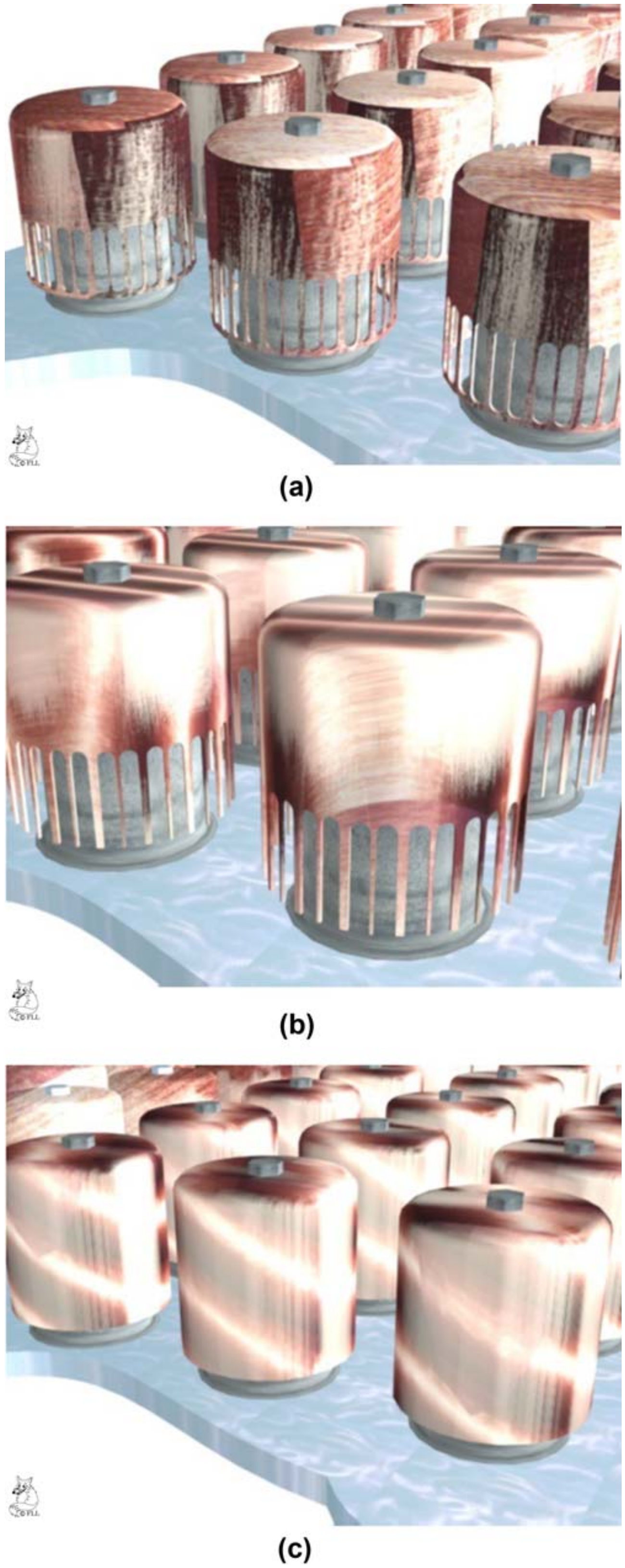


FIGURE 6.41 (a–c) Bubble cap tray.

FIGURE 6.42 Sieve tray.

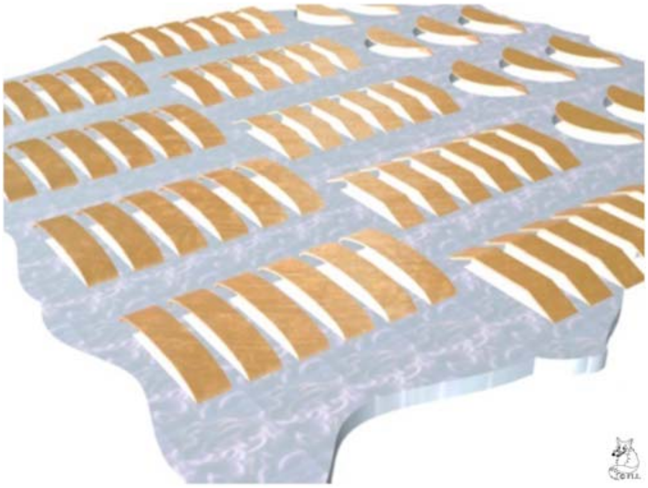


FIGURE 6.43 Fixed-valve tray.

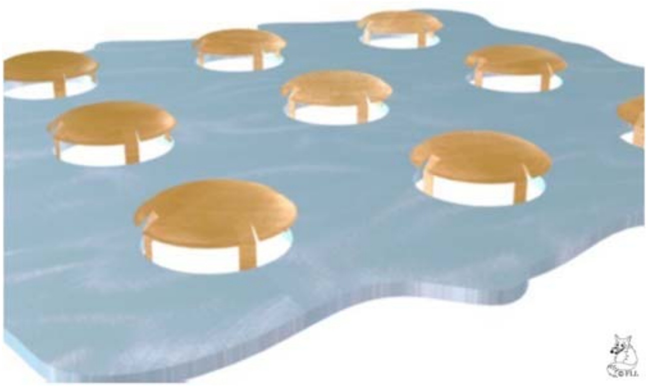


FIGURE 6.44 Floating-valve tray.

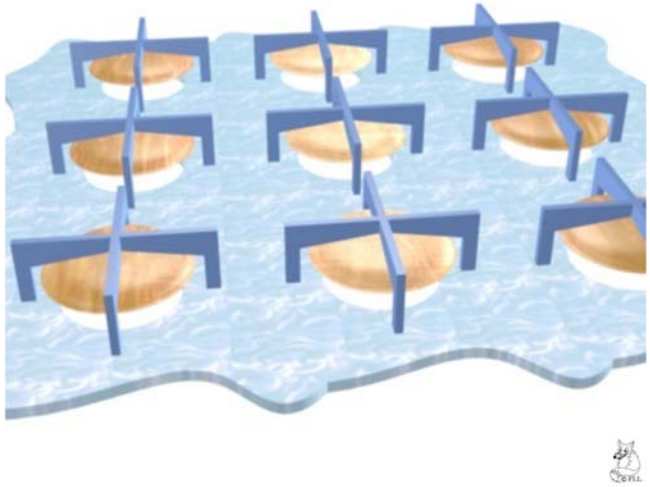


FIGURE 6.45 Caged Floating-valve tray.

example keep in mind that the extraction and refinement of these by-products would require multiple stages of further processing, taking place in numerous additional fractionation columns. In the typical fractional distillation process, heavy by-products such as asphalt and tar come off the bottom of the column as residue. As the vapors rise and temperatures begin to decrease, the molecules of heavy oil products, which include fuel and lubricating oils, condensed, collected on a tray, and are extracted. At higher elevations in the column, light oil products such as diesel fuel and kerosene are removed. Above the kerosene, heavy naphtha, used in making motor gasoline, and light naphtha, used to make aviation gasoline, are collected for further processing. The light naphtha is a prime example of how further processing can yield additional products.

When the light naphtha vapors are removed from the top of the column, they are sent through exchangers to be condensed. As the liquid naphtha is condensed, it is piped to an accumulator for collection. In the accumulator the liquid naphtha settles to the bottom and is pumped away for additional processing to later become aviation gasoline (av gas). The naphtha vapors left in the accumulator rise to the top and are removed by a compressor to be further processed into liquefied petroleum gases (LPG) such as butane, methane, and propane of burned in a flare stack as waste gases.

EQUIPMENT TERMINOLOGY

The following list identifies items generally associated with mechanical equipment and vessels:

- ***Base plate***—A flat, metal ring welded to the bottom of a vessel's supporting skirt that rests on a concrete

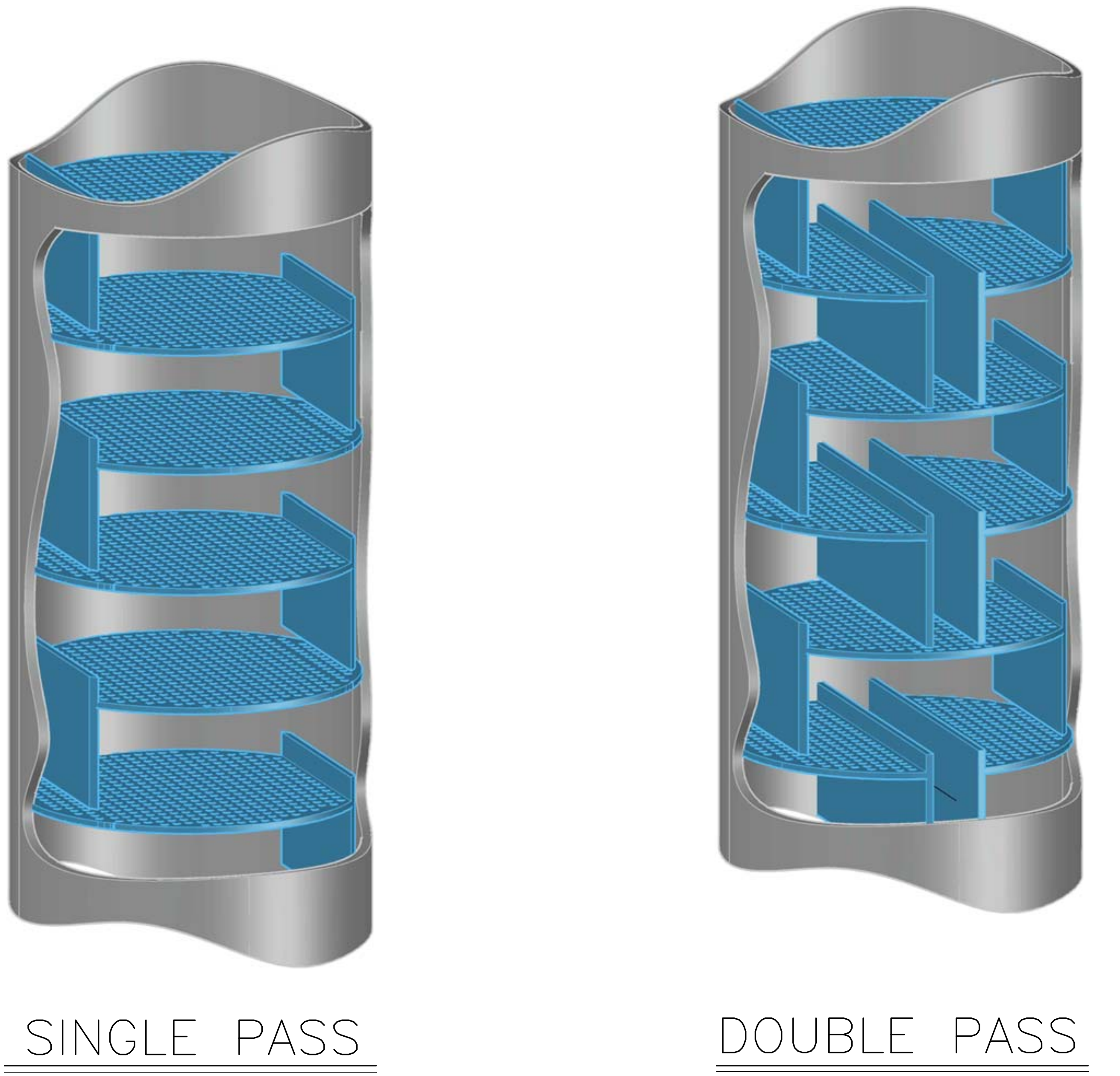


FIGURE 6.46 Single-pass and double-pass sieve tray configurations.

foundation. Holes around the perimeter of the metal ring make it possible to position it over anchor bolts and secure it to the foundation.

- ***Downcomers***—Vertical openings adjacent to a tray that allow liquids flowing over a weir plate to fall to the tray below and begin the fractionation process again.
- ***Head***—The end enclosures of a vessel. Heads shapes can be variations of elliptical, semielliptical, spherical, hemispherical, torispherical, dished, flat, and conical shapes. Most vessel's heads are welded to the vessel's shell. Heads on exchangers are typically either welded or flanged. See Figure 6.49 for various head shapes.
- ***Insulation rings***—Continuous circular rings welded to the exterior of a vertical vessel that support a vessel's insulation. They are typically spaced on 12′-0″ centers.
- ***Lifting lugs***—Donut-shaped rings welded to the vessel's shell or head that allow the vessel to be raised and positioned during installation.
- ***Manholes***—Similar to large nozzles that allow workers entry points into a vessel. They generally are 18″ ID and are accessible by ladders and

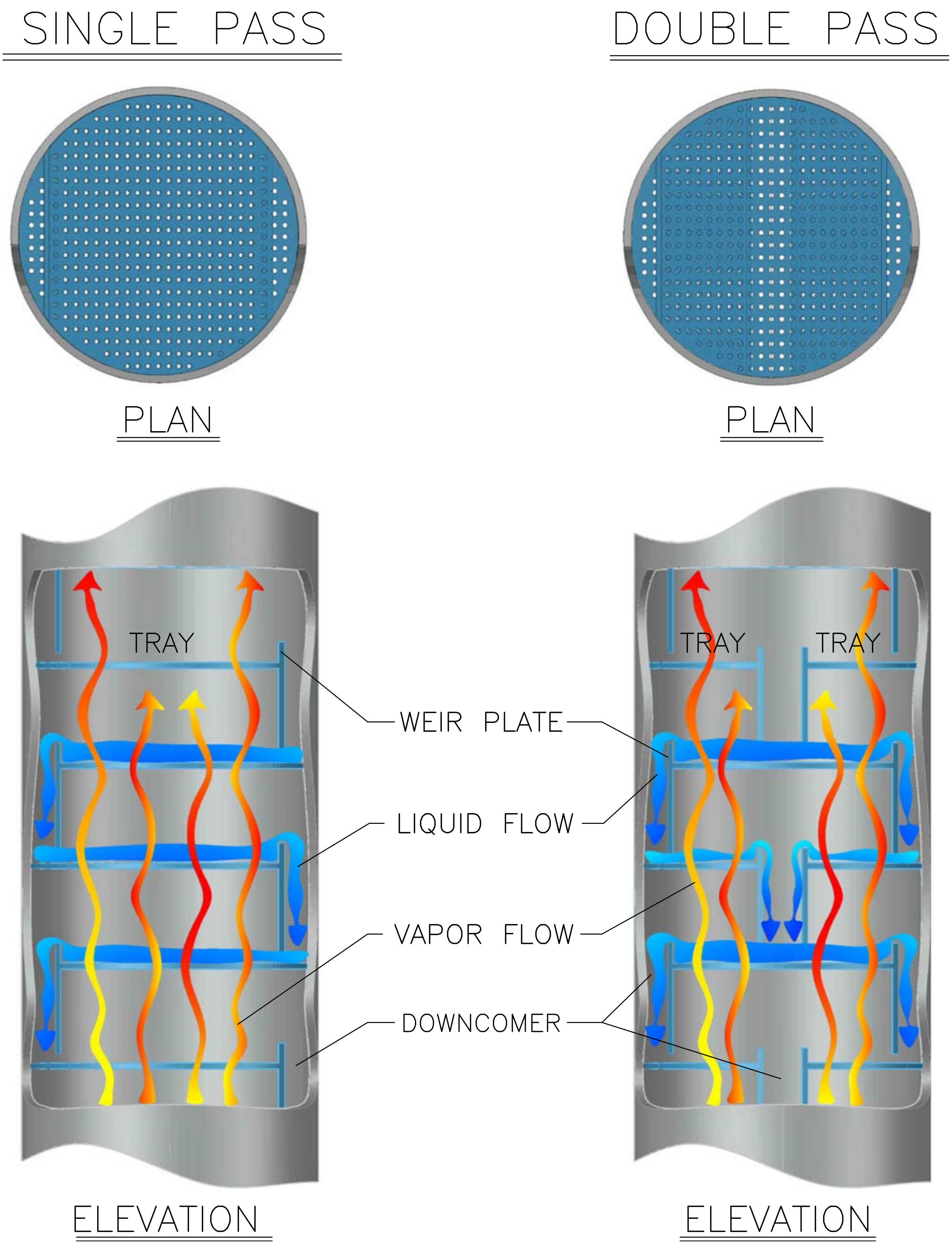


FIGURE 6.47 Vapor and liquid flows on single-pass and double-pass sieve trays.

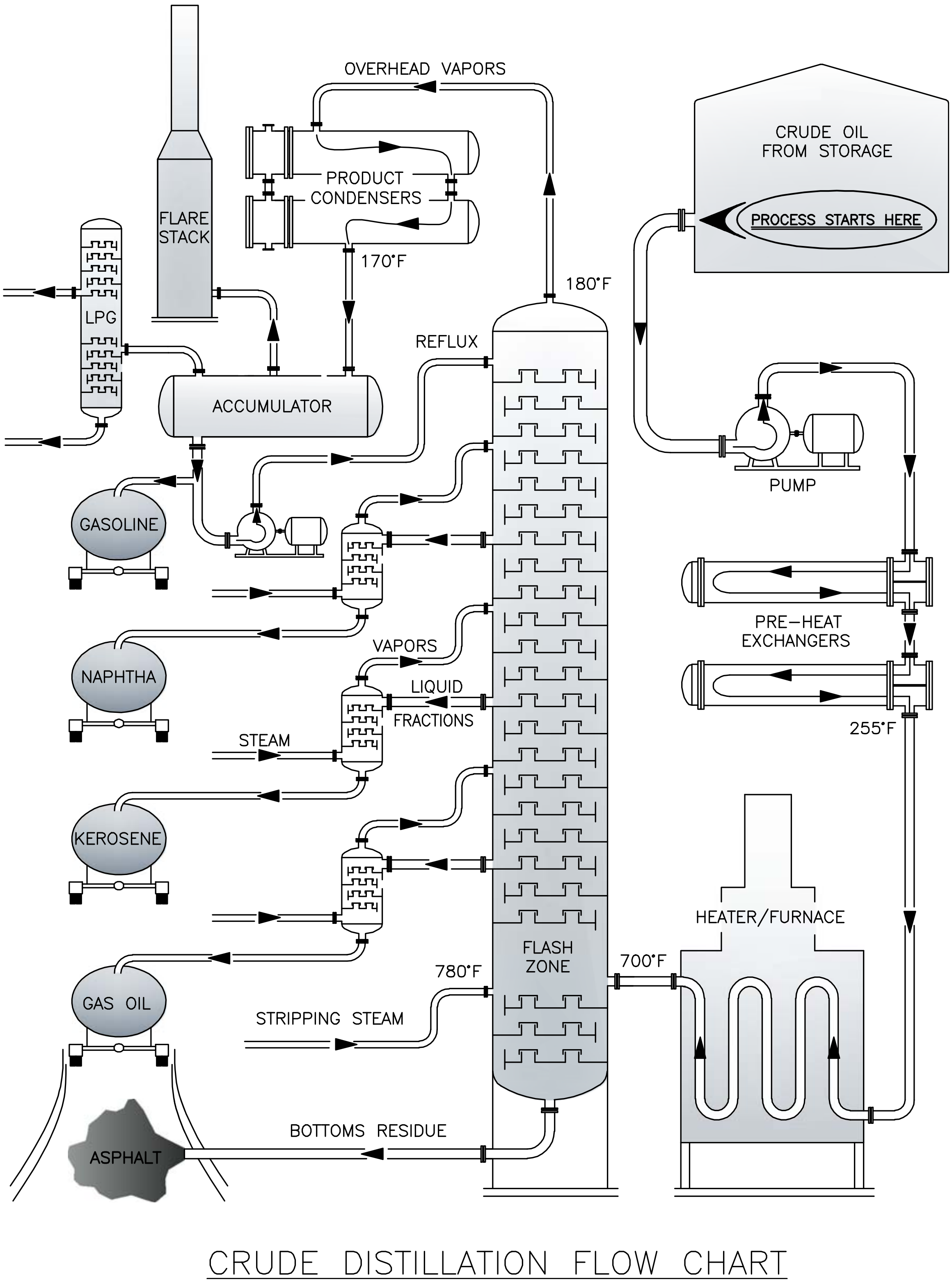


FIGURE 6.48 Flow chart of fractional distillation process.

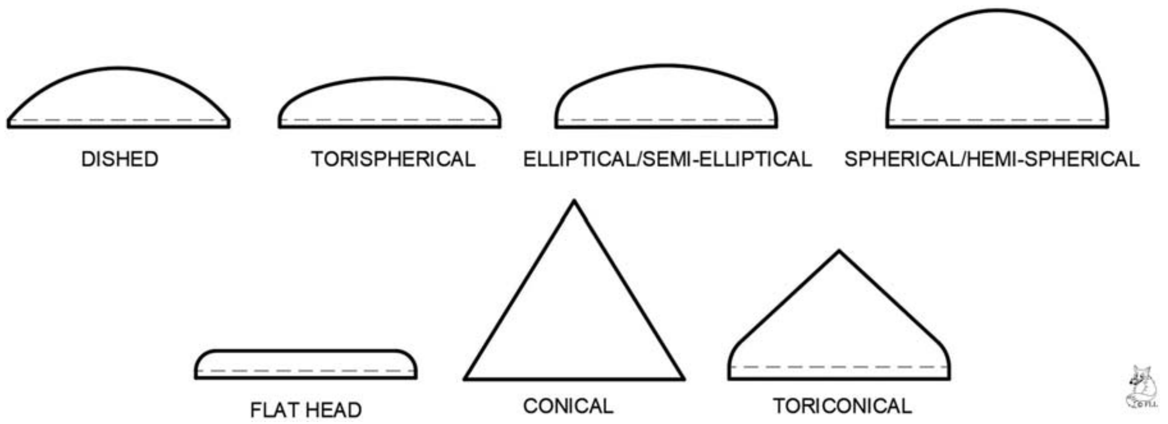


FIGURE 6.49 Head shapes.

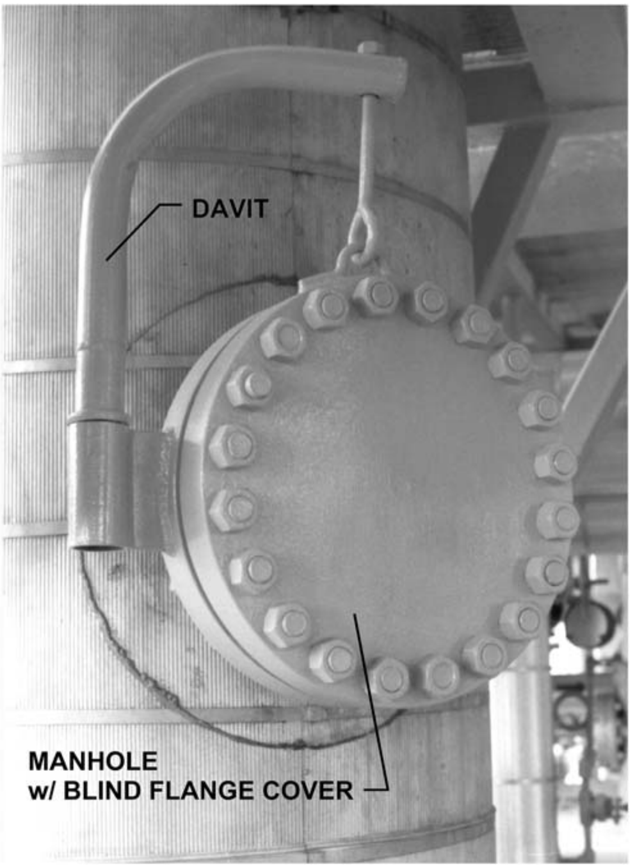


FIGURE 6.50 Manhole with blind flange cover and manhole davit. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

platforms. When not in use, the manhole is sealed with a blind flange. See Figure 6.50.

- ***Manhole davit*—**An L-shaped arm attached to the blind flange covering a manhole which allows the flange to swing and pivot away from the manhole opening after it is unbolted. See Figure 6.50.
- ***Manhole hinge*—**A hinge that creates a pivot point allowing the blind flange attached to the manhole to be swung open, much like a door, for worker entrance.
- ***Nozzle*—**A flange-faced tie-in connection that allows a piping configuration to be bolted to a vessel, pump, exchanger, or other piece of mechanical equipment. Nozzles are provided in locations where a commodity is either introduced or removed from a vessel or piece of equipment.
- ***Nozzle orientation*—**The angular arrangement of nozzles around the perimeter of a vessel's shell.
- ***Nozzle projection*—**Used to establish the distance from the vessel's centerline to the nozzle's face of flange.
- ***Reinforcing pad*—**A plate contoured to the shape of a vessel shell. It is positioned around nozzles and provides additional strength in the areas where metal was removed from the shell.
- ***Saddles*—**U-shaped supports welded on horizontal vessels and exchangers. Saddles are bolted to concrete foundations and create a cradle-like support in which the vessel can rest.
- ***Seal pan*—**A tray installed below the bottom tray in a vessel to prevent liquids from bypassing the trays.
- ***Shell*—**The cylindrical walls of a vessel.
- ***Skirt*—**A cylinder shaped support for a vertical vessel. One end is welded to the base plate allowing it to rest on a concrete foundation or structural steel platform, and the other end is welded to the bottom head of a vertical vessel. See Figure 6.51.
- ***Skirt access opening*—**An 18″ ID hole 2′-6″ above the foundation or platform which allows workers entrance for inspection and maintenance. See Figure 6.51.
- ***Skirt fireproofing*—**Generally, brick or gunite, fireproofing is applied around the interior and

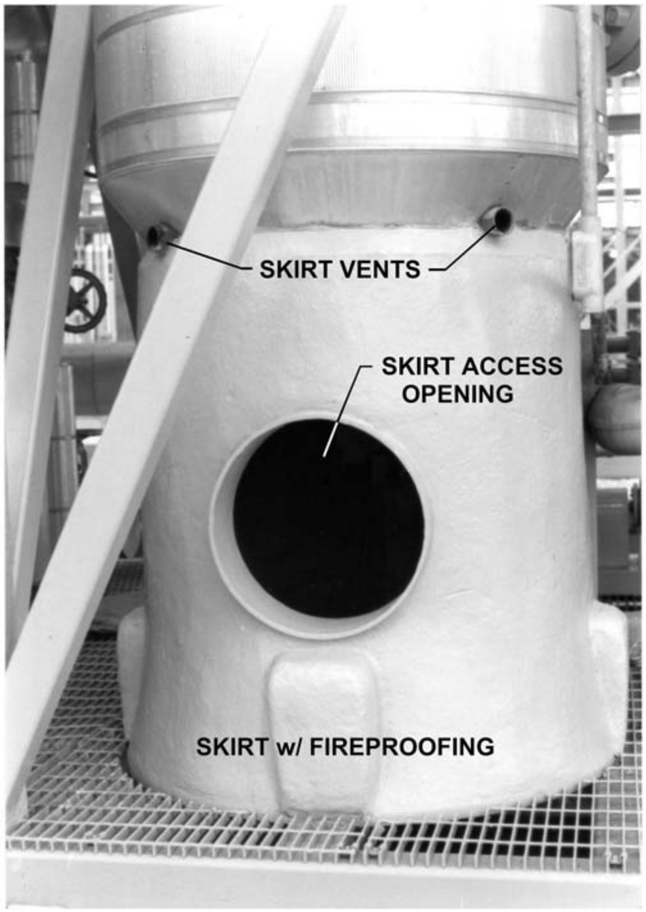


FIGURE 6.51 Skirt with fire proofing, skirt access opening, and skirt vents. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

exterior walls of a vessel skirt. It is necessary to prevent damage to vessel skirt in case a fire occurs.

- ***Skirt vents***—Equally spaced holes, sometimes with pipe inserts, approximately 3″–4″ in diameter placed near the top of the vessel skirt that allow toxic and explosive gases to escape. See Figure 6.51.
- ***Trays***—Flat metal plates spaced approximately 18″–24″ apart inside a vertical vessel. They can be bolted or welded to the vessel shell. Trays are perforated to allow rising vapors and falling liquids to pass through with the aid of a valving mechanism called a *cap*.
- ***Weir***—A dam-like plate welded on a tray that allows a fractionated by-product to collect and be extracted by a nozzle.

VENDOR DATA DRAWINGS

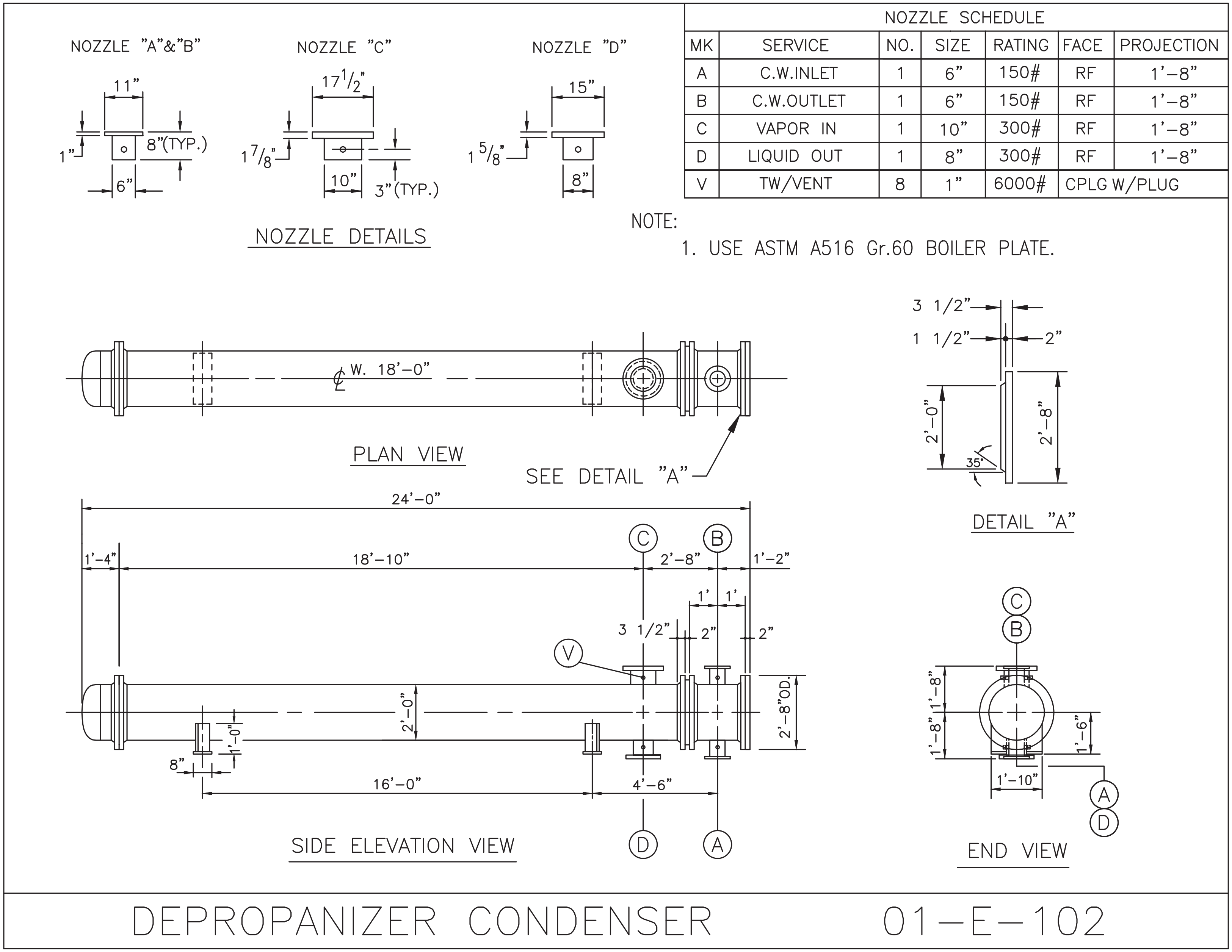
With a myriad of piping facilities in operation, one should not expect specialized piping equipment to be an item stored in a warehouse or found on a shelf like parts for an automobile. Each piece of equipment has certain criteria that must be met before it can become part of a process unit, boiler room, or production facility. Although duplicate pieces of equipment are found within the same facility, every piping facility has equipment installations unique unto itself. Therefore equipment must be specifically designed and fabricated for each situation.

Once specific performance requirements for equipment have been established by engineering, process, and other design groups, purchase orders are placed with companies called *vendors* who specialize in manufacturing the specialized equipment. While equipment such as pumps and compressors are considered to be somewhat “standard” and are readily available, other pieces of equipment such as vessels, heaters, and exchangers must be custom-made for a specific application. Vendors provide engineering and construction companies data drawings that show exact measurements, locations, pound ratings, and overall sizes of the newly manufactured item. Engineering companies then use the information found on these *vendor data drawings* as a reference so pipe connecting to the piece of equipment can be designed, drawn, fabricated, and installed with precision. Vendor data drawings also provide designers the necessary information required to build foundations, locate supports, and calculate interferences without having the actual piece of equipment available to measure.

DRAWING EQUIPMENT

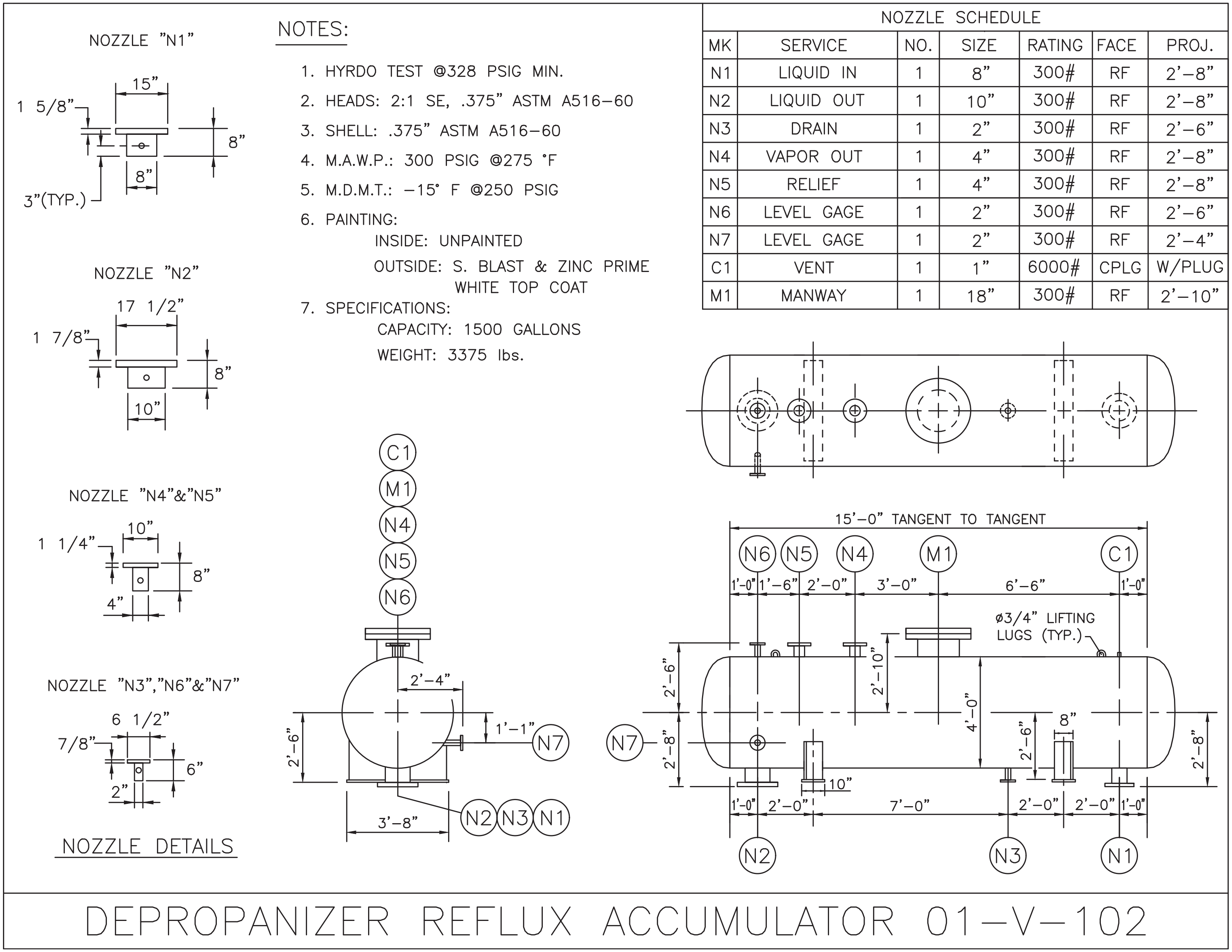
Vendor data drawings are valuable sources of information when the need to represent equipment on a piping drawing arises. Although piping drawings do not require the duplication of all the information shown on equipment data drawings, they do require representation of overall equipment lengths and heights, along with nozzle sizes, locations, projections, orientations, and pound ratings. The drawings shown in the Figures 6.52 and 6.53 are typical representations of vendor data drawings for a shell and tube exchanger and horizontal vessel, respectively.

Without using a 3D modeling software program, a Piping Arrangement drawing can be tedious and time-consuming to create. The step-by-step procedures shown in Figure 6.54 can be used as a guide to develop the various elements of a horizontal vessel. The measurements used to represent vessel 01-V-102 on a Plan, Elevation, or Section view are taken from the vendor data drawing shown in Figure 6.53. This accumulator is capped on each end with a 2:1 semielliptical head. Drawing the vessel’s shell is not difficult, but development of the 2:1 semielliptical head can be challenging.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJECTION
A	C.W.INLET	1	6"	150#	RF	1'–8"
B	C.W.OUTLET	1	6"	150#	RF	1'–8"
C	VAPOR IN	1	10"	300#	RF	1'–8"
D	LIQUID OUT	1	8"	300#	RF	1'–8"
V	TW/VENT	8	1"	6000#	CPLG W/PLUG	

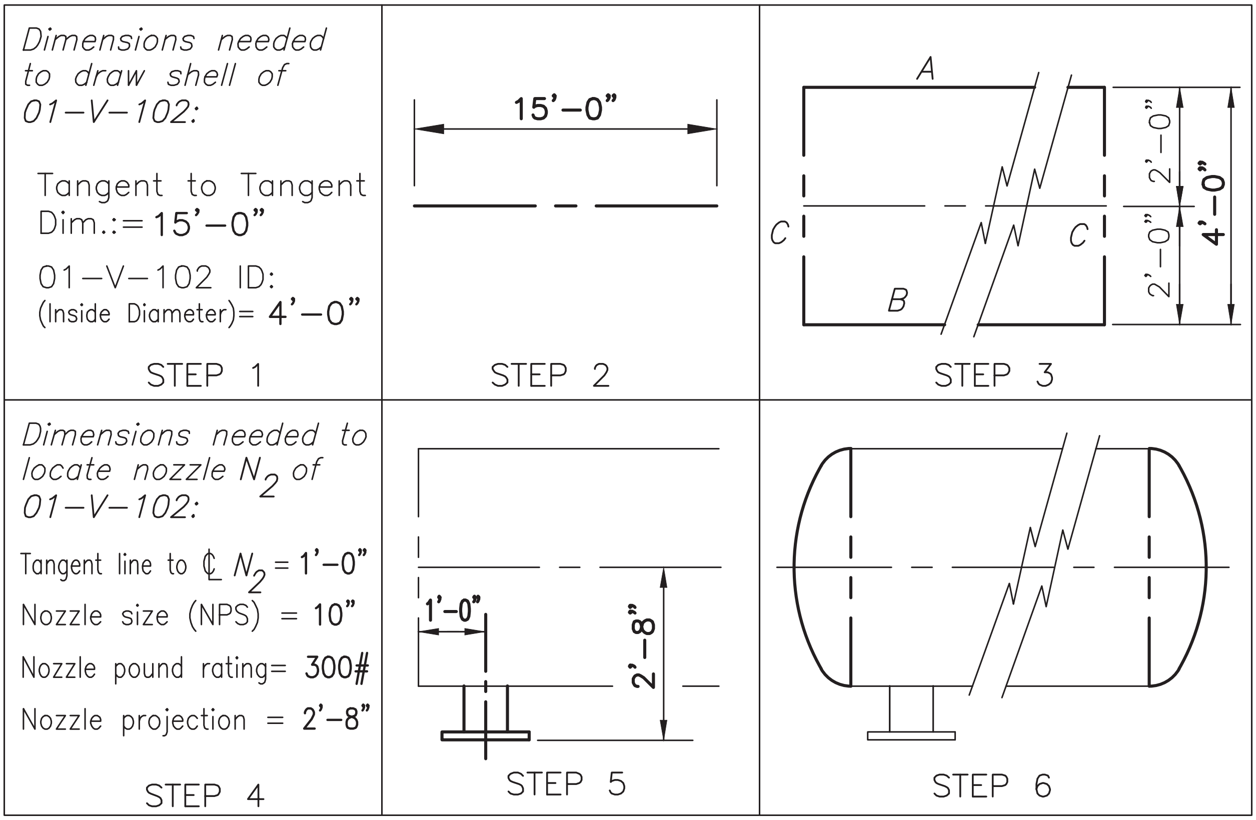
FIGURE 6.52 Shell and tube exchanger vendor data drawing.



NOZZLE SCHEDULE

MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	LIQUID IN	1	8"	300#	RF	2'-8"
N2	LIQUID OUT	1	10"	300#	RF	2'-8"
N3	DRAIN	1	2"	300#	RF	2'-6"
N4	VAPOR OUT	1	4"	300#	RF	2'-8"
N5	RELIEF	1	4"	300#	RF	2'-8"
N6	LEVEL GAGE	1	2"	300#	RF	2'-6"
N7	LEVEL GAGE	1	2"	300#	RF	2'-4"
C1	VENT	1	1"	6000#	CPLG	W/PLUG
M1	MANWAY	1	18"	300#	RF	2'-10"

FIGURE 6.53 Horizontal vessel vendor data drawing.



Step 1. Determine the vessel's diameter and length as provided by the vendor drawing. Using the measurements from Figure 6-53, the vessel's ID (Inside Diameter) is 4′-0″ and its length from Tangent line to Tangent line (T/T) is 15′-0″.

Step 2. Draw a horizontal centerline equal to the vessel's length (15'-0").

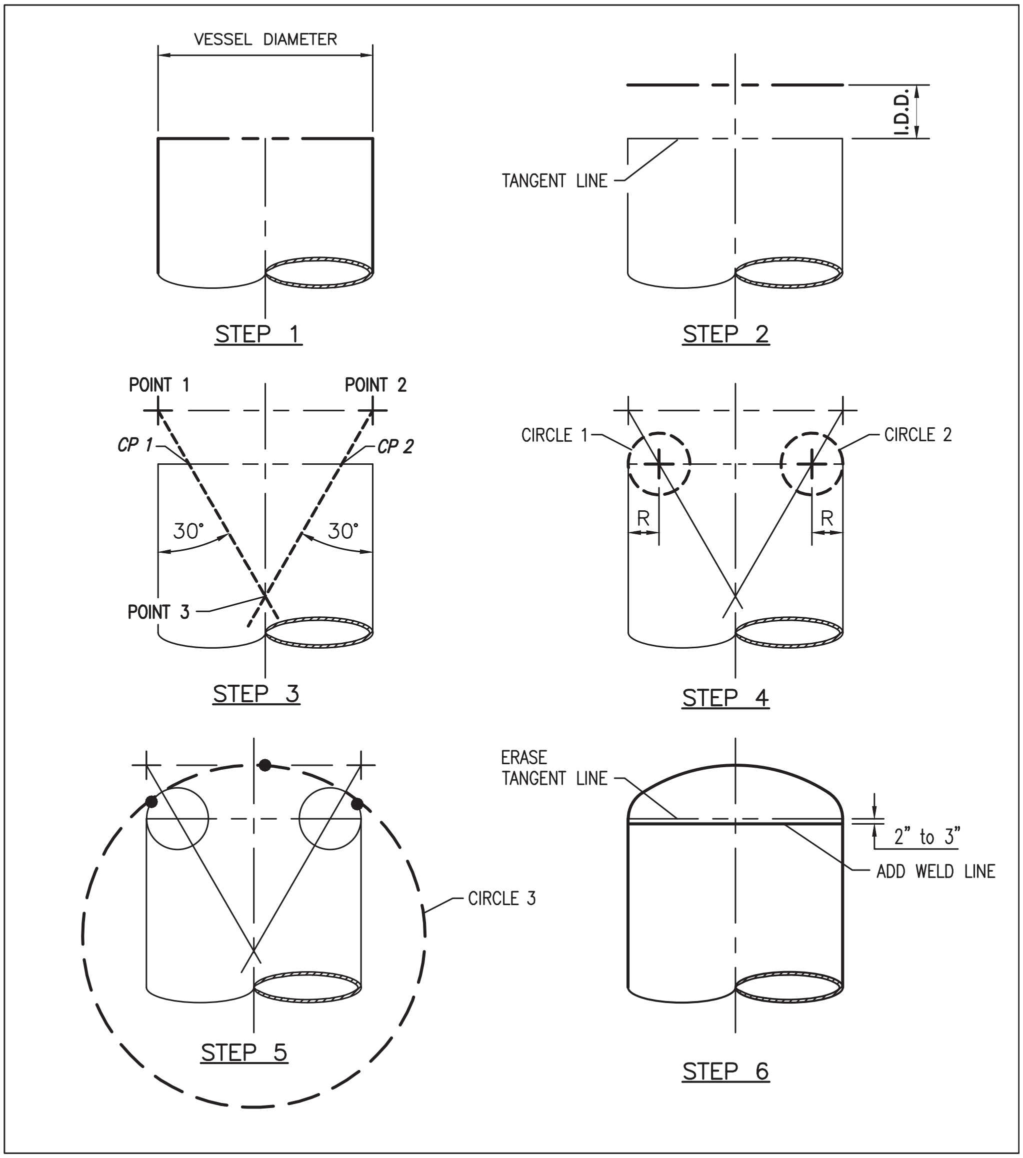
Step 3. Create two lines parallel to the centerline measuring one-half of the vessel's ID (2′-0″) above (***A***) and below (***B***) the centerline. The total height should be equal to the vessel's ID (4′-0″). Connect the endpoints of the two new horizontal lines with Phantom lines to establish the ends of the vessel's shell (***C***).

Step 4. Using measurements provided on the 01-V-102 vendor drawing, determine the following values for nozzle **N2:** the distance the nozzle's centerline measures from the Tangent line (12″), nozzle size (10″), nozzle pound rating (300#), and nozzle projection length (2′-8″).

Step 5. From the left tangent line, **OFFSET** a parallel line 12″ to the right to establish the centerline of nozzle **N2.** From the centerline of the vessel, **OFFSET** a parallel line 2′-8″ below, to establish the face of the nozzle. Using dimensions found on the 300# Welded Fittings-Flanges dimensioning chart in Appendix A, draw the nozzle using the flange's OD (17½″) and face thickness (1⅞″**).**

Step 6. Use the step-by-step procedures shown in Figure 6-55 to develop the 2:1 semi-elliptical heads.

FIGURE 6.54 Step-by-step procedures for drawing 01-V-102.



Step 1. Develop the vessel's shell using the step-by-step procedures shown in Figure 6-54.

Step 2. **OFFSET** a line above and parallel to the Tangent line that is a distance equal to the *IDD* (Inside Depth of Dish) dimension. Use the following formula to establish the IDD dimension.
IDD = *vessel diameter × .25*

Step 3. Draw 30° lines from *Points **1*** and ***2*** that will intersect on the vessel's centerline and establish *Point **3***.

Step 4. Construct *Circle 1* by drawing a **CIRCLE** having its centerpoint at the intersection of the 30° line and the Tangent line (***CP1*** in Step 3). The radius of *Circle 1* is measured from ***CP1***, then horizontally to the left end of the vessel. *Circle 2* is constructed in a similar manner on the opposite side of the vessel using ***CP2*** as its centerpoint.

Step 5. *Circle 3* is a **TANgent**, **TANgent**, **TANgent** circle type. The three tangent selection points are identified by the three 'dots' shown in the Step 5 figure. The resulting circle is shown as dashed lines.

Step 6. Use **OFFSET** to construct a weld line that measures 2″ to 3″ below and parallel to the Tangent line. **TRIM** the arcs as necessary. **ERASE** the Tangent line.

FIGURE 6.55 Step-by-step procedures for drawing a 2:1 Semielliptical head.

Use the step-by-step procedure shown in Figure 6.55 to create a 2:1 semielliptical head on each end of 01-V-102.

Drawing the Horizontal Vessel

See Figure 6.54

Drawing the 2:1 Semielliptical Head

See Figure 6.55

CHAPTER 6 REVIEW QUIZ

1. Define *mechanical equipment*.
2. What is an *accumulator*?
3. Explain *fractional distillation*.
4. What is a *'by-product'*?
5. What does a pump do?
6. What are the five pump nozzle configurations?
7. Name three types of pump drivers.
8. What does a compressor do?
9. Describe the function of an *exchanger*.
10. How does a cooling tower perform its function?
11. What items are typically found on a tank farm?
12. Name some of the common by-products derived from crude oil feed stock?
13. What internal device is used as a separator and collector of molecules in a fractionation column?
14. Which directions do light and heavy molecules travel within a fractionation column?
15. Where is dimensional data used to draw/model mechanical equipment found?

CHAPTER 6 DRAWING EXERCISES

Exercises: Drawing Equipment

Exercise 6.1. Draw the Plan and Elevation views of the shell and tube exchanger as shown in Figure 6.52 to Full scale and place in an "A" size border to 3⁄8″ = 1′-0″ scale.

Exercise 6.2. Draw the Plan and Elevation v × iews of the horizontal vessel as shown in Figure 6.53 Full scale and place in an "A" size border to 3⁄8″ = 1′-0″ scale.

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CHAPTER

7

Flow Diagrams and Instrumentation

Flow diagrams describe, in a schematic drawing format, the sequential flow of liquids, gases, and vapors as they enter, flow through, and exit the process facility. By using simplified drawing symbols, to represent various pieces of mechanical equipment, valving, and instrumentation, and specific notes, callouts, and abbreviations, the flow diagram provides the piping designer with an overall view of the operation of a facility.

The flow diagrams presented in this chapter are representative of the types used by many engineering and design companies. While actual symbols may vary slightly from company to company, the general appearance of flow diagrams is the same throughout the piping industry.

Anyone new to flow diagrams must become familiar with the piping, equipment, and instrumentation symbols, as well as the abbreviations used on flow diagrams, in order to be able to interpret them.

One of the most difficult concepts for students to comprehend is the absence of scale in the preparation of flow diagrams. The flow diagram should be laid out in a very simplistic and logical order and be "read" from left to right. It guides the drafter and designer in the same manner a road map guides a traveler.

USES OF FLOW DIAGRAMS

The flow diagram is used by the piping group to develop and lay out the plot plan. When developing the plot plan, the arrangement of the mechanical equipment in the facility reflects, in part, the logical sequence of flow depicted on the flow diagram. However, many other factors such as code requirements, client standards and preferences, worker safety, and cost influence the positioning of equipment.

Once the plot plan is finalized, the piping designer routes the pipe between the various pieces of mechanical equipment as indicated by the flow diagram using project specifications, standards, and accepted design practices. The flow diagram is usually "yellowed out" as each line is completed and incorporated into the design.

TYPE OF FLOW DIAGRAMS

Process engineers are responsible for developing flow diagrams. In many large engineering firms, an entire department is dedicated to the development of flow diagrams. Today almost all flow diagrams are laid out with CAD drafting software or a 3D plant modeling software program that has a flow diagram package included. Although there are various types of flow diagrams used during the design phase, we will concentrate on just three; the Process, Mechanical, and Utility flow diagrams.

Process Flow Diagram

The *Process flow diagram* is the first flow diagram developed during the design process. The Process flow diagram will include the following:

1. Major mechanical equipment
2. Main piping
3. Direction of commodity flow
4. Operating pressures and temperatures of the facility components
5. Major controlling instrumentation

The Process flow diagram will denote the following:

- Conditions to be used for the design of various pieces of mechanical equipment required for facility operation, that is, fractionation columns, pumps, and heaters.
- The o*perating* and *design* conditions (pressures and temperatures) of which a particular piece of mechanical equipment will function. Design conditions establish the limits that certain

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00020-0

components such as gaskets and valve seats used in the facility can withstand. Design pressure is calculated to be at least 10% above the maximum operating pressure or 25# greater (whichever is largest). The design temperature will be at least the maximum operating temperature but should be at least 25 degrees above the normal operating temperature.
- Composition of the commodities used in the refining or treatment process sequence as they enter and leave the unit.

Figure 7.1 is the Process flow diagram of Unit-01.

Mechanical Flow Diagram

From the Process flow diagram, the Mechanical group develops the Mechanical flow diagram. The *Mechanical flow diagram* provides much more detailed data than the Process flow diagram. Many companies refer to the Mechanical flow diagram as the "P&ID" (Piping and Instrument diagram). Often referred to as the "bible" of the design process, this drawing provides the pipe drafter with specific design criteria. Mechanical flow diagrams include the following:

1. Pipe line numbers with direction of commodity flow
2. Pipe specifications and line sizes
3. All mechanical equipment
4. All operating and isolating valves
5. All controlling instrumentation with transmitting devices

Mechanical flow diagrams define the exact sequence in which all mechanical equipment, valves, instrumentation, connections, and so on are to be made on each process pipe routed through the facility. Figure 7.2 is the Mechanical flow diagram of Unit-01.

The Utility Flow Diagram

The *Utility flow diagram* includes all pipe, valves, and instrumentation of the facility utilities. Utilities are services that are essential to the proper function of the facility. Although the facility is not being constructed to make condensate, condensate will be present in the facility and must be dealt with. Similarly, the facility is not being designed to gather and sell rainwater; but the collection, treatment, and disposing of rainwater must be incorporated into the facility's design. Some utilities found in a petro-chemical facility correspond to those found in a typical house, such as water, gas, heating oil, and sewer drains. Others are specific to industrial applications such as compressed air for pneumatic tools and steam for high-pressure cleaning.

Some of the common plant utilities are:

- Steam
- Fuel oil
- Instrument air
- Drainage systems
- Condensate
- Utility air
- Cooling water
- Flare system

Once flow diagrams that have been finalized, they will be stamped for "release" by a registered professional engineer approving them for construction by the engineering group. The flow diagram is a dynamic document. They may be revised and updated during the project's design phase to reflect the client changes or modifications imposed by governmental regulations. Continual review of relevant flow diagrams must occur on a regular basis. Figure 7.3 is the Utility flow diagram of Unit-01.

FLOW DIAGRAM INSTRUMENTS

To ensure the safe and efficient operation of a facility, controlling instrumentation is an absolute necessity. Controlling instruments function by sensing conditional changes in the commodities they monitor, either in pipes or mechanical equipment. These conditional changes comprise the four basic instrument groups; they are:

Flow	(F)
Level	(L)
Pressure	(P)
Temperature	(T)

Within these four instrument groups are uniquely designed instruments which carry out the sensing, controlling, and monitoring of the commodity. These instruments can be one or a combination of five specific types; they are:

Controller	(C)
Indicator	(I)
Gauge	(G)
Alarm	(A)
Recorder	(R)

By learning the combination of these nine instrument groups and types, students will be able to interpret most of the instrumentation symbols found on a Mechanical flow diagram.

Figure 7.4 illustrates a combination of the instrument group and type to develop symbols and abbreviations

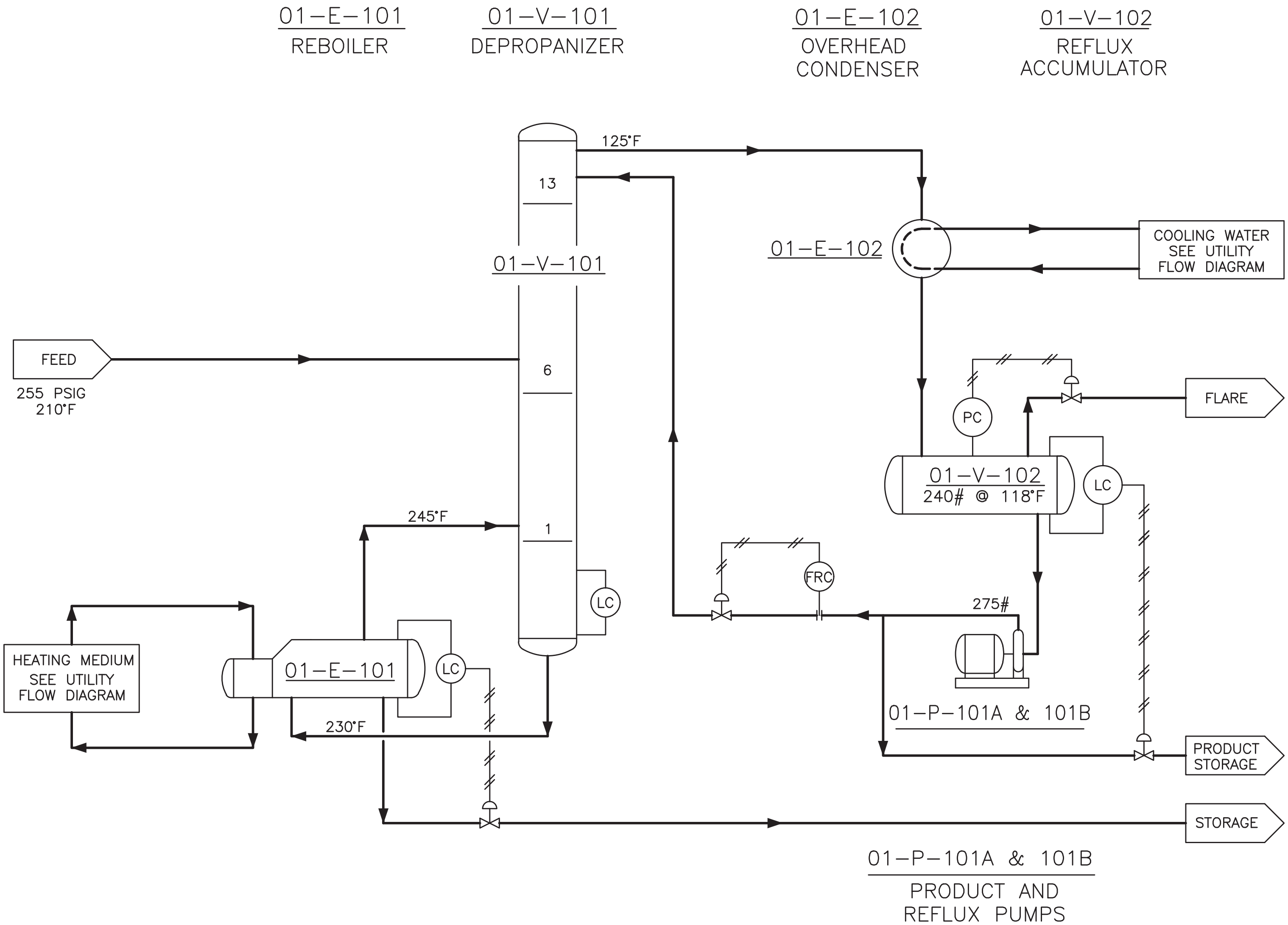

FIGURE 7.1 Process flow diagram of Unit-01.

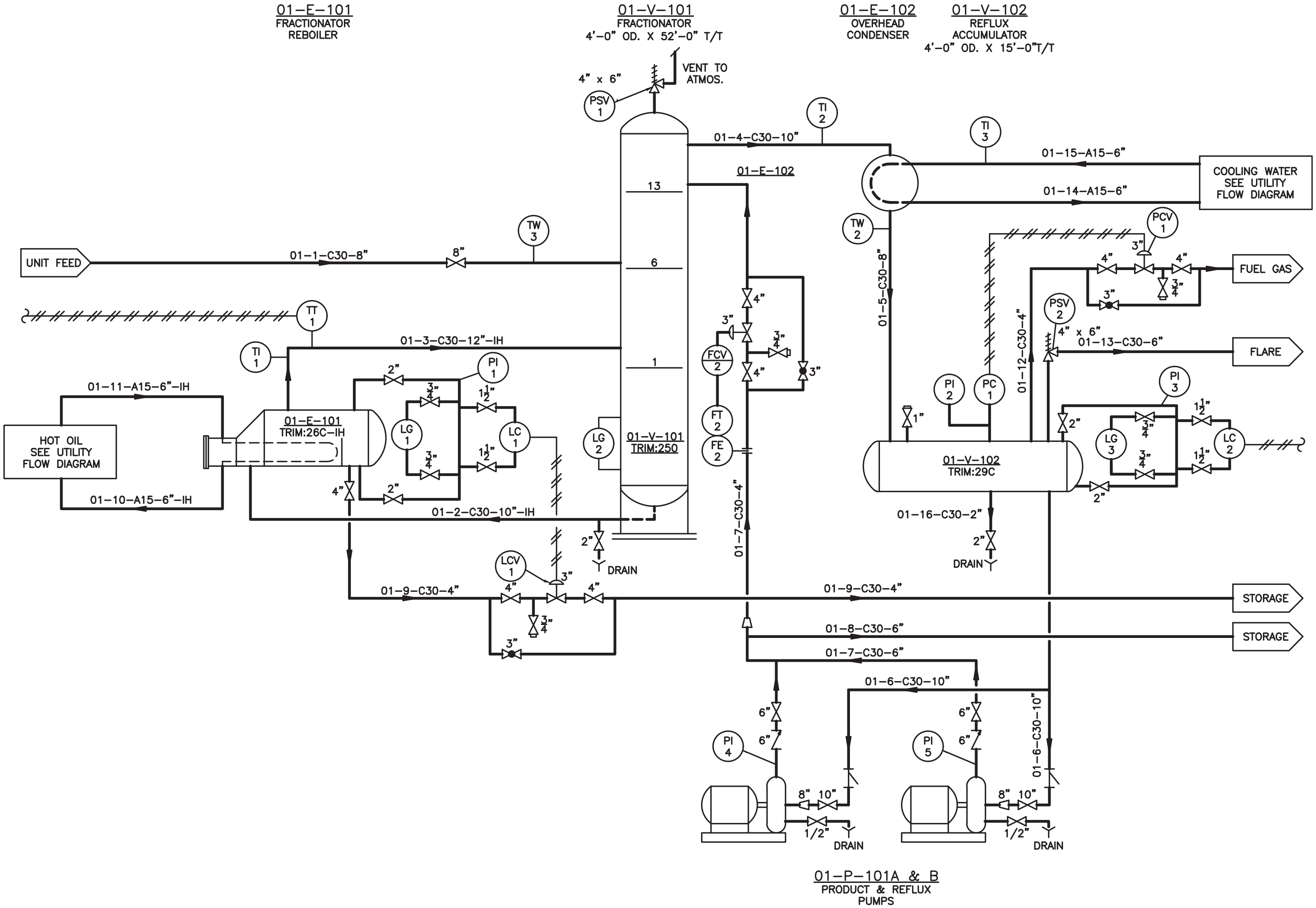

FIGURE 7.2 Mechanical flow diagram of Unit-01.

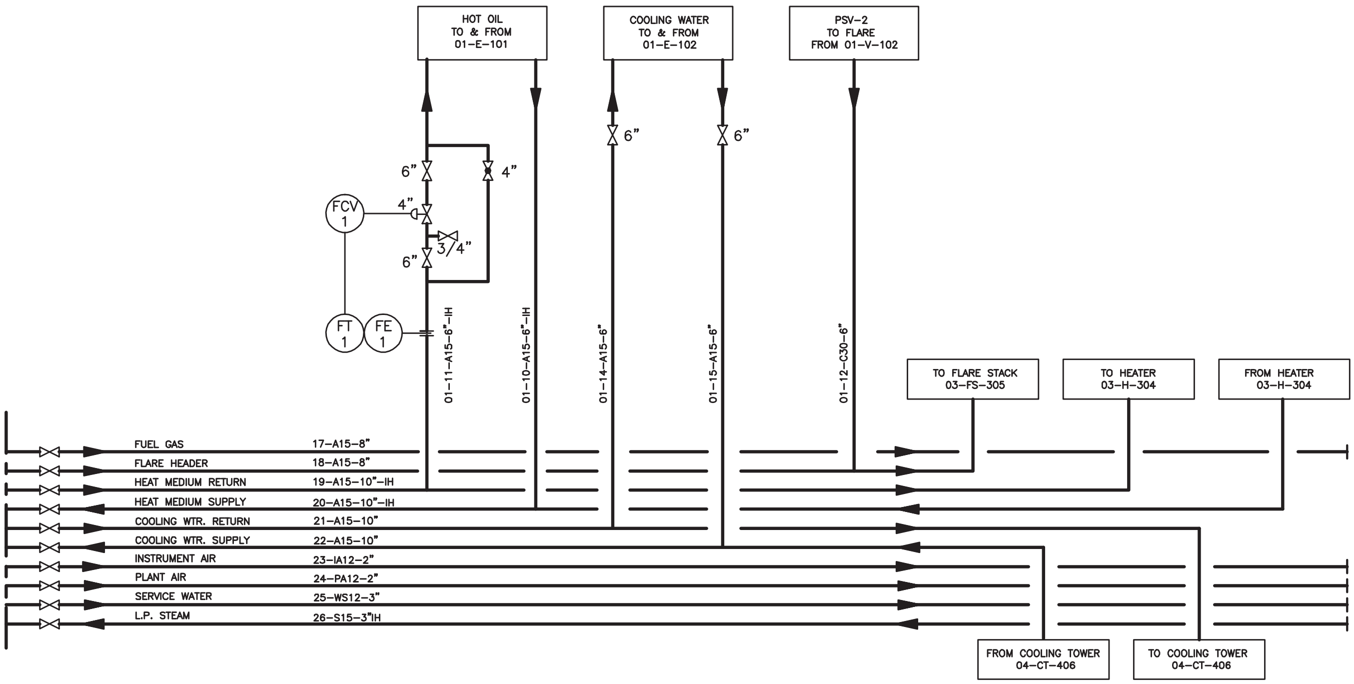

FIGURE 7.3 Utility flow diagram of Unit-01.

that represent an instrument's function on a flow diagram. The first letter in the symbol typically indicates the instrument group, whereas the second and/or third letters indicate the instrument type.

To respond to a change in, or to control the flow, level, pressure, or temperature of a commodity, an instrument must first sense a change in a particular variable. Once a change has been detected, the instrument then transmits this information, via mechanical, electronic, or pneumatic means, to a control panel where it can be observed, recorded, and responded to. At the same time the instrument may activate other devices that will affect and change process conditions elsewhere in the facility. Some instruments are read in the plant at the instrument's actual location, and others are displayed on a control panel located in the operator's control room.

Instrument Types

Controllers—devices used to maintain a specified liquid level, temperature, pressure, or flow inside a vessel or piping system. Controllers can activate a control valve which regulates the level, temperature, pressure, or flow of the commodity coming into or out of a vessel.

Indicators—devices used to indicate the liquid level, temperature, pressure, or flow rate inside a piping system.

Gauges—instruments that measure the liquid level inside a vessel or the temperature and/or pressure in the piping system. Level, temperature, or pressure gauges can be locally mounted to enable plant operators to obtain a visual reading.

Alarms—instruments which send a signal via lights, horns, or sirens that indicate the liquid level, temperature, or pressure inside a vessel is too high or too low or that there is no flow or reverse flow.

Recorders—electronic devices used to record the liquid level, temperature, pressure, and flow rate inside a vessel or piping system throughout a certain shift or period of time.

Although they are often installed independently, multitype instrument are engineered to perform various functions simultaneously. If there were the need to record and control the level of a commodity in a vessel, one would install a Level Recording Controller. The LRC would not only record the level of the commodity in the vessel but also send a signal to a control valve opens or closes to adjust the commodity level inside the vessel.

FLOW DIAGRAM SYMBOLS

Figure 7.5a–e provides some examples of many mechanical equipment symbols that can be found on flow diagrams. Figure 7.5f shows some of the common valve symbols used on flow diagrams along with

FIGURE 7.4 Flow diagram instrument symbols.

various pipe and instrument line symbols. Notice all valves, no matter their pipe size or pound rating, are drawn the same size. Remember, flow diagrams are schematic drawings where drawing to the exact dimensional size is not necessary. Generally, nozzles and reducers are not shown on the Mechanical flow diagram. The flow diagram in Figure 7.2 shows reducers in order to aid in the visualization and understanding of the flow diagram and its relationship to the Piping Arrangement drawing. Symbols used on flow diagrams are symbolic representations of actual pieces of equipment. Typically, these symbols have a rudimentary resemblance to the actual piece of mechanical equipment what will be installed in the field.

FLOW PLAN ARRANGEMENT

The flow plan, or sequence of flow, should be arranged in a logical order of commodity flow. Even

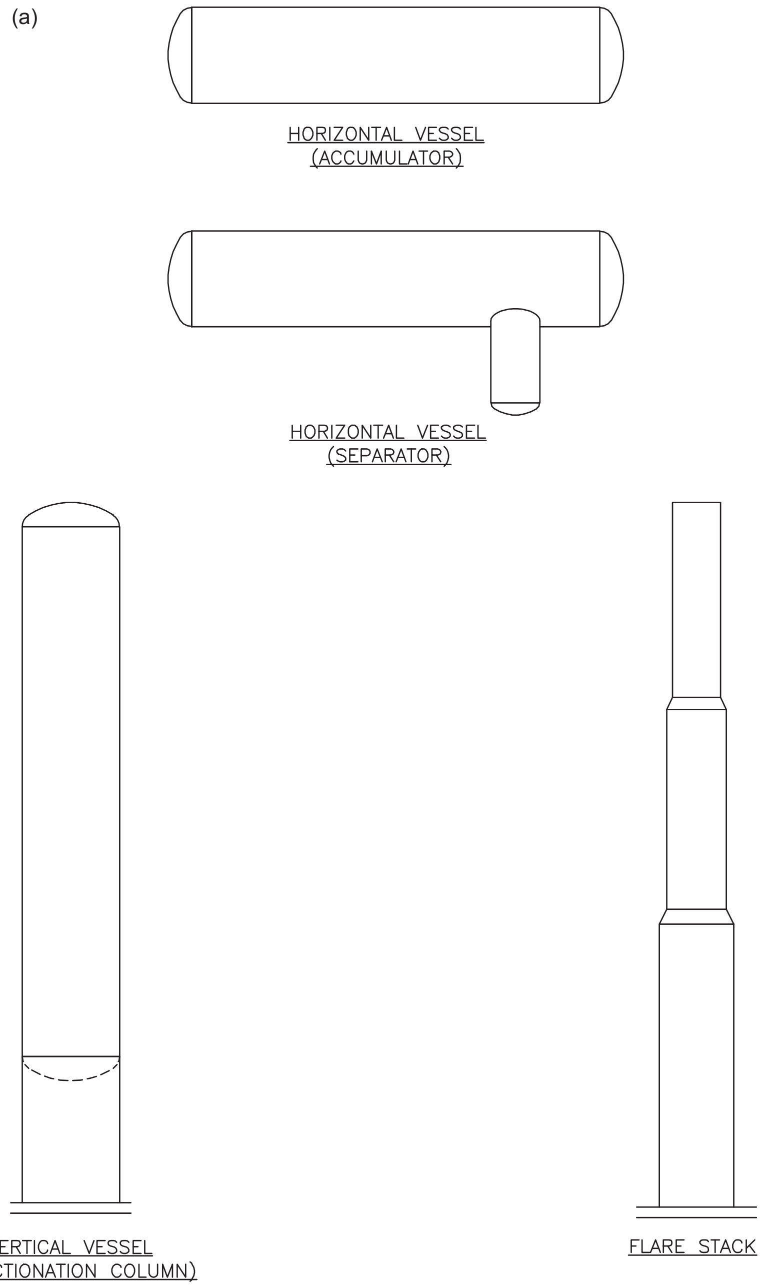

FIGURE 7.5 (a–e) Flow diagram mechanical equipment symbols. (f) Flow diagram piping symbols and abbreviations.

with a brief examination of the flow diagram, the primary flow of commodity through the facility should be obvious. Use the following checklist as an aid when developing a flow diagram.

- Avoid crossing lines where possible.
- Space mechanical equipment to avoid overcrowding.
- Add notes to symbols where necessary for clarity.
- Use arrows to show commodity flow direction.
- Show equipment numbers when it is necessary to identify mechanical equipment.
- Show control systems on the sketch. The control scheme is frequently the most important part of a flow plan sketch.
- Show important valves, orifice flanges, and control valves.
- Show commodity flow directions through exchangers with arrows.
- Do not run lines diagonally across the drawing.
- Label feed lines entering the unit from the field where the line enters the unit. Label product lines leaving the unit by name.
- Do not draw lines any closer together than necessary.

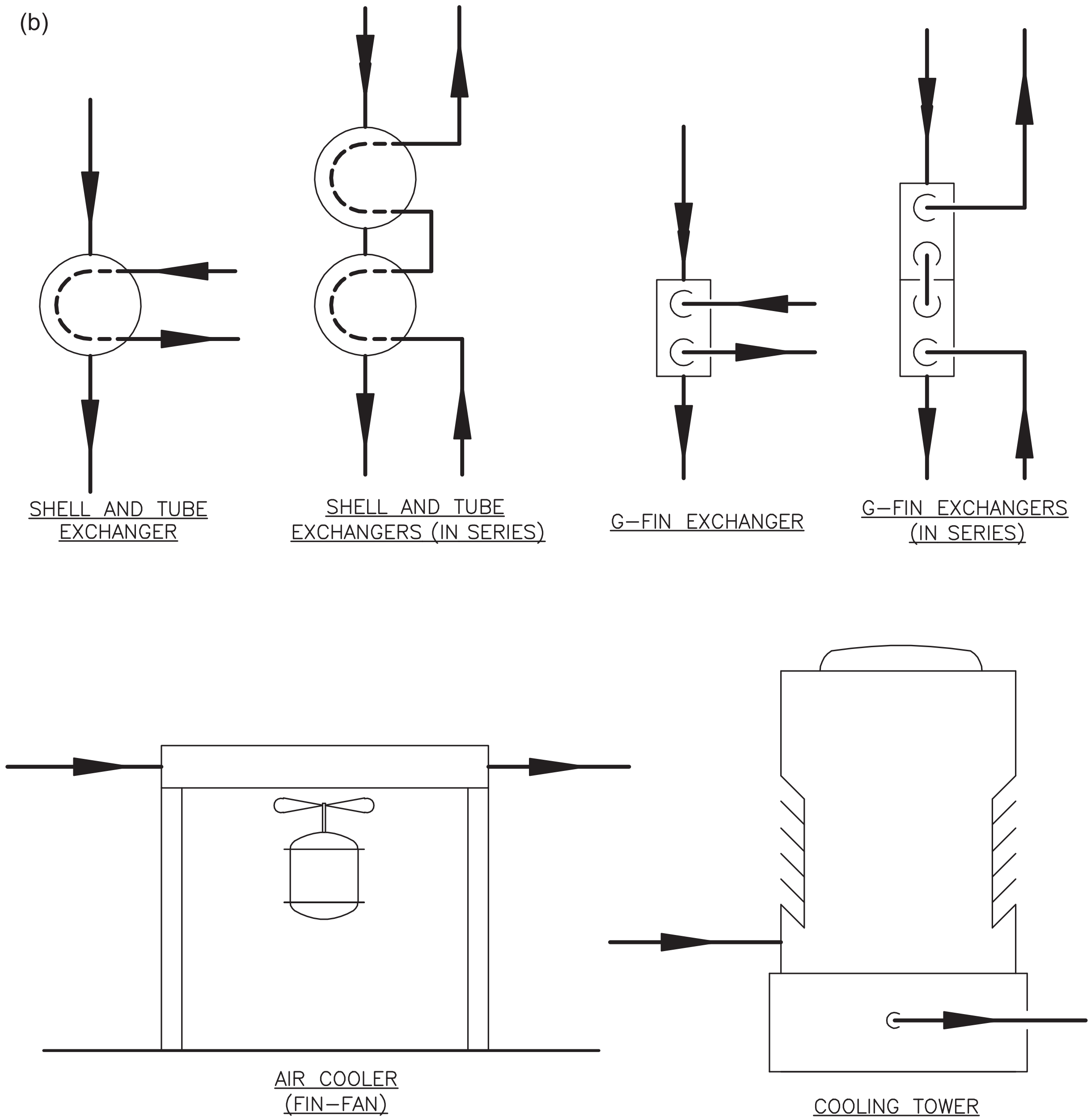

FIGURE 7.5 (*Continued*)

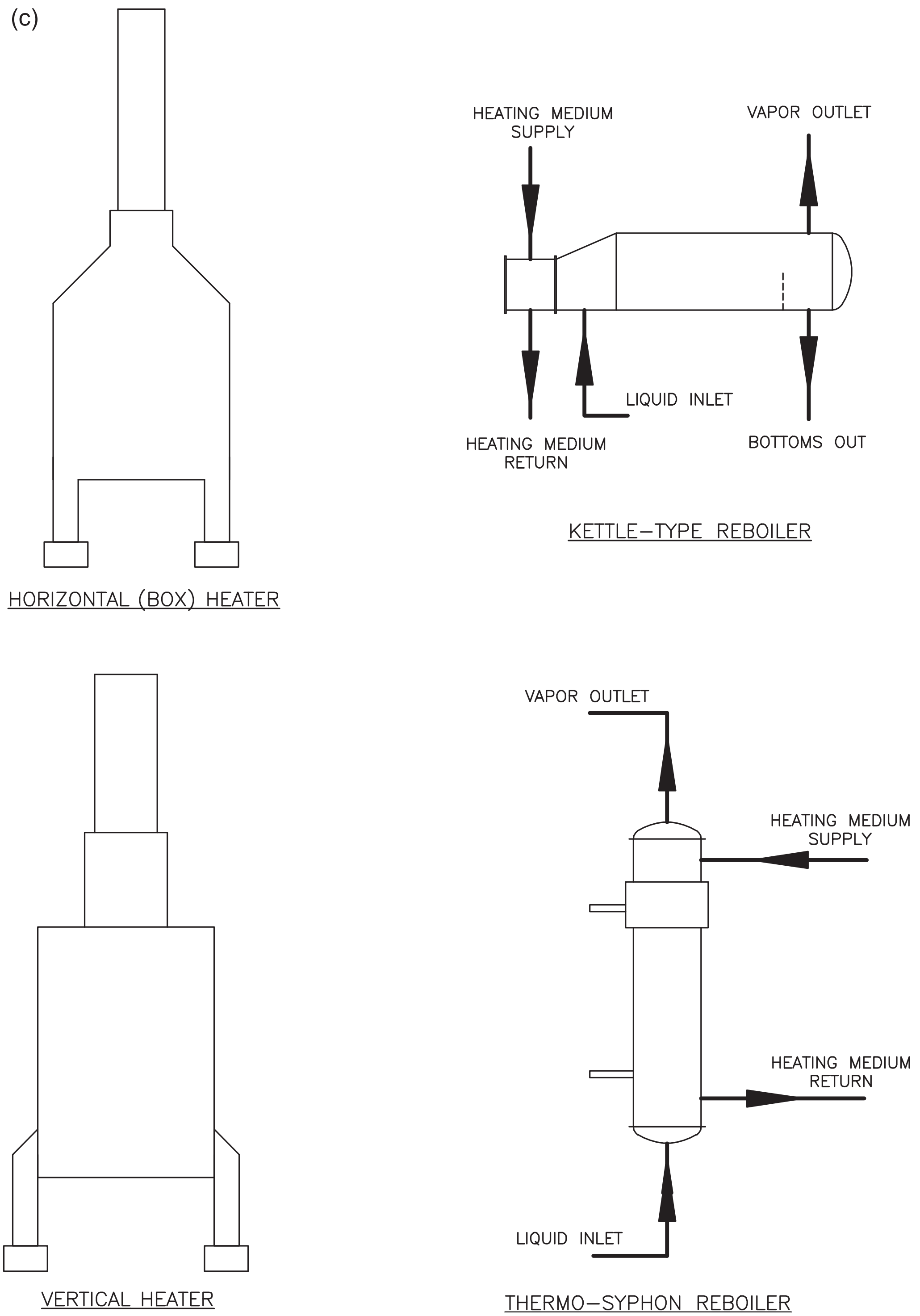

FIGURE 7.5 (*Continued*)

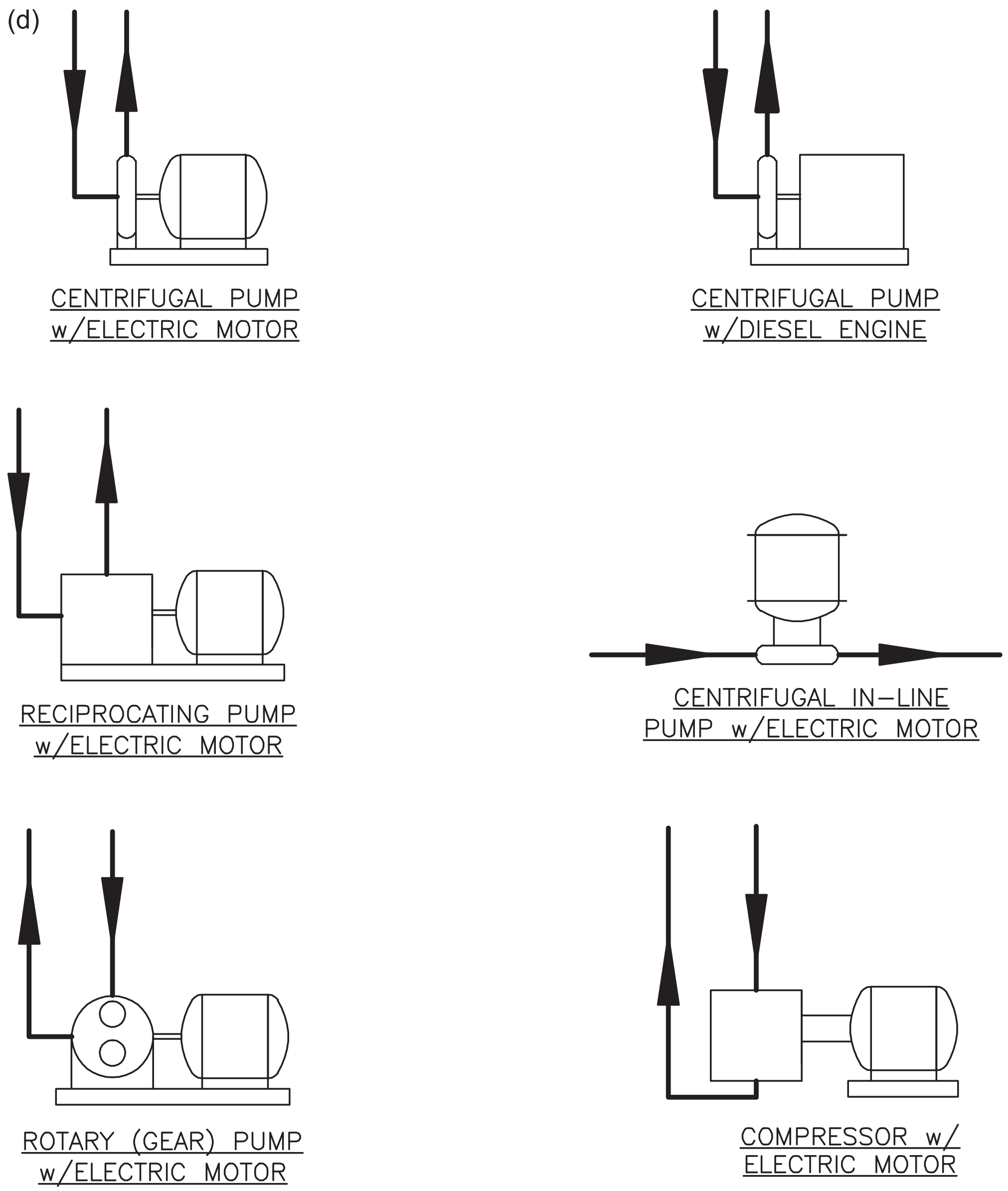

FIGURE 7.5 (*Continued*)

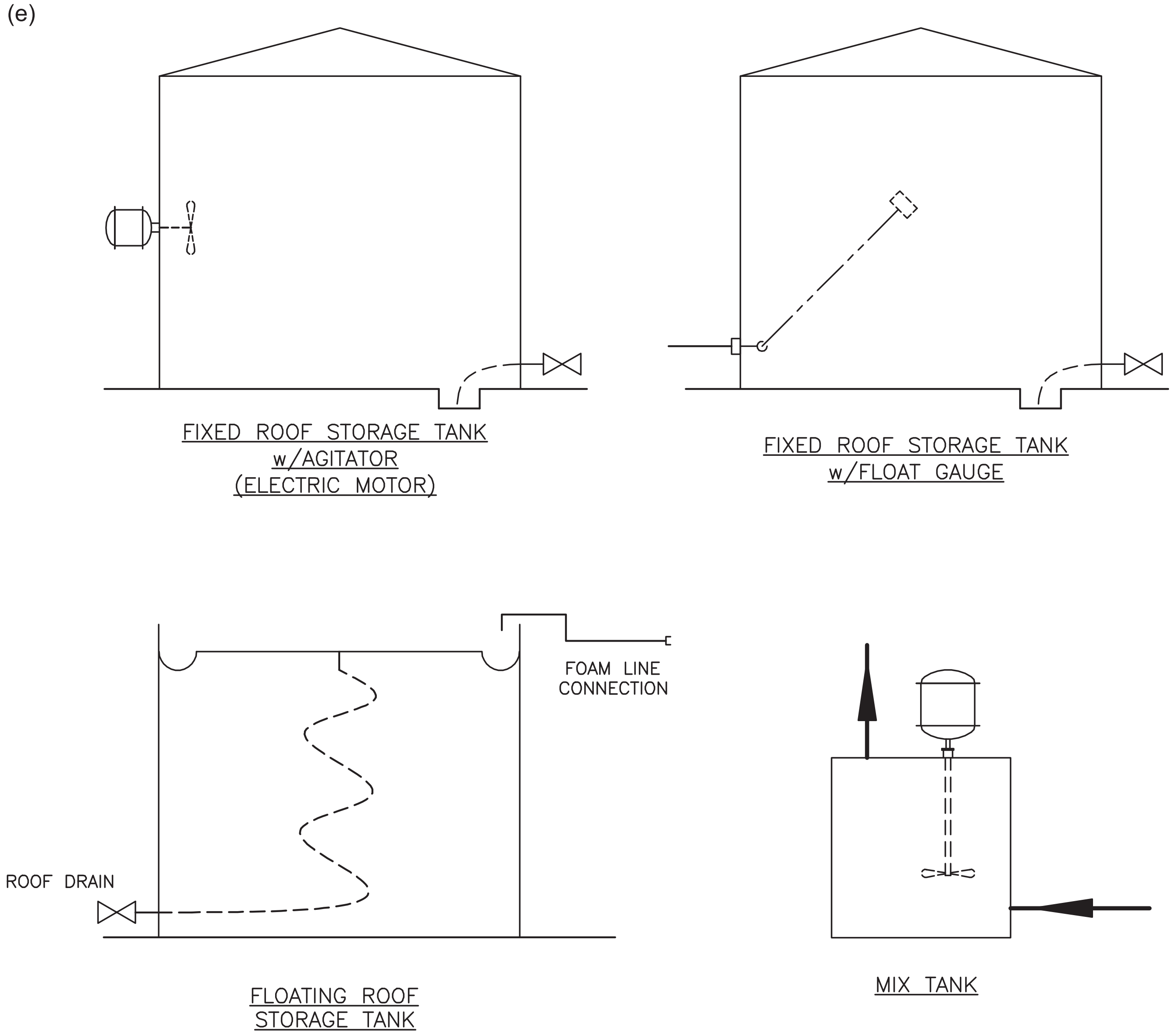

FIGURE 7.5 (*Continued*)

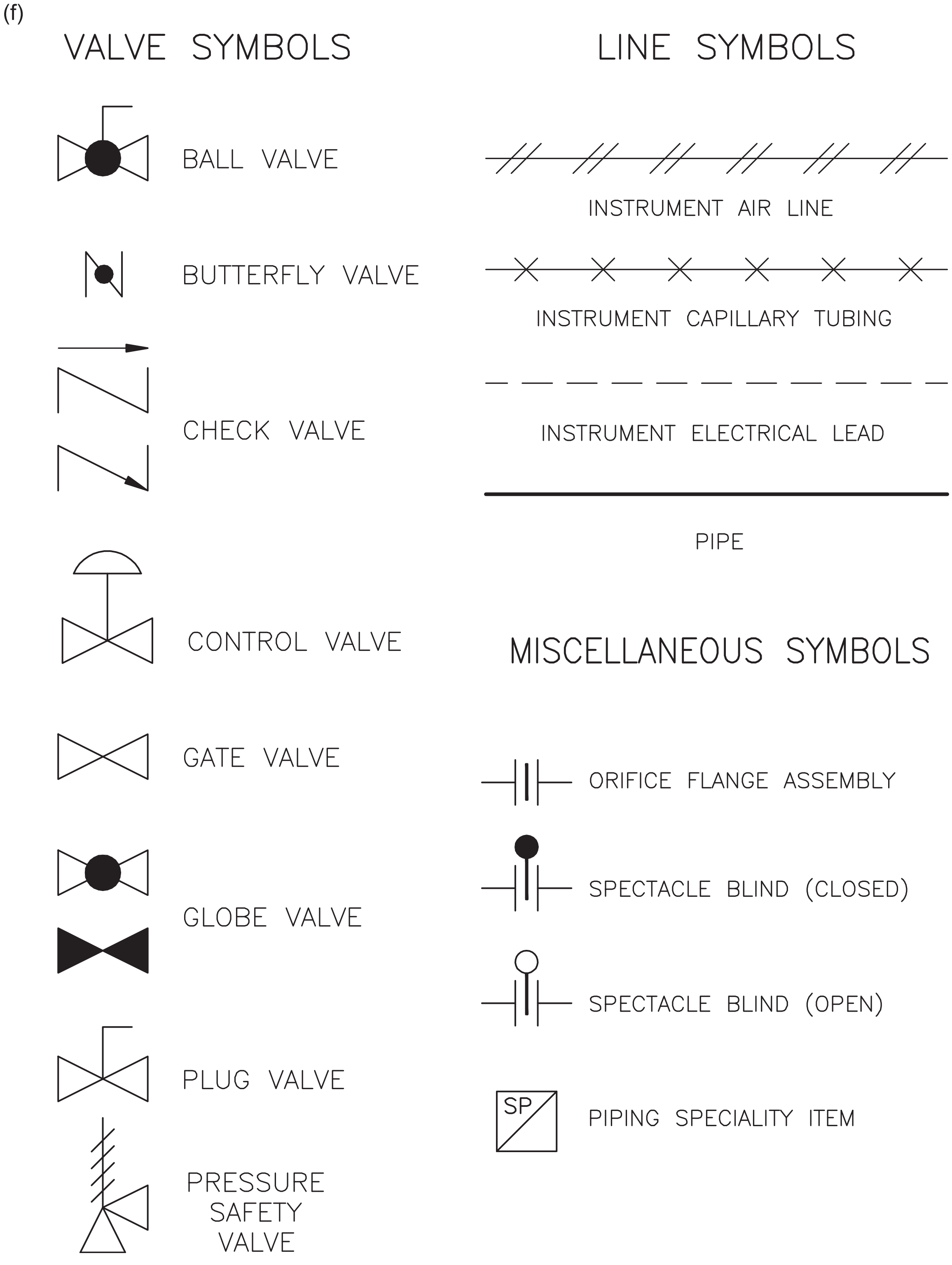

FIGURE 7.5 (*Continued*)

CHAPTER 7 REVIEW QUIZ

1. List five items shown on the Process flow diagram.

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2. List five items shown on the Mechanical flow diagram.

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3. List the four basic instrument groups.

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4. Describe the functions of the five instrument types.

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____
____
____
____

5. What type of instrument is used to maintain a certain liquid level?

____

6. Identify the following instrument abbreviations:

a. LG ____________________________________
b. FA ____________________________________
c. TI ____________________________________
d. PC ____________________________________
e. TRC ___________________________________
f. LC ____________________________________
g. PSV ___________________________________
h. HCV ___________________________________
i. LAH ___________________________________
j. LAL ___________________________________

7. Identify the following flow diagram abbreviations:

a. DF ____________________________________
b. SC ____________________________________
c. PSO ___________________________________
d. LC ____________________________________
e. NO ____________________________________

EXERCISE INFORMATION

Use the instructions included in Figure 7.6 to create the flow diagram symbols with **AutoCAD** as shown. **BLOCK** each symbol individually, without text. Place the base point in the location specified. Give the symbols a concise, yet descriptive name. **SAVE** the drawing as **FLOW SYMBOLS**.

Exercises 1, 2, and 3

Recreate the flow diagrams as shown, using the symbols in Figure 7.6 where applicable. Symbols representing other pieces of mechanical equipment can be developed on an as-needed basis. Although mechanical equipment is not drawn to scale, it should be proportional to the other symbols used in the drawing.

FLOW DIAGRAM SYMBOLS

TO DRAW FLOW DIAGRAM SYMBOLS, SET GRID TO .125" AND SNAP TO .0625". THE .125" GRID REPRESENTED BELOW HAS BEEN ENLARGED FOR BETTER VISUALIZATION. DRAW AND BLOCK EACH SYMBOL. SYMBOL NAME [NAME] AND INSERTION BASE POINT (⊗) HAVE BEEN INCLUDED FOR PROPER IDENTIFICATION.

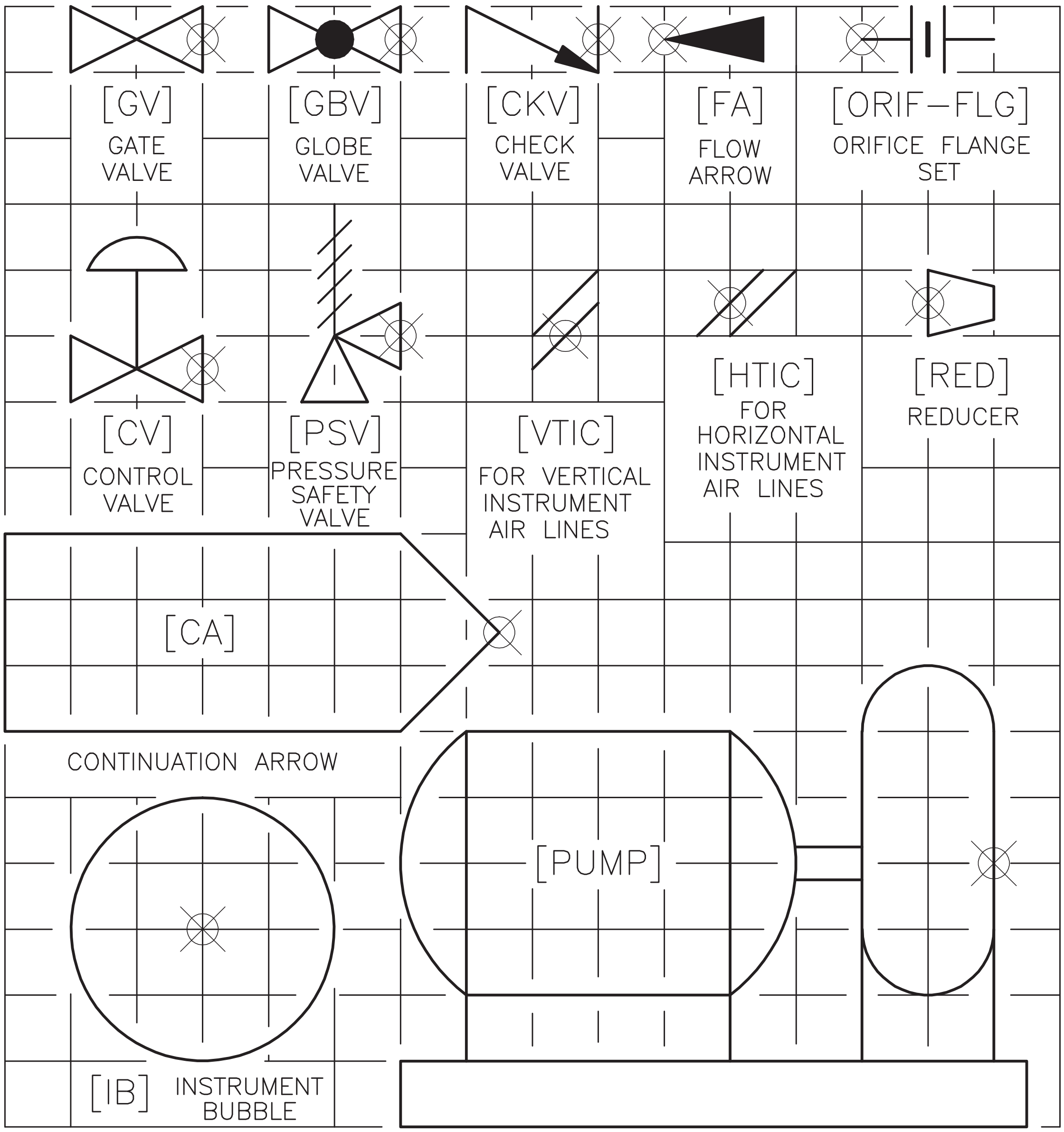
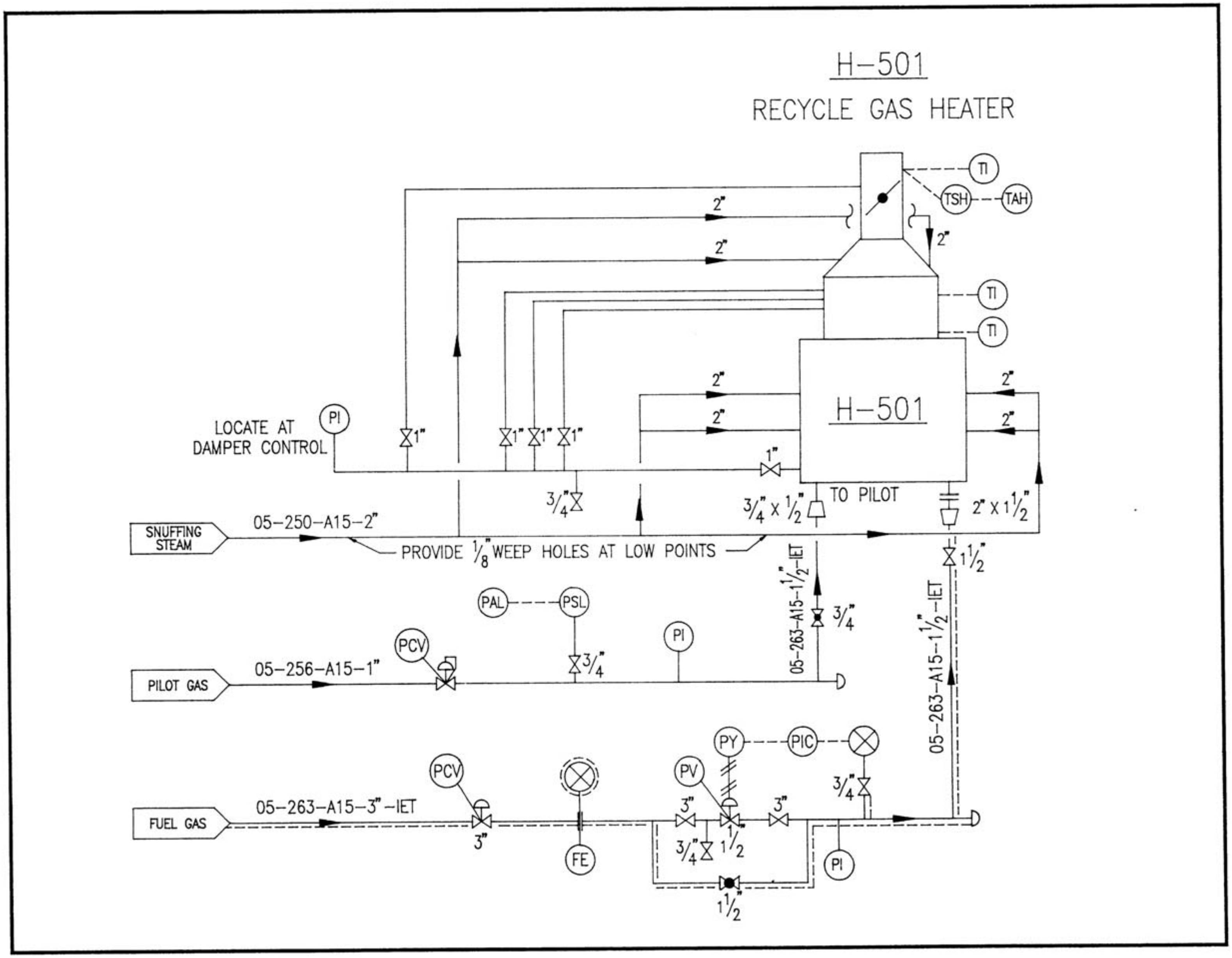
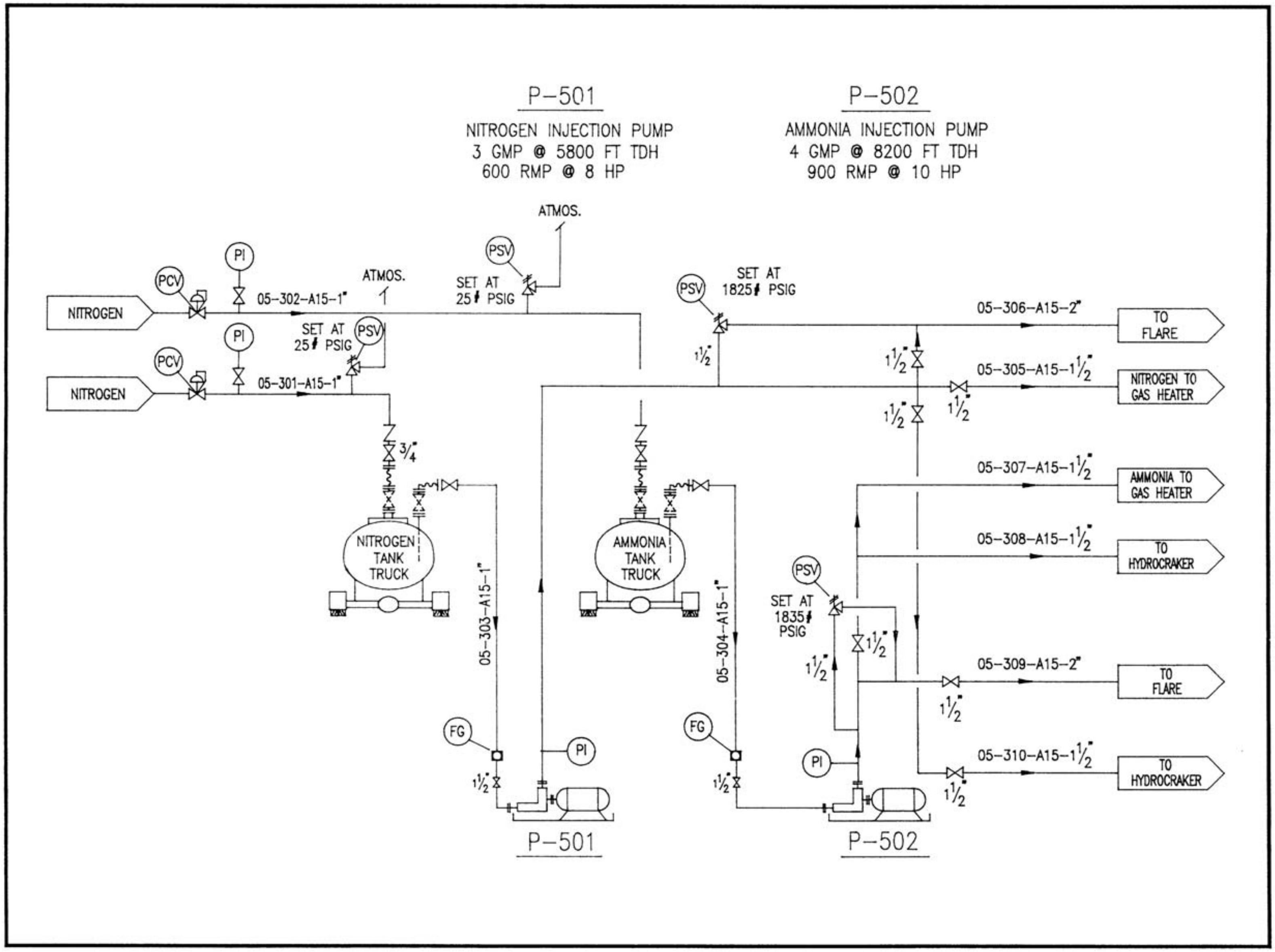


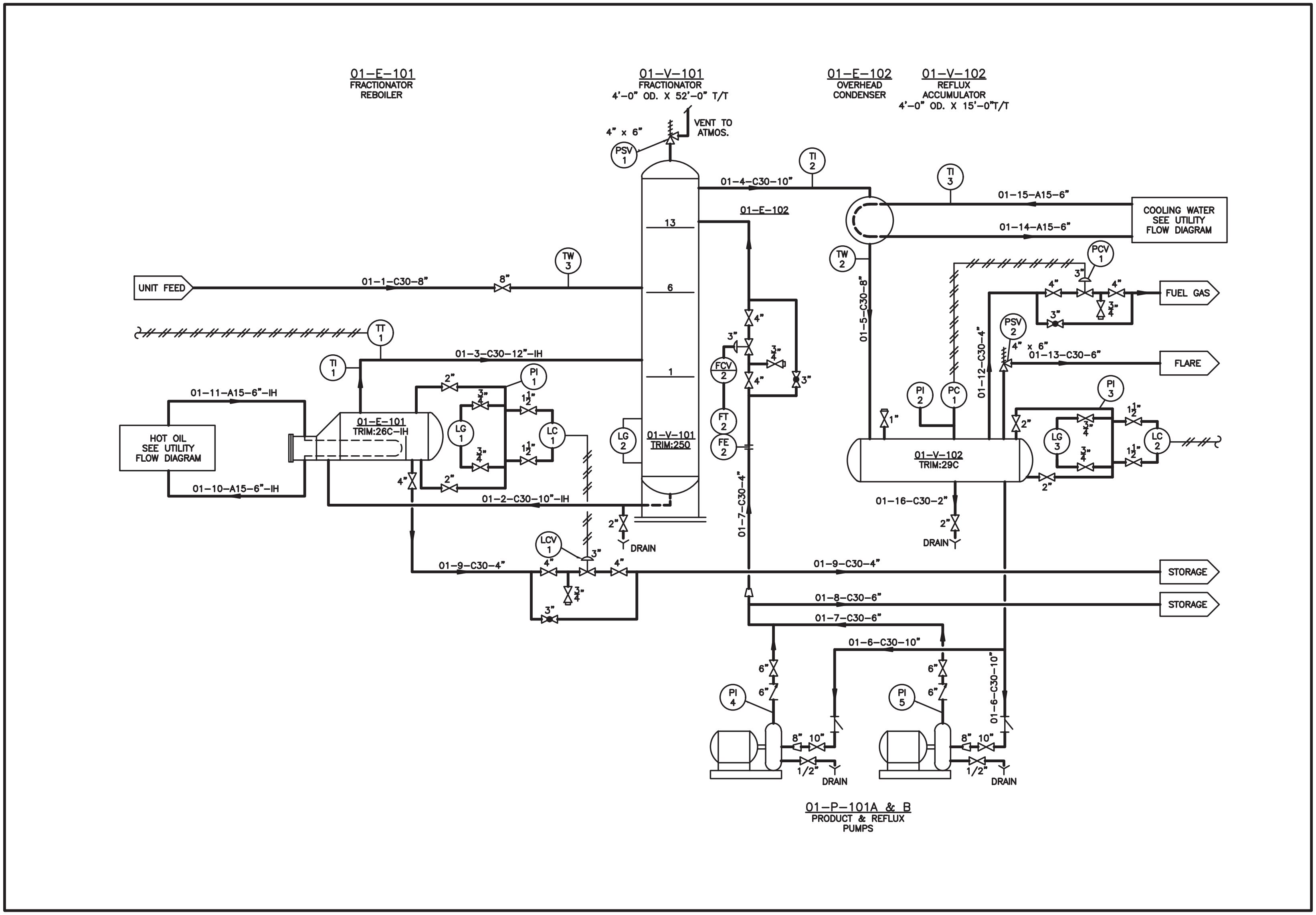
FIGURE 7.6 Flow diagram exercise symbols.


H-501
RECYCLE GAS HEATER
TI
TSH
TAH
2"
2"
2"
TI
TI
H-501
2"
2"
2"
2"
LOCATE AT
DAMPER CONTROL
PI
1"
1"
1"
1"
1"
3/4"
3/4" x 1/2"
TO PILOT
2" x 1 1/2"
SNUFFING STEAM
05-250-A15-2"
PROVIDE 1/8" WEEP HOLES AT LOW POINTS
1 1/2"
05-263-A15-1 1/2"-IET
3/4"
PAL
PSL
PI
PCV
3/4"
PILOT GAS
05-256-A15-1"
05-263-A15-1 1/2"-IET
PY
PIC
PCV
PV
3/4"
FUEL GAS
05-263-A15-3"-IET
3"
3"
3"
FE
3/4"
1 1/2"
PI
1 1/2"

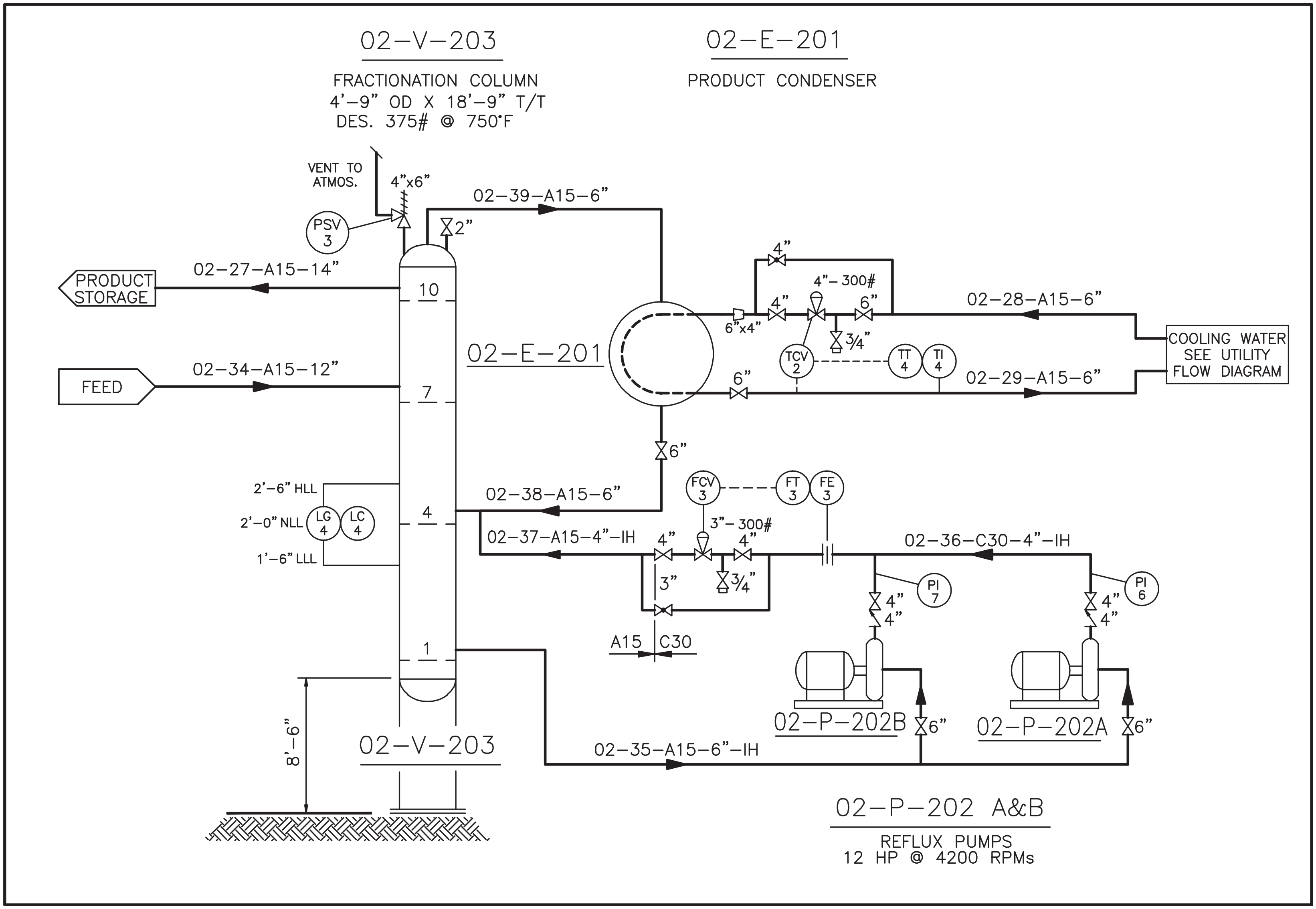
EXERCISE 7.1


P-501
NITROGEN INJECTION PUMP
3 GMP @ 5800 FT TDH
600 RMP @ 8 HP
P-502
AMMONIA INJECTION PUMP
4 GMP @ 8200 FT TDH
900 RMP @ 10 HP
ATMOS.
PSV
SET AT 25# PSIG
PI
PCV
NITROGEN
05-302-A15-1"
ATMOS.
SET AT 25# PSIG
PSV
PI
PCV
NITROGEN
05-301-A15-1"
3/4"
PSV
SET AT 1825# PSIG
1 1/2"
05-306-A15-2"
TO FLARE
05-305-A15-1 1/2"
NITROGEN TO GAS HEATER
05-307-A15-1 1/2"
AMMONIA TO GAS HEATER
05-308-A15-1 1/2"
TO HYDROCRAKER
NITROGEN TANK TRUCK
AMMONIA TANK TRUCK
05-303-A15-1"
05-304-A15-1"
PSV
SET AT 1835# PSIG
05-309-A15-2"
TO FLARE
05-310-A15-1 1/2"
TO HYDROCRAKER
FG
PI
FG
PI
P-501
P-502

EXERCISE 7.2

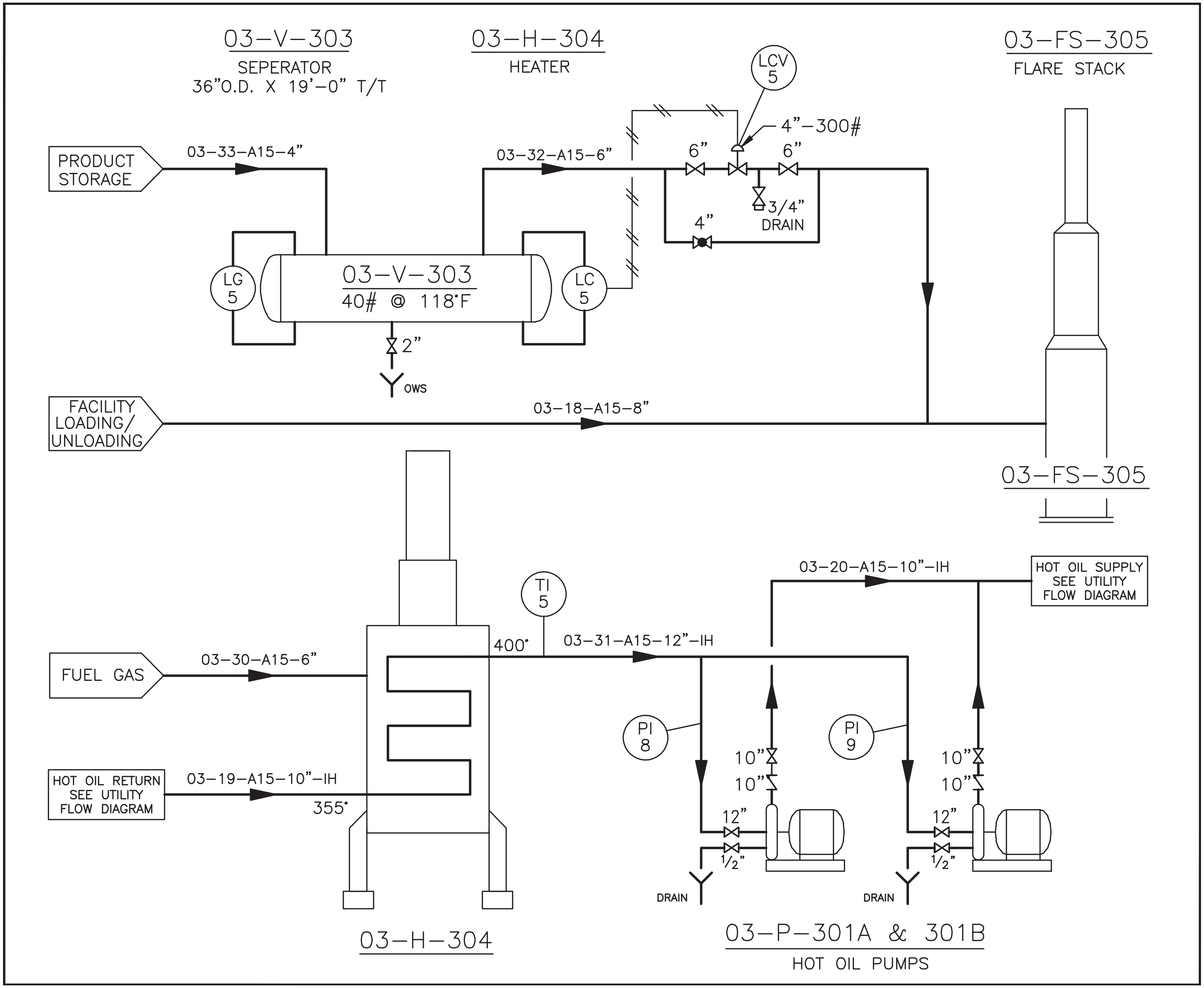

01-E-101
FRACTIONATOR REBOILER
01-V-101
FRACTIONATOR
4'-0" OD. X 52'-0" T/T
01-E-102
OVERHEAD CONDENSER
01-V-102
REFLUX ACCUMULATOR
4'-0" OD. X 15'-0" T/T
VENT TO ATMOS.
4" x 6"
PSV 1
01-4-C30-10"
TI 2
TI 3
01-15-A15-6"
01-14-A15-6"
COOLING WATER SEE UTILITY FLOW DIAGRAM
01-E-102
13
6
1
UNIT FEED
01-1-C30-8"
8"
TW 3
TW 2
TT 1
TI 1
01-3-C30-12"-IH
01-5-C30-8"
PCV 1
FUEL GAS
PSV 2
01-13-C30-6"
FLARE
01-12-C30-4"
HOT OIL SEE UTILITY FLOW DIAGRAM
01-11-A15-6"-IH
01-10-A15-6"-IH
01-E-101
TRIM:26C-IH
PI 1
LG 1
LC 1
LG 2
01-V-101
TRIM:250
FCV 2
FT 2
FE 2
PI 2
PC 1
PI 3
LG 3
LC 2
01-V-102
TRIM:29C
01-2-C30-10"-IH
01-16-C30-2"
DRAIN
LCV 1
01-9-C30-4"
01-7-C30-4"
01-9-C30-4"
STORAGE
01-8-C30-6"
STORAGE
01-7-C30-6"
01-6-C30-10"
01-6-C30-10"
PI 4
PI 5
1/2"
DRAIN
01-P-101A & B
PRODUCT & REFLUX PUMPS

EXERCISE 7.3

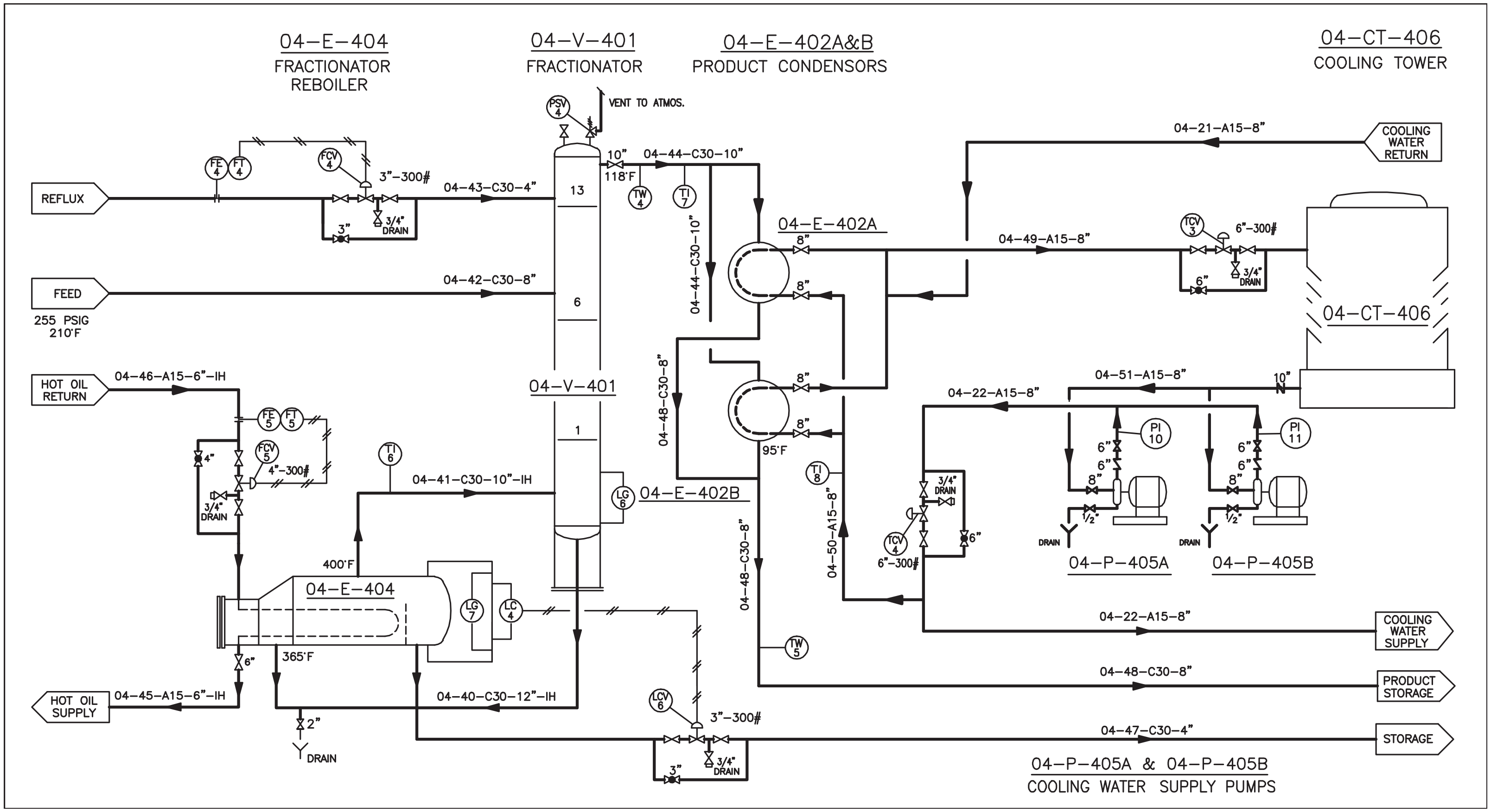


02–V–203
FRACTIONATION COLUMN
4'–9" OD X 18'–9" T/T
DES. 375# @ 750°F
02–E–201
PRODUCT CONDENSER
VENT TO ATMOS.
4"x6"
02–39–A15–6"
PSV 3
2"
02–27–A15–14"
PRODUCT STORAGE
10
4"
4"–300#
4"
6"
02–28–A15–6"
6"x4"
3/4"
02–E–201
COOLING WATER SEE UTILITY FLOW DIAGRAM
TCV 2
TT 4
TI 4
02–34–A15–12"
FEED
7
6"
02–29–A15–6"
6"
FCV 3
FT 3
FE 3
2'–6" HLL
2'–0" NLL
1'–6" LLL
LG 4
LC 4
4
02–38–A15–6"
02–37–A15–4"–IH
4"
3"–300#
4"
02–36–C30–4"–IH
3"
3/4"
PI 7
PI 6
4"
4"
4"
4"
A15
C30
1
02–P–202B
6"
02–P–202A
6"
8'–6"
02–V–203
02–35–A15–6"–IH
02–P–202 A&B
REFLUX PUMPS
12 HP @ 4200 RPMs

EXERCISE 7.4


03–V–303
SEPERATOR
36"O.D. X 19'–0" T/T
03–H–304
HEATER
03–FS–305
FLARE STACK
LCV
5
4"–300#
PRODUCT
STORAGE
03–33–A15–4"
03–32–A15–6"
6"
6"
3/4"
DRAIN
4"
LG
5
03–V–303
40# @ 118°F
LC
5
2"
OWS
FACILITY
LOADING/
UNLOADING
03–18–A15–8"
03–FS–305
TI
5
03–20–A15–10"–IH
HOT OIL SUPPLY
SEE UTILITY
FLOW DIAGRAM
400°
03–31–A15–12"–IH
FUEL GAS
03–30–A15–6"
PI
8
PI
9
10"
10"
10"
10"
HOT OIL RETURN
SEE UTILITY
FLOW DIAGRAM
03–19–A15–10"–IH
355°
12"
½"
12"
½"
DRAIN
DRAIN
03–H–304
03–P–301A & 301B
HOT OIL PUMPS

EXERCISE 7.5


04–E–404
FRACTIONATOR
REBOILER
04–V–401
FRACTIONATOR
04–E–402A&B
PRODUCT CONDENSORS
04–CT–406
COOLING TOWER
VENT TO ATMOS.
REFLUX
FEED
255 PSIG
210°F
HOT OIL
RETURN
HOT OIL
SUPPLY
04–43–C30–4"
04–42–C30–8"
04–46–A15–6"–IH
04–41–C30–10"–IH
04–40–C30–12"–IH
04–45–A15–6"–IH
04–44–C30–10"
04–48–C30–8"
04–50–A15–8"
04–21–A15–8"
04–49–A15–8"
04–51–A15–8"
04–22–A15–8"
04–47–C30–4"
COOLING
WATER
RETURN
COOLING
WATER
SUPPLY
PRODUCT
STORAGE
STORAGE
04–E–402A
04–E–402B
04–CT–406
04–P–405A
04–P–405B
04–P–405A & 04–P–405B
COOLING WATER SUPPLY PUMPS
DRAIN
400°F
365°F
118°F
95°F

EXERCISE 7.6

CHAPTER

8

Codes and Specifications

As anyone who has ever played a game can tell you, there are specific rules that must be followed if the game is to be played correctly. The same holds true for building a piping facility. Just as the rules of a game establish the basic guidelines for acceptable play, codes and specifications establish guidelines for piping facilities to ensure everything from quality construction to worker safety.

Codes are a broad-based set of guidelines that govern the total scope of a project. Codes originate from a number of sources. Some sources are governmental agencies such as OSHA and the EPA. Others are organizations, institutes, societies, or associations such as ANSI (American National Standards Institute) and ASME (American Society of Mechanical Engineers). The ASME has developed the *Code for Pressure Piping B31* which governs the engineering of petroleum refineries, chemical, pharmaceutical, and related processing plants and the requirements necessary for their safe design and construction.

Specifications, or *specs*, on the other hand, are developed as a specific set of guidelines for the engineering, design, fabrication, and construction of a piping facility. Engineering specifications establish the basis from which the final plant design is produced. Broken into groups specific to the various design disciplines needed for a particular project, such as piping, civil, structural, or electrical, specs will include guidelines on a number of topics including initial site selection, procurement guidelines for piping materials, and mechanical equipment, as well as equipment hydrostatic testing and commissioning guidelines. Written to maintain consistency and uniformity throughout all phases of a project, engineering specifications are very detailed. While codes can be as broad as a statement indicating that all piping components must conform to ASME standards, specs are so detailed that they may include instructions to the drafter stating that dimensions are to be written in feet and inches with precision to the nearest $^1/_{16}$″.

As we look at codes and specs, remember that they have been developed through years of trial, application, and error. When something purchased did not fit, something built broke, or something heated blew up, someone made a note of the mistake, remembered it the next time a similar situation occurred, and made it an operational procedure. Eventually, the operational procedure evolved into either a piping code or engineering specification.

CODES

Although you may not be familiar with codes specific to piping facilities, you are familiar with a structure to which codes also apply: the typical house or apartment. Codes have been written concerning door sizes, window sizes, lumber dimensions, electrical requirements, and so on. Take windows as an example. National building codes state, when needed for emergency egress, in case of a fire, windows are placed a maximum of 40″ above the floor, in habitable rooms. Additionally, national building codes mandate that windows in sleeping rooms must have a net glazing area of 5.7 sq ft with a minimum opening height of 2′-0″ and a width of 1′-8″. The codes established by various governmental agencies affect everyone on a daily basis. Codes exist that mandate safety requirements for automobile manufacturers, the use of fire retardant fabrics in clothing, even acceptable radiation levels for microwave ovens. As you can see, codes affect common, everyday life. Although you may be unaware of them, codes impact each of us in a very personal way.

Codes for piping facilities have been implemented in a similar fashion. Regulations have been established that govern pressure and temperature limits, material composition and stress allowances, worker safety, emergency evacuation procedures, and many other topics. A partial list of the ASME codes written for piping facilities is shown in Section 2.01 of the General Piping Specifications.

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00001-7

SPECIFICATIONS

As previously mentioned, engineering specifications stipulate specific details for engineering, design, fabrication, and construction of a facility. Piping specifications in particular are used by numerous groups, whose goal it is to see a piping project through to completion. Engineers, designers, and drafters will use piping specs to establish sizes, pound ratings, and dimensions of pipe and equipment. Stress calculations are made from information provided in the specs to ensure columns, beams, and supports will withstand the loads and forces placed on them. Purchasing personnel need specs to ensure proper piping materials and mechanical equipment are bought. Welders and fabricators use specs to erect structures, supports, and route the proper size pipe. Piping specs also provide workers installing instrumentation controls proper temperature and pressure settings.

When applied to a piping facility, piping specifications become quite lengthy and are very detailed. General Piping Specifications, as they are known, comprise volumes of printed material, often seeming to be never-ending. The General Piping Specifications that follows is an abbreviated sample of a typical specification document.

GENERAL PIPING SPECIFICATIONS

1. SCOPE

1.01 This specification covers the materials and procedures for all process and utility piping.

2. CODE REQUIREMENTS

2.01 Piping shall be in accordance with the following applicable ASME codes:

ASME	B31	Code for Pressure Piping
ASME	B31.1-2010	Power Piping
ASME	B31.3-2008	Process Piping
ASME	B31.4-2009	Pipeline Transportation Systems
ASME	B31.5-2010	Refrigeration Piping and Heat Transfer Components
ASME	B31.8-2007	Gas Transportation and Distribution Piping Systems
ASME	BPVC-2010	Boiler and Pressure Vessel Code

2.02 Stress relieving shall conform to the piping code. The stress relieving method used will depend on job location, quantity, and available tools; but, the preferred postheat treatment method shall be furnace treatment for all "shop" fabricated piping and exothermic/stress relieving type packages (or equal) for field assembly welds and field fabricated piping.

3. DRAWING AND PROCEDURES

3.01 All piping drawings shall be complete with sufficient detail to clearly indicate all clearances, intersections, anchors, guides, supports, expansion provisions, and connections to associated mechanical equipment.

3.02 All piping drawings shall show dimensions in feet and inches. Inches shall be used when the dimensions are less than 1′-0″. Dimensions will be to the nearest 1/16″.

3.03 Intersecting coordinates shall be used to position all mechanical equipment, pumps, pipe supports, structures, and buildings. All drawings are to be CAD generated or plotted from an approved 3D modeling software package.

3.03.1 Pipe shall be dimensioned from coordinates to show location. Elevations shall be used to indicate height measurements.

3.04 All piping 12″ and below will be shown single-line, and piping 14″ and larger will be shown double-line, except in congested areas where double-line work is required for clarity. Standard symbols shall be used throughout. Drawings will be plotted to 3/8″ = 1″-0″ scale, except details where needed for clarity.

3.05 Each pipe line shown on drawings shall be clearly marked with a line number. The line number will provide Unit number, pipe number, piping specification class, and nominal pipe size. The following example illustrates the approved line number:

01-20-A15-10″-IH where:

	01 is the Unit number
	20 is the line number
	A15 is the pipe specification class
	10″ is the nominal pipe size
	IH is insulate for heat conservation

***A typical line number is shown in* Figure 8.1**.

4. PIPING

4.01 Piping materials shall be in accordance with piping material specifications, and any deviations shall be noted on the drawings.

4.02 All piping, as far as practicable, shall be routed overhead on pipe stanchions, or pipe sleepers, and shall be routed the shortest possible run

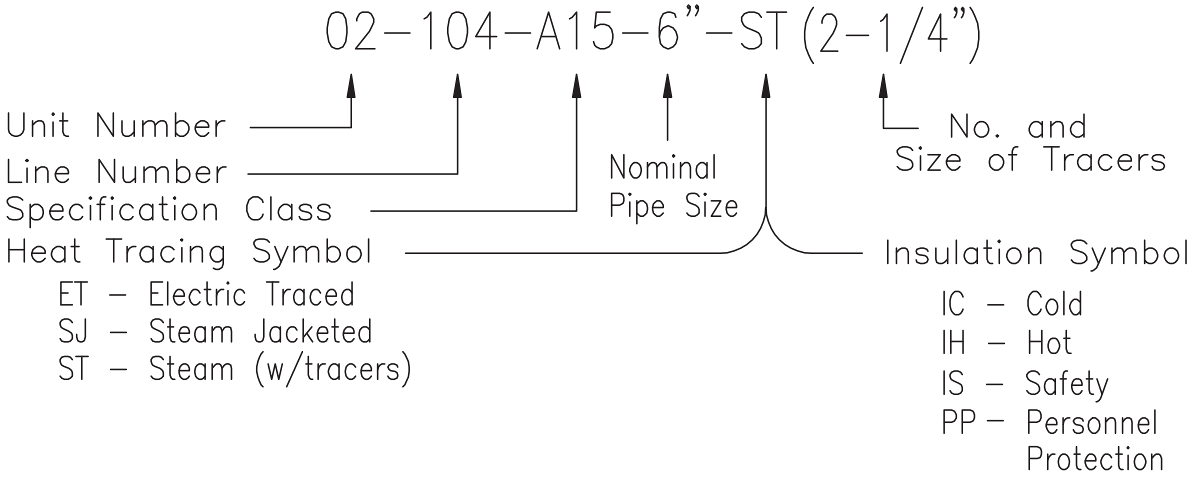


FIGURE 8.1 Line number.

and require the minimum number of fittings; pipe configurations also shall be free from appreciable vibration with suitable expansion provided for hot lines.

4.03 All nongalvanized steel underground lines shall be coated and wrapped in accordance with Engineering Specifications.

4.04 All operating valves 6′-0″ above grade or platform shall be chain operated. Some of the valves *not* to be considered as operating valves are: branch line block valves from header, by-pass valve, and block valves on control manifold stations, level controllers, main header blocks on all utility services, and block valves on exchangers and coolers.

4.05 Expansion or contraction shall be considered for each line. *Cold spring* shall be considered for each line. *Cold spring* shall be used where it is beneficial and in accordance with the ASA Code for Pressure Piping and noted on spool drawings.

4.06 Slip-on flanges may be substituted for weld neck flanges to suit space limitations where allowed in the specifications. In other specifications, slip-on flanges may be used only when approved by the Design Supervisor.

4.07 Pipe sizes of 1¼″, 2½″, 3½″, 5″, and 7″ shall not be used except as required for equipment connections.

4.08 Basket type with 10-mesh screen start-up strainers shall be used in all pump suctions.

4.09 Clips, lugs, anchors, guides, and so on shall be installed in field after erection on standard piping. For any special alloy where field welding would have adverse effect on the material, all attachments shall be installed by shop fabricator.

4.11 When couplings are used for thermometer and thermocouple well connections, the inside surface shall be free of any weld metal and the opening shall be clear and free to receive a well.

4.12 Steam tracing shall be installed in accordance with Job Standards.

4.13 Pipe supports spacing shall be 20′-0″ maximum with pickup supports as required for lines 3″ and smaller.

5. INSTRUMENTS AND INSTRUMENT CONNECTIONS

5.01 Liquid level controllers and gage glasses shall be located so as to be accessible from grade, ladder, or platform.

5.02 Pressure gage connections shall be ¾″.

5.03 Test connections shall be ¾″.

5.04 Temperature instruments such as TW, TI, TIC, and TRC shall have 1″ NPT.

5.05 TW and TI connections in piping shall be located 45° off centerline or in the horizontal.

6. VENTS AND DRAINS

6.00 Process vents and drains

6.01 All process vents and drains shall be ¾″. Increase drain size to match hydrostatic drains per NPS range listed below for heavy viscous commodities and slurries based on process engineer recommendations.

6.02 Any vent or drain required for plant operation shall be sized and shown on flow diagram.

6.1.0 Hydrostatic Vents and Drains

6.1.01 All vents to ¾″.

6.1.02 All drains to be sized as follows

- ¾″—up to and including 8″ NPS (Nominal Pipe Size),
- 1″-10″ NPS and 12″ NPS, and
- 1½″-14″ NPS and above.

Piping group will position all hydrostatic vents and drains to be used for hydrostatic testing of the piping systems. Vents and drains need not be represented on P&IDs. Whenever possible, vents and drains are to be grouped together on the same east/west and north/south coordinate and near the perimeter of modules for ease of access by Operations. Vents shall be located at **ALL** high points, and drains shall be located at **ALL** low points within the Piping System. For these applications the Piping System is recognized to be the complete routing of a line (pipe) and all of its branch connections.

6.1.03 It not acceptable to "crack flanges" at a vessel nozzle to vent. Install a vent upstream of the nozzle. When the routing is fitting make-up (elbow, flange, and nozzle), use an elbow-let to vent. If a valved instrument connection, such as a PI (Pressure Indicator) is at the high point, it may be used as a vent alternative.

6.1.04 Install hydrostatic vents and/or drains on each side of a spec-break.

6.1.05 Hydrostatic vents and drains are not required on Utility and Instrument Air systems.

6.1.06 Hydrostatic vents and drains are considered permanent installations. Valving shall not be removed/reused after completion of testing.

6.2.0 Bleed Connections

6.2.01 Tie-in point connections are permitted as a vent (bleed connection). All bleed connections to be ¾″. DO NOT use tapped blind flanges as bleed connections, use hub flanges.

7. ORIFICES

7.01 Generally the minimum requirements for orifice runs shall be in accordance with the AGA-ASME Standards. Orifice taps shall be vertical for air and gas service and shall be on the horizontal for liquid and steam service.

8. CLEARANCES AND SPACING

8.00 Roadways

8.01 Minimum clearance over main roadways shall be 18′-0″ to the lowest projection.

8.02 Minimum clearance over secondary roadways is 14′-6″ to the lowest projection.

8.03 Minimum width of secondary roadways is 10′-0″, excluding 3′-0″ shoulders.

8.1.0 Walkways

8.1.01 Head room beneath main overhead piperack shall be a minimum of 11′-0″. Special attention shall be given to instrument and electrical trays along with any lines that drop from bottom level of piperack, to maintain minimum clearance.

8.1.02 Maintain a minimum headroom clearance over aisle way of 7′-0″.

8.1.03 Maintain minimum headroom clearance of 7′-6″ inside buildings and for miscellaneous pipe supports.

8.1.04 Clear passageway between equipment or equipment piping and adjacent equipment shall be 2′-6″ minimum.

Exception: Horizontal clear space between exchanger flanges shall be a minimum of 18″.

8.2.0 Platforms

8.2.01 Maintain minimum platform width of 2′-6″.

8.2.02 Maintain minimum headroom clearance above platforms of 7′-0″.

8.2.03 Platforms shall be placed 2′-6″ below the centerline of manways.

8.2.04 Maximum vertical distance between platforms (ladder length) is 30′-0″.

8.2.05 Cages are not required for ladders 8′-0″ long or less or ladders that end 20′-0″ or less above the high point of paving.

8.2.06 Platforms shall be provided for manways which have a centerline 15′-0″ or higher above high point of paving.

An example of how Clearance and Spacing specifications are applied to piping drawings is represented in Figure 8.2.

9. INSULATION AND PAINTING

9.01 All hot insulated lines 2½″ larger shall be on 3″ minimum height insulation shoes. All low-temperature piping will rest on the insulation with a steel cradle outside of the insulation to distribute the load at the point of support.

9.02 Insulation thickness for piping is indicated on the Pipe Line List. All insulation materials shall be installed in accordance with Insulation Specifications.

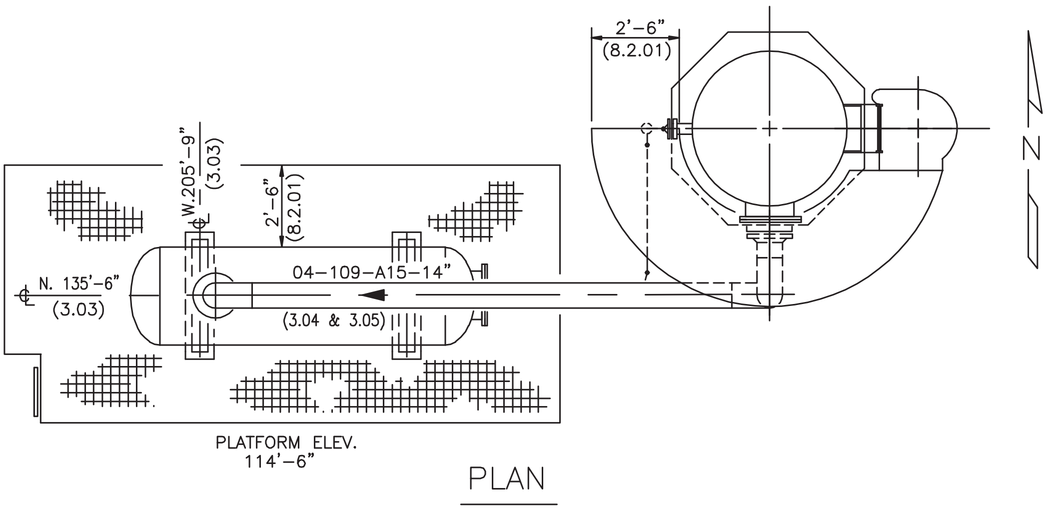
9.03 All painting shall be done in accordance with Painting Specifications.

10. FABRICATION TOLERANCES

10.01 Flange bolt holes shall straddle the vertical, horizontal or North-South centerline unless otherwise noted. Rotation of flange bolt holes shall not exceed 1/16″ measured across the flange face parallel to a centerline and between the holes nearest to it.

11. SHIPPING LENGTHS

11.01 Shop fabricated pipe shall be prefabricated in the number of pieces shown on the spool drawing unless otherwise approved in writing. If Piece Mark numbers are not shown on drawings, piping shall be prefabricated in as few pieces as possible, consistent with rail or truck shipment, to minimize field welding, typically 40′-0″ (l) × 8′-0″ (d) × 12′-0″ (h). Field welds shall be straight butt welds unless otherwise specifically shown or approved.



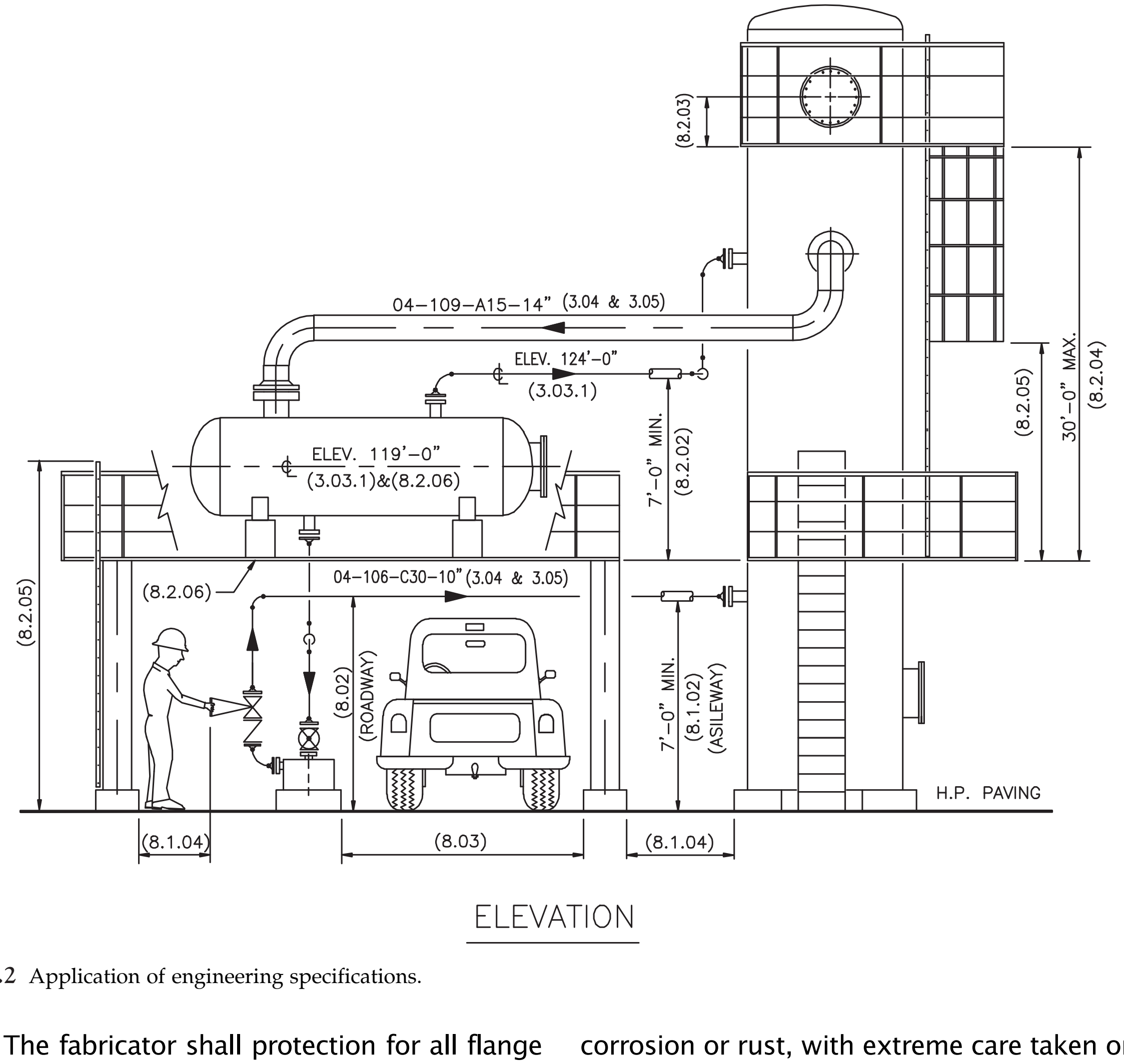


FIGURE 8.2 Application of engineering specifications.

11.02 The fabricator shall protection for all flange faces, male threaded connections, plugs for all female threaded connections, covers for all open pipe, etc., to prevent damage during shipment and storage as noted in the welding specifications. Both shop and field shall ensure that flange faces are protected from corrosion or rust, with extreme care taken on RTJ and T&G flanges.

12. PIECE MARKING AND SHOP PAINTING

12.01 Each shop fabricated spool piece shall have a mark number assigned. The fabricator shall paint the number on the piece or, if another method of identification is to be used, written approval must be obtained.

12.02 The fabricator shall be supplied with a sepia original of each spool. The fabricator shall complete the spools with mark numbers and field weld locations and return.

12.03 Shop fabricated piping shall be cleaned of all rust, mill scale, weld slag, and splatter and primed before shipment. Unless otherwise specified, the primer shall consist of one coat of zinc chromate.

13. TESTING

13.01 Where practical, all lines shall be hydrostatically tested in place. Testing shall be in accordance with ASME Code for Process Piping, latest revision.

13.02 Where water may have a deleterious effect on piping or equipment, the system shall be tested with air and soap suds.

13.03 Lines venting or draining to atmosphere shall not be tested.

14. COLOR CODE

14.01 The following color code shall be used to assist the Construction Department with a method of identification for valves and other piping materials.

14.02 For standard steel, bronze, cast malleable, and wrought iron, the field Material receiving group can best code material as received.

14.03 Special carbon steel and any alloys shall be color coded by the manufacturer, vendor, or fabricator.

Color	Specification
Black	WD12
Blue	A15
Green	WS12
Orange	C30
Red	PA12
White	IA12
Yellow	S15

15. UTILITY HOSE STATIONS

15.01 Utility hose stations shall be installed in accordance to the following:

- Stations shall use a 50 ft length of hose for clean-up and air-tool operation and shall be located to access areas at Grade, within elevated structures and in buildings.
- Utility outlet connections shall be grouped and sequenced together as much as possible, that is, LP steam, Plant/Utility air, Service water, and, when required, Instrument air (inert gas).
- Low-Pressure Steam shall be limited to less than 200 psig and 400°F.
- Install condensate traps on all steam and air lines when required.
- Insulate and/or trace steam lines up to the first block valve of the station and where needed for personnel protection.
- The following locations shall have utility stations or standpipes to provide LP steam and Plant/Utility air only:
  - At alternate platform levels required for servicing of manways in vessels and/or towers.
  - At alternate levels within an elevated structure so a 50 ft hose can service all areas of the structure.
- Service water shall be provided at Grade locations only.
- Inert gas shall be provided only when required.
- Each utility station shall have obvious and local identification for personnel safety.
- Utility stations shall be installed in such a manner as remain in full operation during a Unit shut-down.

An example of how engineering specifications are applied to piping drawings is presented in Figure. 8.2.

SPECIFICATION CLASSES

As extensive as general piping specifications are, they should not be considered all encompassing. Engineering specifications are divided into groups, or *classes*, developed especially for particular services. Classes are categorized generally by the commodity flowing within the pipe and its associated pressure and temperature. Specification Classes take into account whether the commodity is a gas or liquid, including design and operating temperatures and pressures, even corrosiveness. Table 8.1 is a sample of a Piping Specification Class Directory. It includes the Class designation, flange type and ratings, material, and service commodity type.

Specification Classes use service parameters to establish flange pound ratings, pipe wall thickness, pressure and temperature limits, as well as the type of pipe and fitting connections to be used, that is, screwed, socket-weld, butt-weld, flanged, etc. Classes are extremely detailed. They specify which manufacture to purchase valves from, as well as the specific manufacturer's model number to be used. Classes specify the material

TABLE 8.1 Piping Specification Class Directory.

Class	Rating	Material	Service
A15	150# RF	Carbon Steel	Process
A15C	150# RF	Carbon Steel	Caustic
A15P	150# RF	Special Carbon Steel	Process (−20° to −50°F)
A15F	150# RF	Carbon Steel	Freon
C30	300# RF	Carbon Steel	Process
C30C	300# RF	Carbon Steel	Caustic
C30P	300# RF	Special Carbon Steel	Process (−20° to −50°F)
CW15	150# RF	Carbon Steel	Cooling Water
F60	600# RF	Carbon Steel	Process
F60P	600# RF	Carbon Steel	Pipeline
IP12	125# Scrd	Carbon Steel (Galv.)	Instrument Process Piping
IA12	125# Scrd	Carbon Steel (Galv.)	Instrument Air Header and Utility Piping
IS12	125# Scrd	Carbon Steel (Galv.)	Instrument Air Signal Piping
PA12	125# Scrd	Carbon Steel (Galv.)	Plant Air
R30	300# RF	Carbon Steel	175# Steam and Condensate
S15	150# RF	Carbon Steel	Low-Pressure Steam and Condensate
UA15	150#	Carbon Steel	Utility Air Header
WD12	125# Scrd	Carbon Steel (Galv.)	Domestic Water
WS12	125# Scrd	Carbon Steel (Galv.)	Service Water

gaskets will be made of and whether branch connections are to be made using straight tees, reducing tees, or stub-ins. Specification Classes also stipulate corrosion allowance values. *Corrosion allowance* is the amount of surface material allowed to be eroded by the commodity within the pipe while permitting the pipe to remain usable for the particular service for which it is installed. All encompassing, specs even dictate what color to paint the pipe.

A sampling of the Specification Classes listed in Table 8.1 are presented in detail and are to be applied to the various assignments and projects throughout this text. Use them as a reference to answer specific questions relating to the design and drafting procedures needed to complete Units-01–04. **As with all engineering specifications, including the examples in this text, they should only be used with the project for which they are written and should not be considered typical for every project**.

Specification/Class: A15

Carbon Steel Pipe; 150 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	200	175
°F	350	275

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	1/2″-2″	40 s	Smls., CS (Carbon Steel), PE (Plain End), ASTM A106 Gr B (See Notes 1,5)
	3″-10″	40 s	Smls. or ERW, CS, Bevel End (BE), ASTM A53 Gr B
	12″-24″	STD.	Smls. or ERW, CS, BE, ASTM A53 Gr B
Fittings	1/2″-2″	3000 lb.	Forged Steel (FS), PE, matl. per ASTM A105
	3″-10″	40 s	Smls., CS, Butt-weld (BW), matl. per ASTM A234 Gr WPB
	12″-24″	STD.	Smls., CS, BW, matl. per ASTM A234 Gr WPB, match pipe wall thickness
Flanges	1/2″-2″	150 lb.	SW (Socket-weld), Raised Face (RF), FS matl. per ASTM A105
	3″-24″	150 lb.	RF, Weld neck (WN), FS matl. per ASTM A105, match pipe bore
Gaskets		150 lb.	General Service: Flexitallic Style Spiral Wound, ASME B16.20, 304SS, 1/8″ thck.
		150 lb.	General Service at Flat Face connections, Full-faced compressed nonasbestos, 1/8″ thck, Durlon 9000
Bolts			ASTM A193 Gr B7 Stud bolts w/2 ASTM A194 Gr 2H heavy hex nuts ea.
			UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	1/2″-2″	3,000 lb.	Thdd (Threaded), FS, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
Thread Dope			Use Teflon tape

(Continued)

Branch Connections

CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	SL	TR	T					
4	SL	SL	SL	SL	SL	RT	T				
6	SL	SL	SL	SL	SL	W	RT	T			
8	SL	SL	SL	SL	SL	W	RS	RT	T		
10	SL	SL	SL	SL	SL	W	S	RS	RS	T	
12	SL	SL	SL	SL	SL	W	S	RS	RS	RS	T

LEGEND:

RT — REDUCING TEE
RS — REINFORCED STUB-IN
S — STUB-IN
SL — SOC-O-LET
T — STRAIGHT TEE
TR — TEE and REDUCER
W — WELD-O-LET

FIGURE 8.3 Branch connections.

Valves

Type	Size (in.)	Weight/ SCH./ Rating	Description
Ball	½″-2″	150 lb.	3-piece, Full port, CS body w/316SS trim, SW ends, RPTFE seats and seals, ANSI B16.34 Class 800, Fire test per API 607, Marwin 4700F series or equiv.
	3″ and larger	150 lb.	Flanged, Full port, CS body w/316SS trim, RPTFE seats and seals, ANSI B16.34, Class 800, Fire test per API 607, Marwin 2000F series or equiv.
Butterfly	3″-6″	150 lb.	Wafer, Ductile Iron (DI) body w/316SS disc and shaft, lever handle, Engineer specified seats and seals, ANSI B16.34, Fire test per API 607, Bray 20/21 series or equiv.
Check	½″ and 2″	150 lb.	Swing check, Thrd ends, Bronze body, Threaded bonnet (TB), Powell 578 or equiv.
	3″ and larger	150 lb.	Swing check, RF, CS body w/316SS trim, Bolted bonnet (BB), Powell 1561 or equiv.
Gate	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, Welded bonnet, 13Cr trim, ASTM B16.34, API 602, Vogt SW-2801 or equiv.
	3″ and larger	150 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, Solid wedge, 13Cr trim, ASTM B16.34, API 602, Vogt 353 or equiv.
Globe	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt SW-12141 or equiv.
	3″ and larger	150 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt 473 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be socket-weld; 3″ and above shall be butt-weld.
2. No threaded connections are permitted except for instrument connections, or when specified by engineer. Thread-o-lets are acceptable for branch connections for instruments, vents, and drains.
3. When threaded valves are required at instrument connections, drain valves, etc., use Marwin 9700 threaded ball valve for general service or Vogt 2801 threaded gate valves for steam, condensate, and/or hot oil service.
4. Schedule 80 pipe is to be used for all steam and condensate piping 1″ and smaller and for all threaded nipples used for instrument connections, drain valves, etc.
5. Branch connections shall be made in accordance with chart in Figure 8.3.
6. All valve packing shall be flexible graphite, unless specified otherwise.
7. Use Flat Face flanges and full face gaskets when bolting to flat face nozzles on pumps, and other equipment.

Specification/Class: C30

Carbon Steel Pipe; 300 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	375	285
°F	425	350

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	½″-2″	40 s	Smls., CS (Carbon Steel), PE (Plain End), ASTM A106 Gr B (See Notes 1,5)
	3″-10″	40 s	Smls. or ERW, CS, Bevel End (BE), ASTM A53 Gr B
	12″-24″	STD.	Smls. or ERW, CS, BE, ASTM A53 Gr B
Fittings	½″-2″	3,000 lb.	Forged Steel (FS), PE, matl. per ASTM A105
	3″-10″	40 s	Smls., CS, Butt-weld (BW), matl. per ASTM A234 Gr WPB
	12″-24″	STD.	Smls., CS, BW, matl. per ASTM A234 Gr WPB, match pipe wall thickness
Flanges	½″-2″	300 lb.	SW (Socket-weld), Raised Face (RF), FS matl. per ASTM A105
	3″-24″	300 lb.	RF, Weld neck (WN), FS matl. per ASTM A105, match pipe bore
Gaskets		300 lb.	General Service: Flexitallic Style Spiral Wound, ASME B16.20, 304SS, ⅛″ thick.
		300 lb.	General Service at Flat Face connections, Full-faced compressed nonasbestos, ⅛″ thick, Durlon 9000
Bolts			ASTM A193 Gr B7 Stud bolts w/ 2 ASTM A194 Gr 2H heavy hex nuts ea.
			UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	½″-2″	3,000 lb.	Thrd (Threaded), FS, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
Thread Dope			Use Teflon tape

Branch Connections

CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	SL	RT	T					
4	SL	SL	SL	SL	SL	RT	T				
6	SL	SL	SL	SL	SL	RT	RT	T			
8	SL	SL	SL	SL	SL	S	RT	RT	T		
10	SL	SL	SL	SL	SL	S	RS	RS	RT	T	
12	SL	SL	SL	SL	SL	S	RS	RS	RS	RT	T

LEGEND:

RT — REDUCING TEE
RS — REINFORCED STUB-IN
S — STUB-IN
SL — SOC-O-LET
T — STRAIGHT TEE
TR — TEE and REDUCER
W — WELD-O-LET

FIGURE 8.4 Branch connections.

Valves

Type	Size (in.)	Weight/ SCH./ Rating	Description
Ball	½″-2″	300 lb.	3-piece, Full port, CS body w/316SS trim, SW ends, RPTFE seats and seals, ANSI B16.34 Class 800, Fire test per API 607, Marwin 9700 series or equiv.
	3″ and larger	300 lb.	Flanged, Full port, CS body w/316SS trim, RPTFE seats and seals, ANSI B16.34, Class 800, Fire test per API 607, Marwin 3000 F series or equiv.
Check	½″ and 2″	300 lb.	Swing check, Thrd ends, Bronze body, Threaded bonnet (TB), Powell 560/563 or equiv.
	3″ and larger	300 lb.	Swing check, RF, CS body w/316SS trim, Bolted bonnet (BB), Powell 3061 or equiv.
Gate	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, Welded bonnet, 13Cr trim, ASTM B16.34, API 602, Vogt SW-2801 or equiv.
	3″ and larger	300 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, Solid wedge, 13Cr trim, ASTM B16.34, API 602, Vogt 363 or equiv.
Globe	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt SW-12141 or equiv.
	3″ and larger	300 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt 483 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be socket-weld; 3″ and above shall be butt-weld.
2. No threaded connections are permitted except for instrument connections, or when specified by engineer. Thread-o-lets are acceptable for branch connections for instruments, vents and drains.
3. When threaded valves are required at instrument connections, drain valves, etc., use Marwin 9700 threaded ball valve for general service or Vogt 2801 threaded gate valves for steam, condensate, and/or hot oil service.
4. Schedule 80 pipe is to be used for all steam and condensate piping 1″ and smaller and for all threaded nipples used for instrument connections, drain valves, and so on.
5. Branch connections shall be made in accordance with chart in Figure 8.4.
6. All valve packing shall be flexible graphite, unless specified otherwise.
7. Use Flat Face flanges and full face gaskets when bolting to flat face nozzles on pumps, and other equipment.

Specification/Class: IA12

Galvanized Carbon Steel Pipe; 125 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	200	
°F	150	

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	½″-2″	80 ×	ERW, CSG (Galvanized Carbon Steel), TE (Threaded Ends), ASTM A106 Gr B (See Notes 1,2)
	3″-6″	40 s	ERW, CSG, TE ASTM A53 Gr B
Fittings	½″-2″	3000 lb.	GFS, TE, matl. per ASTM A105
	3″-6″	3000 lb.	GFS, BE, matl. per ASTM A194 Gr WPB, dims per ANSI B16.11, match pipe wall thickness.
Flanges	½″-2″	150 lb.	CSG, RF, TE, matl. per ASTM A105, dims per ANSI B16.5, match pipe bore
	3″-6″	150 lb.	CSG, RF, WN, Threaded, matl. per ASTM A105, ANSI B16.5, match pipe bore
Gaskets		150 lb.	Flat-ring per ANSI B16.21, nonasbestos, 1/16″ thck, Garlock 3200 or equivalent
Bolts			ASTM A193 Gr B7 Stud bolts w/ 2 ASTM A194 Gr 2H heavy hex nuts ea., Teflon coated. UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	½″-2″	3000 lb.	Thrd (Threaded), CSG, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
	3″-6″		Use flanges.
Thread Dope			Jet-Lube TFW white or equilavent

(*Continued*)

(*Continued*)

Branch Connections

GALVANIZED CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	W	TR	T					
4	SL	SL	SL	W	W	W	T				
6	SL	SL	SL	W	W	W	S	T			
8	SL	SL	SL	W	W	W	S	S	T		
10	SL	SL	SL	W	W	W	RS	RS	S	T	
12	SL	SL	SL	W	W	W	RS	RS	RS	S	T

LEGEND:

RT – REDUCING TEE
RS – REINFORCED STUB–IN
S – STUB–IN
SL – SOC–O–LET
T – STRAIGHT TEE
TR – TEE and REDUCER
W – WELD–O–LET

FIGURE 8.5 Branch connections.

VALVES

Type	Size (in.)	Weight/ SCH./ Rating	Description
Ball	½″-2″	600 lb.	Thrd, Bronze body, Cr pltd. ball, bronze stem, TFE seats and seals, Apollo 70–100 series or equiv.
Butterfly	3″-6″	150 lb.	Wafer, Ductile Iron (DI) body w/316SS disc and shaft, lever handle, Engineer specified seats and seals, Bray 20/21 series or equiv.
Check	½″ and 2″	800 lb.	Swing check, TE, FS body, 13Cr—309SS trim, Vogt S74 or equiv.
	3″-6″	150 lb.	Wafer check, RF, CS body and plate, metal seat, Inconel X-70 spring, Duo-Chek or equiv.
Gate	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, Bolted bonnet (BB), 13Cr trim, Vogt 2801 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 353 or equiv.
Globe	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, BB, 13Cr trim, Vogt 12141 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 473 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be threaded; 3″ and above shall be welded and flanged.
2. Branch connections shall be made in accordance with chart in Figure 8.5.

Specification/Class: PA12

Galvanized Carbon Steel Pipe; 125 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	200	
°F	150	

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	½″-2″	80 ×	ERW, CSG (Galvanized Carbon Steel), TE (Threaded Ends), ASTM A106 Gr B (See Notes 1,2)
	3″-6″	40 s	ERW, CSG, TE ASTM A53 Gr B
Fittings	½″-2″	3000 lb.	GFS, TE, matl. per ASTM A105
	3″-6″	3000 lb.	GFS, BE, matl. per ASTM A194 Gr WPB, dims per ANSI B16.11, match pipe wall thickness.
Flanges	½″-2″	150 lb.	CSG, RF, TE, matl. per ASTM A105, dims per ANSI B16.5, match pipe bore

(*Continued*)

(*Continued*)

Components	Size (in.)	Weight/ SCH./ Rating	Description
	3″-6″	150 lb.	CSG, RF, WN, Threaded, matl. per ASTM A105, ANSI B16.5, match pipe bore
Gaskets		150 lb.	Flat-ring per ANSI B16.21, nonasbestos, 1/16″ thck, Garlock 3200 or equivalent
Bolts			ASTM A193 Gr B7 Stud bolts w/ 2 ASTM A194 Gr 2H heavy hex nuts ea., Teflon coated. UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	½″-2″	3000 lb.	Thrd (Threaded), CSG, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
	3″-6″		Use flanges.
Thread Dope			Jet-Lube TFW white or equilavent

Branch Connections

GALVANIZED CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	W	TR	T					
4	SL	SL	SL	W	W	W	T				
6	SL	SL	SL	W	W	W	S	T			
8	SL	SL	SL	W	W	W	S	S	T		
10	SL	SL	SL	W	W	W	RS	RS	S	T	
12	SL	SL	SL	W	W	W	RS	RS	RS	S	T

LEGEND:

- RT – REDUCING TEE
- RS – REINFORCED STUB–IN
- S – STUB–IN
- SL – SOC–O–LET
- T – STRAIGHT TEE
- TR – TEE and REDUCER
- W – WELD–O–LET

FIGURE 8.6 Branch connections.

VALVES

Type	Size (in.)	Weight/SCH./Rating	Description
Ball	½″-2″	600 lb.	Thrd, Bronze body, Cr pltd. ball, bronze stem, TFE seats and seals, Apollo 70—100 series or equiv.
Butterfly	3″-6″	150 lb.	Wafer, Ductile Iron (DI) body w/316SS disc and shaft, lever handle, Engineer specified seats and seals, Bray 20/21 series or equiv.
Check	½″ and 2″	800 lb.	Swing check, TE, FS body, 13Cr—309SS trim, Vogt S74 or equiv.
	3″-6″	150 lb.	Wafer check, RF, CS body and plate, metal seat, Inconel X-70 spring, Duo-Chek or equiv.
Gate	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, Bolted bonnet (BB), 13Cr trim, Vogt 2801 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 353 or equiv.
Globe	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, BB, 13Cr trim, Vogt 12141 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 473 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be threaded; 3″ and above shall be welded and flanged.
2. Branch connections shall be made in accordance with chart in Figure 8.6.

Specification/Class: S15

Carbon Steel Pipe; 150 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	200	175
°F	350	275

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	½″-2″	40 s	Smls., CS (Carbon Steel), PE (Plain End), ASTM A106 Gr B (See Notes 1,5)
	3″-10″	40 s	Smls. or ERW, CS, Bevel End (BE), ASTM A53 Gr B
	12″-24″	STD.	Smls. or ERW, CS, BE, ASTM A53 Gr B
Fittings	½″-2″	3000 lb.	Forged Steel (FS), PE, matl. per ASTM A105
	3″-10″	40 s	Smls., CS, Butt-weld (BW), matl. per ASTM A234 Gr WPB
	12″-24″	STD.	Smls., CS, BW, matl. per ASTM A234 Gr WPB, match pipe wall thickness
Flanges	½″-2″	150 lb.	SW (Socket-weld), Raised Face (RF), FS matl. per ASTM A105
	3″-24″	150 lb.	RF, Weld neck (WN), FS matl. per ASTM A105, match pipe bore
Gaskets		150 lb.	General Service: Flexitallic Style Spiral Wound, ASME B16.20, 304SS, ⅛″ thck.
		150 lb.	General Service at Flat Face connections, Full-faced compressed nonasbestos, ⅛″ thck, Durlon 9000
Bolts			ASTM A193 Gr B7 Stud bolts w/ 2 ASTM A194 Gr 2H heavy hex nuts ea.
			UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	½″-2″	3000 lb.	Thdd (Threaded), FS, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
ThreadHREAD Dope			Use Teflon tape
Steam Trap	½″-3/4″	125 lb.	Thrd (Threaded), CI, Watson-McDaniel WFT series

Branch Connections

CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	SL	TR	T					
4	SL	SL	SL	SL	SL	RT	T				
6	SL	SL	SL	SL	SL	W	RT	T			
8	SL	SL	SL	SL	SL	W	RS	RT	T		
10	SL	SL	SL	SL	SL	W	S	RS	RS	T	
12	SL	SL	SL	SL	SL	W	S	RS	RS	RS	T

LEGEND:

RT — REDUCING TEE
RS — REINFORCED STUB-IN
S — STUB-IN
SL — SOC-O-LET
T — STRAIGHT TEE
TR — TEE and REDUCER
W — WELD-O-LET

FIGURE 8.7 Branch connections.

VALVES

Type	Size (in.)	Weight/ SCH./ Rating	Description
Ball	½″-2″	150 lb.	3-piece, Full port, CS body w/ 316SS trim, SW ends, RPTFE seats and seals, ANSI B16.34 Class 800, Fire test per API 607, Marwin 4700 F series or equiv.
	3″ and larger	150 lb.	Flanged, Full port, CS body w/ 316SS trim, RPTFE seats and seals, ANSI B16.34, Class 800, Fire test per API 607, Marwin 2000F series or equiv.
Butterfly	3″-6″	150 lb.	Wafer, Ductile Iron (DI) body w/ 316SS disc and shaft, lever handle, Engineer specified seats and seals, ANSI B16.34, Fire test per API 607, Bray 20/21 series or equiv.
Check	½″ and 2″	150 lb.	Swing check, Thrd ends, Bronze body, Threaded bonnet (TB), Powell 578 or equiv.
	3″ and larger	150 lb.	Swing check, RF, CS body w/316SS trim, Bolted bonnet (BB), Powell 1561 or equiv.
Gate	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, Welded bonnet, 13Cr trim, ASTM B16.34, API 602, Vogt SW-2801 or equiv.
	3″ and larger	150 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, Solid wedge, 13Cr trim, ASTM B16.34, API 602, Vogt 353 or equiv.
Globe	½″ and 2″	800 lb.	SW ends, FS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt SW-12141 or equiv.
	3″ and larger	150 lb.	Flgd ends, CS body, Conv. port, OS&Y, BB, 13Cr trim, ASTM B16.34, API 602, Vogt 473 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be socket-weld; 3″ and above shall be butt-weld.
2. No threaded connections are permitted except for instrument connections, or when specified by engineer. Thread-o-lets are acceptable for branch connections for instruments, vents and drains.
3. When threaded valves are required at instrument connections, drain valves, etc., use Marwin 9700 threaded ball valve for general service or Vogt 2801 threaded gate valves for steam, condensate, and/or hot oil service.
4. Schedule 80 pipe is to be used for all steam and condensate piping 1″ and smaller and for all threaded nipples used for instrument connections, drain valves, and so on.
5. Branch connections shall be made in accordance with chart in Figure 8.7.
6. All valve packing shall be flexible graphite, unless specified otherwise.
7. Use Flat Face flanges and full face gaskets when bolting to flat face nozzles on pumps, and other equipment.

Specification/Class: WS12

Galvanized Carbon Steel Pipe; 125 lb. rating; 0.05″ Corrosion allowance;

Conditions	Design	Operating
PSIG	200	
°F	150	

Components	Size (in.)	Weight/ SCH./ Rating	Description
Pipe	½″-2″	80×	ERW, CSG (Galvanized Carbon Steel), TE (Threaded Ends), ASTM A106 Gr B (See Notes 1,2)
	3″-6″	40 s	ERW, CSG, TE ASTM A53 Gr B
Fittings	½″-2″	3000 lb.	GFS, TE, matl. per ASTM A105
	3″-6″	3000 lb.	GFS, BE, matl. per ASTM A194 Gr WPB, dims per ANSI B16.11, match pipe wall thickness.
Flanges	½″-2″	150 lb.	CSG, RF, TE, matl. per ASTM A105, dims per ANSI B16.5, match pipe bore
	3″-6″	150 lb.	CSG, RF, WN, Threaded, matl. per ASTM A105, ANSI B16.5, match pipe bore
Gaskets		150 lb.	Flat-ring per ANSI B16.21, nonasbestos, 1/16″ thck, Garlock 3200 or equivalent
Bolts			ASTM A193 Gr B7 Stud bolts w/ 2 ASTM A194 Gr 2H heavy hex nuts ea., Teflon coated. UNC thrd. on sizes smaller than 1″. 8UN thrd. on all sizes 1″ and above.
Unions	½″-2″	3000 lb.	Thrd (Threaded), CSG, GJ, int steel seat, internal NPT, matl. per ASTM A105, ANSI B2.1
	3″ -6″		Use flanges.
Thread Dope			Jet-Lube TFW white or equilavent

(Continued)

Branch Connections

GALVANIZED CARBON STEEL HEADER TO BRANCH CONNECTIONS

HEADER SIZE	BRANCH SIZE (INCHES)										
	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12
1/2	T										
3/4	TR	T									
1	TR	TR	T								
1 1/2	SL	SL	TR	T							
2	SL	SL	SL	TR	T						
3	SL	SL	SL	W	TR	T					
4	SL	SL	SL	W	W	W	T				
6	SL	SL	SL	W	W	W	S	T			
8	SL	SL	SL	W	W	W	S	S	T		
10	SL	SL	SL	W	W	W	RS	RS	S	T	
12	SL	SL	SL	W	W	W	RS	RS	RS	S	T

LEGEND:

RT — REDUCING TEE
RS — REINFORCED STUB-IN
S — STUB-IN
SL — SOC-O-LET
T — STRAIGHT TEE
TR — TEE and REDUCER
W — WELD-O-LET

FIGURE 8.8 Branch connections.

VALVES

Type	Size (in.)	Weight/ SCH./ Rating	Description
Ball	½″-2″	600 lb.	Thrd, Bronze body, Cr pltd. ball, bronze stem, TFE seats and seals, Apollo 70–100 series or equiv.
Butterfly	3″-6″	150 lb.	Wafer, Ductile Iron (DI) body w/ 316SS disc and shaft, lever handle, Engineer specified seats and seals, Bray 20/21 series or equiv.
Check	½″ and 2″	800 lb.	Swing check, TE, FS body, 13Cr—309SS trim, Vogt S74 or equiv.
	3″-6″	150 lb.	Wafer check, RF, CS body and plate, metal seat, Inconel X-70 spring, Duo-Chek or equiv.
Gate	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, Bolted bonnet (BB), 13Cr trim, Vogt 2801 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 353 or equiv.
Globe	½″ and 2″	800 lb.	Thrd ends, FS body, OS&Y, BB, 13Cr trim, Vogt 12141 or equiv.
	3″-6″	150 lb.	Flgd ends, CS body, OS&Y, BB, Solid or flex wedge, 13Cr trim, Vogt 473 or equiv.

General Notes:

1. Nominal Pipe Size (NPS) 2″ and below shall be threaded; 3″ and above shall be welded and flanged.
2. Branch connections shall be made in accordance with chart in Figure 8.8.

ABBREVIATIONS

As a piping facility becomes more complex, so do the piping drawings. Facilities such as multistoried structures, specialized refining systems, and complex equipment arrangements compound the crowdedness of a drawing. To alleviate the crowded conditions, abbreviations should be used to reduce the space requirements of callouts and notes. The following compilation is an alphabetical listing of many common abbreviations found on piping arrangement drawings, elevations, details, flow diagrams, and/or isometrics. A complete listing is almost impossible to assemble as engineering companies and their clients often develop abbreviations that are unique to specific projects.

PIPING ABBREVIATIONS

A

A	Alarm
A	Anchor
ACCUM	Accumulator
AL	Aluminum
ANSI	American National Standards Institute
API	American Petroleum Institute
ASSY	Assembly
ASTM	American Society for Testing and Materials
ATMOS	Atmosphere
AUX	Auxiliary
AVG	Average
AZ	Azimuth

B

B	Beveled
BB	Bolted Bonnet
BBE	Bevel Both Ends
BBL	Barrel(s)
BC	Bolt Circle
BD	Blow Down
BE	Beveled End(s)
BF	Blind Flange
BL	Battery Limits
BLDG	Building
BLE	Bevel Large End
BOM	Bill of Materials
BOP	Bottom of Pipe
B&S	Bell and Spigot
BSE	Bevel Small End
BTU	British Thermal Unit
BV	Ball Valve
BW	Butt-weld

C

CB	Catch Basin
CHKV	Check Valve
Ch. Op.	Chain Operator
CI	Cast Iron
CL	Clearance
CO	Clean Out
COL	Column
COLS	Columns
CONC	Concentric
COND	Condensate
CONN	Connection
CORR	Corrosion
CPLG	Coupling
CS	Carbon Steel
CS	Cast Steel
CS	Cold Spring
CSC	Car Seal Closed
CSO	Car Seal Open
CTRLV	Control Valve
CWR	Cooling Water Return
CWS	Cooling Water Supply

D

DA	Directional Anchor
DF	Drain Funnel
DIA	Diameter
DIM	Dimension
DISCH	Discharge
DR	Drain
DW	Dummy Weld
DWG	Drawing
DRWN	Drawn

E

E	East
ECC	Eccentric
EL	Elevation
ELL	Elbow
ELEV	Elevation
EQUIP	Equipment
ERW	Electric Resistance Welded
EXCH	Exchanger
EXIST	Existing

F

FA	Flow Alarm
FBO	Furnished By Others
FDN	Foundation
FE	Flow Element
F/F	Face-to-Face

FF	Flat Face
FF	Full Face
FI	Flow Indicator
FIC	Flow Indicating Controller
FIG	Figure
FLR	Floor
FLD FAB	Field Fabricate
FL	Flange
FOB	Flat on Bottom
FOT	Flat on Top
FR	Flow Recorder
FRC	Flow Recording Controller
FS	Field Support
FS	Forged Steel
FT	Foot or Feet
FW	Field Weld

G

G	Gauge or gage
GAL	Gallon(s)
GALV	Galvanized
GPH	Gallons Per Hour
GPM	Gallons Per Minute
GR	Grade
GaV	Gate Valve
GIV	Globe Valve

H

HCV	Hand Control Valve
HDR	Header
HIC	Hand Indicating Controller
HLL	High Liquid Level
HOR	Horizontal
HP	High Pressure
HPFS	High Point Finished Surface
HPP	High Point Paving
HR	Hanger Rod
Hour	
HTR	Heater
HVAC	Heating, Ventilating, and Air Conditioning
HVY	Heavy
HYD	Hydraulic

I

IA	Instrument Air
IA	Insulation (anti sweat)
IC	Insulation (cold)
ID	Inside Diameter
IDD	Inside Depth of Dish
IET	Electric Trace
IGT	Glycol Trace
IH	Insulation (heat conservation)
IN	Inch(es)
INS	Insulate or Insulation
INST	Instrument(ation)
INV	Invert Elevation
IPS	Iron Pipe Size
IS	Insulation Safety
ISA	Instrumentation Society of America
ISO	International Organization for Standardization
ISO	Isometric
IST	Steam Trace

J

JCT	Junction
JS	Jack Screw
JT	Joint

L

L	Level
LA	Level Alarm
LAH	Level Alarm-High
LAL	Level Alarm-Low
LBS	Pounds
LC	Level Controller
LC	Lock Closed
LG	Level Gauge
LG	Level Glass
LI	Level Indicator
LIC	Level Indicating Controller
LLL	Low Liquid Level
LN	Line
LO	Lock Open
LP	Low Pressure
LPG	Liquefied Petroleum Gas
LPT	Low Point
LR	Level Recorder
LR	Long Radius
LRC	Level Recording Controller
LS	Level Switch

M

mm	millimeter
M	Meter
M&F	Male and Female
MATL	Material
MAX	Maximum
MECH	Mechanical
MFG	Manufacturing
MFR	Manufacturer
MI	Malleable Iron
MIN	Minimum

MIN	Minute
MISC	Miscellaneous
MK	Piece Mark
MW	Manway
MW	Miter weld

N

N	North
NC	Normally Closed
NEC	National Electric Code
NEG	Negative
NIP	Nipple
NLL	Normal Liquid Level
NO	Normally Open
NO	Number
NOM	Nominal
NOZZ	Nozzle
NPS	Nominal Pipe Size
NPSH	Net Positive Suction Head
NPT	National Pipe Thread
NTS	Not to Scale

O

OAL	Overall Length
OD	Outside Diameter
OH	Open Hearth
OPP	Opposite
OS&Y	Outside Screw and Yoke
OVHD	Overhead
OWS	Oily Water Sewer

P

PA	Pipe Anchor
PA	Pressure Alarm
PC	Pressure Controller
PCV	Pressure Control Valve
PdRC	Pressure Differential Recording Controller
PE	Plain End
PI	Point of Intersection
PI	Pressure Indicator
PIC	Pressure Indicating Controller
P&ID	Piping and Instrument Diagram
PLE	Plain Large End
PO	Pump Out
POE	Plain One End
POS	Positive
PP	Personnel Protection
PR	Pressure Recorder
PRC	Pressure Recording Controller
PS	Pipe Support
PSE	Plain Small End
PSI	Pounds per Square Inch
PSIA	Pounds per Square Inch absolute
PSIG	Pounds per Square Inch Gage
PSV	Pressure Safety Valve
PT	Point

Q

QTY	Quantity
QUAD	Quadrant
QUAD	Quadruple

R

R	Radius
REC'D	Received
RED	Reducer
REF	Reference
REINF	Reinforce
REQ'D	Required
REV	Reverse
REV	Revision
RF	Raised Face
RJ	Ring Type Joint
RPM	Rotations Per Minute
RS	Rising Stem
RTJ	Ring Type Joint

S

S	South
SC	Sample Connection
SCH	Schedule
SCRD	Screwed
SECT	Section
SH (SHT)	Sheet
SMLS	Seamless
SO	Slip On
SO	Steam Out
SOL	Sock-o-let
SP	Set Point
SP GR	Specific Gravity
SPEC	Specification
SQ	Square
SR	Short Radius
STD	Standard
STL	Steel
STM	Steam
SUCT	Suction
SUPT	Support
SW	Socket-weld
SWG	Swage
SWP	Standard Working Pressure
SYS	System

T

T	Steam Trap
TA	Temperature Alarm
Tan	Tangent
TBE	Thread Both Ends
TC	Temperature Controller
TCV	Temperature Control Valve
TE	Threaded End
TEMP	Temperature
T&C	Thread and Coupled
T&G	Tongue and Groove
THRD	Thread
TI	Temperature Indicator
TIC	Temperature Indicating Controller
TLE	Thread Large End
TOC	Top of Concrete
TOG	Top of Grout
TOL	Thread-o-let
TOS	Top of Steel
TR	Temperature Recorder
TRC	Temperature Recording Controller
TSE	Thread Small End
T/T	Tangent to Tangent
TW	Temperature Well
TW	Thermowell
TYP	Typical

U

UA	Utility Air
US	Utility Station

V

VA	Valve
VA	Vent to Atmosphere
VB	Vortex Breaker
VC	Vitrified Clay
VERT	Vertical
VF	Vent to Flare
VOL	Volume
VS	Vent to Stack

W

w/	with
W	West
WB	Welded Bonnet
WE	Weld End
WLD	Weld
WN	Weld Neck
WOG	Water, Oil, Gas
WOL	Weld-o-let
WT	Weight

X

XH	Extra Heavy
XS	Extra Strong
XXH	Double Extra Heavy
XXS	Double Extra Strong

CHAPTER 8 REVIEW QUIZ

1. Explain the difference between codes and specifications.

____

____

____

Using information found in the General Piping Specifications, answer the following questions.

2. Dimensions are provided on drawings to the nearest________________of an inch.

3. Piping drawings are drawn to which scale?

____

4. What is the minimum headroom clearance of a secondary roadway?

____

5. What is the minimum headroom clearance over an aisle way?

____

6. All operating valves_____________above grade or platform shall be chain operated.

7. What is the minimum width of a platform?

____

8. What is maximum vertical distance between platforms?

____

9. What type of 'start-up' strainers are used at all pump suctions?

____

10. All lines shall have vents and drains. What size is the vent and drain connections?

____

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CHAPTER

9

Equipment Layout

PLANT COORDINATE SYSTEM

Plot plans, Foundation Location plans, Equipment Location plans, and Piping Arrangement drawings use the *plant coordinate system* method of arranging and positioning drawing elements. Universally recognized throughout the piping industry, the plant coordinate system uses intersecting grid lines, similar to the Cartesian coordinate system, drawn relative to an established North direction, to locate buildings, structures, steel columns, concrete foundations, mechanical equipment, and pipe configurations. The grid lines, which originate from a designated control point, are drawn parallel to north/south and east/west axes (Figure 9.1).

The control point, more commonly known as a *bench mark*, is a permanent marker erected at a specified location somewhere within the proposed facility. It is often located so it cannot be accidentally damaged or destroyed. The control point is the precise location from which the intersecting north/south and east/west grid lines originate. From this point the grid lines are measured incrementally and labeled with numerical values known as coordinates. The control point therefore becomes the primary reference point for the entire facility. By labeling the control point with a positional value of 0′-0″, 0′-0″ and using a North arrow to establish orientation, the numerical values assigned to the coordinates allow for exact positioning of all facility components. Each facility component will be precisely located using two intersecting coordinates. *Coordinates* indicate the distance and direction the particular structure, foundation, or piece of mechanical equipment measures from the control point.

The North arrow typically points up, or toward the top of the drawing sheet, and creates directional bearing for the facility. As an alternate orientation the North arrow may point to the right on the drawing. Assuming the North arrow points up, horizontal lines drawn above, or north of, the 0′-0″, 0′-0″ origin are designated as North coordinates and are labeled to indicate their linear distance from the control point, for example, N. 10′-0″. Although these lines are drawn in an east/west alignment, they are labeled as North coordinates because they measure distance from the control point northward. Vertical lines drawn to the right of 0′-0″, 0′-0″ are designated as East coordinates and are labeled as such, for example, E. 20′-0″. Lines drawn to the south and west of the control point will have S. or W. designations, respectively. Piping arrangement drawings are often severely overcrowded with extensive amounts of graphical symbols and written information. The use of coordinates reduces the amount of written information and simplifies the drawing by minimizing the use of location dimensions. Figure 9.2 demonstrates the use of coordinates to label the positions of mechanical equipment.

Depending on the direction of the North Arrow, we know north/south and east/west plant coordinates translate to $+x/-x$ and $+y/-y$ Cartesian coordinates. Therefore we can assume up/down plant directions translate to $+z/-z$ Cartesian coordinates. Figure 9.3 incorporates the height dimension (up/down) in the $+z$ direction by illustrating a 3D model of the mechanical equipment support pedestals in their specified coordinate locations.

The format used to identify plant coordinates will vary with each design project. Some projects use feet and inch designations, whereas others may

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00017-0

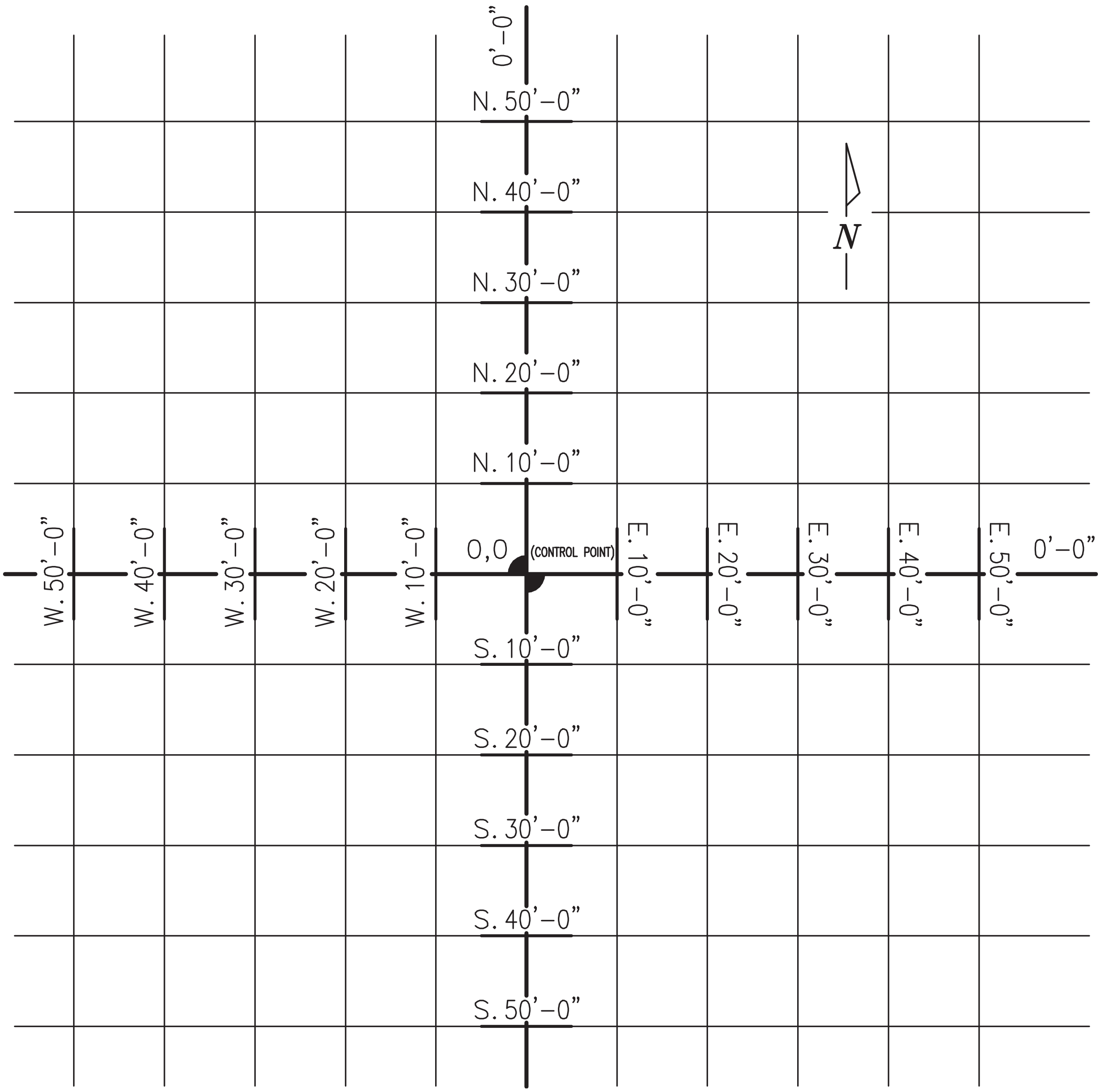


FIGURE 9.1 Plant coordinate system.

use decimals of a foot or millimeters. No matter the format, coordinates are preceded by the letters N, S, E, or W, except for 0′-0″. The projects in this chapter will use feet and inches measurements. As mentioned previously, the use of coordinates eliminates the need for excessive dimensions. However, when location dimensions are required on drawings, they use a known coordinate as a datum, usually the centerline of a column, foundation, or piece of mechanical equipment. Whatever the unit of measurement, one rule to remember is; *horizontal length dimensions are found by adding or subtracting coordinates*.

Figure 9.4 allows you to see the amount of space required to include linear dimensions on a drawing and how the use of coordinates can free a significant amount of drawing space.

PLANT ELEVATIONS

Similar to the way a plan view drawing has a control point to help establish horizontal dimensions in a piping facility, a control point is also needed to establish vertical dimensions, or elevation, in the facility. Elevation, as it is

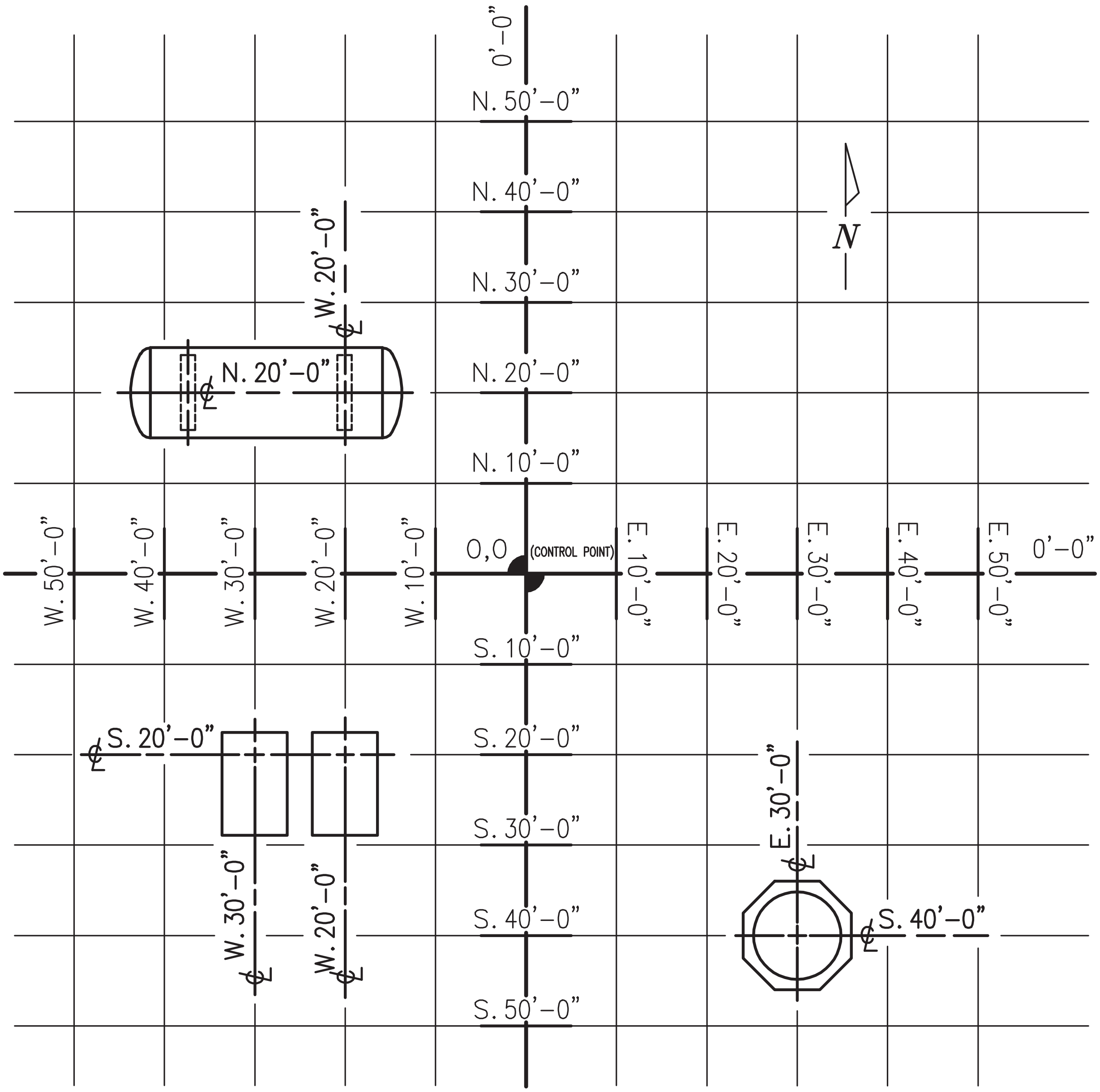


FIGURE 9.2 Using coordinates to locate mechanical equipment.

traditionally known, is the vertical distance an object rises above sea level, such as the height of a mountain. But in piping facilities, *elevation* is used to designate the height of an object measures from the ground. In piping terminology the ground is referred to as *Grade*. It is from Grade that all elevation references are based. But, rather than using numbers based on the actual height of the ground measures above sea level, many facilities use an arbitrary Grade elevation of 100′-0″, as a matter of convenience. In all petro-chemical facilities, pipes are installed both above and below Grade. The use of 100′-0″ as the control point of reference prevents the use of negative numbers when dimensioning pipes below grade. This simplifies the mathematical calculations that the interpolation of positive and negative numbers may cause.

Very few actual dimensions are shown on piping section or elevation drawings. However, numerous callouts are placed on drawings to convey elevation information to the reader. Some of the callouts and corresponding terms are shown below.

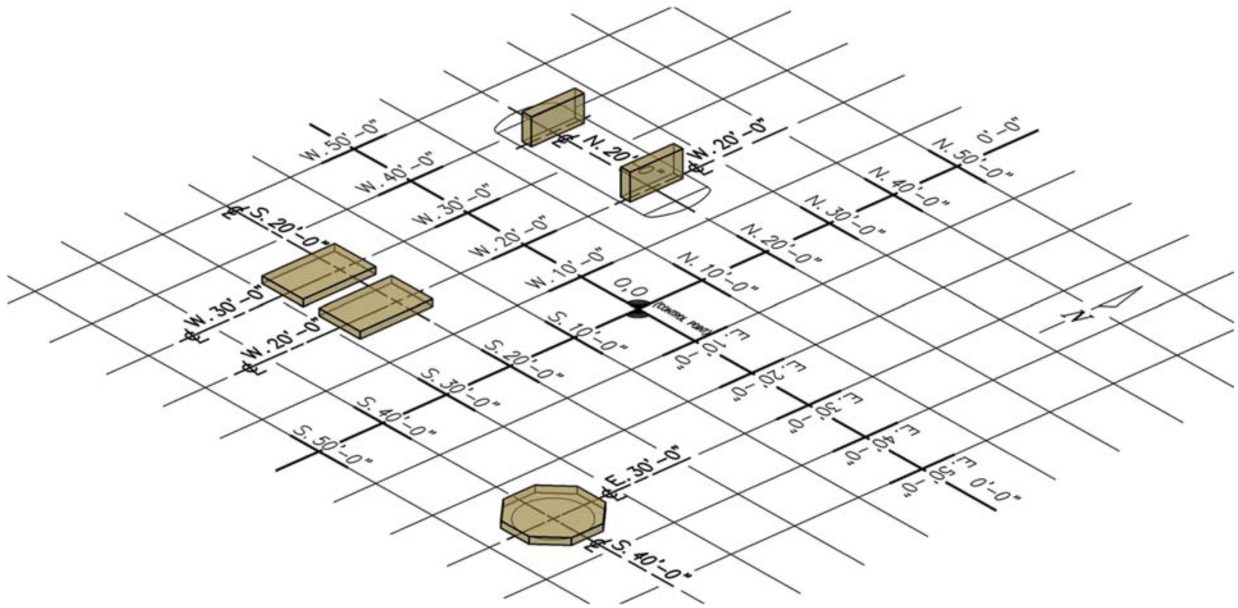


FIGURE 9.3 3D model of mechanical equipment pedestals.

See Figure 9.5 for examples of the plant elevation system.

Piping terminology	Piping callout
Grade elevation	GRADE EL.100′-0″
High point of paving	H.P PAVING 100′-0″
Centerline elevation	℄ EL. 102′-0″
Top of concrete	T.O.C. EL.101′-0″
Top of steel	T.O.S. EL. 112′-0″
Bottom of pipe	B.O.P. EL. 112′-0″
Face of flange	F.O.F. EL. 105′-0″
Top of platform	T.O. PLAT. EL. 137′-6″

The repeated use of coordinates and elevations makes it imperative that correct numbers be used to calculate accurate dimensions. To avoid inadvertent mixing of coordinate and elevation values, follow this simple guideline: *Use only coordinates to calculate horizontal dimensions and use only elevations to calculate vertical dimensions*. By adding or subtracting coordinates, horizontal distances between steel supports, concrete foundations, and mechanical equipment can be determined. Knowing when to add and when to subtract can be confusing, however. A basic rule to remember when calculating horizontal distances is: *Subtract like coordinates and add unlike coordinates*. This basic rule is illustrated in Figure 9.6.

Calculating vertical dimensions is somewhat easier. Simply subtract the lower elevation from the higher elevation to determine the distance between the two. However, you must be certain that elevations of the same type are used. For example, always use two "Centerline" elevations, not one "Centerline" and one "Bottom of Pipe" (BOP). You must convert BOP elevations to Centerline elevations before subtracting. This is accomplished by adding one-half the actual outside diameter (OD) of the pipe to the BOP elevation, before subtracting. Also, be aware that lines installed below grade are labeled using *invert* elevations. Invert elevations identify the inside bottom of pipe elevation, that is, the distance from the bottom inside of the pipe to the ground above it. Figure 9.7 illustrates the use of elevations to calculate vertical dimensions.

SITE PLANS

The civil/topographic drafting department of a company prepares the Site Plan for the piping facility. A Site Plans is an overhead, or top, view drawn to show the overall appearance of the facility site and adjacent area. Site Plans can also be modified overlays of aerial photographs or images captured from orbiting satellites. Site Plans may include roadways, railways, harbors, ship channels, aircraft landing zones, office buildings, and recreation

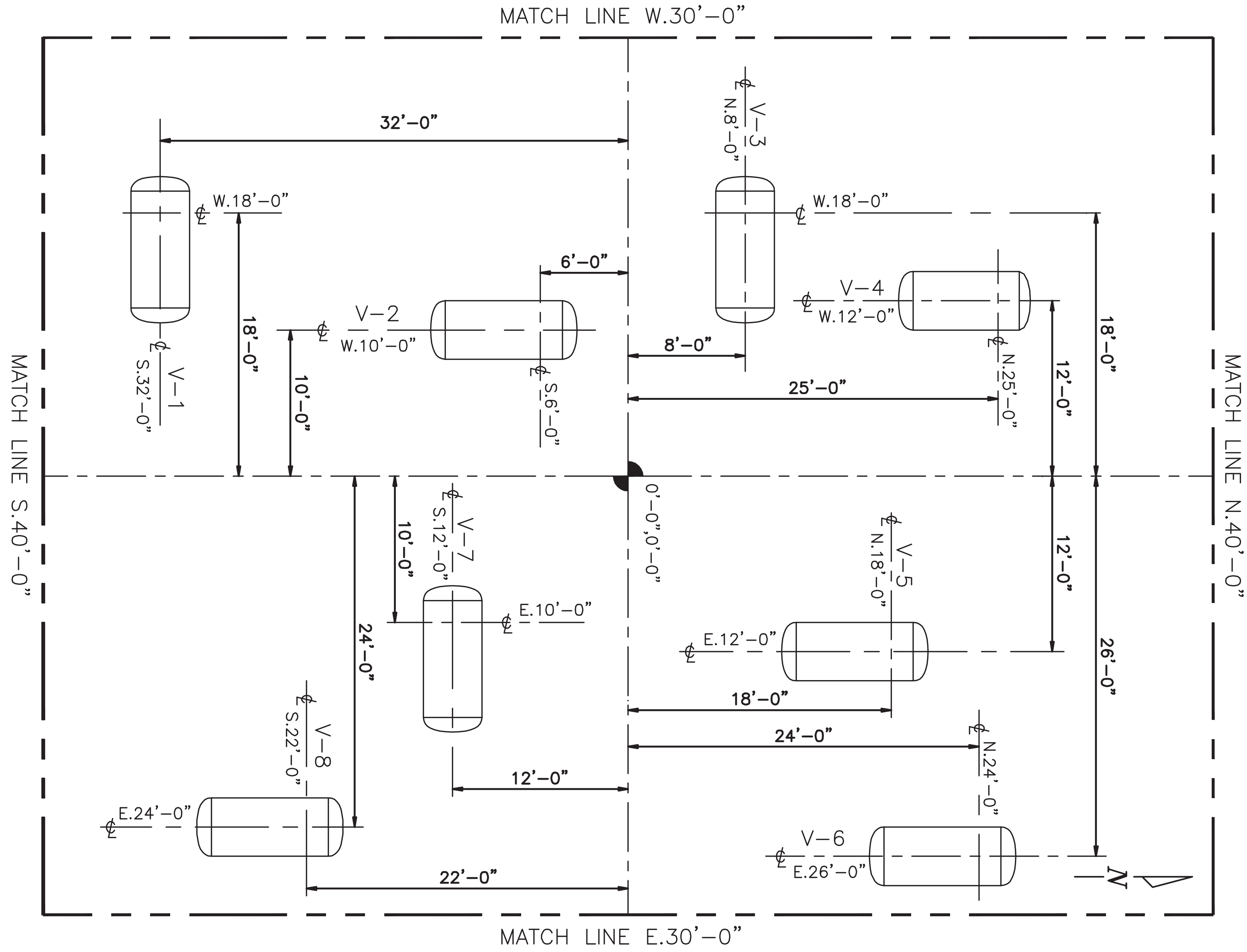


FIGURE 9.4 Replacing dimensions with coordinates.

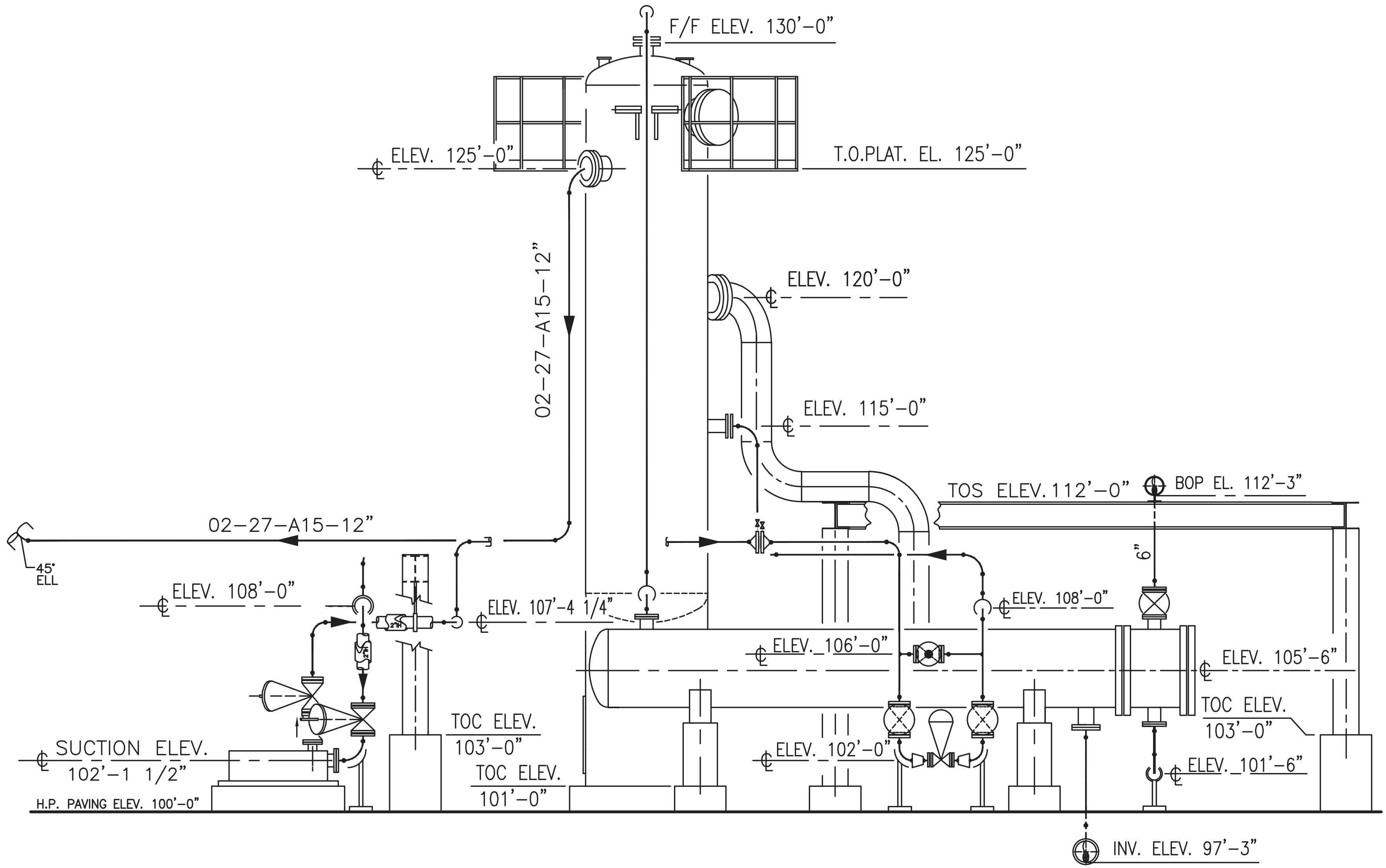


FIGURE 9.5 Plant elevation system.

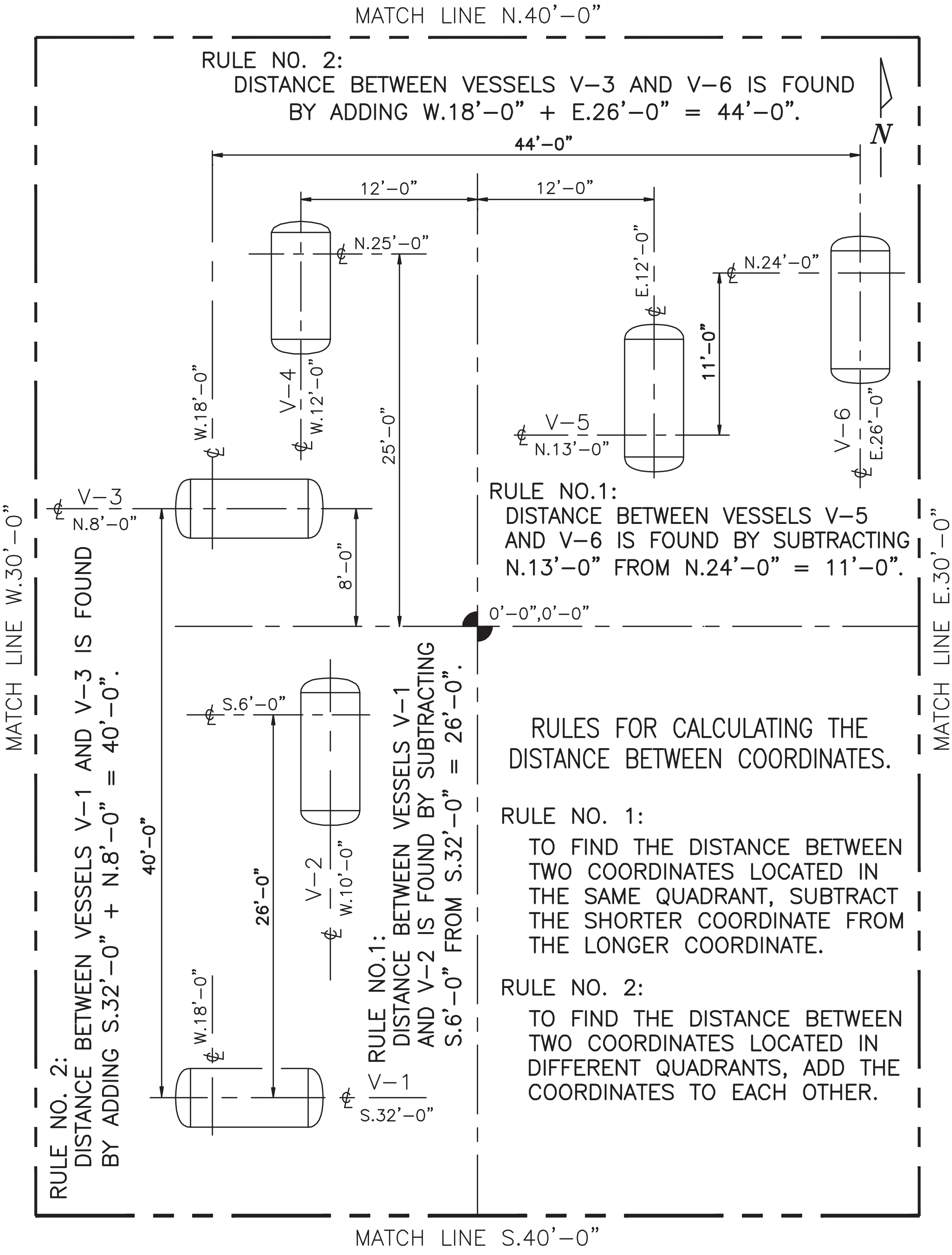


FIGURE 9.6 Horizontal distance calculations with coordinates.

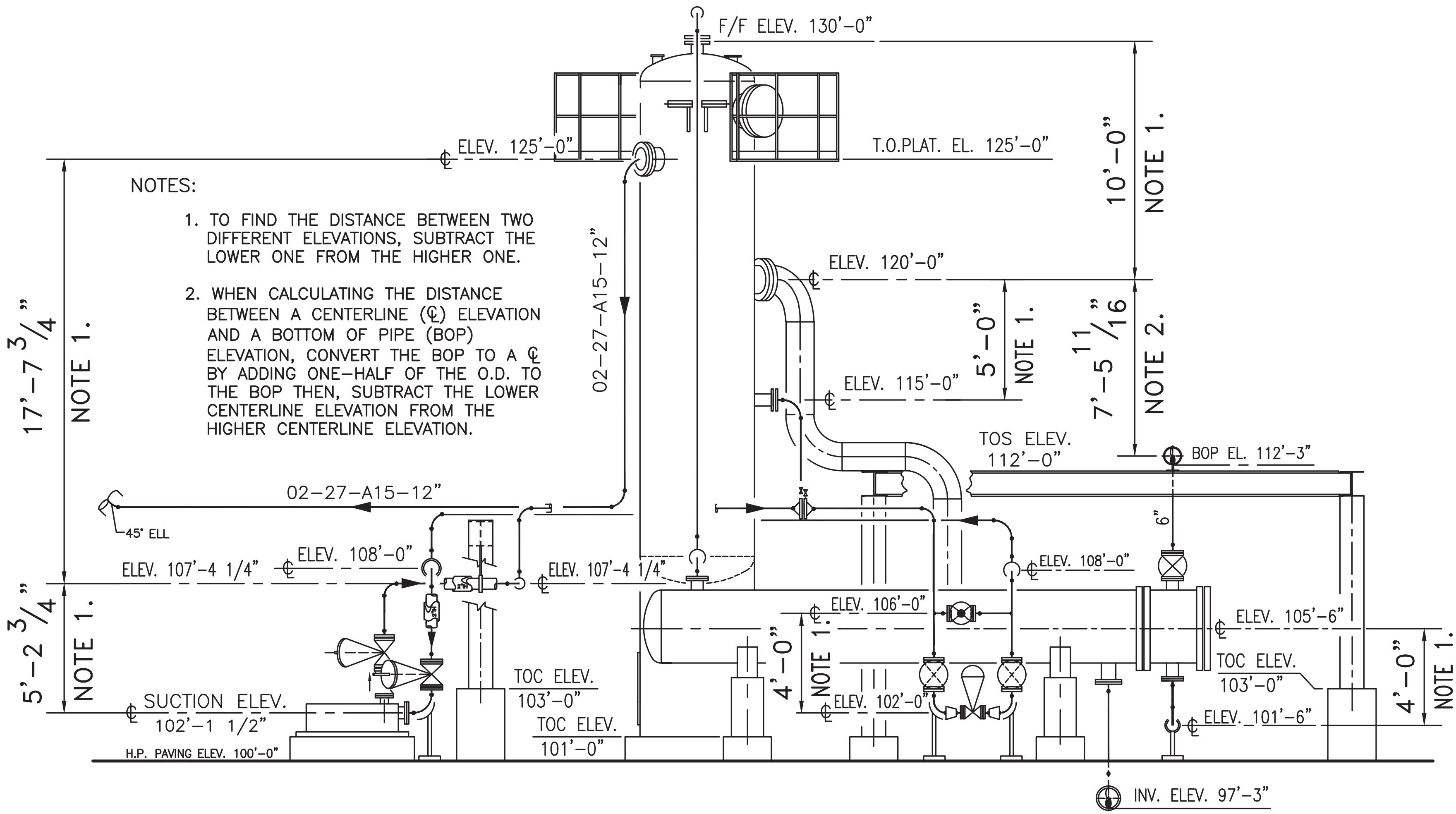


FIGURE 9.7 Vertical distance calculations with coordinates.

areas. Drawings of this size do not show significant detail. Detailed areas of the facility are usually denoted by rectangular outlines with notes or titles describing the area's purpose. Mechanical equipment within the facility is typically too small to be represented on a Site Plan. Therefore the complete facility is usually divided into smaller areas called *Units*. Each Unit can then be drawn separately on drawings called *Unit Plot Plans*.

UNIT PLOT PLAN

Unit Plot Plans are generally defined by imaginary lines called *Battery Limits*. Battery Limits are used to establish a Unit's perimeter boundaries. The Unit Plot Plan is usually drawn to small scale, such as: 1″ = 10′, 1″ = 20′, or 1″ = 30′.

Unit Plot Plans show the location of all the buildings, mechanical equipment, pipe racks, tank farms, and other items of importance in the Unit. True North and Plant North are also shown as actual and theoretical points of orientation. The purpose of this drawing is not to show detail, but rather, the arrangement of various components to be erected in the Unit.

The piping group is typically responsible for the development of the Unit Plot Plan. Unit Plot Plans are developed using the Mechanical flow diagram, client specifications, codes, and input from the client's engineers and the plant manager will ultimately oversee the operation of the facility. Figure 9.8 shows an example of a Unit Plot Plan.

EQUIPMENT LOCATION DRAWING

In order to arrange and adequately space all the components required in the Unit, the piping group will use the approved Plot Plan to assign coordinate positions to vessels, pumps, heaters, exchangers, pipe supports, and control rooms and develop the Equipment Location drawing. Keeping in mind there will be plant operators and maintenance personnel in the facility 24 hours a day, adequate arrangement and spacing of components within the facility becomes important. Equipment location depends on a number of factors, including piping codes, space availability, worker accessibility as well as client preferences. All pieces of mechanical equipment to be installed within the facility are positioned using two intersecting coordinate lines, one north/south, and one east/west. These intersecting coordinates define the precise position of all vessels, pumps, exchangers, and so onlocating the centerline of its foundation. When locating equipment such as exchangers and reboilers, that have a foundational support on each end, at least one of the equipment's supporting foundations must be located with coordinates. By using the plant coordinate system, it is impossible for any other component in the facility to have the same pair of intersecting coordinates. Figure 9.9 provides an example of an Equipment Location drawing.

FOUNDATION LOCATION DRAWING

The structural drafting department uses information provided on the Equipment Location drawing to show the position of foundations for mechanical equipment, structural supports, and control buildings. On Foundation Location drawings, foundations that are to be built above grade are drawn as solid lines and spread footings. The portion of the foundation that lies below grade is shown as hidden lines. Figure 9.10 shows an example of a Foundation Location drawing.

PIPING DRAWING INDEX

The Piping Drawing Index is developed from the Plot Plan. This drawing divides the Plot Plan into smaller drawing areas, using *match lines*. Match lines are lines drawn and labeled that allow the smaller drawing areas to be pieced together to form the larger Plot Plan, similar to a puzzle. Larger areas are divided in such a way as to keep related pieces of mechanical equipment on the same drawing if possible. These drawing areas are given a drawing number for easy identification and then assigned to various designers on the project. During the design phase, it is crucial that designers interface with those working on adjacent drawing areas. The position, size, and pound rating of lines entering or leaving an area and continuing into an adjacent area must be properly noted and located on all related drawings. Figure 9.11 is a sample Piping Drawing Index.

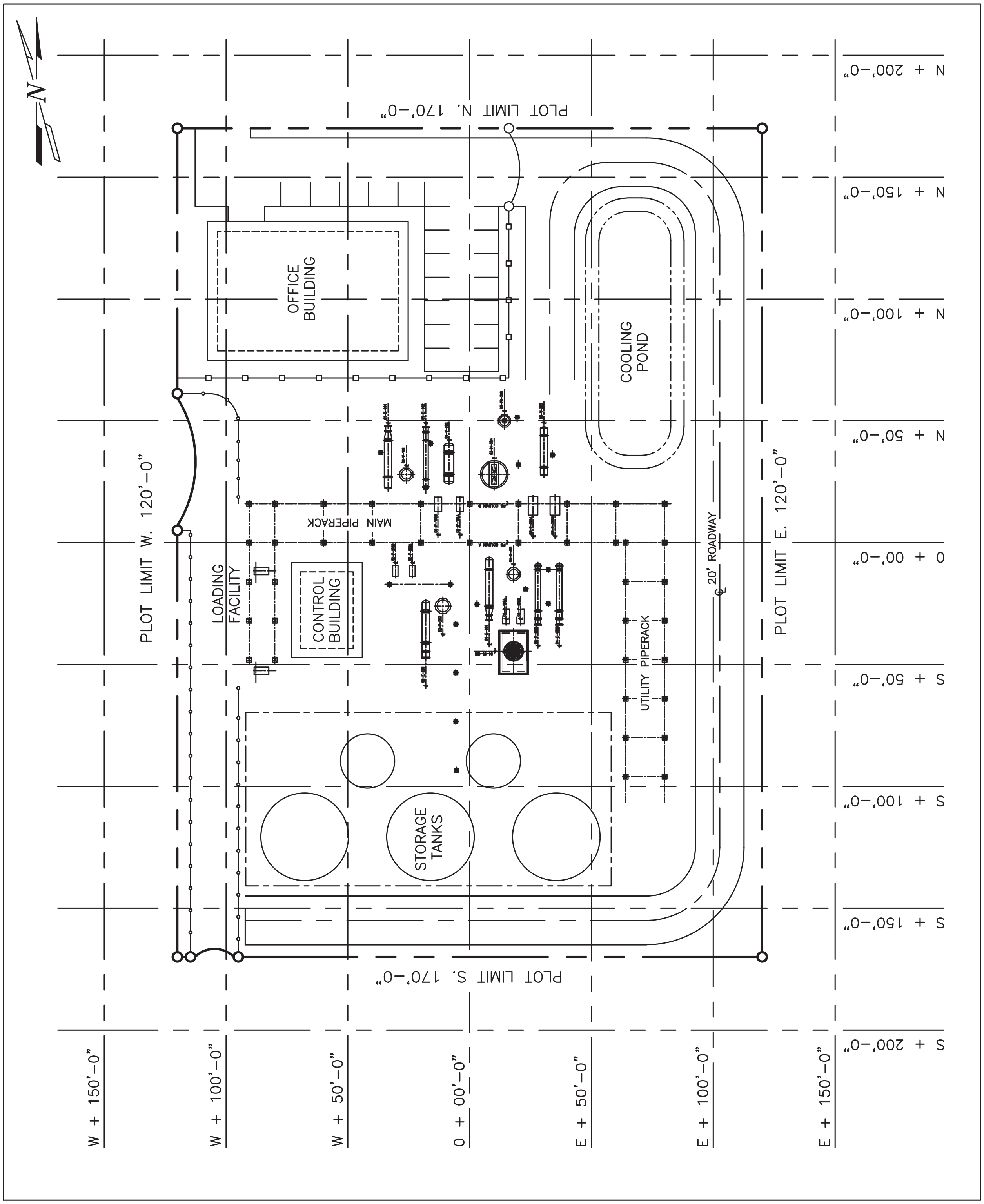


FIGURE 9.8 Unit Plot Plan.

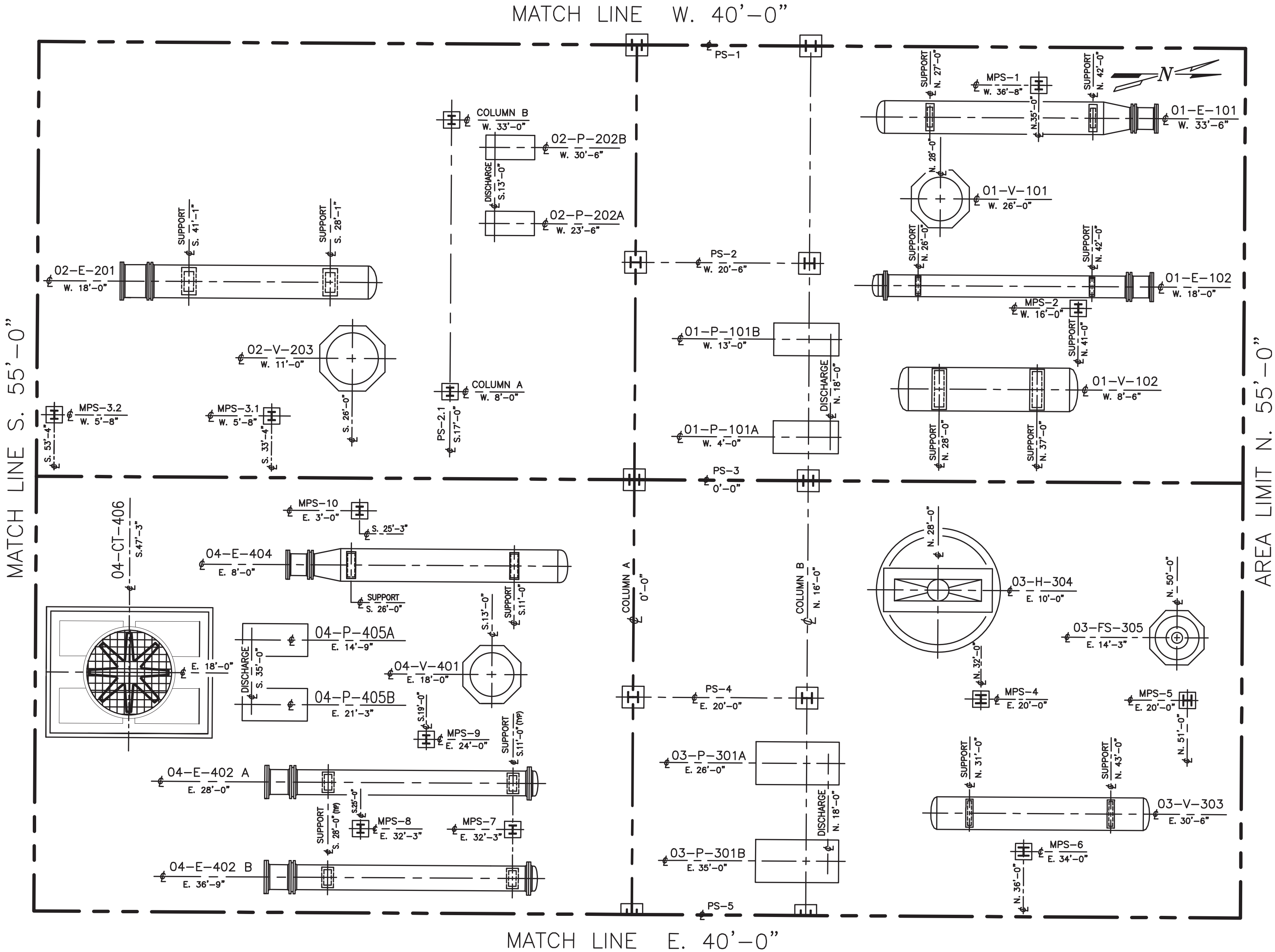


FIGURE 9.9 Equipment Location drawing.

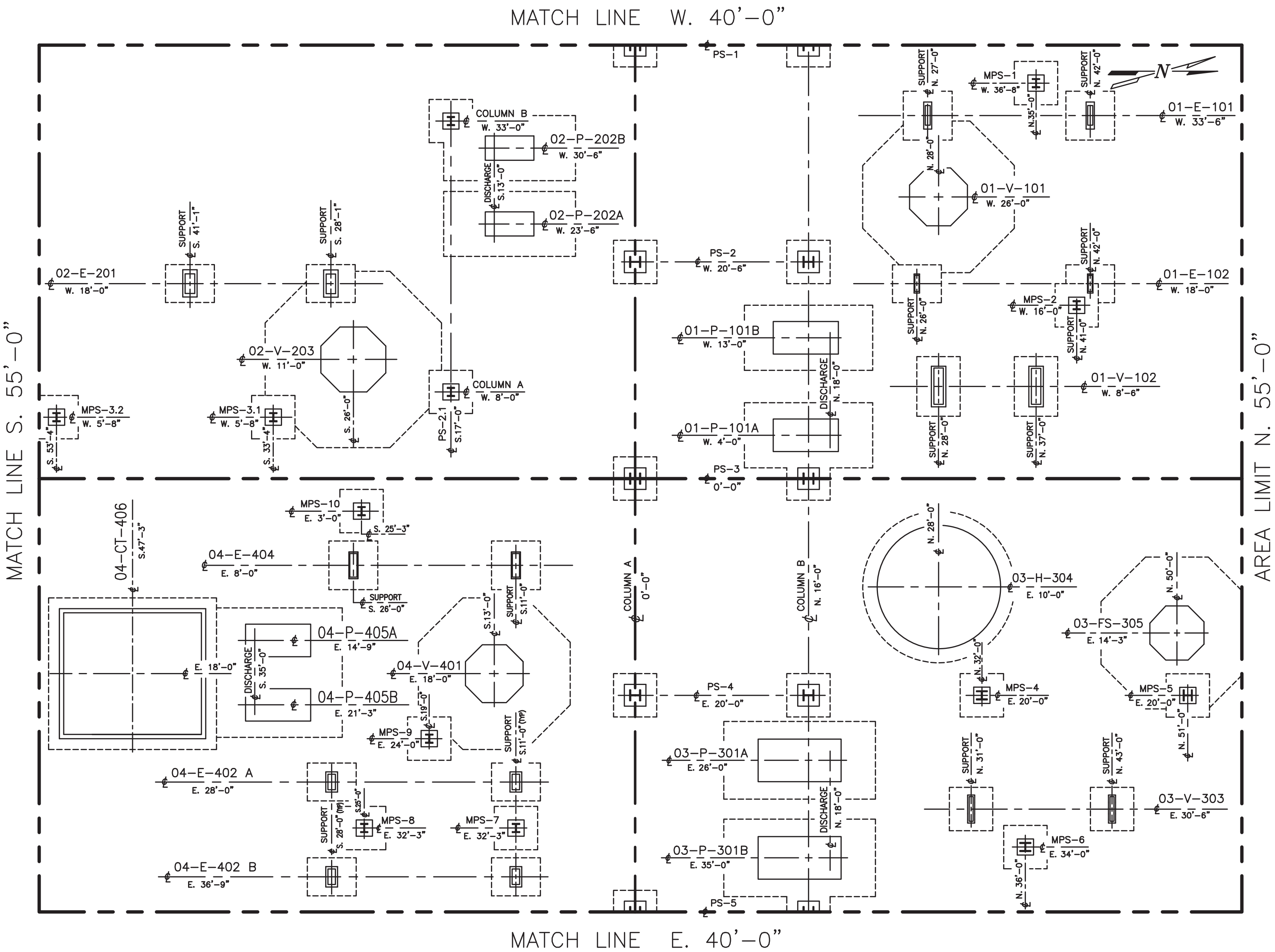


FIGURE 9.10 Foundation Location drawing.

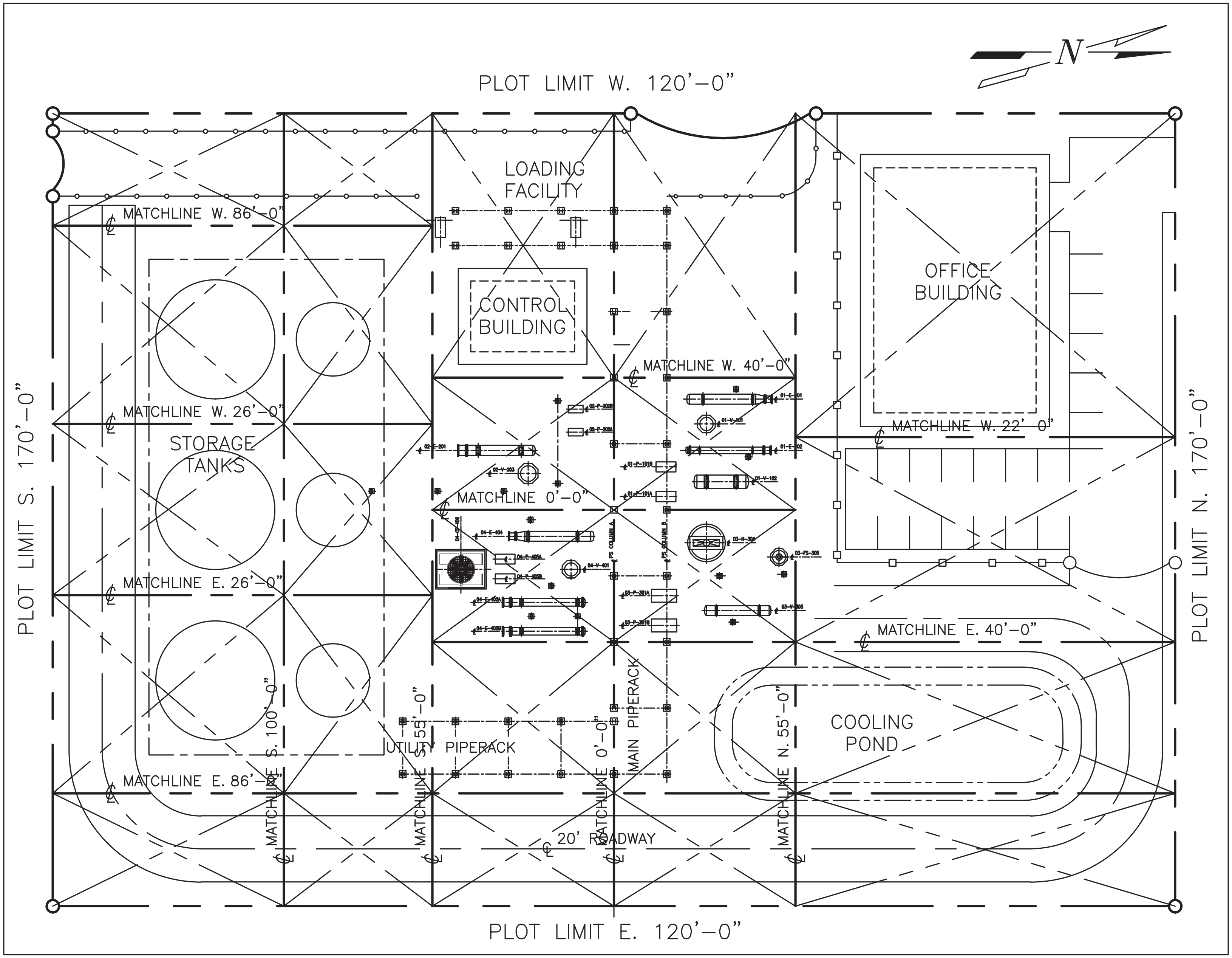


FIGURE 9.11 Piping Drawing Index.

CHAPTER 9 REVIEW QUIZ

1. Define *plant coordinate system*.

____

____

____

2. Name the three units of measurement by which coordinates can be labeled.

____

____

____

3. What is the typical arbitrary value for the elevation of Grade?

____

4. Define the following terms.
H.P. Paving

____

____

T.O.C. EL.

____

T.O.S. EL.

____

____

B.O.P. EL.

____

____

F./F. EL.

____

____

5. Use only coordinates to determine_______________ ______________dimensions.

6. Use only elevations to determine________________ ______________dimensions.

7. Define *Battery Limits*.

____

____

8. Name three factors that influence the arrangement and spacing of mechanical equipment.

____

____

____

9. How are above-grade foundations represented on a Foundation Location drawing?

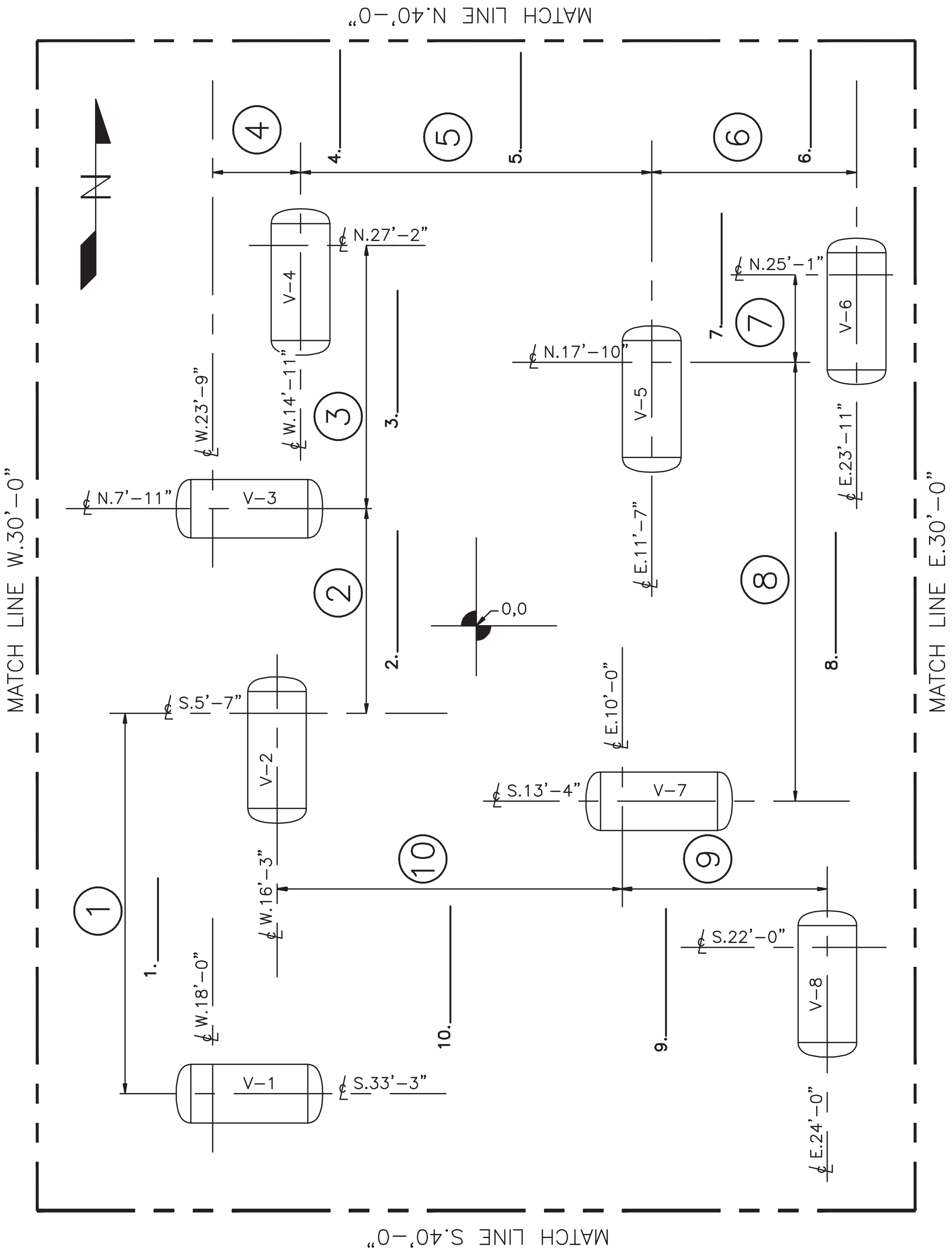
____

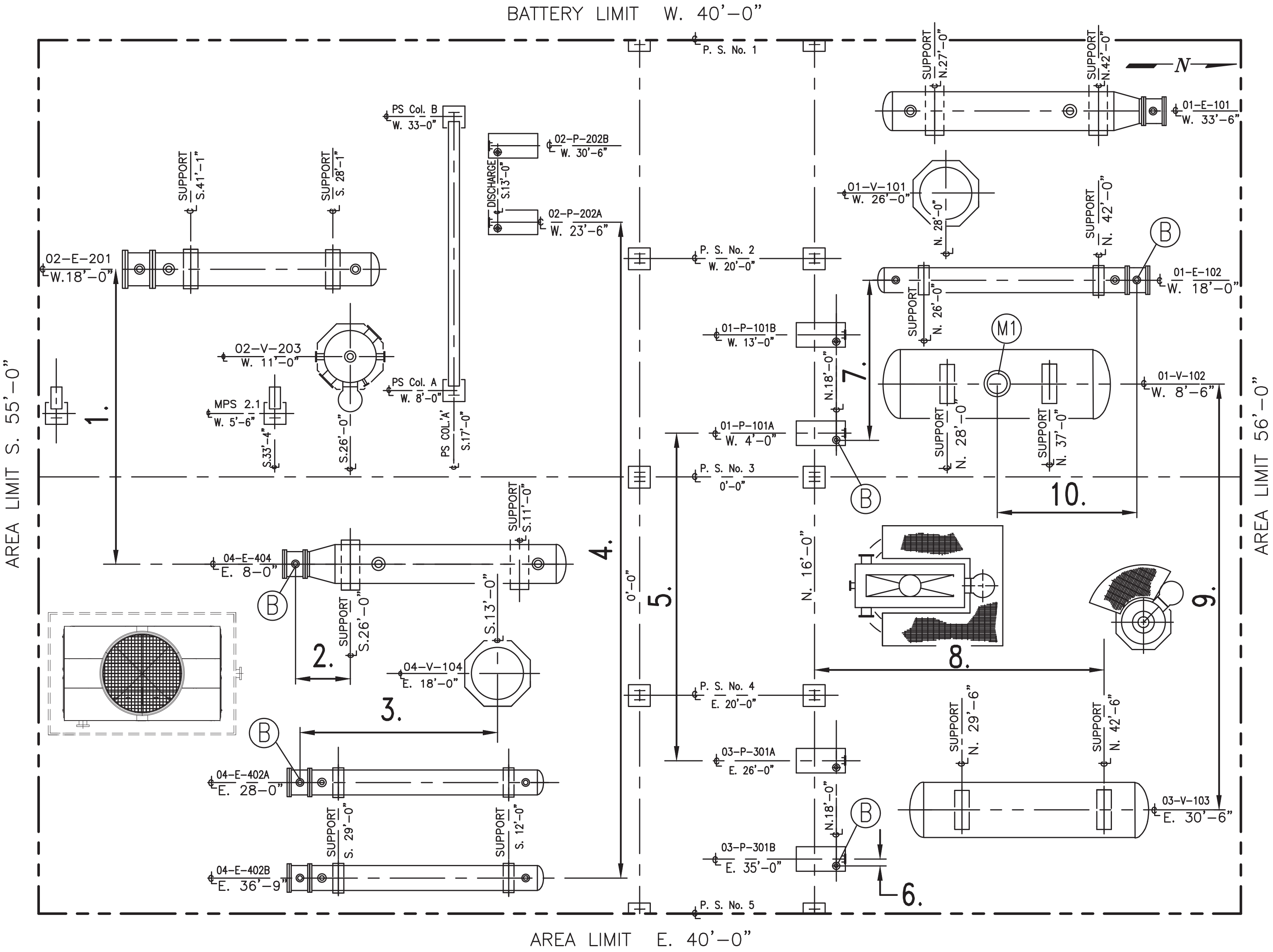
10. What is a *Match Line*?

____

CHAPTER 9 DRAWING EXERCISES

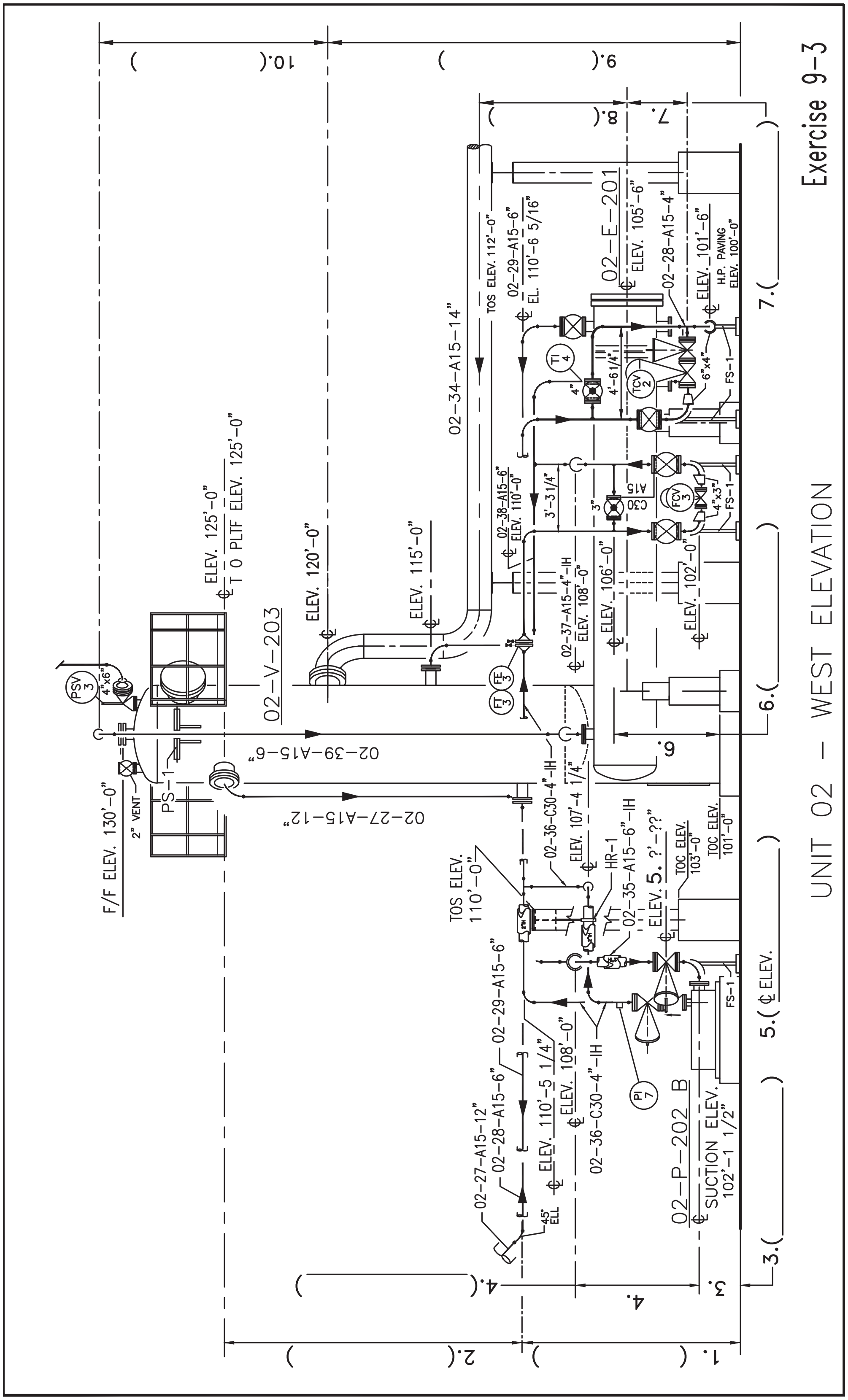
Exercises 9.1 and 9.2. Solve the unknown horizontal dimensions. Provide all answers in feet and inch values.





BATTERY LIMIT W. 40'-0"
AREA LIMIT E. 40'-0"
AREA LIMIT S. 55'-0"
AREA LIMIT 56'-0"
N
P. S. No. 1
P. S. No. 2 W. 20'-0"
P. S. No. 3 0'-0"
P. S. No. 4 E. 20'-0"
P. S. No. 5
02-E-201 W.18'-0"
SUPPORT S.41'-1"
SUPPORT S. 28'-1"
PS Col. B W. 33'-0"
PS Col. A W. 8'-0"
PS COL'A' S.17'-0"
02-P-202B W. 30'-6"
02-P-202A W. 23'-6"
DISCHARGE S.13'-0"
02-V-203 W. 11'-0"
S.26'-0"
MPS 2.1 W. 5'-6"
S.33'-4"
01-E-101 W. 33'-6"
SUPPORT N.27'-0"
SUPPORT N.42'-0"
01-V-101 W. 26'-0"
N. 28'-0"
01-E-102 W. 18'-0"
SUPPORT N. 26'-0"
SUPPORT N. 42'-0"
01-P-101B W. 13'-0"
01-P-101A W. 4'-0"
N.18'-0"
01-V-102 W. 8'-6"
M1
SUPPORT N. 28'-0"
SUPPORT N. 37'-0"
04-E-404 E. 8'-0"
SUPPORT S.11'-0"
SUPPORT S.26'-0"
S.13'-0"
04-V-104 E. 18'-0"
04-E-402A E. 28'-0"
04-E-402B E. 36'-9"
SUPPORT S. 29'-0"
SUPPORT S. 12'-0"
0'-0"
N. 16'-0"
03-P-301A E. 26'-0"
03-P-301B E. 35'-0"
03-V-103 E. 30'-6"
SUPPORT N. 29'-6"
SUPPORT N. 42'-6"
B
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Exercise 9.3. Solve the unknown vertical dimensions. Provide all answers in feet and inch values.



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CHAPTER

10

Piping Arrangement Drawings, Sections, and Elevations

ARRANGEMENT DRAWINGS

The Piping Arrangement drawing is the most significant drawing developed by a piping designer. This plan-view drawing, also known as the Piping Layout drawing, is a major source of information used in the fabrication and erection of the piping facility. And when using the traditional, manual method of design, information on the arrangement drawing aids in the development of the piping model and isometric drawings.

The Piping Arrangement drawing evolves from the Foundation Location and Equipment Location drawings. It shows all mechanical equipment, including vessels in the unit and the pipes connecting them, including manholes, ladders, platforms, cages, and davits. It identifies all structural steel supports such as the main and miscellaneous pipe racks, equipment structures, columns, braces, and any fireproofing they may have. Once locations for foundations and mechanical equipment have been established, piping configurations are added to the drawing with the aid of symbols that represent fittings, flanges, and valves.

Written information placed on the arrangement drawing includes mechanical equipment coordinates, identification numbers, elevation callouts, line numbers, flow arrows, and dimensions establishing pipe locations. Instrumentation symbols are included to indicate type, position, and orientation for accessibility by plant personnel. Ladders and platforms are also shown on equipment and structures that have them. A nozzle schedule is included that contains detailed information about all piping and instrument connections for every piece of mechanical equipment. Information such as nozzle number, size and pound rating, orientation, elevation, and projection is also included. With so much required information on a drawing, it is easy to understand why the Piping Arrangement drawing must be neat, accurate, and legible. The development if 3D modeling software programs has had a significant effect on the process and procedure relating to the development of the Piping Arrangement drawing, as will be discussed in Chapter 14.

RESPONSIBILITIES OF THE PIPING DESIGNER

Only after many years of experience does the drafter become a piping designer. The time invested in learning company specifications, layout procedures, and mechanical equipment requirements makes the designer a valuable employee.

As the arrangement drawing is being developed, a piping designer should, among other things, consider the following:

How can the drawing be simplified? Has each pipe been routed in such a way as to allow for construction, repairs, and equipment maintenance? How will construction, repairs, and routine maintenance be performed in this unit? Has enough room been provided for access between mechanical equipment? Foremost on a designer's mind should be the safety and protection of plant operators and maintenance personnel.

INFORMATION SOURCES FOR PIPING ARRANGEMENT DRAWINGS

A piping designer must assemble the various reference drawings and documents needed to lay out the Piping Arrangement drawing. These may include:

- mechanical flow diagram,
- plot plan,

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00003-0

- foundation or mechanical equipment location plan,
- piping index drawing,
- mechanical equipment (vendor) drawings and foundation drawings,
- piping specifications,
- pipe line list, and
- list of special requirements, if any, for the project.

Construction document include all of the drawings and documentation which relate to the fabrication, erection, commissioning, and operation of the process facility. These will include as-builts, equipment certification and name-plate information, operating manuals, testing procedures, field changes, and possibly photographs of the completed construction.

LAYOUT PROCEDURES

To develop a Piping Arrangement drawing, the designer must be familiar with company and client job specifications and requirements of the current project. Many different layout and design techniques can be used depending on client requirements, company policy, budget limitations, manpower, and available computer software.

Piping Arrangement drawings are quite complex and congested. Therefore a systematic layout procedure is recommended to ensure all necessary items are included. The following are the recommended procedures for layout of Piping Arrangement drawings.

1. Define proposed area outline or drawing matchlines.
2. Fill in drawing number and title block information.
3. Place a north arrow in upper right-hand corner of the drawing.
4. Locate foundations for buildings, pipe rack columns, and mechanical equipment from the coordinates used to develop the foundation location drawing and dimensions provided on the equipment foundation drawing.
5. Draw equipment foundations.
6. Lay out mechanical equipment.

   NOTE:
   - Show only enough detail on mechanical equipment outlines to provide a generalized description.
   - Represent mechanical equipment centerlines, outlines, and foundations with thin dark lines.
   - Show all piping and instrumentation connections (nozzles, couplings, etc.) on mechanical equipment.

7. Prepare a study drawing of each individual piping configuration in the facility. This procedure will allow the designer to explore all requirements necessary for design, operation, and maintenance prior to the final layout.
8. Lay out the piping system as shown on the study drawing. Include instrumentation connections on the piping configuration. Note that every piping facility has different process, mechanical, and instrumentation requirements. It would be extremely difficult to establish set rules and procedures for methods of piping development. Each line on the layout is, in itself, a special design problem and must be dealt with accordingly.
9. Add platforms, ladders and cages, pipe guides, anchors, supports, and hangers as required.
10. Include line numbers, codes, specs, specialty item numbers, and callouts.
11. Place locating dimensions for piping.
12. Label coordinates for mechanical equipment, pipe supports, etc., if required for job.
13. Add instrument balloons and callouts.
14. Include nozzle schedules and notes as required.
15. Complete drawing. Add match line, area limit, and battery limit callouts, reference details, and section or elevation cutting plane symbols.
16. Print/plot the completed drawing and check your work.
17. Correct any mistakes you find before releasing the drawing to your instructor or supervisor.

PIPING ARRANGEMENT DRAWING LAYOUT

This section provides a detailed explanation of the procedural steps to lay out the single-line representation of the Piping Arrangement drawing of Unit-01 shown in Figure 10.1. The double-line alternative of Unit-01 is shown in Figure 10.2. These procedures will simulate those undertaken on any design project by an actual engineering company. To simplify the layout procedures and consolidate the reference drawings and other related information, a copy of the Foundation Location drawing, Equipment Location drawing, main pipe rack, miscellaneous pipe supports, equipment vendor drawings, elevation, and the structural drawings are provided in this chapter.

The following procedures present the recommended method of developing a Piping Arrangement drawing with a 2D CAD software program. When using a drafting software program, such as AutoCAD, the drawings are typically created full size and then placed into the appropriate border at $^3/_8'' = 1'\text{-}0''$ (0.03125) scale. When then initial drawing is developed, full-scale layouts are used to create various "sheets" of the facility at any desired scale.

Procedures 1–3: Drawing setup; Location of Area and Unit boundaries, title block, and North arrow.

References Drawing: Foundation Location plan and company drawing standards

Set the following:

- **UNITS**

  Length: *Type*—**Architectural**

  Precision: 1/16″.

  The "visibility" of various linetypes will require different values when viewing the drawing in Model Space and Paper Space.

- **LTSCALE**

  Set to **32**

  A value of 32 will make the linetypes visible in Model Space and a setting of 1 will make them visible in Paper Space.

- Create the following layers with corresponding colors, line types, and line weights.

Layer name	Color	Line type	Lineweight control
Matchlines	Black/White	Phantom	0.70 mm
Centerlines	Black/White	Center	Default
Foundations	Green	Continuous	Default
Steel	Cyan	Continuous	Default
Equipment	Orange	Continuous	0.30 mm
Pipe	Blue	Continuous	0.53 mm
Platforms, Ladders, and Cages	Cyan	Continuous	Default
Instruments	Red	Continuous	Default
Text	Black/White	Continuous	Default
Dimensions	Black/White	Continuous	Default

- Make "*Matchlines*" the current working layer.
- **OBJECT PROPERTIES**

  Set **COLOR Control, LINETYPE Control**, and **LINEWEIGHT Control** to "Bylayer" in the Object Properties toolbar.

- Draw a rectangle 55′-0″ wide and 40′-0″ deep to represent the Unit-01 boundary matchlines. The lower, left corner of the rectangle will be at the 0′-0″, 0′-0″ origin.

Use Figure 10.3 as a reference to lay out the Unit-01's perimeter from the 0′-0″, 0′-0″ origin.

Procedure 4: Layout the Centerlines for the main pipe rack and equipment foundations.

Reference drawing: Equipment location plan

Set the following:

- Make "*Centerlines*" the current working layer.
- Use **OFFSET** to create lines parallel to the North and West matchlines that will represent the intersecting coordinates of the main pipe rack, miscellaneous pipe supports, and mechanical equipment centerlines.
- Change the intersecting lines to the "*Centerlines*" layer.
- **TRIM** or use the line's **Grips to** shorten the intersecting lines which will represent the various equipment and structural support's foundation centerlines.

Once the foundation centerlines are completed, your drawing should appear as shown in Figure 10.4, without the text.

Procedure 5: Drawing pipe rack and equipment foundations.

Reference drawing: Equipment Location drawing (Figure 10.5) and Foundation drawings for individual pieces of mechanical equipment (Figures 10.6 through 10.10).

- Make "*Foundations*" the current working layer.
- Use the appropriate commands to draw mechanical equipment, pipe rack, and pipe support foundations from coordinates and dimensions shown on the Equipment Foundation drawings. Your drawing should appear as shown in Figure 10.5 when Procedure 5 is completed.

Procedure 6: Equipment layout.

Reference drawings: Mechanical Equipment Vendor drawings

Use dimensions provided on the Mechanical Equipment Vendor drawings to lay out the mechanical equipment as represented in Figure 10.19. The equipment vendor drawings are shown in Figures 10.20 through 10.25.

- Make "*Equipment*" the current working layer.
- Draw all mechanical equipment with the necessary commands. The dimensions needed to draw and orientate the ladder and platforms for 01-V-101 are supplied with vendor drawings. The dimensions needed to draw the cages are shown in Figures 10.44 and 10.45. Change the linetype of those portions of the foundations located below the mechanical equipment from "continuous" lines to "hidden" lines.
- Make "*Steel*" the current working layer.
- Use the necessary commands to draw the main pipe rack, miscellaneous pipe supports, and accumulator access platform. The dimensions needed to draw and orientate the steel columns are provided in the Section and Detail drawings in Figures 10.11 through 10.18. Change the linetype of those portions of the beams, columns, and foundations that are hidden from "continuous" lines to "hidden" lines.
- When Procedure 6 is completed, your drawing should look like Figure 10.19.

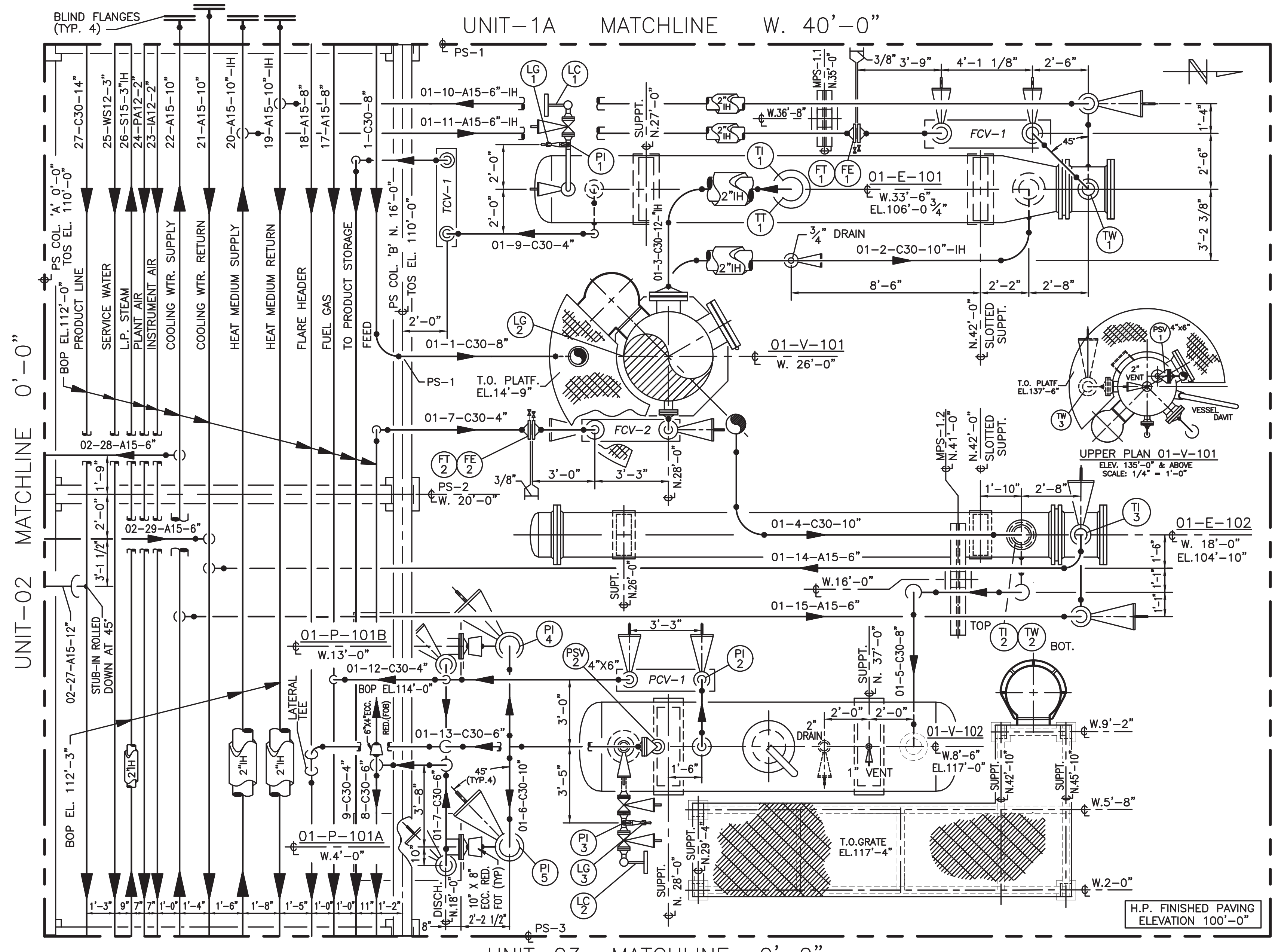


FIGURE 10.1 Unit-01 Piping Arrangement drawing; Single-line.

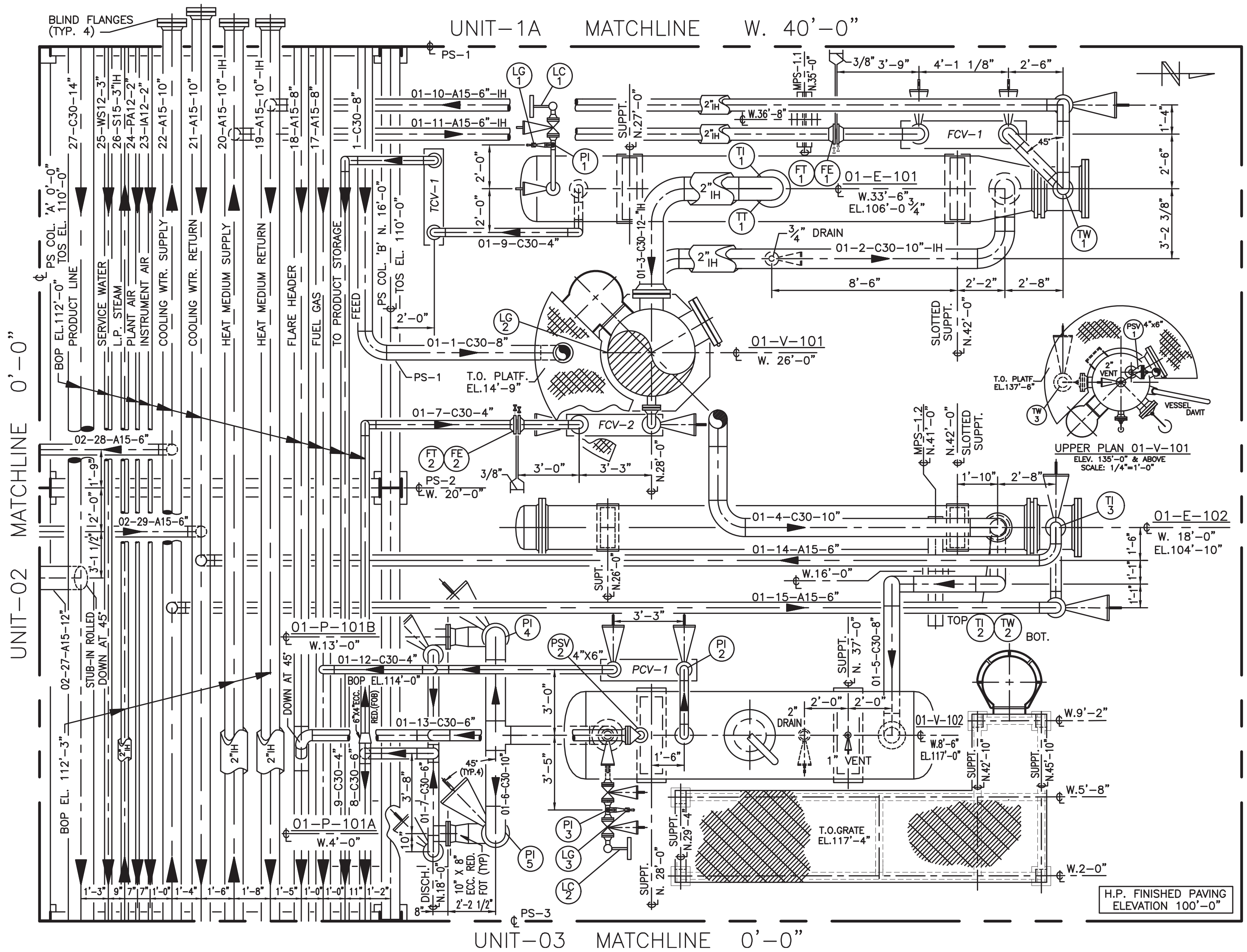


FIGURE 10.2 Unit-01 Piping Arrangement drawing; Double-line.

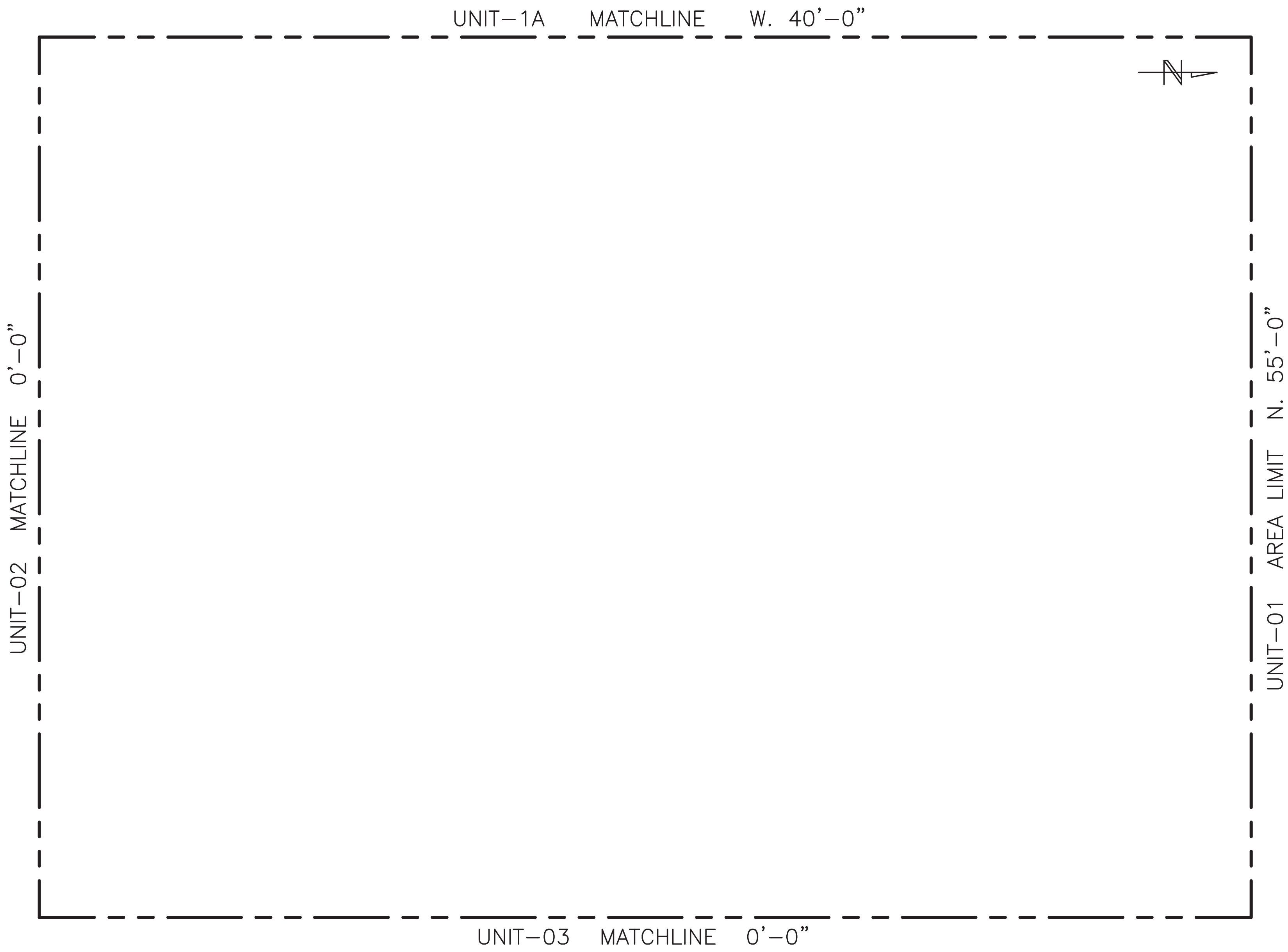


FIGURE 10.3 Unit-01 Matchline boundaries.

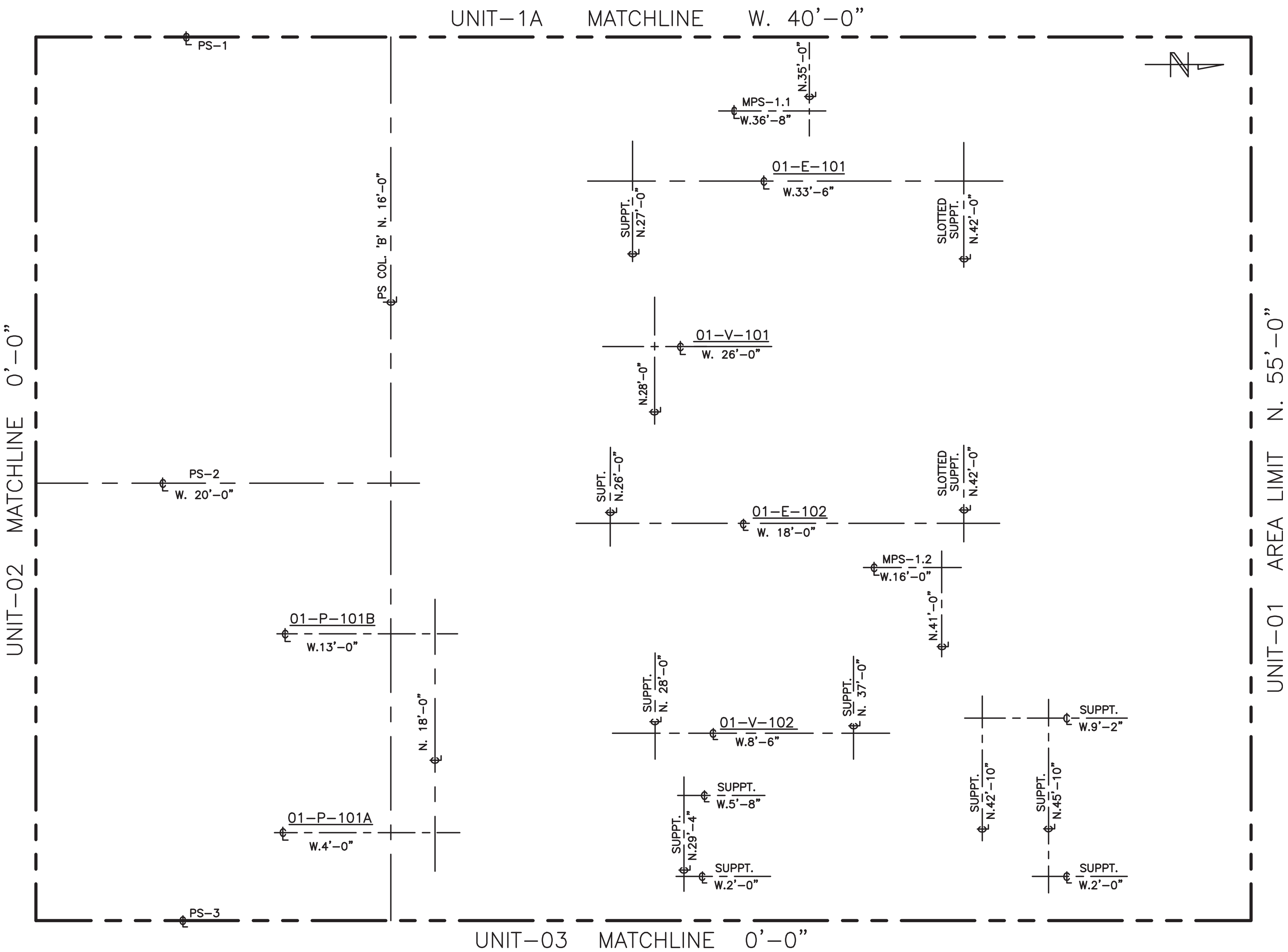


FIGURE 10.4 Foundation centerlines.

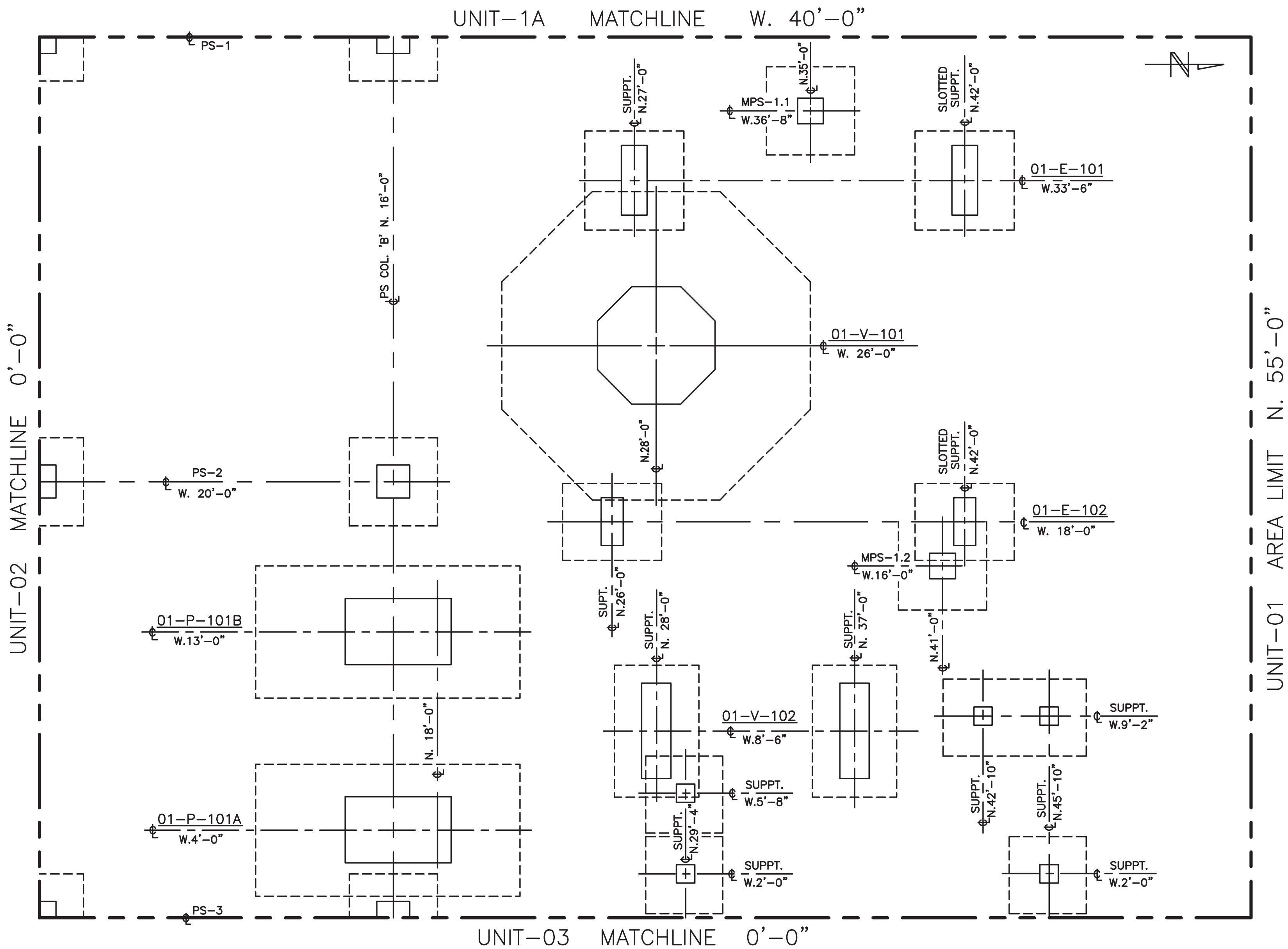


FIGURE 10.5 Foundation location drawing.

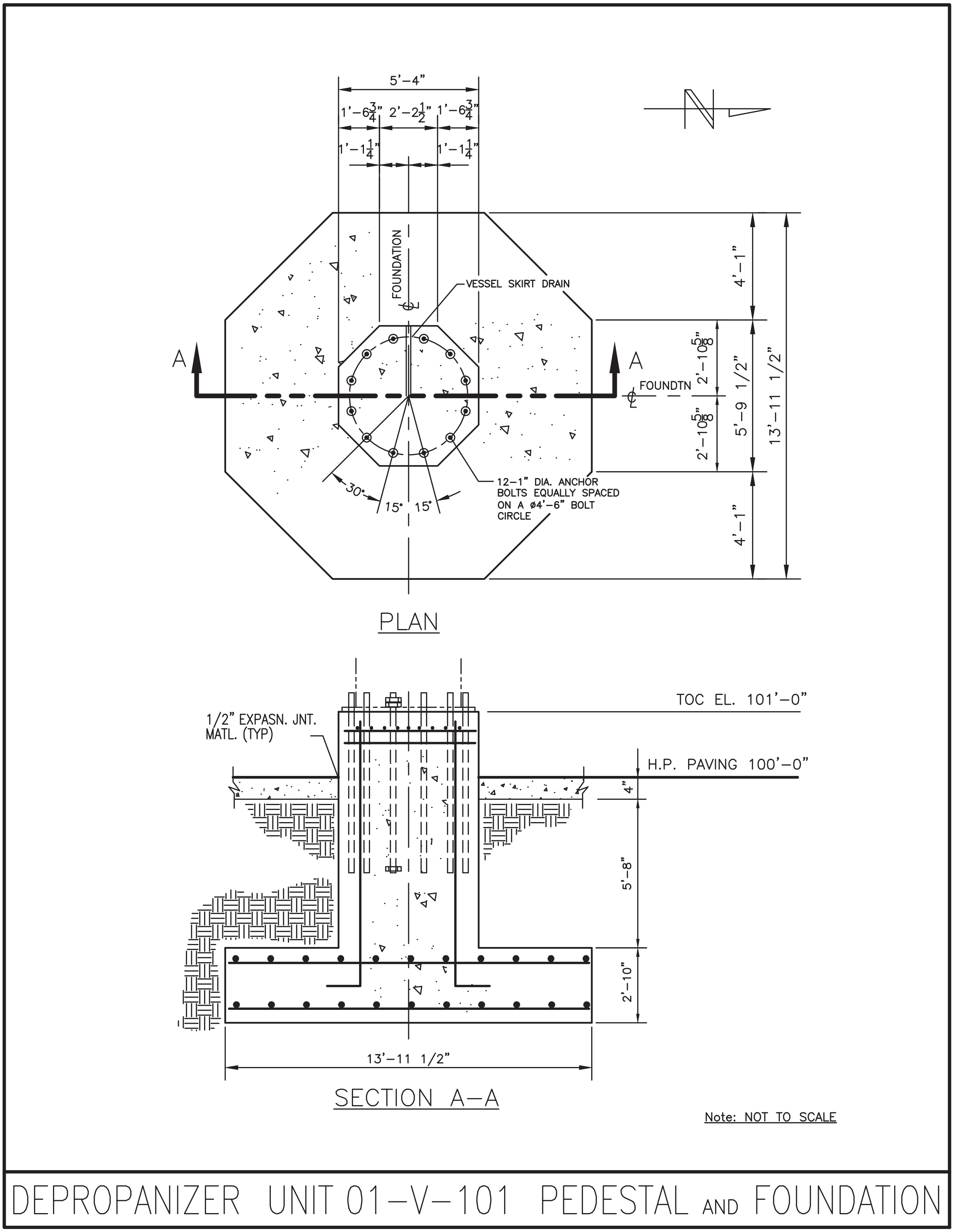


FIGURE 10.6 Depropanizer 01-V-101 Pedestal and Foundation drawing.

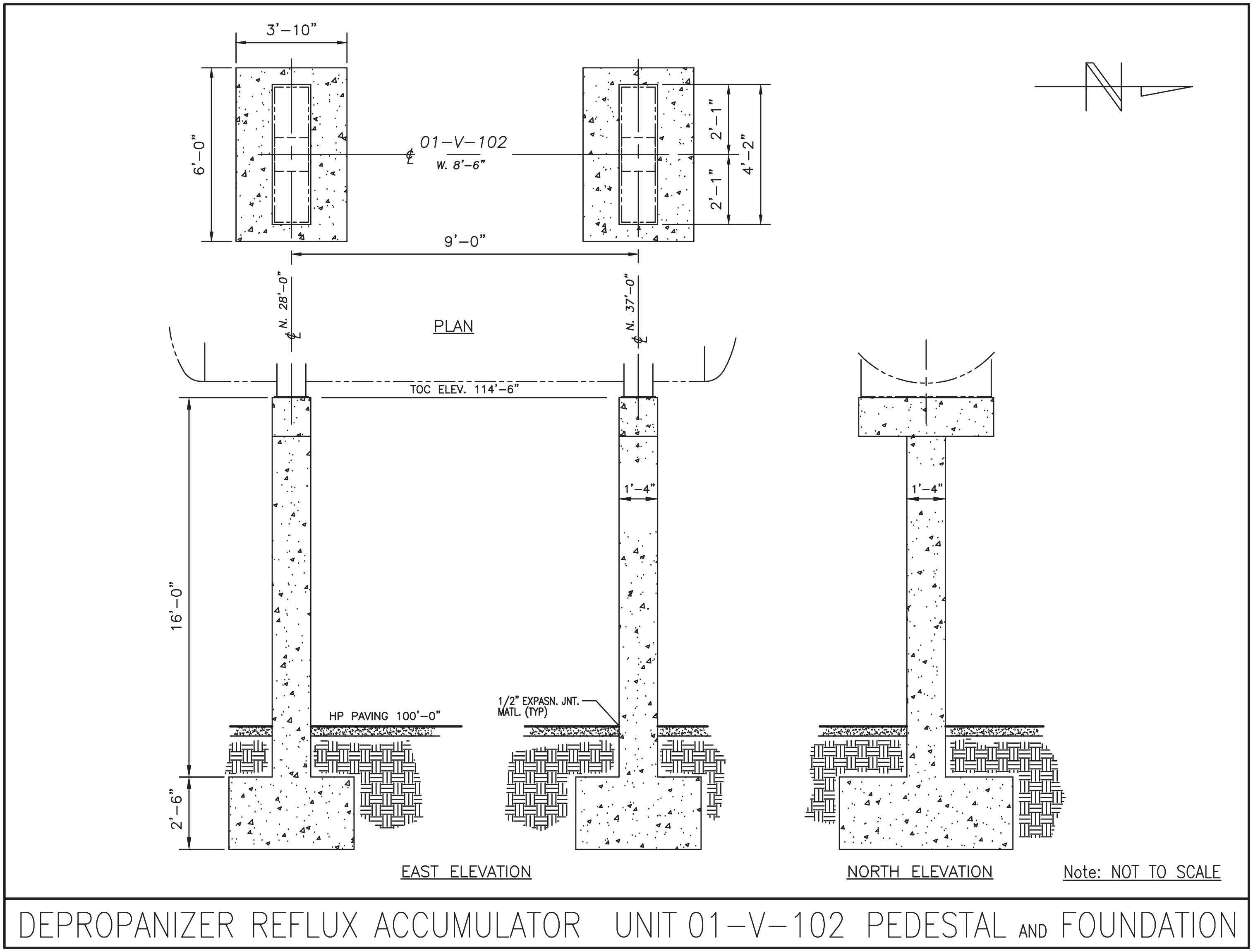


FIGURE 10.7 Depropanizer Accumulator 01-V-102 Pedestal and Foundation drawing.

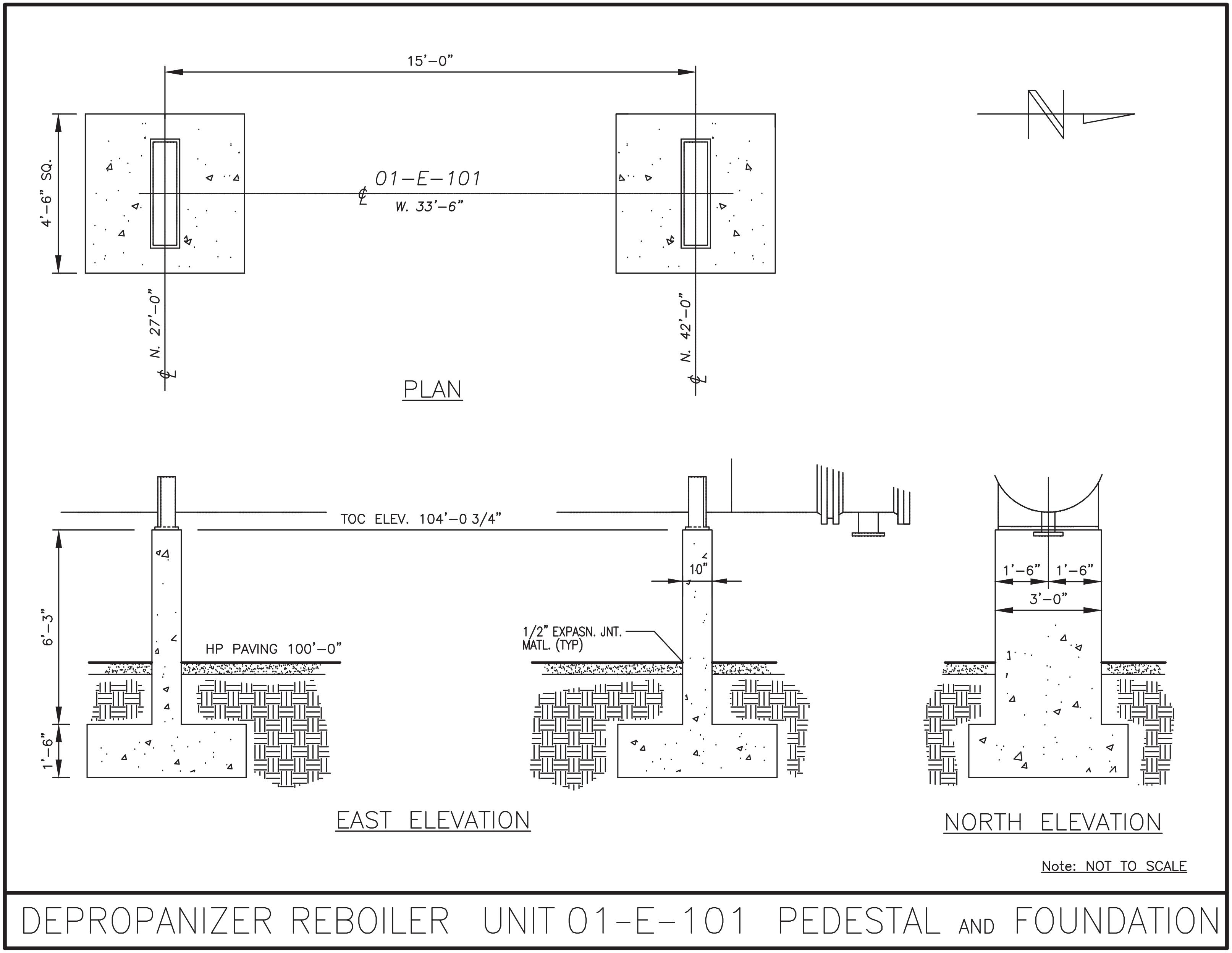


FIGURE 10.8 Depropanizer Reboiler 01-E-101 Pedestal and Foundation drawing.

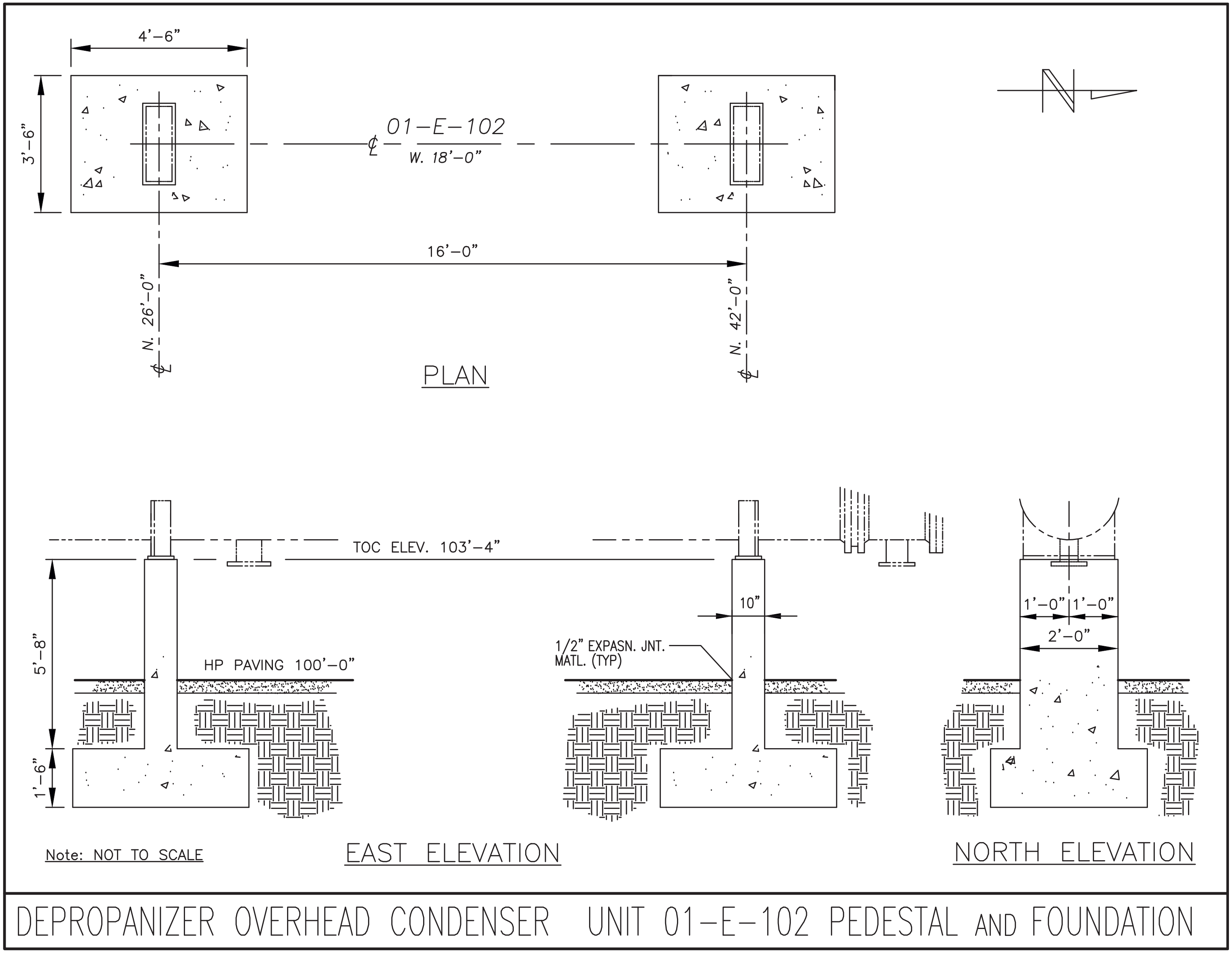


FIGURE 10.9 Depropanizer Condenser 01-E-102 Pedestal and Foundation drawing.

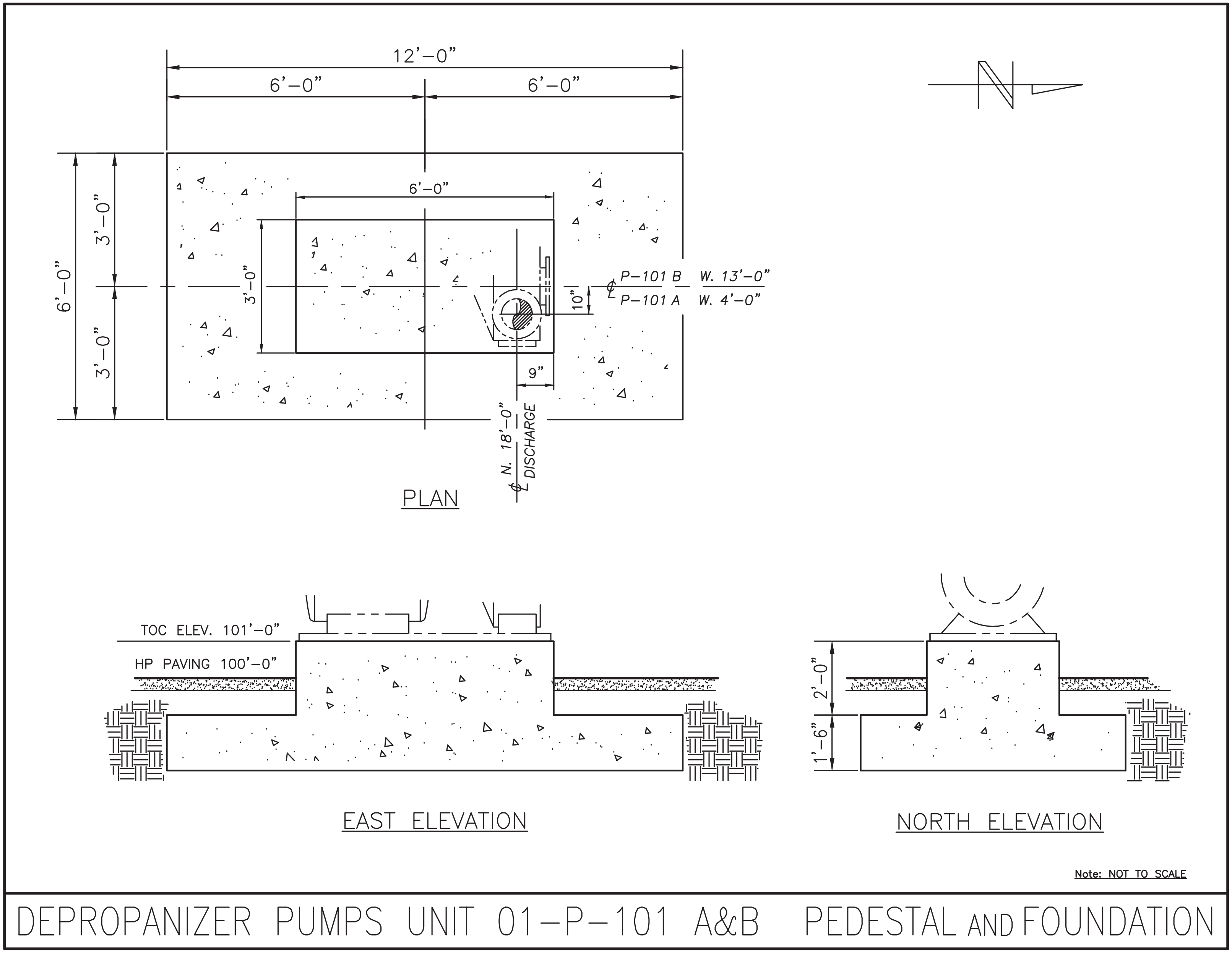


FIGURE 10.10 Depropanizer Pumps 01-P-101A and B Pedestal and Foundation drawing.

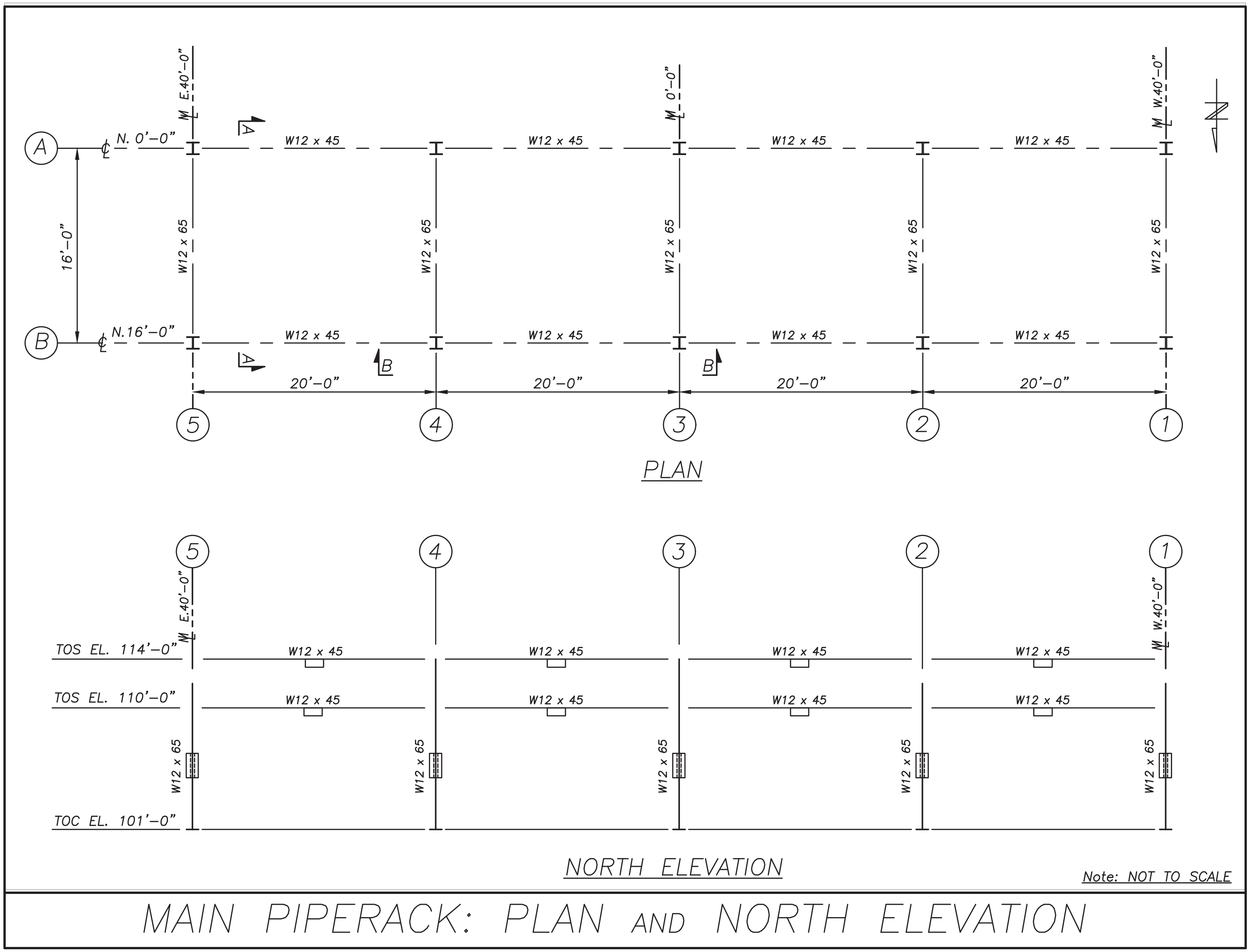


FIGURE 10.11 Main Pipe rack: Plan and North elevation drawing.

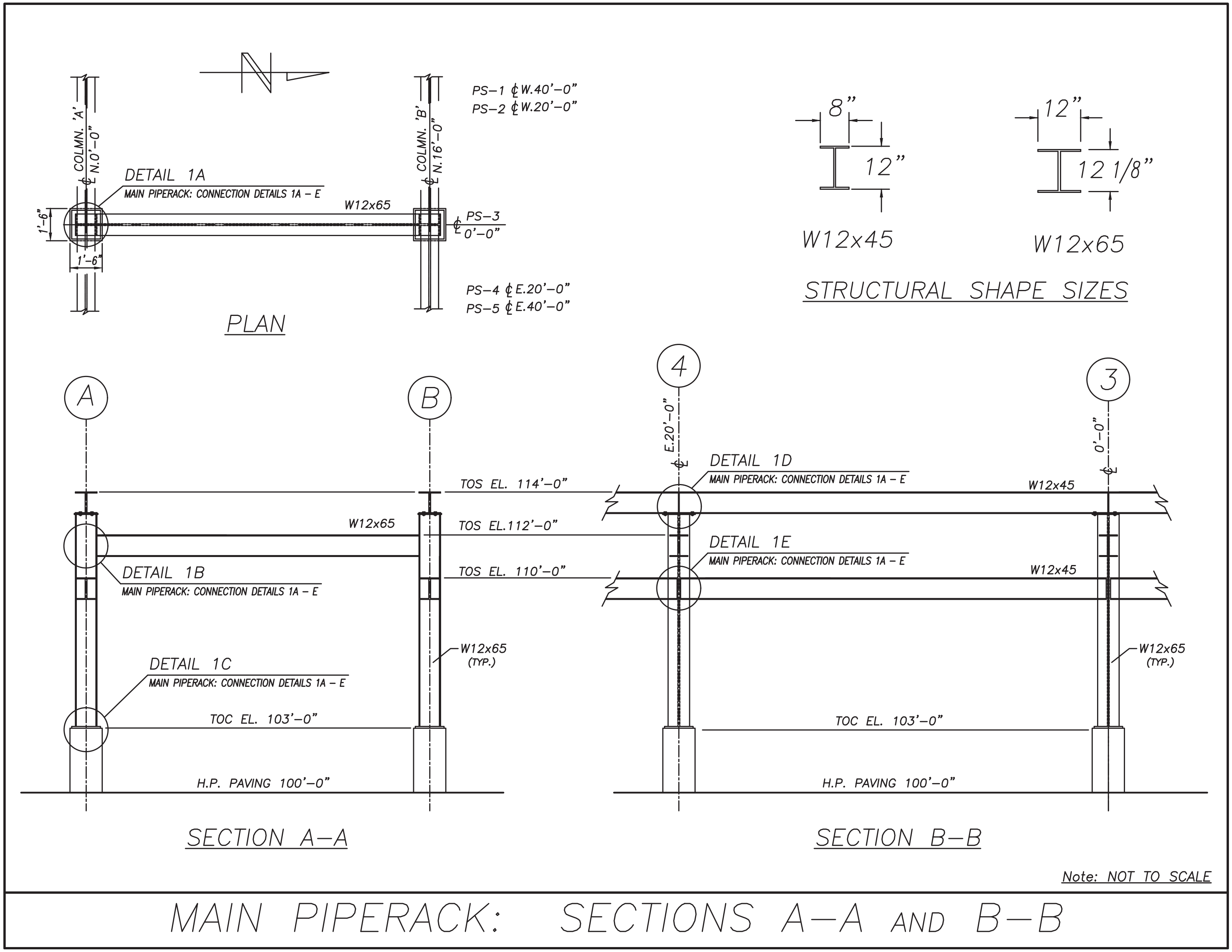


FIGURE 10.12 Main Pipe rack; Sections A-A and B-B.

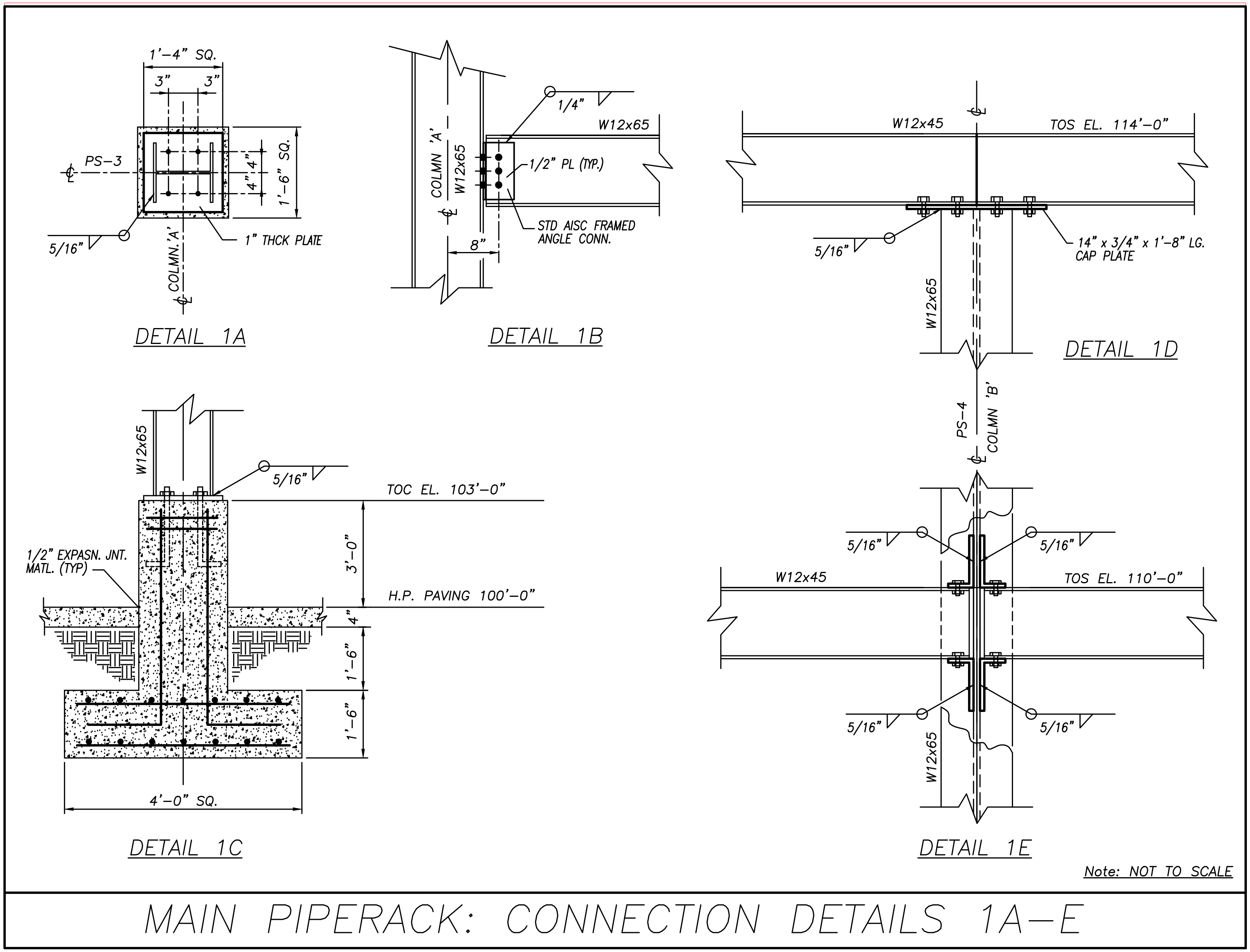


FIGURE 10.13 Main Pipe rack; Connection details 1A-E.

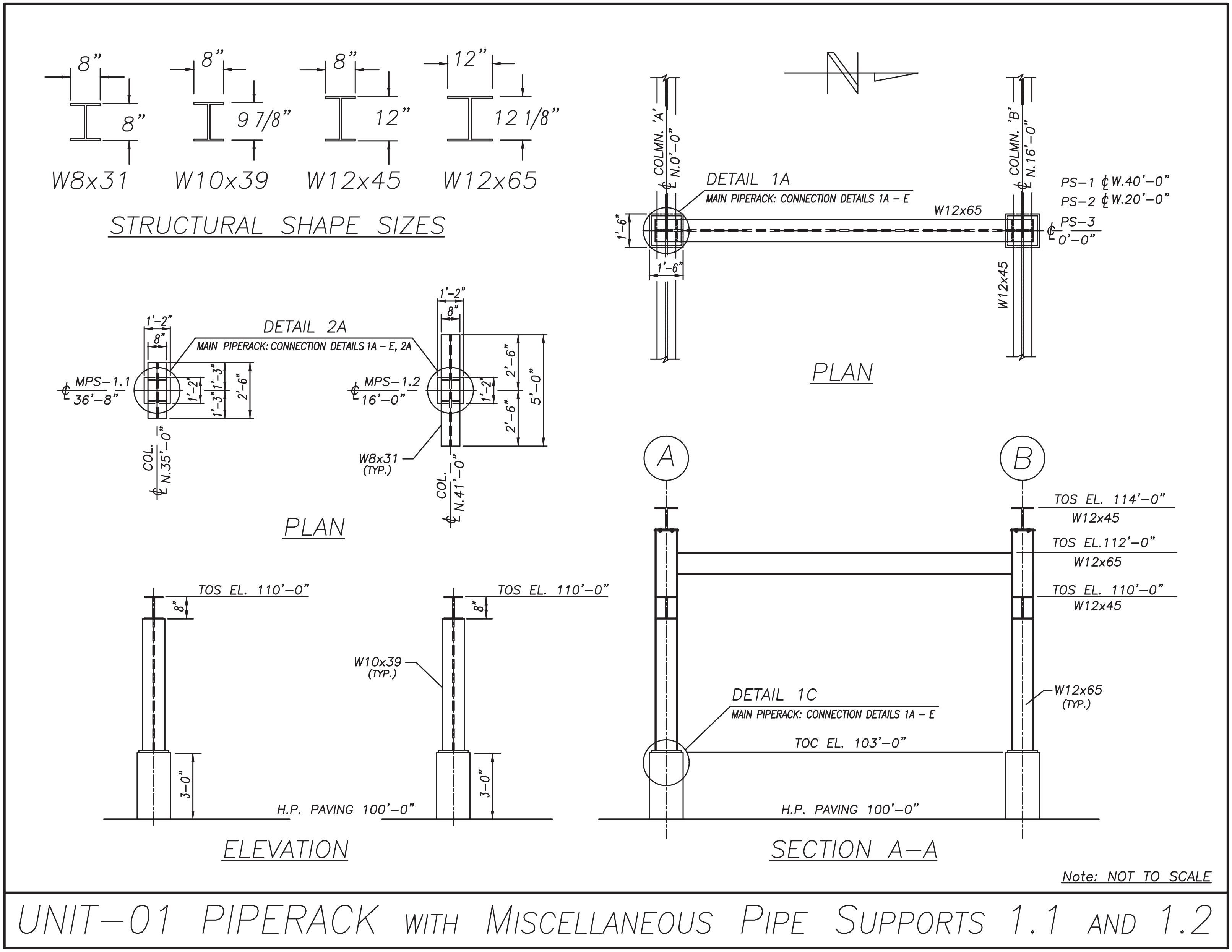


FIGURE 10.14 Main Pipe rack with Miscellaneous Pipe Supports 1.1 and 1.2.

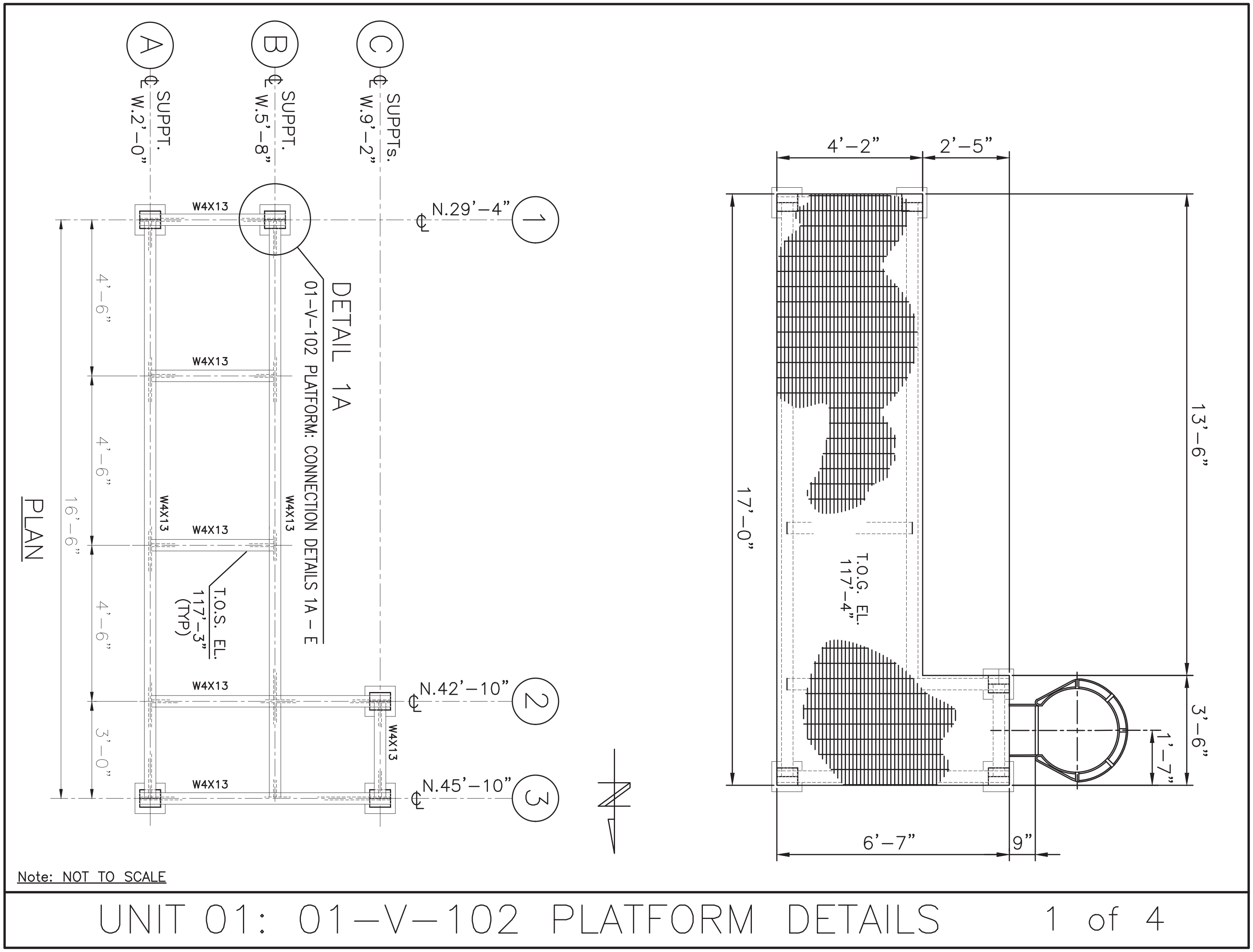


FIGURE 10.15 Unit-01: 01-V-102 Platform Details 1 of 4.

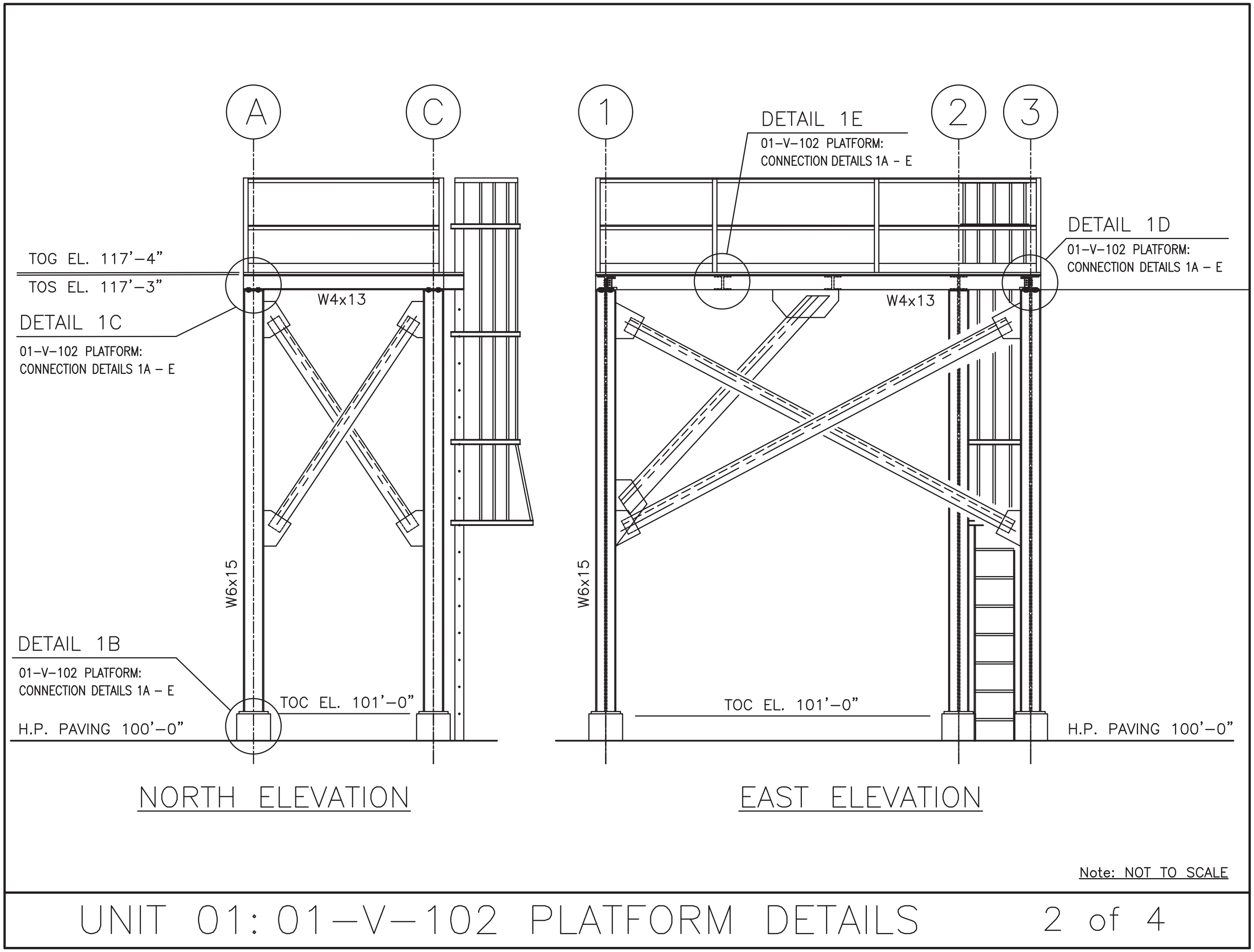


FIGURE 10.16 Unit-01: 01-V-102 Platform Details 2 of 4.

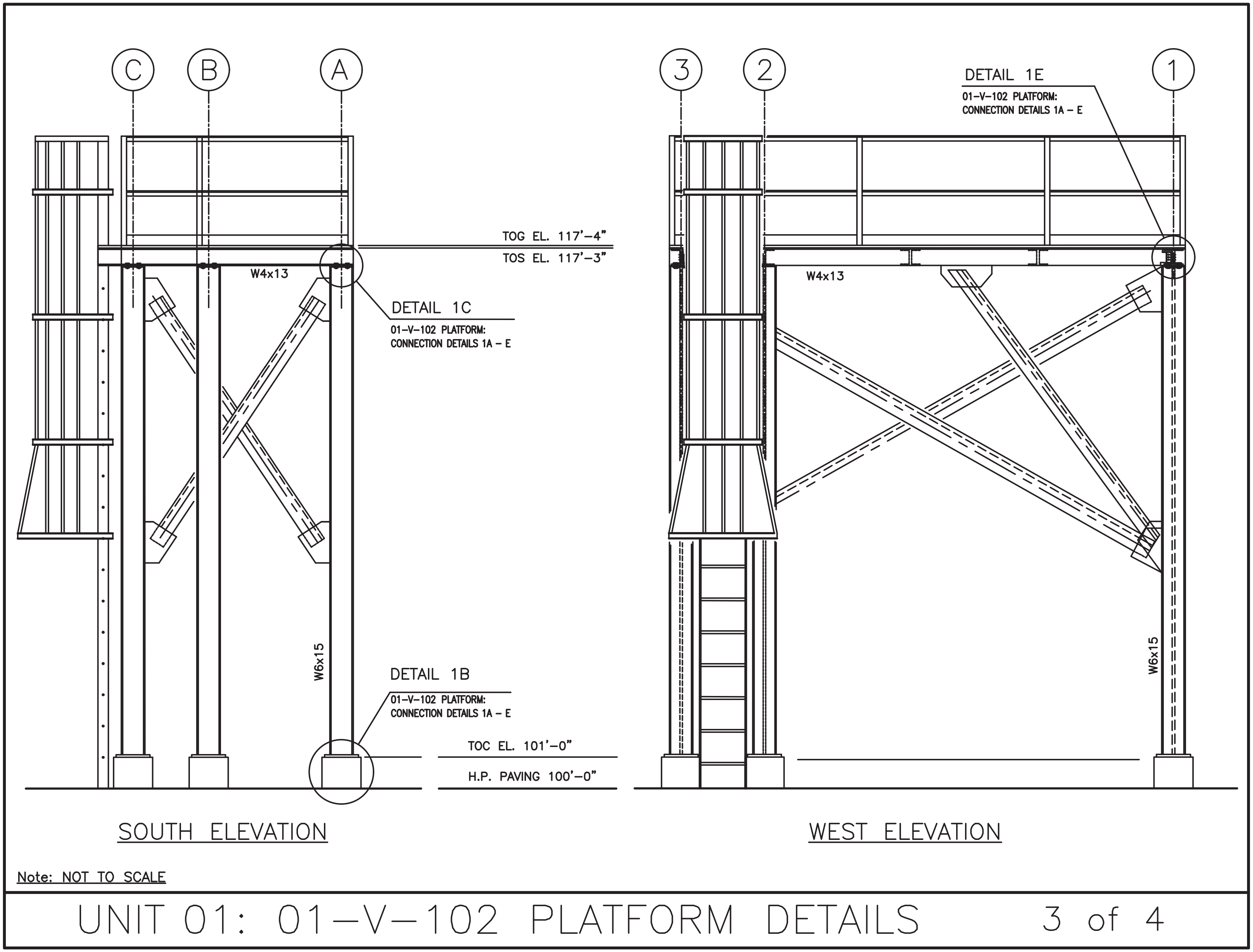


FIGURE 10.17 Unit-01: 01-V-102 Platform Details 3 of 4.

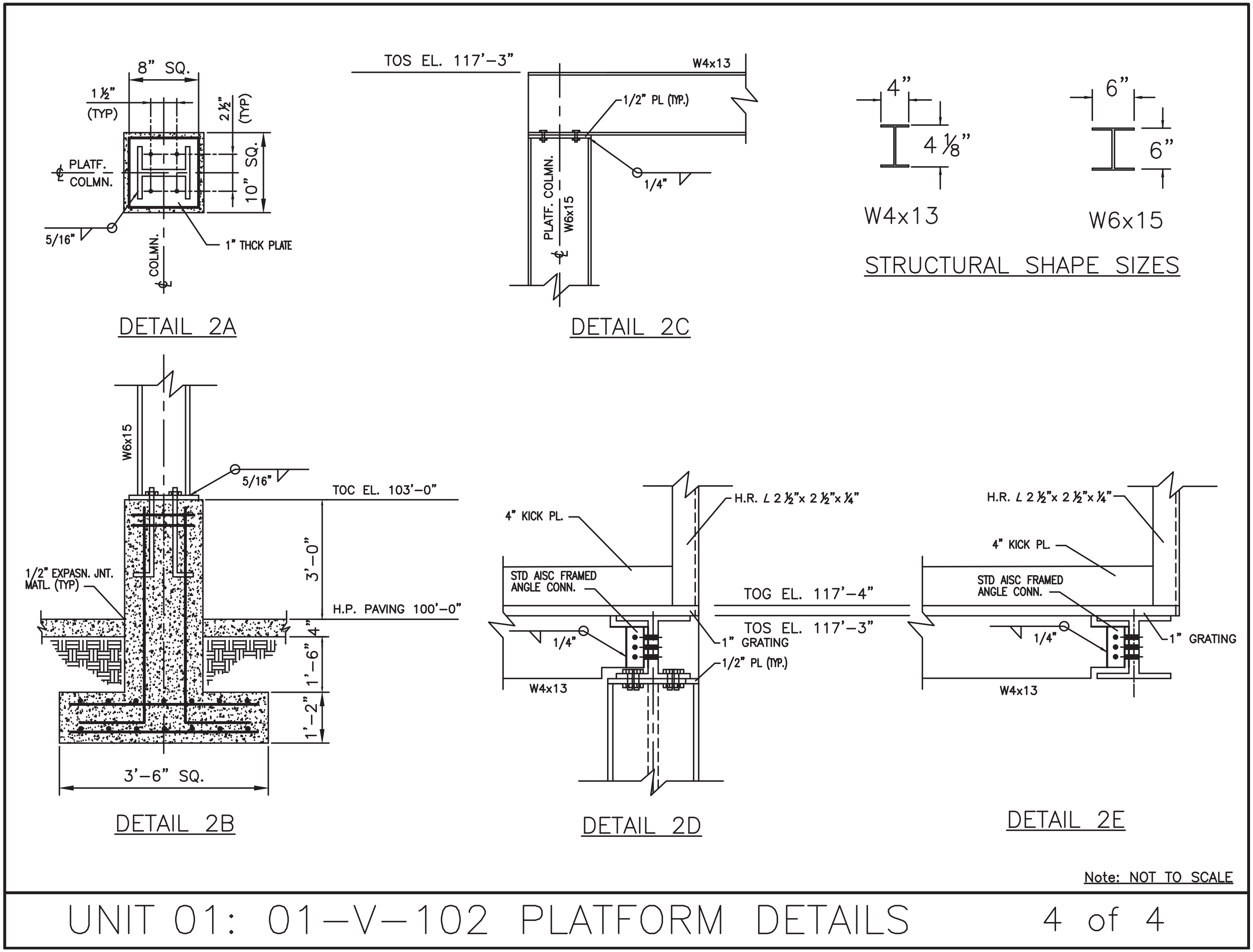


FIGURE 10.18 Unit-01: 01-V-102 Platform Details 4 of 4.

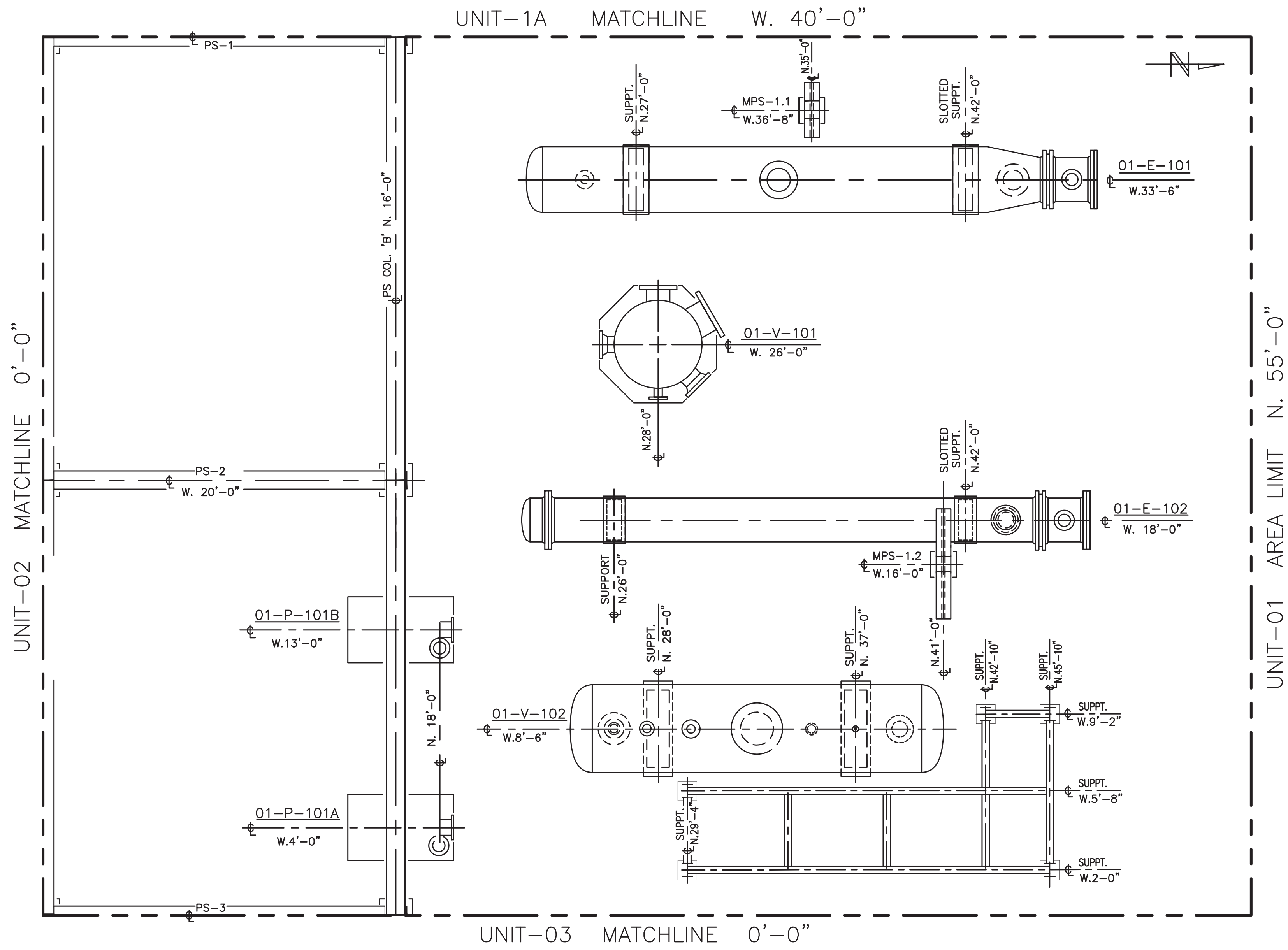
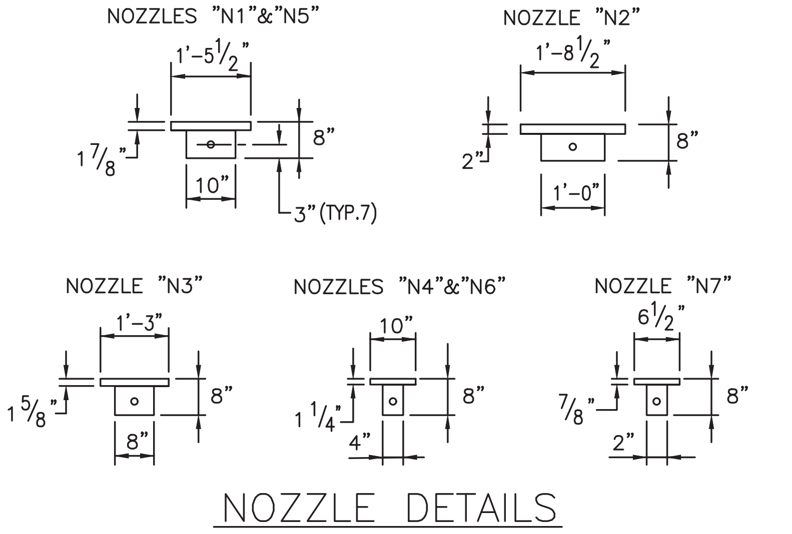
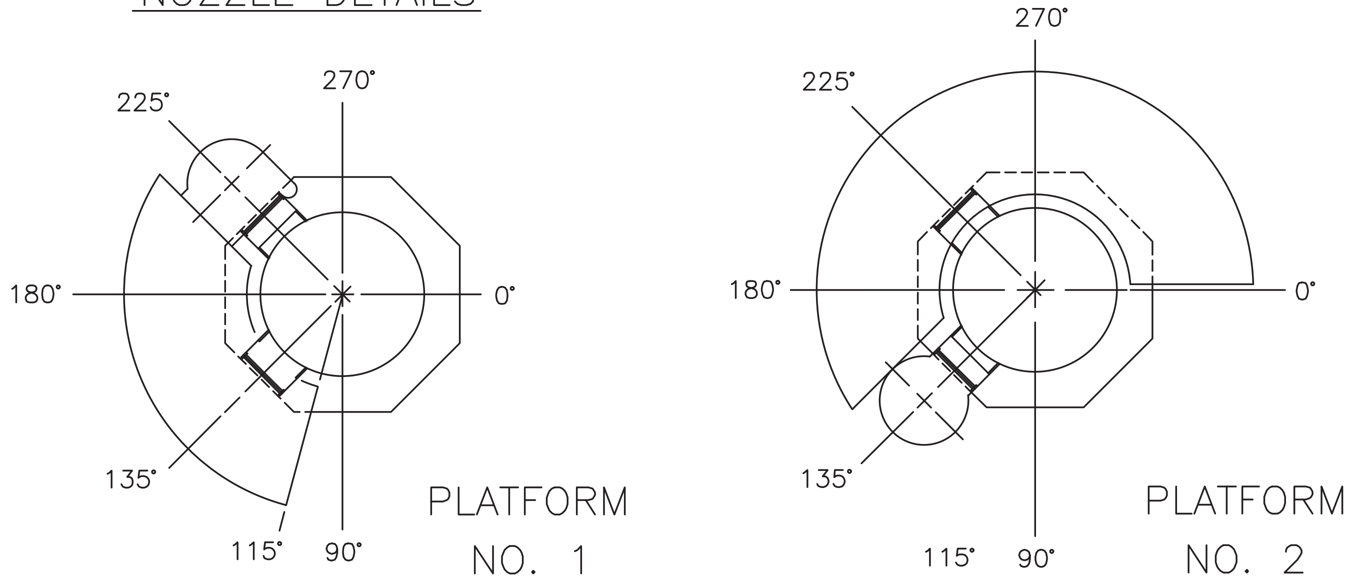


FIGURE 10.19 Equipment location drawing.

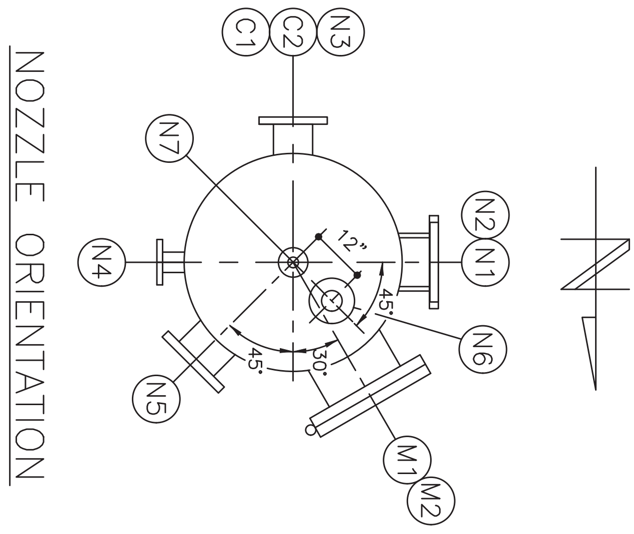


NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJECTION
N1	BOTTOM OUT	1	10"	300#	RF	2'–8"
N2	REBOILER RETURN	1	12"	300#	RF	2'–8"
N3	FEED INLET	1	8"	300#	RF	2'–8"
N4	REFLUX	1	4"	300#	RF	2'–6"
N5	OVHD.VAPOR OUT	1	10"	300#	RF	2'–8"
N6	P.S.V.	1	4"	300#	RF	
N7	VENT	1	2"	300#	RF	
C1&2	L.G.CONN.	2	3/4"	3000#	CPLG	
M1&2	MANWAY	2	18"	300#	RF	2'–10"



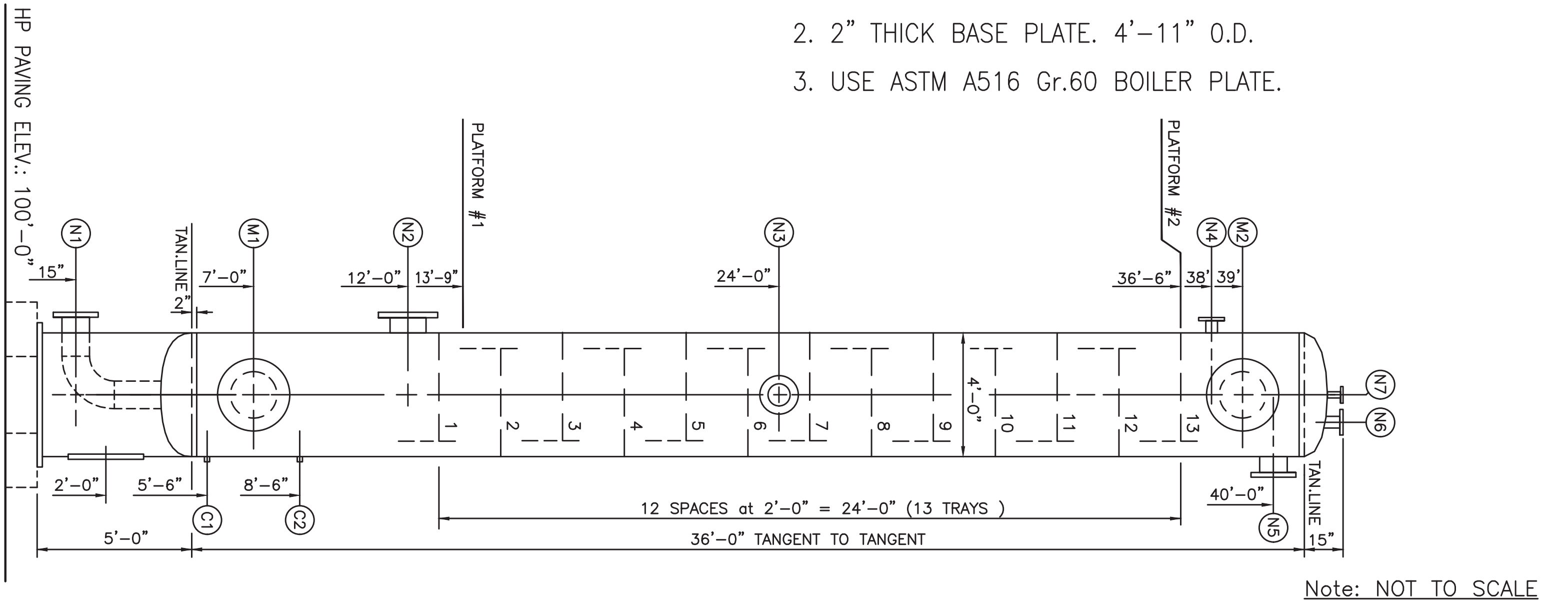
DEPROPANIZER 01–V–101 SHEET 1 of 2

FIGURE 10.20 Depropanizer 01-V-101 Sheet 1 of 2.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJECTION
N1	BOTTOM OUT	1	10"	300#	RF	2'–8"
N2	REBOILER RETURN	1	12"	300#	RF	2'–8"
N3	FEED INLET	1	8"	300#	RF	2'–8"
N4	REFLUX	1	4"	300#	RF	2'–6"
N5	OVHD.VAPOR OUT	1	10"	300#	RF	2'–8"
N6	P.S.V.	1	4"	300#	RF	
N7	VENT	1	2"	300#	RF	
C1&2	L.G.CONN.	2	3/4"	3000#	CPLG	
M1&2	MANWAY	2	18"	300#	RF	2'–10"

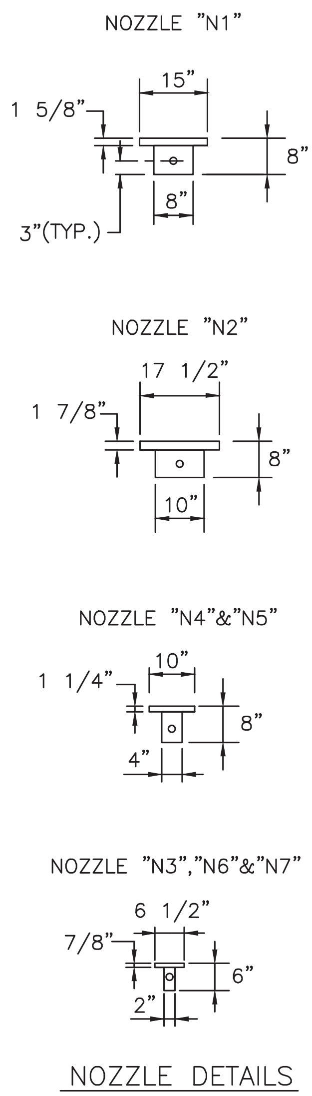
NOTES:
1. THE TAIL DIMENSIONS SHOWN ON THIS EQUIPMENT DRAWING DO NOT INCLUDE THE 1'–0" CONCRETE PEDESTAL. TAIL DIMENSIONS ARE FROM BOTTOM OF BASE PLATE.
2. 2" THICK BASE PLATE. 4'–11" O.D.
3. USE ASTM A516 Gr.60 BOILER PLATE.



Note: NOT TO SCALE

DEPROPANIZER 01–V–101 SHEET 2 of 2

FIGURE 10.21 Depropanizer 01-V-101 Sheet 2 of 2.

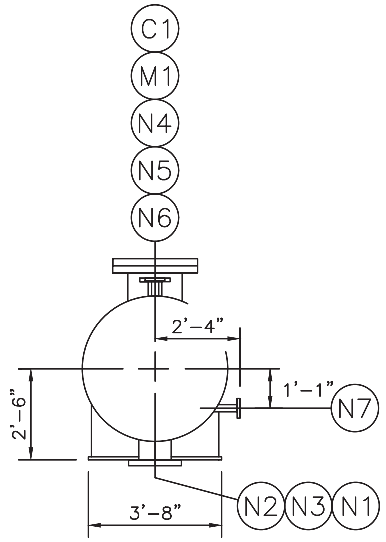


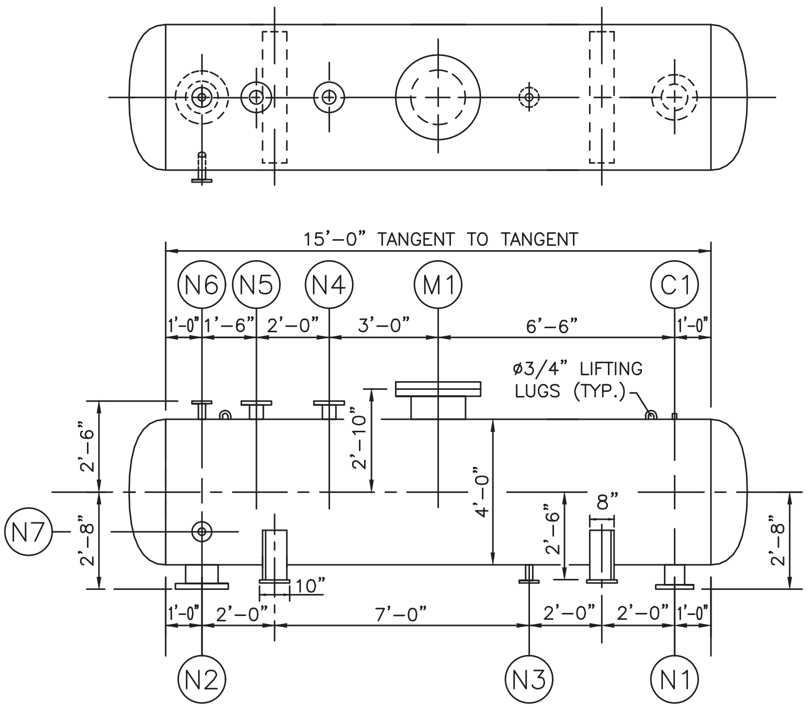
NOTES:

1. HYRDO TEST @328 PSIG MIN.
2. HEADS: 2:1 SE, .375" ASTM A516-60
3. SHELL: .375" ASTM A516-60
4. M.A.W.P.: 300 PSIG @275 °F
5. M.D.M.T.: −15° F @250 PSIG
6. PAINTING:
   INSIDE: UNPAINTED
   OUTSIDE: S. BLAST & ZINC PRIME WHITE TOP COAT
7. SPECIFICATIONS:
   CAPACITY: 1500 GALLONS
   WEIGHT: 3375 lbs.

NOZZLE SCHEDULE

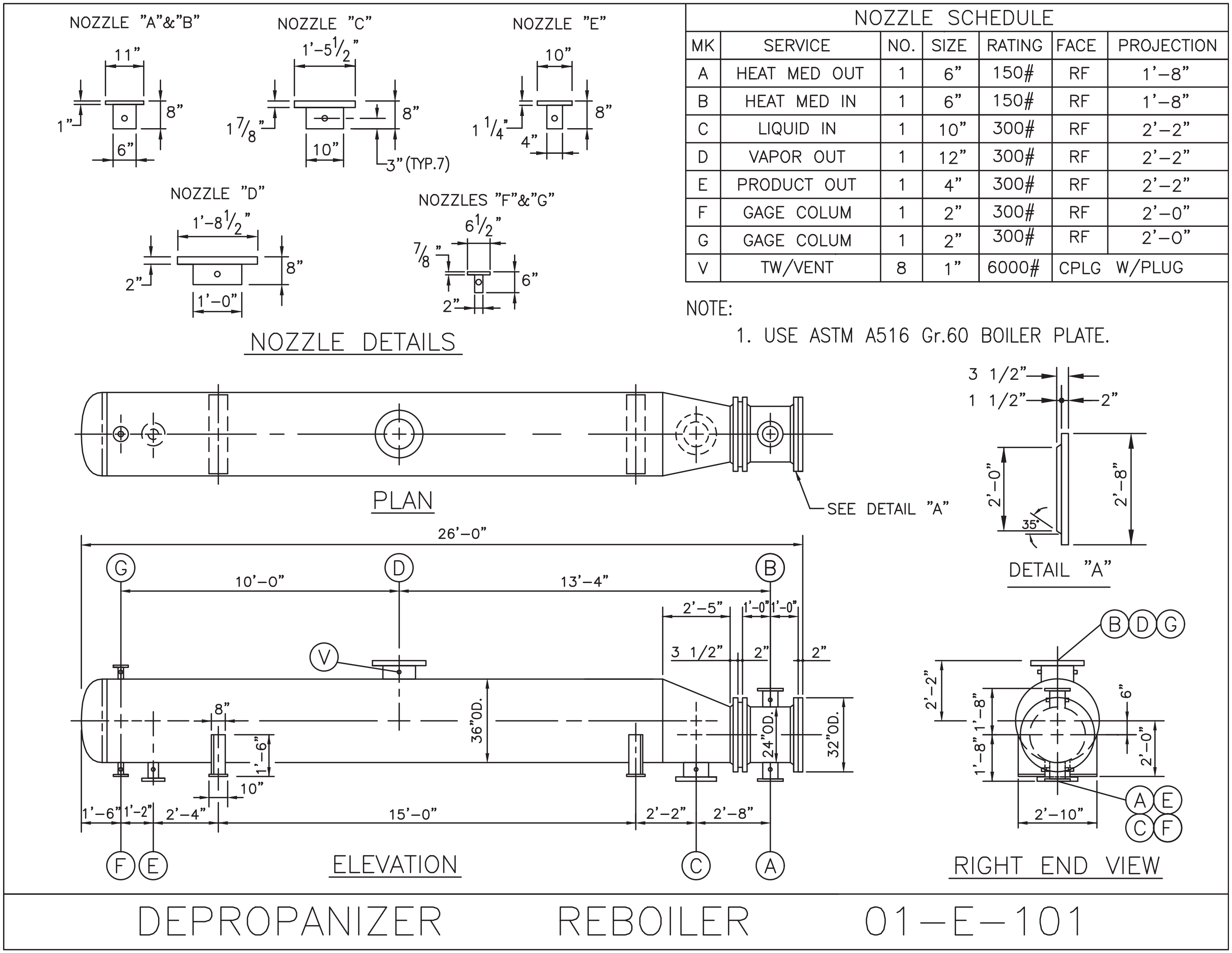
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	LIQUID IN	1	8"	300#	RF	2'−8"
N2	LIQUID OUT	1	10"	300#	RF	2'−8"
N3	DRAIN	1	2"	300#	RF	2'−6"
N4	VAPOR OUT	1	4"	300#	RF	2'−8"
N5	RELIEF	1	4"	300#	RF	2'−8"
N6	LEVEL GAGE	1	2"	300#	RF	2'−6"
N7	LEVEL GAGE	1	2"	300#	RF	2'−4"
C1	VENT	1	1"	6000#	CPLG	W/PLUG
M1	MANWAY	1	18"	300#	RF	2'−10"





DEPROPANIZER REFLUX ACCUMULATOR 01−V−102

FIGURE 10.22 Depropanizer Reflux Accumulator 01-V-102.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJECTION
A	HEAT MED OUT	1	6"	150#	RF	1'–8"
B	HEAT MED IN	1	6"	150#	RF	1'–8"
C	LIQUID IN	1	10"	300#	RF	2'–2"
D	VAPOR OUT	1	12"	300#	RF	2'–2"
E	PRODUCT OUT	1	4"	300#	RF	2'–2"
F	GAGE COLUM	1	2"	300#	RF	2'–0"
G	GAGE COLUM	1	2"	300#	RF	2'–0"
V	TW/VENT	8	1"	6000#	CPLG W/PLUG	

FIGURE 10.23 Depropanizer Reboiler 01-E-101.

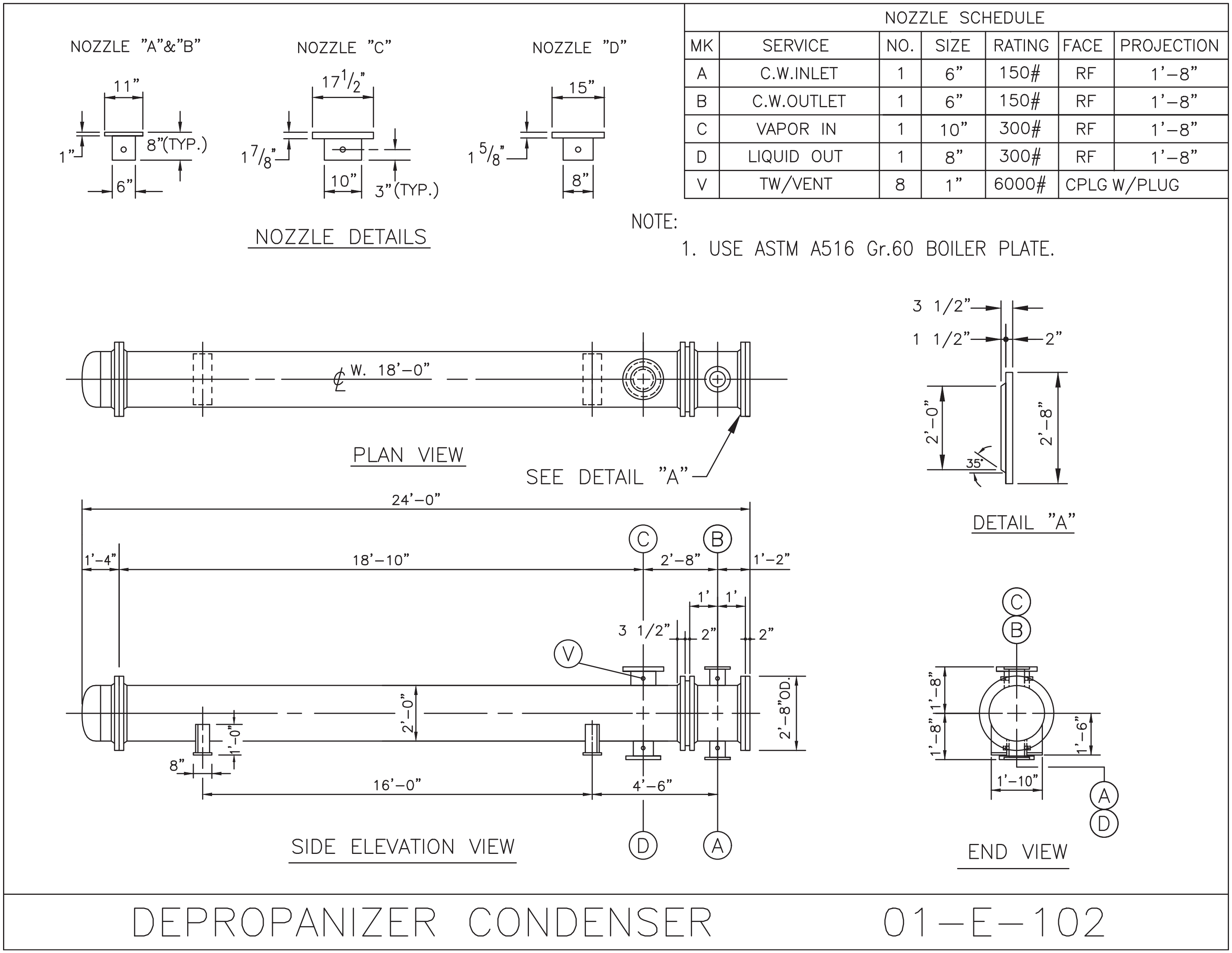
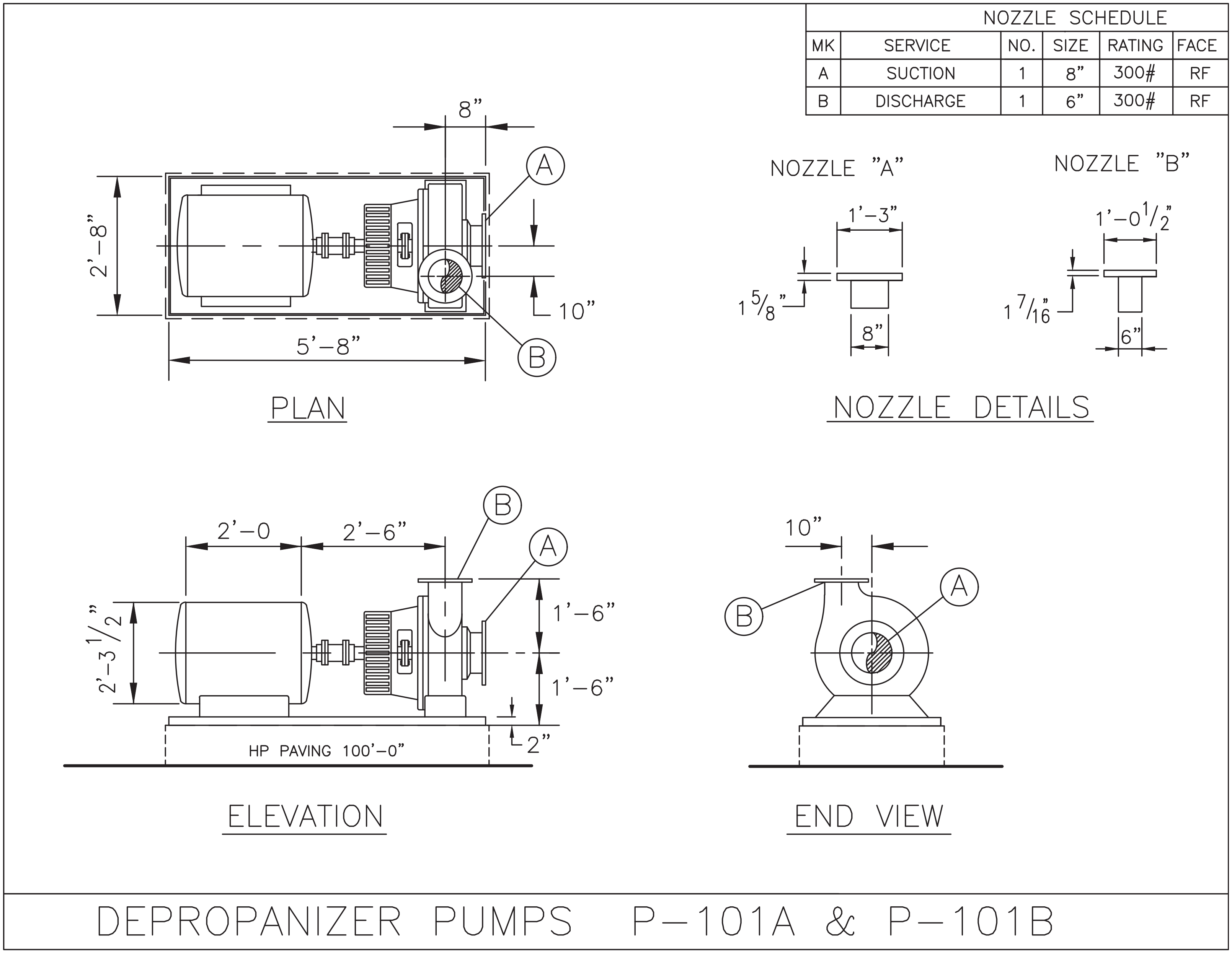


FIGURE 10.24 Depropanizer Condenser 01-E-102.



MK	SERVICE	NO.	SIZE	RATING	FACE
A	SUCTION	1	8"	300#	RF
B	DISCHARGE	1	6"	300#	RF

FIGURE 10.25 Depropanizer pumps 01-P-101A and 01-P-101B.

Procedures 7 and 8: Development of pipe line configurations for Unit-01.

Reference drawings: Mechanical flow diagram, equipment vendor drawings, and piping specifications.

In Procedures 7 and 8 the step-by-step routing of each pipe configuration from beginning to end will be described relative to the commodity flow direction. That is, the written explanation of the development of each pipe configuration found in Unit-01 will dictate the sequential placement and orientation of fittings, flanges, and valves as it follows the direction of the flow of the commodity within the pipe. The written descriptions of the configurations will not include exact placement or size dimensions of the fittings, flanges, or valves required for the layout. Those dimensions, which are needed to place the pipe on the arrangement drawing in its proper location and orientation, can be found on the various dimensioning charts and vendor drawings found in this chapter and in Appendix A. The 3D modeled, isometric view of each line is shown in the upper right corner of the drawing associated with each pipe. This view will be especially beneficial to help visualize the routing and placement of pipe components needed to accurately depict the lines on the arrangement drawing.

- Make "*Pipe*" the current working layer.
- Use the **LINE** command to draw all lines. Pipes 14″ in diameter and larger are drawn double-line with actual OD dimensions having "*Default*" lineweight. The centerlines for double-line pipes are represented as a "*Center*" linetype. Draw all single-line pipes, those 12″ in diameter and smaller, with a 0.53 mm lineweight. The fitting, flange, and valve symbols created in Chapters 3, 4, and 5, respectively, can be inserted into their appropriate locations.

Routing

Configurations for lines 01−1-C30−8″ through 01−16-C30−2″

As shown in Figure 10.26, line 01−1-C30−8″ enters Unit-01 from the west end of the main pipe rack having a centerline elevation of 110′-4 5/16″. After the line travels 14′-0″ into Unit-01, from Match Line W. 40′-0″, an elbow flat-turns the line north toward vessel 01-V-101. A PS-1 pipe support supports the pipe from the steel beam at elevation 110′-0″. 01−1-C30−8″ travels north before it turns up and into nozzle **N3** of 01-V-101 at EL. 125′-0″. A 300# gate valve is located fitting make-up below nozzle **N3**. Its handwheel is oriented toward the west.

Figure 10.27 provides the Plan and Elevation views of the depropanizer, 01-V-101, and the kettle reboiler, 01-E-101. Also shown is their associated piping, lines 01−2-C30−10″ and 01−3-C30−12″.

Line 01−2-C30−10″ starts at nozzle **N1** of 01-V-101. Begin at nozzle **N1** with a flange and an elbow that are welded together. The elbow is welded onto the flange so that it points north. A straight run of pipe travels north and another elbow flat-turns west into nozzle **C** of 01-E-101. After a short run of pipe, an elbow turns up and a flange connects to nozzle **C**. A 2″ drain drops out of the bottom of 01−2-C30−10″and connects to the oily water sewer. It is located 10′-8″ south of the centerline of nozzle **C**, its handwheel points north.

Line 01−3-C30−12″ rises out of the top of 01-E-101 at nozzle **D** with a flange and short vertical length of pipe. An elbow is attached that is oriented south. Another short run of pipe travels south until an elbow flat-turns west into 01-V-101, at nozzle **N2**.

Notice in Figure 10.28 that nozzle **N5** is oriented on vessel 01-V-101 at a 45° angle, pointing toward the northeast. Line 01−4-C30−10″ comes out of nozzle **N5** fitting make-up at EL. 141′-0″, where an elbow turns down alongside the vessel. A long, vertical drop descends to centerline elevation 110′-5 3/8″, where it turns east. A short, easterly run of pipe will align 01−4-C30−10″ with the centerline of 01-E-102, where it flat-turns north, toward nozzle **C**. As the line travels north it rests on a Miscellaneous Pipe Support-2, then it turns down into nozzle **C** of 01-E-102. Lines that drop such a long distance down the side of a vertical vessel, as 01−4-C30−10″ does, typically require pipe supports and/or pipe guides. The support used in this particular situation is a *trunion*, which is welded to the side of a vessel. Figure 10.29 shows a typical trunion pipe support.

Line 01−5-C30−8″ transports condensed vapor from condenser 01-E-102 to the overhead accumulator 01-V-102. It attaches to nozzle **D**, which comes off the bottom of 01-E-102 and travels to nozzle **N1** on 01-V-102. This 300# line drops out of nozzle **D** fitting make-up and turns east for 2′-7″, where turns up. After a vertical run of pipe, an elbow turns the configuration south to rest on Miscellaneous Pipe Support-2 at elevation 110′-0″. The pipe continues south to align with nozzle **N1** of 01-V-102. Once aligned with nozzle **N1**, an elbow turns up to an elevation that is fitting make-up when measuring against the flow, or backwards, from nozzle N1 of 01-V-102. The pipe runs east before turning up into **N1** (see Figure 10.30).

Lines 01−6-C30−10″ and 01−7-C30−6″/4″ are suction and discharge lines for pumps 01-P-101A and 01-P-101B, respectively. Line 01−6-C30−10″, the suction line, is a 10″ configuration that drops out of the bottom of 01-V-102 from nozzle **N2**. After a vertical drop to centerline elevation 108′-9″ an elbow turns south. After a short southerly run, the line tees to align with the centerline of pumps 01-P-101A, to the east, and 01-P-101B, to the west. Once the east and west branches

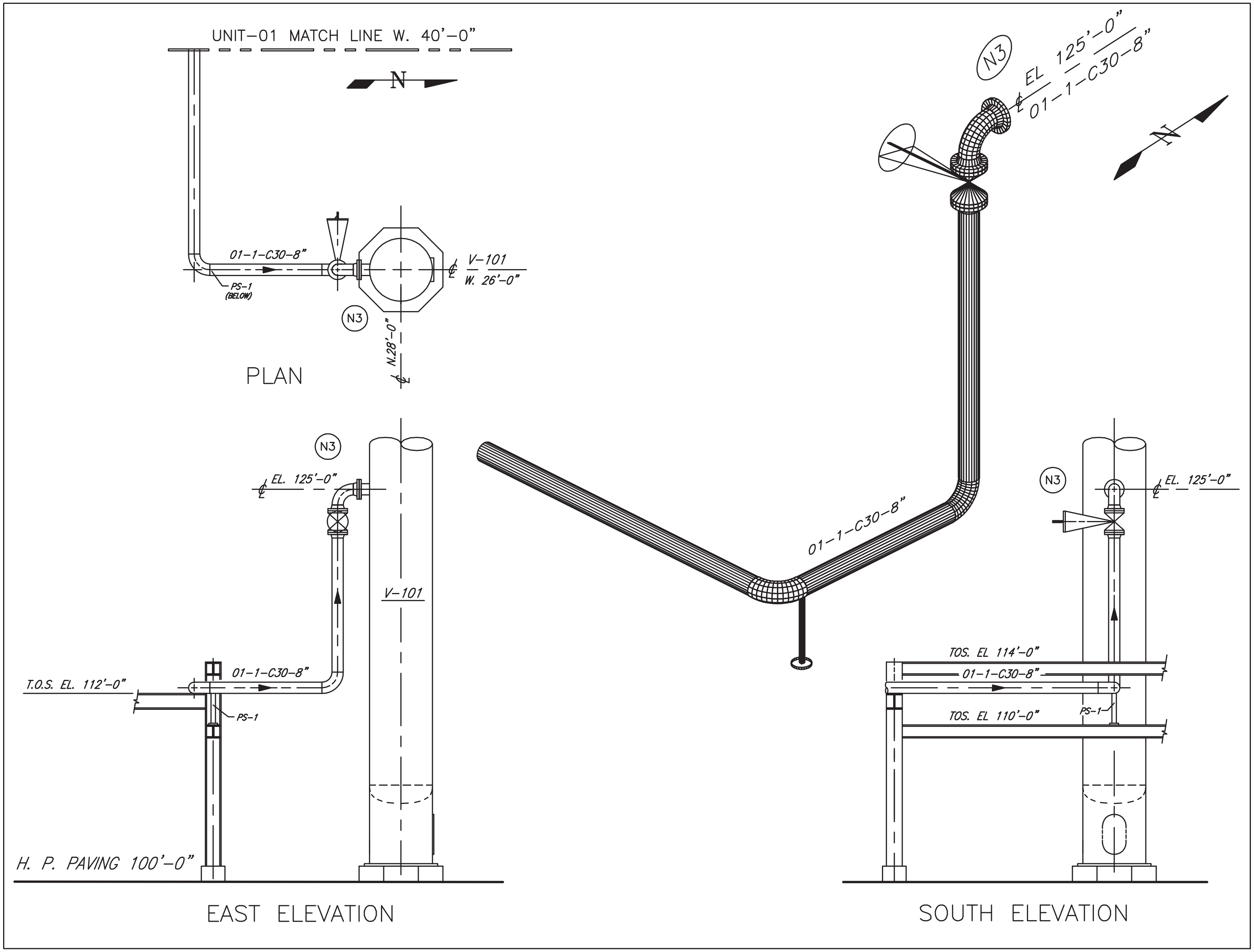


FIGURE 10.26 Line 01–1-C30–8″.

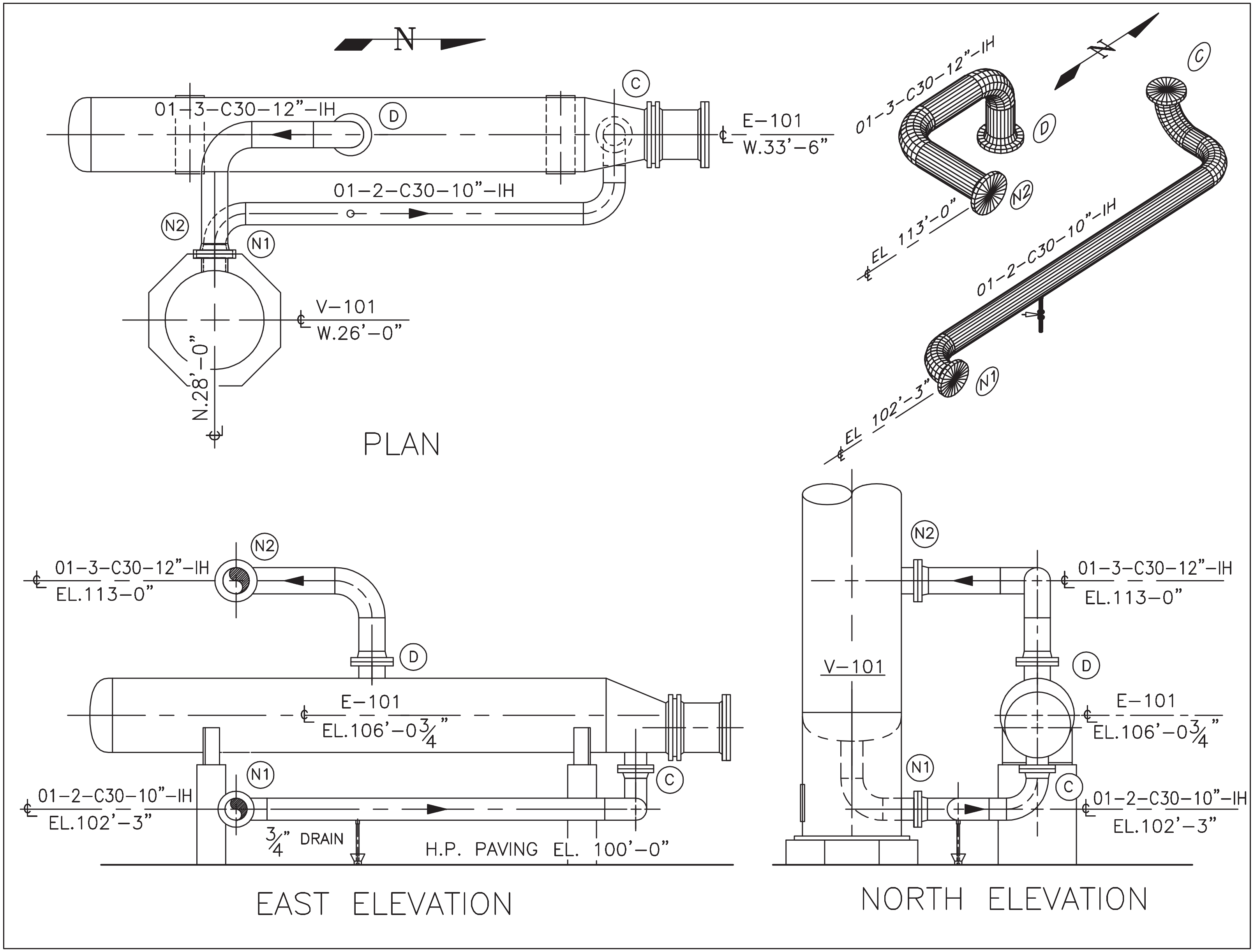


FIGURE 10.27 Lines 01–2-C30–10″-IH and 01–3-C30–12″-IH.

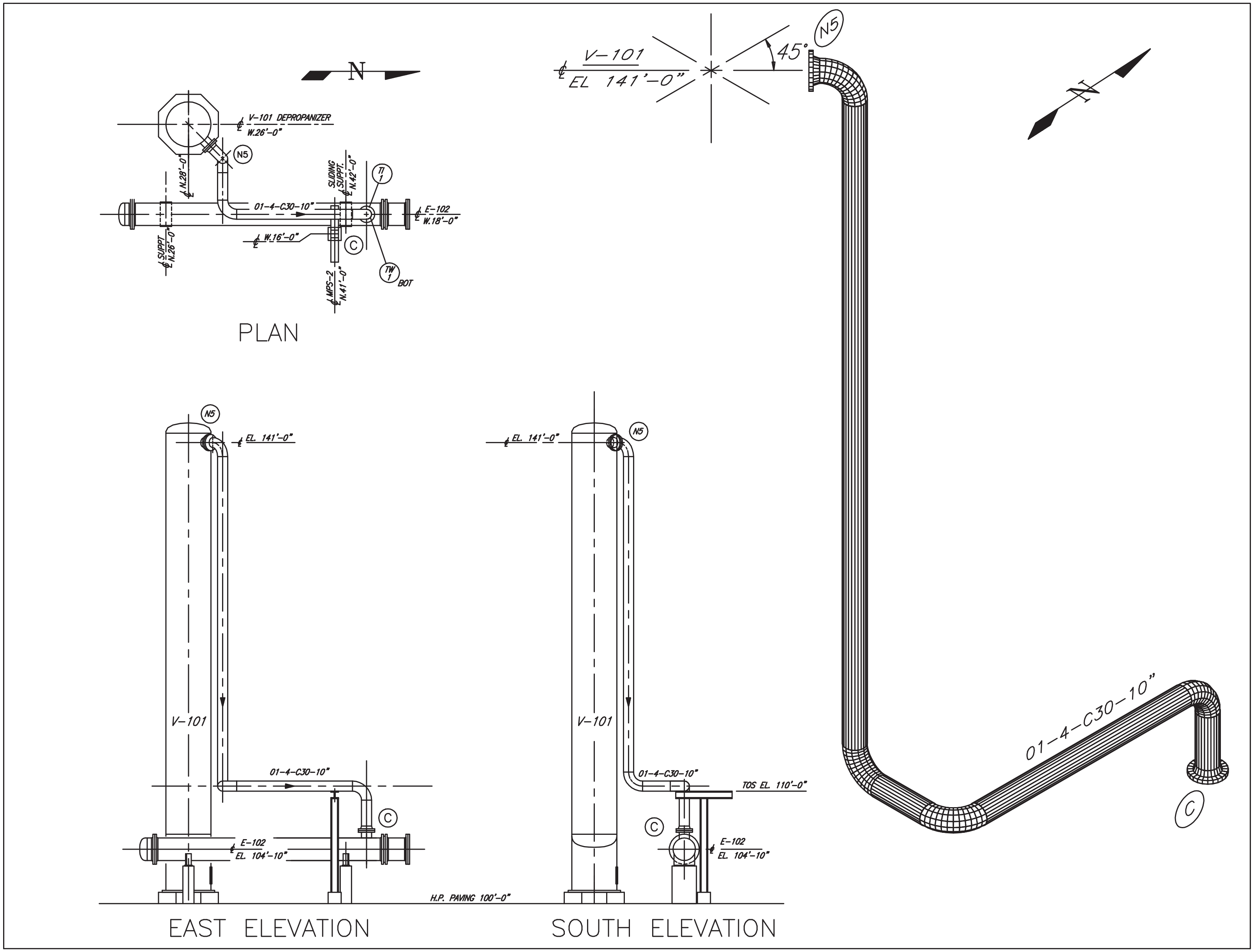


FIGURE 10.28 Line 01−4-C30−10″.

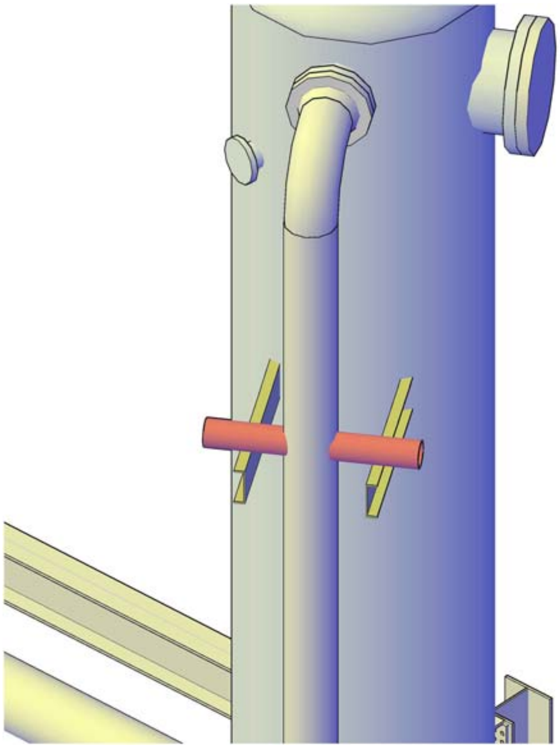


FIGURE 10.29 Trunion pipe support.

align with the centerline of the two pumps, an elbow turns down into a vertical run. Within each of these vertical drops is a gate valve that has been installed with its handwheel rotated 45° to the southwest. Attaching fitting make-up to the bottom of the valve is a flange and elbow that turns south. A 10″ × 8″ eccentric reducer is installed with the flat side on top (FOT), before the line connects to the pump suction nozzle **A** of 01-P-101A and 01-P-101B with a flange (see Figure 10.31).

Line 01−7-C30−6″/4″ shown in Figures 10.32 and 10.33 is a long line that connects the discharge nozzles of pumps 01-P-101A and 01-P-101B to nozzle **N4** on vessel 01-V-101. Rising vertically out of the pump discharge nozzle **B** the configuration is a 6″ NPS. A check valve, which is attached to the discharge nozzle, precedes a block valve, whose handwheel has been rotated 45° to the southwest. A short vertical run of pipe is installed prior to two elbows, whose centerline elevation is at EL. 108′-5″, turn toward each other. Equidistant between the two pumps, the line tees with the branch oriented up to create another vertical run. At a centerline elevation of 110′-3⁵⁄₁₆″ an elbow turns south, travels 3′-2″, turns up 2′-0″ into the main pipe rack, and tees again, branching in the east and west directions. A 6″ × 4″ eccentric reducer (FOB) is welded to the west side of the tee. All piping components attached to the east side of the tee are part of line 01−8-C30−6″, which continues down the pipe rack into Unit-03.

Exiting the 6″ × 4″ tee to the west, the line becomes 01−7-C30−4″. From the center of the tee, a 14″-10¹⁄₂″ run of pipe ends with an elbow that turns down 2′-0″. Below that elbow another on turns north, out of the rack. This section of pipe has an orifice flange assembly positioned 3′-0″ from the north end of the run. Long runs of pipe that have an orifice flange assembly, such as this one, are known as a *meter runs*. The precise positioning of the orifice flange within the meter run is based on a formula which will be discussed in greater detail in Chapter 12, Piping Systems. Line 01−7-C30−4″ then turns down into control valve manifold FRC-2, also discussed in Chapter 12, Piping Systems. The control valve manifold, also known as a "control station" or "control set," keeps the line in a north orientation as it runs along the east side of 01-V-101. The line rises up, out of the FRC-2 control manifold, when it is aligned with the centerline of 01-V-101, eventually attaching to nozzle **N4** at EL. 139′-0″. The Plan and Section views of control station FRC-2 can be seen in Figure 10.33.

Line 01−9-C30−4″ drops out of the bottom of 01-E-101 connected to nozzle **E**, fitting make-up. The line turns east before rising to centerline elevation 110′-2¹⁄₄″. Once at this height, an elbow turns south, travels 6′-8″ and drops down into control station TCV-1. This control station is similar in size and appearance to the one used in line 01−7-C30−4″. The control station runs in an east to west direction and lies 2′-0″ to the north of the centerline of the pipe rack. The handwheels of the block valves point south. Use the dimensions in Figure 10.34 to represent the control station on your drawing.

The west end of the control station rises to centerline elevation 110′-2¹⁄₄″, turns south and runs below the pipe rack as it rests on Column B on the main pipe rack. The line then rises up through the rack, turns east, and travels through Unit-01 into Unit-03.

As shown in Figures 10.35 and 10.36, lines 01−10-A15−6″ IH and 01−11-A15−6″ IH are heating medium return and supply lines for 01-E-101, respectively. Line 01−10-A15−6″ IH, the heating medium return line, is a simple line dropping out of 01-E-101 from nozzle **A** fitting make-up. The bottom elbow turns the line west for a short distance, then up, fitting make-up into a block valve, whose handwheel is oriented north. The line continues vertically to EL. 110′-6⁵⁄₁₆″, where it turns south, rests on Miscellaneous Pipe Support-1 (with a pipe shoe), then runs toward the main pipe rack. Line 01−10-A15−6″ IH will rest on Column B as it enters the main pipe rack. Once below the rack, the line turns up and stubs (stub-in) into line 19-A15−10″-IH.

Line 01−11-A15−6″-IH is the heating medium supply line for 01-E-101. It drops out of the heating medium supply header, 20-A15−10″-IH with a stub-in. After dropping out of 20-A15−10″-IH, an elbow turns the line

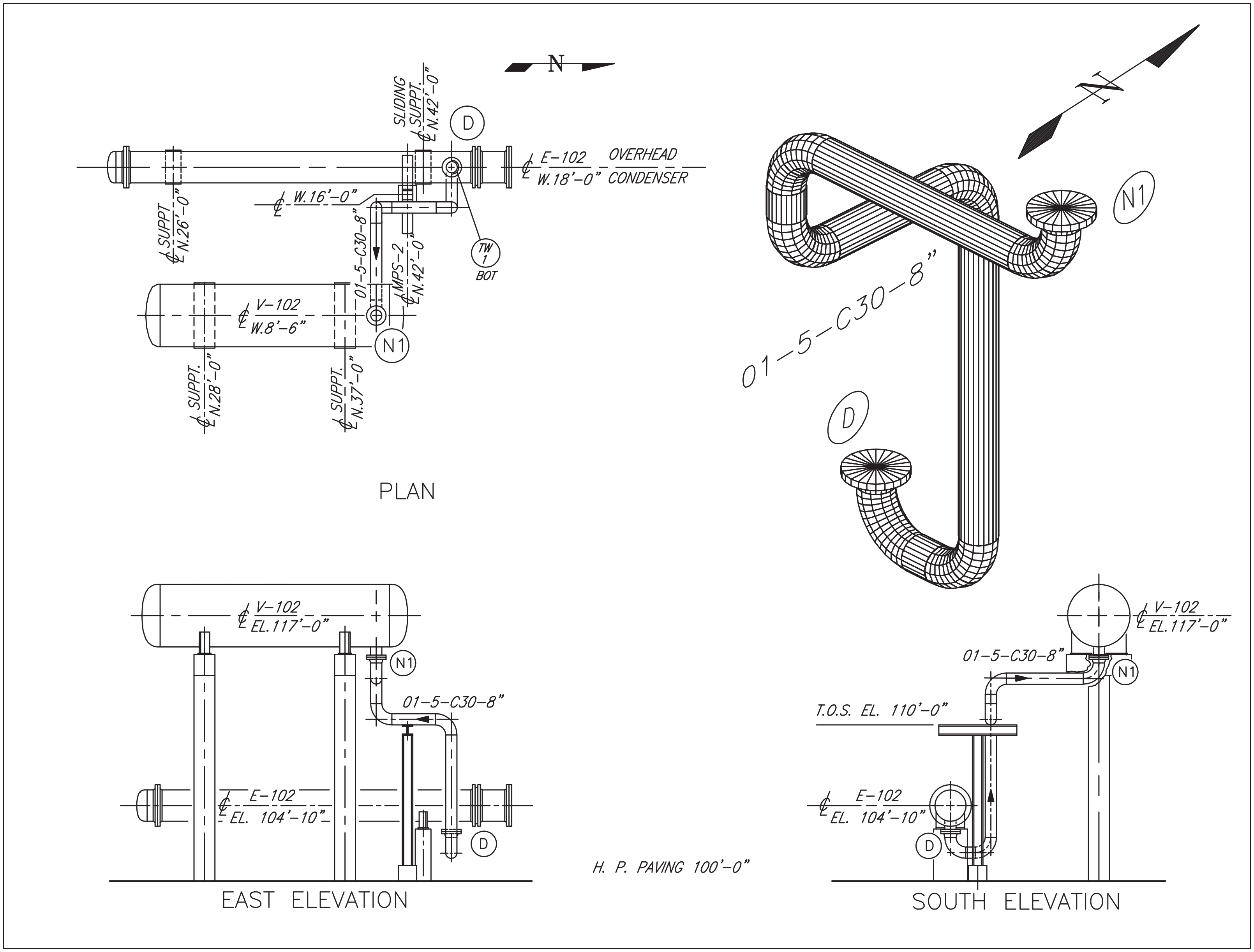


FIGURE 10.30 Line 01–5-C30–8″.

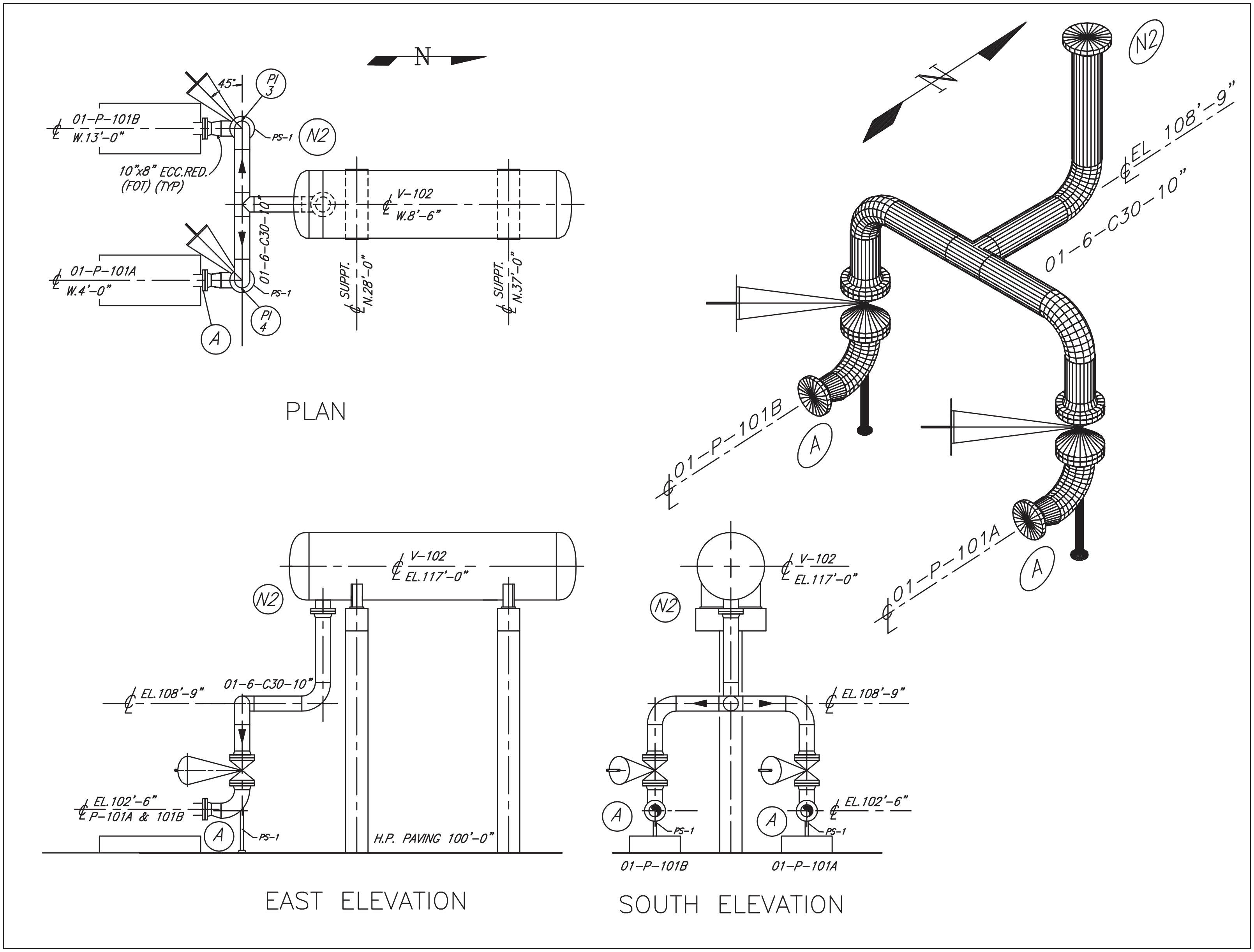


FIGURE 10.31 Line 01–6-C30–10″.

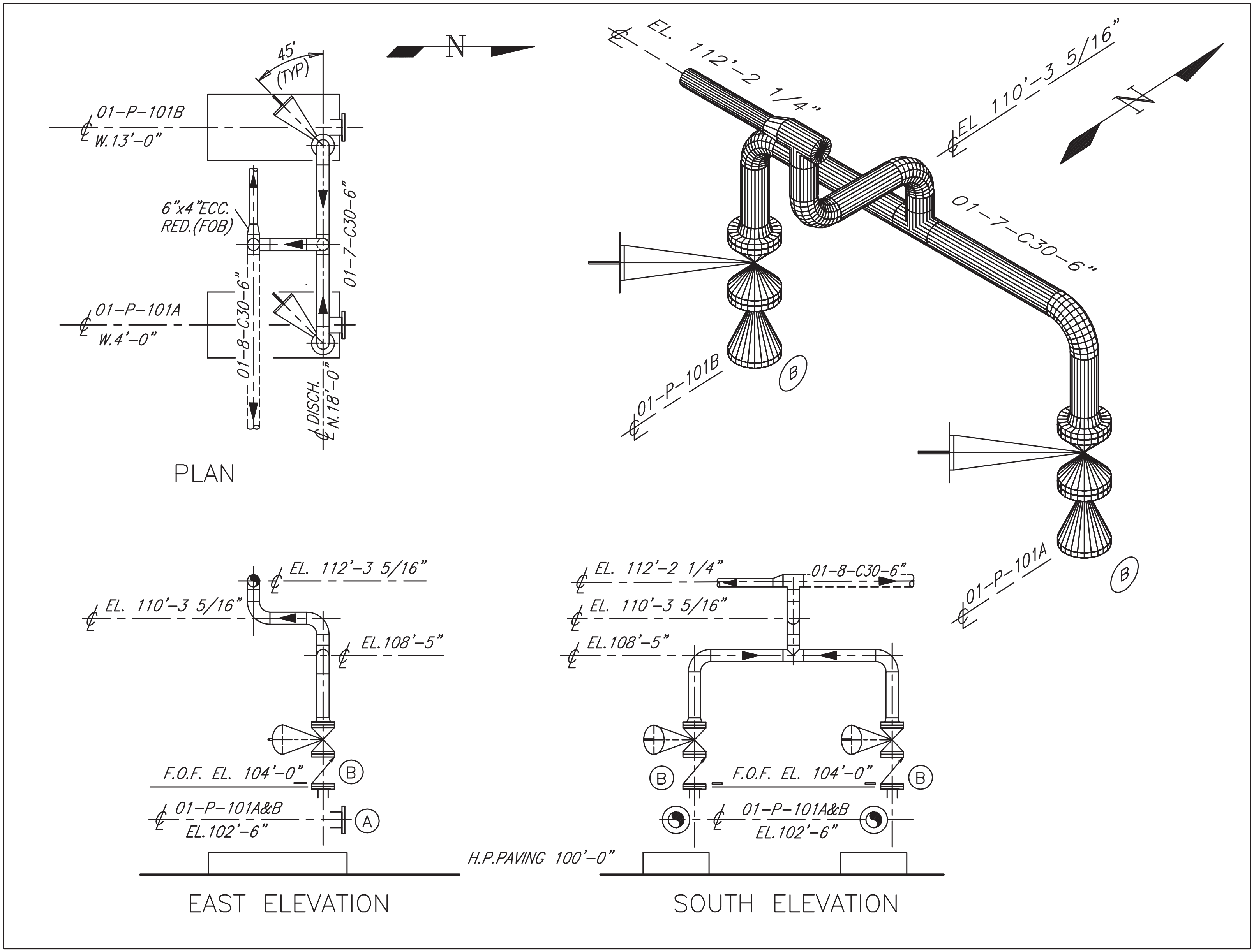


FIGURE 10.32 Line 01–7-C30–6″.

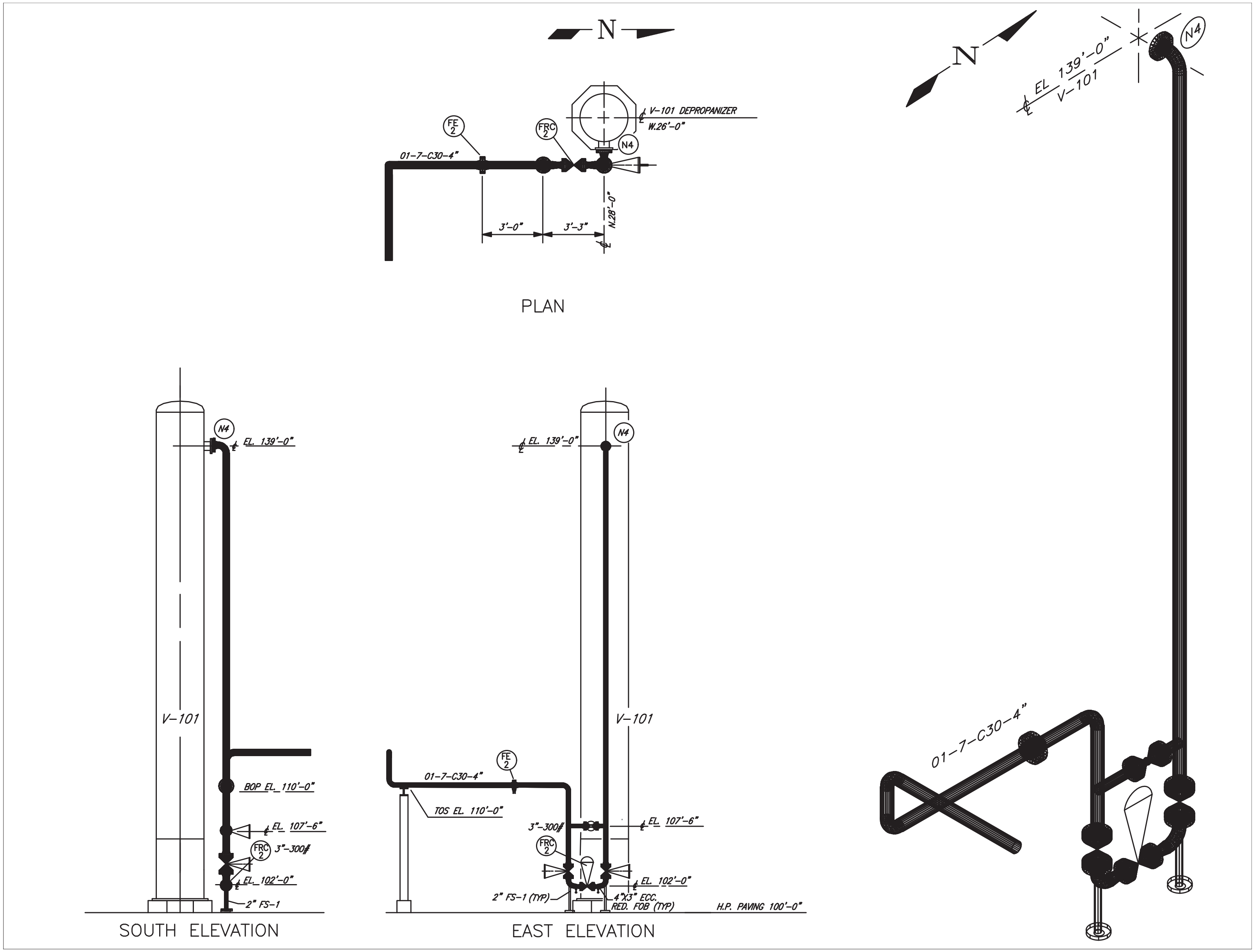


FIGURE 10.33 Line 01–7-C30–4″.

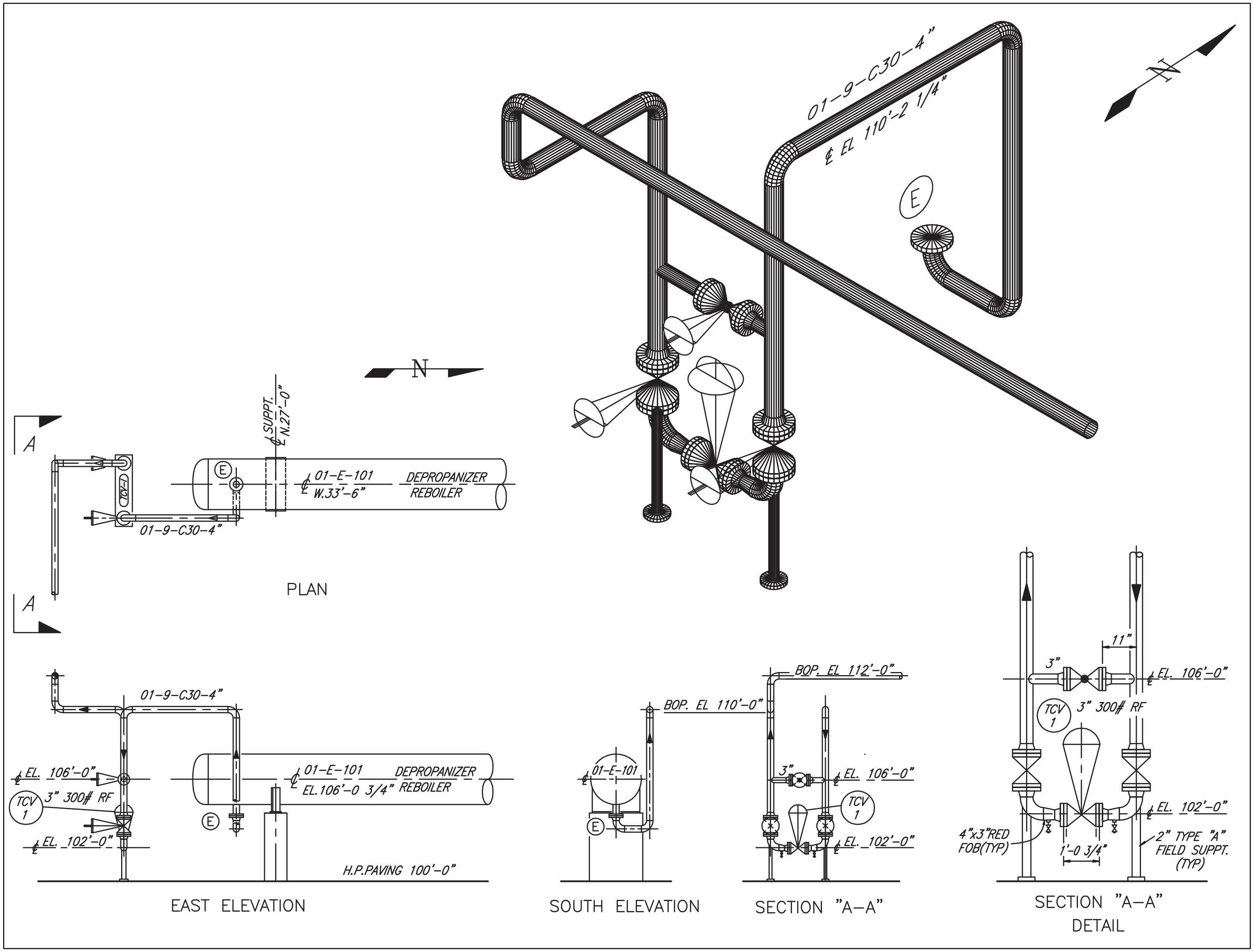


FIGURE 10.34 Line 01–9-C30–4″.

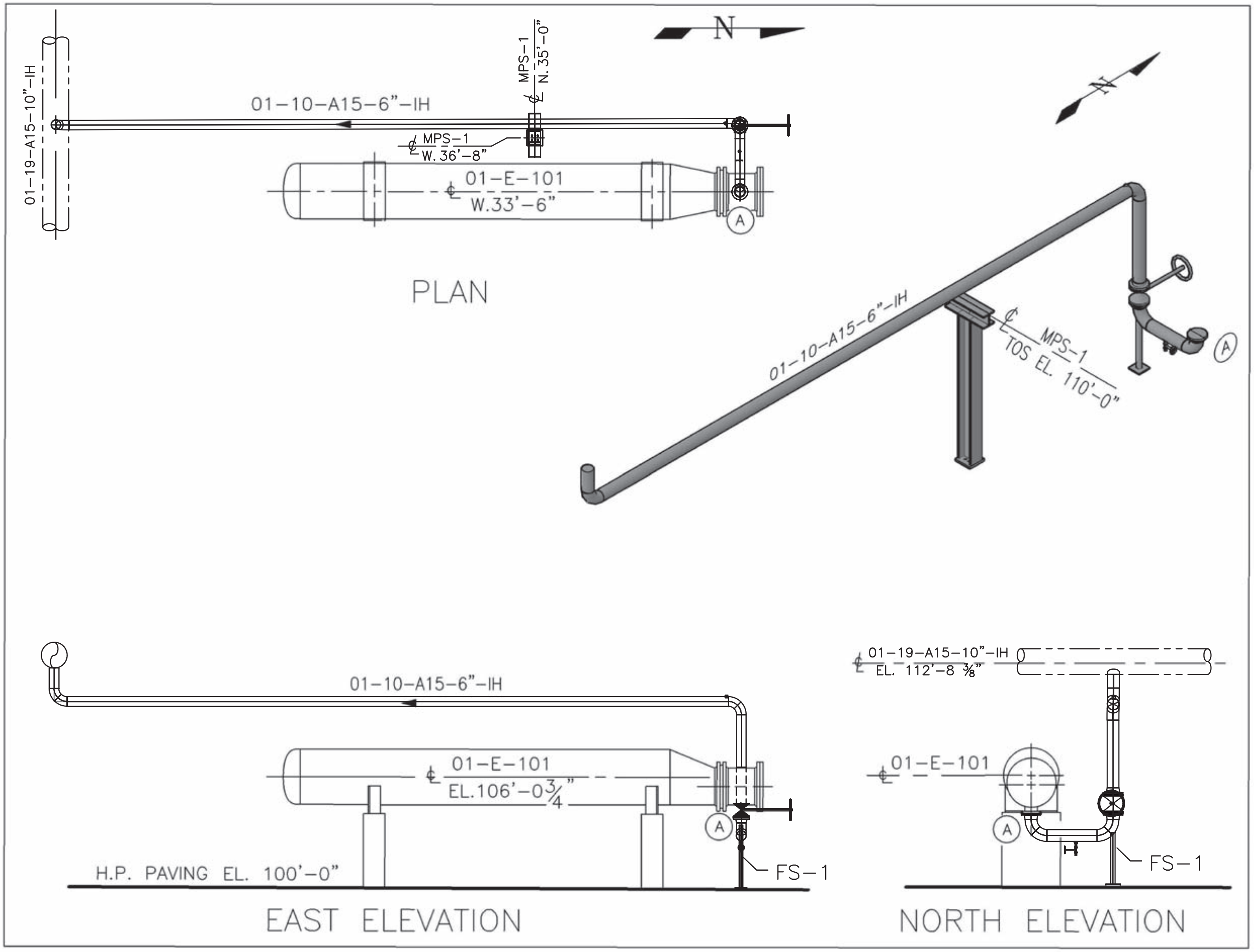


FIGURE 10.35 Line 01–10-A15–6″-IH.

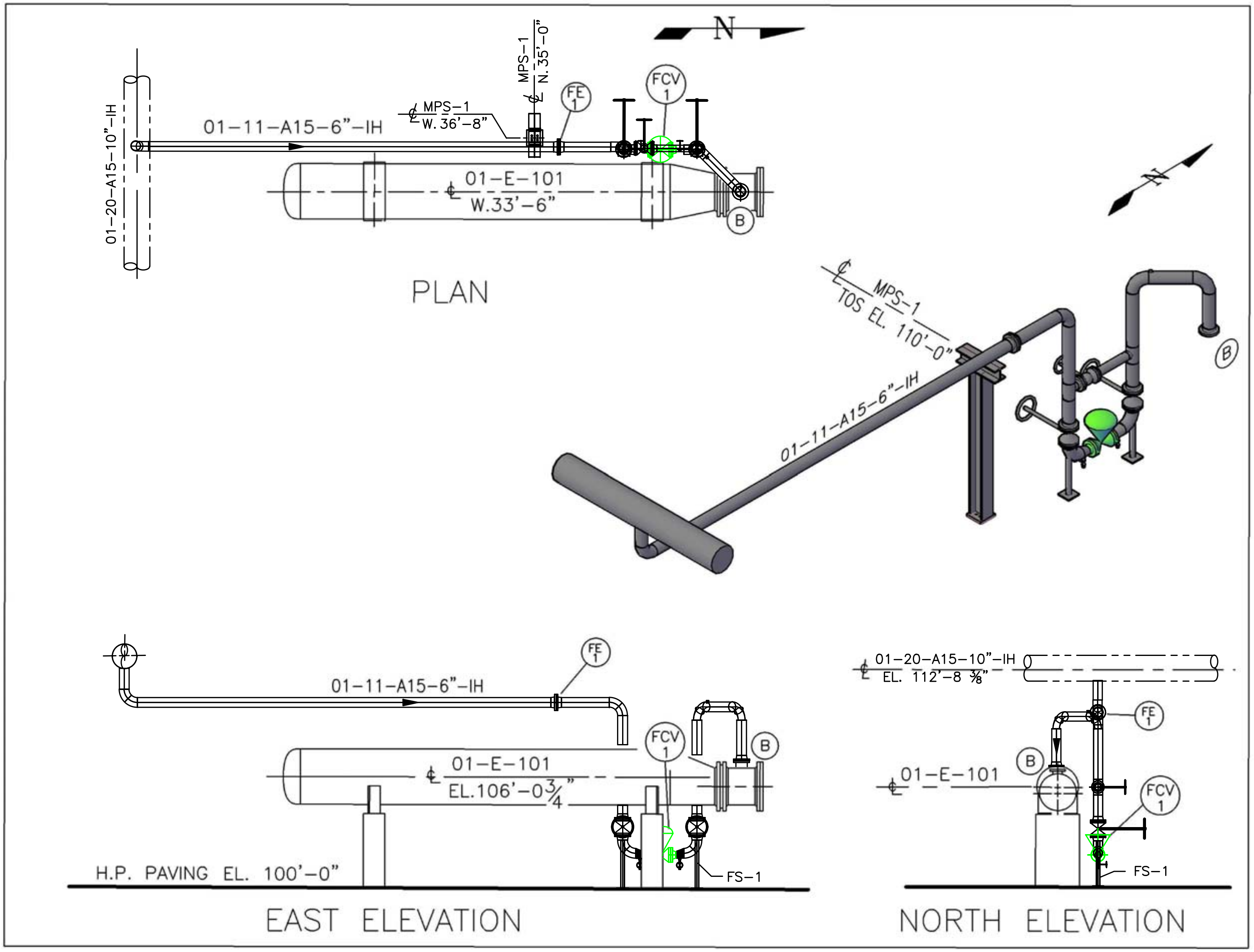


FIGURE 10.36 Line 01–11-A15–6″-IH.

north where it rests on column B with a pipe shoe. The pipe will continue north, cross Miscellaneous Pipe Support-1 and into a meter run. Precise positioning of the orifice flange assembly, FE-1, must be established at this time. Because there is adequate upstream clearance to locate the assembly, its position will be established based on the required downstream distance. Using the guideline of 6 pipe diameters downstream, a minimum straight-run pipe distance of 3′-0″ (6 pipe diameters × 6″ pipe size = 36″) is required to the first weld. To locate the center of the orifice flange assembly, add 3′-0″ plus 9″, the center-to-end dimension of a 6″ elbow, which totals 3′-9″. This 3′-9″ total dimension establishes the position of the orifice flange assembly from the center of the elbow on the downstream side.

From the north end of the meter run, the line drops down into control station FCV-1. The control station runs south to north and lies on the west side of 01-E-101. Out of the north end of the control station, the elbow is rolled at a 45° angle to the northeast where it drops into nozzle **B** of 01-E-101.

This layout conforms to the basic rule of piping for exchangers: hot stream in the top, cold stream out the bottom. As the hot oil goes through the tube bundle of the kettle reboiler, it loses its heat and begins to cool. Line 01−10-A15−6″-IH picks up this stream at nozzle **A** of 01-E-101 and pipes it back to the pipe rack to be returned, via the heat medium return header, to the fired heater 03-H-304 on Unit-03 for reheating. Both lines 01−10-A15−6″ IH and 01−11-A15−6″ IH are 6″ lines that branch from a 10″ header. To determine the type of branch connection to be made, we must follow Piping Specification Class A15. A15 mandates that a stub-in be used to make the branch connection on these lines. Notice these are liquid lines. The typical procedure for branching lines with a liquid commodity is to branch off of the bottom of the rack headers. If these lines contained steam, we would rise off the top of the header pipe to avoid getting condensate in the line.

As shown in Figure 10.37, line 01−12-C30−4″ rises fitting make-up off the top of 01-V-102 from nozzle **N4** with an elbow turning west. Another elbow turning down routes the pipe through a control station PCV-1. The control station runs parallel to the north/south centerline of 01-V-102. Being that 01−12-C30−4″ is the same pipe diameter and pound rating as 01−9-C30−4″ the measurements required to lay out control station PCV-1can be derived from TCV-1 in Figure 10.34. The south end to the control station rises to a centerline elevation of 110′-2$\frac{1}{2}$″ and turns south. A dummy support is required to support the southerly run of pipe from Column B in the pipe rack. For a further explanation of dummy supports and their required pipe size is shown in Chapter 11, Standard Piping Details. From the dummy support 01−12-C30−4″ turns up, then south again and drops into the 8″ fuel gas line, 17-A15−8″ in the pipe rack.

Line 01−13-A-15−6″, shown in Figure 10.38, is designed to transport waste gas from 01-V-102 to the flare stack. Line 01−13-A-15−6″ rises off the top of 01-V-102, connected to nozzle **N5**. A gate valve, whose handwheel is oriented east and is bolted to **N5**, precedes the pressure safety valve, PSV-2, which has a 4″-300# inlet and a 6″-150# outlet. Coming out of PSV-2 the line travels south, where it drops down onto Column **B** at TOS EL. 114′-3$\frac{5}{16}$″. An elbow turns the line south again where it rolls down and east to stub into the top of 18-A15−8″, the flare header at a 45° angle. The 8″ flare header then travels offsite to the flare stack 03-FS-305, in Unit-03.

Lines 01−14-A15−6″ and 01−15-A15−6″ are cooling water return and supply lines, respectively. They are used to circulate the cooling water between 01-E-102 and Cooling Tower 04-CT-406. Line 01−14-A15−6″ is the cooling water return line. This pipe will circulate the cooling water that has been heated in 01-E-101 back to 04-CT-406 to reduce its temperature. 01−14-A15−6″ rises off the top of 01-E-102 at nozzle **B** with a gate valve whose handwheel is oriented to the west. After a short vertical run up and out of the valve, the line turns east then immediately south, fitting make-up. As the line travels south, it will rest on Miscellaneous Pipe Support-1 then further south to rest on Column **B** at centerline elevation 110′-3$\frac{5}{16}$″. From there is runs below the main pipe rack and turns up to stub into the cooling water return header 21-A15−10″.

Line 01−15-A15−6″ is the cooling water supply line. It routes water that has been cooled in Cooling Tower 04-CT-406 back to 01-E-102. This line drops out of the bottom of 22-A15−10″, the cooling water supply line to centerline elevation 110′-3$\frac{5}{16}$″ and turns north. When the pipe aligns with nozzle **A** of 01-E-102, it drops down to EL. 109′-0$\frac{7}{16}$″ and turns west. When it reaches the centerline of 01-V-102 it turns up into a block valve. The block valve, whose handwheel is oriented west, is bolted directly to nozzle **A**. See Figures 10.39 and 10.40 for plan and elevation views of lines 01−14-A15−6″ and 01−15-A15−6″.

Line 01−16-C30−2″ is a short drain line dropping out of the bottom of 01-V-102. This 2″ line is attached to nozzle **N3** and drops straight below the nozzle into a drain funnel. A block valve is located at centerline elevation 104′-6″. Its handwheel is oriented to the east (see Figure 10.41).

The level gauges and level controllers depicted in Figures 10.42 and 10.43 are mounted on a bridle attached to vessels 01-E-101 and 01-V-102, respectively. The level gauge and level controller are installed so an operator can easily monitor and control the normal

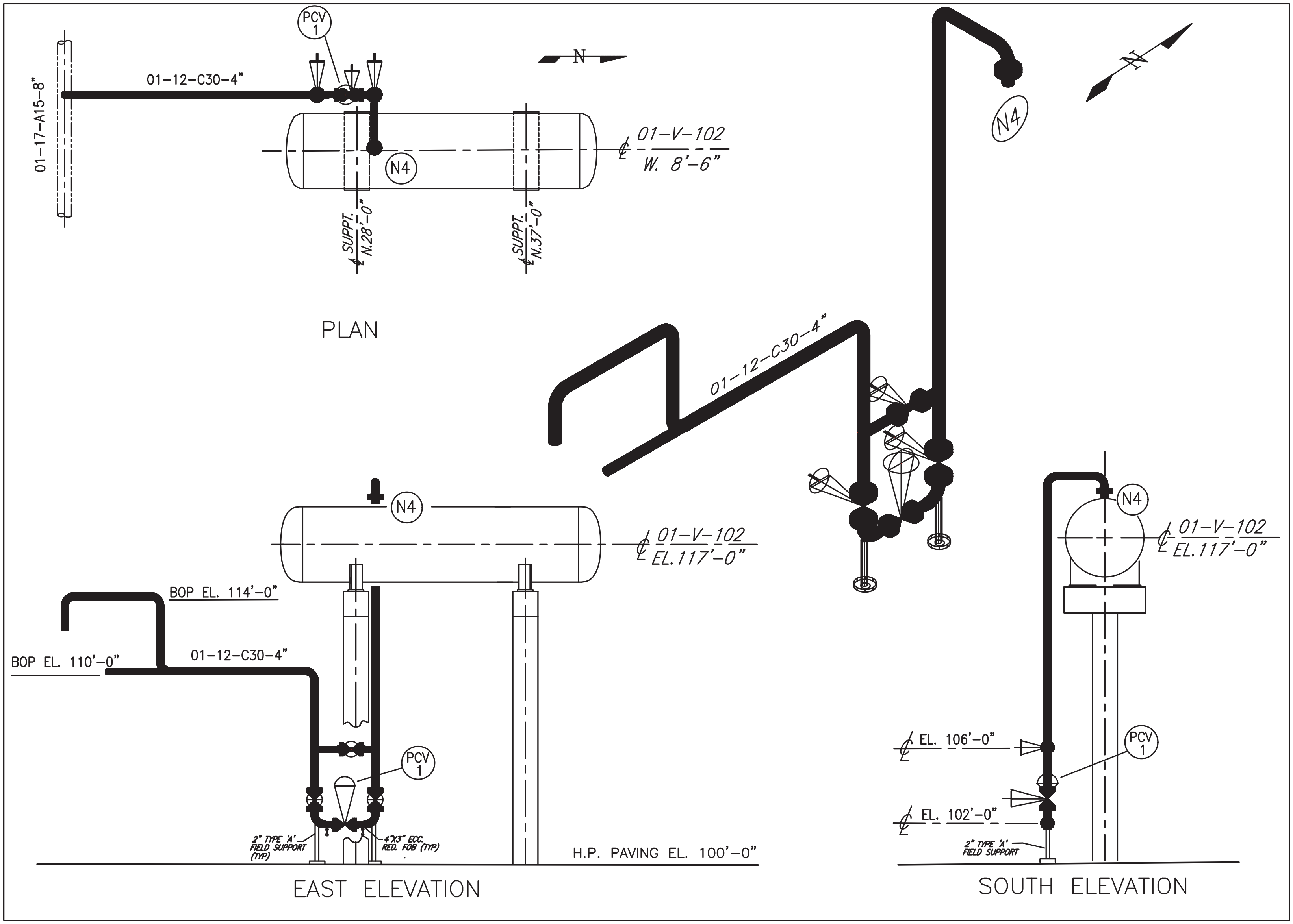


FIGURE 10.37 Line 01–12-C30–4″.

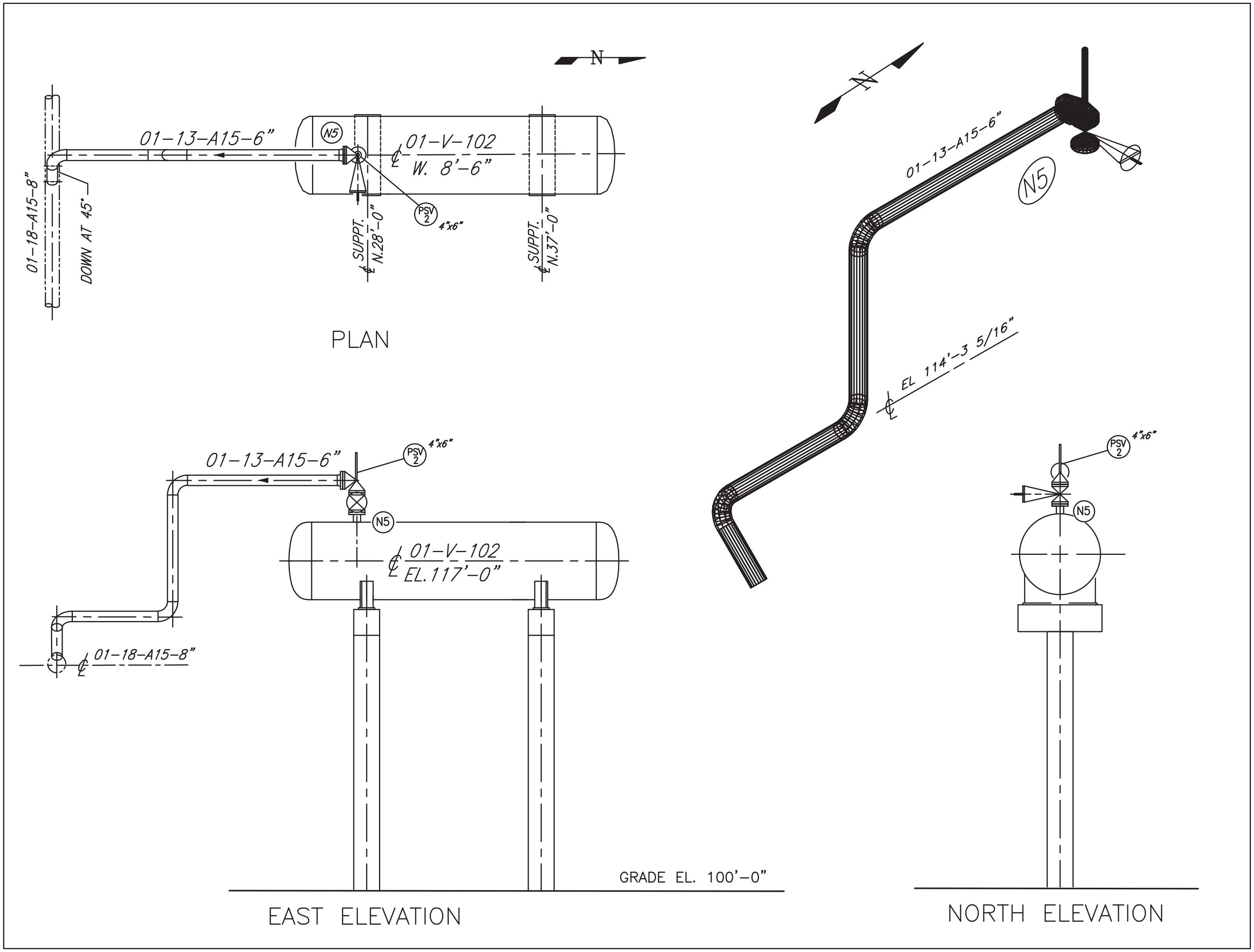


FIGURE 10.38 Line 01–13-A15–6″.

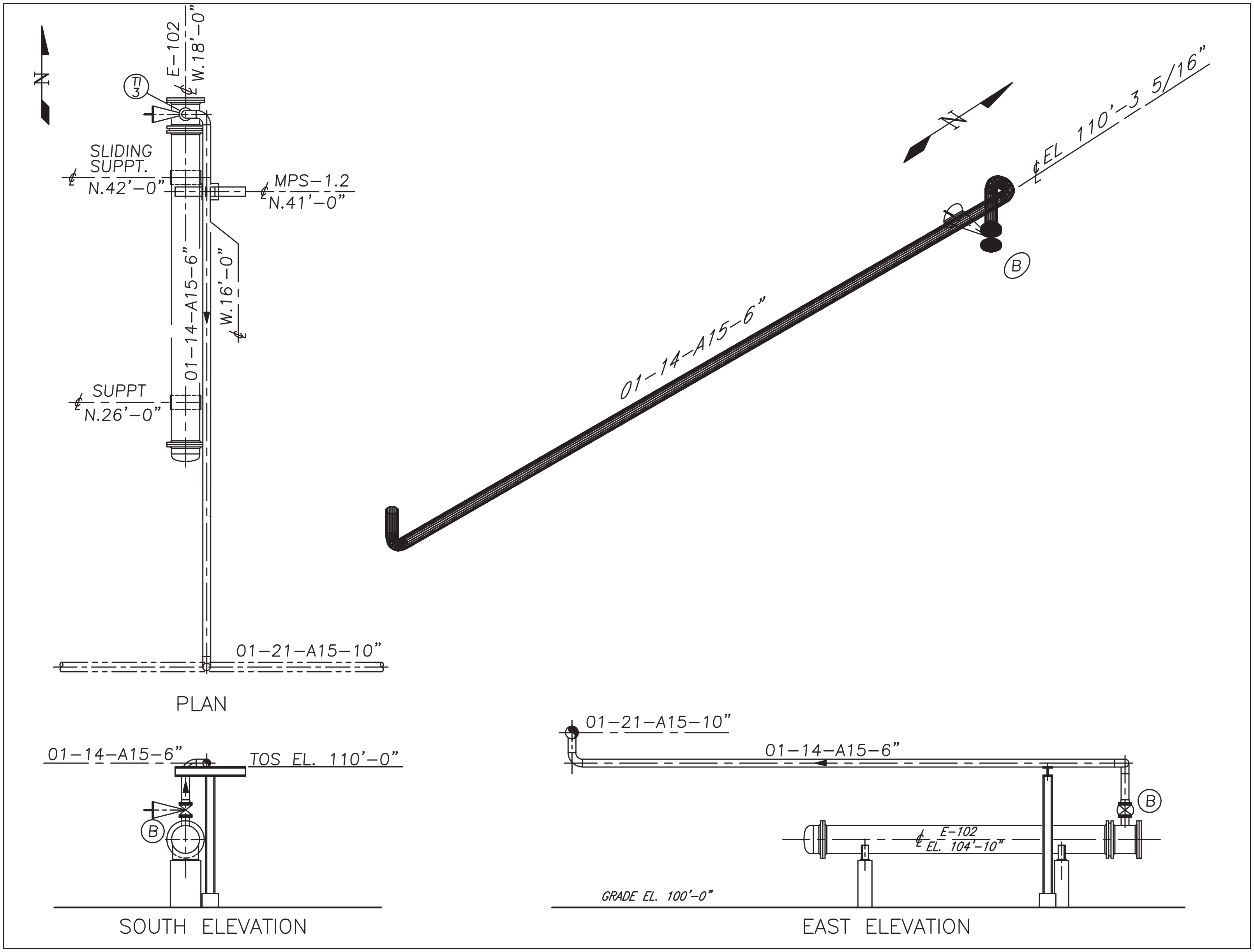


FIGURE 10.39 Line 01–14-A15–6″.

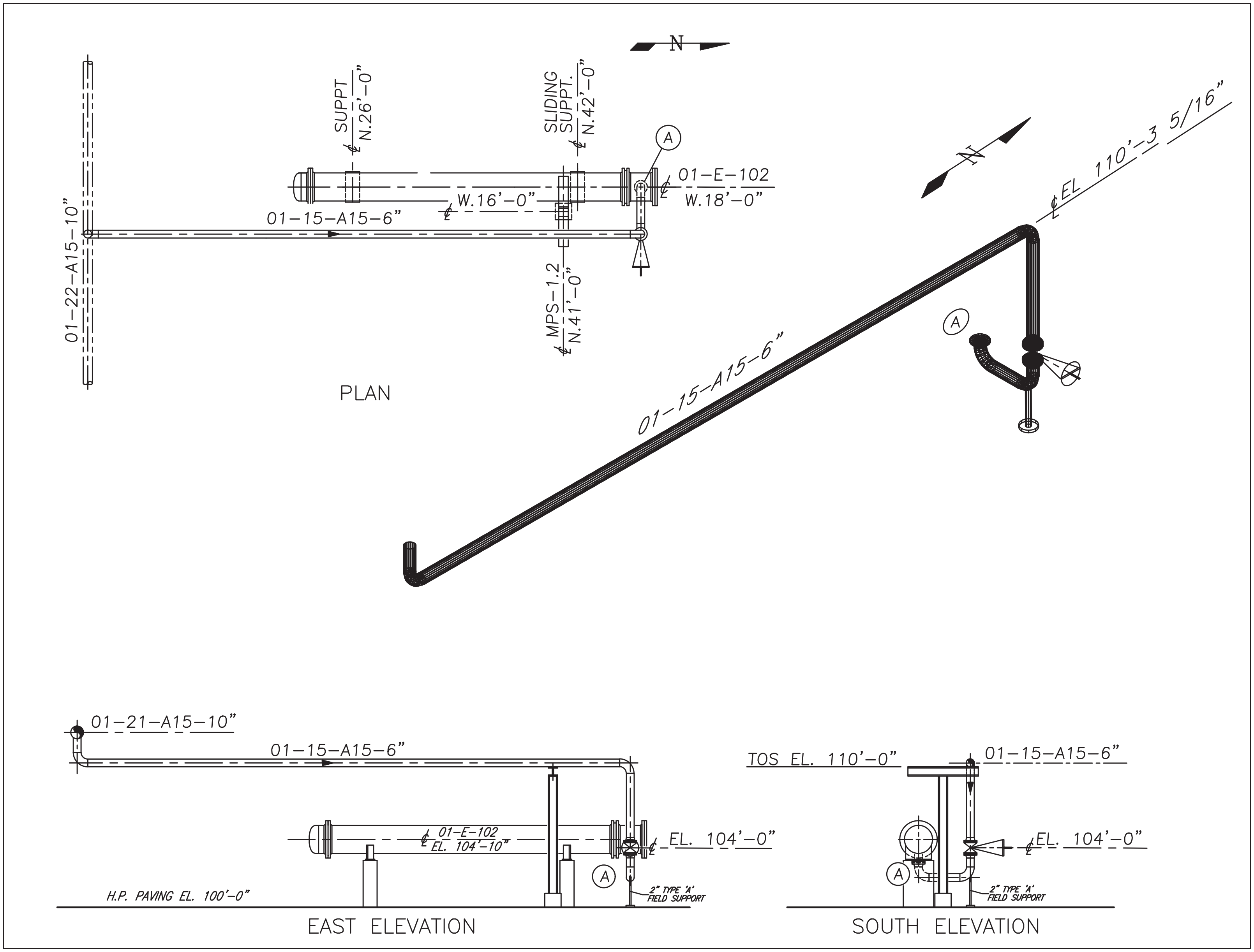


FIGURE 10.40 Line 01–15-A15–6″.

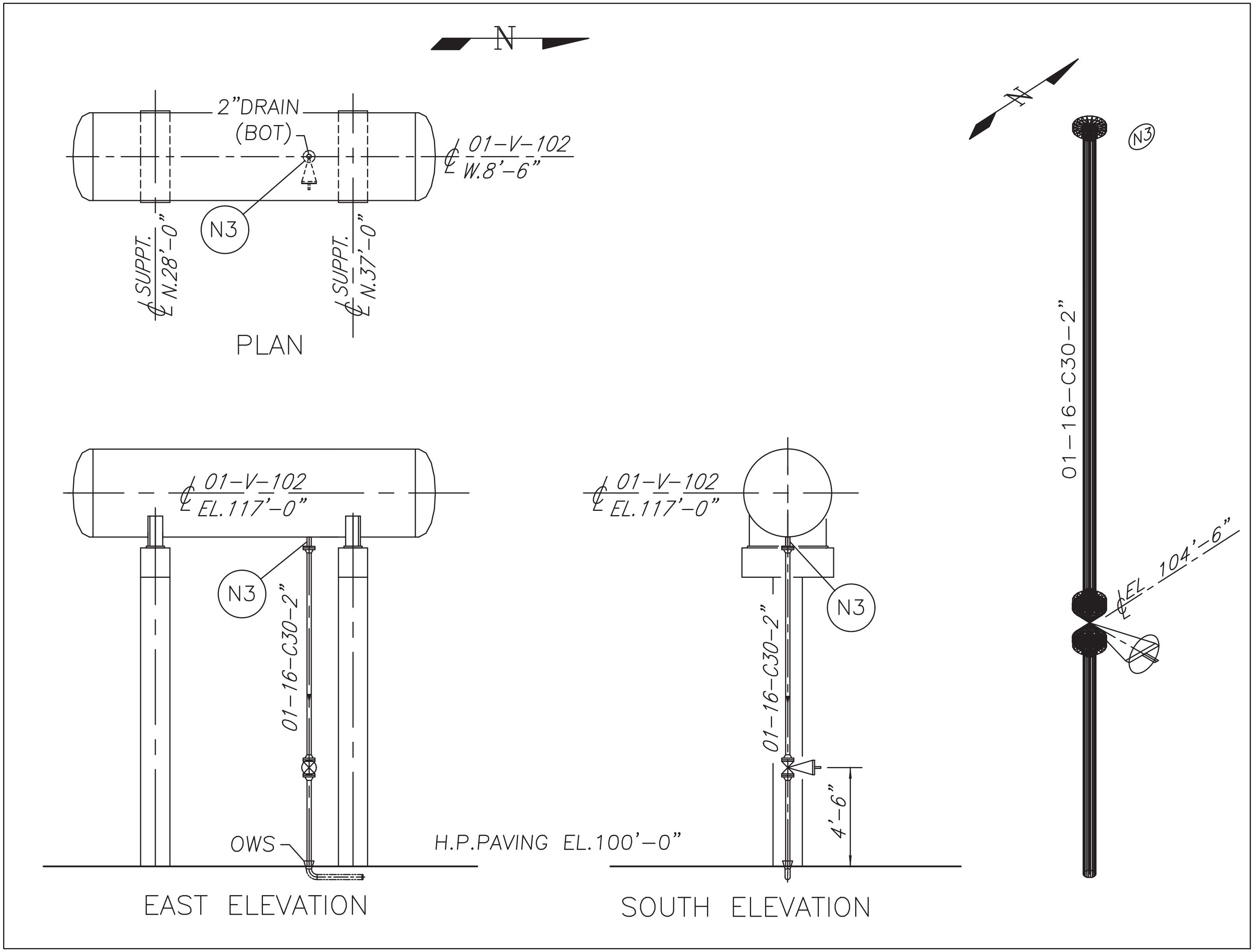


FIGURE 10.41 Line 01–16-C30–2″.

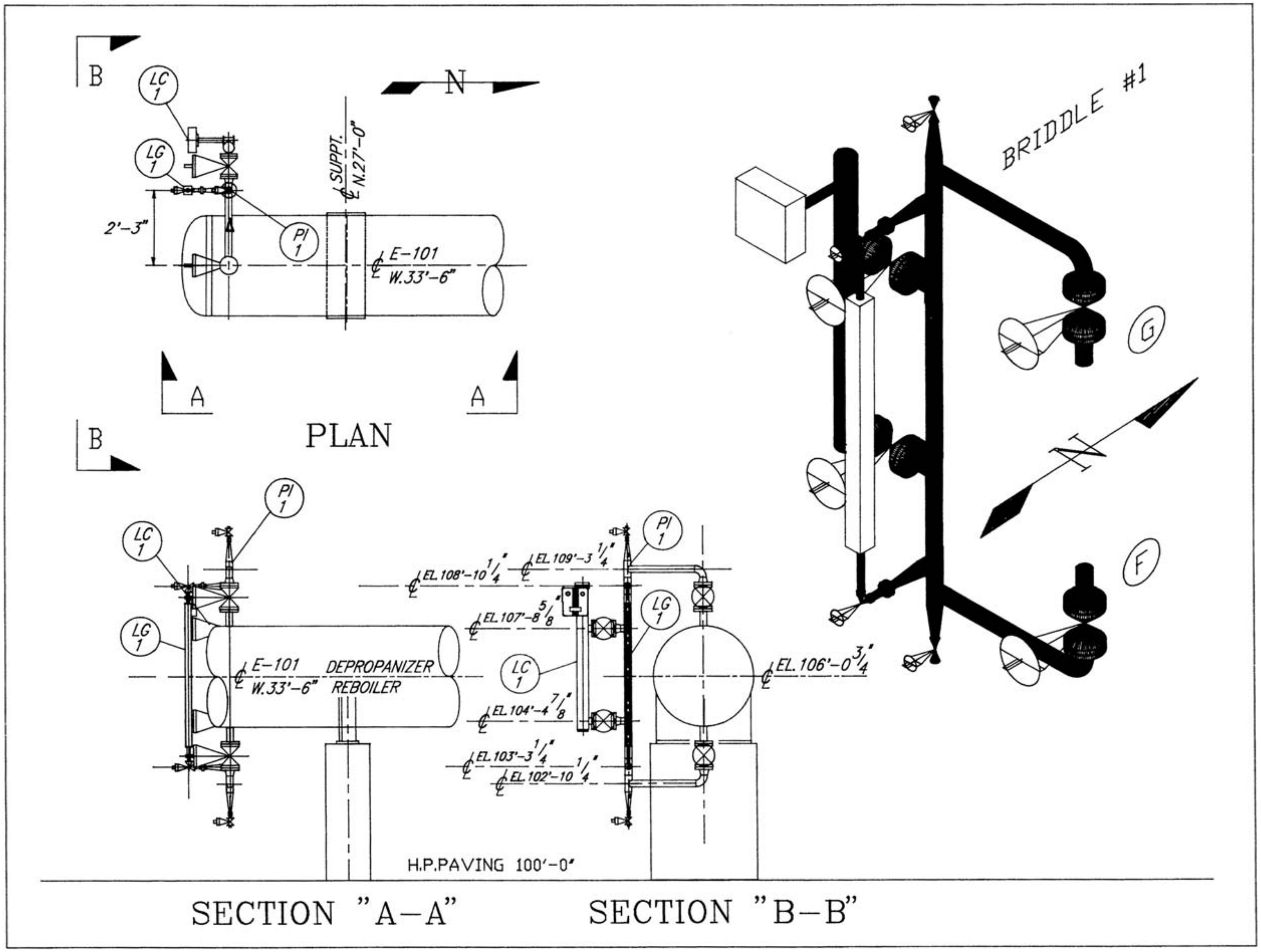


FIGURE 10.42 Bridle attachments for 01-E-101.

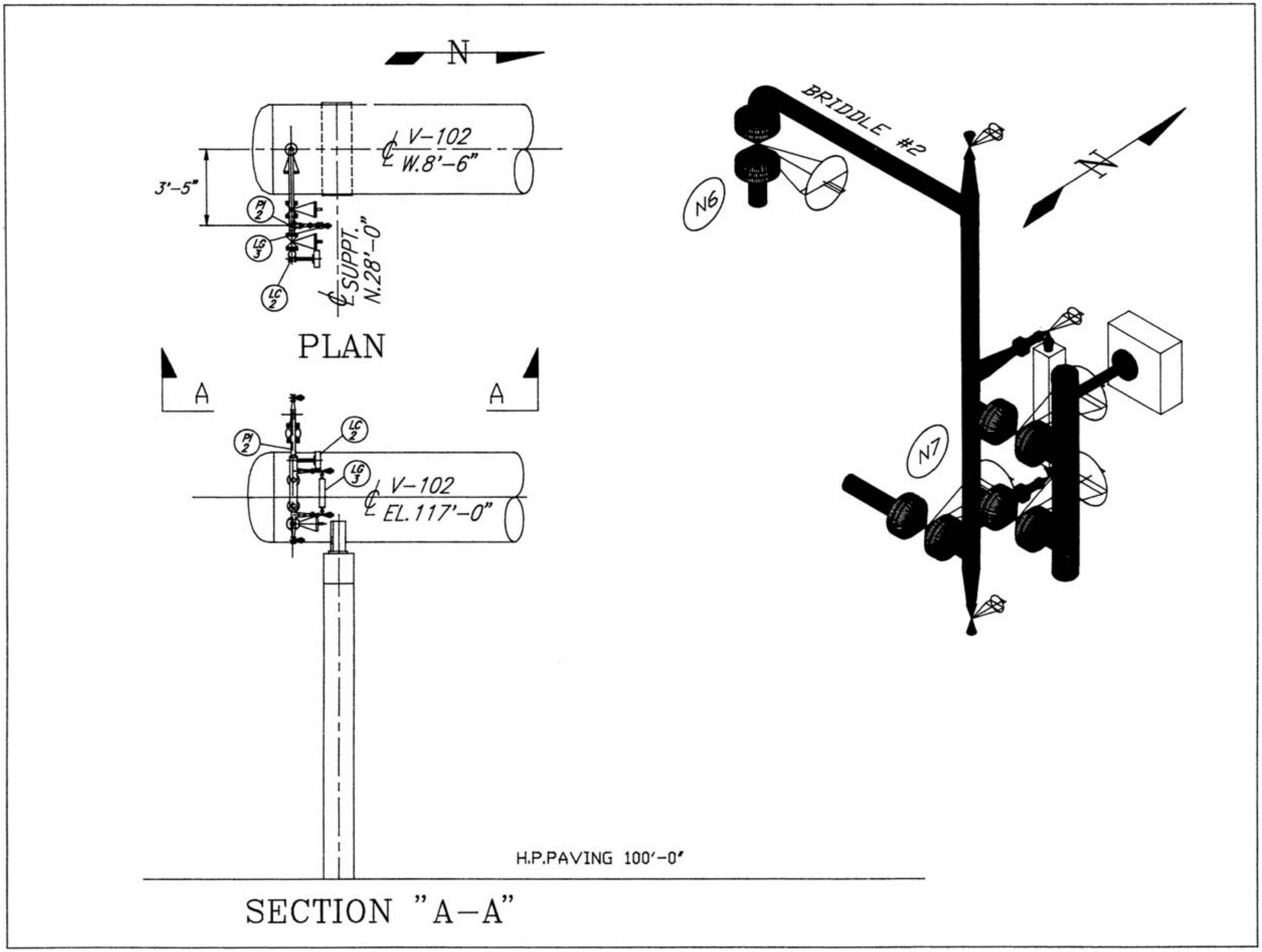


FIGURE 10.43 Bridle attachments for 01-V-102.

liquid level of each vessel. The normal liquid level of 01-V-102, the overhead accumulator, is typically controlled to be level with the centerline of the accumulator. The normal liquid level of 01-E-101, the kettle reboiler, is usually one-half the weir height. The weir, in this application, is a vertical plate inside the kettle reboiler that serves as a dam to keep the tube bundle submerged under liquid. As the liquid level increases, the excess liquid will flow over the weir and be drawn out through nozzle **E**, which is line 01−9-C30−4″.

Procedure 9: Platform, ladder, and cage layouts
Reference drawing: Vendor drawings

- Make "*Platforms, Ladders, and Cages*" the current working layer.
- The size and location dimensions for the platforms, ladders, and cages are established from dimensions provided on the vendor drawings for 01-V-101. Figures 10.44 and 10.45 provide an enlarged view of 01-V-101 describing Platforms 1 and 2, respectively. Use dimensions provided in these figures to place the platforms, ladders, and cages on 01-V-101 in your Piping Arrangement drawing.

Procedures 10−15: Placement of line numbers, callouts, coordinates, and dimensions
Reference drawing: Flow diagram, pipe line list, job specifications

Key information about a piping facility is not always depicted graphically. Some information must be communicated in written form. Certain components of a drawing such as dimensions, coordinates, elevations, line numbers, fitting and equipment callouts, and design and fabrication notes can only be represented as written information. The arrangement of information and reference notes on an arrangement drawing usually requires preplanning and proper placement to achieve a good sense of balance on the drawing. This information must be arranged logically and in a clear legible manner. Therefore interferences among reference notes, dimensioning, and object line work must be kept to a minimum.

The following items must be included on Piping Arrangement drawings:

- Completed title block information.
- North arrow. Place the north arrow in the upper right corner of the drawing. It should point up or toward the right.
- Coordinates for matchlines, area limits, battery limits, mechanical equipment, and structural support foundations, all pump suction and discharge nozzles.
- Labels for angular degrees of orientation (30°, 45°, etc.) to indicate orientation of all vertical vessel nozzles.
- Tag numbers (N1, N2, N3, etc.) for all nozzles on mechanical equipment that corresponds to the vessel outline drawings, mechanical equipment vendor drawings, and nozzle schedule.
- Show mechanical equipment numbers and title information.

NOTE: *To avoid congestion on a drawing, extend centerlines away from the equipment symbol and label the equipment's description and coordinates in an open area of the drawing.*

- Labels for all pipelines with the following information:
  - Line number
  - Flow direction
  - Insulation symbol and thickness
  - Steam, heat, or electrical tracing if required
- Place a reference note somewhere within the Area Limits of the drawing to indicate the finished Grade or High Point of Paving elevation.
- Label all instrumentation per the mechanical flow diagram. All instrumentation should be accounted for one time in either the Plan view or Section view. Use ½″ diameter instrument bubble.
- Label for the top of platform (TOP) elevation on plan drawing.
- Reference notes to describe the following:
  - Piping specialty items
  - Reducers and reducing tees
  - Out of spec flanges
  - Any nonstandard item not covered in piping spec
  - Vessel davits
  - Chain operators for valve handwheels
  - Pipe guides, supports, anchors, hangers
- Cutting plane callouts that identify the name and direction of the section or elevation to be drawn.
- Labels for lines running through a pipe rack to specify the commodities they contain.

NOTE: *For clarity and neatness, group similar callouts together in one common location where possible (see Chapter 11, Figure 11.2).*

- Identification for any miscellaneous items. Locate and describe as required.

As a general rule, drawing notes and callouts are drawn 0.125″ tall. When the drawing is created full scale, as with **AutoCAD**, the actual text height is determined by multiplying the desired text height by the drawing's Scale Factor. Scale Factor is established from the desired Plot Scale of the drawing, in this case, ⅜″ = 1′-0″. To find the Scale Factor, find the decimal equivalent of ⅜″ then divide that into 1′-0″ (12″). Example, 3 divided by 8 equals 0.375. Then, 12″ divided by 0.375 equals 32. When applied to text height, 0.125 (text height) times 32 (Scale Factor) equals 4″.

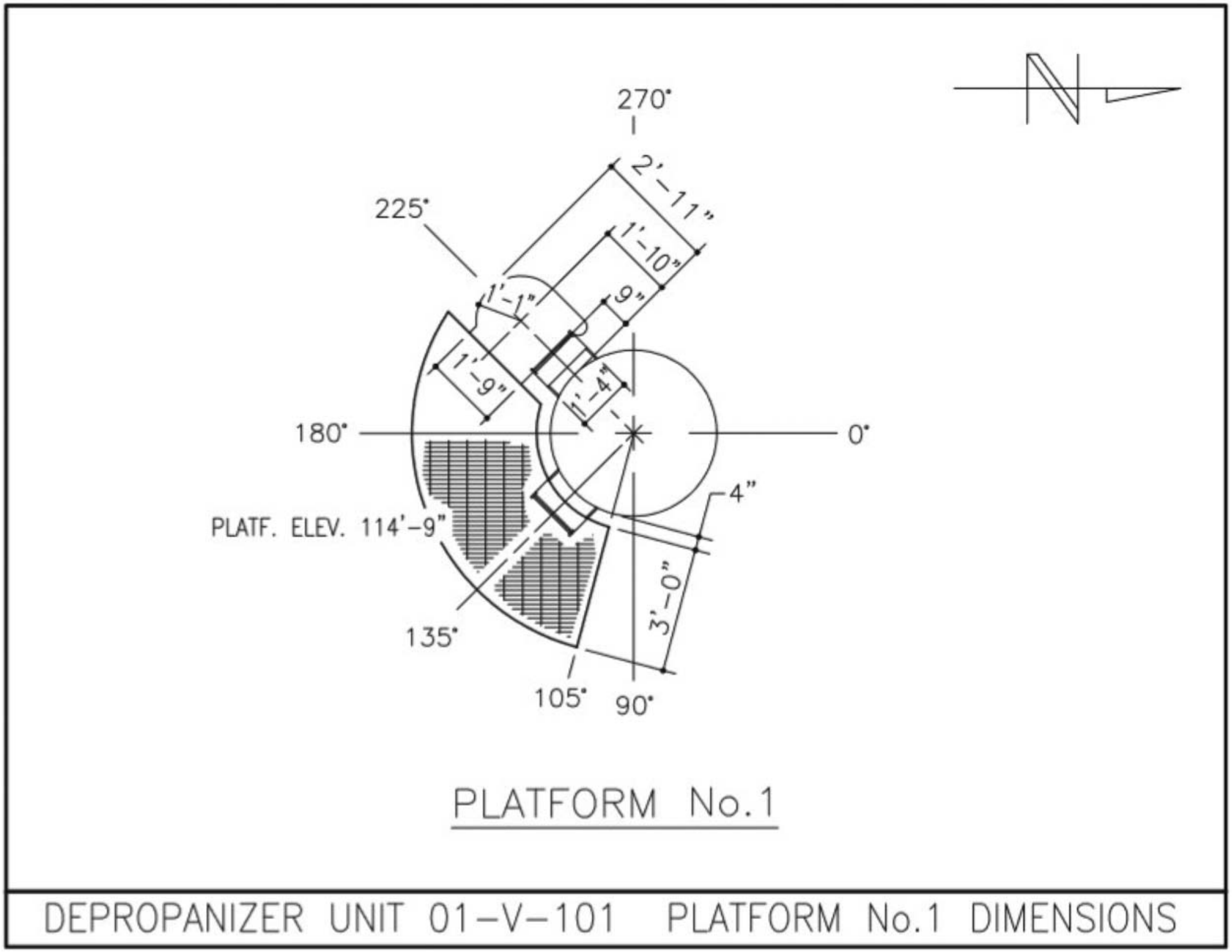


FIGURE 10.44 Platform No. 1.

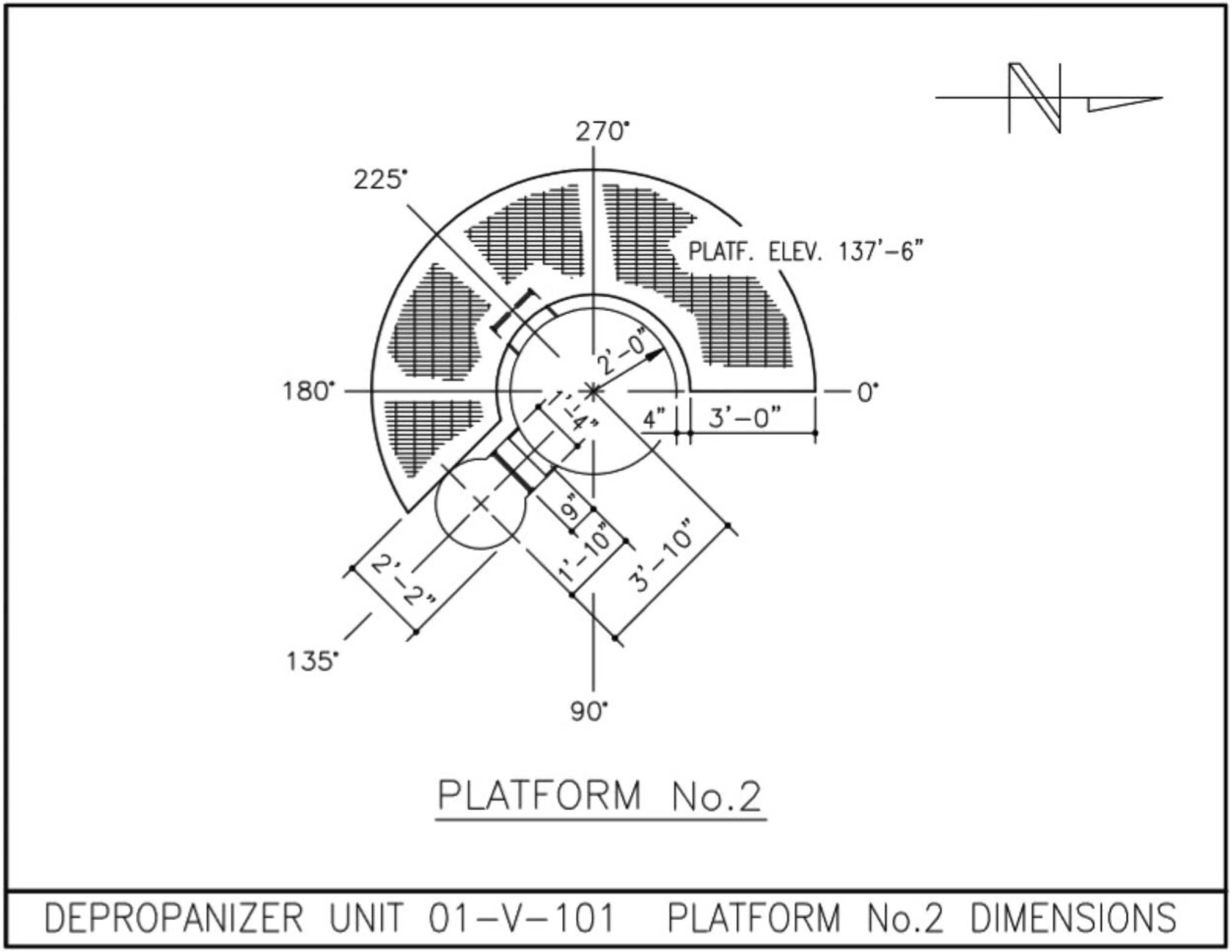


FIGURE 10.45 Platform No. 2.

Therefore all text in the full-scale drawing should be a minimum of 4″ tall. Ultimately, when placed in the appropriate border to 3/8″ = 1′-0″ scale, the result would be text 0.125″ tall.

All notes should be read from the bottom of the drawing. Information such as coordinate labels for Matchlines, Area Limits, or Battery Limits, line numbers, and equipment names, coordinates, and elevations should be labeled parallel to the item to which they apply. This may result in notes being read from the bottom or the right side of the drawing. *No written information should be read from the left side of a drawing*.

DIMENSIONING

Developing drawings with a high degree of dimensional accuracy is of primary importance. Good dimensional arrangement and placement enhances a drawing's effectiveness. Clear, concise, well-placed dimensions not only reflect a well-thought-out drawing, they simplify communication, which minimizes checking and reduces drawing revisions.

Dimensioning Guidelines

When placing dimensions on a drawing apply, the following guidelines to maximize the use of the limited space on a drawing. General dimensioning guidelines include:

- Avoid duplication of information. Do not repeat dimensions or notes in each view of a piece of mechanical equipment.
- Dimensions on plan drawings are to be placed within the drawing's Limits, that is, Matchlines, Drawing Limits, Area Limits, and Battery Limits.
- Dimension lines should be in a continuous string. Avoid staggered or offset dimensions.
- Group dimensions outside of a detailed area, where possible. Avoid crossing elements of the drawing with dimension or extension lines.
- Avoid placing dimensions between coordinates.
- Place dimensions for horizontal lengths on a plan drawing. Dimensions for vertical lengths should be shown on sections or elevations.
- Dimension all piping from centerline to centerline, centerline to face-of-flange, or face-of-flange to face-of-flange; do not dimension to welds.
- When required, include gasket thickness in dimensions. Indicate gasket location relative to flange extension lines with gasket symbol (tick mark).
- Provide spacing dimensions (between centerlines) of lines in a pipe rack. Do not place a continuous string of dimensions completely across the pipe rack if the pipe rack's supporting column coordinates are provided.
- Indicate TOS or BOP elevation of lines in the pipe rack.
- Dimensioning should be minimal. Provide only those dimensions, coordinates, and elevations required to draw and check piping isometrics or spools. Avoid referral to other drawings such as vessel drawings, vendor drawings, and plot plan.
- Show all angular offsets. Indicate degree of offset and plane direction (horizontal or vertical).

Procedure 16: Checking your work

Reference drawing: All available information and drawings

Now that the drawing is complete, it must be reviewed carefully. A plotted copy of the drawing will be required. If the drawing was created manually on vellum, mylar, or other reproducible medium, a blueprint must be obtained. If the drawing was computer generated, a copy of the drawing must be plotted. Although the drawing will be thoroughly checked by your instructor or supervisor for completeness and correctness, a drafter should always review the drawing to check for any errors, deletions, or inaccuracies. It may be necessary to systematically review the layout procedure in one's mind to duplicate the sequences used to develop the drawing.

Equipment location and size should be verified. Fitting and flange dimensions must be confirmed, and valve handwheel orientations must be reviewed. It is also the drafter's responsibility to assure the drawing was developed in accordance to any and all client or company specifications and governing federal regulations.

Procedure 17: Drawing release

Once you have checked and corrected your drawing, it is customary to indicate the "Completed Date" in the drawing title block. Some companies may also require that a drafter initial the drawing as an affirmation this is his or her work. Plot a new copy of the drawing to provide to your instructor or supervisor. The drafter may also elect to make an additional copy of the drawing to use as future reference.

PIPING SECTIONS AND ELEVATIONS: WHAT ARE THEY?

As previously mentioned, plan view drawings, such as the Piping Arrangement drawing, provide horizontal dimensions that establish a facility's width and depth measurements. An occasional note or callout is the only reference to height measurements found on plan drawings. To supply more detailed information on height measurements, drawings called S*ections* and

Elevations are developed. Height is the most important dimension on section and elevation drawings. Although these two terms have come to have synonymous meanings, they are conceptually different.

The word *elevation* has a literal meaning of "height above sea level." Both sections and elevations provide height measurements from an object to the ground (Grade). The primary difference is that elevation drawings provide a view of the exterior features of a facility, whereas section drawings represent interior components of a facility that may not be visible from an exterior viewpoint. Comparing this to the features of a house, an elevation represents what the house looks like from the street, whereas a section might show how the furniture in a room is arranged, what type of wallpaper is on the walls, how many pictures are hanging on the walls, or how much attic space is provided above the ceiling.

Height References

Section and elevation drawings are the standard on which vertical measurements for foundations, platforms, steel supports, nozzles, and centerlines for mechanical equipment and pipe are shown. As mentioned in Chapter 9, Equipment Layout, Coordinates and Elevations, the ground, or Grade, is often given an arbitrary value called a *datum elevation*. Since the use of the exact height above sea level dimension is not practical, a datum elevation of 100′-0″ is typically used. All height dimensions are referenced from this 100′-0″ setting and are assigned elevation names to describe their type and location. Elevation names for items above Grade can appear in various forms, such as centerline (¢), top of steel (TOS), top of concrete (TOC), bottom of pipe (BOP), or face of flange (FOF or F/F). Elevation names for items below grade are referred to as *invert* (INV) elevations. The obvious need for the drawing of sections and elevations is to show piping tie-ins to mechanical equipment, calculate lengths for vertical piping runs, check for interferences, verify lines are properly supported, confirm worker and operator access clearances, and establish sufficient overhead clearance required for equipment installation, maintenance, or removal.

Where to Begin?

Sections come from the Piping Arrangement drawing. Once buildings, mechanical equipment, and structural support foundations have been established and pipe, fittings, valves, and instrumentation have been represented on the plan view drawing, some indication of where an internal, vertical view of the facility is needed. The *cutting plane* is such an indicator. The cutting plane callout can be represented in a number of ways. One can resemble a large letter **"L"** with an arrowhead on one end. The direction the arrowhead points indicates the direction from which the facility is being viewed. This "point of view" is the direction from which the section will be drawn. Two cutting planes are spaced a specified distance apart to represent the horizontal extents of the sectional view. Since multiple cutting planes can be used to reference different views, labeling the cutting planes is necessary. Section views will have different sheet numbers so, labeling the cutting plane makes referencing between the plan and section views possible. See Figure 10.46 for three examples of cutting plane callouts.

Named Elevations

Similar to the way section drawings are identified, so too must elevations be identified for reference purposes. The North Arrow, which is placed on the plan view for proper orientation, is also the basis from which the elevation views are named. If an elevation view is named the North Elevation, it means that the drawing is looking at the facility from the north direction as specified by the North arrow on the plan view. If its labeled as an East Elevation, then it is looking at the facility from the east direction. See Figure 10.47 for the North, South, East, and West elevation orientations for Unit-01. Figures 10.48 through 10.51 represent the North, South, East, and West elevations, respectively. These four elevations are rendered views from a 3D model of Unit-01 created with CADWorx software.

Depending on the direction from which the facility is viewed, only one horizontal dimension, either width

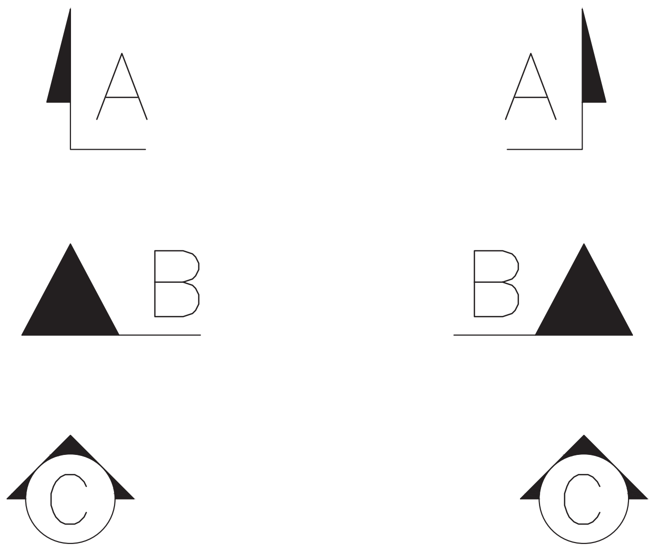


FIGURE 10.46 Cutting Plane examples.

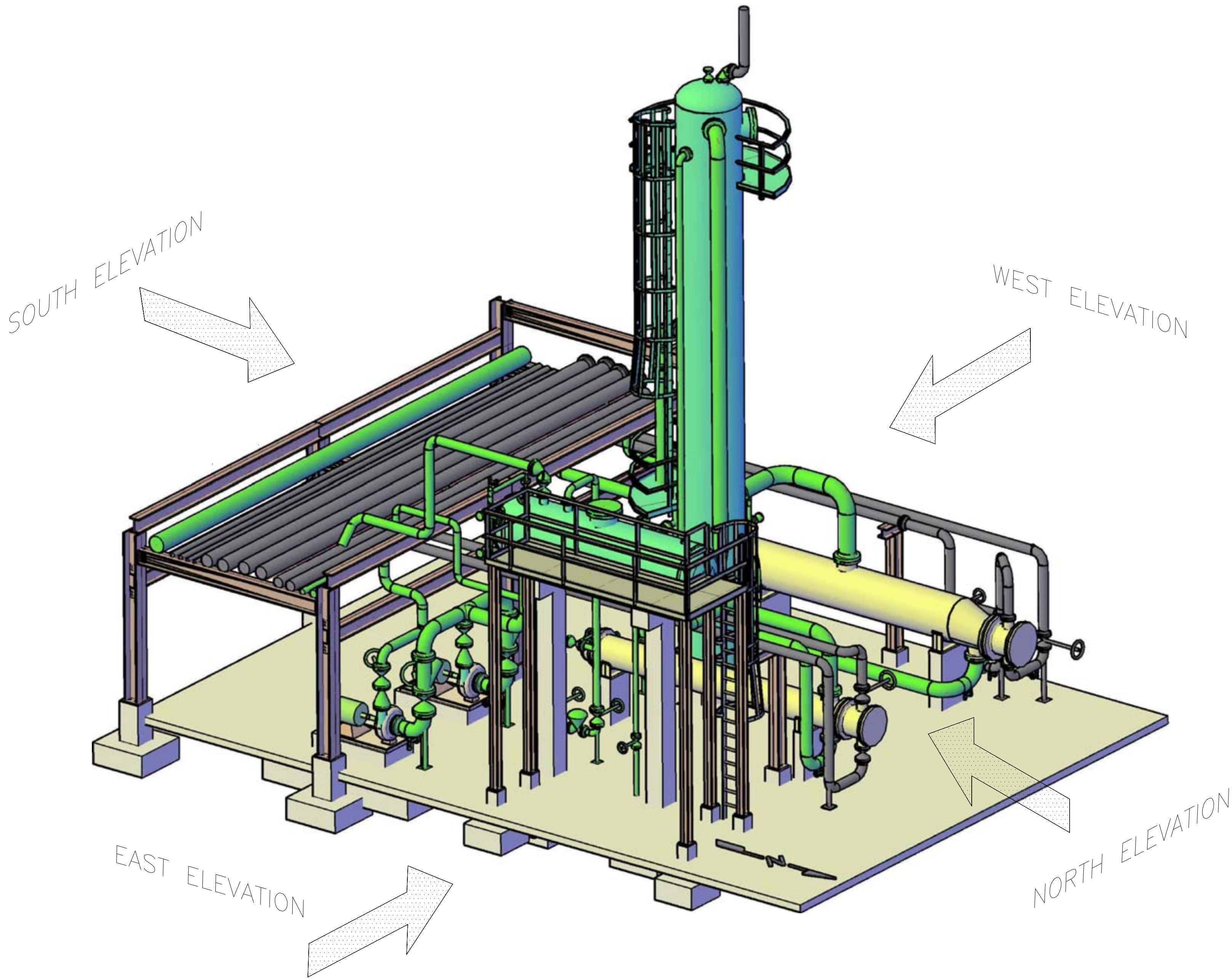


FIGURE 10.47 North, South, East, and West elevation orientations.

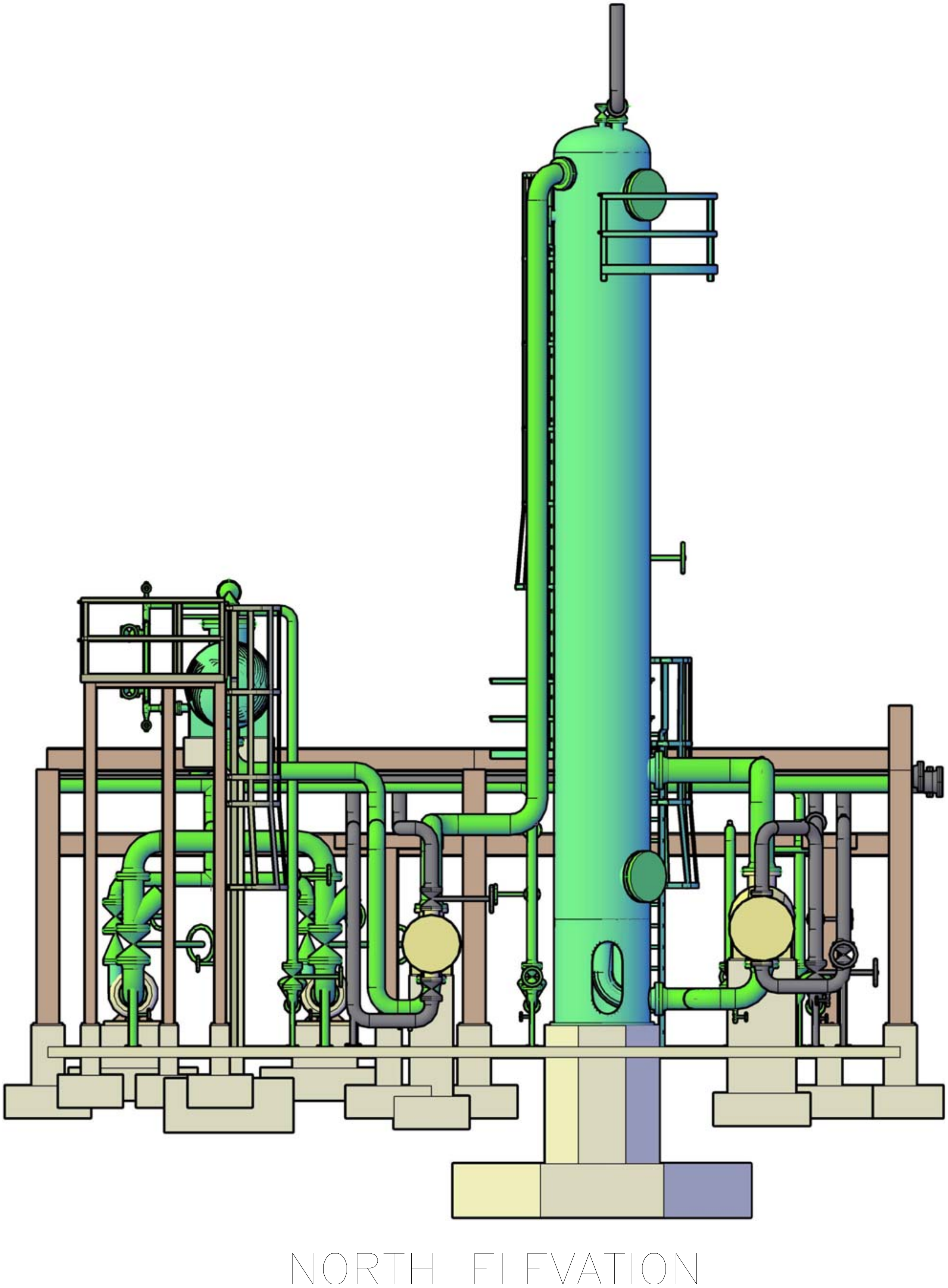


FIGURE 10.48 North elevation of Unit-01.

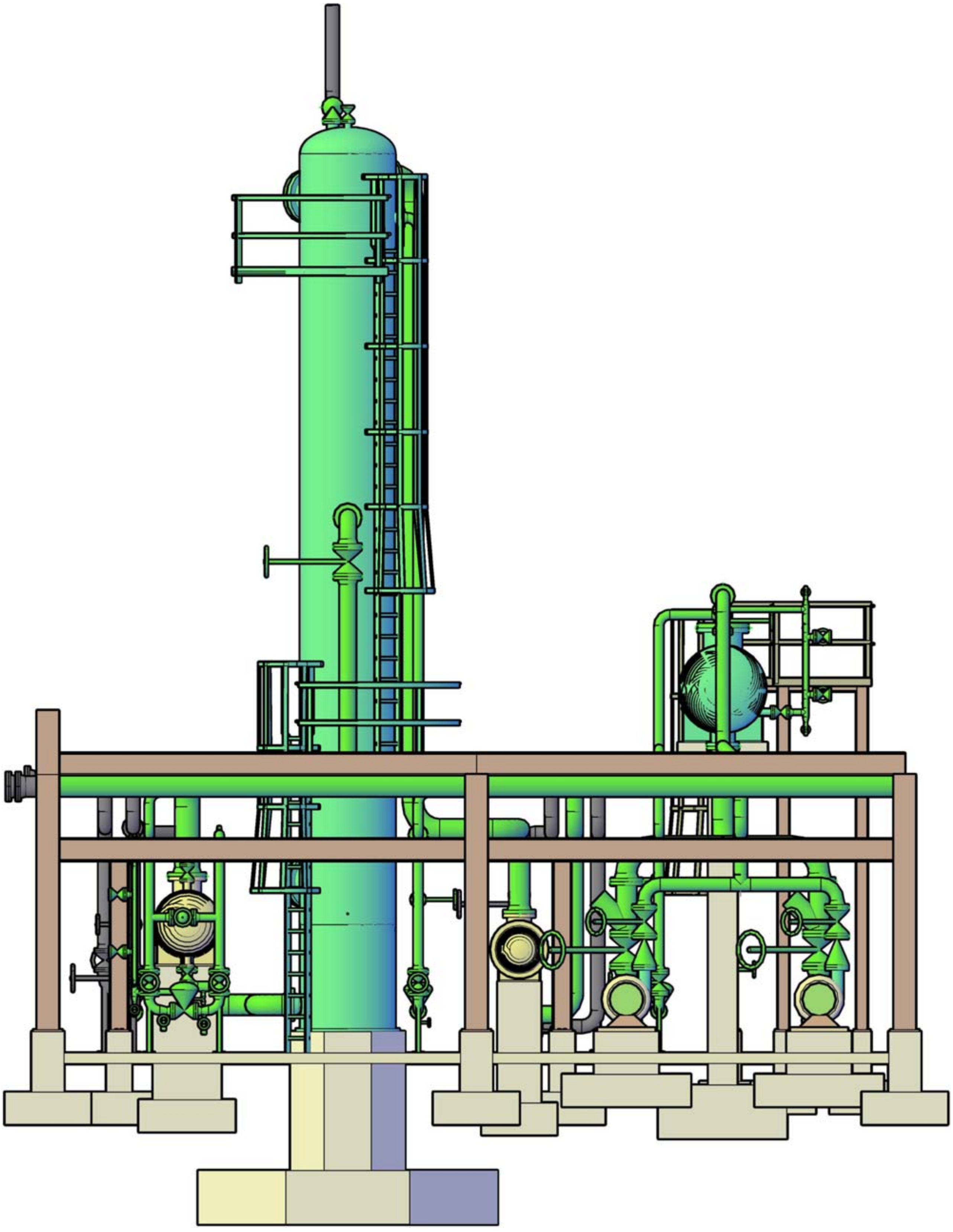


FIGURE 10.49 South elevation of Unit-01.

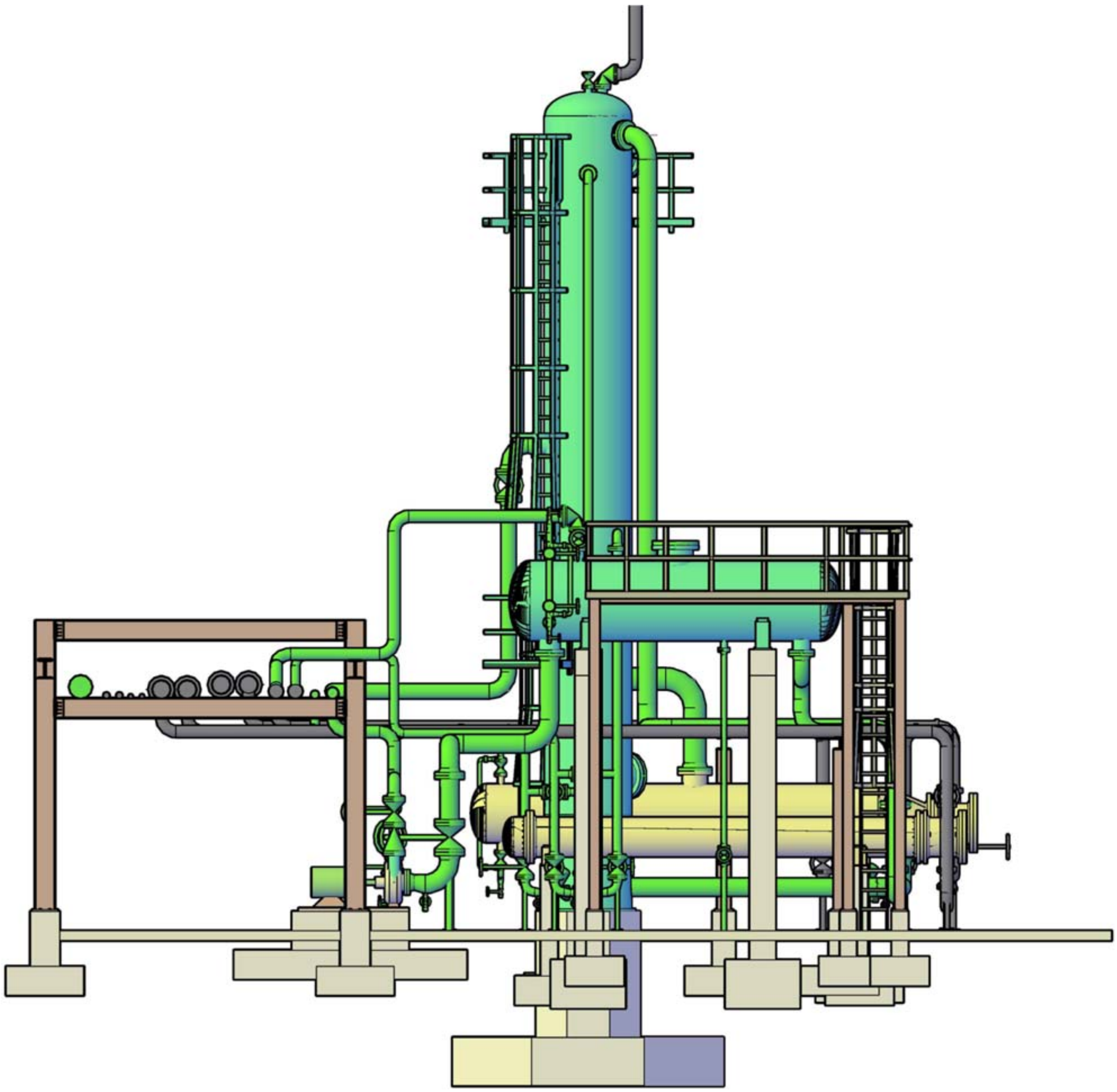


FIGURE 10.50 East elevation of Unit-01.

or depth, is required to locate equipment, foundations, pipe racks, etc. on an elevation drawing. This is unlike plan view drawings that require two intersecting coordinates to locate items. Coordinates for Matchlines, Area Limits, and Battery Limits taken from the Piping Arrangement drawing are used to establish boundaries on the right and left sides of section and elevation drawings. With only one locating coordinate, mechanical equipment can be positioned from the right or left drawing boundaries. It is recommended that all locating measurements be made from either the right boundary or left boundary to avoid misplacement of mechanical equipment and other components. Figures 10.52 and 10.53 illustrate how alignment of Plan and Elevation views can make coordinate location quicker by projecting component positions from the Plan view into an Elevation view.

Vendor drawings are used to establish sizes of mechanical equipment. Nozzle schedules and dimensioning charts provide location, size, and pound ratings

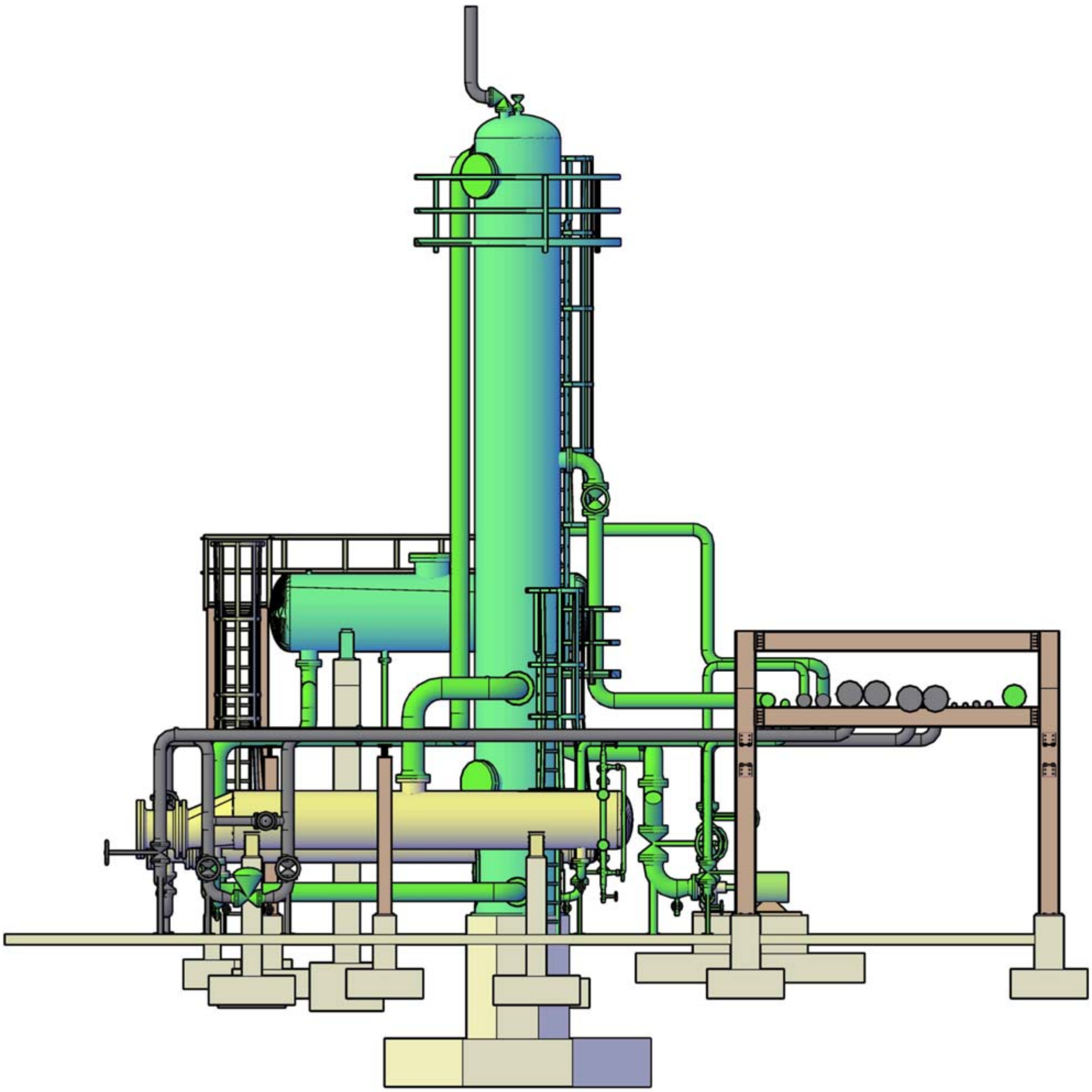


FIGURE 10.51 West elevation of Unit-01.

for equipment nozzles and their mating flanges. Pipe routings, fitting rotations, and handwheel orientations on the arrangement drawings are interpreted and rendered accordingly on the elevation. Although fitting, flange, and valve symbols are the same for plans, sections, and elevations, the rotation and orientation of the symbols will vary. Representation of an elbow that turns down on a Piping Arrangement drawing will be drawn differently when viewed from above than when viewed from the side, as in an elevation drawing.

DETAIL DRAWINGS

Although a simple note or callout can be sufficient in conveying information to a reader, an actual drawing representation will provide much more detailed information. One case in point is the **TOS** callout. Known to mean *top of steel*, this note, and others like it, is the only way of representing height on a plan view drawing. But on a section or elevation drawing, the actual structural steel member can be drawn to provide a graphical representation to the reader. By rendering, height measurements become easily recognizable. Headroom clearances, pipe support spacing, and possible interferences become self-evident. Figure 10.53 represents the East Elevation of Unit-01 as projected from the Plan view (Figure 10.52).

The following guidelines should be used when placing callouts on section or elevation drawings;

- Provide top of steel (TOS) elevations of all pipe supports.
- Include centerline elevations of exchangers and horizontal vessels.
- Specify top of concrete (TOC) or grout elevations for all equipment foundations.
- Provide centerline elevations of horizontal nozzles on mechanical equipment, including piping and instrumentation nozzle connections.
- Label face of flange elevations for nozzles attached to the top or bottom of vertical vessels, exchangers, and suction and discharge nozzles on pumps, turbines, and compressors.
- Indicate high point of finished grade (datum elevation).
- Mark top of grating or plate on platforms.
- Include bottom of pipe (BOP) elevation for pipelines on shoes.
- Provide centerline elevation of relief valves.

The following list contains some DO NOTS relating to the dimensioning of plan, elevation, or section drawings.

DO NOT

- Dimension from underground lines to aboveground lines.

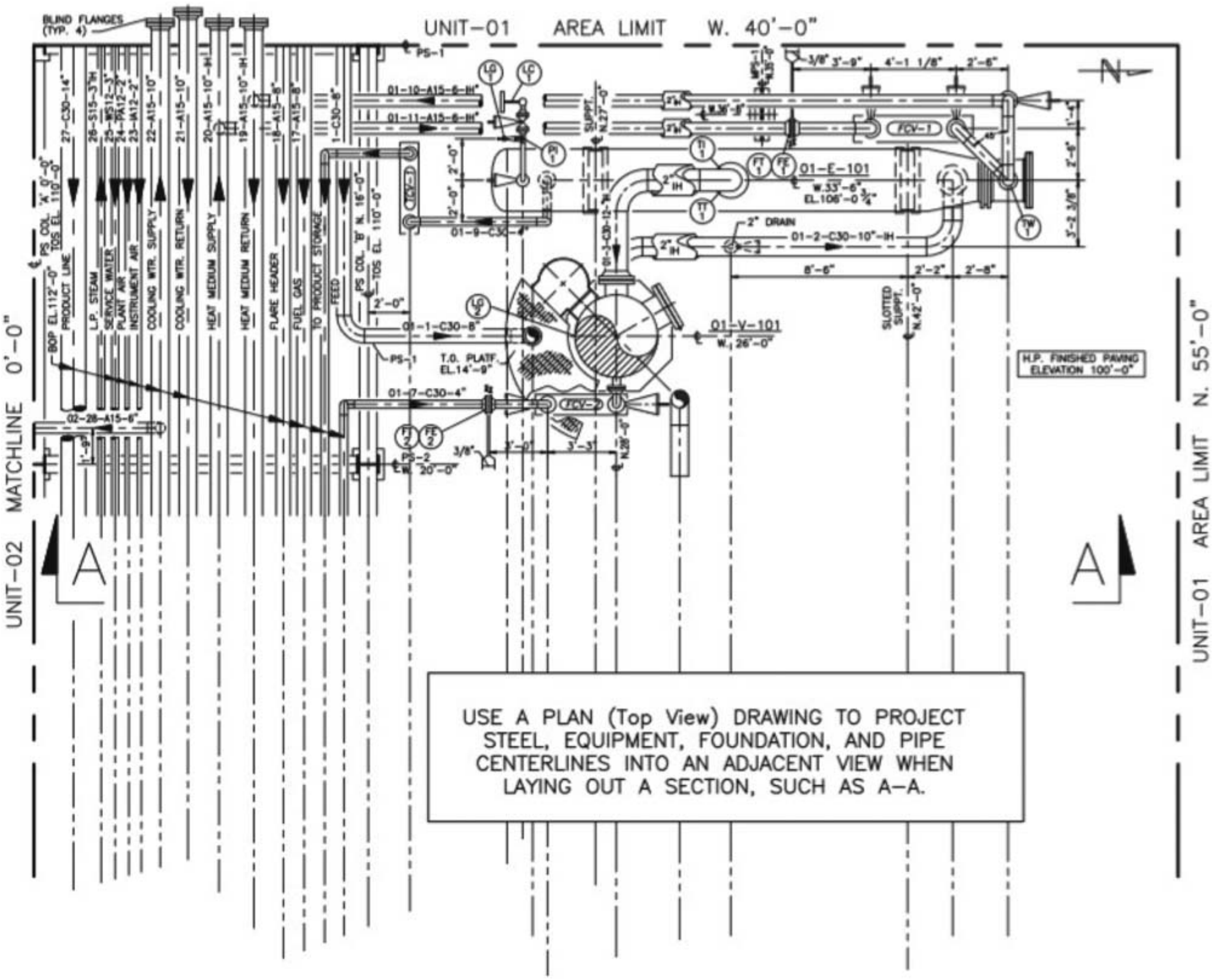


FIGURE 10.52 Projection of coordinates.

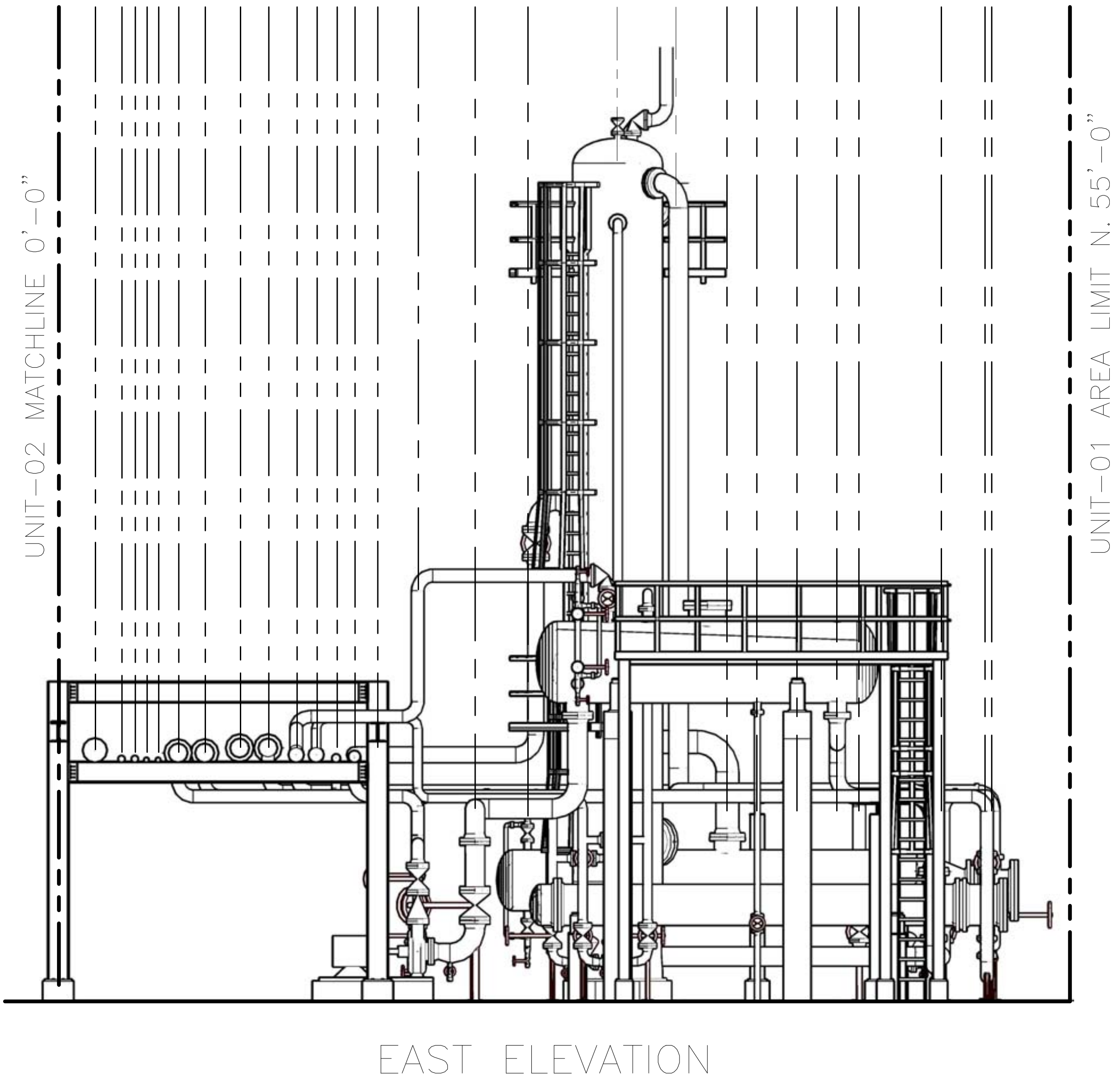


FIGURE 10.53 East Elevation of Unit-01.

- Dimension from lines running at one elevation to lines running at a different elevation within pipe racks or other areas.
- Dimension to the center of a valve, except with small bore screwed or socket-weld valves.
- Dimension piping from electrical cable trays, conduit, or instrument tray runs.
- Dimension internal equipment piping to external piping.
- Dimension piping from outlines of buildings, structures, or mechanical equipment.
- Dimension "fitting make-up" installations.
- Dimension the lengths of standard piping components such as elbows, tees, reducers, etc.

PIPE LINE LIST

The Pipe Line List is a compilation of the named lines that exist in a facility. Developed early in the design phase, the Pipe Line List contains valuable

PIPE LINE LIST

REVISION	UNIT No.	LINE No.	LINE CLASS	LINE SIZE	INSUL	COMMODITY	VAP / LIQ	DESCRIPTION: ORIGIN FROM	DESCRIPTION: TERMINUS TO	DESGN PSIG	OPER. PSIG	DESGN °F	OPER. °F
△	01	1	C30	8"	NO	HYDRO-CARBON FEED	V / L	LOADING FACILITY/STORAGE	V-101	300	255	250	210
△	01	2	C30	10"	2" IH	HYDRO-CARBON	V / L	V-101	E-101	300	250	275	245
△	01	3	C30	12"	2" IH	HYDRO-CARBON	L	E-101	V-101	300	250	275	230
△	01	4	C30	10"	NO	HYDRO-CARBON	V	V-101	E-102	300	250	275	245
△	01	5	C30	8"	NO	HYDRO-CARBON	L	E-102	V-102	300	245	150	125
△	01	6	C30	10"	NO	HYDRO-CARBON	L	V-102	P-101A P-101B	300	240	150	118
△	01	7	C30	6"	NO	HYDRO-CARBON	L	P-101A P-101B	V-101	300	240	150	118
△	01	8	C30	6"	NO	HYDRO-CARBON	L	P-101A P-101B	UNIT-03 AREA LIMITS/ STORAGE	300	240	150	118
△	01	9	C30	4"	NO	HYDRO-CARBON	L	E-101	PRODUCT STORAGE	300	240	150	118
△	01	10	A15	6"	2" IH	HEATING MEDIUM RETURN	L	E-101	UNIT SUPPLY HEADER (01-19-A15-10"-IH)	150	100	500	400
△	01	11	A15	6"	2" IH	HEATING MEDIUM SUPPLY	L	UNIT SUPPLY HEADER (01-20-A15-10"-IH)	E-101	150	100	500	400
△	01	12	C30	4"	NO	PROPANE	L	V-102	FUEL GAS HEADER (01-17-A15-8")	310	280	150	118
△	01	13	A15	6"	NO	HYDRO-CARBON	V	V-102	FLARE HEADER (01-18-A15-8")	300	250	275	230
△	01	14	A15	6"	NO	COOLING WATER RETURN	L	E-102	UNIT SUPPLY HEADER (01-21-A15-10")	100	40	100	75
△	01	15	A15	6"	NO	COOLING WATER SUPPLY	L	UNIT SUPPLY HEADER (01-22-A15-10")	E-102	100	40	125	95
△	01	16	C30	2"	NO	HOT OIL	L	V-102	OWS	——	——	——	——
△	01 / 03	17	A15	8"	NO	PROPANE	V	UNIT-01 AREA LIMITS/ LOADING	UNIT-03 AREA LIMITS/ STORAGE	150	80	500	180
△	01 / 03	18	A15	10"	NO	HC FLARE	V	UNIT-01 AREA LIMITS/ LOADING/UNLOADING	FLARE STACK 03-FS-305	100	40	150	118
△	01 / 03	19	A15	10"	2" IH	HEATING MEDIUM RETURN	L	UNIT-01 AREA LIMITS/ FUTURE	HEATER 03-H-304	150	100	500	400
△	03 / 01	20	A15	10"	2" IH	HEATING MEDIUM SUPPLY	L	P-301A P-301B	UNIT-01 AREA LIMITS/ FUTURE	150	100	500	400
△	01 / 04	21	A15	10"	NO	COOLING WATER SUPPLY	L	UNIT-01 AREA LIMITS/ FUTURE	PRODUCT CONDENSER 04-E-402A&B	100	60	100	75
△	04 / 01	22	A15	10"	NO	COOLING WATER RETURN	L	COOLING TOWER 04-CT-406	UNIT-01 AREA LIMITS/ FUTURE	100	40	125	95
△	01 / 03	23	IA12	2"	NO	INSTR AIR	V	UNIT-01 AREA LIMITS/ CTRL BLDG	UTILITY STATION No.1	100	90	125	100
△	01 / 03	24	PA12	2"	NO	UTILITY AIR	V	UNIT-01 AREA LIMITS/ CTRL BLDG	UTILITY STATION No.1	150	100	125	100
△	01 / 03	25	WS12	3"	NO	SERVICE WATER	L	UNIT-01 AREA LIMITS/ CTRL BLDG	UTILITY STATION No.1	90	50	125	100
△	01 / 03	26	S15	3"	2" IH	50# STEAM	V	UNIT-03 AREA LIMITS	UNIT-01 AREA LIMITS/ LOADING/UNLOADING	75	50	320	298

SHEET 1 of 2

FIGURE 10.54 Pipe Line List, (a) Sheet 1 of 2 and (b) Sheet 2 of 2.

PIPE LINE LIST

REVISION	UNIT No.	LINE No.	LINE CLASS	LINE SIZE	INSUL	COMMODITY	VAP / LIQ	DESCRIPTION ORIGIN FROM	DESCRIPTION TERMINUS TO	DESGN PSIG / OPER. PSIG	DESGN °F / OPER. °F
△	01/02 03	27	C30	14”	NO	PRO-DUCT FEED	V L	UNIT-02 02-V-203	UNIT-03 AREA LIMITS/ PRODUCT STORAGE LOADING/UNLOADING	300 255	250 210
△	01 02	28	A15	10”	NO	COOLING WATER SUPPLY	L	UNIT SUPPLY HEADER (01-22-A15-10”)	02-E-201	100 40	100 75
△	02 01	29	A15	6”	NO	COOLING WATER RETURN	L	02-E-201	UNIT SUPPLY HEADER (01-21-A15-10”)	100 40	125 95
△	03	30	A15	6”	NO	FUEL GAS	V	FUEL GAS HEADER (01-17-A15-8”)	HEATER 03-H-304	150 80	500 180
△	03	31	A15	12”	2” IH	HEATING MEDIUM SUPPLY	L	HEATER 03-H-304	P-301A P-301B	150 100	500 400
△	03	32	A15	6”	NO	HC FLARE	V	03-V-303	FLARE STACK 03-FS-305	100 40	150 118
△	03	33	A15	4”	NO	HC FLARE	V	UNIT-03 AREA LIMITS	03-V-303	100 40	150 118
△	02	34	A15	12”	NO	HYDRO-CARBON	L	UNIT-02 AREA LIMITS/ PRODUCT STORAGE	02-V-203	300 240	150 118
△	02	35	A15	6”	2” IH	HYDRO-CARBON	L	02-V-203	02-P-202A 02-P-202B	300 240	150 118
△	02	36	C30	4”	2” IH	HYDRO-CARBON	L	02-P-202A 02-P-202B	02-37-A15-4”-IH	150 100	500 400
△	02	37	A15	4”	2” IH	HYDRO-CARBON	L	02-36-C30-6”-IH	02-38-A15-6”-IH	150 100	500 400
△	02	38	A15	6”	NO	HYDRO-CARBON	L	02-E-201	02-V-203	310 280	150 118
△	02	39	A15	6”	NO	HYDRO-CARBON	V	02-V-203	02-E-201	300 250	275 230
△	04	40	C30	12”	2” IH	HYDRO-CARBON	L	04-V-401	04-E-404	310 280	500 365
△	04	41	C30	10”	2” IH	HYDRO-CARBON	L	04-E-404	04-V-401	310 280	500 400
△	03 04	42	C30	8”	NO	PRO-DUCT FEED	V L	03-27-C30-14”	04-V-401	300 255	250 210
△	03 04	43	C30	4”	NO	HYDRO-CARBON	V L	03-8-C30-6”	04-V-401	300 240	150 118
△	04	44	C30	10”	NO	REFLUX	V	04-V-401	04-E-402A 04-E-402B	100 40	150 118
△	04 03	45	A15	6”	2” IH	HEATING MEDIUM RETURN	L	03-19-A15-10”-IH	04-E-404	150 100	500 400
△	03 04	46	A15	6”	2” IH	HEATING MEDIUM SUPPLY	L	04-E-404	03-20-A15-10”-IH	150 100	500 400
△	04 03	47	C30	4”	NO	HYDRO-CARBON	L	04-E-404	03-9-C30-4”	300 240	150 118
△	03 04	48	C30	8”	NO	PRO-DUCT FEED	L	04-E-402A 04-E-402B	03-27-C30-14”	100 40	125 95
△	04	49	A15	8”	NO	COOLING WATER RETURN	L	04-E-402A 04-E-402B	04-CT-406	100 90	125 100
△	04	50	A15	8”	NO	COOLING WATER SUPPLY	L	04-22-A15-8”	04-E-402A 04-E-402B	100 100	100 75
△	04	51	A15	8”	NO	COOLING WATER SUPPLY	L	04-CT-406	04-P-405A 04-P-405B	100 100	100 75
△	03	52	A15	6”	NO	PROPANE	V	FUEL GAS HEADER (01-17-A15-8”)	FLARE STACK 03-FS-305	150 80	500 180

SHEET 2 of 2

FIGURE 10.54 (Continued).

information used by many disciplines throughout the project's development. The Line List will indicate each pipe's number, specification class, and nominal pipe size. It will also specify what Unit the pipe is in, which pieces of mechanical equipment it is attached to, and if the pipe is insulated or not. The commodity in the pipe is shown, along with its Design and Operating temperature and pressure. Figure 10.54a and b lists all of the pipes included in Units 01–04.

CHAPTER 10 REVIEW QUIZ

1. What is a Piping Arrangement drawing?

____

____

2. What is a nozzle schedule?

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____

3. Name five reference drawings or documents needed by a piping designer to lay out the Piping Arrangement drawing.

____

____

____

____

____

4. To what scale are full-scale piping drawings placed inside a border?

____

____

5. How is Scale Factor determined?

____

____

____

6. Which drawing is used as a reference drawing when locating centerlines for pipe racks and equipment foundations?

____

____

7. What is the minimum height of text used on piping drawings that are going to be placed in a border at 3/8″ = 1′-0′ scale?

____

____

8. Explain the difference between Section and Elevation views.

____

____

____

____

9. Define datum elevation.

____

____

____

10. What is the most important measurement shown on Section or Elevation drawings?

____

CHAPTER 10 DRAWING EXERCISES

Exercises: Plans, Elevations, and Sections

Exercise 10.1. Using the layout procedures discussed in this chapter, develop the Piping Arrangement drawing of Unit-01 as shown in Figure 10.1.

Exercise 10.2. Render the elevation view of Unit-01 as shown in Figure 10.53.

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CHAPTER

11

Standard Piping Details

Any project having the complexity of a piping facility will undoubtedly have many components that are used repeatedly throughout the facility. In an attempt to reduce the volume of drawings produced, many companies employ the use of *Standard Piping Details*. The standard piping detail is a drawing that depicts an item or items that are used with such frequency and having such consistency in their installation procedure that a single drawing can be created and duplicated for use to represent their installation in almost every situation. Situations in which standard piping details are most likely to be used are for the support, anchoring, guiding, and spacing of pipe. This chapter discusses the methods and devices used in these applications.

PIPE RACK SPACING

Arrangement and positioning are important factors in the layout of a piping facility. Space is limited. Area and boundary limits force conservation of space. Arranging equipment throughout the unit in an orderly and sequential fashion is a necessity. Therefore proper spacing and arrangement of pipe in the pipe rack requires special attention. A pipe rack has a defined width; therefore working within the allotted space makes spacing crucial. Not only must pipe be arranged to take up a minimum amount of space, but also allowances should be made for any pipe that might be added in the future.

Line spacing dimensions are based on a clearance of 1″ between the outside diameter of the largest flange and that of the adjacent pipe. The minimum spacing between any two lines is 4″. If either of the lines is insulated, the thickness of the insulation must be added. When lines are placed adjacent to a building, wall, column, or other structure, a minimum clearance of 2″ is required from the outside diameter of a flange. Pipes having orifice flanges will require a larger minimum clearance than indicated on the charts because of the valve taps and connecting instrumentation. Typically, a minimum clearance of 2′-0″ is used on either side of a pipe having orifice flanges. Figure 11.1 shows the requirements for establishing the minimum clearances for line spacing.

The line spacing chart shown in Table 11.1 provides the minimum clearances for pipe without insulation.

DRAWING PIPE IN THE RACK

When representing pipe in a pipe rack, the careful arrangement and organization of names, dimensions, and line numbers will make the drawing easier to read. Figure 11.2 shows a pipe rack that has been well organized. Notice how the alignment of notes, dimensions, and other callouts makes the drawing easy to read.

The following guidelines will help you organize your drawing:

1. Keep flow arrows the same size and aligned.
2. Line numbers should be left justified when possible.
3. Pipe commodity should be identified on utility lines only.
4. Line spacing dimensions should align across the pipe rack from one pipe support column to the other. This allows coordinates for each pipe to be calculated since each pipe support column is positioned using a coordinate.

PIPE FLEXIBILITY

A major concern when arranging pipe in a rack is the amount of expansion and, to an extent, contraction that occurs when a cold pipe is heated to its normal operating temperature. Because the dimensions provided in the line spacing chart do not account for expansion of a pipe during the start-up of a unit, consideration must be given to the amount of expansion a

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00012-1

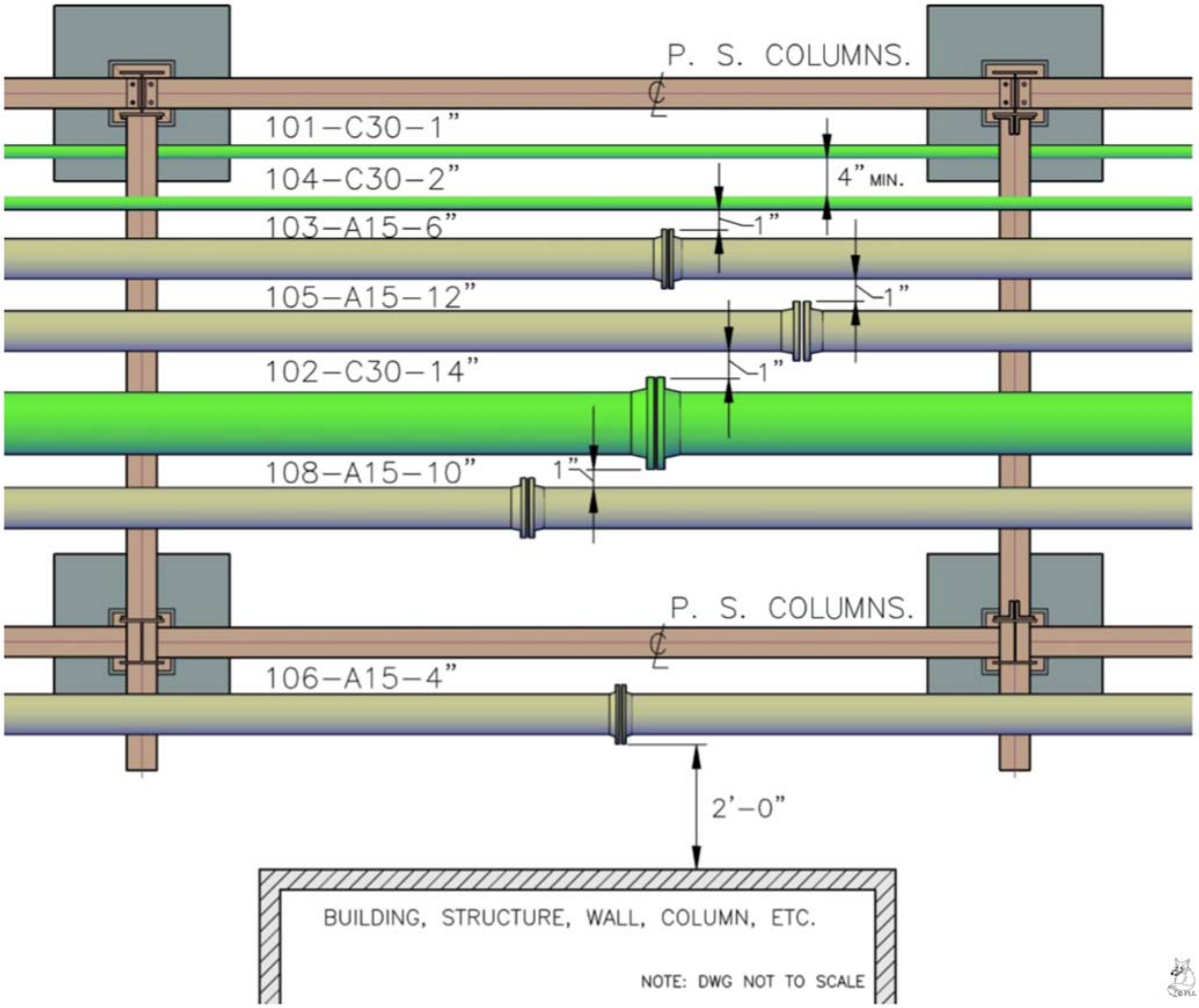


FIGURE 11.1 Line spacing clearance requirements.

pipe will undergo as its temperature begins to rise. If the expansion of a pipe will result in its interference with an adjacent pipe, line spacing will have to be increased. If the normal expansion of a pipe will not result in interference, line spacing will not be affected. Remember, space in the rack is limited. Overspacing must be avoided. Figure 11.3 provides two illustrations where additional line spacing may be required.

The interference occurring at point *1* is a result of linear expansion. Lines 103 and 104 have similar spacing in the rack. Both pipes drop out of the rack and rest on a support beam before attaching to a piece of equipment. Using the spacing dimension provided in the line spacing chart, these lines need 8″ for adequate clearance. Additional calculations indicate that line 103 is expanding 2″ to the south and line 104 is expanding 2″ to the north. By adding one-half the OD of line 103 ($2\frac{1}{4}$″) and one-half the OD of line 104 ($2\frac{1}{4}$″) and the 2″ of expansion for each pipe, it is obvious an interference will result. To avoid this interference, two alternatives are feasible:

1. Increase the spacing between the two pipes if the ends of the pipe where they attach to the pieces of equipment allow it. If this is not possible, use the next alternative.
2. *Cold spring* lines 103 and 104 1″. Cold spring is an installation technique that requires the length of the pipe that is expanding to be cut short by a distance equal to one-half of the length of expansion. In this case, 1″ for each line.

When trying to solve the interference problem occurring at point 2, a similar approach can be taken. Either add 1″, the amount of expansion, to the line

TABLE 11.1 Line Spacing Chart.

150# PIPE SIZE	300# 16	14	12	10	8	6	4	3	2
2	15	14	13	11	10	9	8	7	6
3	16	15	13	12	11	9	8	7	6
4	16	15	13	12	11	10	9	8	7
6	18	16	15	14	12	11	10	9	8
8	19	17	16	15	13	12	11	10	9
10	20	18	17	16	14	13	12	11	11
12	21	19	18	17	15	14	13	13	12
14	21	20	19	17	16	15	14	14	13
16	22	21	20	19	18	17	15	15	14

150#	150# 16	14	12	10	8	6	4	3	2
2	14	13	12	11	9	8	7	6	6
3	15	14	13	11	10	9	8	7	
4	15	14	13	12	10	9	8		
6	17	15	14	13	12	10			
8	18	16	15	14	13				
10	19	17	16	15					
12	20	18	17						
14	20	19							
16	21								

300#	300# 16	14	12	10	8	6	4	3	2
2	15	14	13	11	10	9	8	7	6
3	16	15	13	12	11	9	8	7	
4	16	15	14	12	11	10	9		
6	18	16	15	14	12	11			
8	19	17	16	15	13				
10	20	18	17	16					
12	21	19	18						
14	21	20							
16	22								

spacing dimension or cold spring line 101½″ to the west and add ½″ to the line spacing dimension.

PLANNING FOR HEAT EXPANSION

Thermal expansion will have an effect on pipe, pipe supports, and even come process commodities. The amount of expansion caused by rising temperatures can be quite significant on long runs of pipe, especially those in a pipe rack. To absorb the expansion of pipe in a rack, *pipe loops* are often incorporated. Figure 11.4 shows a pipe loop as a *U-shaped* routing of the line designed to contain the expansion of the pipe. Loops are typically located near the midpoint of a long run of pipe. Expansion will cause the two ends of the pipe to grow toward one another resulting in the distortion of the loop as shown in Figure 11.5.

When multiple loops are placed at the same location, as shown in Figure 11.4, adequate line spacing requires the deflection of each loop be calculated to avoid interference.

Lines resting on *T-supports* must be designed carefully as well. If a line is positioned too close to the end

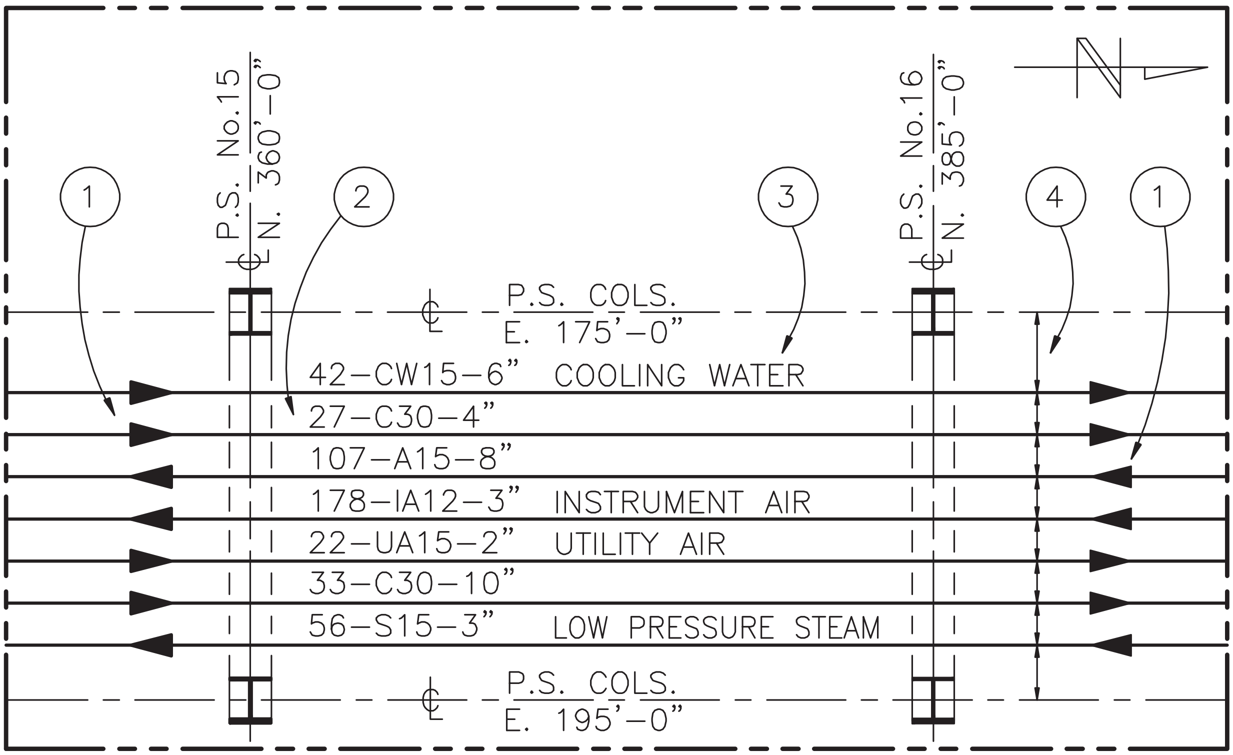


FIGURE 11.2 Pipe rack drawing organization.

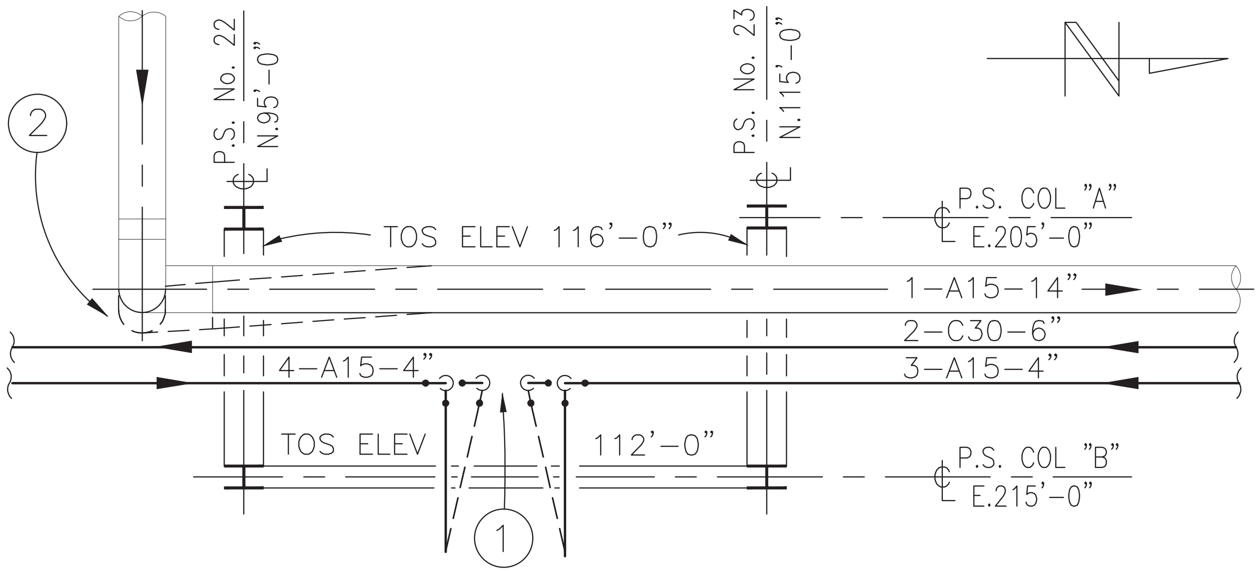


FIGURE 11.3 Pipe expansion.

of a support, expansion may push the pipe off the support (see Figure 11.6). Situations like this may require a cold spring or a longer *T-support*.

When multiple lines resting adjacent to one another turn in the same direction, attention must be given to the fact that one line can grow, whereas the other does not. In Figure 11.7, assume lines 105 and 106 are both expanding at the same rate and in the same direction. As they both grow, adequate line spacing will be maintained. But what if line 106 was a cold line and did not grow at the same rate as line 105? Expansion from line 105 would cause interference with 106. To avoid this, the line spacing dimensions *X* and *Y* in Figure 11.7 must be calculated to reflect the conditions of one line being hot and the other cold. Calculations using the hot/cold scenario will guarantee adequate spacing at all times.

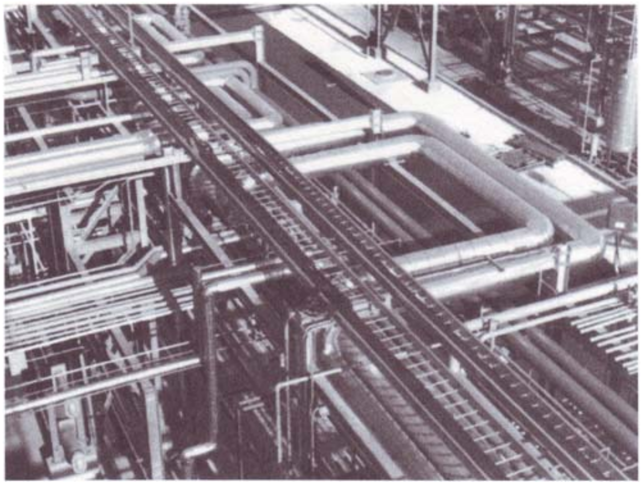


FIGURE 11.4 Pipe expansion loop. *Courtesy Nisseki Chemical Texas, Inc. Bayport, Texas.*

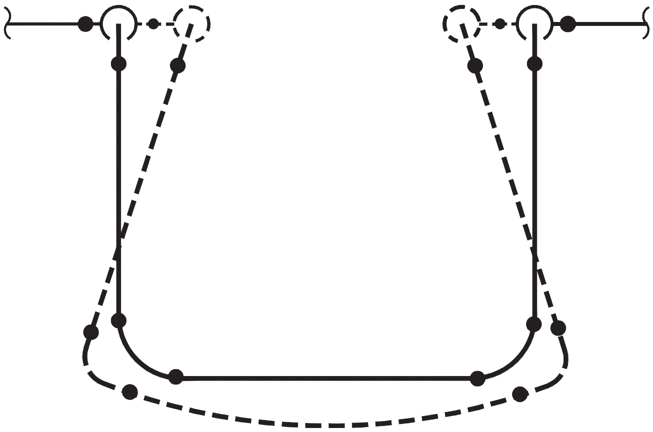


FIGURE 11.5 Pipe loop distortion.

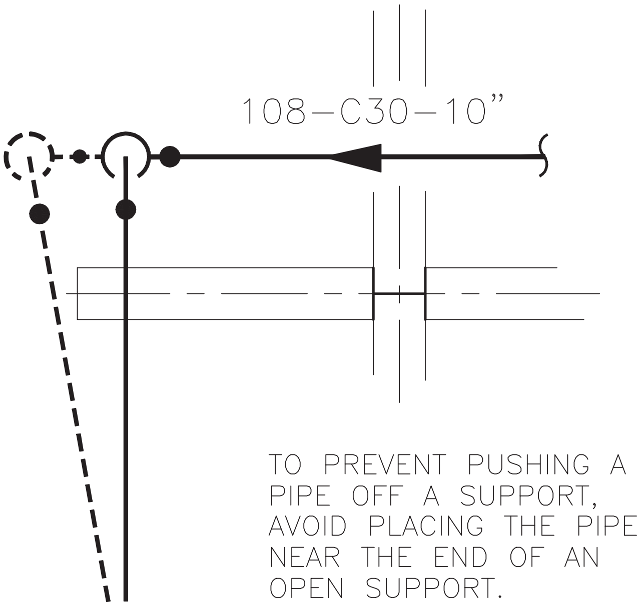


FIGURE 11.6 Pipe expansion on T-supports.

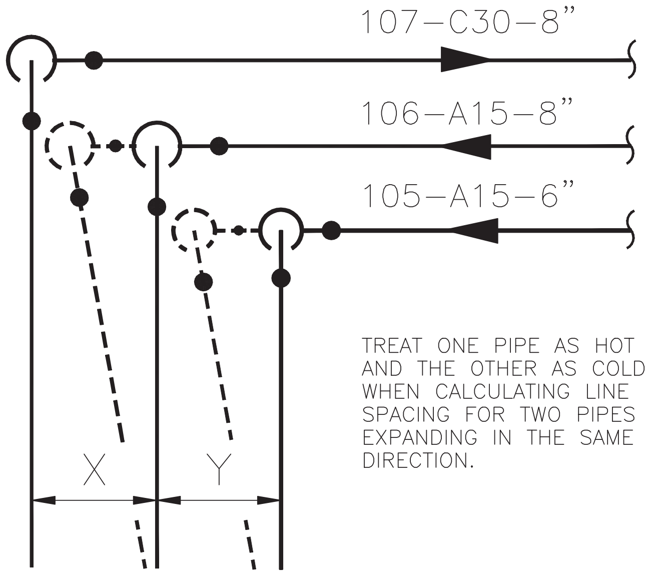


FIGURE 11.7 Hot and cold line spacing.

PIPE ANCHORS

Expansion is not the only force that can alter the alignment of a pipe. Vibration, commodity turbulence, and other external forces, such as wind, cause a pipe to move. Often restriction of a pipe's movement becomes necessary. To prevent movement or to control the direction of movement, *pipe anchors* are often used. Two types of pipe anchors exist: *fixed* and *directional*. Fixed anchors are used in locations where all movement of a line must be prevented. The most common way to anchor a pipe is to weld the pipe directly to a support or structural member. If the pipe to be anchored is insulated, the pipe *shoe* is welded to the structural support. Shoes will be discussed later.

Directional anchors are used to force movement to occur in one direction while preventing it from occurring in the opposite direction. Directional anchors are often used to direct a pipe's movement away from buildings, structures, or pieces of equipment. Figure 11.8 depicts the anchoring of uninsulated pipe 4″ and smaller. Figure 11.9 depicts the anchoring of uninsulated pipe 6″ and larger.

PIPE INSULATION SHOES

Pipe is often insulated to prevent heat loss or to ensure worker safety. Anchoring lines with insulation require special preparation. Resting insulated pipe directly on structural support damages the insulation. To protect the insulation, some *pipe shoes* are welded to the pipe at the location where it rests on a support. In Figure 11.10 the rendering on the left depicts the

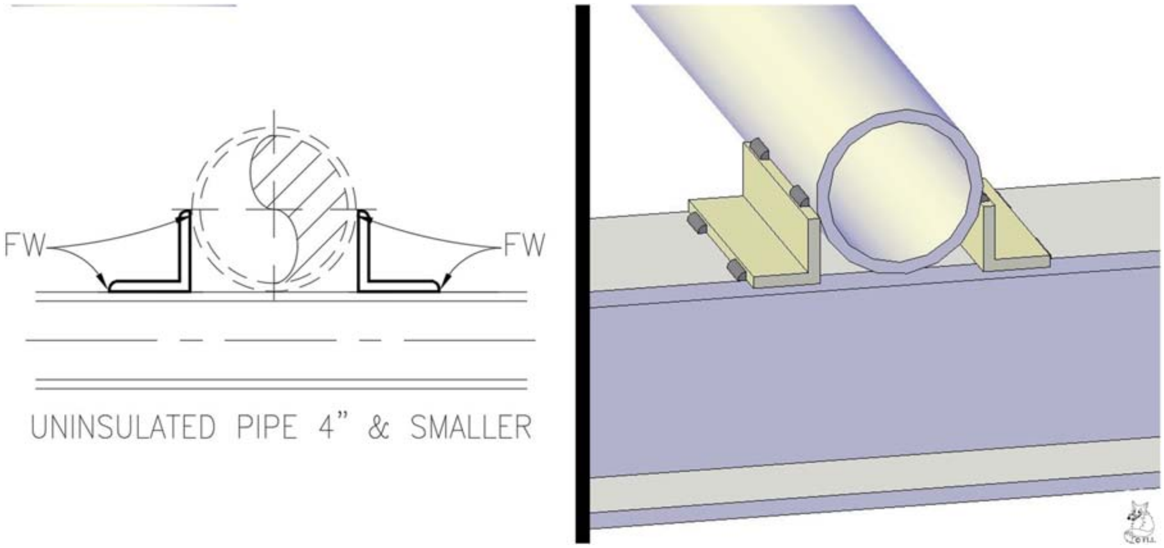


FIGURE 11.8 Uninsulated 4″ and smaller pipe anchors.

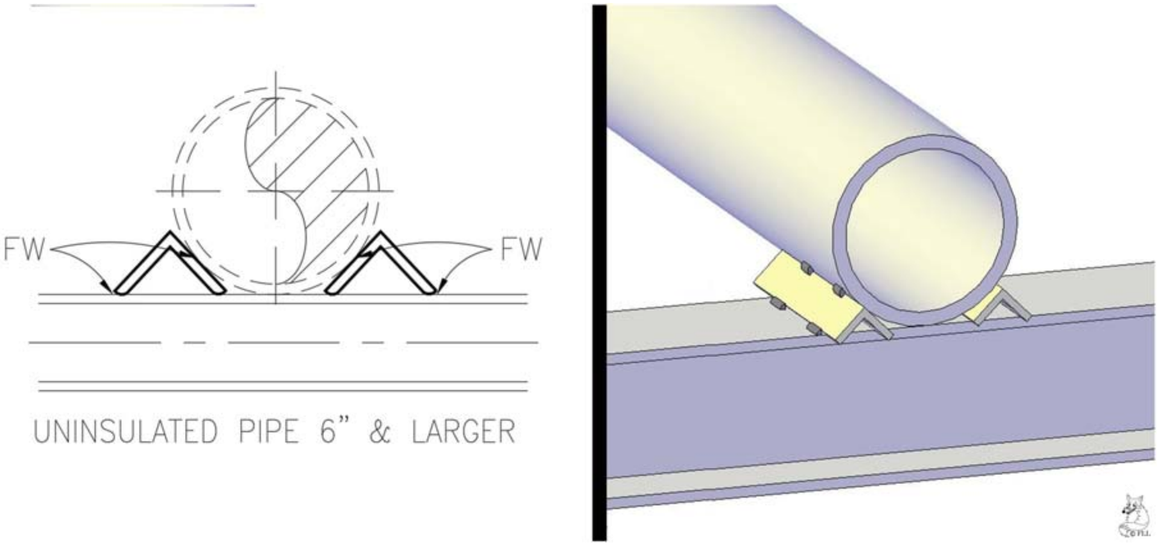


FIGURE 11.9 Uninsulated 6″ and larger pipe anchors.

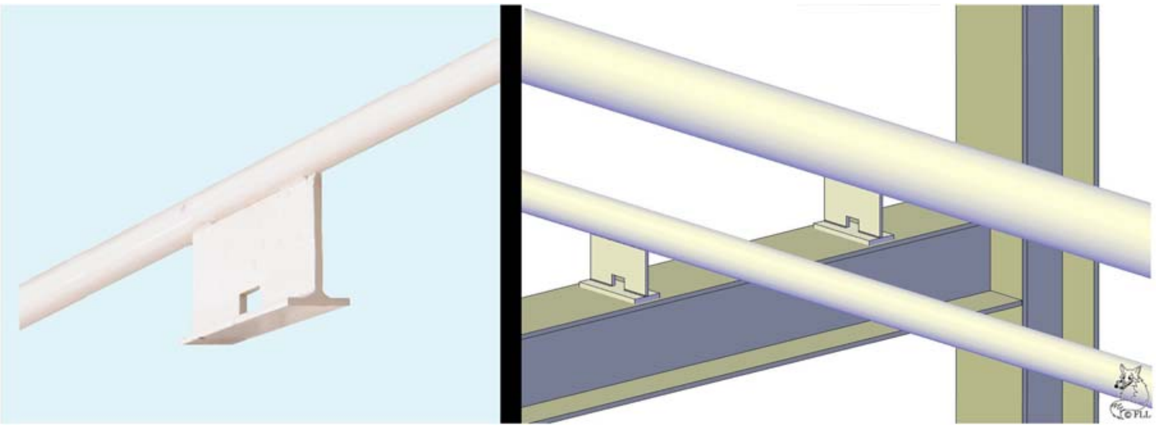


FIGURE 11.10 Welded pipe shoe.

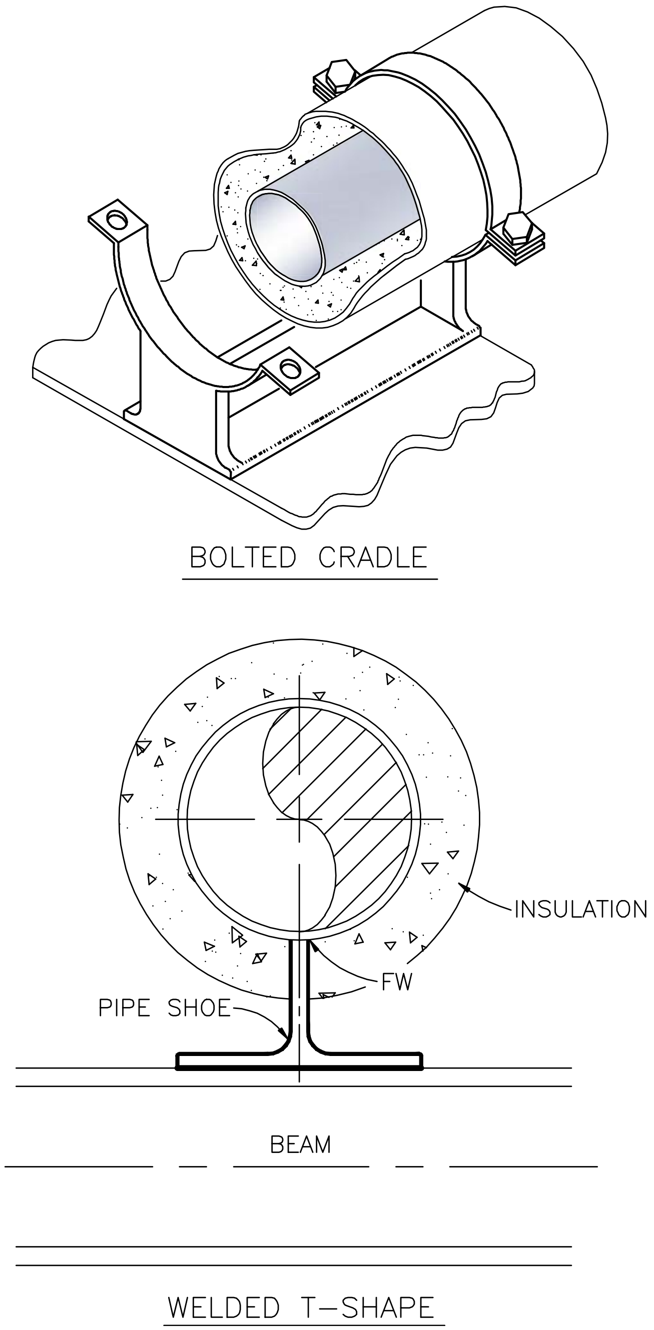


FIGURE 11.11 Bolted and welded pipe shoe.

welded shoe prior to the pipe's installation in a pipe rack. The rendering on the right in Figure 11.10 illustrates how the pipe shoe rests on a beam and lifts the pipe above the supporting beam prior to insulation being installed.

Shoes are approximately 12″ long and can made from steel plate, or 3″ tall structural T-shapes. If job specifications specify no welding, typically on larger diameter pipe, a bolted cradle shoe is attached to the pipe at the point where it rests on a support (see Figure 11.11). As with a welded shoe, the pipe is elevated above the support, preventing damage to the insulation. Some job specifications stipulate pipe smaller than 3″ NPS to have insulation thin enough that it can be cut away from the pipe at the point where the insulation would rest on a support. Therefore no shoes are required.

PIPE GUIDES

When total restriction of pipe movement is not required, *pipe guides* are used. Pipe guides confine movement along the pipe's lineal axis. Used primarily to maintain proper line spacing in a pipe rack, pipe guides prevent lateral or sideways movement. Unlike the pipe anchor, which is welded to the pipe and structural support, the guide allows pipe to slide lengthwise between two angle shapes. Figure 11.12 depicts how guides are placed on uninsulated pipe 4″ and smaller. Figure 11.13 depicts how guides are placed on uninsulated pipe 6″ and larger. When a pipe is supported on shoes, the angle shapes are positioned on either side of the shoe to prevent side-to-side movement (see Figure 11.14).

PIPE SUPPORTS

The proper design of any pipe routing and configuration must account for the limitations of the pipe itself. Depending on the pipe's diameter and wall thickness (schedule), a pipe can only span a specified distance before it begins to deform. For pipes installed horizontally, this deformation is called *deflection*. Deflection is the amount of sag or droop that is allowed in a run of pipe before it adversely affects commodity flow. If a pipe is not properly supported, it will sag to the point where the commodity flowing inside will either slow down, thereby reducing the efficiency of the unit, or it may collect or *pocket* in the low point of the run of pipe. The following chart, shown in Figure 11.15, provides "Recommended" and "Maximum" pipe spans and deflection amounts for carbon steel pipe filled with water of various sizes and schedules. The left side of the chart is for uninsulated pipe 200°F and below. The right side of the chart is for insulated lines 201°F through 599°F.

On long, vertical runs of pipe it is crucial not to exceed load allowances on mechanical equipment nozzles. To avoid ripping a nozzle off the top or side of a vertical vessel, pipe supports are used to keep the shear forces within acceptable limits. A pipe's size, both diameter and length, wall thickness, pound rating, and insulation thickness all contribute to the load on a nozzle. Additionally, movement in the form of

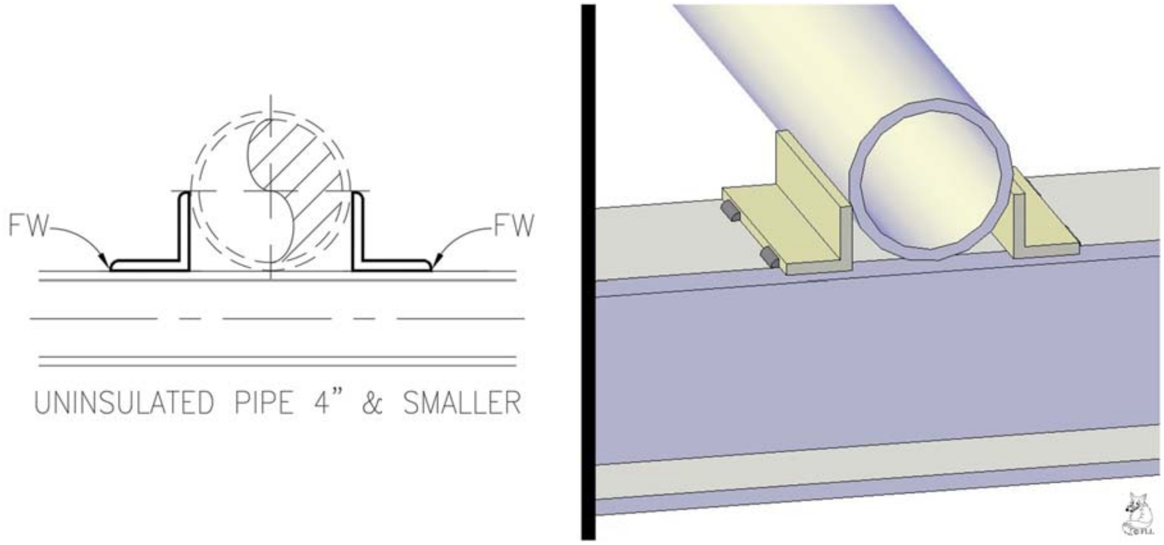


FIGURE 11.12 Uninsulated 4″ and smaller pipe guides.

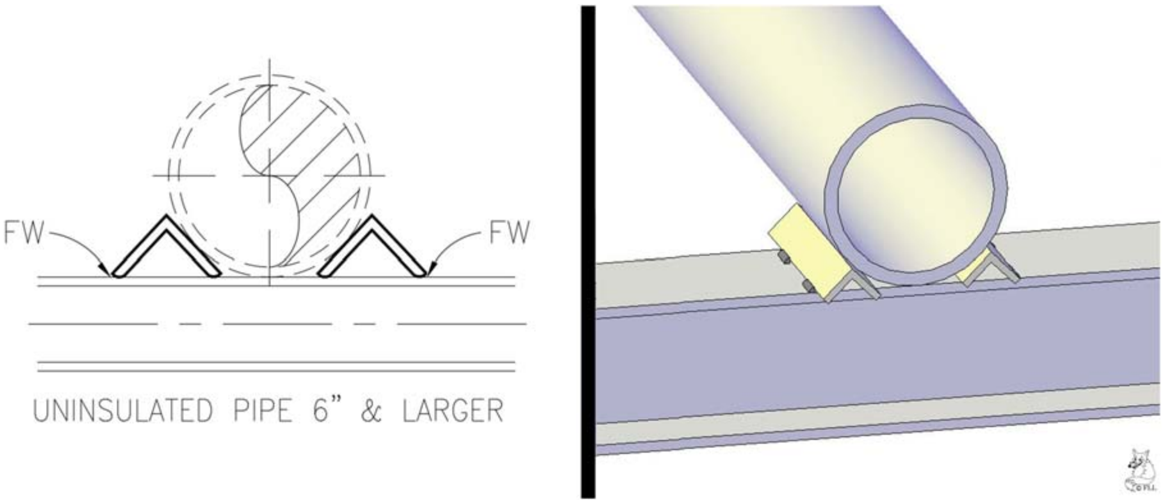


FIGURE 11.13 Uninsulated 6″ and larger pipe guides.

vibration, wind, and thermal expansion contributes to nozzle stresses that must be controlled. Pipe supports are designed to be positioned at precise points to relieve the high loads and stresses that are exerted on equipment nozzles. On longer drops of pipe, guides are employed to further control movement. Figure 11.16 depicts various scenarios where pipe supports and guides are located.

FIELD SUPPORTS

Once a pipe drops out of the rack, support must be provided to relieve weight stresses that heavy piping systems can place on nozzles, weld joints, and other critical points. Nozzles and welded joints are not designed to carry heavy loads. Extreme loads placed on a nozzle could result in the nozzle being pulled off the vessel or piece of equipment. Lateral forces applied to weld joints could have the same result. Field supports can be at ground level, in a pipe rack or anywhere where structural support is not provided. Figure 11.17 shows a field support being used to carry the load that would otherwise be placed directly on a horizontal stub-in branch connection.

The *base support* is a type of field support that rests on the ground, platform, or other stationary surface and is used to support control stations and other pipes routed no more than 2′-0″ above Grade level. As seen in Figure 11.18, some base supports are “dummy” welded to the bottom surface of an elbow to provide support. Also known as a “base ell

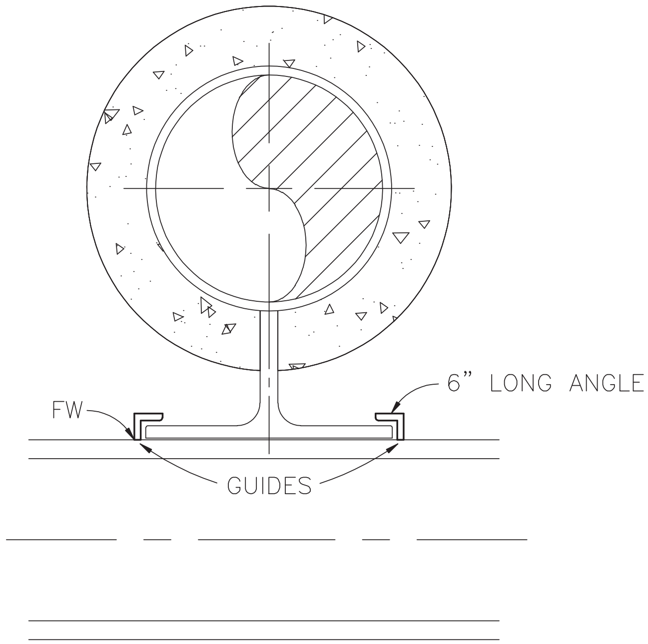


FIGURE 11.14 Pipe shoe with guides.

support," base supports can be "fixed," adjustable, or spring loaded depending on their specific need. Figures 11.19 and 11.20 represent "fixed" and adjustable base supports. Typically identified on a drawing as no more than a note, such as FS-1 or FS-2, base supports differ in size, attachment methods, adjustability, and load capacity.

When the distance from pipe to grade makes the base support inappropriate, a support fabricated from a steel angle or structural channel is used. These "channel" supports are generally bolted or welded to structural steel or concrete columns. Channel supports are typically less than 2′-6″ in length and, with a load capacity of 500 pounds, are used only on pipe sizes 12″ and smaller. Figures 11.21 and 11.22 depicts the C-1 and C-2 types of channel supports.

DUMMY SUPPORTS

The dummy support or *dummy leg* as it is also known is used to support pipe that would not otherwise be supported due to its short length or change in direction. The dummy leg is a piece of open pipe welded to the outside of an elbow. The piece of open pipe acts as a continuation of the pipe's axis thereby allowing it to extend across a horizontal structural support (see Figure 11.23). The sizing chart shown in Figure 11.24 provides the required "leg" pipe diameter, and the offset placement dimension required to maintain a common Bottom of Pipe elevation.

HANGER RODS

Hanger rods are the standard supporting device used when a pipe, or pipes, must be supported from above. Hanger rods are suspended from overhead lines or structural supports. Two major styles of hanger rods are used. One is designed to support a single pipe, and one intended to support multiple lines. Used on lines up to 24″ in diameter, and having a load capacity of 4,800 pounds, the single pipe hanger uses a rod and clevis to provide support (see Figure 11.25). The charts shown in Figures 11.26 and 11.27 represent a HR-1 and HR-3 hanger rods, respectively. A HR-1 rod is used on uninsulated pipe, and a HR-3 is used on insulated pipe.

When multiple pipes which run parallel to each other require support, the multiline hanger is used. Often called a *trapeze*, it uses a length of steel angle suspended by two metal rods at the ends to provide support to the group of lines simultaneously (see Figure 11.28). The trapeze can vary from 3′-0″ to 10′-0″ long from center to center of the rods with the shorter length carrying a maximum load of up to 4,900 pounds.

SPRING HANGERS

Lines having significant growth, due to expansion, prevent the use of a stiff support such as a hanger rod or trapeze. These lines require the use of *spring hangers*. Spring hangers allow expanding pipes room to grow without placing stress on the supporting rod (see Figure 11.29).

PICK-UP PIPE SUPPORTS

In most piping facilities, structural column spacing in the pipe rack is 25′-0″. For large diameter pipe, spanning this distance poses no problem. Smaller diameter pipes, however, do not have the strength necessary to span this distance and will sag between supports. These sags or *pockets* can become so severe they can prevent commodity flow. *Pick-ups* are designed to use the larger pipes to support the smaller pipes. Using a length of steel angle attached to the larger diameter pipe with U-bolts allows the small diameter pipes to be supported at their weakest point (see Figure 11.30). Pick-ups can span up to 10′-0″ and carry a load of 1,200 pounds.

The various guides, supports, and anchors discussed in this chapter play a significant role in the overall design of a piping facility. Each one requires special analysis and calculations to be properly installed. Most companies have strict guidelines governing the use of these items. Only designers with years of experience should make decisions on when and where to use these devices.

ALLOWABLE PIPE SPANS

USING CARBON STEEL *(ASTM 106–Gr. B)* PIPE FILLED WITH WATER

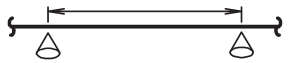
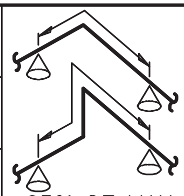
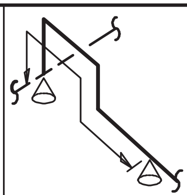
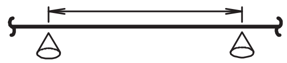
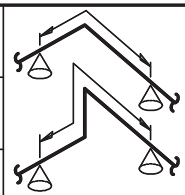
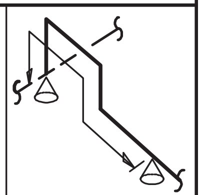
PIPE SIZE	SCHEDULE	200°F AND UNDER–LIMITING STRESS = 7600 PSI (UNINSULATED)						201°F TO 599°F–LIMITING STRESS = 6175 PSI (INSULATED)					
													
		RECOMMENDED		MAXIMUM				RECOMMENDED		MAXIMUM			
		SPAN	DEFL.	SPAN	DEFL.	65% OF MAX	75% OF MAX	SPAN	DEFL.	SPAN	DEFL.	65% OF MAX	75% OF MAX
2”	40	22’-6”	1”	26’-3”	1 13/16”	17’–2”	19’–8”	18’-6”	3/4”	18’-9”	3/4”	12’–2”	14’–0”
3”	40	27’-6”	1”	32’-0”	1 7/8”	20’–9”	24’–0”	23’-6”	3/4”	24’-6”	7/8”	16’–0”	18’–4”
4”	40	30’-9”	1”	35’-3”	1 3/4”	22’–11”	26’–6”	26’-6”	3/4”	28’-0”	15/16”	18’–2”	21’–0”
6”	40	36’-9”	1”	41’-3”	1 5/8”	26’–10”	31’–0”	32’-0”	3/4”	33’-3”	15/16”	21’–7”	25’–0”
8”	40	41’-6”	1”	46’-0”	1 9/16”	30’–0”	34’–6”	36’-0”	3/4”	37’-6”	13/16”	24’–5”	28’–0”
10”	40	45’-9”	1”	50’-6”	1 1/2”	32’–9”	37’–10”	40’-6”	3/4”	42’-0”	13/16”	27’–3”	31’–6”
12”	STD	49’-0”	1”	53’-0”	1 3/8”	34’–6”	39’–9”	43’-6”	3/4”	44’-3”	13/16”	28’–9”	33’–3”
14”	30	50’-9”	1”	54’-6”	1 5/16”	35’–6”	41’–0”	45’-6”	3/4”	45’-9”	3/4”	29’–9”	34’–3”
16”	30	53’-3”	1”	56’-0”	1 1/4”	36’–3”	42’–0”	45’-6”	5/8”	47’-3”	3/4”	30’–8”	35’–6”
18”	STD	51’-9”	3/4”	57’-6”	1 3/16”	37’–4”	43’–0”	47’-6”	5/8”	48’-9”	11/16”	31’–9”	36’–7”
20”	20	53’-9”	3/4”	58’-9”	1 1/16”	38’–3”	44’–0”	47’-6”	1/2”	50’-0”	5/8”	32’–6”	37’–6”

FIGURE 11.15 Allowable pipe span chart.

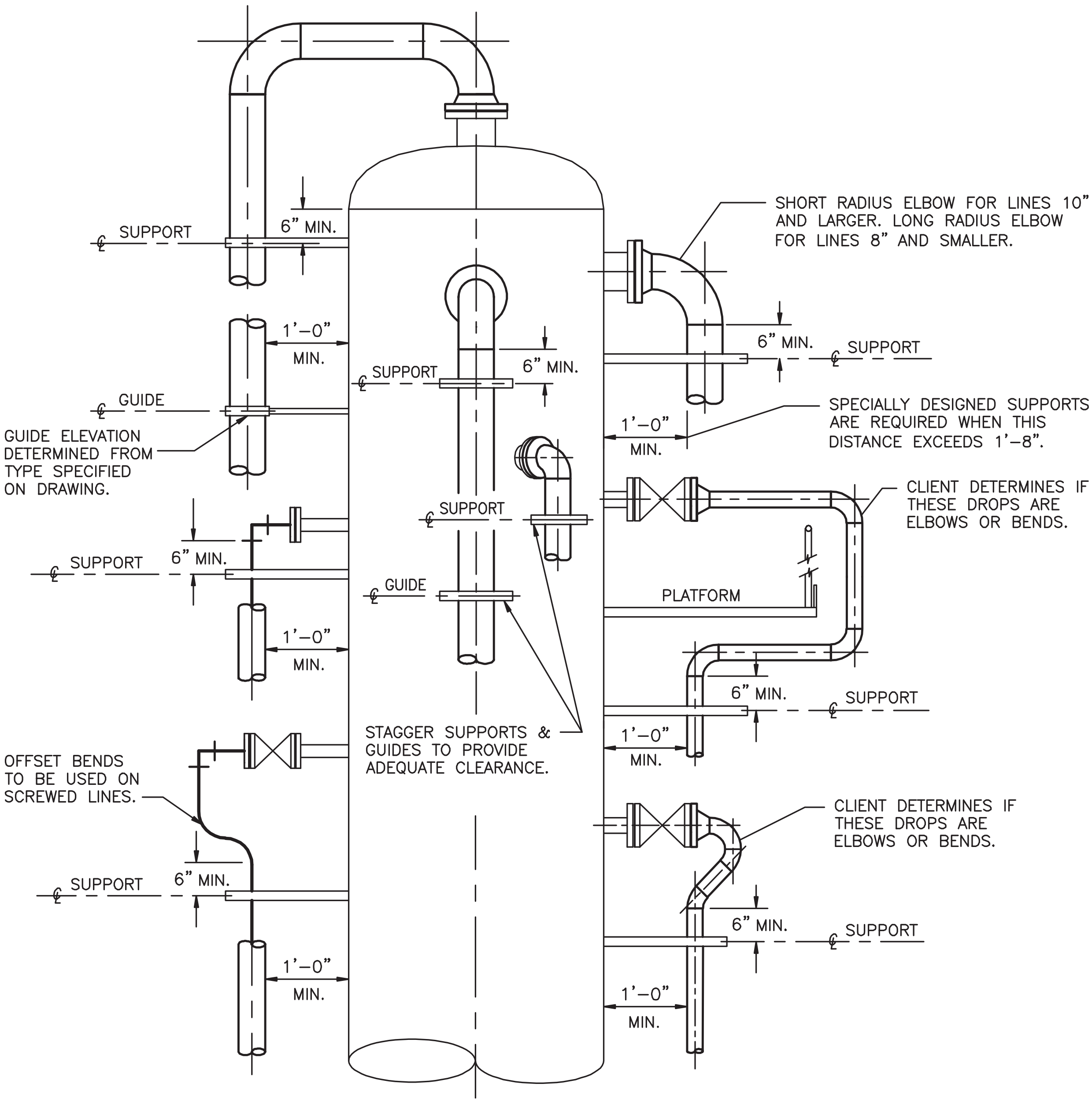


FIGURE 11.16 Vertical pipe supports and guides.

FIGURE 11.17 Field support. *Courtesy Nisseki Chemical Texas, Inc., Bayport, Texas.*

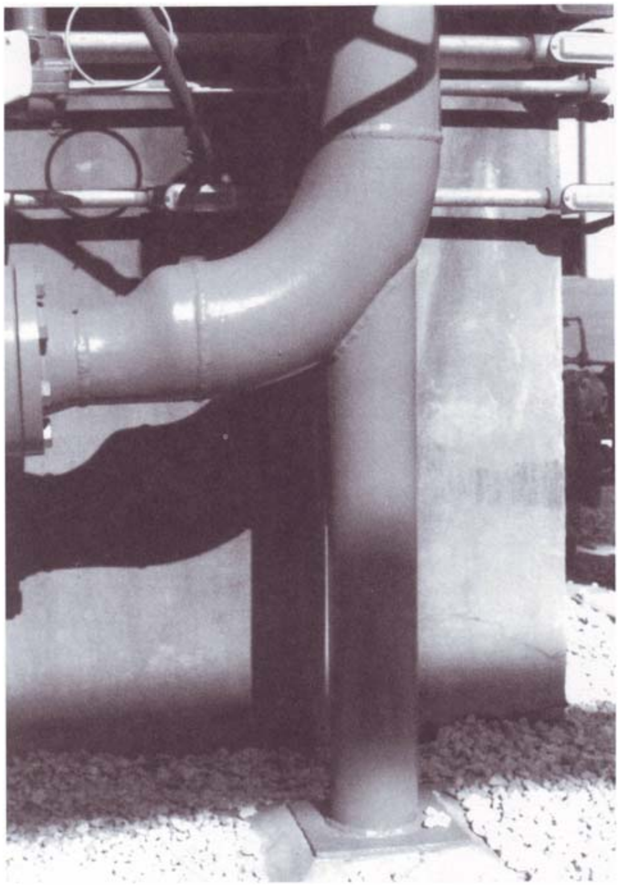
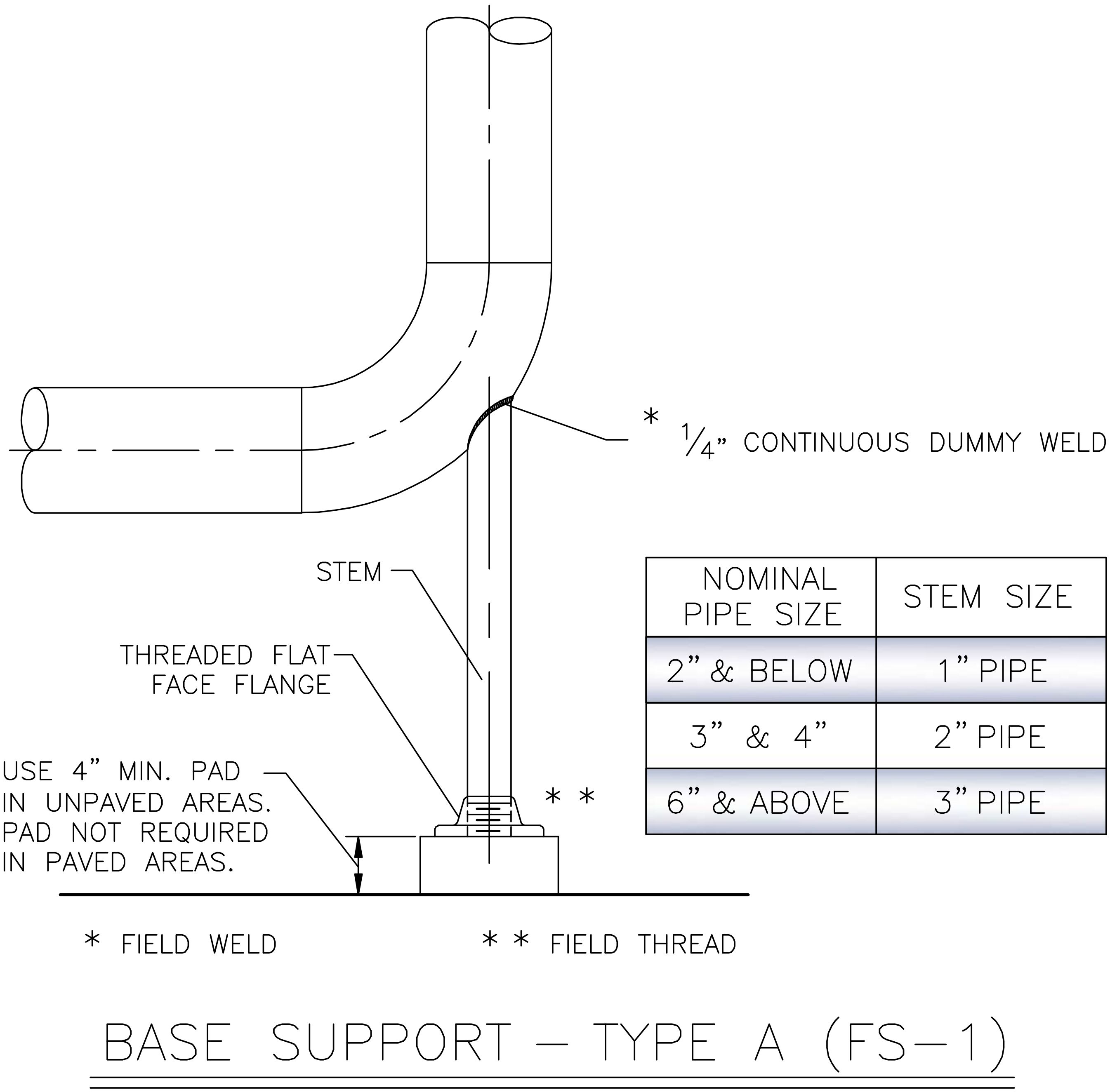
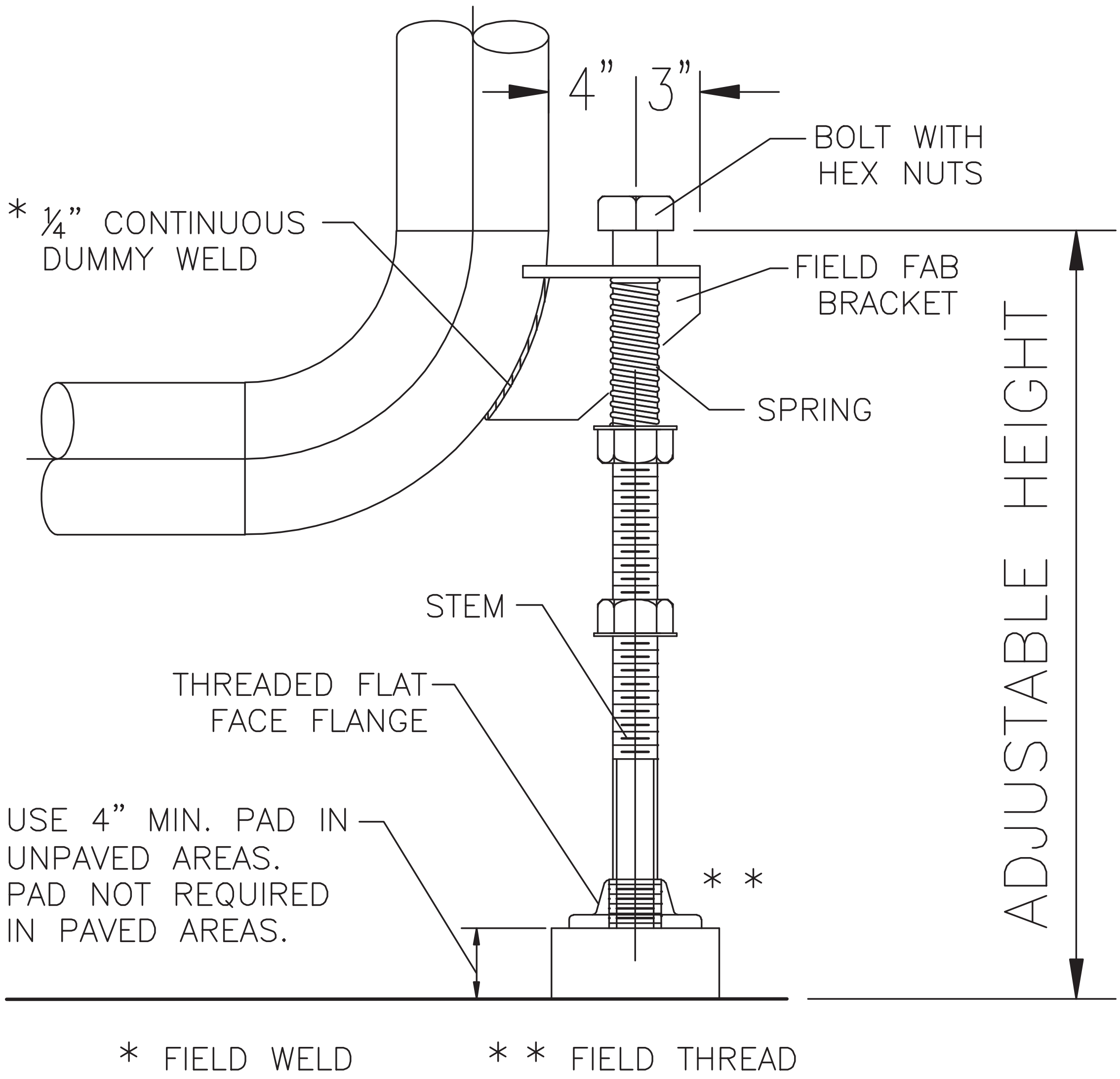


FIGURE 11.18 Base support. *Courtesy Nisseki Chemical Texas, Inc., Bayport, Texas.*



NOMINAL PIPE SIZE	STEM SIZE
2" & BELOW	1" PIPE
3" & 4"	2" PIPE
6" & ABOVE	3" PIPE

FIGURE 11.19 Base support—Type A (FS-1).



NOMINAL PIPE SIZE	STEM SIZE	BOLT SIZE	BRACKET SIZE
2" & BELOW	1" PIPE	¾" X 10"	2" x 2" x ¼"
3" & 4"	2" PIPE	1⅛" X 12"	3" x 3" x 5/16"
6" THRU 14"	3" PIPE	1½" X 12"	4" x 3" x ⅜"

BASE SUPPORT – TYPE B (FS–2)

FIGURE 11.20 Base support—Type B (FS-2).

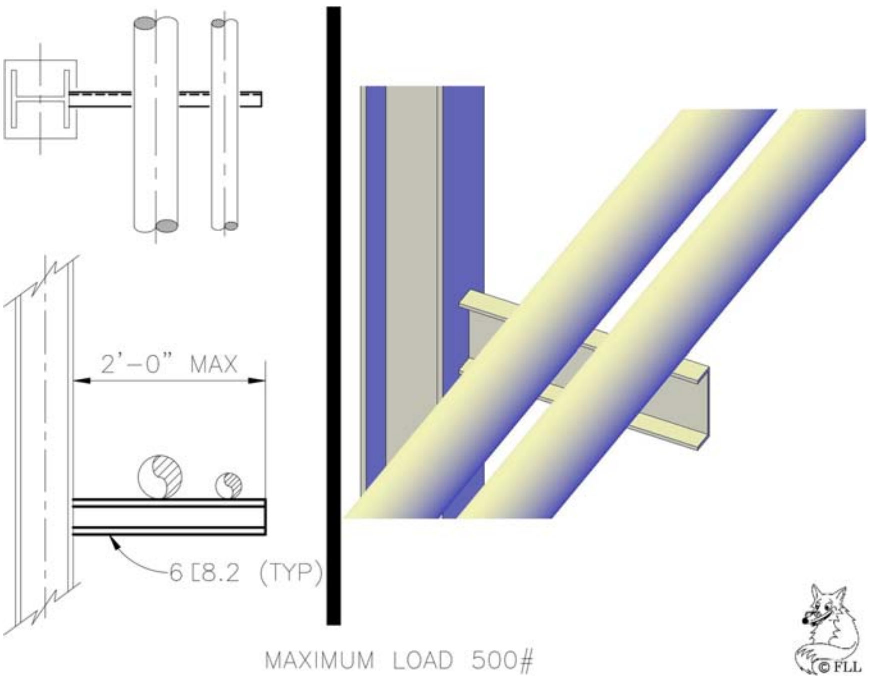


FIGURE 11.21 Type C-1 channel supports.

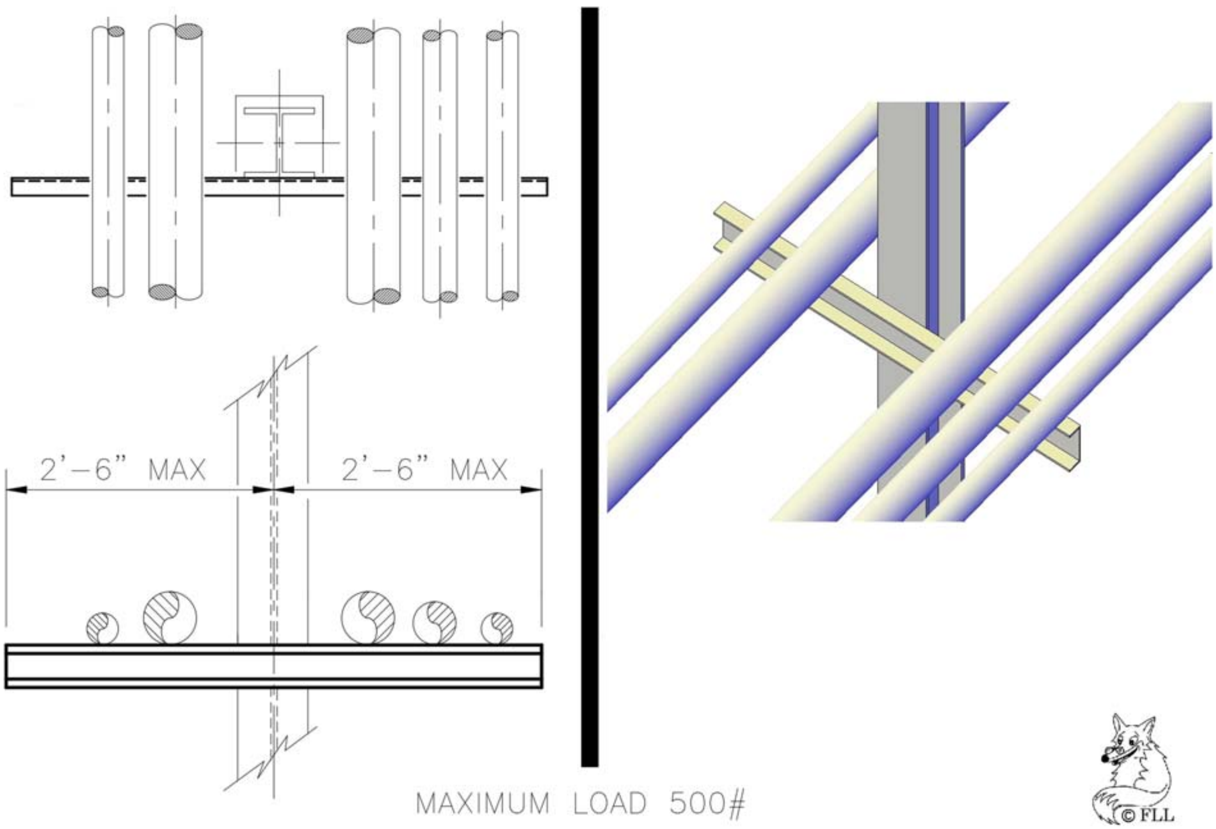


FIGURE 11.22 Type C-2 channel supports.

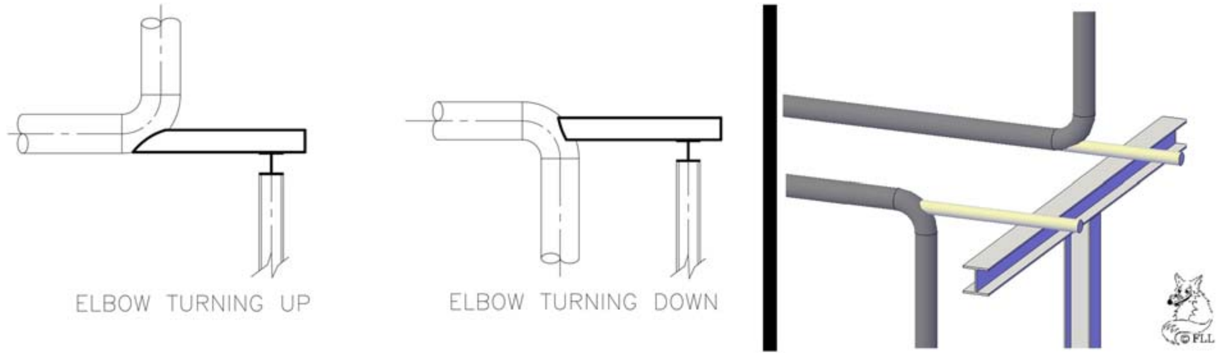
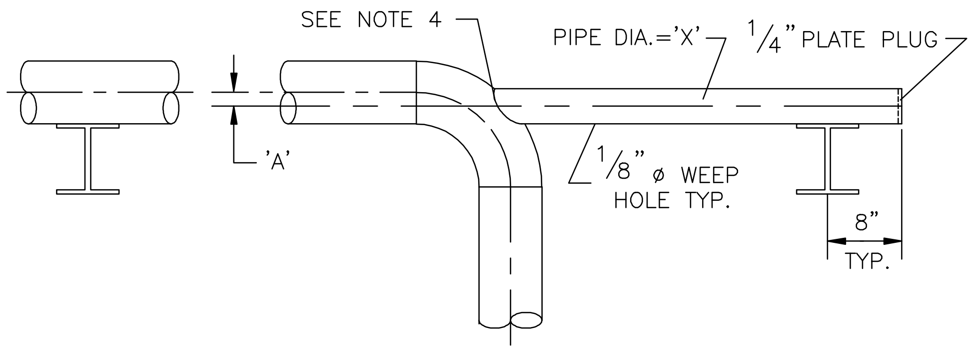


FIGURE 11.23 Dummy support.

DUMMY SUPPORT – DS–1



LINE SIZE	'A' DIM	'X' DIA
2"	1/4"	1 1/2"
3"	9/16"	2"
4"	1/2"	3"
6"	1 1/16"	4"
8"	1"	6"
10"	1 1/16"	8"
12"	2 1/16"	8"
14"	1 5/8"	10"
16"	2 5/8"	10"
18"	3 5/8"	10"
20"	3 5/8"	12"
24"	5 5/8"	12"

Notes:

1. Dummy–weld extensions are sch. 40 pipe unless otherwise noted
2. Pipe fabricator to supply dummy–weld extensions.
3. On stess relieved lines, dummy–weld extensions are welded to pipe before extress releiving.
4. Dummy–weld: do not cut hole in pipe, use line–class welding rods.
5. Material: line–class.

FIGURE 11.24 DS-1 dummy support sizing chart.

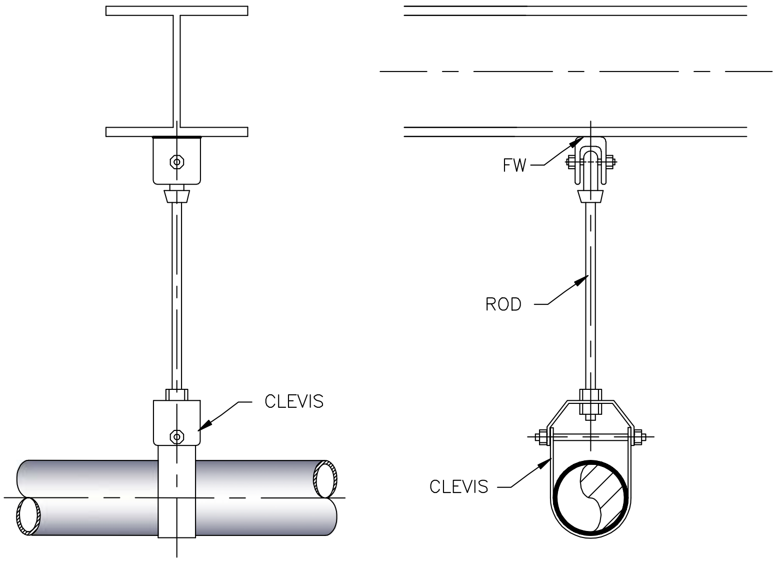
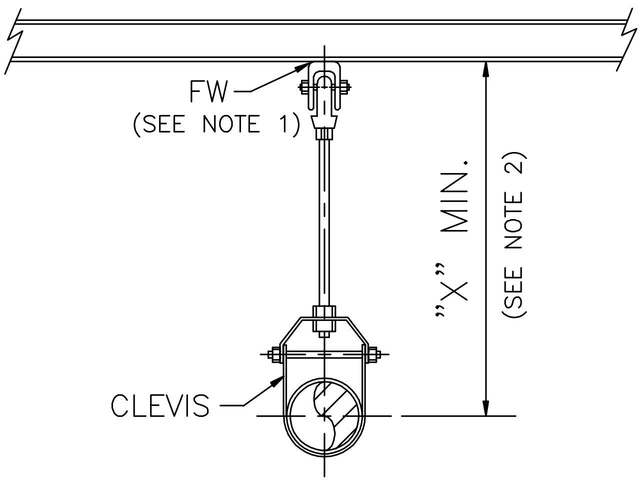


FIGURE 11.25 Rod and clevis.

HANGER ROD – HR-1



HR-1 HANGER DATA

CLEVIS SIZE	PIPE SIZE	"X" DIM.	MAX. ALLOWABLE HANGER LOAD #(lbs)
2	1½" & 2"	9½"	250
3	3"	10½"	350
4	4"	11½"	400
6	6"	1'–2½"	1940
8	8"	1'–5"	2000
10	10"	1'–6½"	3600
12	12"	1'–8"	3770
14	14"	1'–10½"	4200
16	16"	2'–0"	4600
18	18"	2'–2"	4800

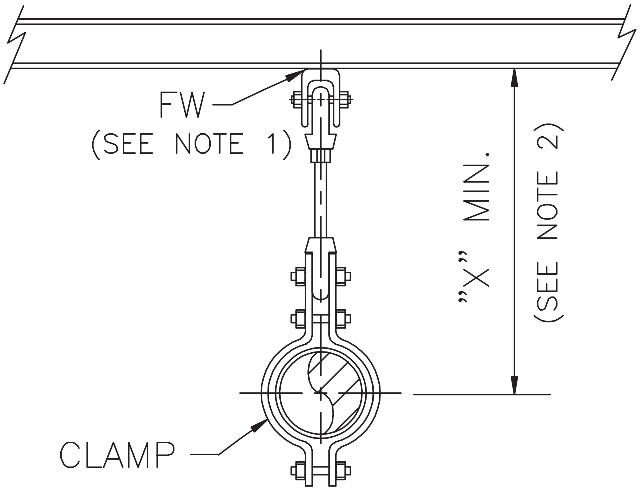
NORMALLY USED ON UNINSULATED PIPE.

Notes:

1. Loads exceeding 500lbs. at attachment surface shall be submitted for approval.
2. Where expansion causes horizontal movement, "X" dimension must be calculated.

FIGURE 11.26 Hanger rod HR-1 data.

HANGER ROD – HR-3



HR-3 HANGER DATA

CLAMP SIZE	PIPE SIZE	"X" DIM.	MAX. ALLOWABLE HANGER LOAD #(lbs)
2	2"	1'–10"	610
3	3"	1'–10½"	1130
4	4"	1'–11"	1130
6	6"	2'–2"	2555
8	8"	2'–4"	2555
10	10"	2'–5"	2890
12	12"	2'–6"	2890
14	14"	2'–8½"	3835
16	16"	2'–9½"	3835
18	18"	2'–10½"	3835

NORMALLY USED ON INSULATED PIPE TO 750°.

Notes:

1. Loads exceeding 500lbs. at attachment surface shall be submitted for approval.
2. Where expansion causes horizontal movement, "X" dimension must be calculated.

FIGURE 11.27 Hanger rod HR-3 data.

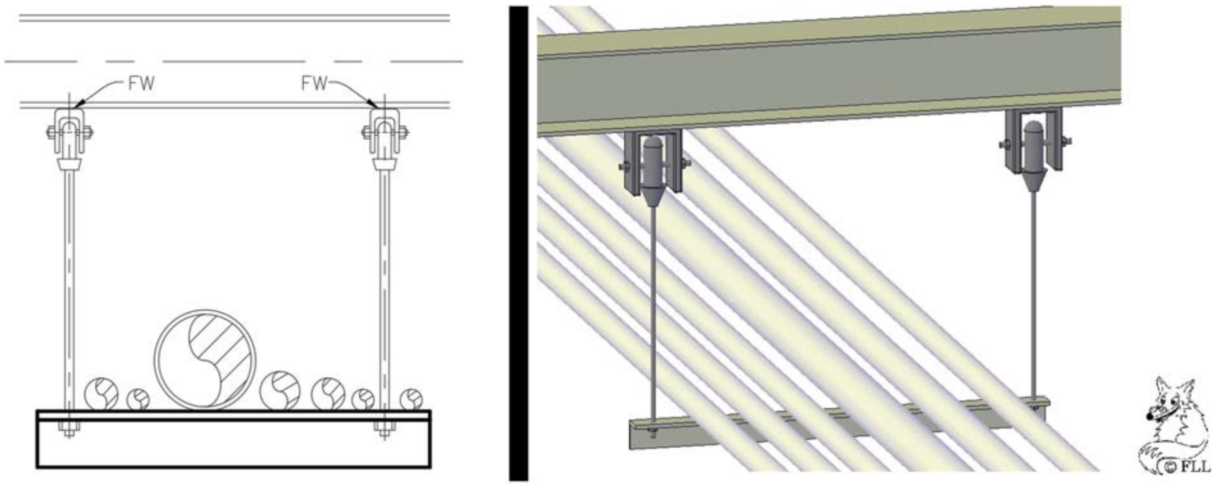


FIGURE 11.28 Trapeze.

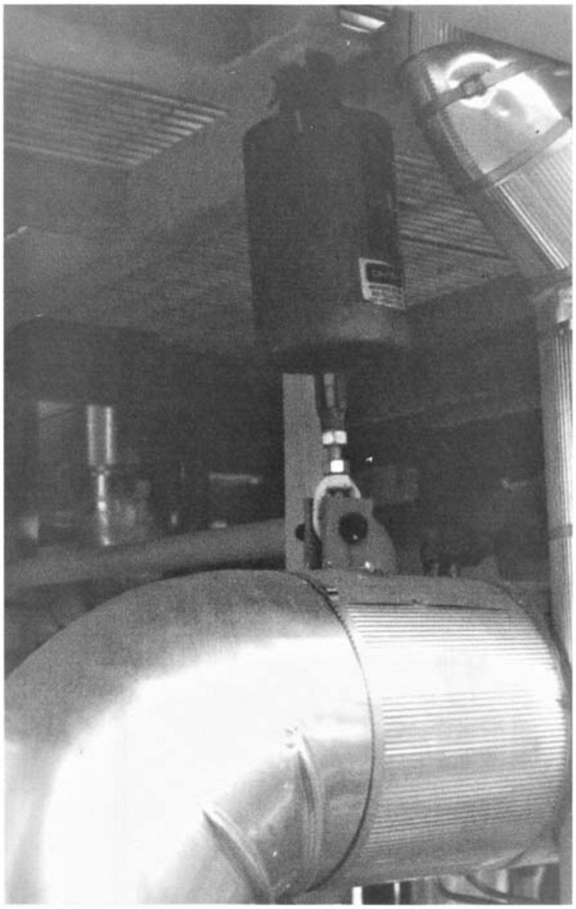


FIGURE 11.29 Spring hanger. *Courtesy Nisseki Chemical Texas, Inc., Bayport, Texas.*

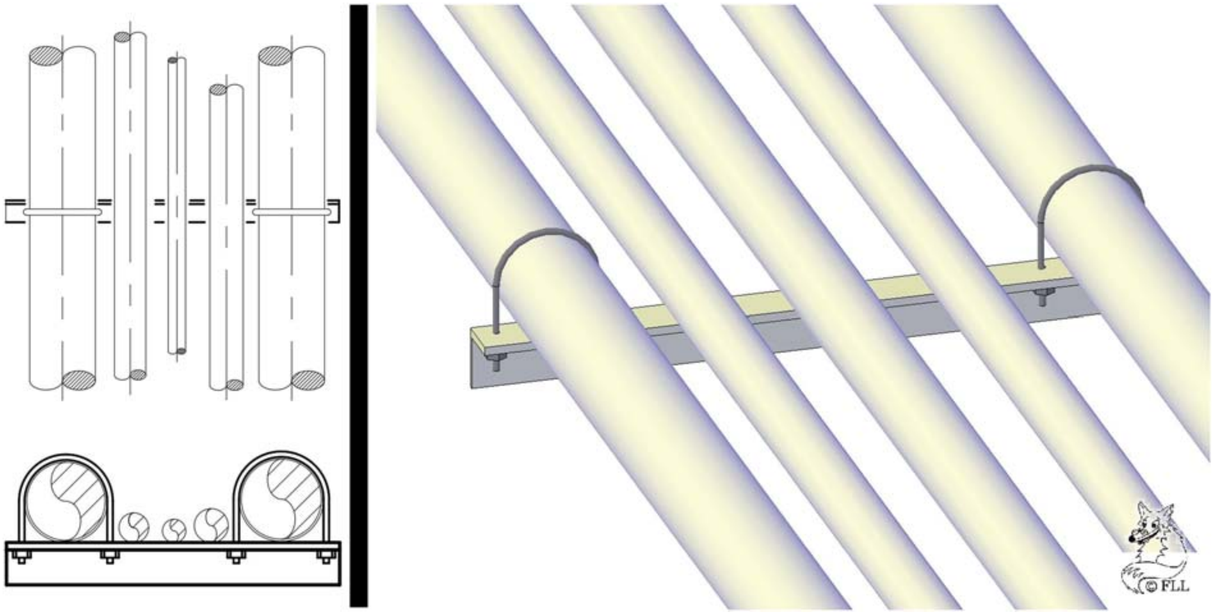


FIGURE 11.30 Pick-up support.

CHAPTER 11 REVIEW QUIZ

1. Why is *line spacing* critical?

2. What is the minimum spacing between lines?

3. Define *cold spring*.

4. What is a *pipe expansion loop?*

5. Name two types of pipe anchors.

6. What is a *pipe shoe?*

7. Explain the difference between a pipe anchor and a pipe guide.

8. What is the function of a *dummy leg?*

9. What is pipe *deflection*?

10. What are *pick-up* supports designed to prevent?

CHAPTER

12

Piping Systems

Within every piping facility, there are specific piping systems that perform specialized functions. These systems vary in their importance to the overall operation of the facility and can range from vital to peripheral. These systems can be complex in design or simple in function. The systems described in this chapter are examples of those commonly found in many piping facilities.

PLANT UTILITIES

Every piping facility is designed for a definite purpose. Most commonly that purpose is to produce a product that can be sold for profit. In order to achieve the intended purpose of the facility, certain components are incorporated into its design. Plant utilities are among these. By design, they are not the profit-producing product. However, plant utilities provide services that are essential to the efficient operation of the facility. Utilities include systems such as water, steam, condensate, fuel oil and gas, flares, and air. Each utility is shown on the Piping Arrangement drawing and is designed according to their specific duty, independent of process piping.

Water Systems

Often overlooked, water systems play an important part in a piping facility's successful operation. Water systems can include cooling water, boiler water, plant water, utility water, and emergency water.

Cooling Water

Cooling water flows through a closed piping system that circulates water through various pieces of equipment. Exchangers and condensers require chilled water to reduce the temperature of the process commodity. As water circulates through the shell of an exchanger, heat is transferred from the process commodity to the cooling water. To maintain its effectiveness, the cooling water is piped to a cooling tower where the heated water is aerated to reduce its heat gain. After the heat has been removed from the cooling water, the chilled water travels back to the exchanger and repeats the process.

Boiler Water

Boiler water is the piping system that delivers feed water to all steam generating equipment in a facility. Steam is generated by boilers, heaters, and even nuclear reactors and is used in a wide variety of piping facilities.

Emergency Water

Designed specifically for worker safety, emergency water systems include eye wash and emergency shower stations. Emergency shower stations are provided in all areas where maintenance and operational personnel are subject to hazardous leaks or spills. Eye wash stations are also provided for situations where physical injury may be caused by chemical sprays or hazardous fumes.

Steam and Condensate

Steam has a number of uses in various piping facilities. Made by on-site equipment, steam is relatively inexpensive. Many utility companies use steam as their source for powering huge generators to produce electricity. Multistoried buildings use steam to heat a building's occupied areas during winter months. Cargo ships once used steam as their primary source of power. In petrochemical facilities, steam is used to power the steam turbines used as drivers on pumps and compressors.

Superheated steam is steam that is heated to a temperature which is above the saturation temperature for its designed pressure. In petrochemical facilities, superheated steam is also used as *stripping steam*. Stripping steam is used in fractionation columns to enhance the effectiveness of the fractionation process. In situations where heat tracing is required, steam is used to maintain constant temperatures and prevent commodities with slow flow characteristics from freezing. During shutdowns, steam is used as a means of cleaning parts and equipment.

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00010-8

Condensate is the visible evidence of steam cooling, therefore condensing. In its purest form, steam is invisible. Only when just-saturated steam cools and becomes heavy with water vapor is it visible. Condensate is undesirable in certain situations so it must be removed from steam lines. When moved under extreme pressure, condensate can be damaging to equipment such as turbine impellers. Condensate is separated from the steam by *traps*. Steam traps are placed at pocketed low points and at the dead ends of steam headers to collect condensate. Condensate is then piped back to fired equipment where it is converted back into steam.

Fuel Oil and Fuel Gas

These commodities are used as fuel for heat sources such as fired heaters and boilers.

Flare Systems

The most noticeable piece of equipment in use, especially after dark, the flare is where waste gases and vapors are burned. Flare systems collect gases created during start-ups and those released from pressure safety valves and routes them to the flare stack to be burned. Flare stacks are typically located upwind of process units and are placed a minimum distance of 200′ from the closest piece of process equipment, storage tanks, or cooling towers. Figures 12.1 and 12.2 illustrate a typical flare stack.

FIGURE 12.1 Flare stack.

Air Systems

Another plant utility that is essential to the operation of the facility is its air system. There are two types of air systems: utility air and instrument air.

Utility Air

Utility air is compressed air piped throughout the facility to power pneumatic tools and equipment. Impact wrenches, grinders, and other pneumatic tools are commonly used during normal plant operations. During times of a shut-down, scheduled maintenance and repairs require workers to loosen nuts and bolts that have not been removed for quite some time. Power driven tools are the only efficient means of timely maintenance.

Instrument Air

Instrument air is also a compressed air system, but with a much different task. Instrument air is used to operate all pneumatic monitoring and controlling instruments in the piping facility. Pneumatic instruments such as control valves, recorders, and indicators require an uninterrupted feed of air to provide continual monitoring and operational control. Routed through small bore pipe and tubing, the compressed air in an instrument air system has been dried and purified to remove all moisture and any airborne particles to prevent damage to the instruments.

CONTROL VALVE MANIFOLDS

Controlling the commodity traveling through pipe and equipment and the accessibility of the controlling apparatus are two major concerns in any piping facility. The control valve manifold addresses both of these concerns. The *control valve manifold*, or manifold control station, is a series of valves and fittings that make use of an automatic valve to control and monitor the flow of a commodity through the pipe. For convenience and accessibility, the control valve

FIGURE 12.2 Flare stack flame.

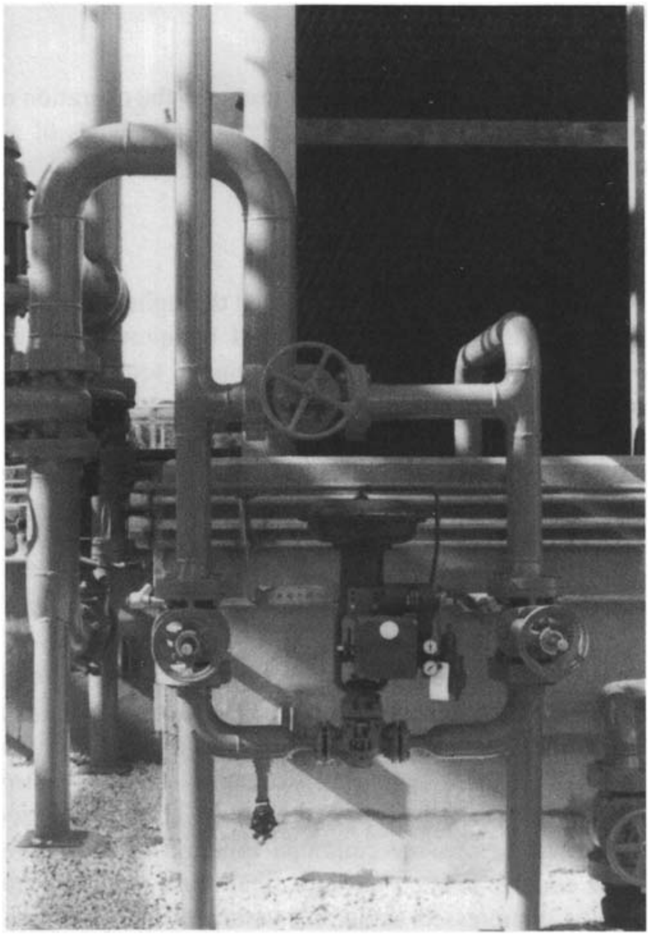


FIGURE 12.3 Control valve manifold. *Courtesy Nisseki Chemical Texas, Inc., Bayport, Texas.*

manifold is usually placed 2′-0″ off the ground or 2′-0″ above the floor of a platform. The photograph in Figure 12.3 shows a typical control valve manifold arrangement.

Notice the different types of valves used in manifold control station shown in Figure 12.3. Four different valves are used in the typical control valve manifold. The main valve in the center of the configuration is the *control* valve. It has a throttling body type, typically a globe or similar body type, and uses a pneumatic or hydraulic actuator to automatically regulate the commodity's rate of flow. The valves installed to the right and left of the control valve are called block valves. A *block* valve is just a descriptive name given to the gate valves that are used to stop the flow of the commodity through the control valve during times of repair or replacement.

When the block valves are closed, and the control valve removed, the commodity must still be regulated. This is done via a by-pass valve. The *by-pass* valve is a globe, plug, or ball valve body style located on the horizontal by-pass line found above the control valve. The by-pass line ties the left and right sides of the manifold station together. The by-pass valve, which is one line-size smaller than the main pipe, is normally closed and is installed as

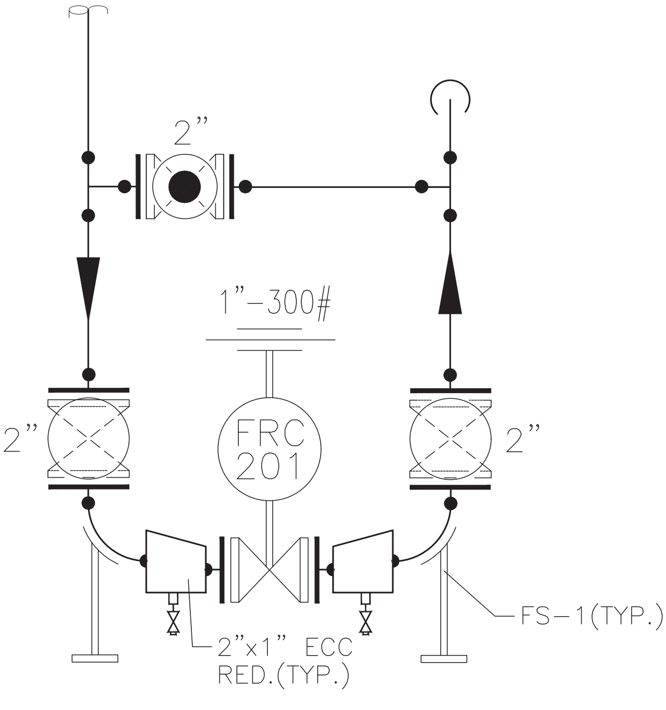


FIGURE 12.4 Control valve manifold drawing.

close as possible to the inlet side of the manifold. When the block valves are closed, the by-pass is opened to allow flow to circulate through the manifold, thus performing the same function as the control valve, only it is manually operated. The fourth valve type is the *drain* valve. It is the small valve shown below the left reducer. The drain valve is opened after the block valves have been closed and before the bolts have been loosened on the flanges that sandwich the control valve. The drain allows the commodity trapped below the two block valves to be captured and disposed of without a spill occurring. Figure 12.4 depicts the graphical representation of the control valve manifold shown in Figure 12.3. When drawing the plan view of a control valve manifold on a piping arrangement drawing, minimal information is provided. Figure 12.5 shows the plan view of a typical control valve manifold. Notice only the overall length and the centerline elevation is provided. An instrument bubble is shown to aid in the identification of the control valve. Handwheel orientation of the block valves must be shown so representation can be made on isometric drawings. If, for clearance purposes, handwheels of the block valves are oriented with an offset angle, the angle of offset must be shown on the arrangement drawing.

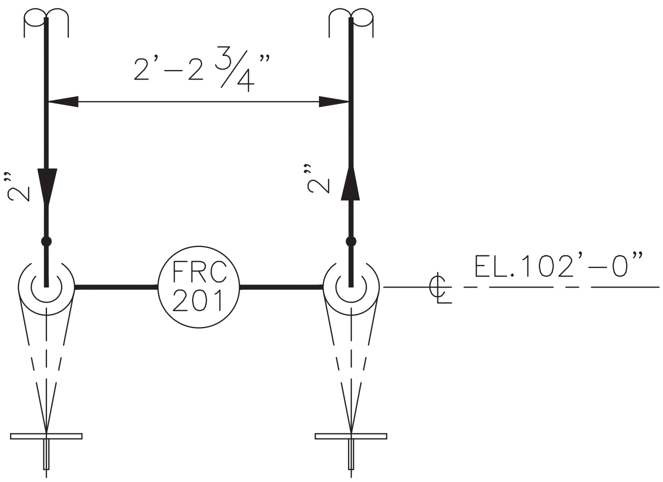


FIGURE 12.5 Control valve manifold on Piping Arrangement drawing.

Control valve manifolds can have various configurations depending on the placement of the block valves. Care must be taken to orient the handwheels away from equipment and other obstructions. When larger pipe sizes are used, valve handwheel lengths can become quite long. Avoid orienting handwheels into aisleways, roadways, and exchanger tube-pulling zones. Figure 12.6 provides a graphical representation of an alternate configuration for a Control valve manifold.

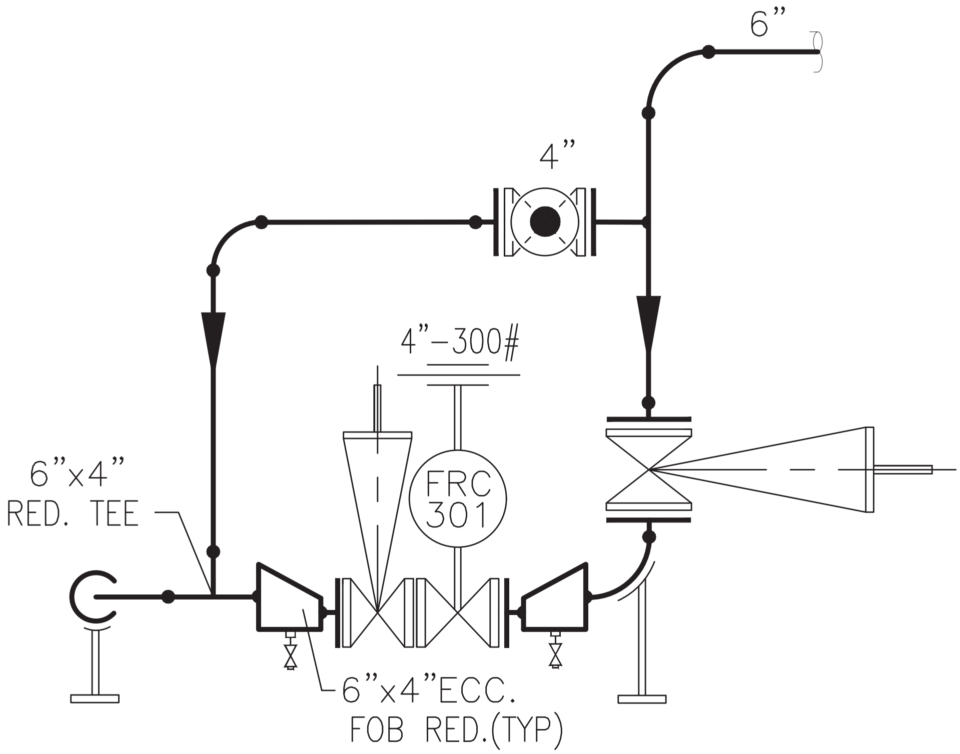


FIGURE 12.6 Control valve manifold, alternate configuration.

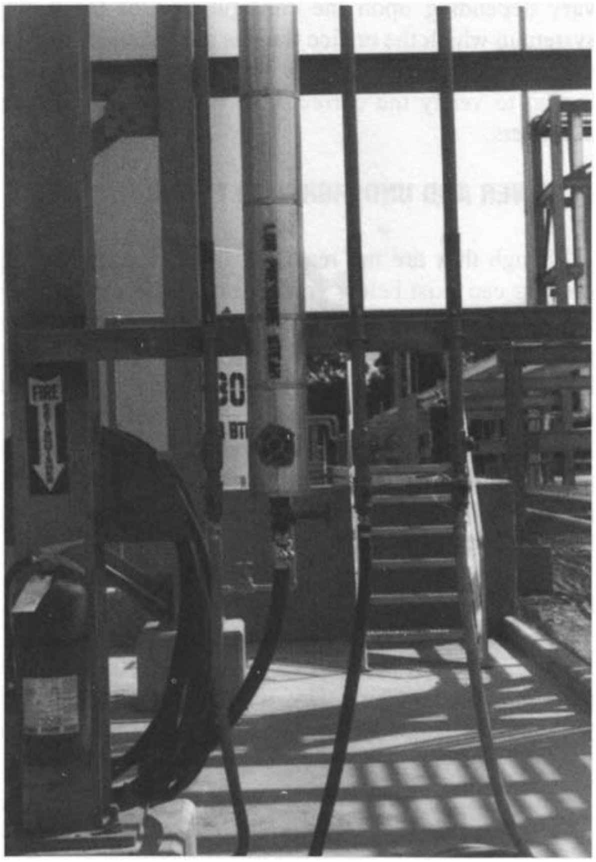


FIGURE 12.7 Utility station. *Courtesy Nisseki Chemical Texas, Inc., Bayport, Texas.*

UTILITY STATIONS

Organization is essential to quality design. Organizing a piping facility with maintenance in mind is crucial to efficient plant operation. Small independent maintenance centers called *utility stations* are located throughout a piping facility. Utility stations provide maintenance and operational personnel with centralized locations to find water, air, steam, and occasionally nitrogen. Utility stations are placed throughout a facility in such a manner to allow a utility hose 50′-0″ long to cover designated areas. A typical utility station is shown in Figure 12.7.

Water and steam are typically found only at utility stations located at grade level. These utilities are necessary for equipment that must be washed or steamed clean. Utility air is a service required at all stations in areas where pneumatic power tools are used. Manways are located at the higher elevations of vertical vessels. Utility stations must be positioned so utility hoses can easily reach them. Nitrogen may be required in specific areas where instrument lines must be purged during times of maintenance or repair.

Figure 12.8 represents a typical utility station as it may appear on a Piping Arrangement drawing, and Figure 12.9 depicts the same utility station in an isometric view.

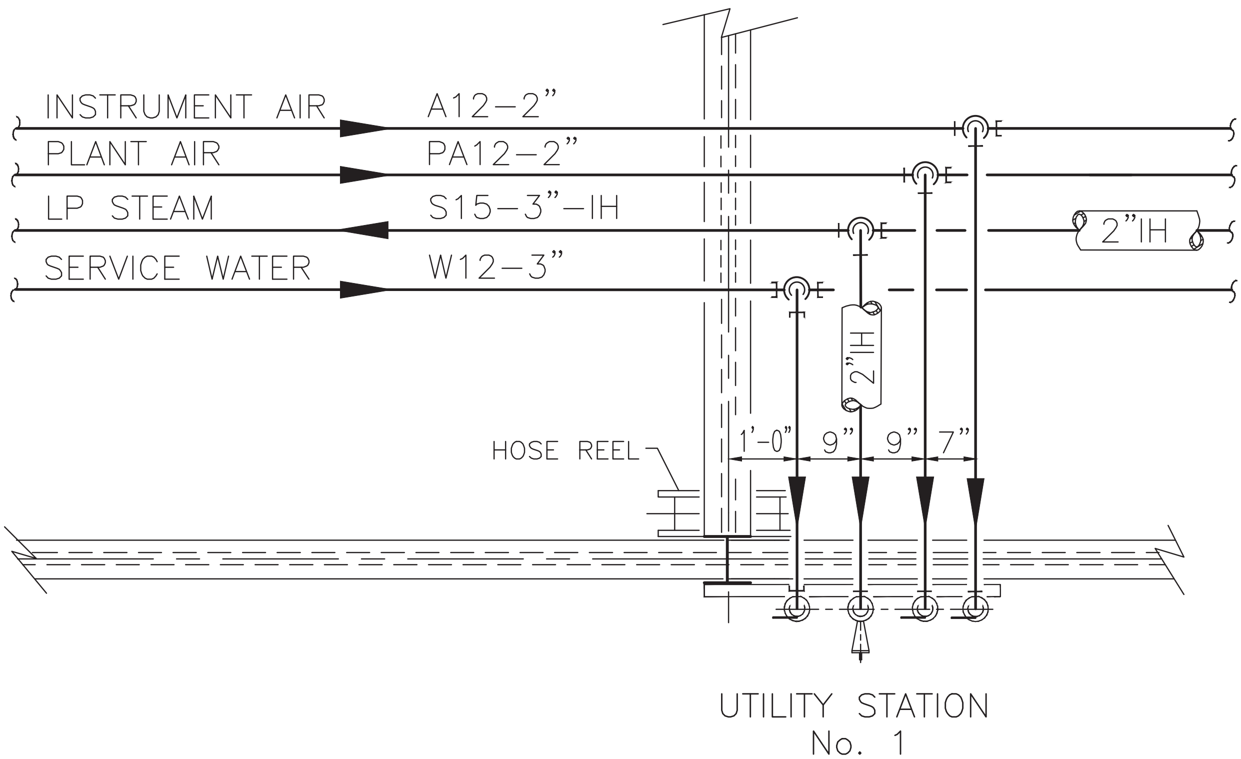


FIGURE 12.8 Utility station on Piping Arrangement drawing.

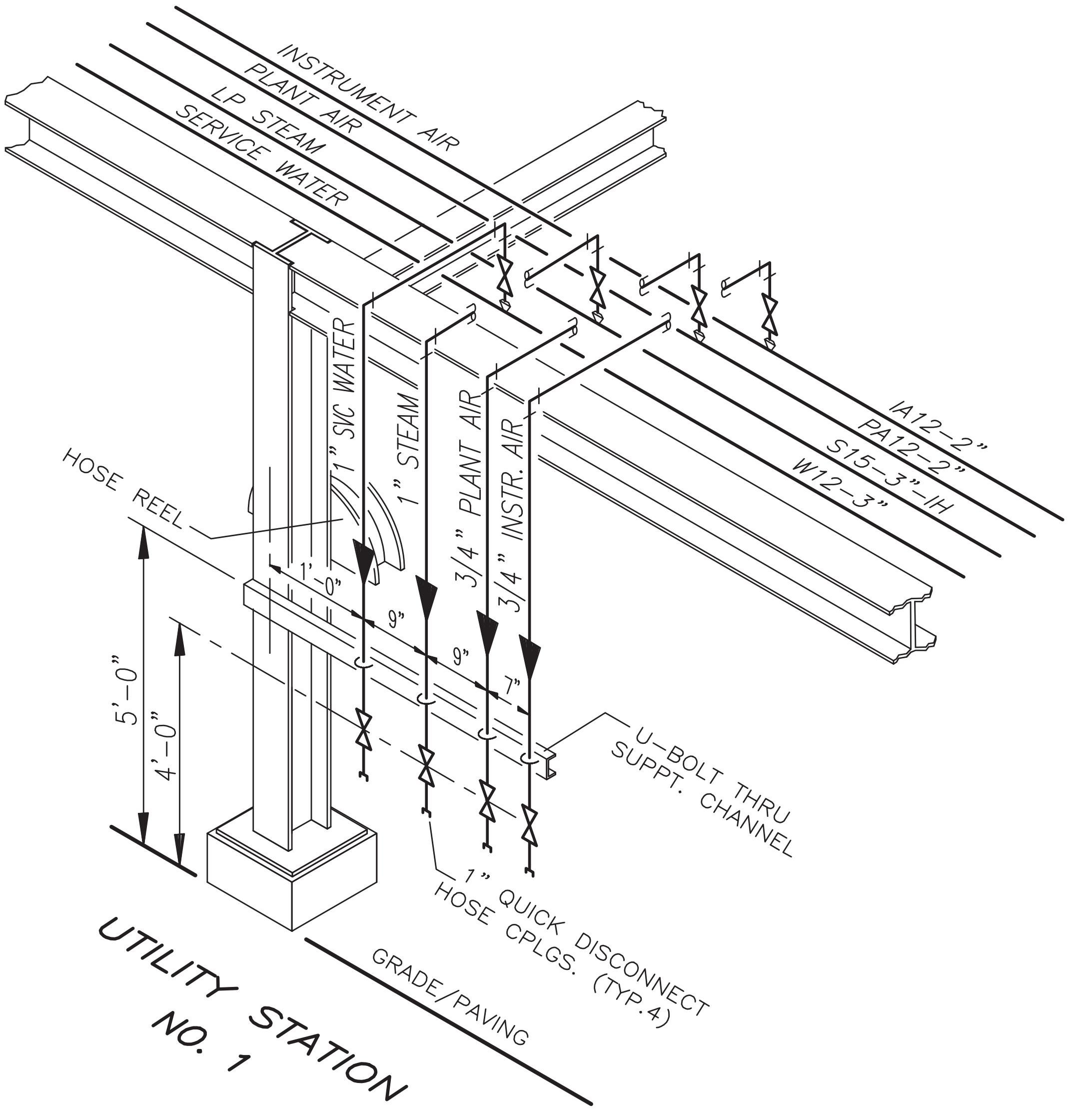


FIGURE 12.9 Utility station in isometric view.

METER RUNS

Developing a piping system that incorporates smooth and consistent flow characteristics is imperative in any piping facility. The ability to measure the rate of flow of a commodity is necessary at various stages throughout a facility. Rate of flow is simply a measurement of the amount of commodity flowing through a pipe in a specified amount of time. Sometimes commodities are flowing too quickly through the piping system and must be constrained and/or controlled. The reduction of *head pressure* is a required drop in pressure and must be monitored continuously. The most common way to achieve this is through a section of pipe referred to as a meter run. A *meter run* is the name given to a straight run of pipe that uses an orifice flange union assembly, a set of orifice flanges and restriction plate, to measure the rate of flow and drop in pressure.

Recall from the discussion in Chapter 4, Flange Basics, orifice flanges have valve taps that allow monitoring equipment to be attached which records the differential pressure of a commodity traveling through an orifice plate. Figure 12.10 is a photograph of the instrumentation attached to an orifice flange union assembly.

A critical component in a meter run is the orifice plate. Most often, the *orifice plate* is a thin, flat, circular disc, made of metal, having a flat handle. Depending

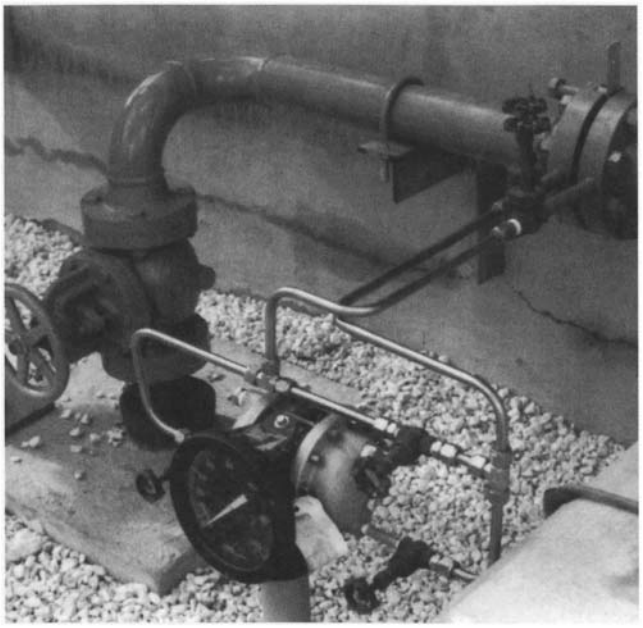


FIGURE 12.10 Orifice flanges with instrumentation. *Courtesy of Nisseki Chemical Texas, Inc., Bayport, Texas.*

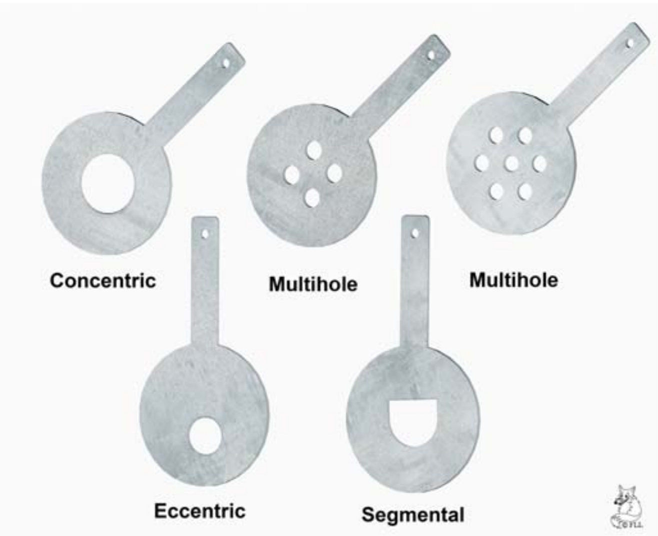


FIGURE 12.11 Orifice plate styles.

on the methods being used and the data being gathered, different orifice plates types are installed. Figure 12.11 provides examples of various orifice plate configurations. Although they are single-stage orifices, some restriction plates have multiple openings in the plate. Multihole plates are installed when commodity flow rates are extremely high. High flow rates create a loud, high-pitched noise as the commodity flows through a restriction plate. Multiple holes divide the incoming commodity into several smaller flow streams, thus reducing the noise. The cumulative area size of all of the hole openings establish the amount of pressure drop downstream of the restriction orifice.

The orifice plate, with a gasket on either side, is sandwiched between two orifice flanges. An exploded view of an installed orifice plate is shown in Figure 12.12. In this example, a single hole is machined through the center of the plate to allow commodity to pass through. The size of the hole in the orifice plate, relative to the size of the pipe, is known as the *Beta* (β) *Ratio* or *Beta* (β) *Factor*. Depending on the application, numerous Beta (β) Ratios can be used. By attaching monitoring equipment to the valve taps, the rate of flow of the commodity and its drop in pressure can be measured as flow travels along the pipe and through the orifice plate.

To receive the most accurate reading possible, turbulence within the pipe must be kept to a minimum. Flow turbulence is created by obstructions in the configuration from items such as fittings and valves. A smooth, consistent flow is created by providing a sufficient amount of straight pipe before and after the orifice flanges. Therefore the length of the run of pipe before, or *upstream*, of the orifice plate and the length of the section of pipe after, or *downstream*, of the plate is precisely calculated. These upstream and downstream measurements are established by using precise lengths of pipe which are based on the diameter of the pipe being used. Additional fitting and valve installations will affect how these lengths are calculated. For example, a different Beta (β) Ratio, ranging from 0.30 to 0.75 (30%−75%), can be used or a multiplane pipe configuration before the orifice plate may be required. As a general rule-of-thumb, 30 pipe diameters upstream and six (6) pipe diameters downstream will provide adequate lengths of pipe to create smooth flow in the meter run. A graphical representation of the values used to calculate these lengths is shown in Figure 12.13.

To use the values shown in Figure 12.13, simply multiply the upstream and downstream diameters times the nominal pipe size. The following is an example to calculate the upstream and downstream pipe lengths for a meter run installed in a 6″ pipe configuration.

$$\text{Upstream distance} = 30(\text{diameters}) \times 6'' = 180'' = 15'\text{-}0''$$

$$\text{Downstream distance} = 6(\text{diameters}) \times 6'' = 36'' = 3'\text{-}0''$$

Again, the formula above is a rule-of-thumb guide. Specific values for upstream and downstream diameters

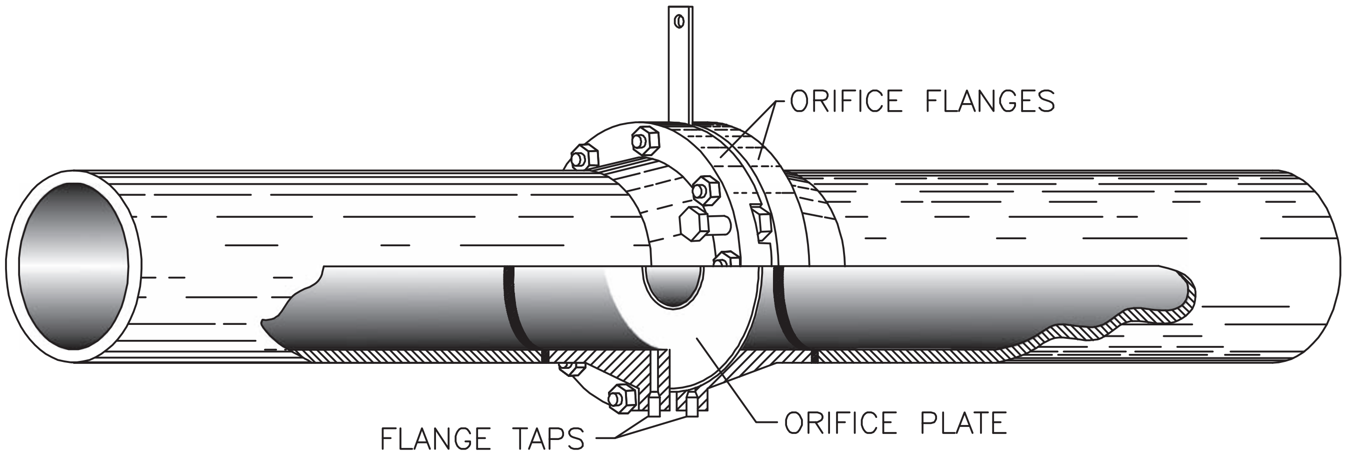


FIGURE 12.12 Installed orifice plate.

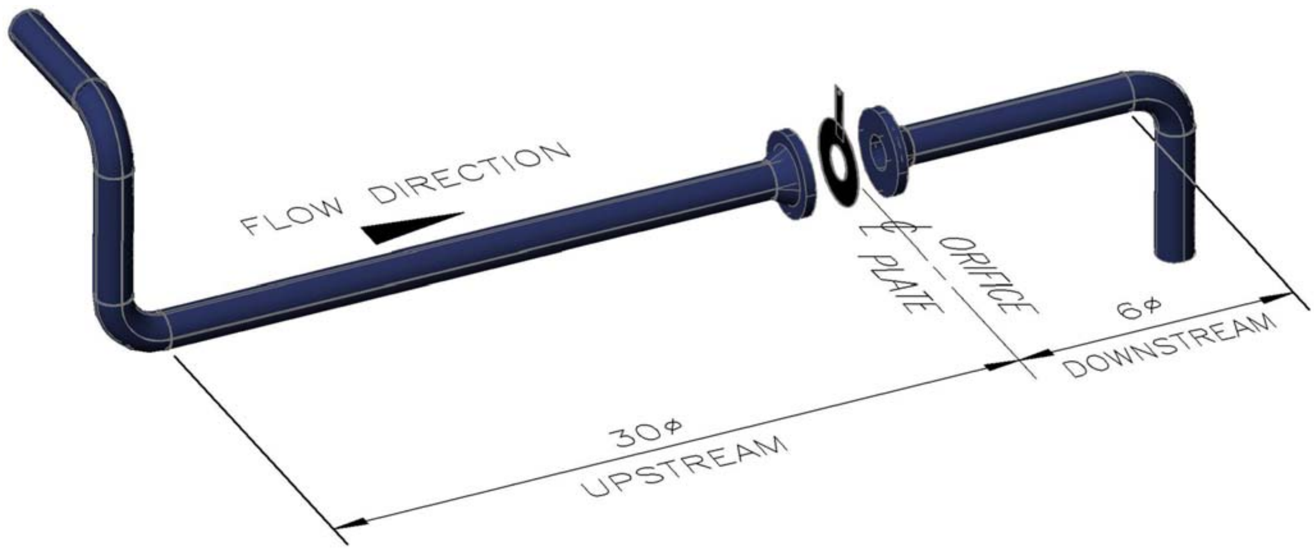


FIGURE 12.13 Meter run pipe lengths.

vary depending upon the configuration of the piping system in which the orifice flanges are installed. Space limitations, configuration components, and routing orientation such as those shown in Figure 12.14 dictate upstream and downstream pipe lengths for prescribed Beta (β) Ratios. One of the more commonly used Beta (β) Ratios in meter run calculations is 0.75. This means the area of the hole or holes machined in the orifice plate are approximately 75% of the inside diameter of the pipe. Figure 12.14 represents the minimum upstream and downstream pipe lengths when a Beta (β) Ratio of 0.75 is used. Review specific project specifications to verify the correct upstream and downstream diameters.

Occasionally, more than a single orifice plate is required. Multistage orifice assemblies, illustrated in Figure 12.15, have multiple phases through which the commodity must flow in order to achieve the desired result. Like single-plate orifices, multistage restriction orifices have instrumentation connections on both ends to accurately read specific characteristics of the commodity as it exits the assembly.

SEWER AND UNDERGROUND PIPING SYSTEMS

Although they are not readily visible, extensive piping systems can exist below grade. Some piping

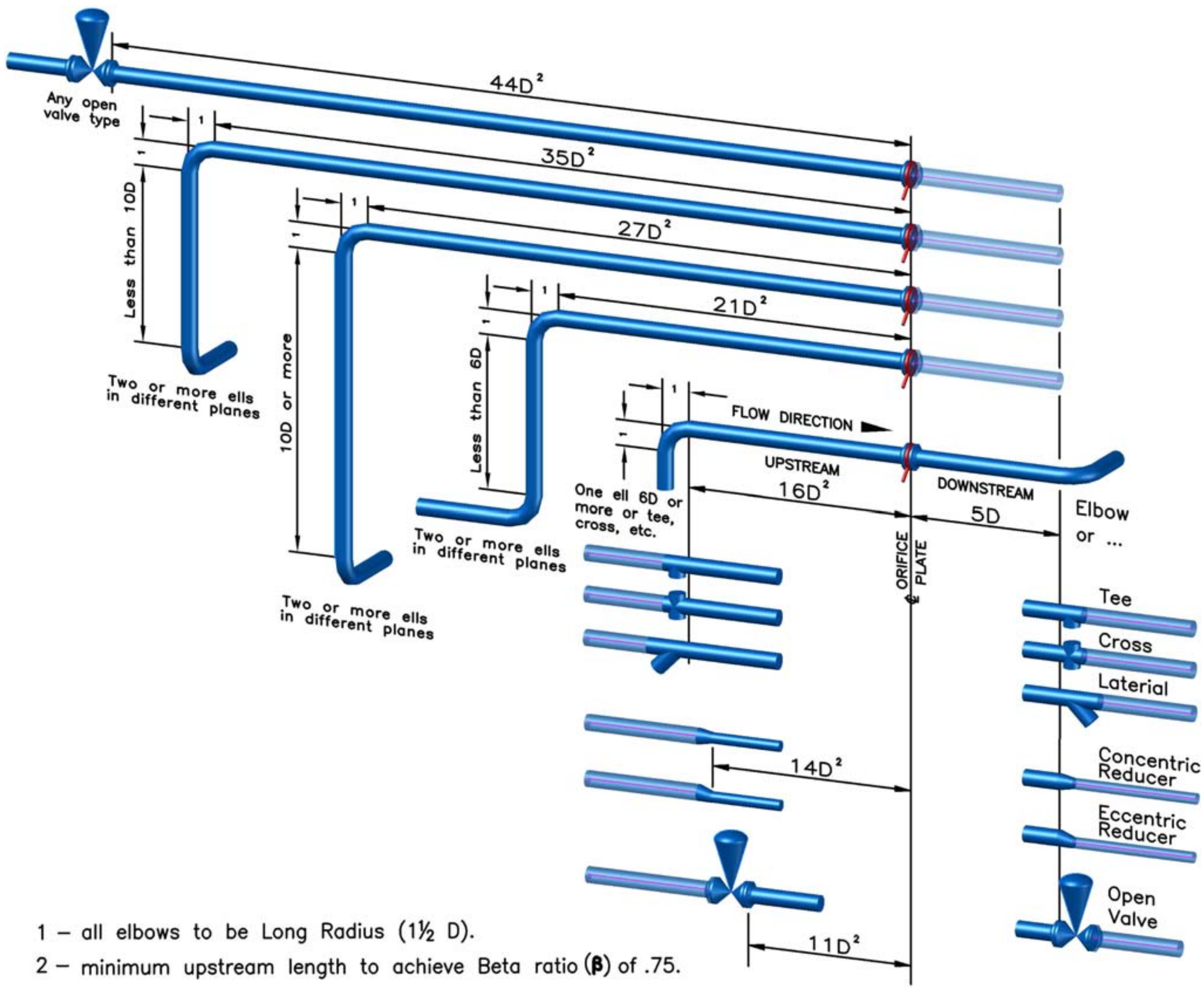


FIGURE 12.14 0.75 Beta (β) Ratio meter run pipe lengths.

systems by their very nature must be run underground. Others are placed there as a matter of convenience. Although they both are placed below grade, there is a difference between underground sewer and piping systems. The main difference is that sewer systems are gravity flow and have an origin that is open to atmosphere, whereas underground piping systems are closed systems that have a defined and constant pressure.

Sewer Systems

Underground sewer systems are designed for a number of commodities. They may include sanitary and raw sewage lines, storm and firewater drains, or process waste run-off and oily water sewers. Storm and firewater drain lines are often run separately for those systems that will carry raw sewage and corrosive chemical wastes. Oily water sewers collect oily waste and residue from compressors, pumps, and other equipment. Each commodity requires special treatment and therefore must be routed to different treatment facilities. Because they are gravity flow, these systems are generally fabricated using no pipe smaller than 4″ in diameter.

Underground Piping Systems

Many lines, not related to sewer systems, are routed either entirely or partially below the ground, or Grade. The commodities in these pipes could be cooling water, firewater, feed supply, hazardous

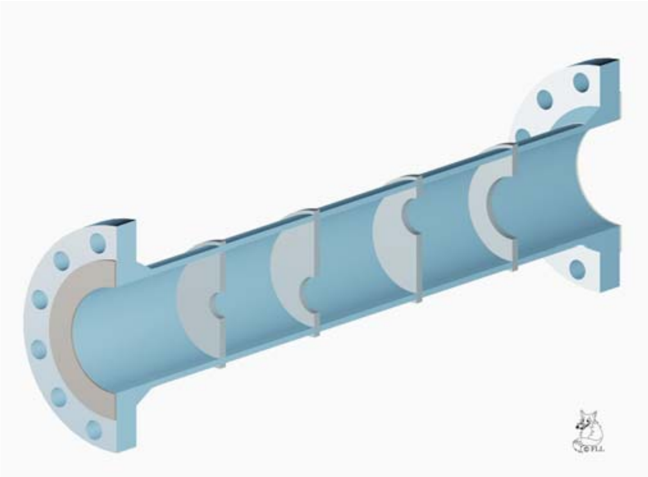


FIGURE 12.15 Multistage orifice.

waste materials, and others. *Hazardous waste materials* are feed by-products that do not conform to the client's critical product specifications or parameters and therefore require special treatment prior to disposal. Hazardous waste materials are often generated during a Unit's start-up or shut-down. They are typically nonrefinable remnants of the feed that are unusable, even with further refining.

To prevent frequent replacement of piping components in underground systems, commodities flowing through underground pipes may be only slightly corrosive or the pipes themselves may have special corrosion allowances to accommodate the commodities flowing through them. Whichever application exists, the corrosion of exposed metal surfaces below the ground is always a matter of concern. When an exposed metal surface lies in moist or salt-laden soil, galvanic corrosion begins to occur. Any number of factors may cause a small amount of electrical current to flow through the soil and onto the pipe. When electric current discharges into the soil, metal is removed from the surface of the pipe and the corrosion process begins. To protect these underground metal surfaces, cathodic protection systems are used. Cathodic protection employs the use of positively charged electrodes being sent down a long, metal rod, to neutralize the corrosive effects of negatively charged particles in the earth.

CHAPTER 12 REVIEW QUIZ

1. What are plant utilities?

2. Name five water systems that can be found in a piping facility

3. Define *super-heated* steam.

4. What is a *steam trap*?

5. What is the minimum distance a flare stack can be installed next to other pieces of equipment?

6. Explain the difference between utility air and instrument air.

7. What is the function of a *control valve manifold*?

8. List the four types of valves used in a control valve manifold.

9. What is a *utility station*?

10. What is a *meter run*?

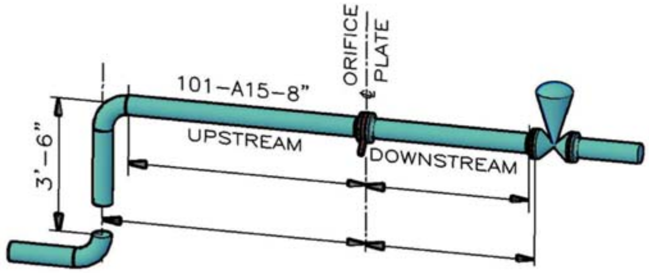
CHAPTER 12 EXERCISE

Exercises: Meter Run Calculations

Exercise 12.1. Calculate the required dimensions for the meter run configurations shown to achieve a Beta (β) Ratio of 0.75. Use the provided line number to determine specification, size, and pound ratings. Show all answers in feet and inch values to the nearest 1/16″.

METER RUN CALCULATIONS

1



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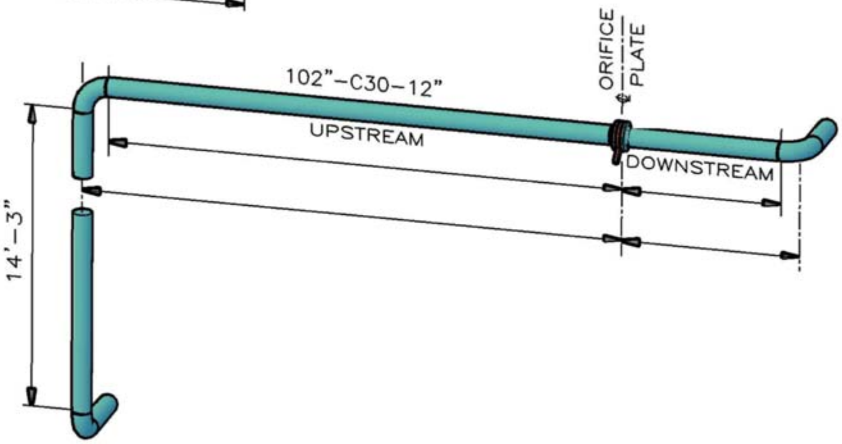

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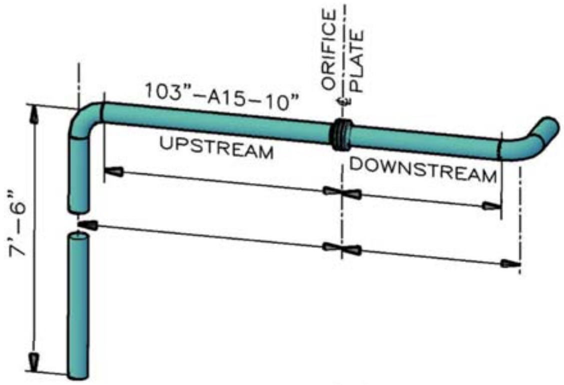

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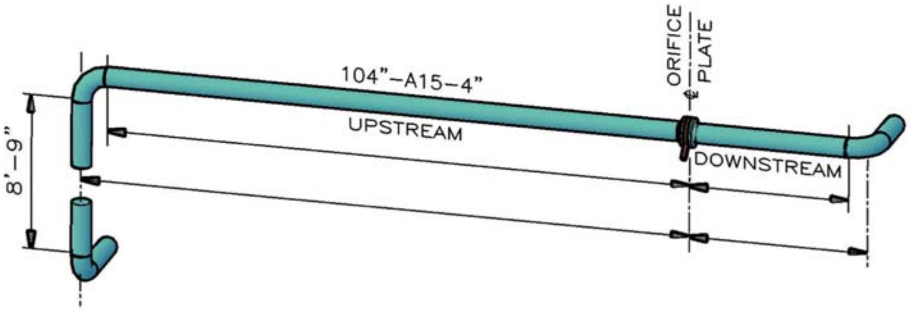

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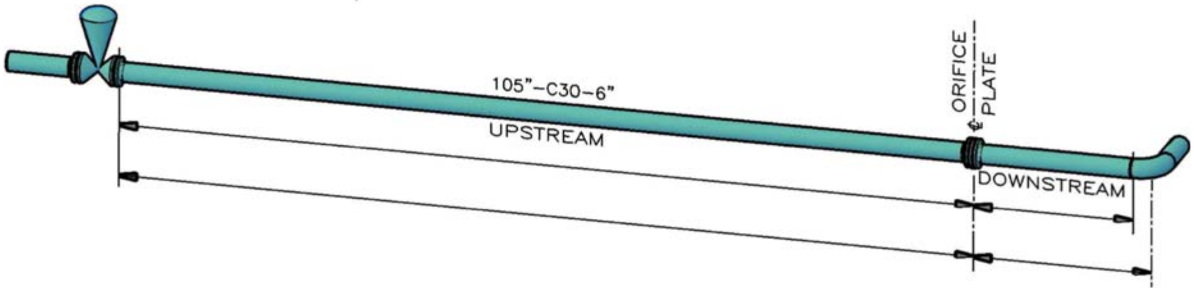

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CHAPTER

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 which display 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 which 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 which 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.

Whether created via traditional hand-drawn techniques or generated automatically by software from 3D models, the piping isometric is an important drawing which serves several purposes. It is the primary source for *material take-off* of each pipe configuration in the facility. Material Take-Off (MTO) is the process by which each individual component used in the fabrication of 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 purchases of those items can be made. The tabulated results are referred to as the Bill of

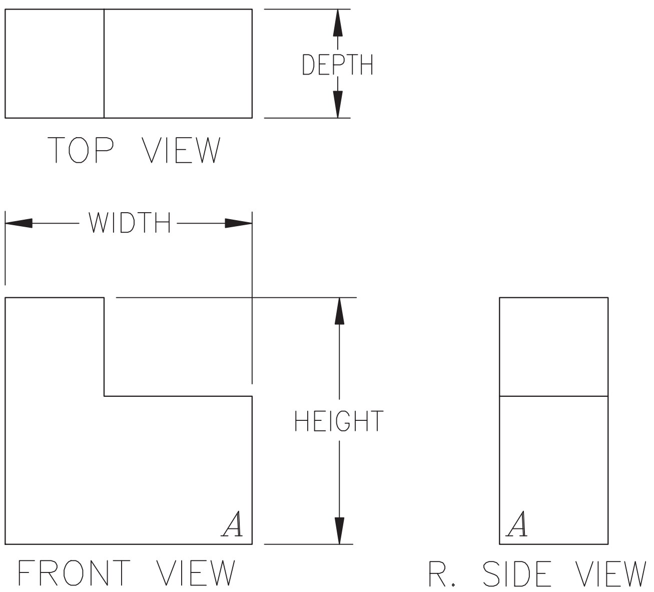


FIGURE 13.1 Orthographic views.

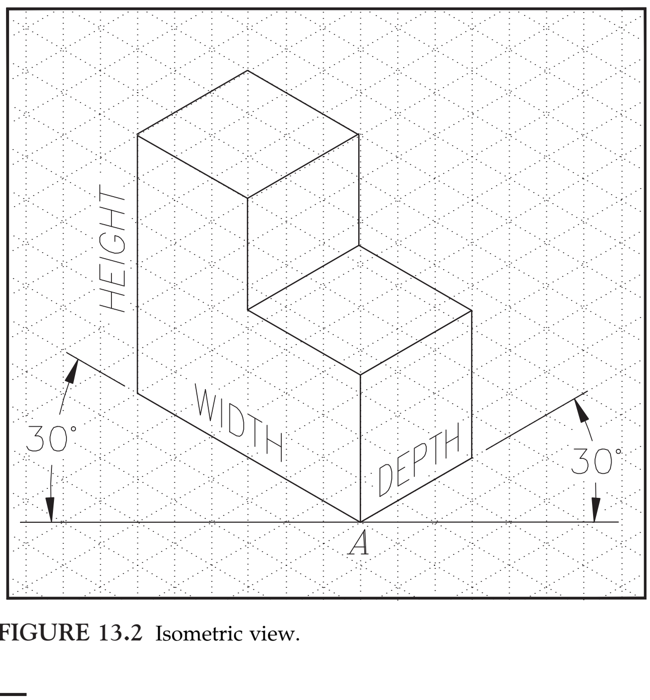


FIGURE 13.2 Isometric view.

Pipe Drafting and Design.
DOI: https://doi.org/10.1016/B978-0-12-822047-4.00006-6

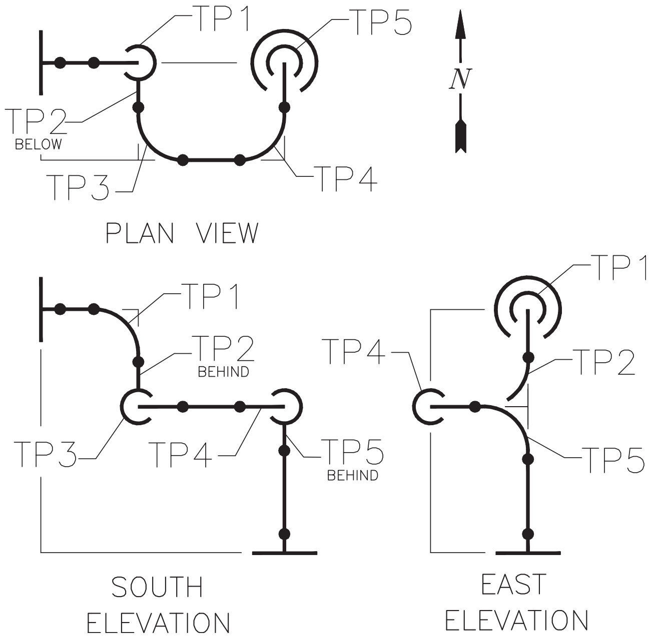


FIGURE 13.3 Piping orthographic views.

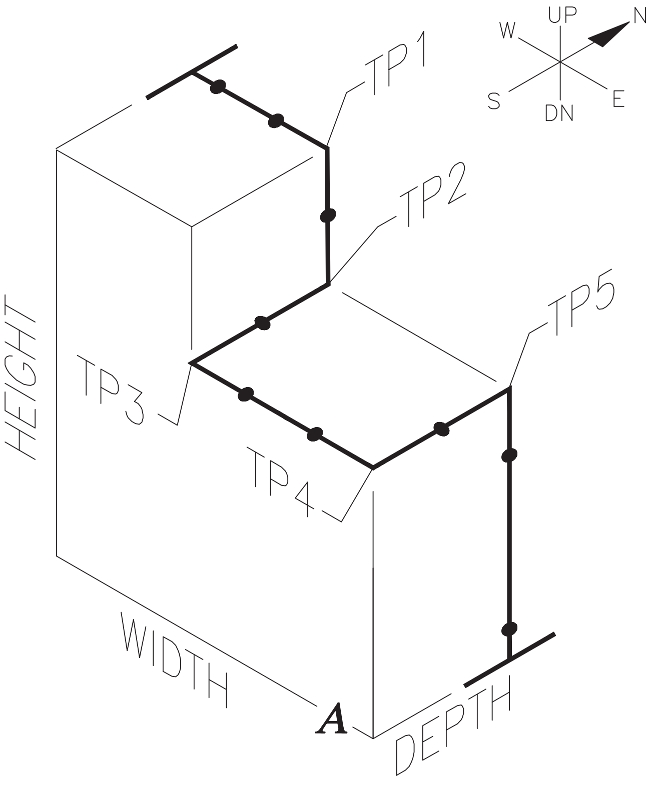


FIGURE 13.4 Piping isometric view.

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 produce a piping isometric of every piping configuration to be installed in the facility. Piping isometrics are typically created single-line, no matter the pipe's nominal size. Each pipe line is drawn or plotted individually on a sheet of paper. On that same sheet is the Bill of Materials with each pipe line drawn on a separate sheet, occasionally having an isometric grid background. Pipe isometrics are also created 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. Software-generated isometrics are notoriously lacking here and are often revised by a CAD drafter.

To be successful in drawing isometrics by hand, 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. After reviewing Figures 13.3 and 13.4, it is evident the elbow symbols in orthographic views and isometric views differ considerably. 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 who hand-draw isometrics use drawing paper having preprinted isometric grid lines which 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

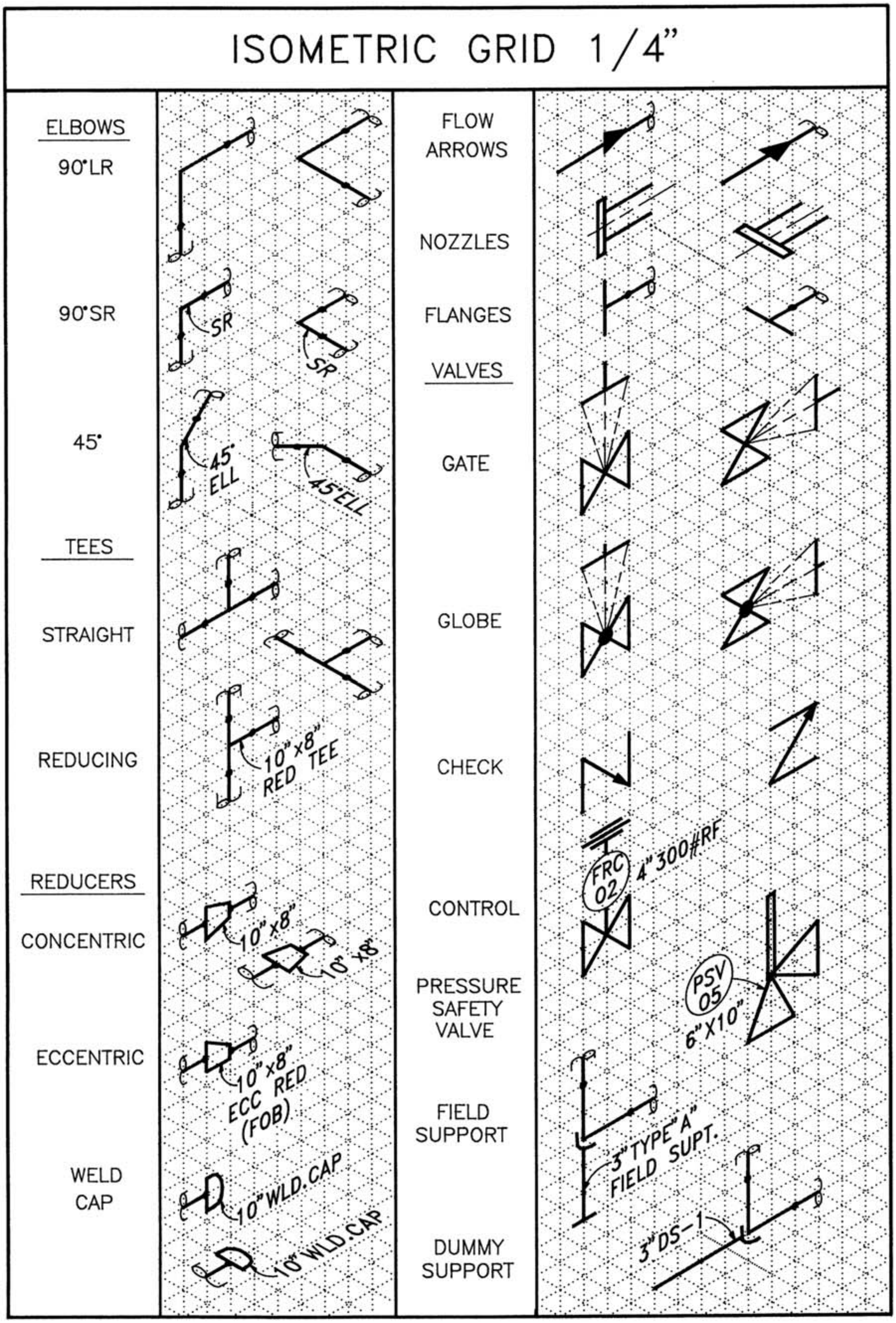


FIGURE 13.5 Isometric piping symbols.

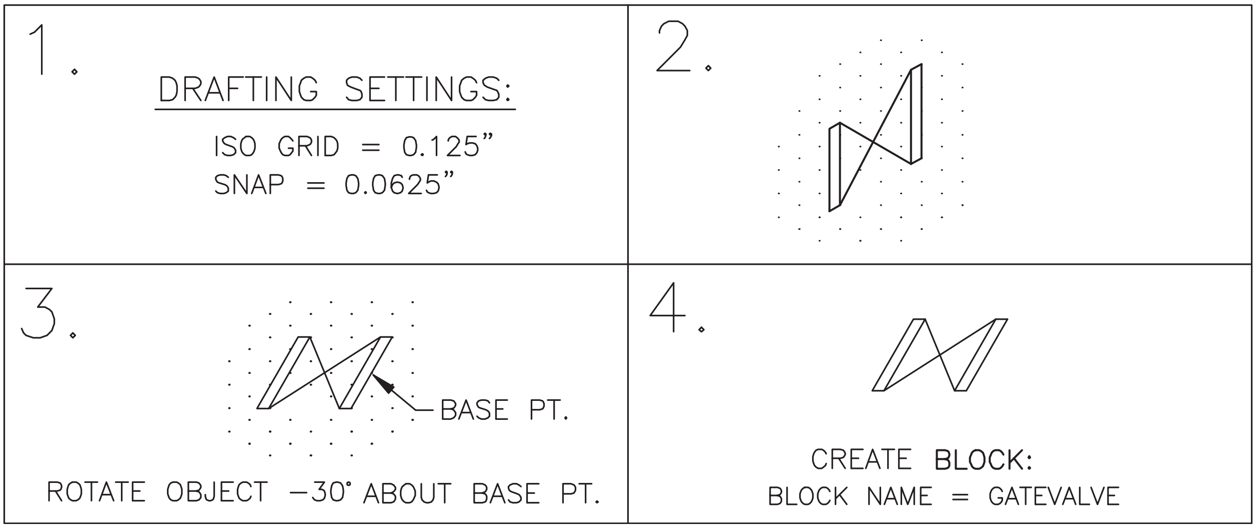


FIGURE 13.6 Creating isometric piping symbols using AutoCAD.

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 which accurately describes the component. Select a Base Point which will permit convenient attachment to other components in an isometric.

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 and interpreting piping isometrics.

Isometric symbols drawn with **AutoCAD** can be developed so 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.

Engineering and Design firms who use 3D plant modeling software use the software's feature which automatically generates isometrics of the modeled pipes. Isos generated by modeling programs are fully dimensioned, including notes and callouts, and have a completed Bill of Materials. It is common however that revisions be made to those isos to reflect client design requirements and drawing enhancements.

ISOMETRIC ORIENTATION

Referring back to Figures 13.1 and 13.2, notice 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 13.7 illustrates

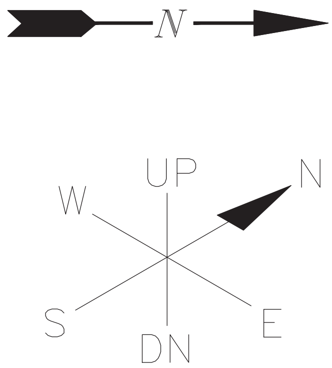


FIGURE 13.7 Orthographic and isometric North Arrows.

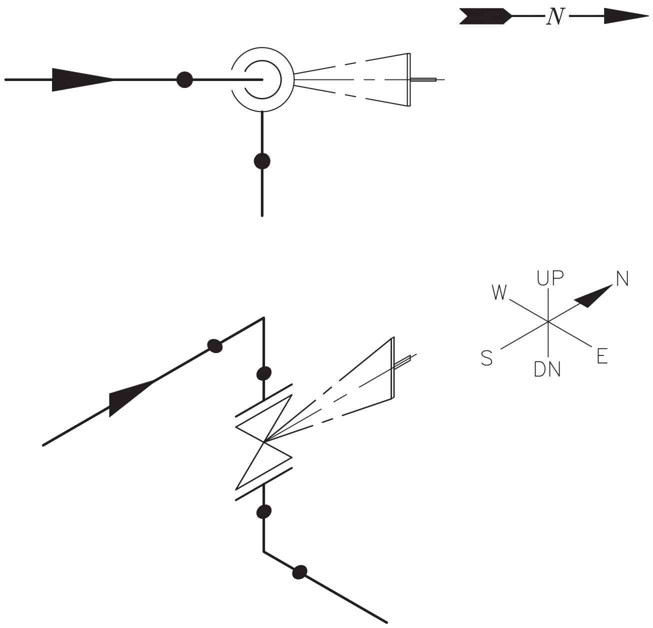


FIGURE 13.8 Isometric orientation.

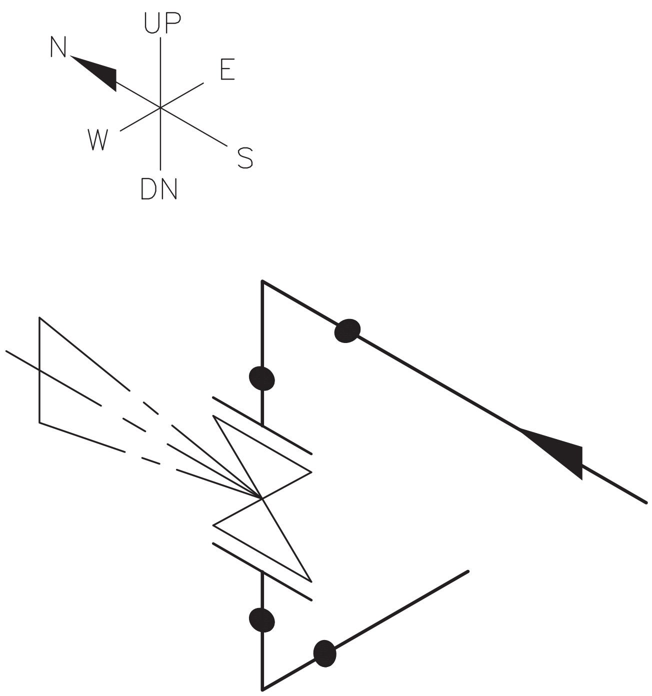


FIGURE 13.9 Alternate isometric orientation.

the representation of the North Arrow on the arrangement drawing and the North Arrow on the isometric.

Knowing 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 which 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 13.8 illustrates the correlation between pipe components shown in a Plan View and those same items in an isometric view. As you may notice, items which are 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 up and to the left. This is done, however, only in exceptional cases to improve drawing clarity. Figure 13.9 uses the configuration from Figure 13.8 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 on an isometric drawing.

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 which correspond to the various orthographic drawing symbols, the pipe drafter 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 piperack. Piping isometrics are generally drawn to represent the configuration up to and including the first fitting in the piperack. Use the procedures that follow to develop a piping isometric of line 01−2-C30−10″-IH.

As shown in Figure 13.10, 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 make-up. 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 which graphically depict 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.

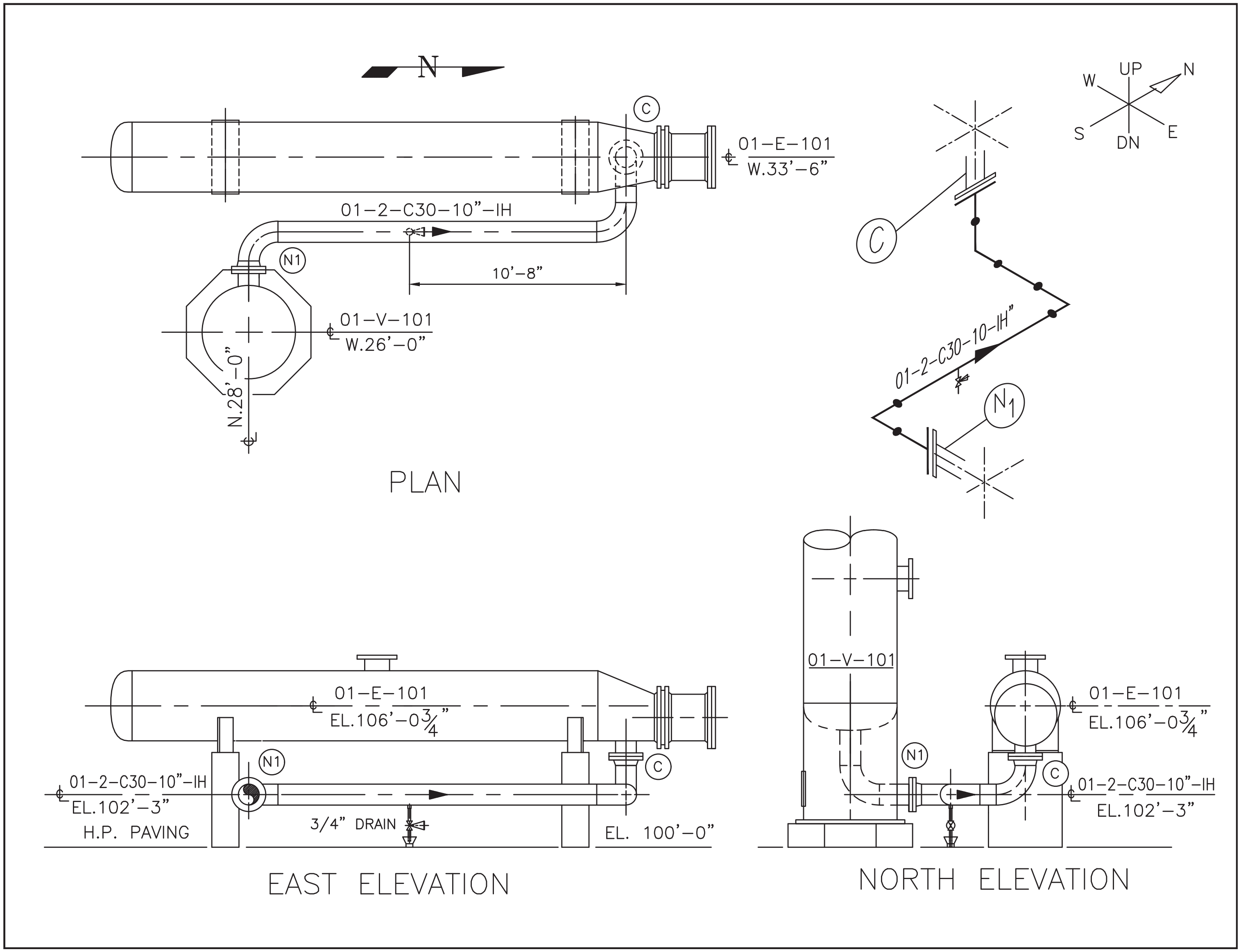


FIGURE 13.10 Line 01–2-C30–10″-IH.

After the north run, an elbow turns west and line 01−2-C30−10″-IH travels below reboiler E-101. Notice 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

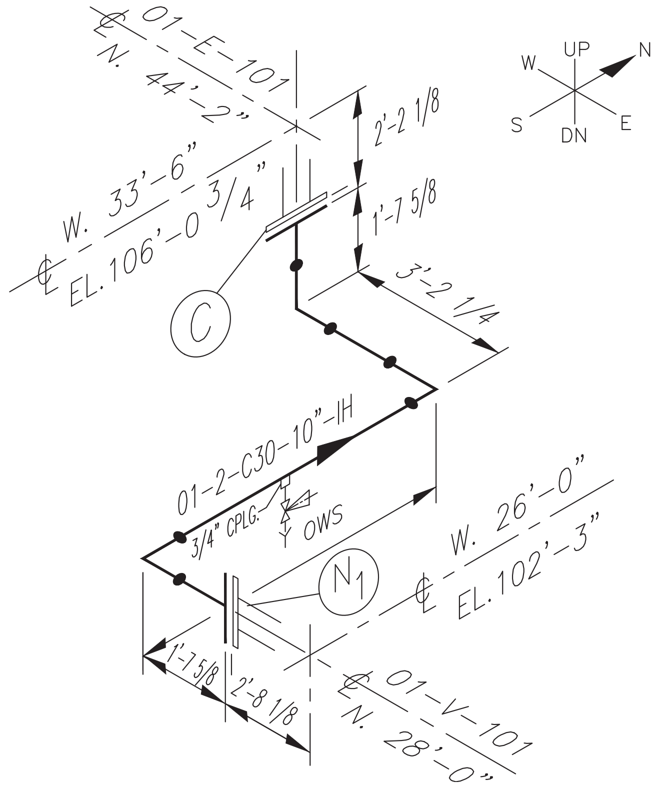


FIGURE 13.11 Line 01−2-C30−10″-IH with dimensions and callouts.

unusual for some companies and CAD software and 3D modeling packages to draw elbow symbols with round corners. Notice 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 which must be represented on the iso are shown in Figure 13.11. 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 the particular nozzle.

The alignment and orientation of written information (name, coordinates, and elevation) about a vessel and/or nozzle on an isometric is sometimes confusing. The four labeling examples in Figure 13.12 indicate callouts for North and South centerline coordinates are actually written on centerlines running in the east/west direction, whereas East and West centerline coordinates are labeled on centerlines which run in the north/south direction. To better understand this concept, remember 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 it be written along the North/South axis so it can be read properly. The ***E. 30′-0***″ coordinate indicates a 30′-0″ distance in the east direction, although it is 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.

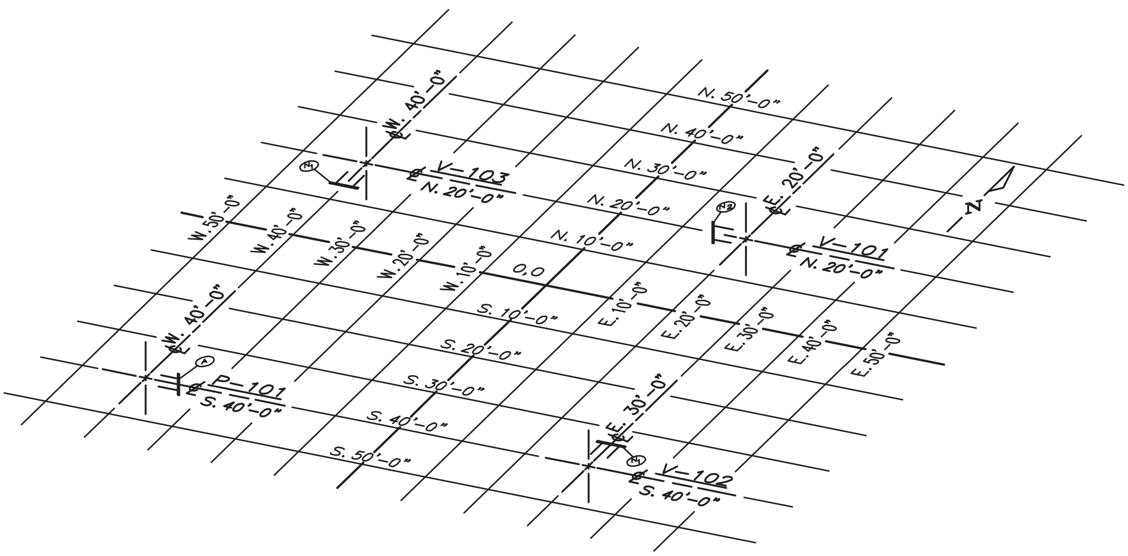


FIGURE 13.12 Isometric orientation and labeling of vessel centerlines.

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. Typically, three methods of applying dimensions exist on an isometric; they are center-to-center, center-to-face, and face-to-face. Figure 13.11 provides dimensions for line 01—2-C30—10″-IH using information found on the Plan and Elevation views shown in Figure 13.10, and the equipment vendor drawings found in Chapter 10, Piping Arrangement Drawings, Sections, and Elevations.

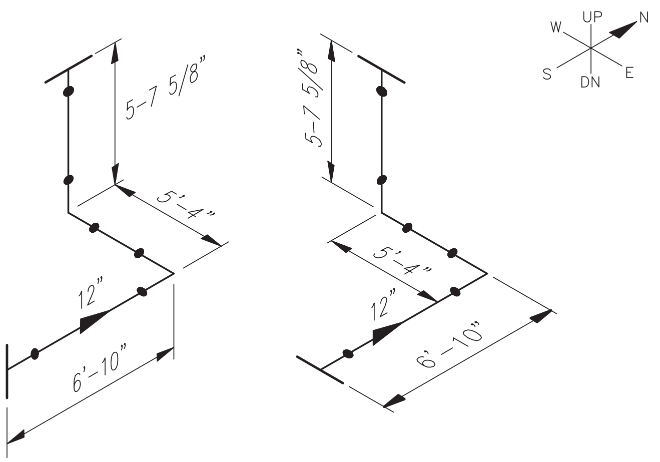


FIGURE 13.13 Dimensioning alternatives.

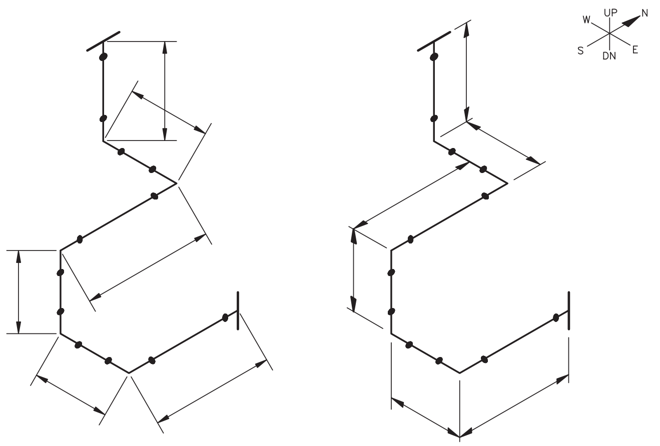


FIGURE 13.14 Aligned and oblique dimensions.

Placing dimensions on a piping isometric with **AutoCAD** requires the use of the *Aligned* and *Oblique* options within the **DIMENSION** command. Figure 13.13 provides two alternatives for placing dimensions on piping isometrics. Dimensions should be aligned with the routed pipe and "oblique" as shown in Figure 13.14.

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 which 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 which 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 13.15.

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 13.16. 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 elbows must always be labeled on an iso for material take-off purposes.

Figure 13.16 represents only three of the many offsets which can be created using 90° and 45° elbows. Example **A** of Figure 13.16 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

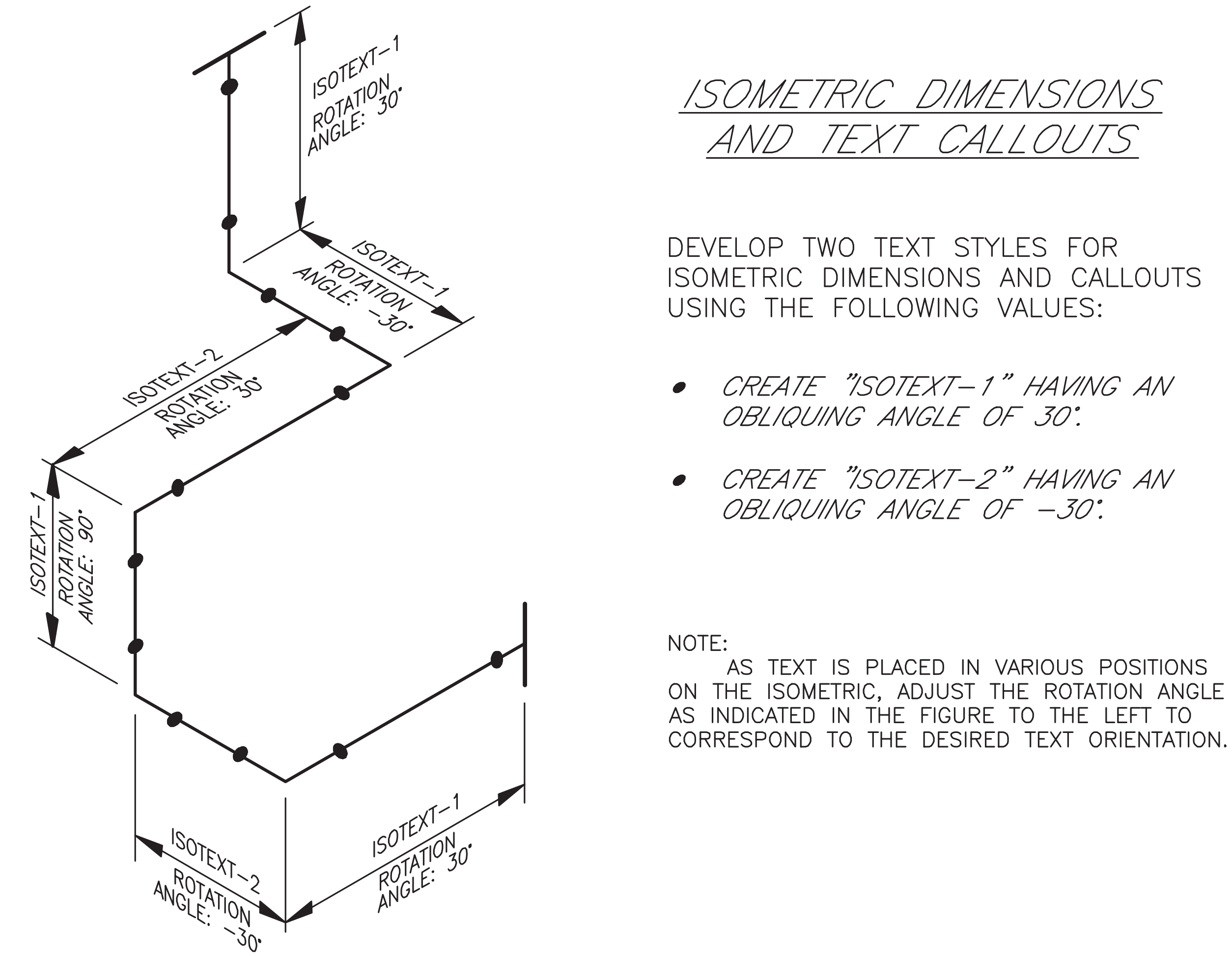


FIGURE 13.15 Creating isometric dimensions and text.

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 13.15.

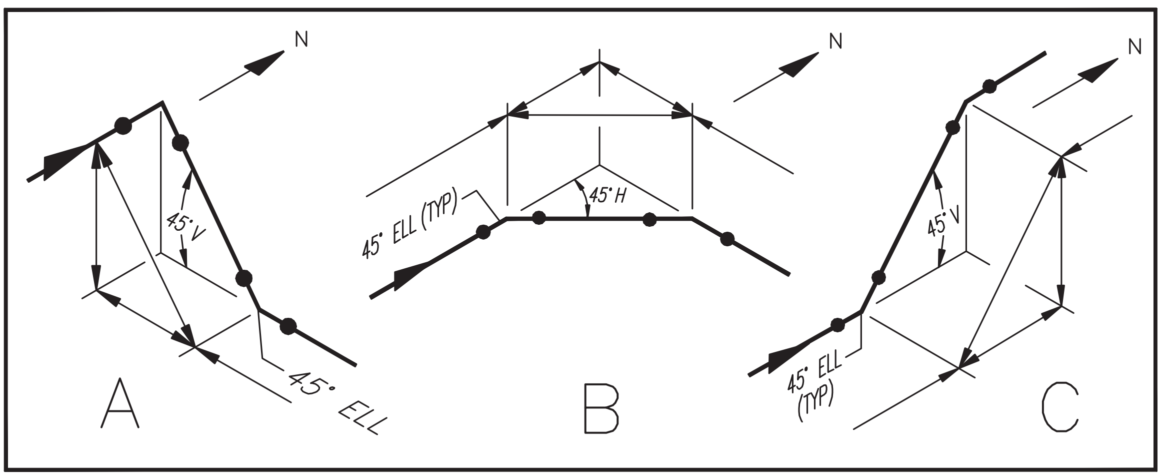
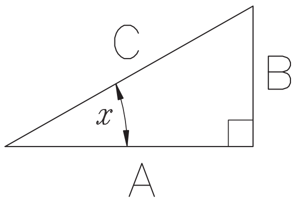


FIGURE 13.16 Isometric offsets.

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 notice 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.

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



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

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

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

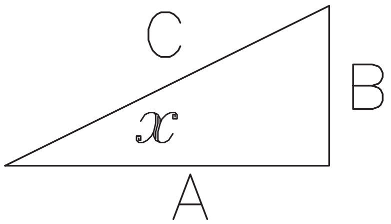
FIGURE 13.17 Pythagorean's theorem formulas.

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 which can be easily solved with simple mathematical formulas. The 90° and 45° elbows form right triangles. By using Pythagorean's Theorem which states the sum of the squares of the two sides is equal to the square of the triangle's hypotenuse, this problem can be solved. Simply stated, $A^2 + B^2 = C^2$. Figure 13.17 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 13.18 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.

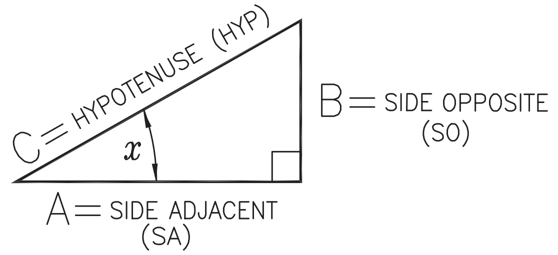
As mentioned previously, 90° elbows can be rolled to form any degree of angular offset. To fabricate such



RIGHT TRIANGLE MULTIPLICATION FACTORS

TO FIND SIDE	WHEN YOU KNOW SIDE	MULTIPLY 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 13.18 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= $\frac{SO}{TAN\ x}$	SO= $\frac{SA}{COT\ x}$	HYP= $\frac{SO}{SIN\ x}$
SA= $\frac{HYP}{SEC\ x}$	SO= $\frac{HYP}{CSC\ x}$	HYP= $\frac{SA}{COS\ x}$

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

FIGURE 13.19 Formulas for solving angle **X**.

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 13.19 to solve for the unknown value of angle **X**. Notice, 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).

The mathematical formulas used to develop the numerical values found in the chart in Figure 13.18 are shown below.

Six Trigonometric Functions

$\sin x = {}^{1}/_{\csc x} = {}^{\tan x}/_{\sec x} = {}^{\text{opposite}}/_{\text{hypotenuse}}$
$\cos x = {}^{1}/_{\sec x} = {}^{\cot x}/_{\csc x} = {}^{\text{adjacent}}/_{\text{hypotenuse}}$
$\tan x = {}^{1}/_{\cot x} = {}^{\sin x}/_{\cos x} = {}^{\text{opposite}}/_{\text{adjacent}}$
$\cot x = {}^{1}/_{\tan x} = {}^{\cos x}/_{\sin x} = {}^{\text{adjacent}}/_{\text{opposite}}$
$\sec x = {}^{1}/_{\cos x} = {}^{\csc x}/_{\cot x} = {}^{\text{hypotenuse}}/_{\text{adjacent}}$
$\csc x = {}^{1}/_{\sin x} = {}^{\sec x}/_{\tan x} = {}^{\text{hypotenuse}}/_{\text{opposite}}$

For example: when "x" is 45°, cos 45° = **0.7071** and $^{1}/\cos 45° =$ **1.4142**.

Multiangle Offsets

Elbows are not the only piping components installed in angular positions. Because of the arrangement 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. Multiangle configurations, such as the one in Figure 13.20, 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 13.20 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. The length of the unknown dimension can only be solved by using the limited information available in Figure 13.20. Figure 13.21 demonstrates the way to position three right triangles to solve for the "unknown" dimension, marked as "**?**" in Figure 13.20.

Numbering the triangles will aid in the discussion which follows, concerning the solution to the lengths of the sides of each triangle. The "unknown" dimension,

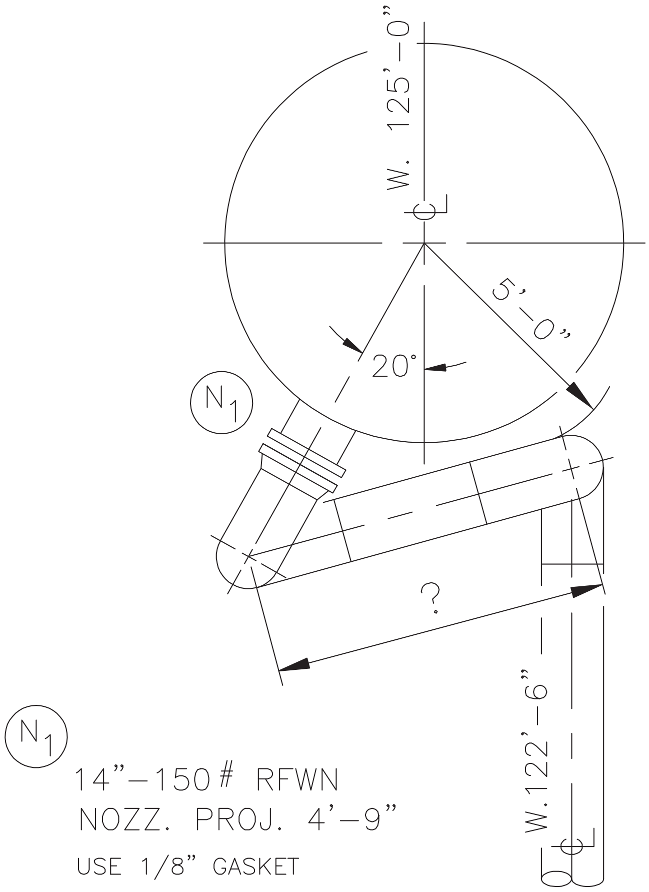


FIGURE 13.20 Multiangle offsets.

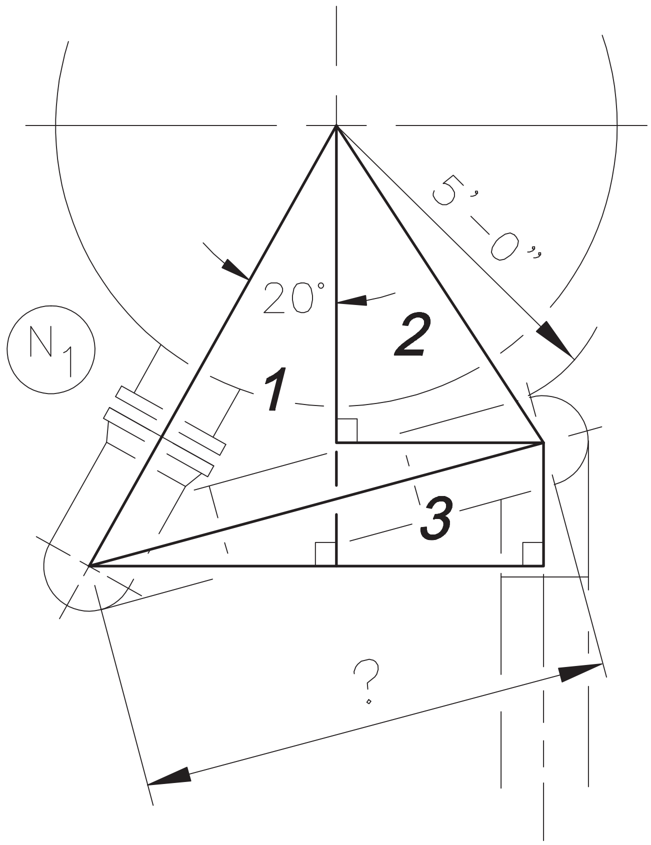


FIGURE 13.21 Locating right triangles.

"?," 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 13.20. Figure 13.22 shows the known values of triangles **1**, **2**, and **3**, placed in their appropriate locations.

The **X** angle for triangle **1** is shown to be 20° in Figure 13.20. The 6′-11⅛″ 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.

Notice 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**, Pythagorean's theorem can be applied to find the hypotenuse, the unknown dimension.

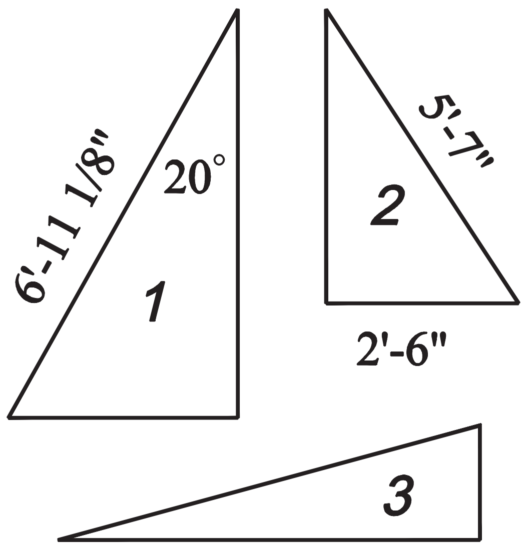


FIGURE 13.22 Known values for triangles **1**, **2**, and **3**.

Using the available formulas, the missing lengths of triangles **1** and **2** must be solved before the sides of triangle **3** can be determined. 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

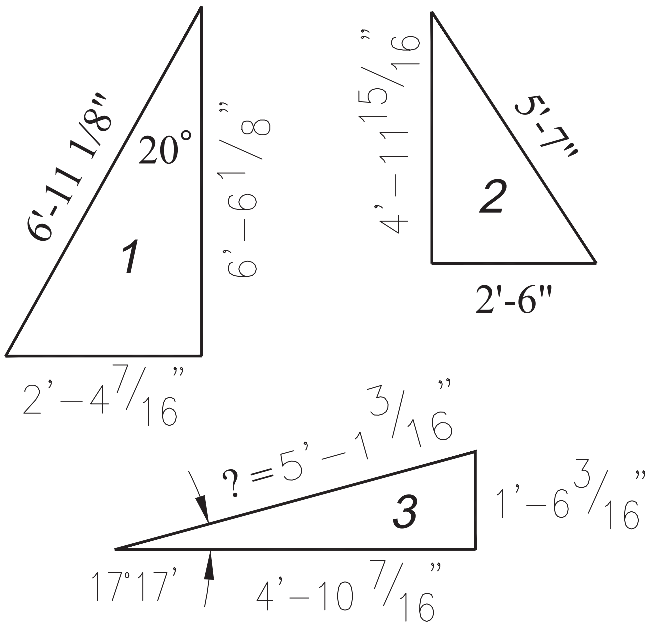


FIGURE 13.23 Solutions for triangles **1**, **2**, and **3**.

of triangle **2** (2′-6″) will yield the SA of triangle **3**. The results of these calculations are shown in Figure 13.23. The length of the "unknown," "?," is dimension is 5′ − 1 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 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 in Figure 13.20 with two 45° elbows. The result is an offset which changes elevation and direction simultaneously. Figure 13.24 shows the Plan and Elevation views of a rolling offset.

Because of its complexity, adequate dimensions cannot be placed on the orthographic views which fully describe the rolling offset. An isometric is the best place for representing and dimensioning the rolling offset. But 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 13.25 shows construction of the rolling offset box and its accompanying dimensions and angles.

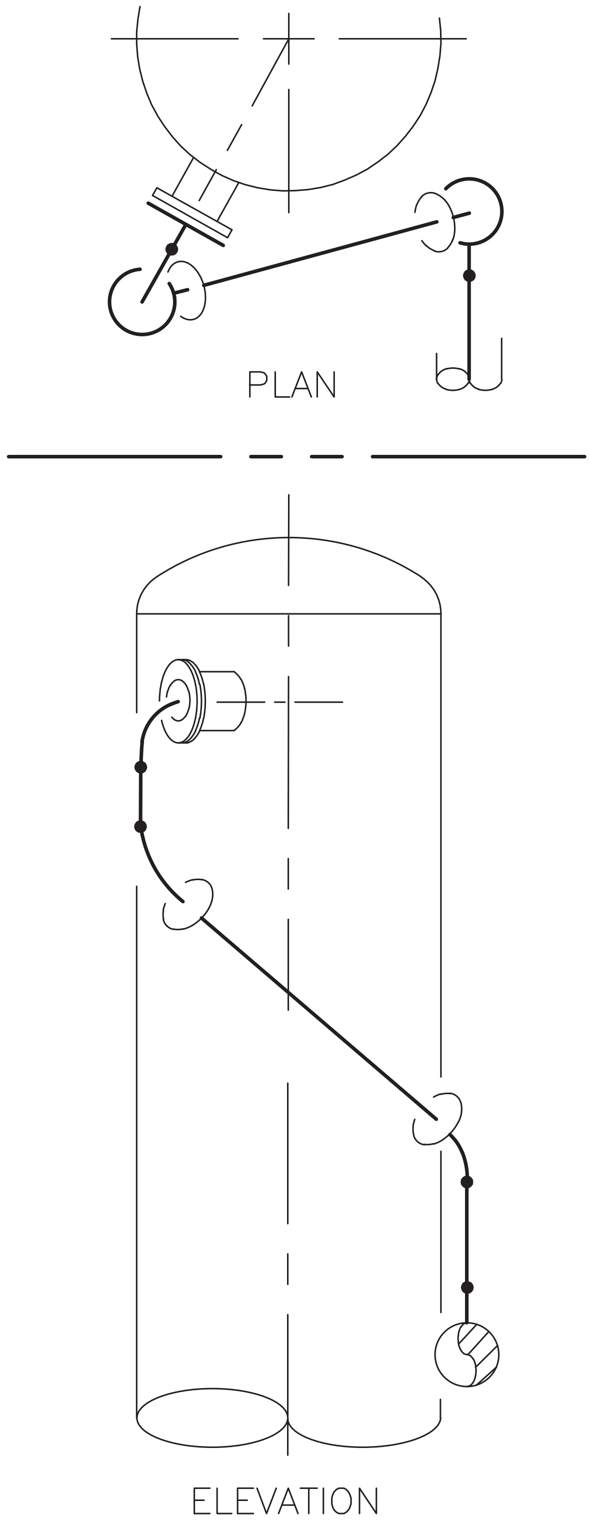


FIGURE 13.24 Plan and Elevation views of a rolling offset.

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

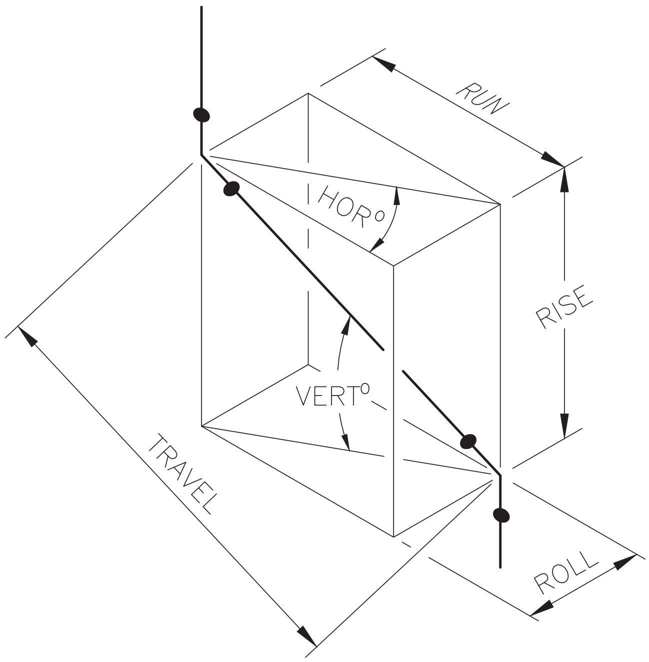


FIGURE 13.25 Rolling offset box.

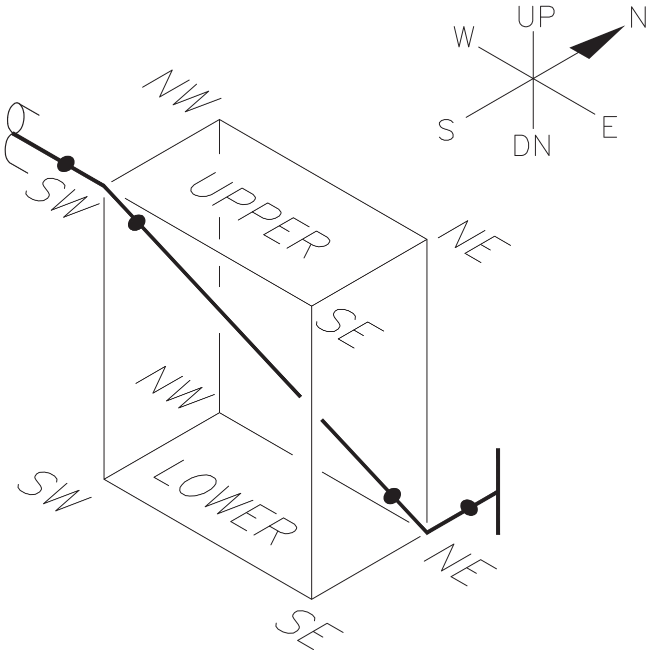


FIGURE 13.27 Isometric of a rolling offset.

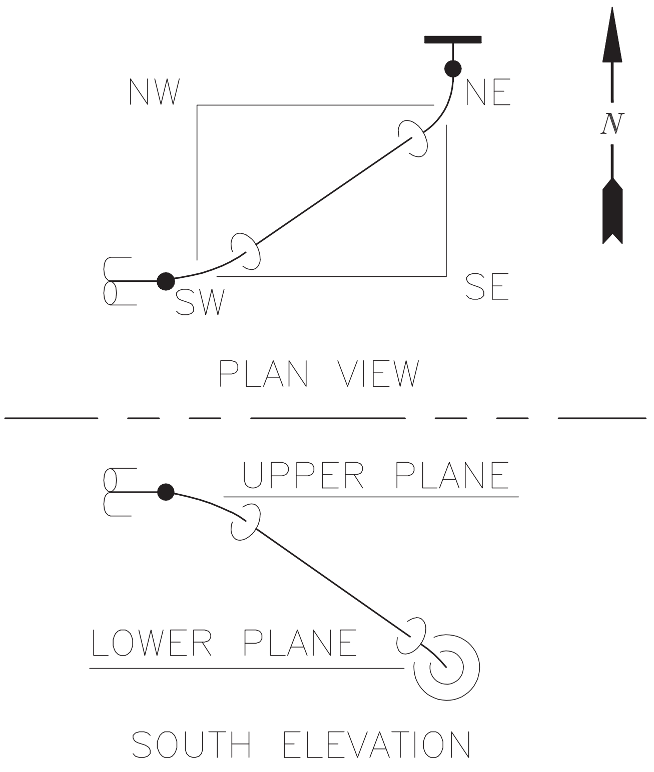


FIGURE 13.26 Visualization aids for rolling offsets.

requires practice and patience. To aid in this visualization process, some helpful notes have been added to the Plan and Elevation views of the rolling offset shown in Figure 13.26. In the Plan View, a box has been drawn through the centers of the two 45° elbows which 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 orientation and the Elevation View depicts vertical changes in elevation.

The Plan View in Figure 13.26 shows the pipe entering the box from the southwest corner and traveling across to the northeast corner, where it ends with a flange. Looking at the Elevation View, 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 the pipe begins in the upper southwest corner and travels down to the lower northeast corner. The resulting isometric representation is shown in Figure 13.27.

Dimensioning Rolling Offsets

Figure 13.25 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 the one shown in Figure 13.28, the lengths of the three sides of triangle **3** are applied to the dimensions of the rolling offset box (see Figure 13.25). Notice the SA of triangle **3** in Figure 13.28 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? Notice the dimension labeled **TRAVEL** in Figure 13.25. 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 13.29 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.

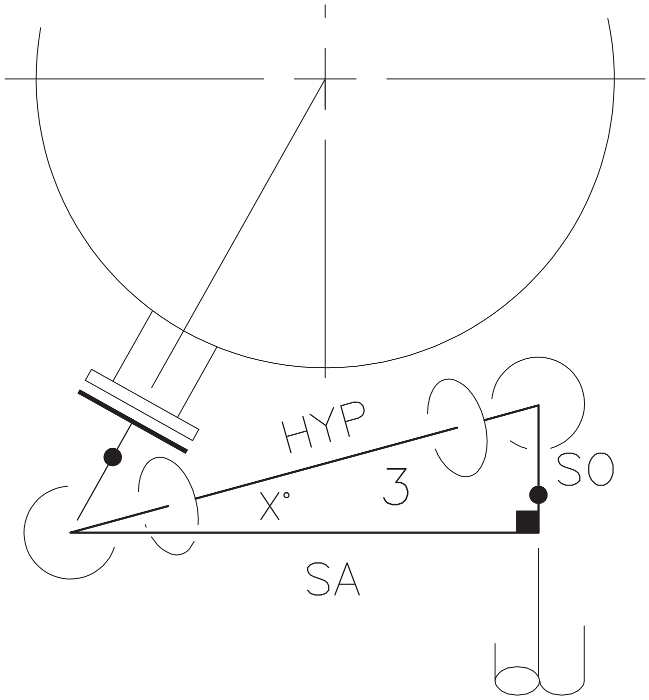


FIGURE 13.28 Rolling offset with right triangle.

Note in example **A**, the pipe enters and exits the rolling offset box in the vertical plane. Example **B** shows the pipe to enter and exit 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 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 13.30 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, Pythagorean's theorem can be used to easily solve the **TRAVEL** dimension of the pipe. Since 45° is a commonly used angle, the

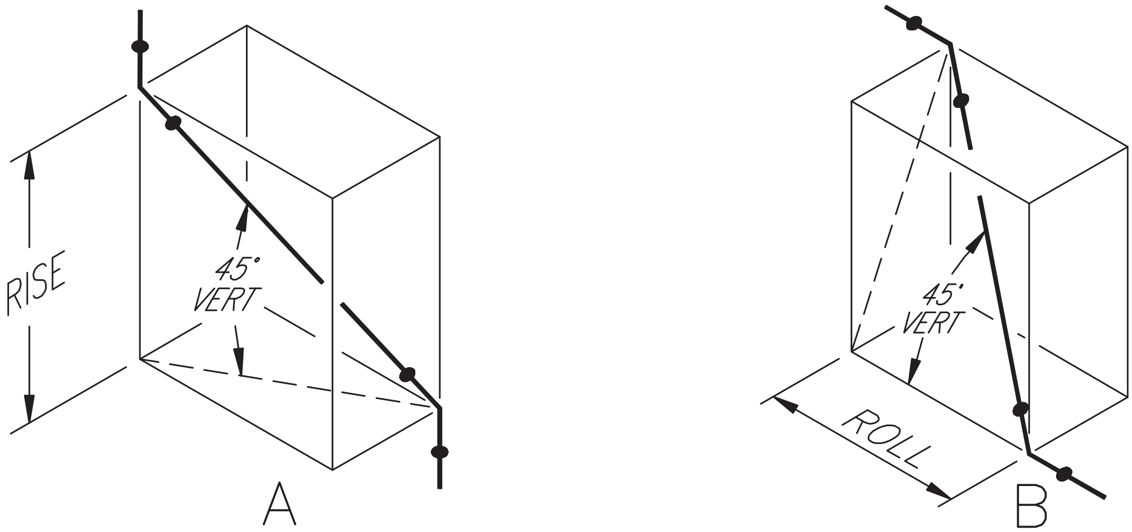


FIGURE 13.29 Vertical and horizontal pipe entering and exiting the rolling offset box.

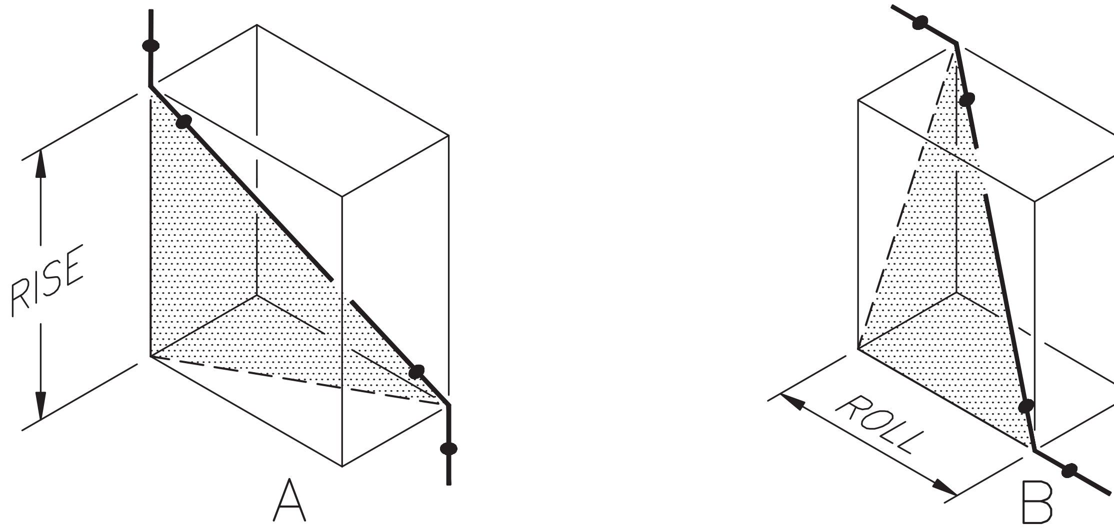


FIGURE 13.30 Right triangles created with **TRAVEL** length as hypotenuse.

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	1.0000		
1/16"	.0052	.0885	.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 13.31 Inch to decimal conversion chart.

numbers found in Figure 13.18 can be used to make the solution even simpler.

The chart in Figure 13.31 converts inches and fractions of an inch into decimals. Multiplication and division of fractions is 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 13.31, 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 8⅝″, follow the column below **8**″ down until it is adjacent to ⅝″ (displayed in the "**Fraction**" column). The number at this intersection is **0.7187**. Therefore 0.7187 is the decimal equivalent of 8⅝″.

Two appendices at the end of the text provide solution examples of the mathematical calculations Figure 13.31 employs. Use these to have an understanding of how to convert inches to decimals and vice versa when Figure 13.31 is not available.

If a decimal number needs to be converted into inches, use the chart in Figure 13.31 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 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 most projects' Specifications requiring dimensions to be given to the nearest 1⁄16 of an inch.

Pipe Stress Analysis

In conjunction with the dimensions needed to fabricate a configuration of pipe, the pipe's measurements are just one piece of data needed to perform precise stress analysis on all pipes in a facility. Other types of data needed to perform a complete analysis of the stress loads a pipe can undergo include: specific codes and specifications related to the Project, each pipe's operating pressure and temperature, vibration cycles, wind loads, and a pipe's intended length of service. Because a pipe has the potential to undergo continual pressure and temperature variations, stress calculations must be made using the combined data inputs for multiple situations.

Knowing each pipe configuration is comprised of many different fitting, flange, and valve combinations, comprehensive stress analysis on each configuration must include axial, radial, and circumferential loads. Complex hand calculations have long since been replaced with software programs such as CAESAR II and CAEPIPE. Plant modeling programs such as AVEVA E3D, AutoCAD Plant 3D, and SmartPlant 3D, all have stress analysis modules.

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 Pythagorean's 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.

____

____

____

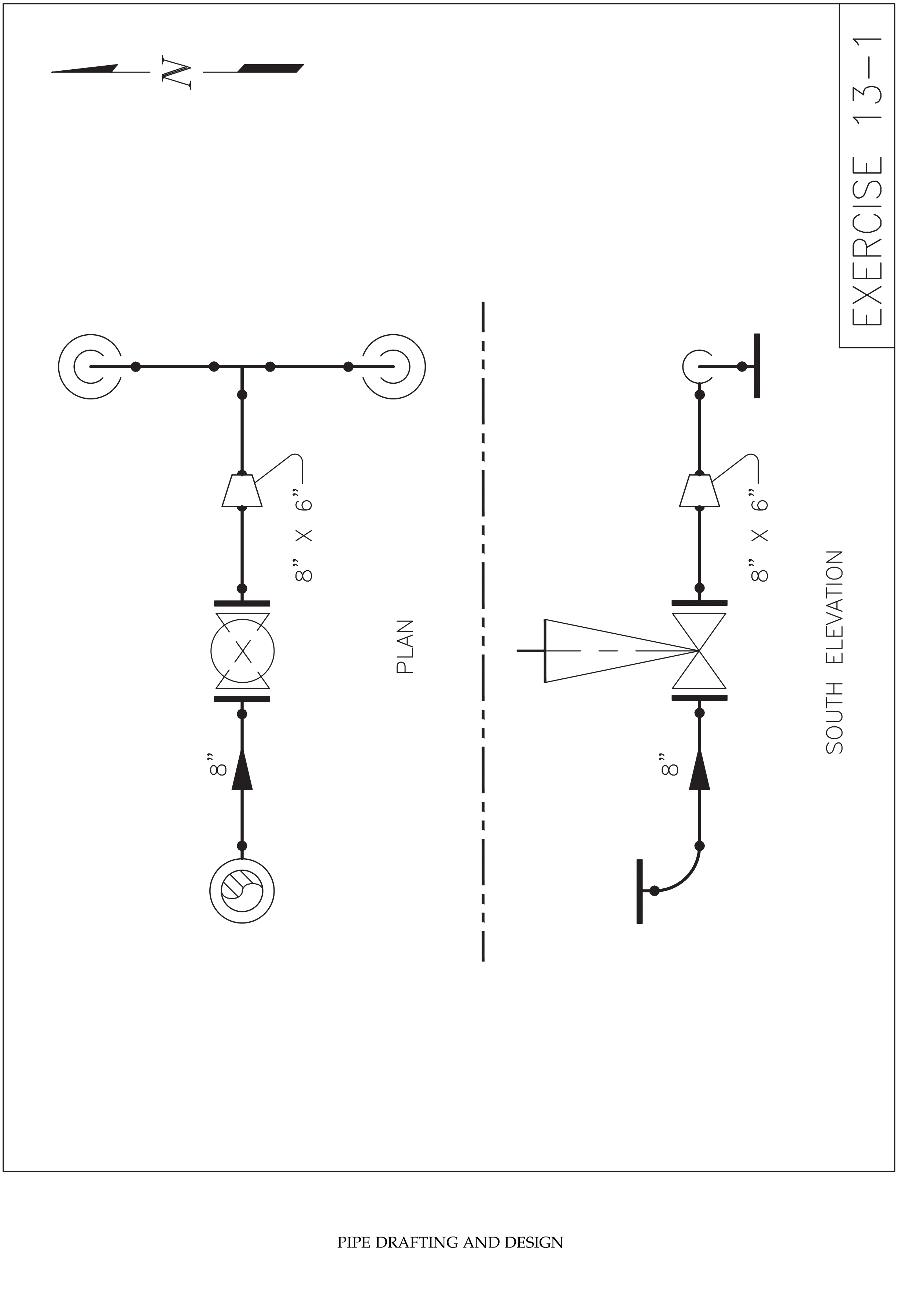
____

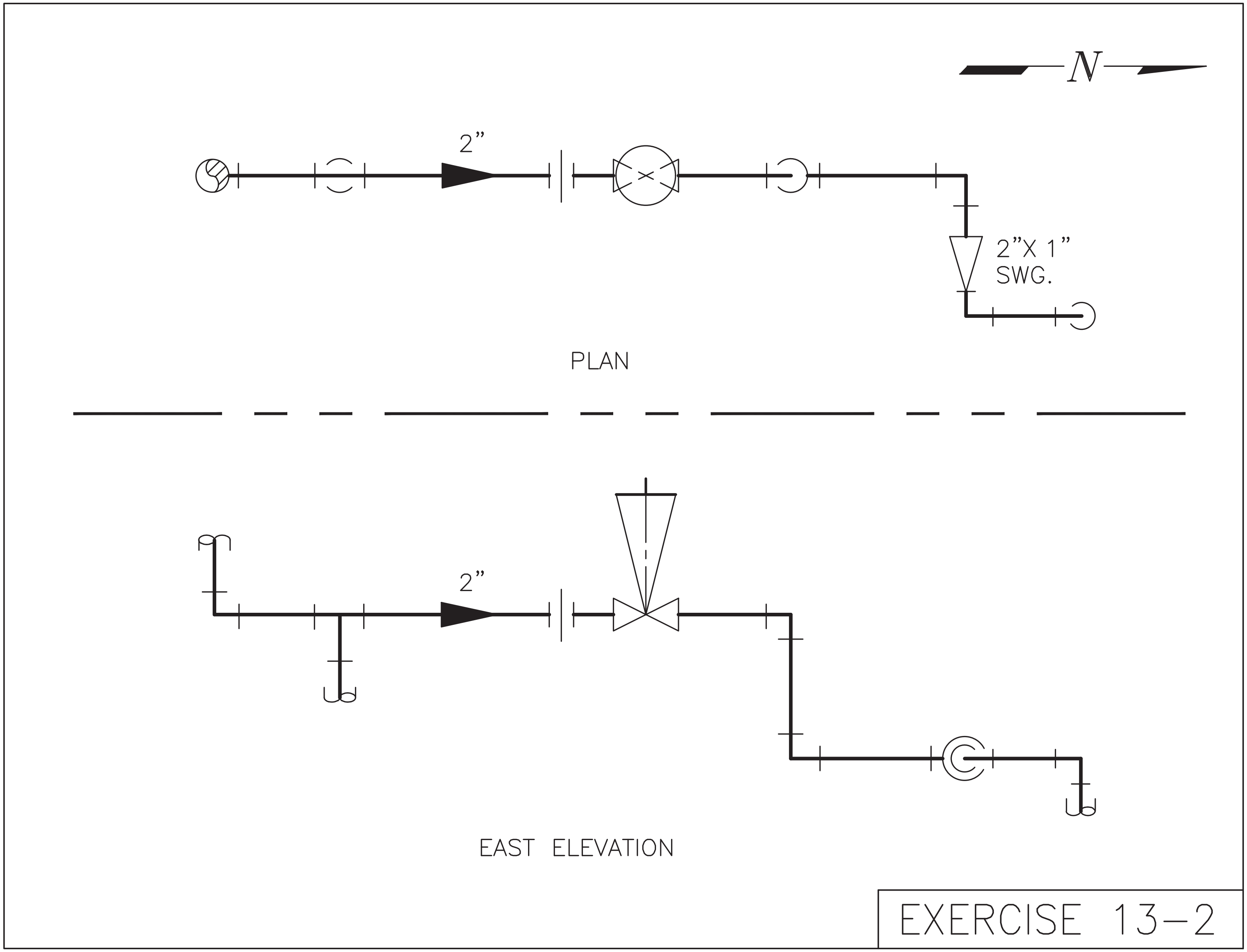
____

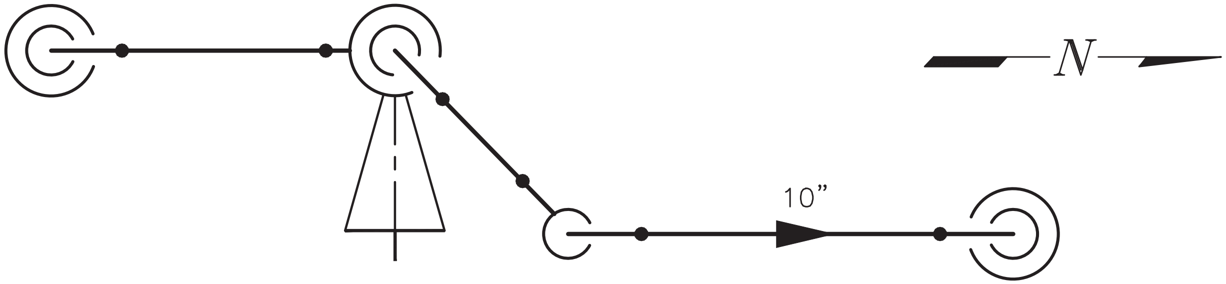
____

CHAPTER 13 DRAWING EXERCISES

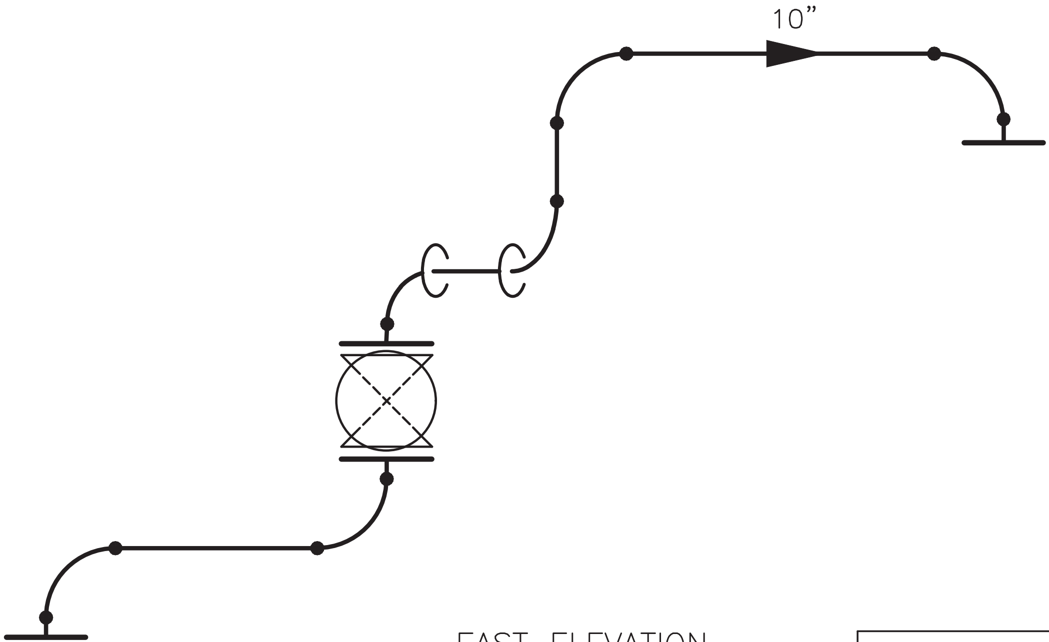
Use the Plan and Elevation views provided to sketch an isometric of the following exercises.




N
2"
2"X 1"
SWG.
PLAN
2"
EAST ELEVATION
EXERCISE 13-2

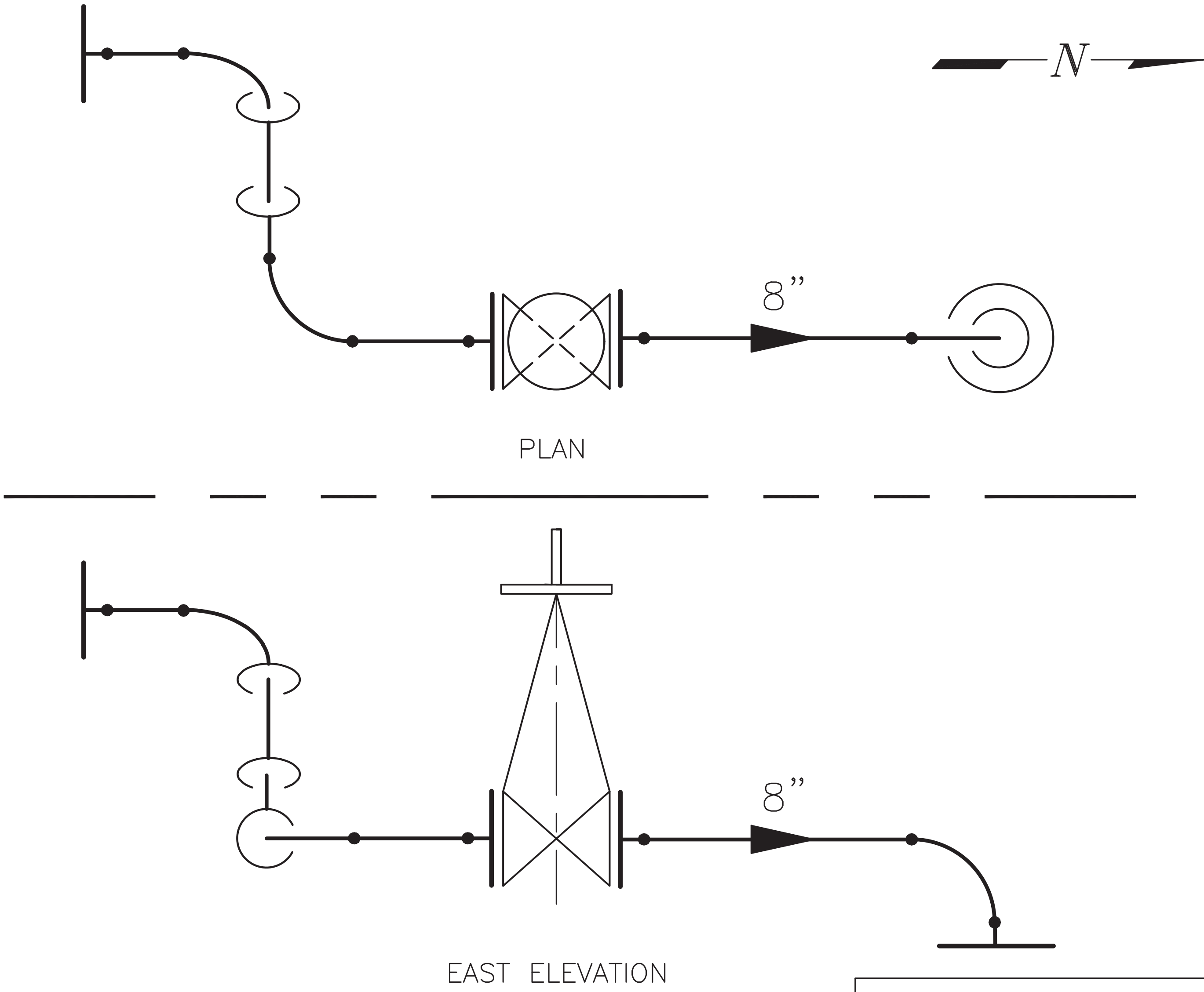


PLAN

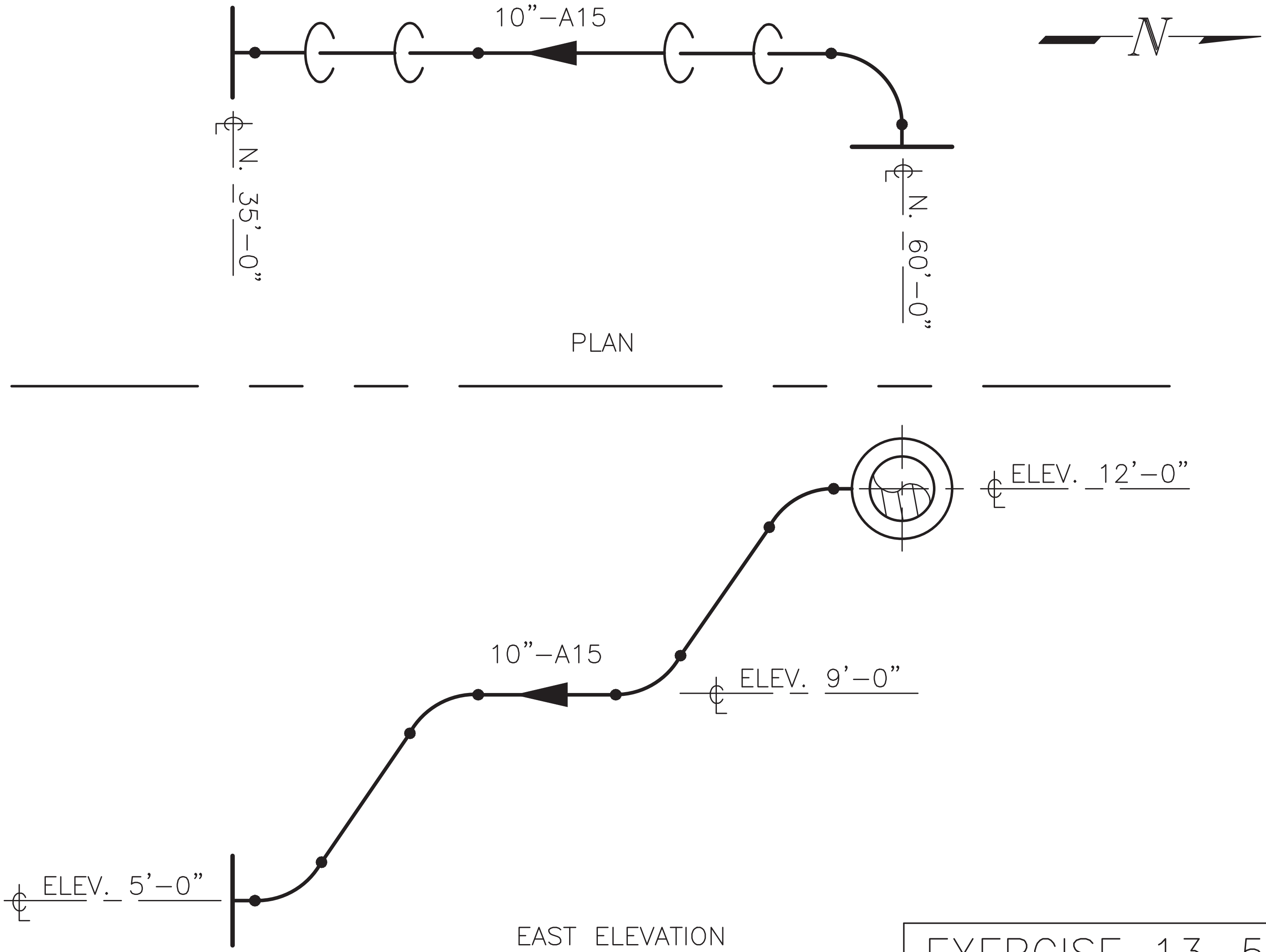


EAST ELEVATION

EXERCISE 13–3

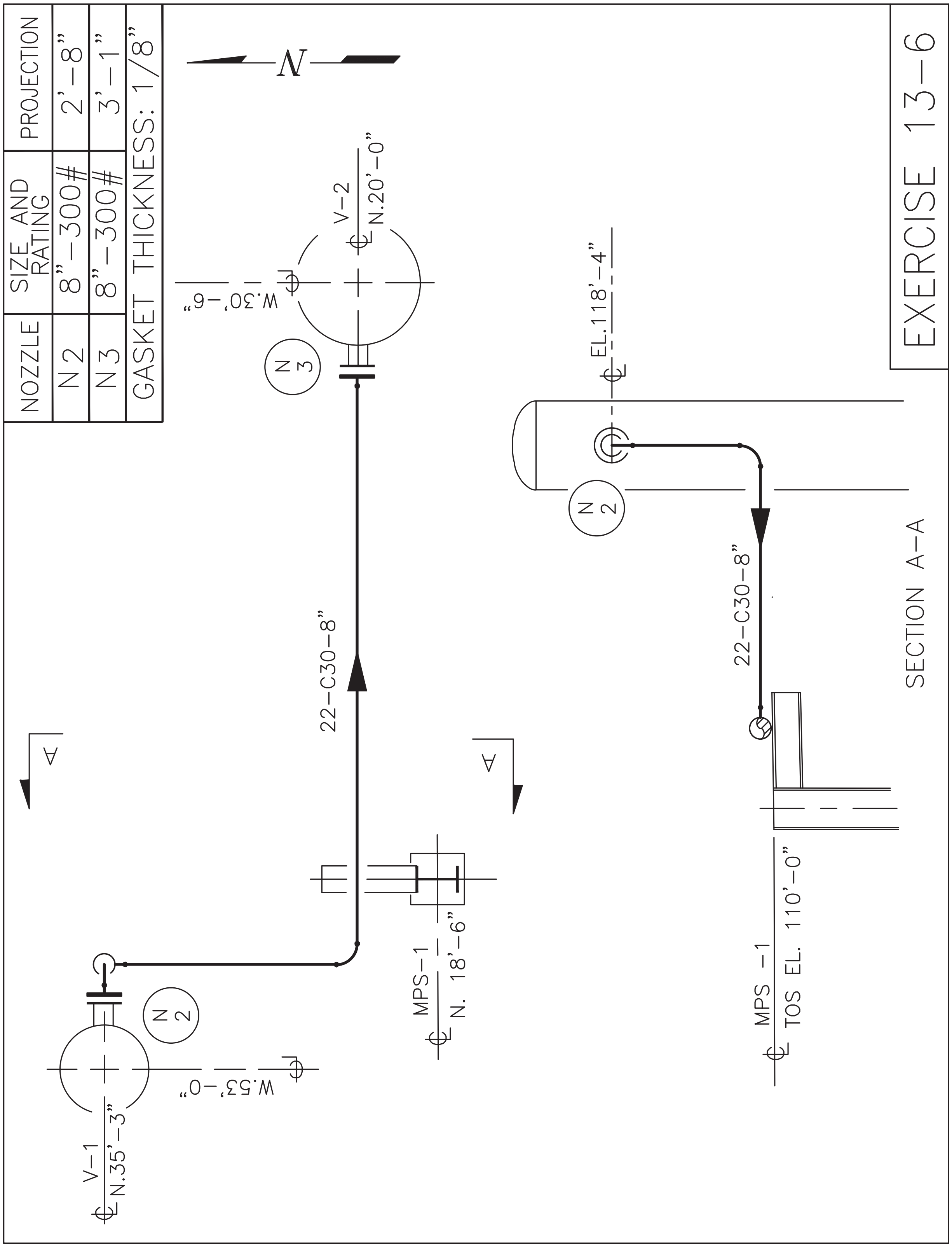


EXERCISE 13-4

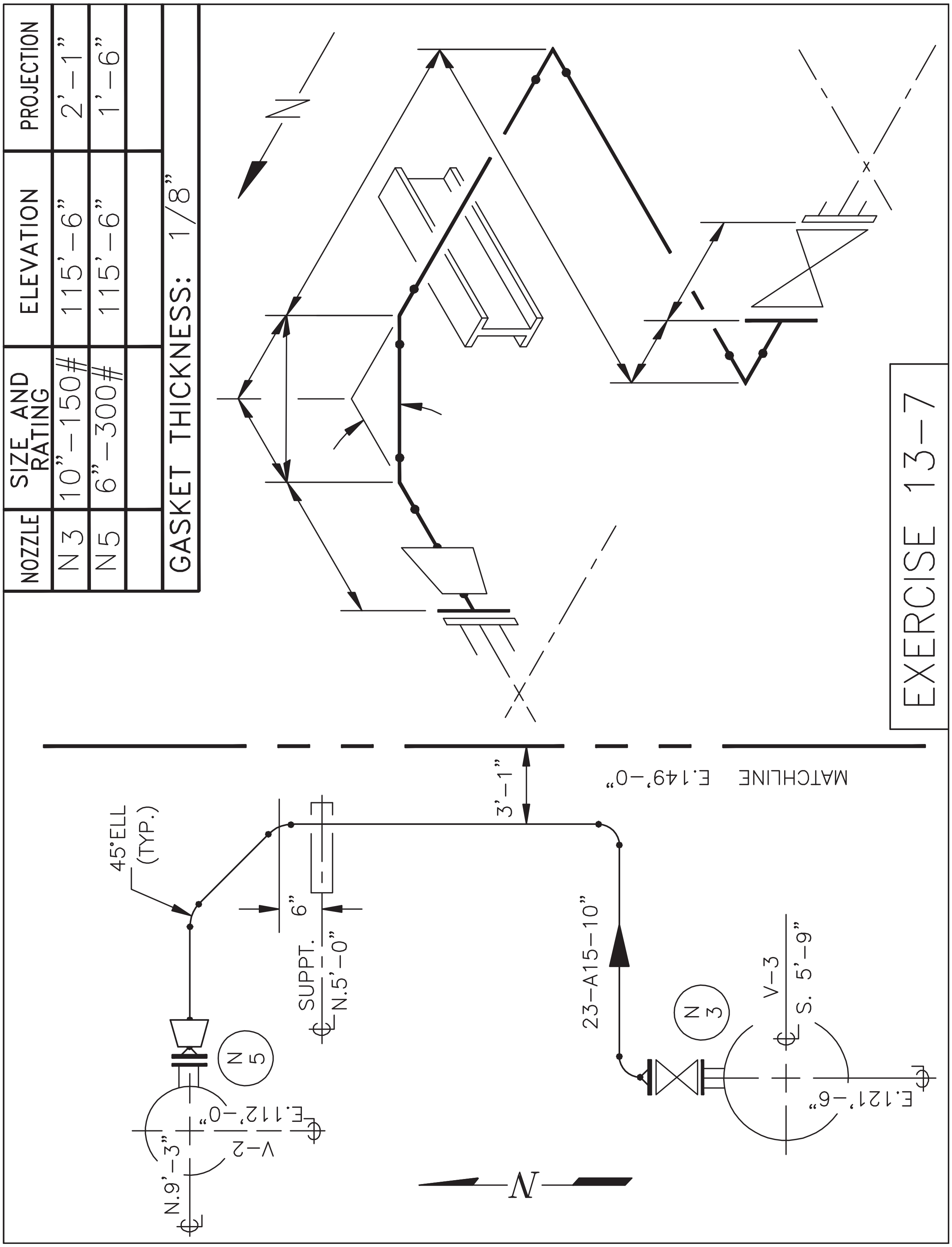


EXERCISE 13–5

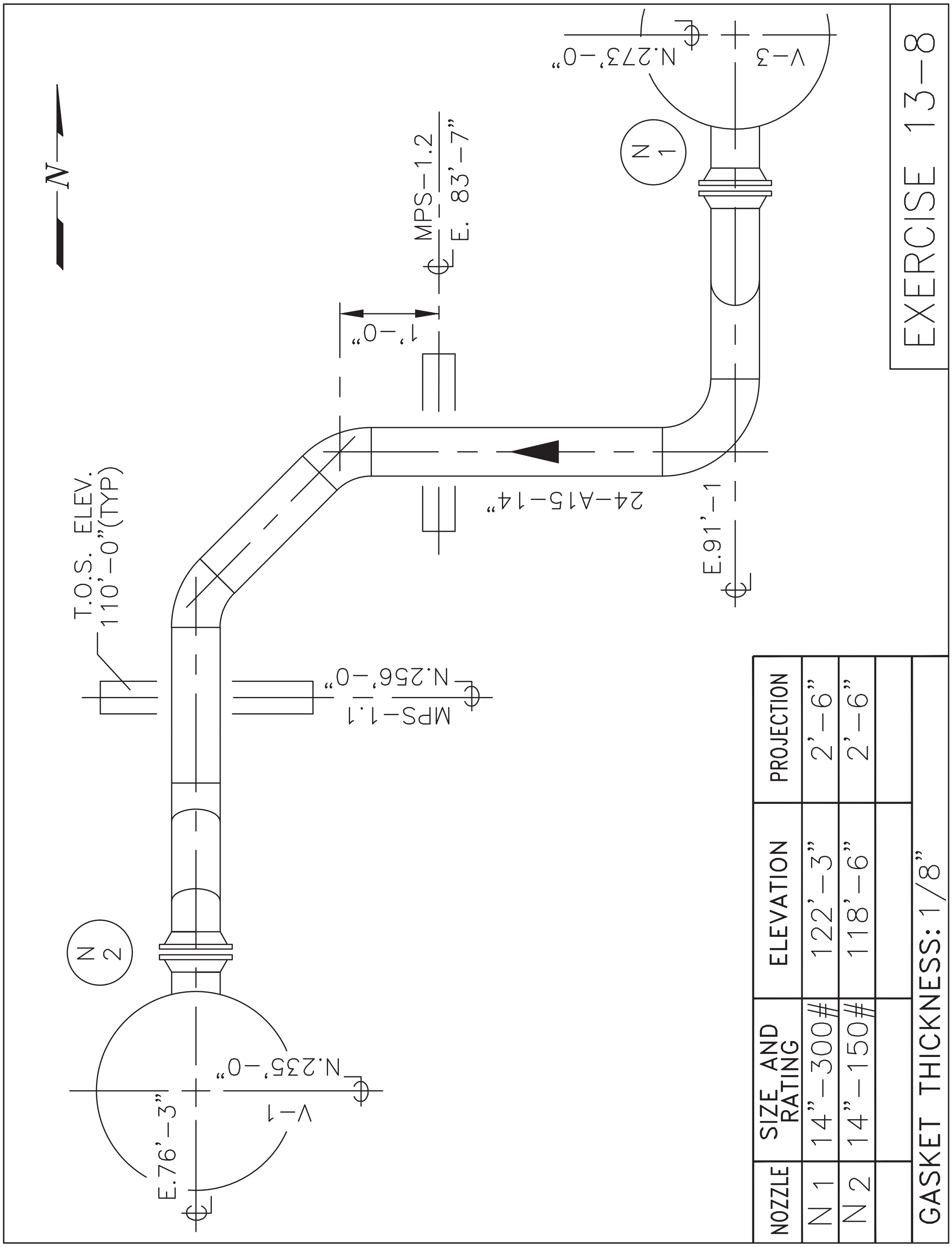
Draw an isometric for the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North arrow direction on the isometric will be up and to the right.



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

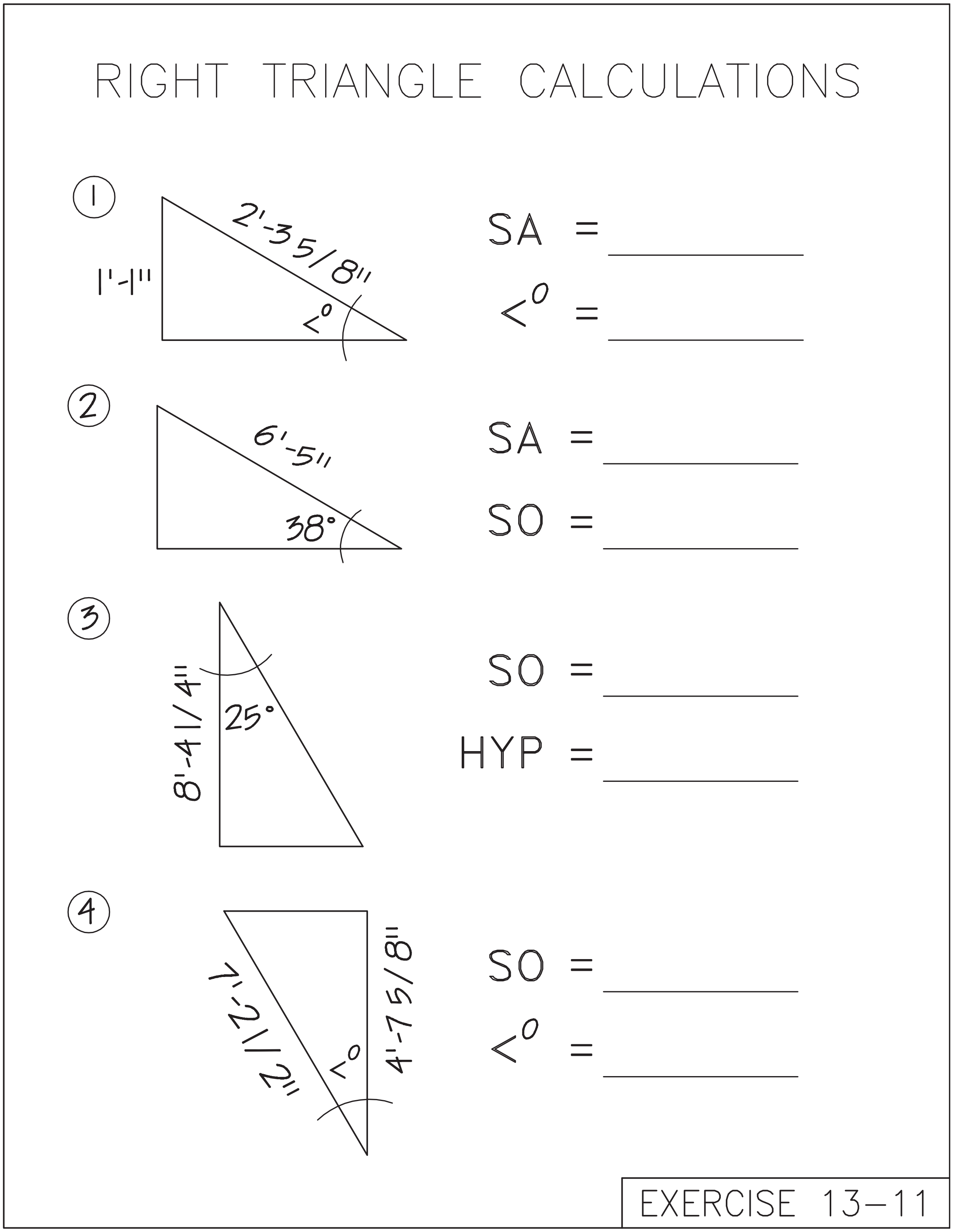
Solve the conversion problems shown. Answers are to be written in degree, minute, and second values. Decimal answers are to be written to the fourth decimal place.

DEGREE TO DECIMAL & DECIMAL TO DEGREE CONVERSIONS

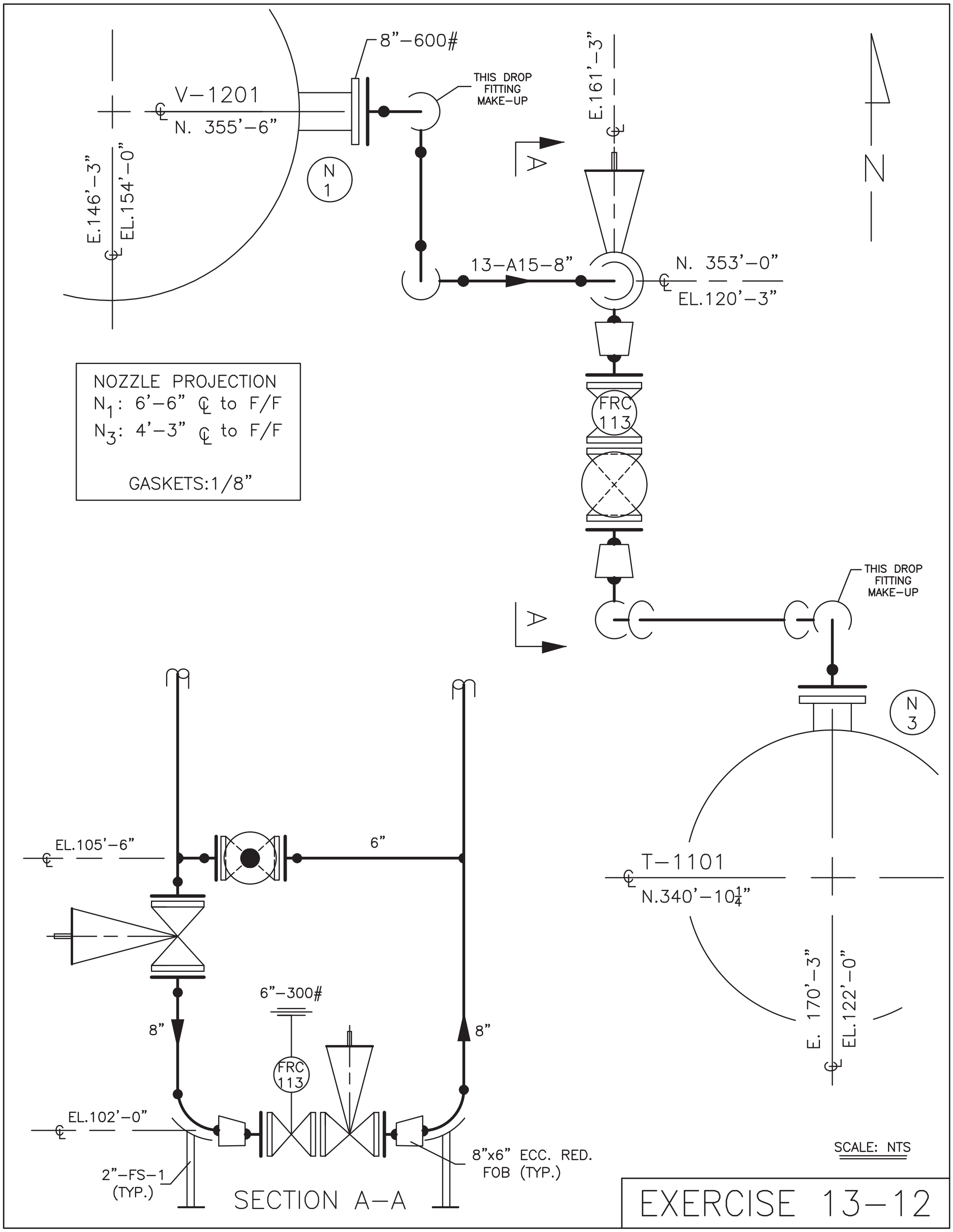
(1) 32° 9' 45" = ________	(11) 24.6137° = ________
(2) 51° 31' 7" = ________	(12) 12.875° = ________
(3) 9° 0' 30" = ________	(13) 38.2113° = ________
(4) 21°35'42" = ________	(14) 9.7281° = ________
(5) 43°33'20" = ________	(15) 39.465° = ________
(6) 19°45' = ________	(16) 43.325° = ________
(7) 34°10'38" = ________	(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

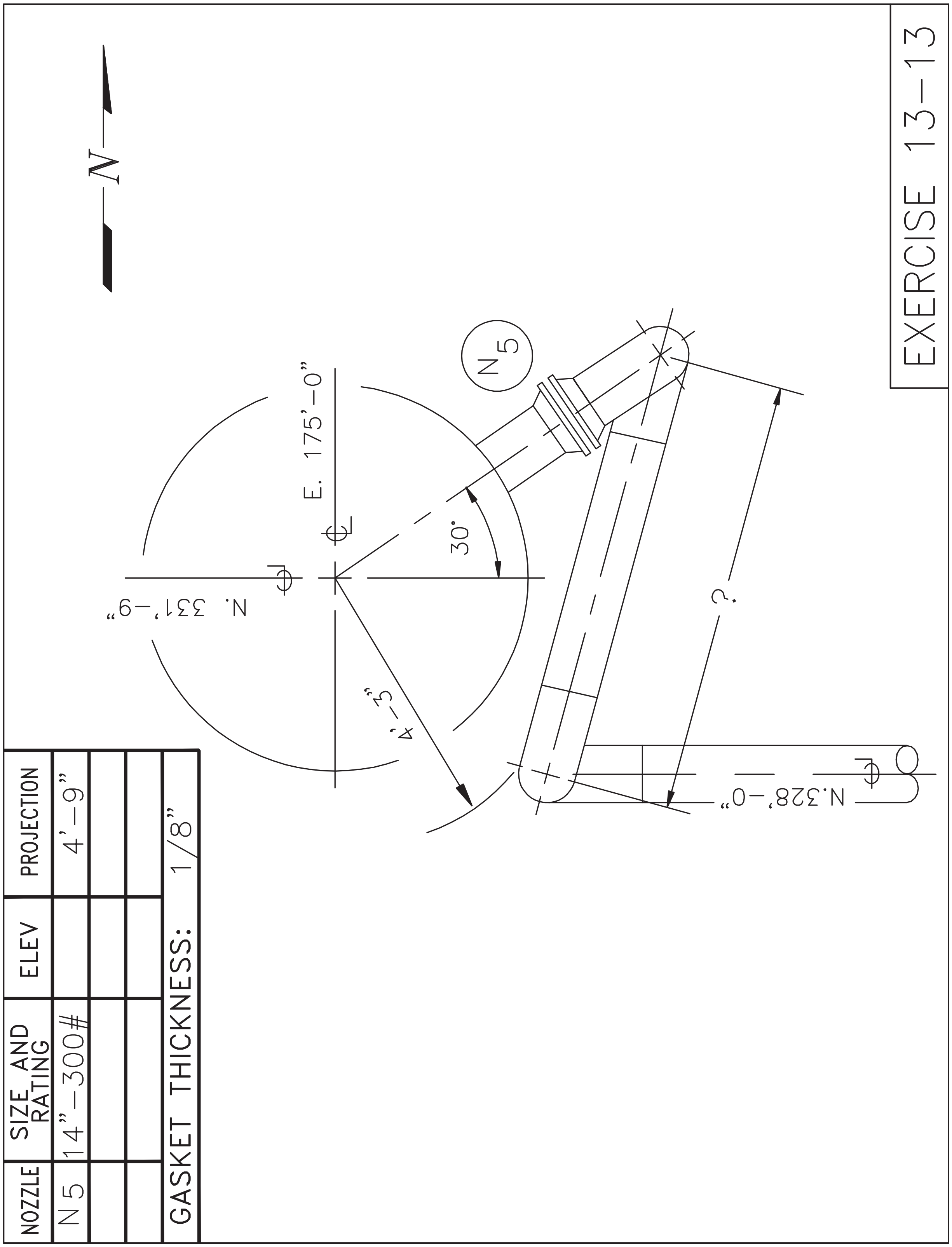
Solve for the missing dimensions of the right triangles shown. All dimensions are to be written in Feet and Inches, rounded to the nearest $^1/_{16}$″. Write the angular answers in degree, minute, and second values.



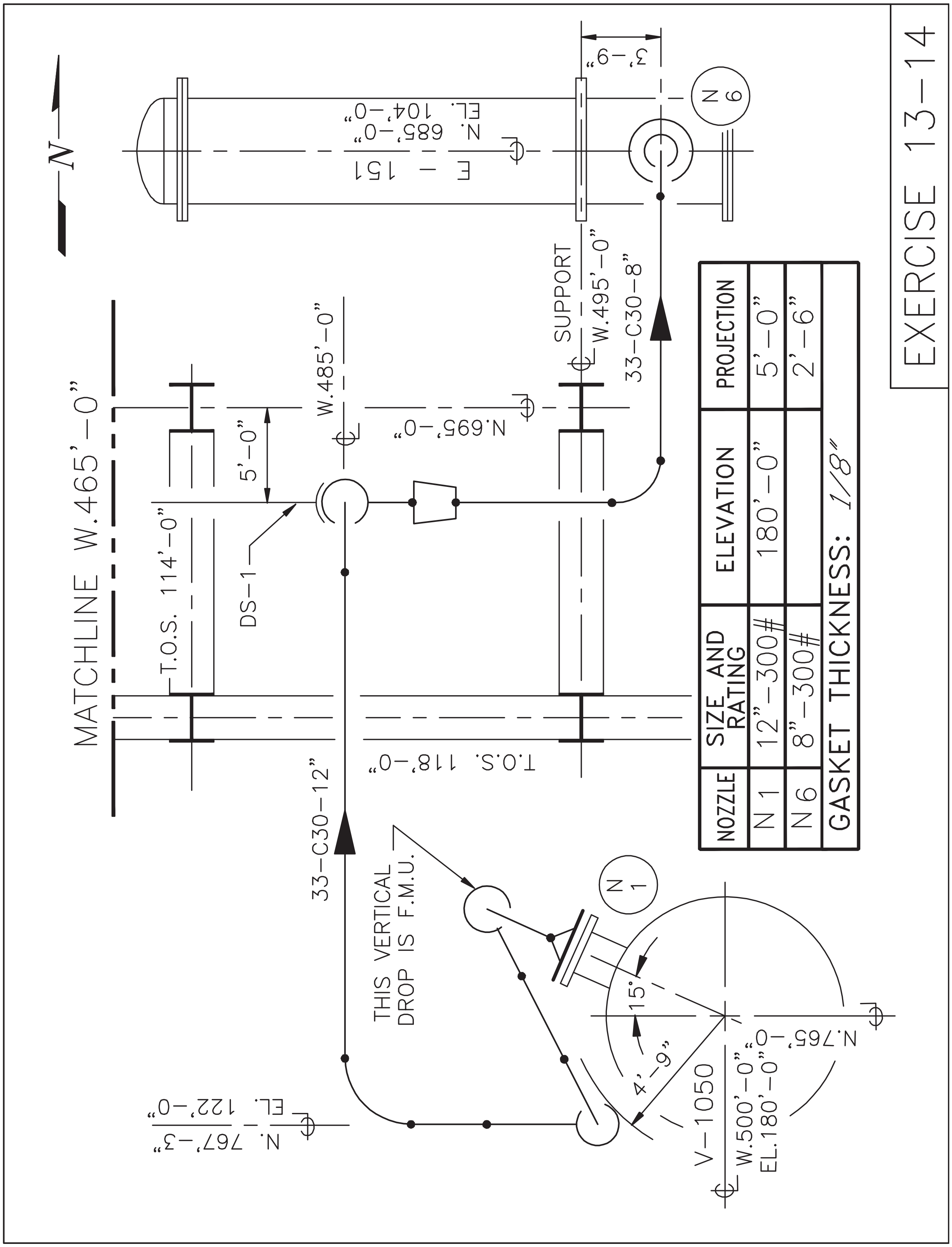
Draw an isometric for the following exercise. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on the isometric will be up and to the right.

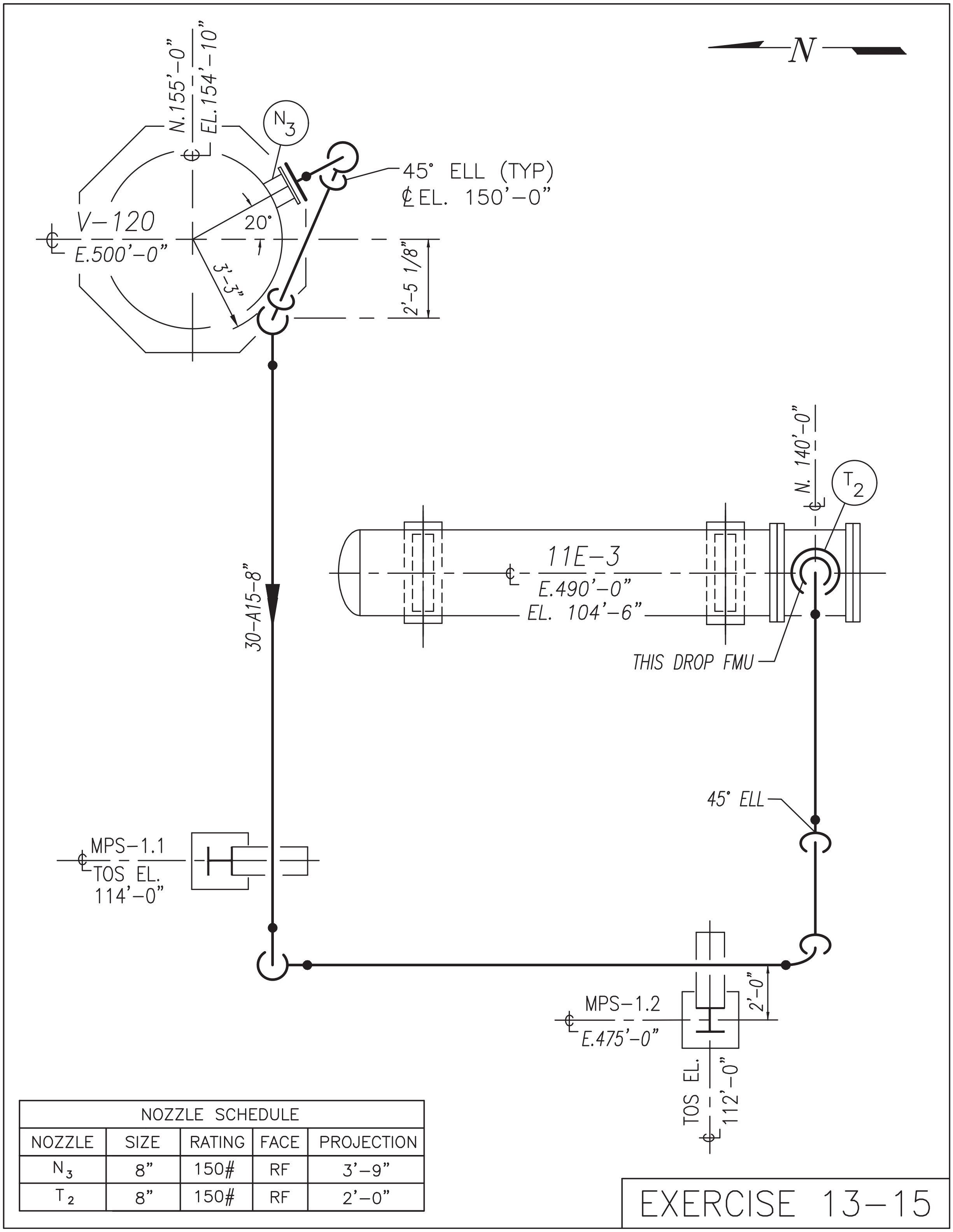


Draw an isometric for the following exercise. Calculate the unknown dimensions and angle for right triangle of the multiangle offset. North Arrow direction on the isometric will be up and to the right.



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.

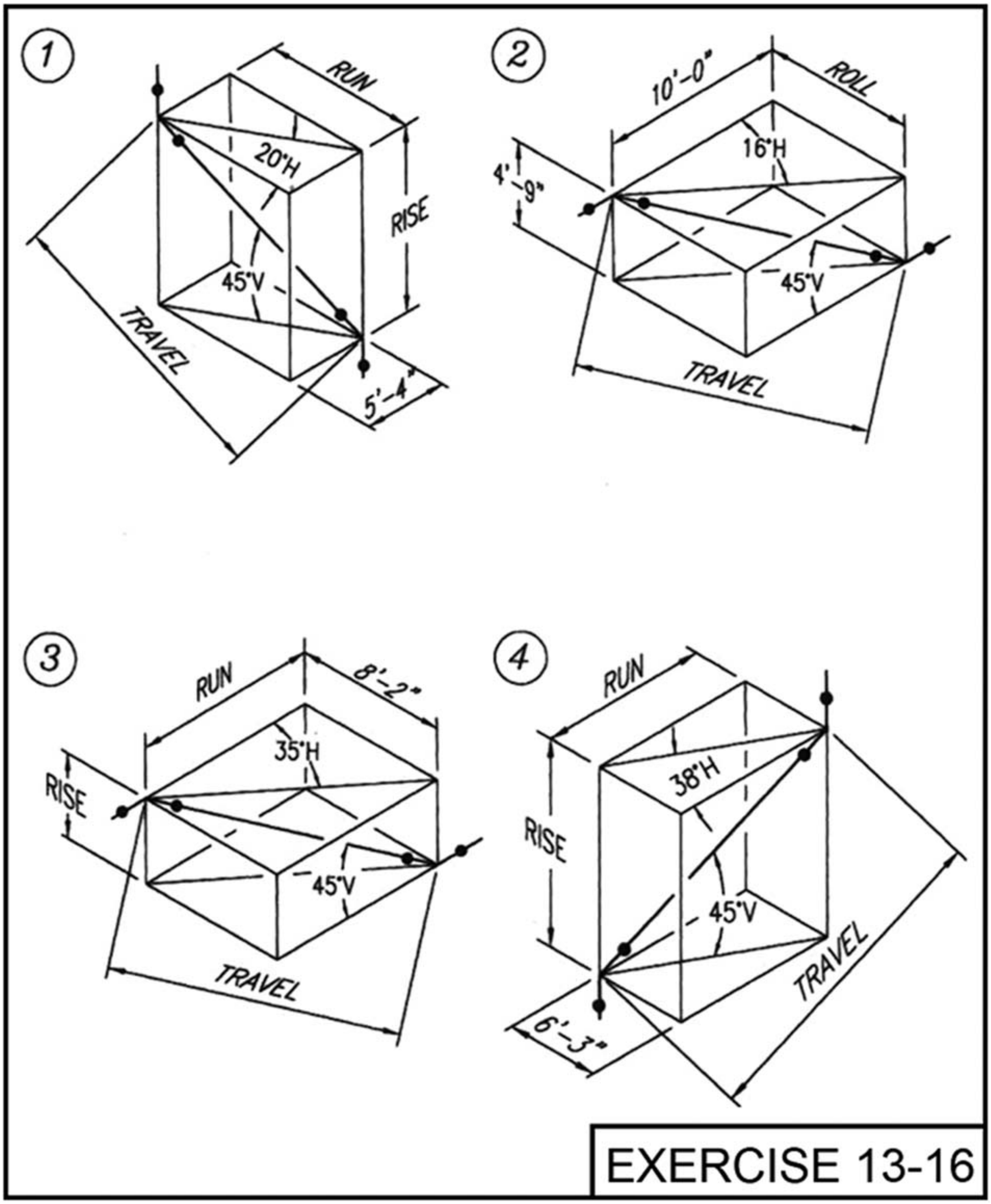




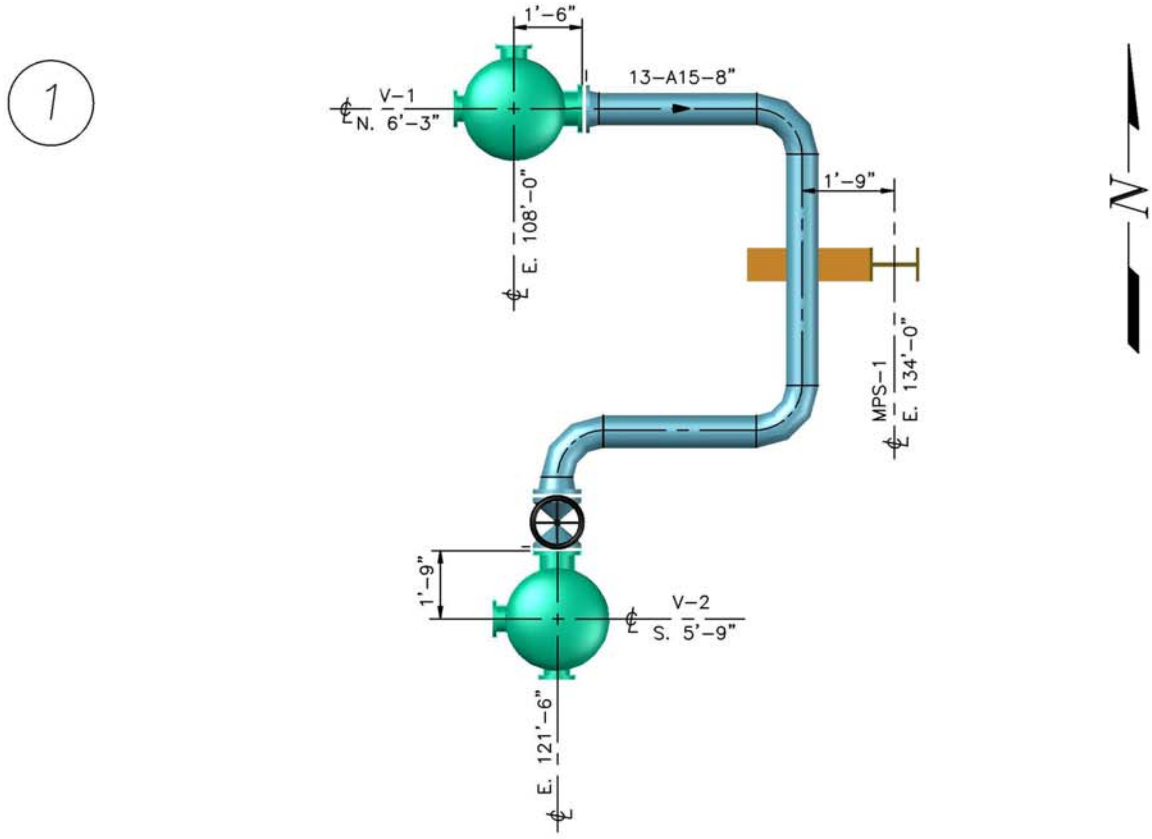
NOZZLE SCHEDULE				
NOZZLE	SIZE	RATING	FACE	PROJECTION
N_3	8"	150#	RF	3'–9"
T_2	8"	150#	RF	2'–0"

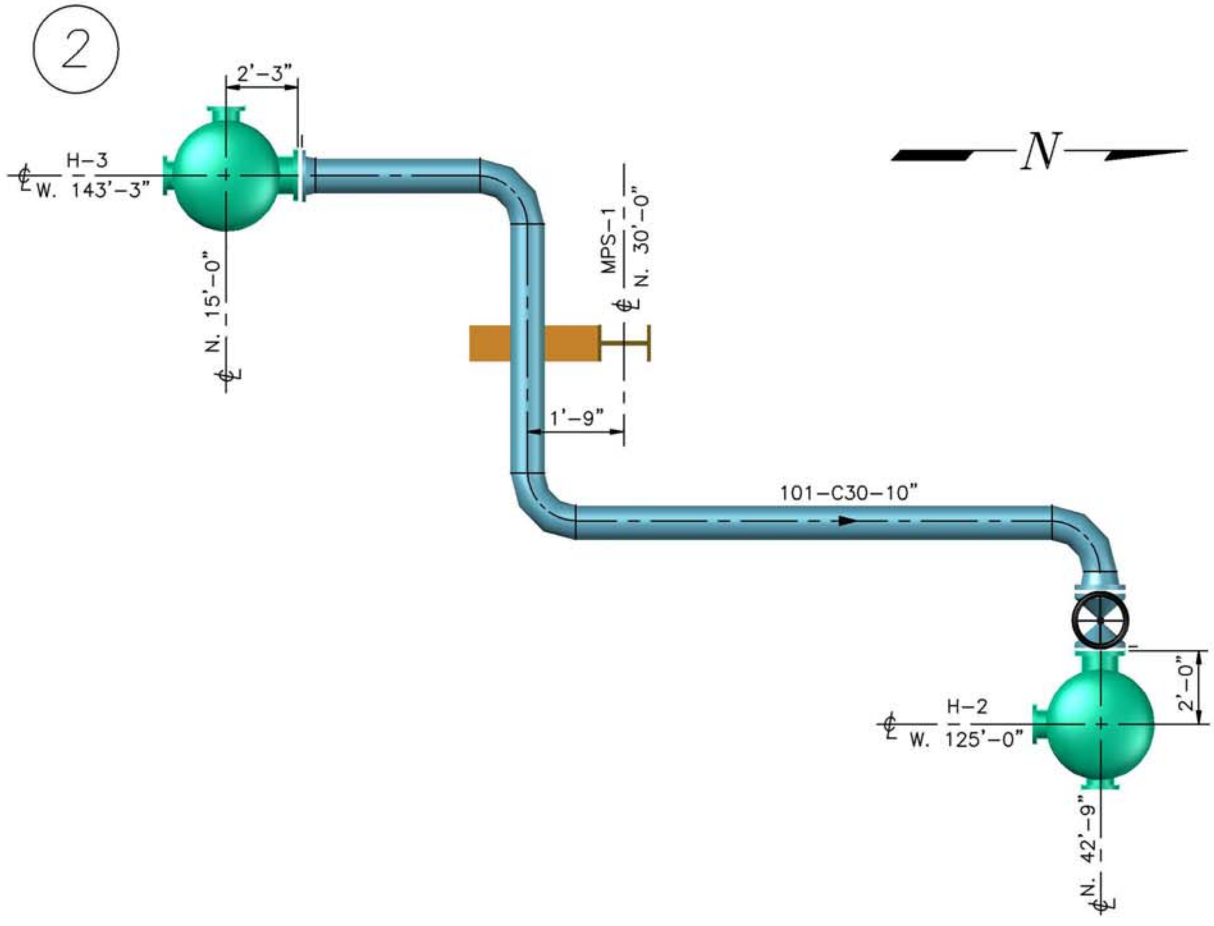
EXERCISE 13–15

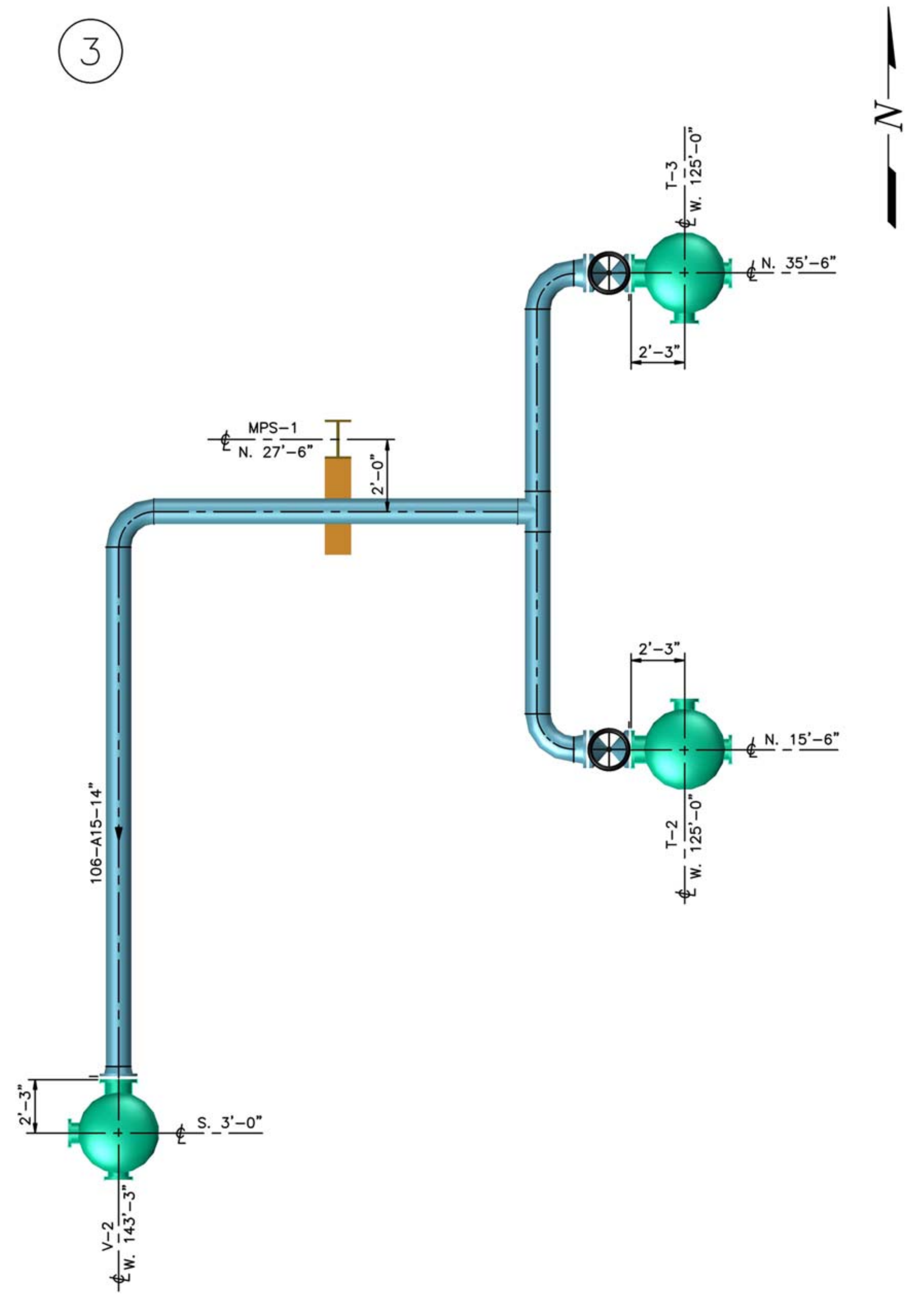
Solve for the missing dimensions on each of the rolling offset boxes shown. All dimensions are to be written in feet and inches, rounded to the nearest $^{1}/_{16}''$.

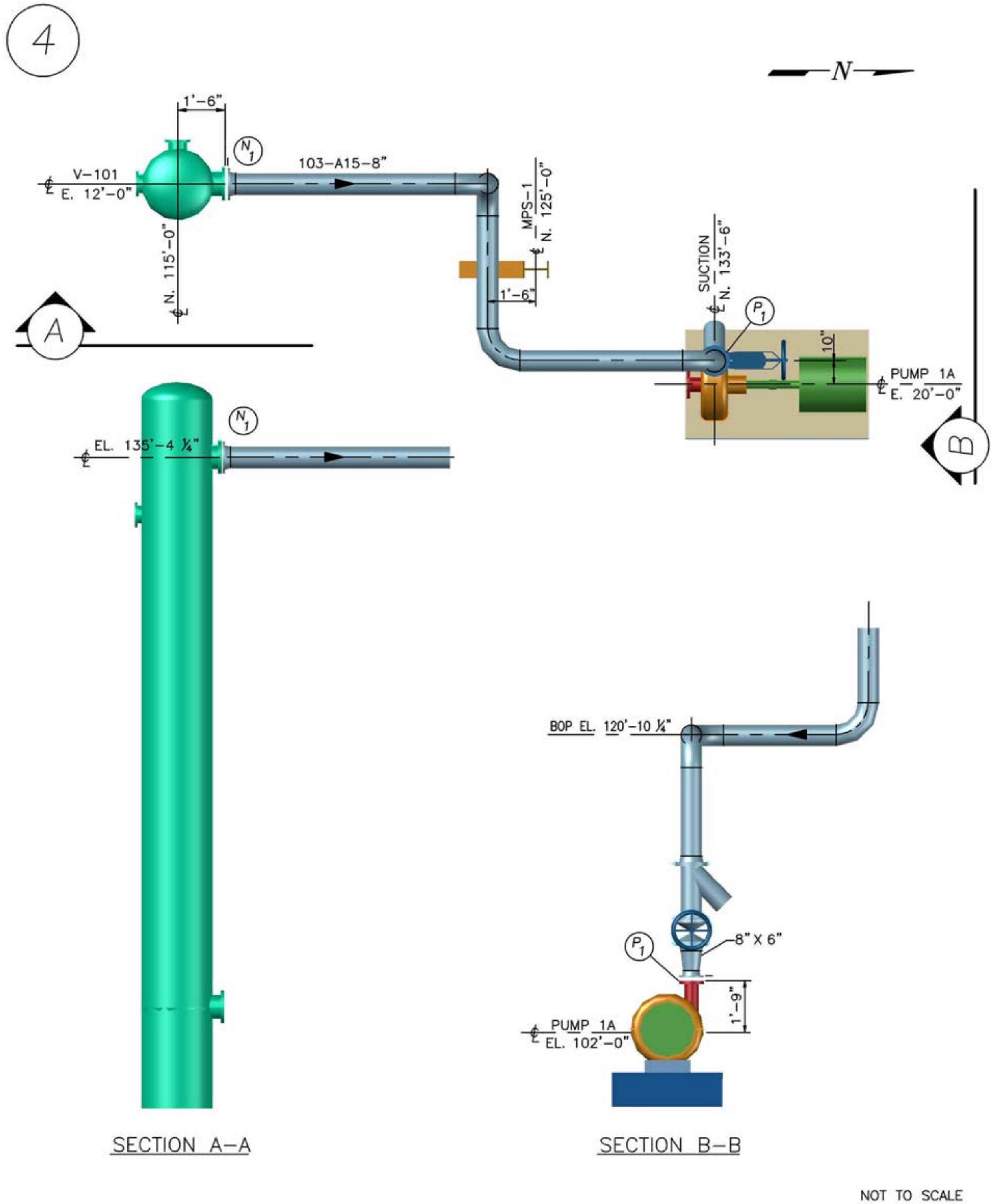


Develop an isometric from the following Plan and Section drawings. Show all necessary dimensions, coordinates, equipment callouts, line numbers, and related information. North Arrow direction on each isometric will be up and to the right.

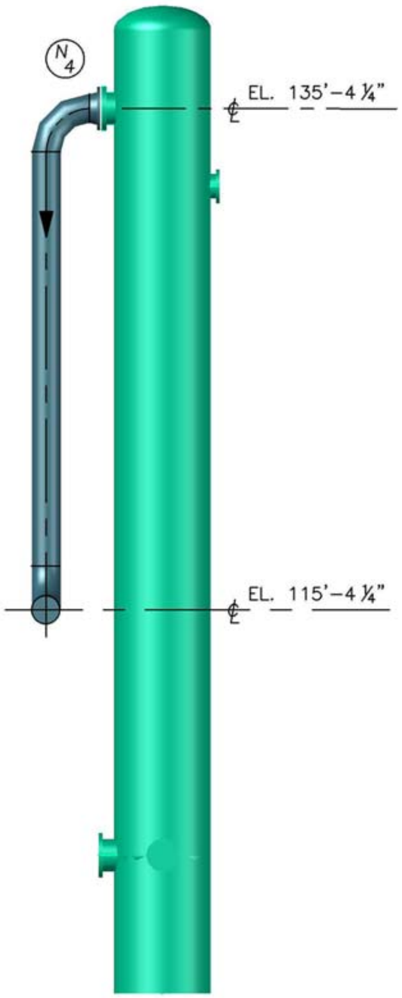




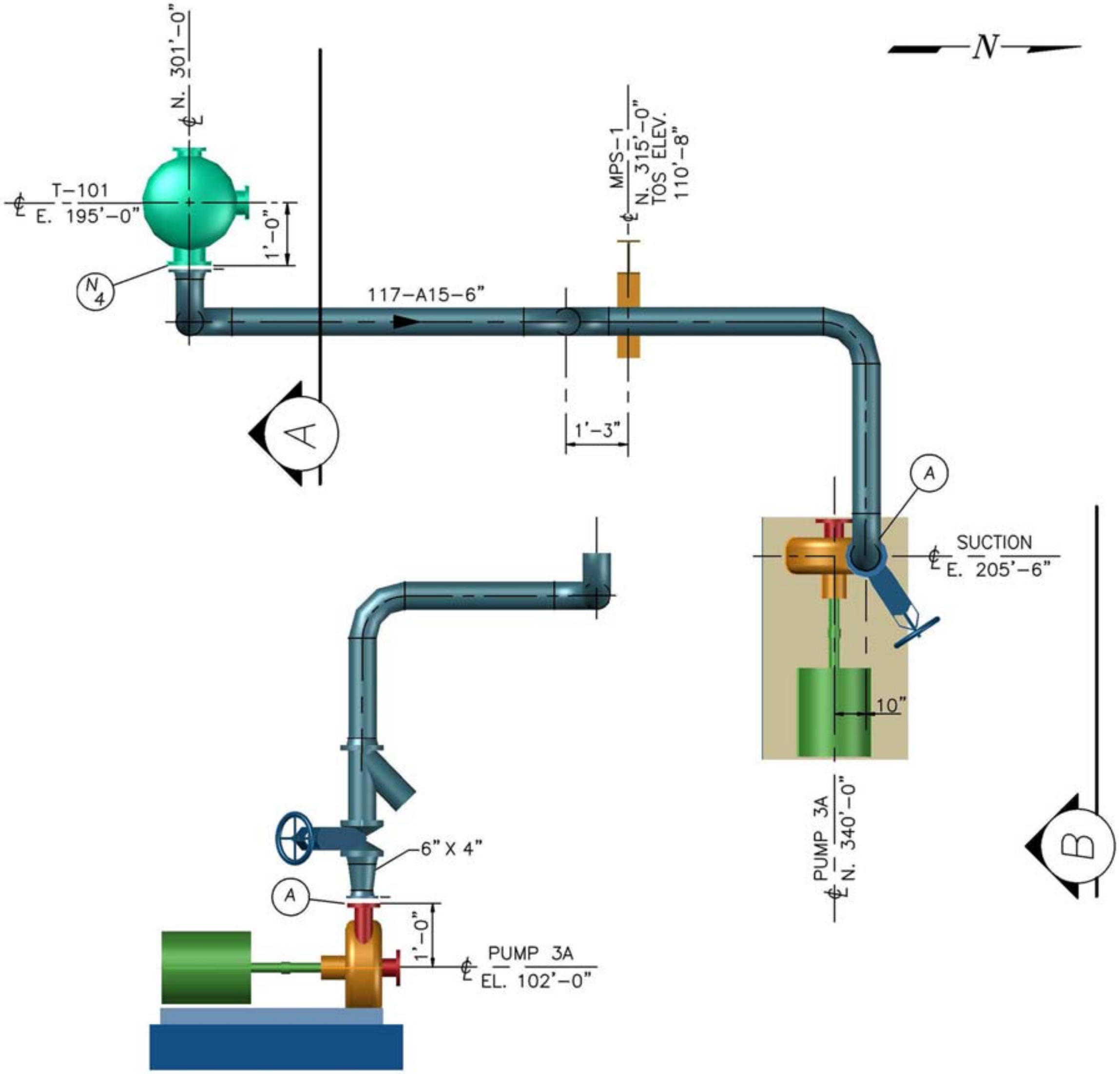

3
N
T-3
℄ W. 125'-0"
℄ N. 35'-6"
2'-3"
MPS-1
℄ N. 27'-6"
2'-0"
2'-3"
℄ N. 15'-6"
T-2
℄ W. 125'-0"
106-A15-14"
2'-3"
℄ S. 3'-0"
V-2
℄ W. 143'-3"


4
N
1'-6"
V-101
E. 12'-0"
N1
103-A15-8"
MPS-1
N. 125'-0"
N. 115'-0"
1'-6"
SUCTION
N. 133'-6"
P1
10"
PUMP 1A
E. 20'-0"
A
B
EL. 135'-4 ¼"
N1
BOP EL. 120'-10 ¼"
8" X 6"
P1
1'-9"
PUMP 1A
EL. 102'-0"
SECTION A-A
SECTION B-B
NOT TO SCALE

5



SECTION A–A



SECTION B–B

NOT TO SCALE

CHAPTER

14

3D Piping Models and As-Built Drawings

The use of three-dimensional pipe modeling software continues to have an impact on the design and engineering of piping projects. Whether they are off-shore production platforms or land-based petro-chemical complexes 3D modeling is the preferred method of designing new piping facilities. Some of the available 3D pipe modeling software packages are **PDMS**, **PDS**, **CADWorx**, **SMARTPLANT 3D**, **AutoPLANT**, and **PLANT 4D**.

ADVANTAGES OF 3D MODELING

One advantage a 3D model has overconventional 2D CAD drawings is an improved ability to demonstrate clearly the thought processes which occur during the design phase of a piping facility. Chemical plants, refineries, off-shore production platforms, and other types of piping facilities are very complex. Vast numbers of foundations and supports, steel columns and beams, pipes and piping components, mechanical equipment, and instrumentation devices must be engineered, designed, fabricated, and erected before a project is considered complete. Even seasoned designers occasionally find it difficult to organize the complexities of the project when working with orthographic drawings alone. Multiple disciplines (civil, structural, electrical, I and E, and piping) have input into a project's development. By using computer-generated three-dimensional models, designers can view the acility from any direction and quickly visualize and understand the intricacies of its design. The Plan and Elevation views shown in Figures 14.1 through 14.3 sufficiently represent the components in Unit-01. From these three views, an experienced designer should be able to "visualize" the appearance of Unit-01. However, just a single rendered pictorial, as shown in Figure 14.4, provides more analytical opportunities than three "flat" drawings do. See Figures 14.1 through 14.4.

Furthermore, to increase comprehension, 3D models make it possible to "zoom" closely into crowed and congested areas of a new facility and have immediate understanding of associated piping components and their routing and configuration. If necessary, any interfering model elements, pipe, mechanical equipment, foundation, or structural support which lies between the viewer and area of concern can be "clipped" or removed by the modeling software. This makes it possible to see "inside" the facility and study its hidden features.

Once a 3D model has been developed, a virtual tour or "walkthrough" can be created. Walkthroughs hasten client approval and are used as training videos by plant personnel who are responsible for safely maintaining and operating the facility. The improved visualization capabilities alone make modeling a piping facility a worthwhile endeavor. The ability to forecast potential design or construction problems during the modeling phase can result in tremendous time and cost savings as opposed to discovering and solving the problem later at the job site.

CHECKING FOR INTERFERENCES

Another valuable benefit of 3D computer modeling is the ability to perform interference or "*clash*" detection. Developing models of complex projects is not something new to piping designers. For years, wood and/or plastic scaled models, taking hundreds of hours to construct and costing thousands of dollars to produce, were built from dimensions provided on hand-created drawings to find interferences not caught during the design and checking phases. One of the main reasons these models are built is to verify the fit of all the components in the facility. During the design phase, it is easy to overlook minor details in something as complex as a piping facility. Only by building a physical model, the designers can verify there are no

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DOI: https://doi.org/10.1016/B978-0-12-822047-4.00004-2

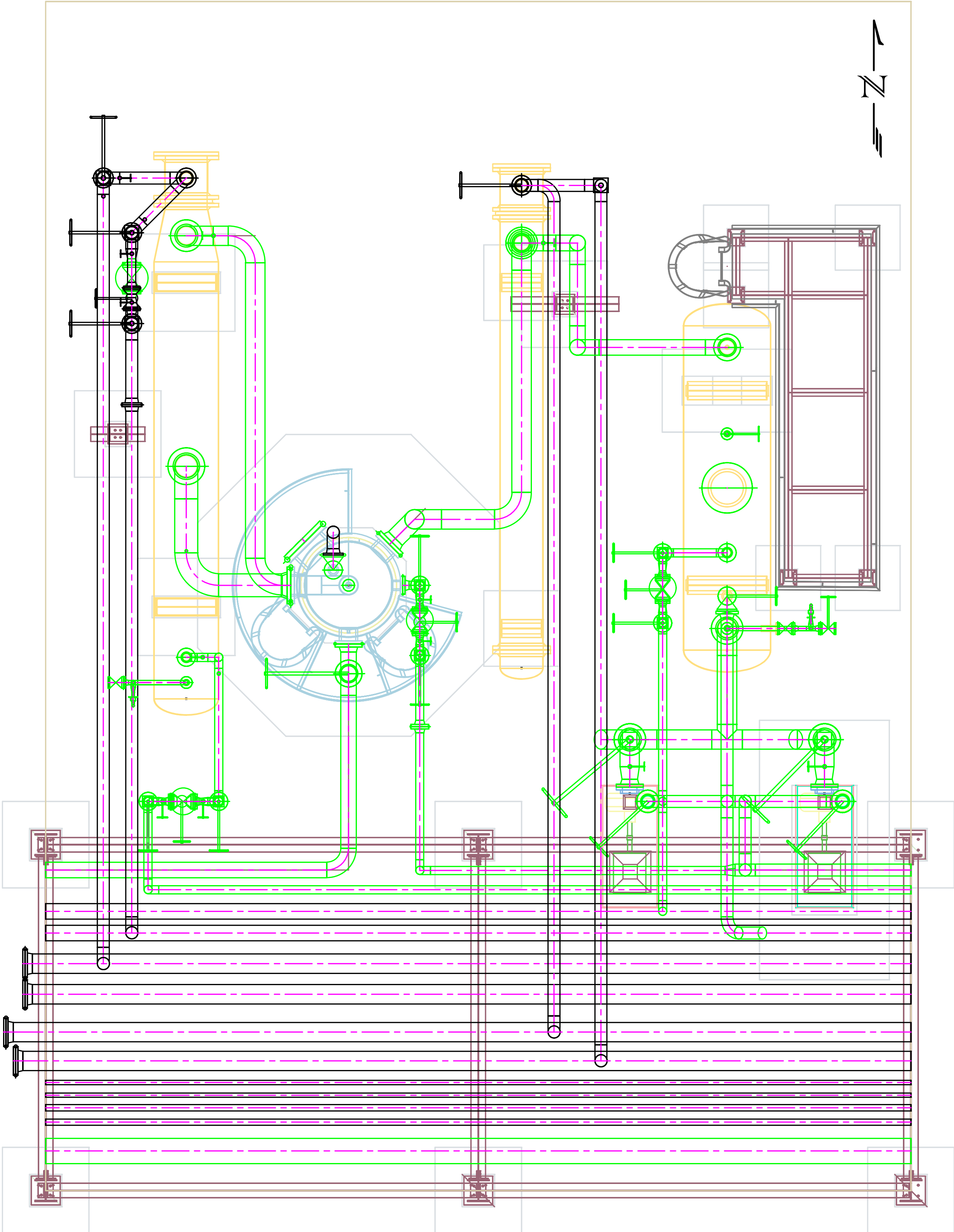

FIGURE 14.1 Unit-01 plan view.

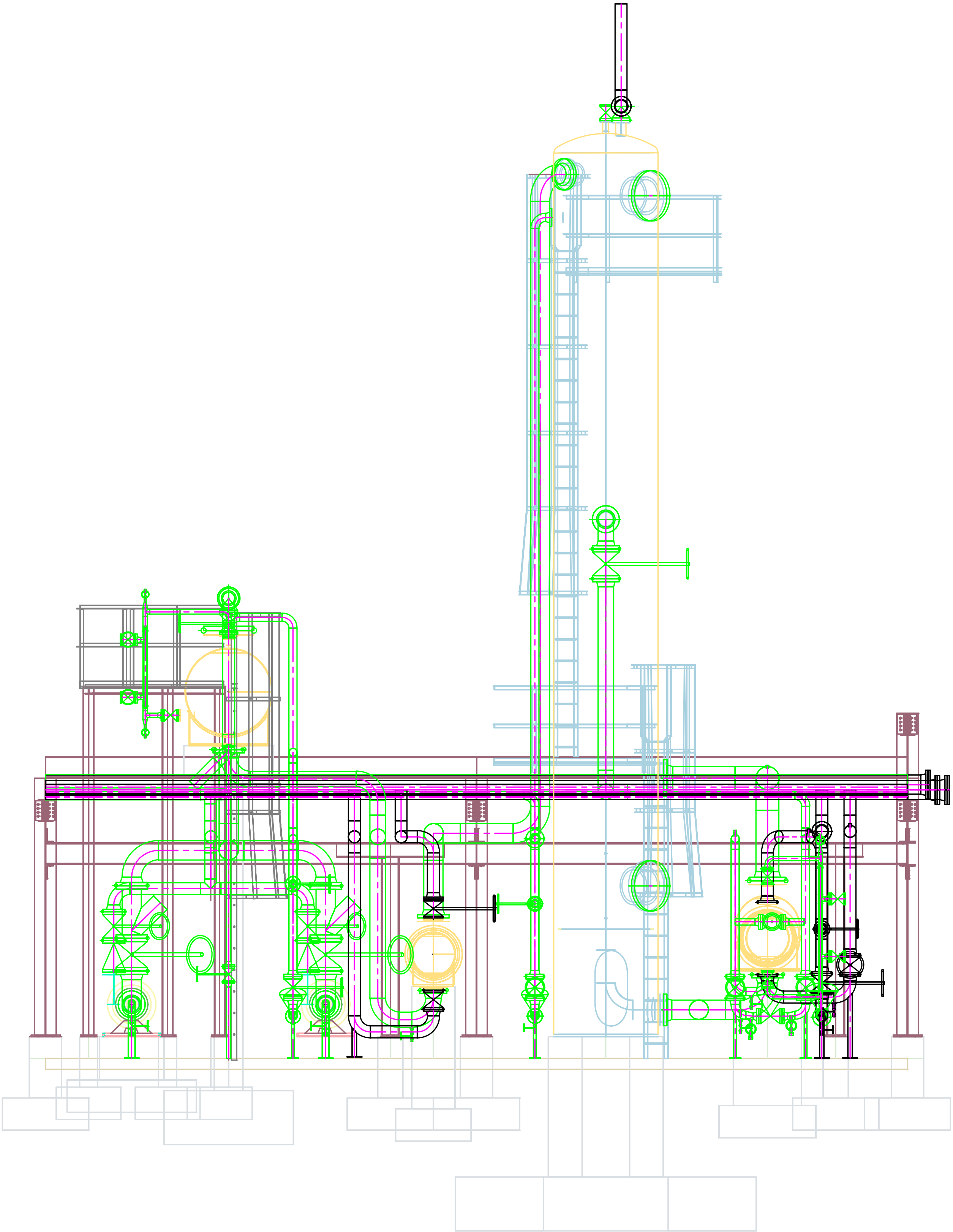

FIGURE 14.2 Unit-01 North elevation.

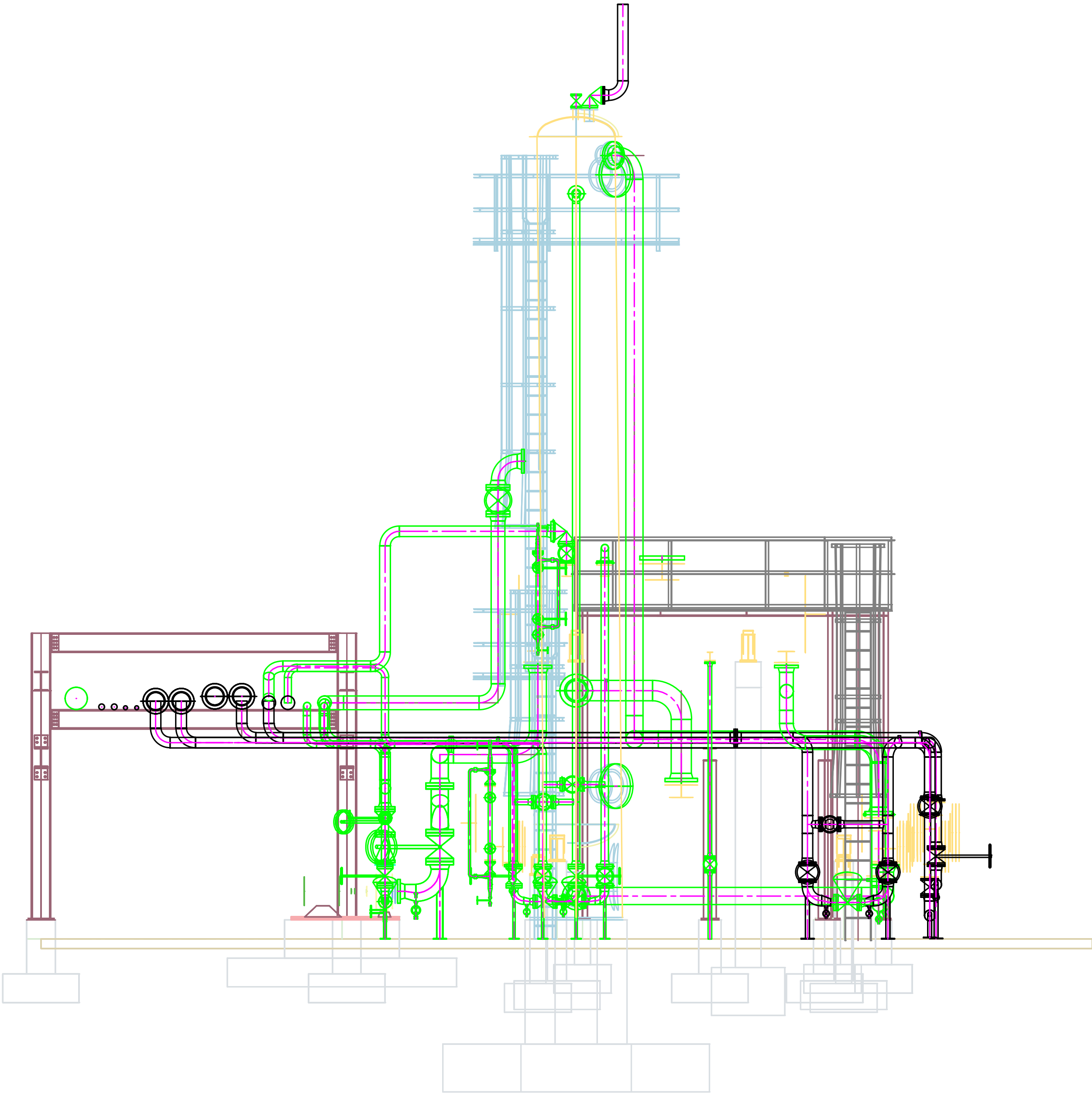

FIGURE 14.3 Unit-01 East elevation.

interferences between components (i.e., a pipe passing through a steel support, a beam hitting a piece of equipment, etc.). If a design team can detect problems such as these before construction begins, savings in building costs can be enormous. Each problem area redesigned in the field adds substantially to the cost of completing the project.

Interference detection features in modeling software work by checking the physical position of the surfaces of each component in a project against other component's surfaces in the project. Usually a project is organized into discipline departments such as piping, structural, equipment, and so on. This is easy to do because a 3D model is typically developed making use of the software's layering capability. Some software programs will automatically place piping components (fittings, flanges, and valves), steel supports, and mechanical equipment on their respective layers. It can even segregate piping components according to pound rating (150, 300, etc.), specification, or material and place them on individual layers. One method of interference checking is performed by checking one layer against another to confirm no two items are occupying the exact same space within the facility. Another

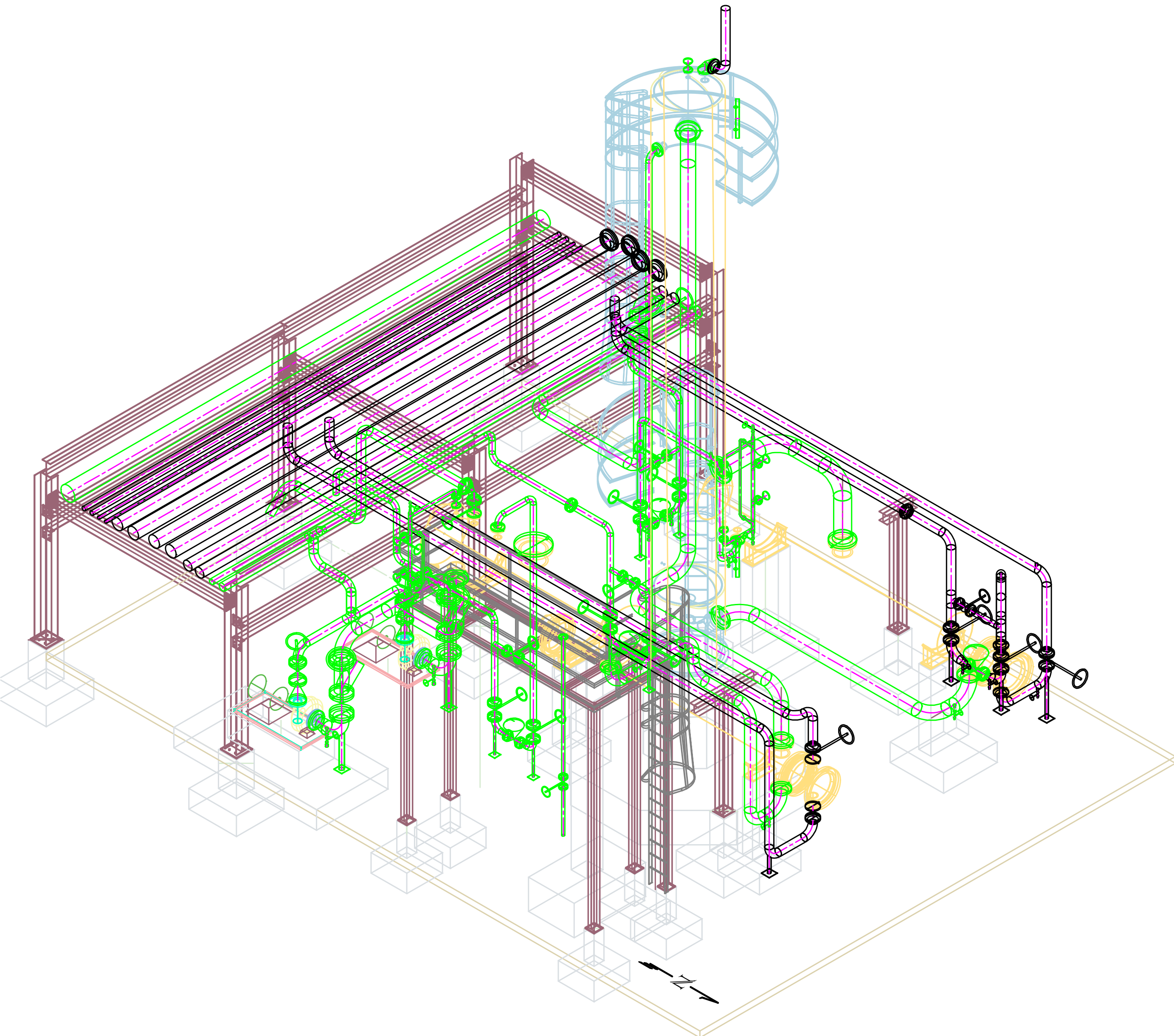

FIGURE 14.4 Unit-01 pictorial.

method analyzes the data base in an attempt to find components identified as "solids" sharing the same space. Figure 14.5 shows a cloud around an interference between a horizontal pipe and a structural support. As the interference detection program is initiated, certain software commands will locate the first clash and change the color of the two elements causing the interference to a different color. The software will reposition the area of the model in question to the center of the display and allow the user to zoom in for a closer look. When multiple interferences are detected, the press of a key instructs the software to proceed to the next problem area, allowing the user to view each area in question. Some of the more sophisticated software packages allow the user to "fly" around the problem area in real time, viewing it from any direction or angle. The ability of computer software to help prevent costly construction errors is another reason why 3D modeling is so valuable.

GENERATING DRAWINGS AUTOMATICALLY FROM A MODEL

Once a 3D model has been built, the routing of each piping configuration is clearly defined. Although the

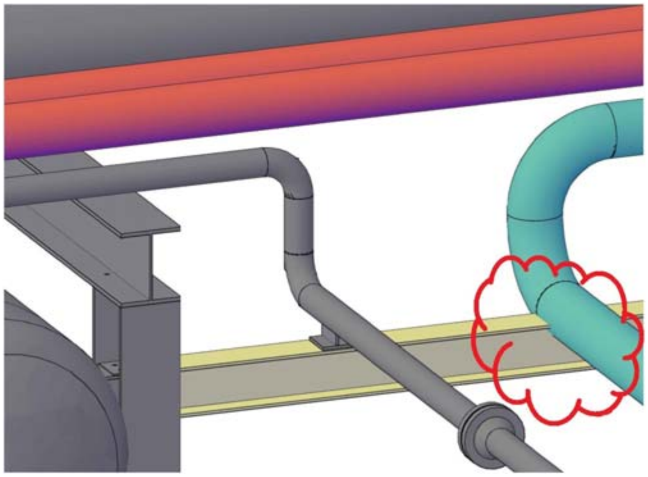

FIGURE 14.5 Interference detection between a pipe and structural support.

procedure is different in each program, designers can then use the modeling software to automatically generate dimensioned Plan, Elevation, and Section drawings of the facility from any desired orientation. If necessary, designers or drafters can then add notes and dimensions to the drawings, prior to sending them to checkers for further approval.

Some software programs generate plans, sections, or elevations in several different drawing formats including single-line, double-line, and 3D views, with hidden lines removed.

Solid modeling is different from wire frame modeling because a solid model can display objects with the hidden surfaces removed. On a wire frame model, all surfaces are visible. Using this solid modeling capability, 3D software can automatically create projected views of solids with all the hidden lines removed. This capability gives the user a powerful tool for displaying piping drawings. Figures 14.6 through 14.9 represent different 3D orientations of the model built from the Units-01, 02, 03, and 04 drawings, presented in Chapter 10, Piping Arrangement Drawings, Sections, and Elevations and Chapter 15.

GENERATING ISOMETRIC DRAWINGS AUTOMATICALLY

In addition to orthographic views, 3D modeling software can generate isometric drawings of pipe configurations automatically. The isometrics are created complete with dimensions and a Bill of Materials. Generally, with just a few manual touchups and additions, they are ready for construction issue (see Figure 14.10). Again, by investing the time to model a project, the engineer, designer, fabricator, and client can reap large informational and economic returns at the conclusion of the project.

COMPUTER-AIDED ENGINEERING OF MODELS

Another important task which can be accomplished with 3D models is that of *stress analysis*. Stress analysis verifies the feasible operation of pipe, steel, and mechanical equipment. The piping system and its supports can be analyzed both statically and dynamically. Stress analysis features include checking for seismic movements, flow-induced vibrations, wind loading, and wave loads. By developing a 3D model and pairing it with a stress analysis program like **CAESAR II**, an engineer can ensure the accuracy of the facility's design.

AS-BUILT DRAWINGS FOR FIELD VERIFICATION AND REVISION

As each phase of a project nears completion, it becomes vitally important to document the actual work that has been finalized. It is quite common for a facility to be designed and modeled with a specific result in mind and yet be constructed totally different. A variety of reasons can result in a facility not being constructed as it was originally designed. But, no matter what those design/construction differences are, they must be documented. After construction is completed, *As-Built* drawings denote revisions to a drawing's or model's original design. *As-Built* drawings document the actual and physical appearance of the facility. *Walk-downs* and *walkthroughs* have traditionally been the methods used by contractors to verify drawing and model accuracy. However, 3D laser scanners are quickly replacing those traditional methods. Field measuring each installed component by hand once took a multiperson crew hours to document and record. Now, the process of validating the 3D model after its approved for construction is performed with 3D laser scans.

A contractor should verify the accuracy of each phase of a project as it is completed. Whether it is the finished elevations of a site's graded contours, the location of concrete foundations, the slope of underground drainage systems, or the positions of buried conduit, all aspects of a facility must be documented as it is completed. For obvious reasons, one cannot guess where concrete piles and foundations, electrical conduit, catch basins, oily water sewer lines, or underground pipe components may lie. As erection and installation of steel columns, mechanical equipment, and pipe configurations begin above ground, there must be no doubt where every underground

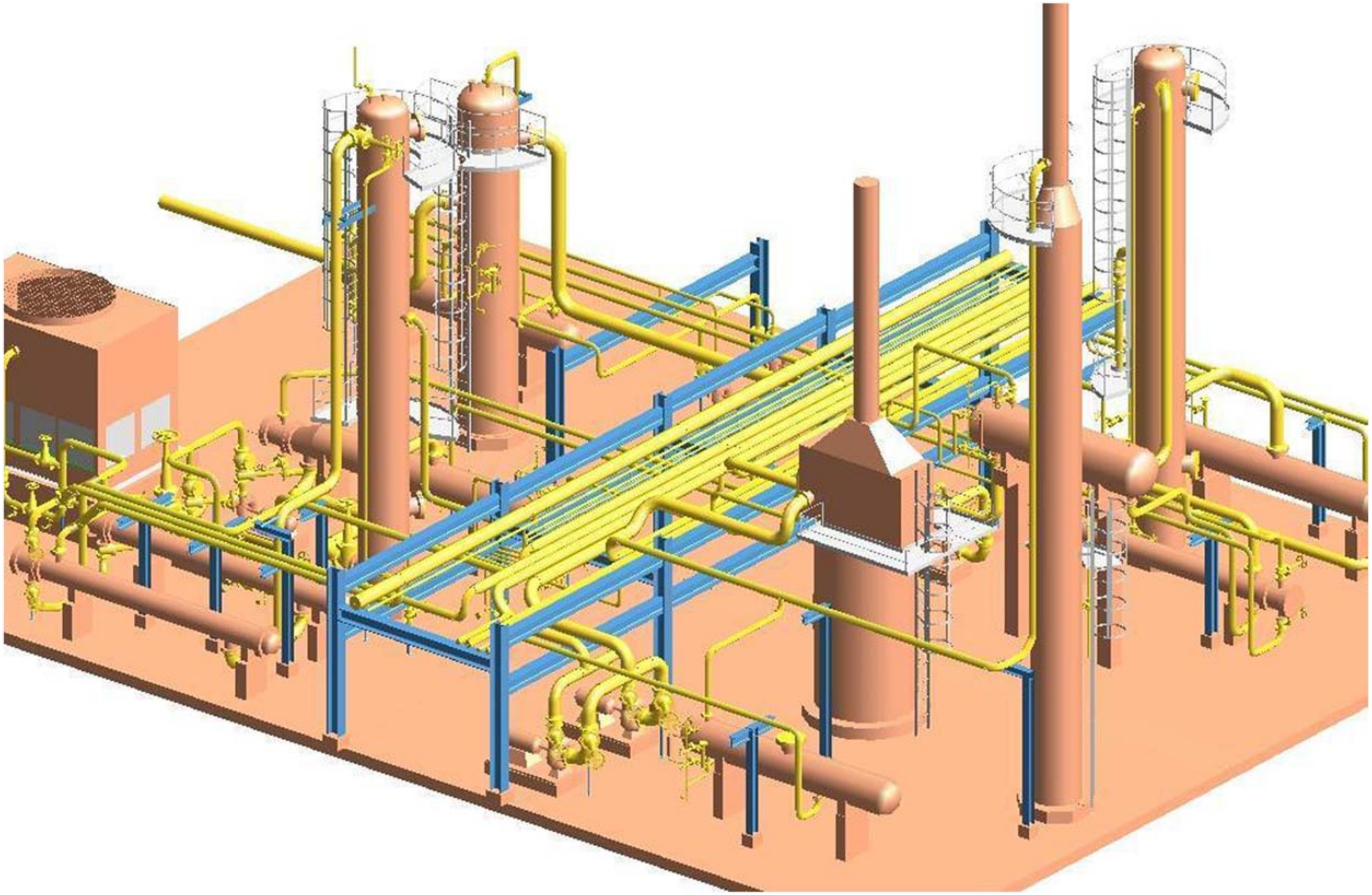

FIGURE 14.6 Units-01−04 Northeast pictorial view.

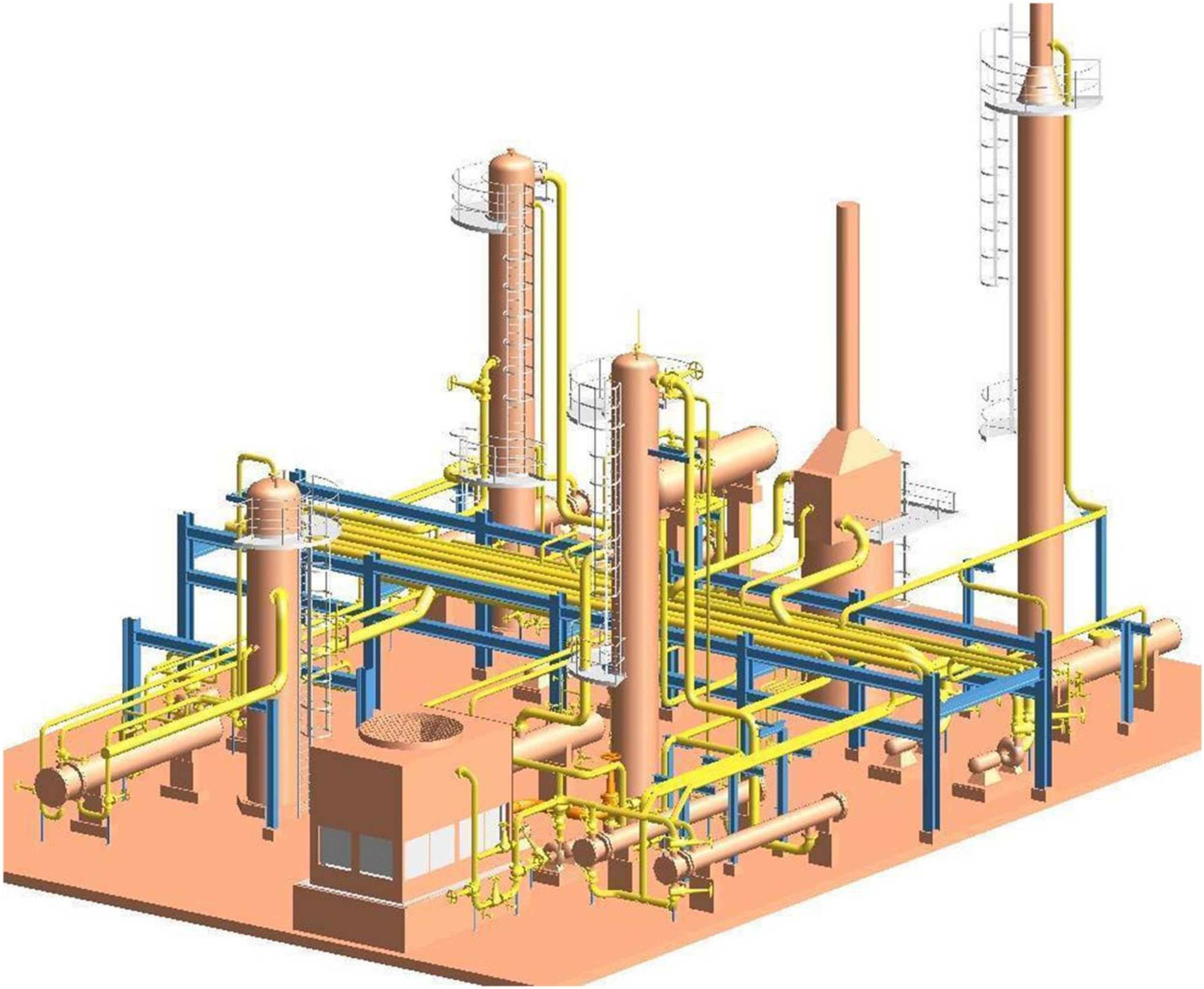

FIGURE 14.7 Units-01−04 Southeast pictorial view.

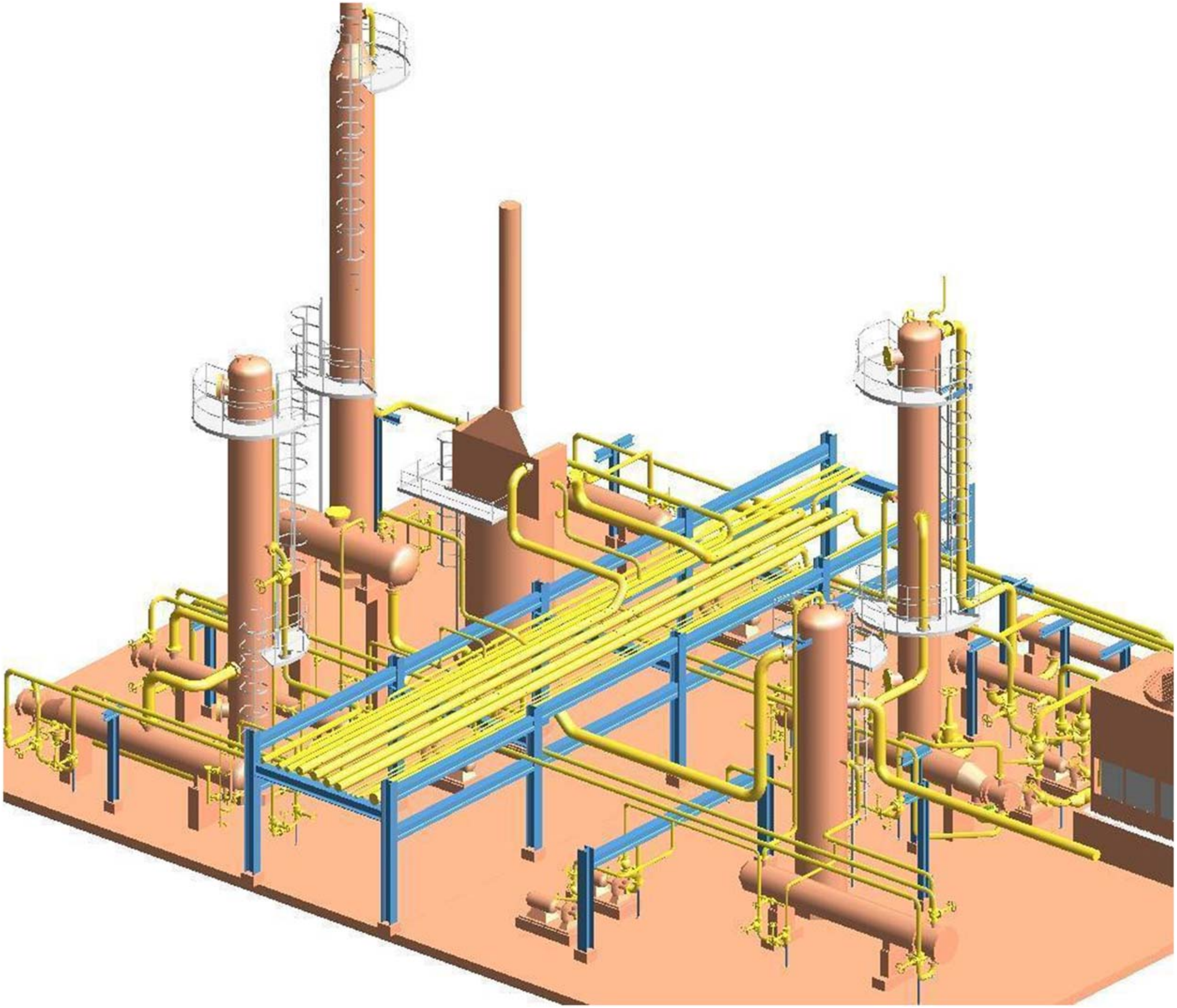

FIGURE 14.8 Units-01–04 Southwest pictorial view.

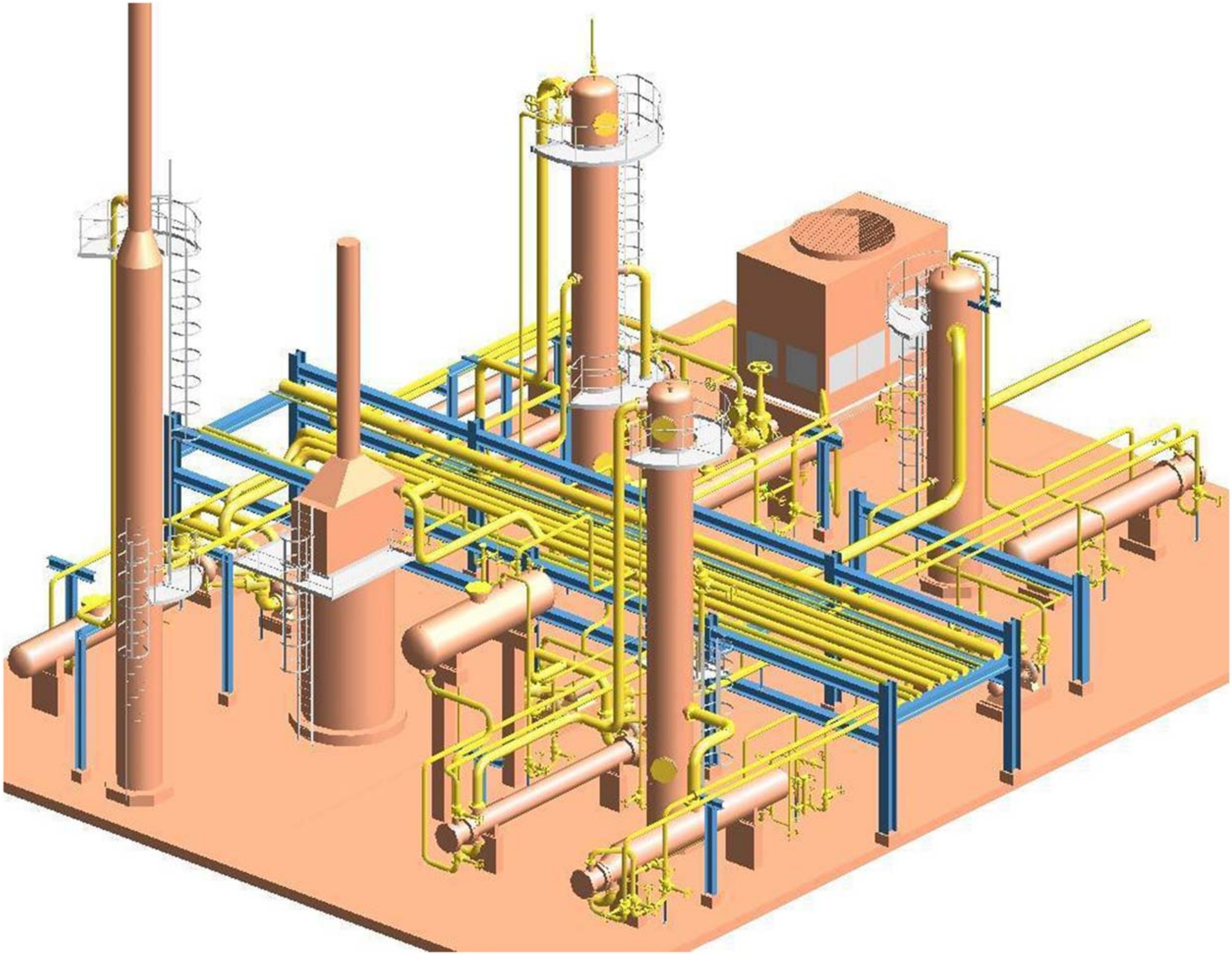

FIGURE 14.9 Units-01–04 Northwest pictorial view.

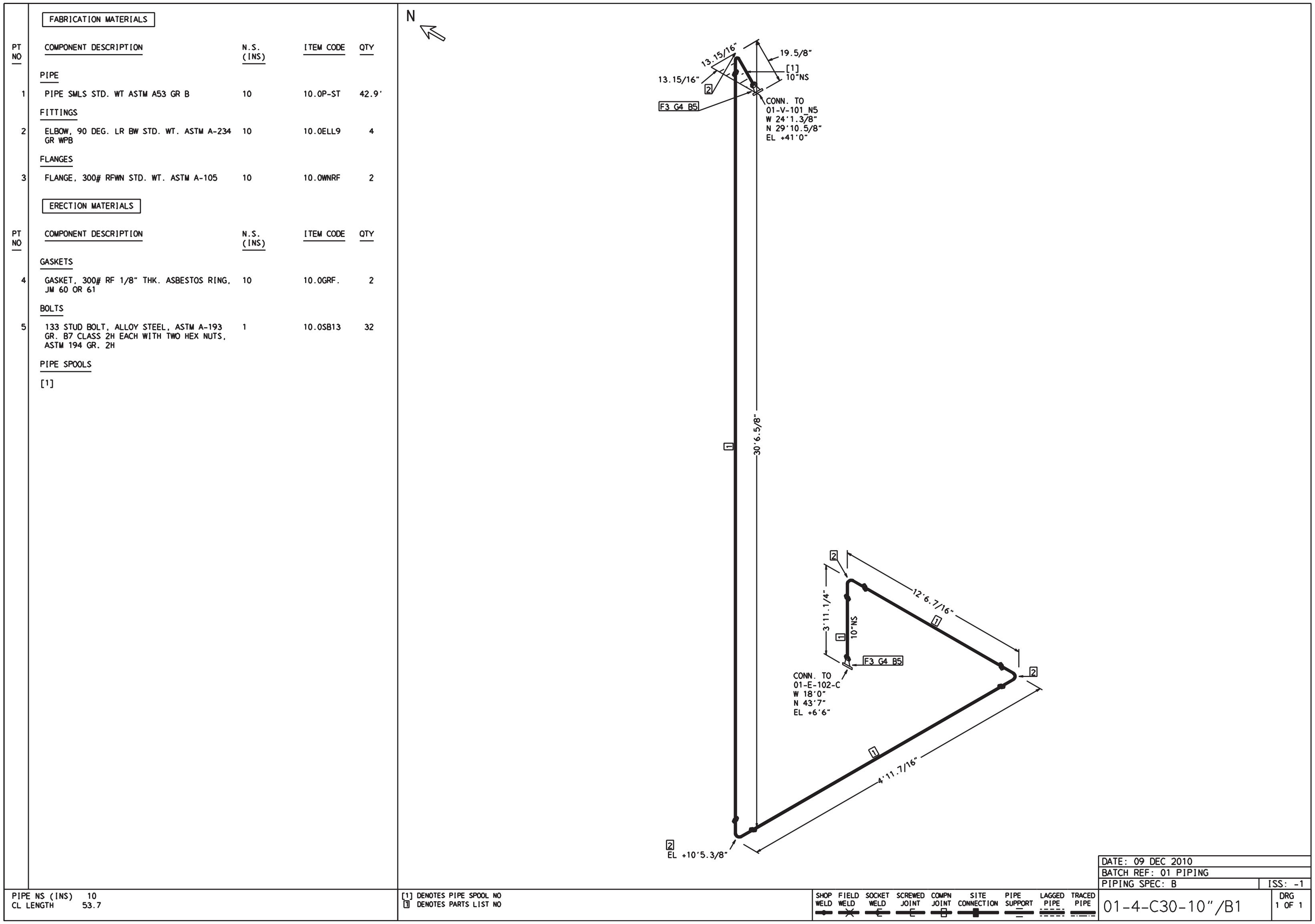

FIGURE 14.10 Piping isometric generated with 3D modeling software. *Courtesy of AVEVA Group, plc.*

component resides. A set of drawings which identifies locations of these buried features must always be on-site for construction and design teams to reference.

Although 3D models have the reputation of detecting clashes and obstructions in the initial design, variances from the initial design invariably find their way into the facility's construction. Traditionally, *as-built* drawings are color coded to reflect additions, deletions, and/or other important revisions. Green is generally used to designate new components added since the original AFC (Approved For Construction) drawings were released. Red is typically used to indicate items which have been removed or deleted from the original AFC drawings. The use of the color red in this manner spawned the common-use phrase "red-line" drawings. The names *As-builts* and *Red-line drawings* are synonymous, although they have some technical differences. Blue is the color used to draw attention to special or unique instructions, details, or information.

Great care must be taken to document every change, no matter how small. It is common to see clearly written, concise explanations, without abbreviations, detailing all revisions. When modifying a physical drawing, it is vital additions be made with the same drawing scale. Another practice not to be overlooked is not to remove original drawing information. Referencing the original design often aids in the understanding of why revisions became necessary.

3D LASER SCANNING

Technological advances have greatly changed many aspects of plant design and construction. For large-scale projects, 3D laser scans have replaced the need for traditional *walk-downs*. Laser scanners capture three-dimensional, geometrically precise (accurate to less than 1/8″), digital images of a facility's topography, including concrete supports, steel columns, mechanical equipment, and pipe configurations. And, perhaps more importantly, interferences and clashes. 3D scans of a facility during all phases of construction are commonplace due to their accuracy and savings in work-hour costs. Because 3D scans are created as digital files, they can have various output formats. This flexibility allows them to be imported into drawing and/or model files allowing designers and drafters to quickly, and with great precision, revise existing 2D drawings or 3D models of a facility. 3D scan files can be attached to as-built submissions.

The adaptability of 3D scans lend themselves to many uses. Available in full-color, laser scanners can create walkthrough point clouds and panoramic renderings. They can be used to generate plan, section, and elevation views. Because they scan in a 360° field-of-view, acquisition of as-built measurements and features in crowded and hard-to-access locations are more accurate, much simpler, and safer to acquire.

CHAPTER

15

Project Coordination and Development

The effective and efficient design of a petro-chemical facility involves engineering disciplines other than piping. The effective coordination of ancillary disciplines such as Civil, Structural, Mechanical, Architectural, Electrical, and Instrumentation is necessary throughout the engineering, design, and construction phases of a facility.

Although pipe might be considered the most critical component of the design, other disciplines can make that claim as well. Without the Structural group, there would be no steel to support the pipe. Without the Mechanical group, there would be no exchangers, pumps, or vessels to connect the pipe to. Without the Electrical group, there would be no power supplied to pump motors or electricity for illumination. Without the Instrumentation group, there would be no means of monitoring or controlling the pressure and temperature levels of the commodity flowing through the pipe and equipment.

Each discipline has a unique impact on the design of a facility in its own specific way. The confluence of so many disciplines in such a rather confined space means that in order for the engineering, design, construction, and, ultimately, operation of a facility to be considered successful, the interaction of all disciplines must be coordinated in a precise and timely manner. For example, the main pipe rack and each miscellaneous pipe support must not only be designed with enough structural strength and space capacity to hold the required pipe, fittings, flanges, valves, and so on being routed through it, but it must also be designed for the inclusion of all electrical and instrumentation trays and conduit. Then, the Civil group must engineer and design the concrete footings and foundations large enough to support not only all the items mentioned previously, but the structural steel columns and beams as well. Additionally, these massive, underground concrete structures must be positioned and oriented so that the below-grade piping and drainage systems can be routed around them with the most direct and economical configuration.

The drawings in this chapter represent those that would be furnished to the Piping group by the Civil, Structural, Instrumentation, and Electrical groups to help develop the Piping Arrangement drawing and/or 3D model. For example, the civil drawings depict the size and shape of the concrete foundations and pedestals which are to be built to support the various pieces of mechanical equipment. Likewise, the structural drawings will allow for the representation of the main pipe rack, equipment rack, pipe supports, platforms, ladders, and cages on the Piping Arrangement drawing. In addition to drawings developed in-house by the various disciplines, the suppliers of the numerous pieces of mechanical equipment such as, pumps, exchangers, vessels, and so on will supply drawings that will allow all equipment to be represented on the Piping Arrangement drawing. Ultimately, coordination between I&E (Instrumentation and Electrical) and the Piping group becomes critical because these groups often must have equal access to the same pieces of equipment. Therefore the drawings they provide help determine where underground conduit and cabling may lie and what space is used by each group in the main pipe rack.

Other than the Lighting and Power Supply drawing and the Grounding plan, which are included in this chapter, all of the discipline-specific drawings needed to develop Unit-01 are found in Chapter 10, Piping Arrangement Drawings, Sections, and Elevations. All of the drawings needed to develop Unit-02, Unit-03, and Unit-04 follow and are grouped by discipline. Included with the discipline drawings are the P&IDs, Foundation Location plans, Equipment Location plans, and section drawings, all of which will be used as an aid in the development of the Piping Arrangement drawing or a 3D model. Since most companies now use some version of a pipe modeling software, four pictorial representations of the three-dimensional model of Units 01–04 are included at the end of the chapter. Use them as a visual reference to better understand the location and size of mechanical equipment, the orientation of ladders and platforms, the routing of pipe, and placement of pipe supports. The numerous dimensioning charts, drawing standards, formulas, and reference tables located throughout the chapter will also be used as reference tools.

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DOI: https://doi.org/10.1016/B978-0-12-822047-4.00008-X

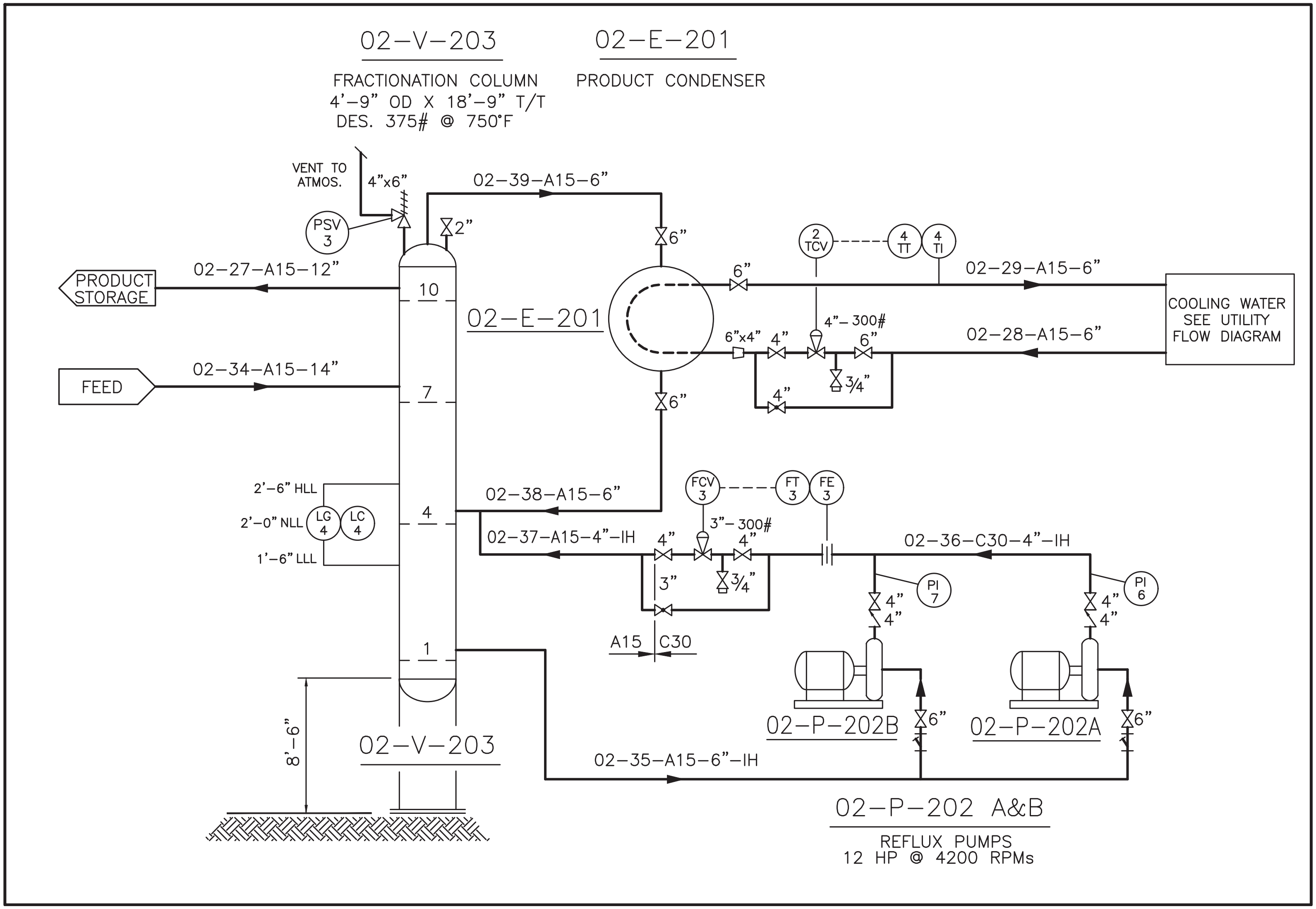


FIGURE 15.1 Unit-02: Mechanical P&ID.

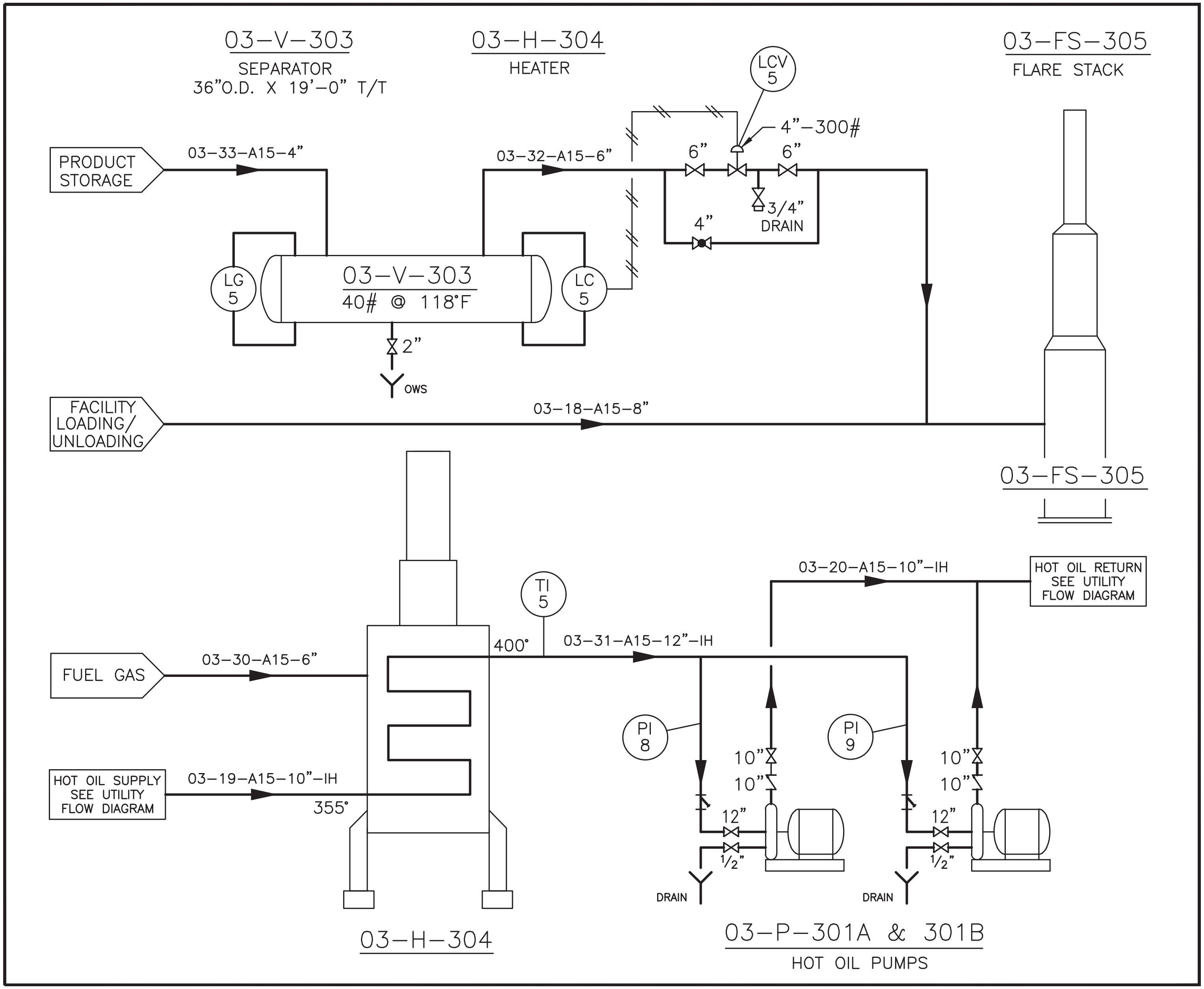


FIGURE 15.2 Unit-03: Mechanical P&ID.

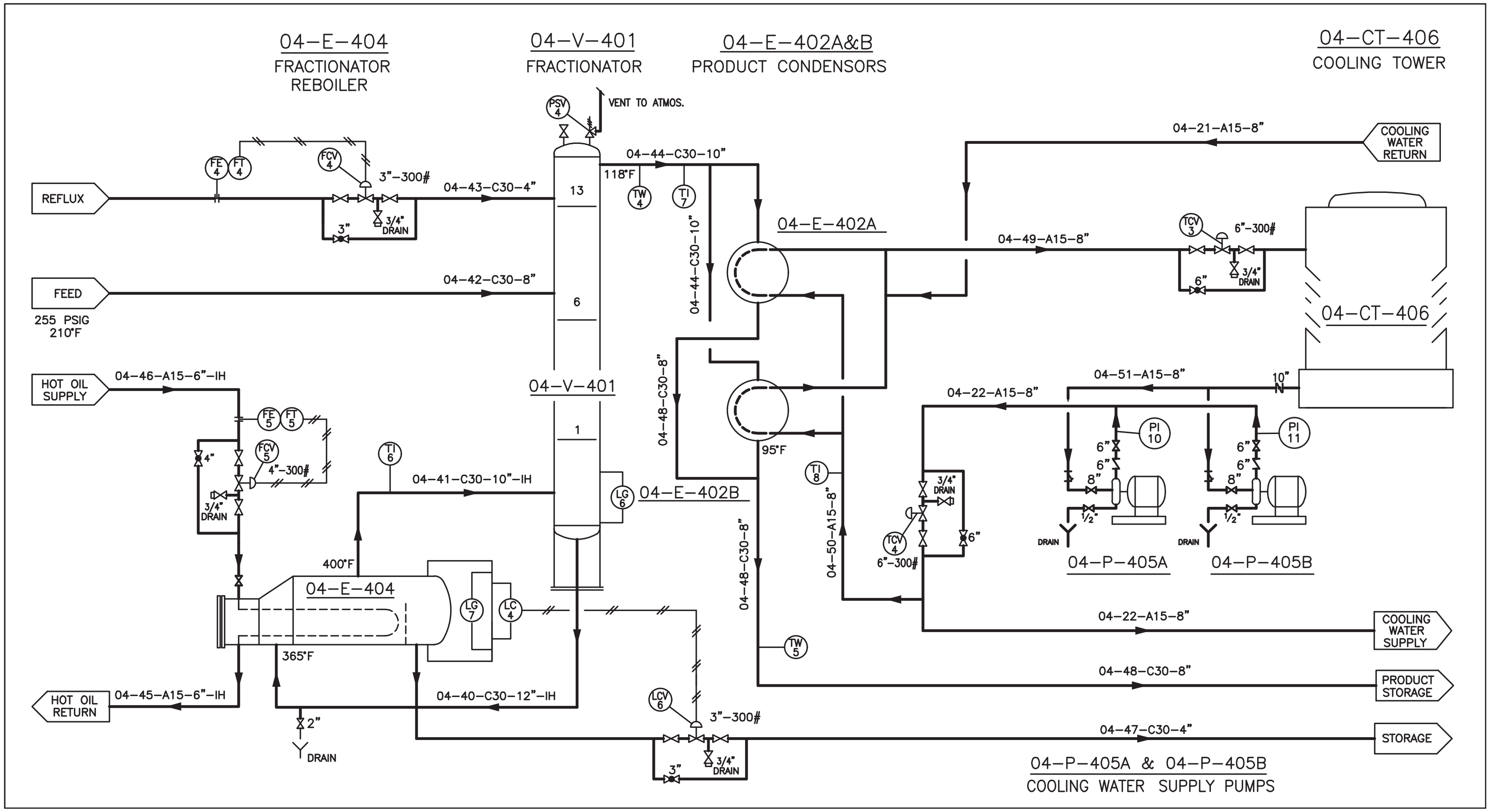


FIGURE 15.3 Unit-04: Mechanical P&ID.

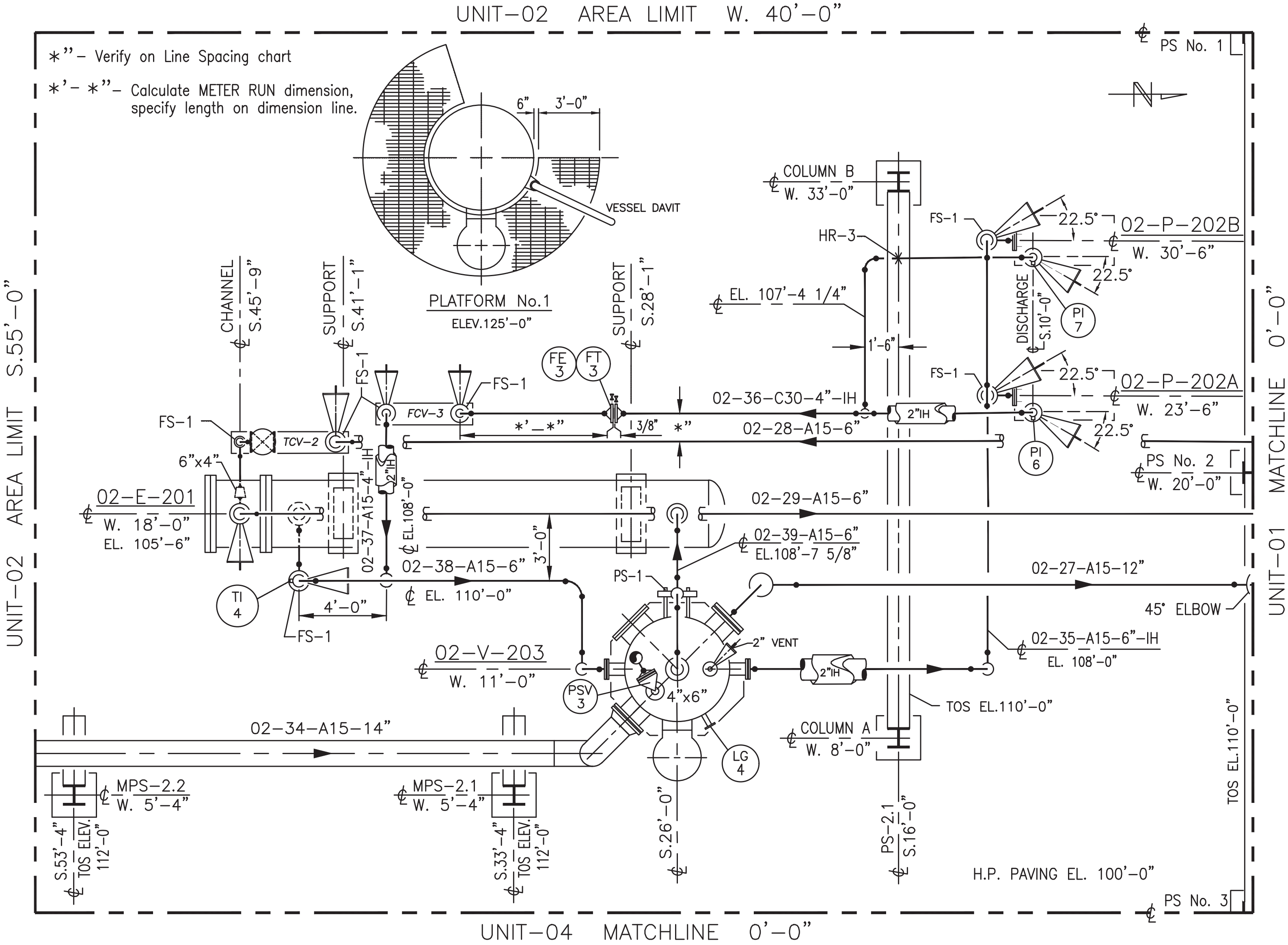


FIGURE 15.4 Unit-02: Piping Arrangement Drawing.

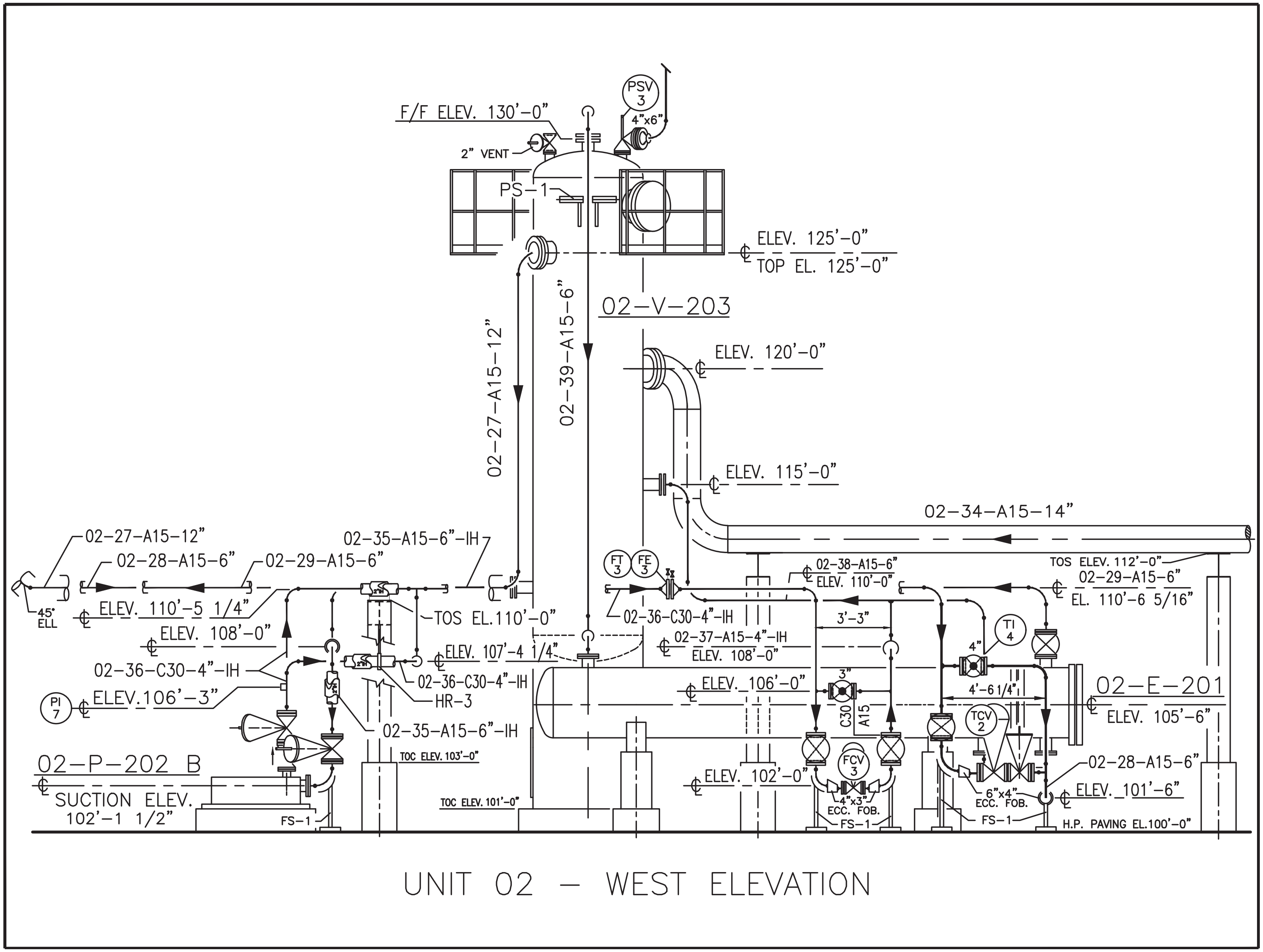


FIGURE 15.5 Unit-02: West Elevation.

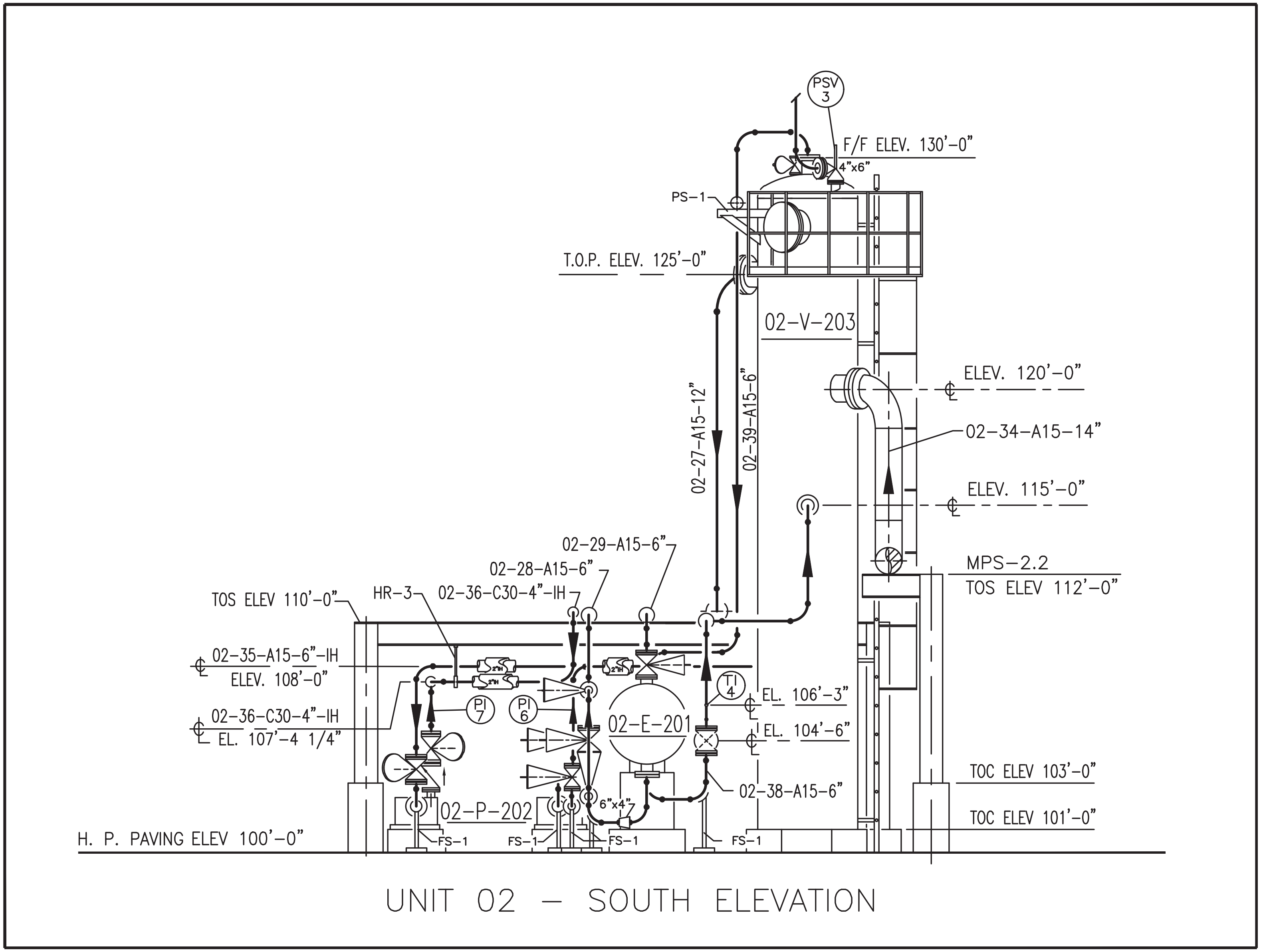


FIGURE 15.6 Unit-02: South Elevation.

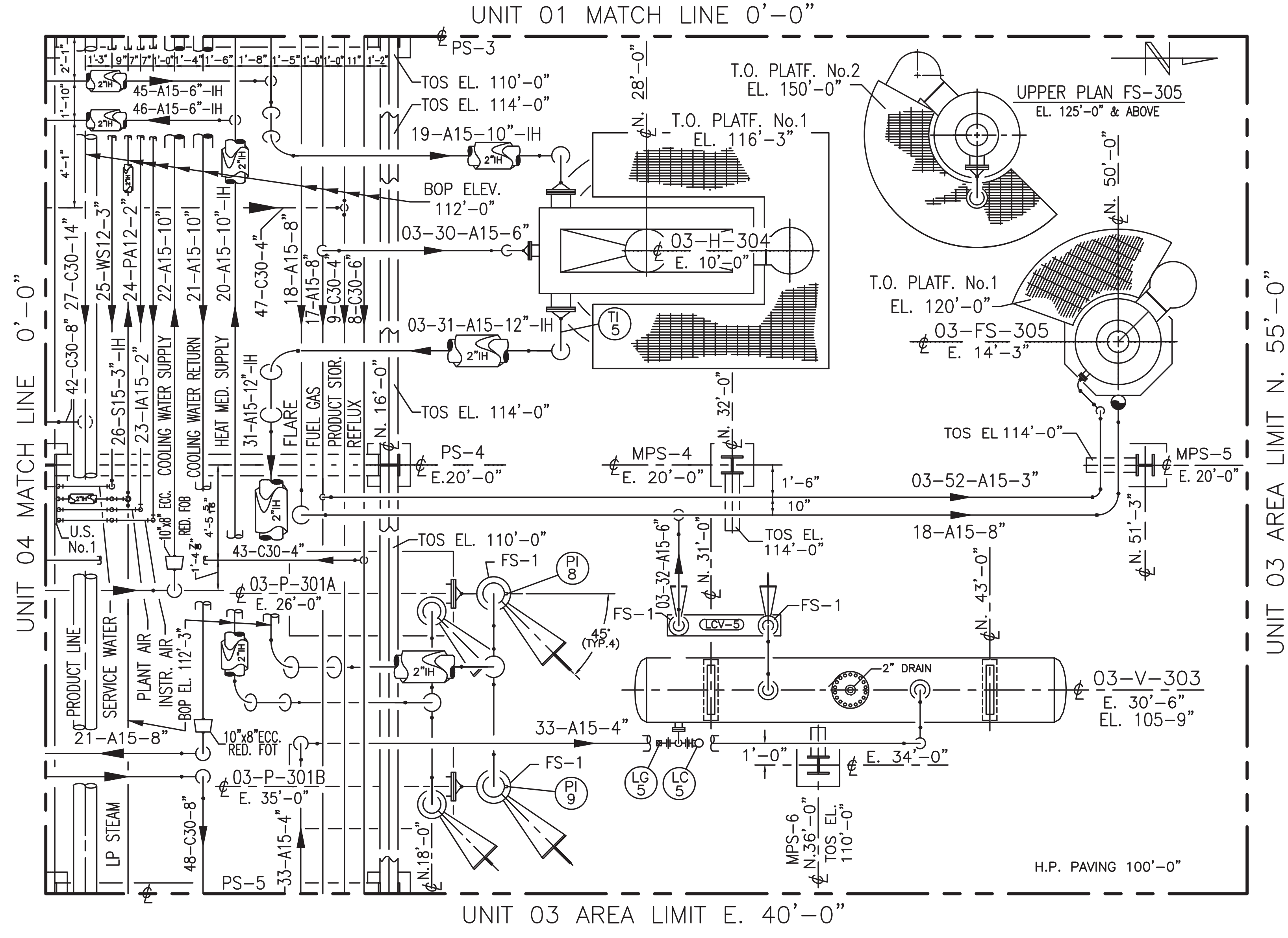


FIGURE 15.7 Unit-03: Piping Arrangement Drawing.

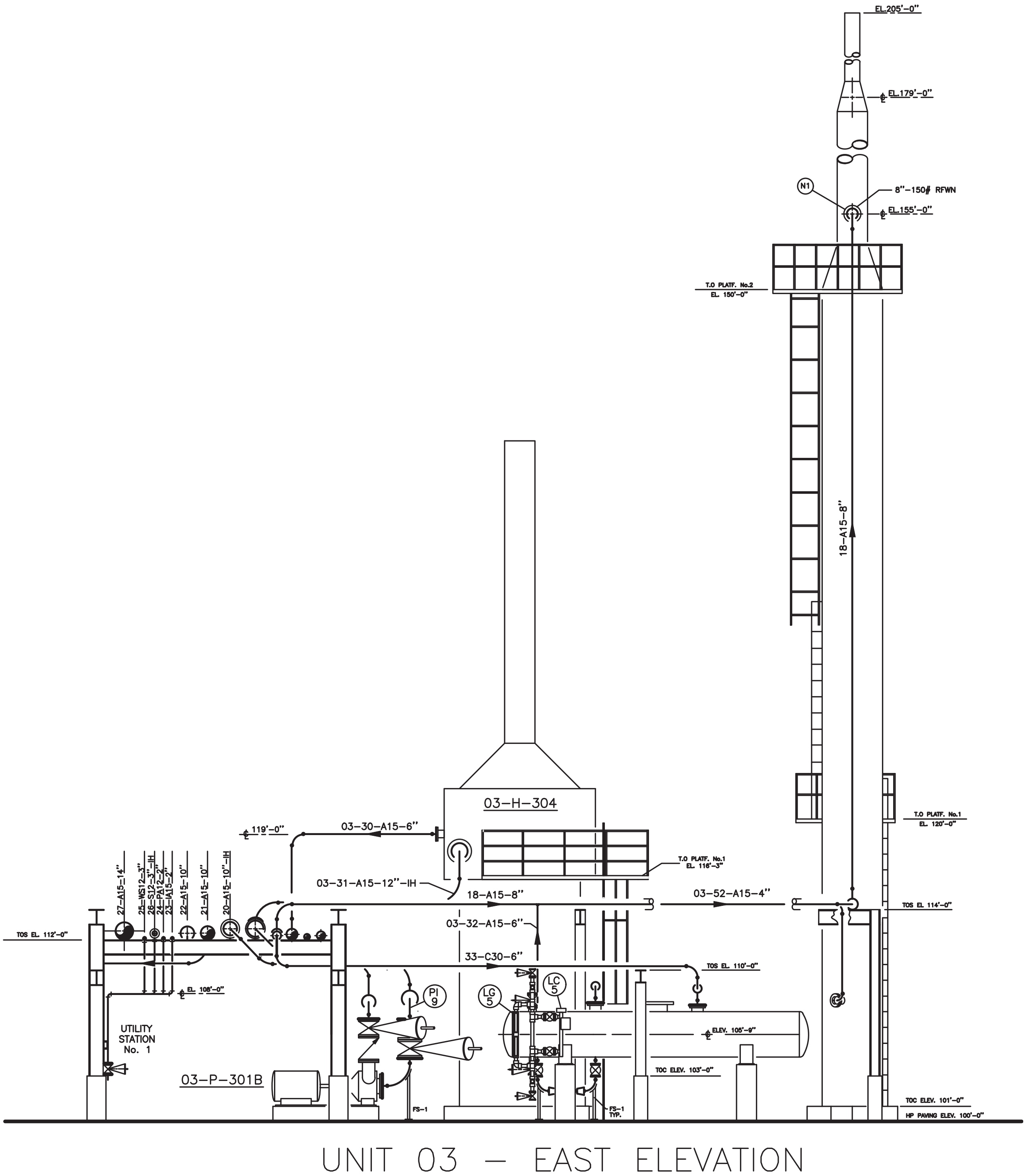


FIGURE 15.8 Unit-03: East Elevation.

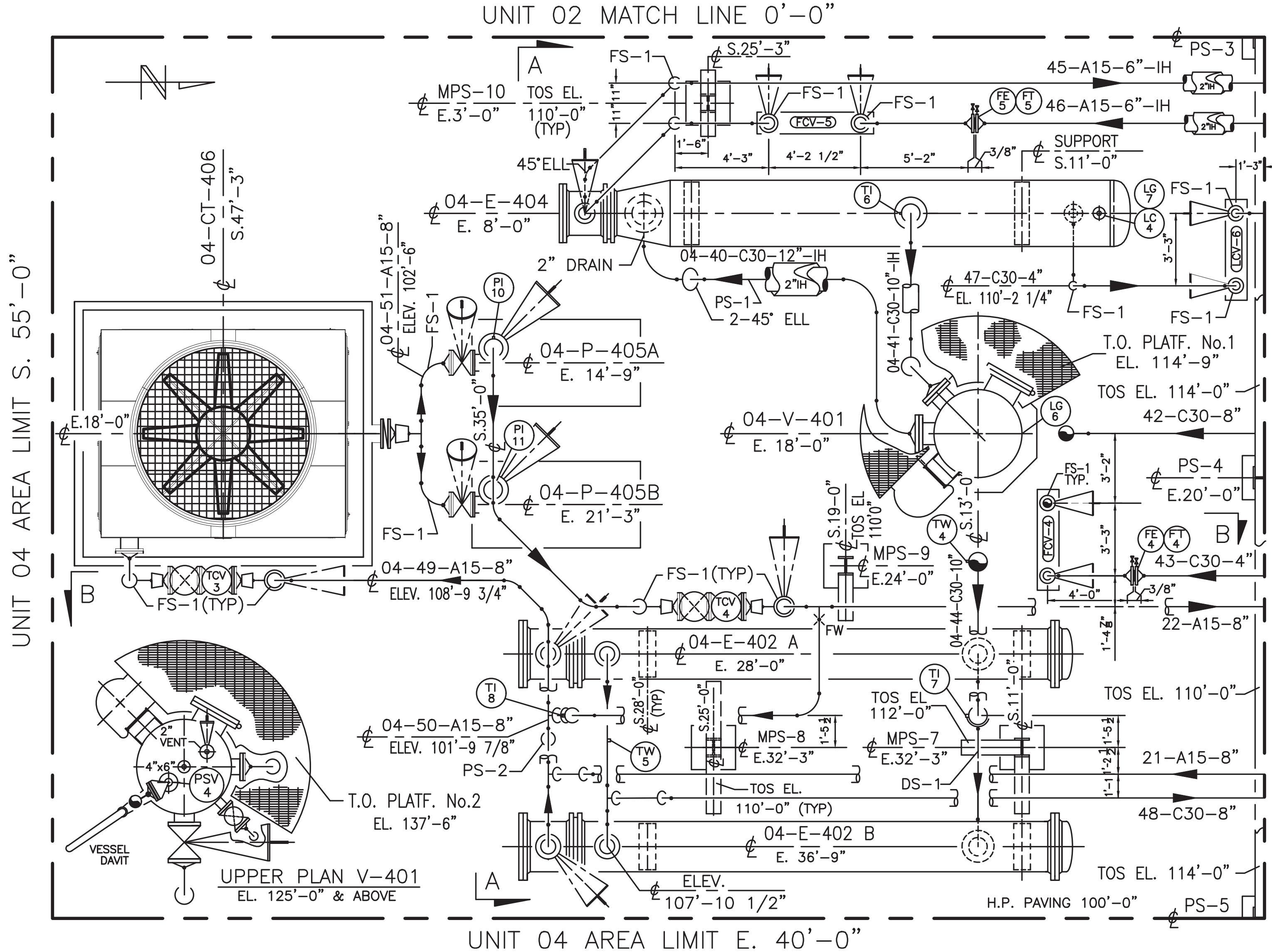


FIGURE 15.9 Unit-04: Piping Arrangement Drawing.

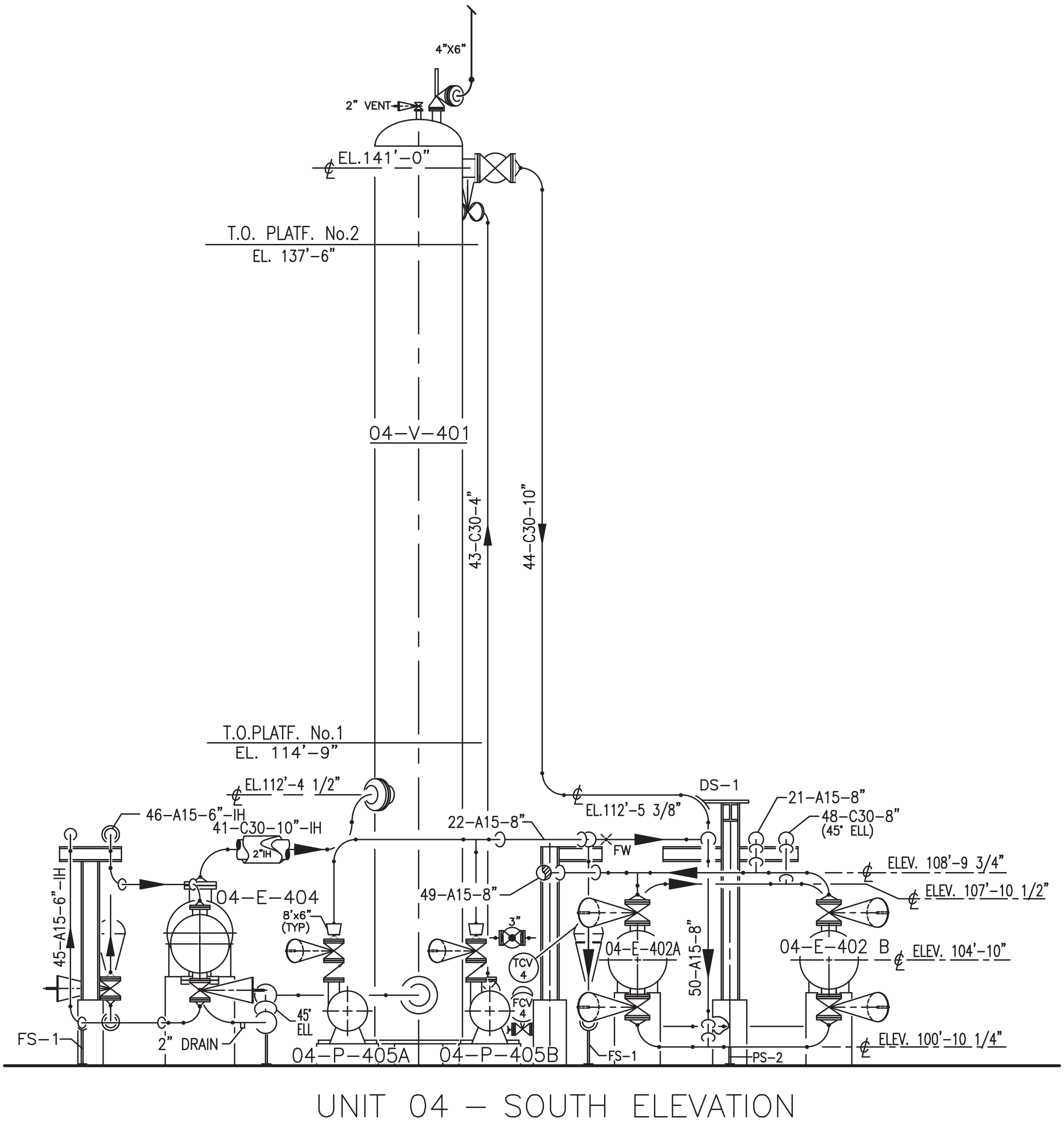


FIGURE 15.10 Unit-04: South Elevation.

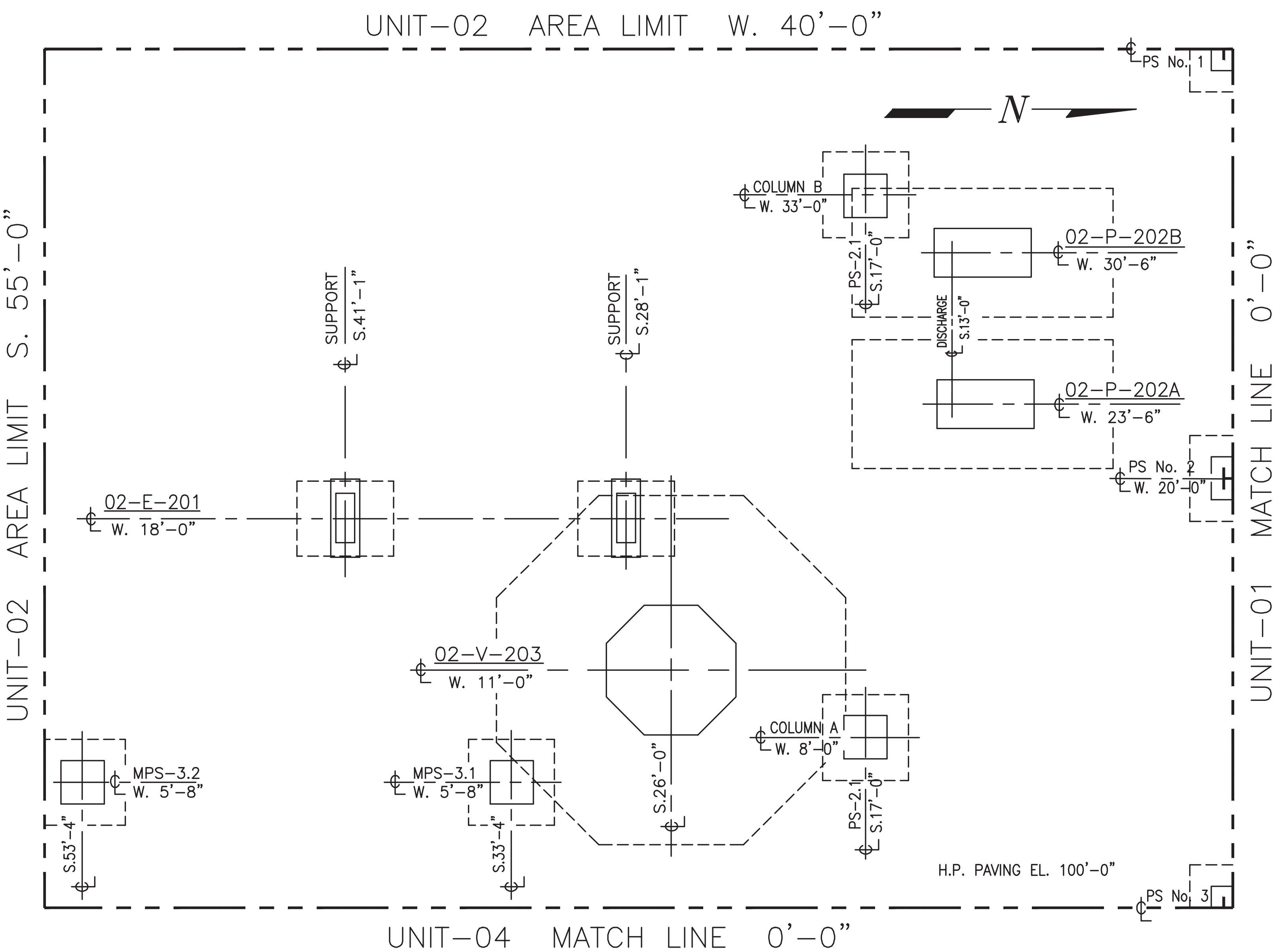


FIGURE 15.11 Unit-02: Foundation Location Plan.

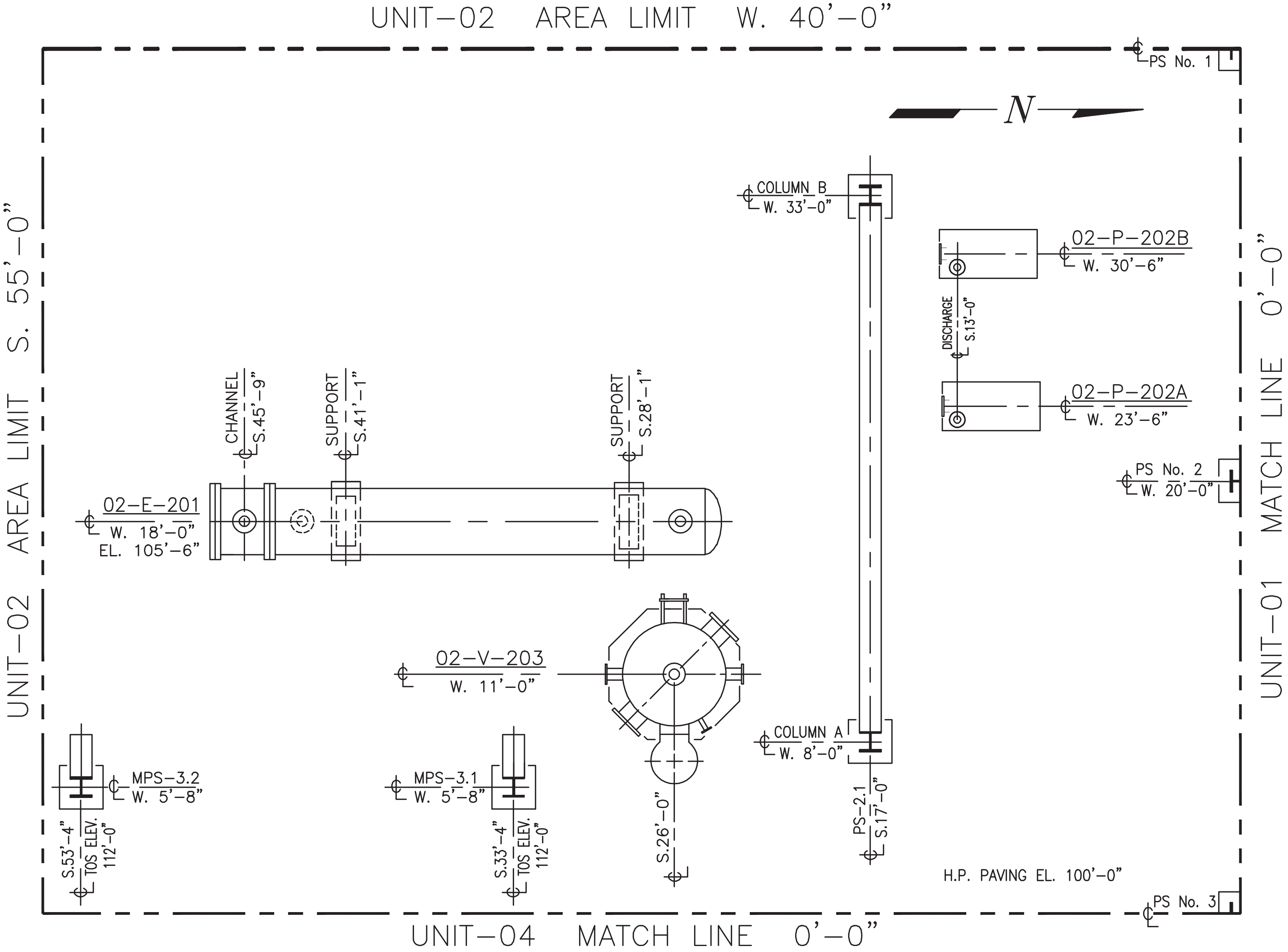


FIGURE 15.12 Unit-02: Equipment Location Plan.

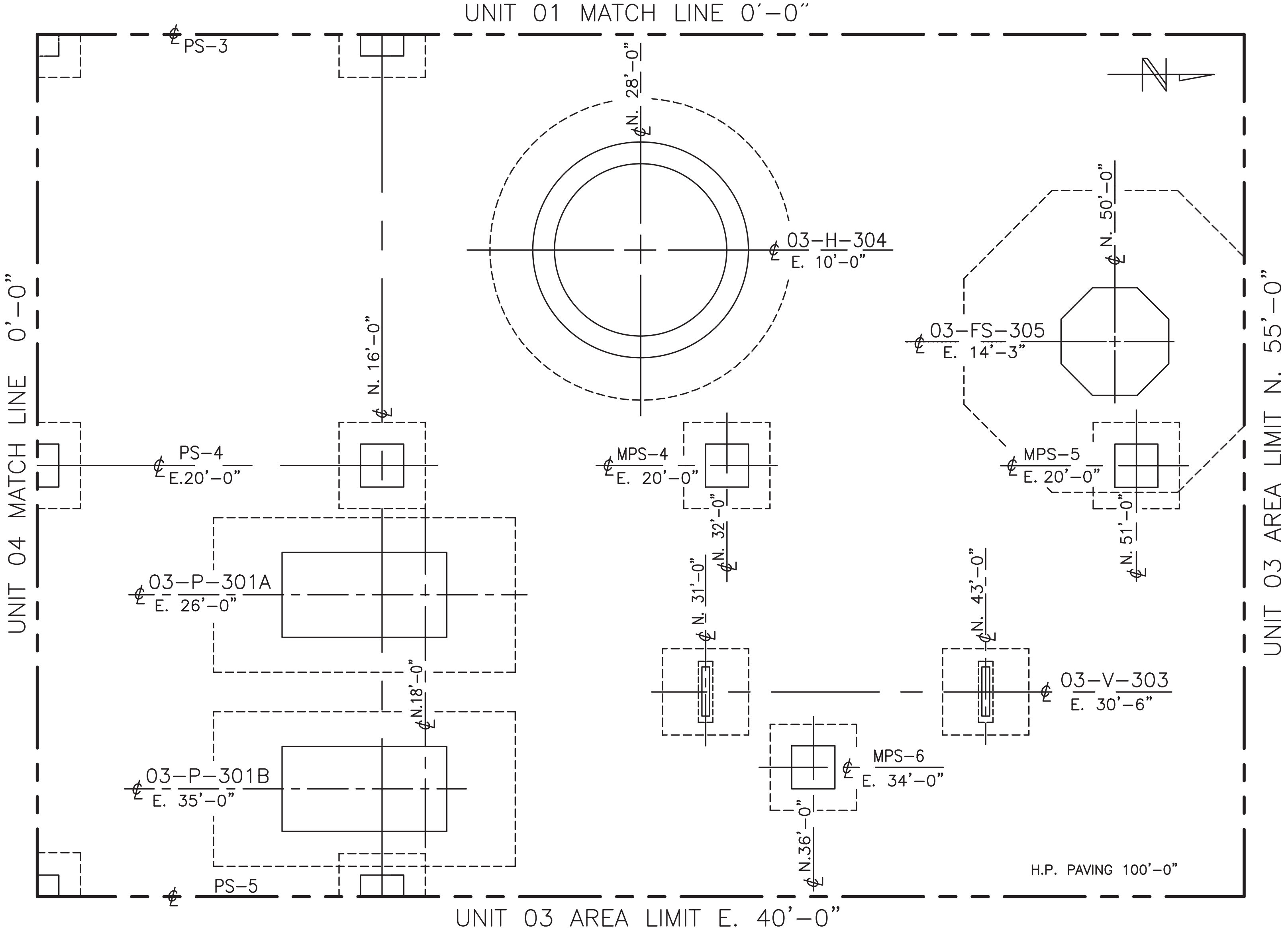


FIGURE 15.13 Unit-03: Foundation Location Plan.

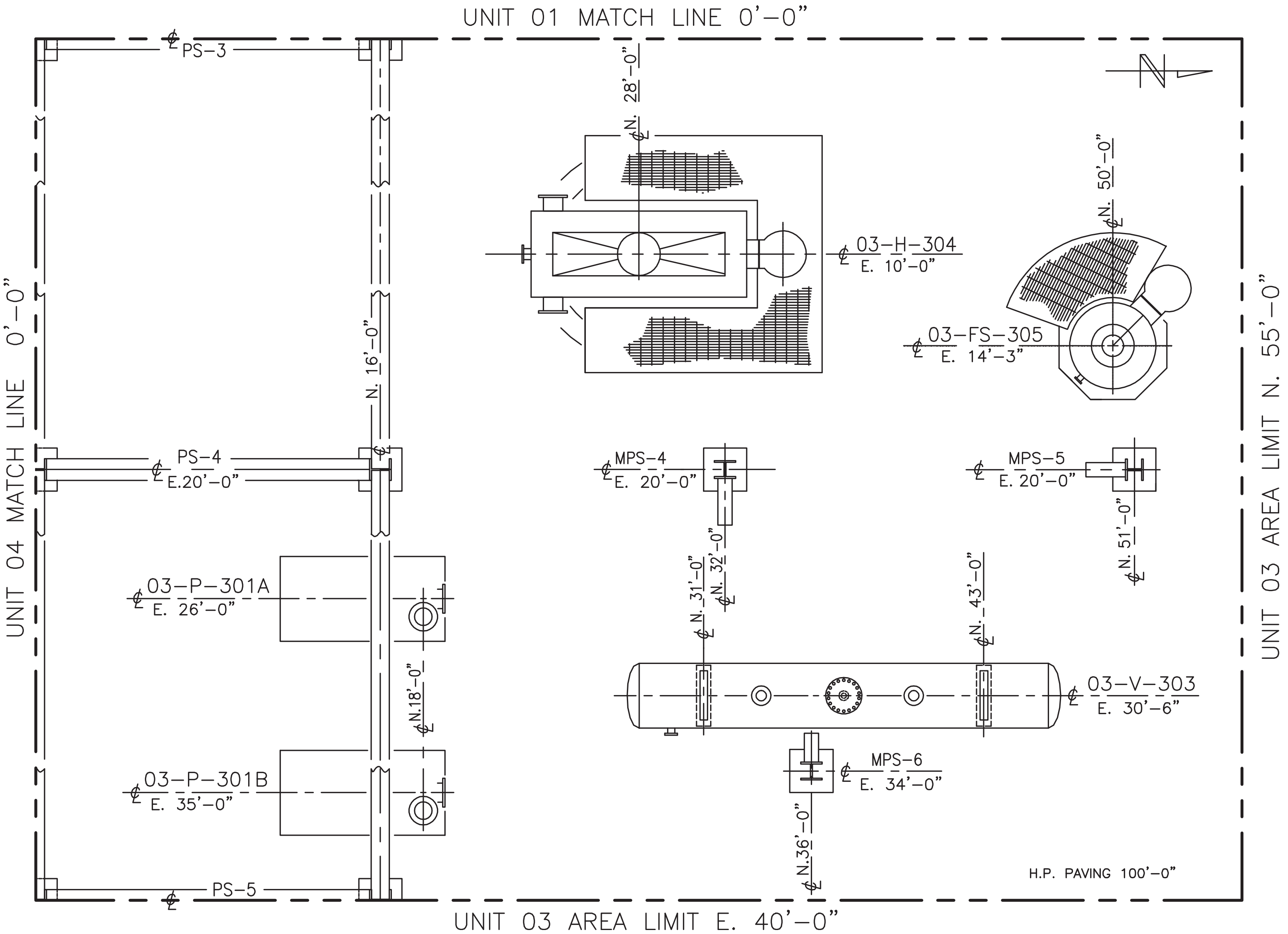


FIGURE 15.14 Unit-03: Equipment Location Plan.

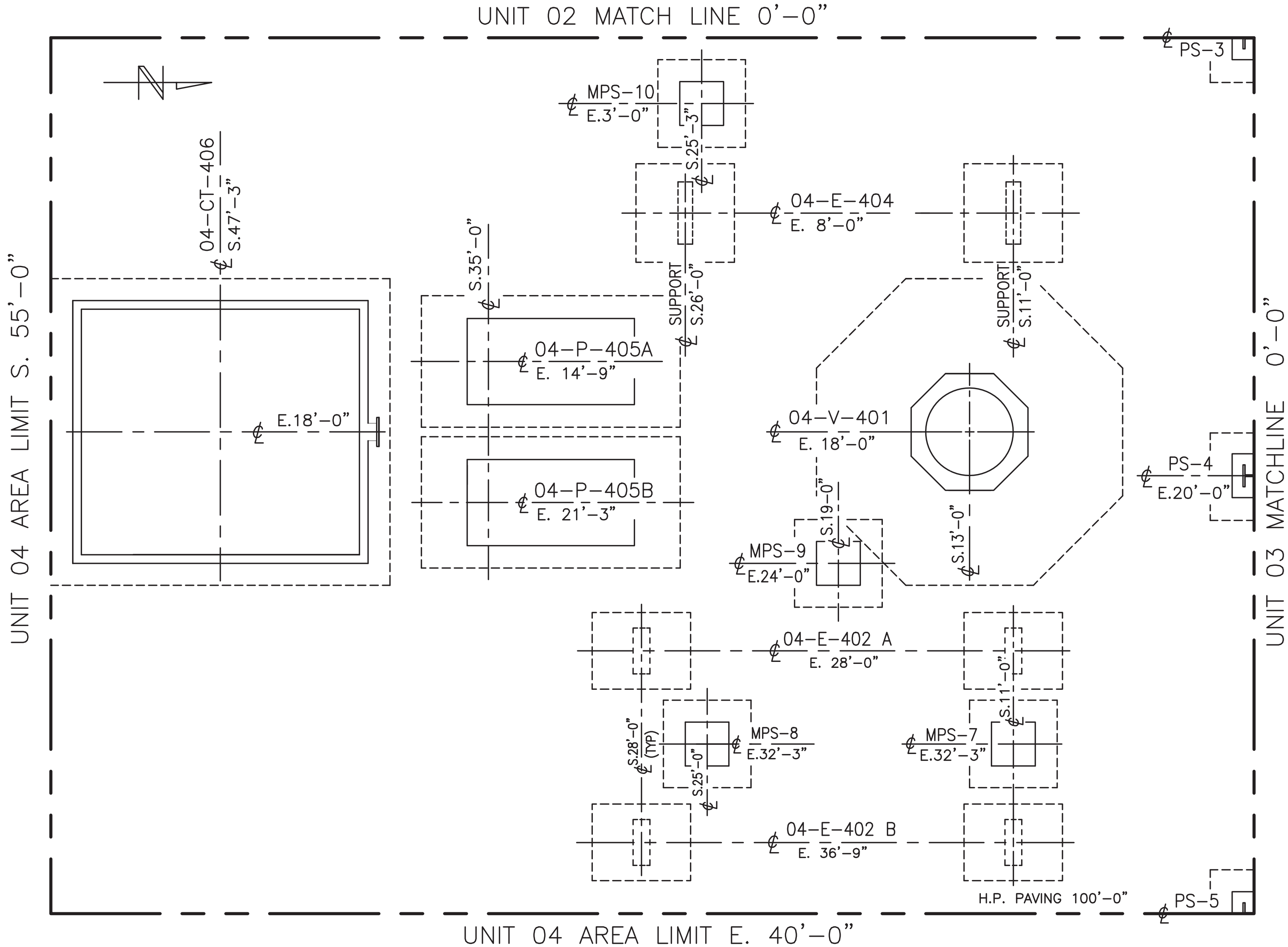


FIGURE 15.15 Unit-04: Foundation Location Plan.

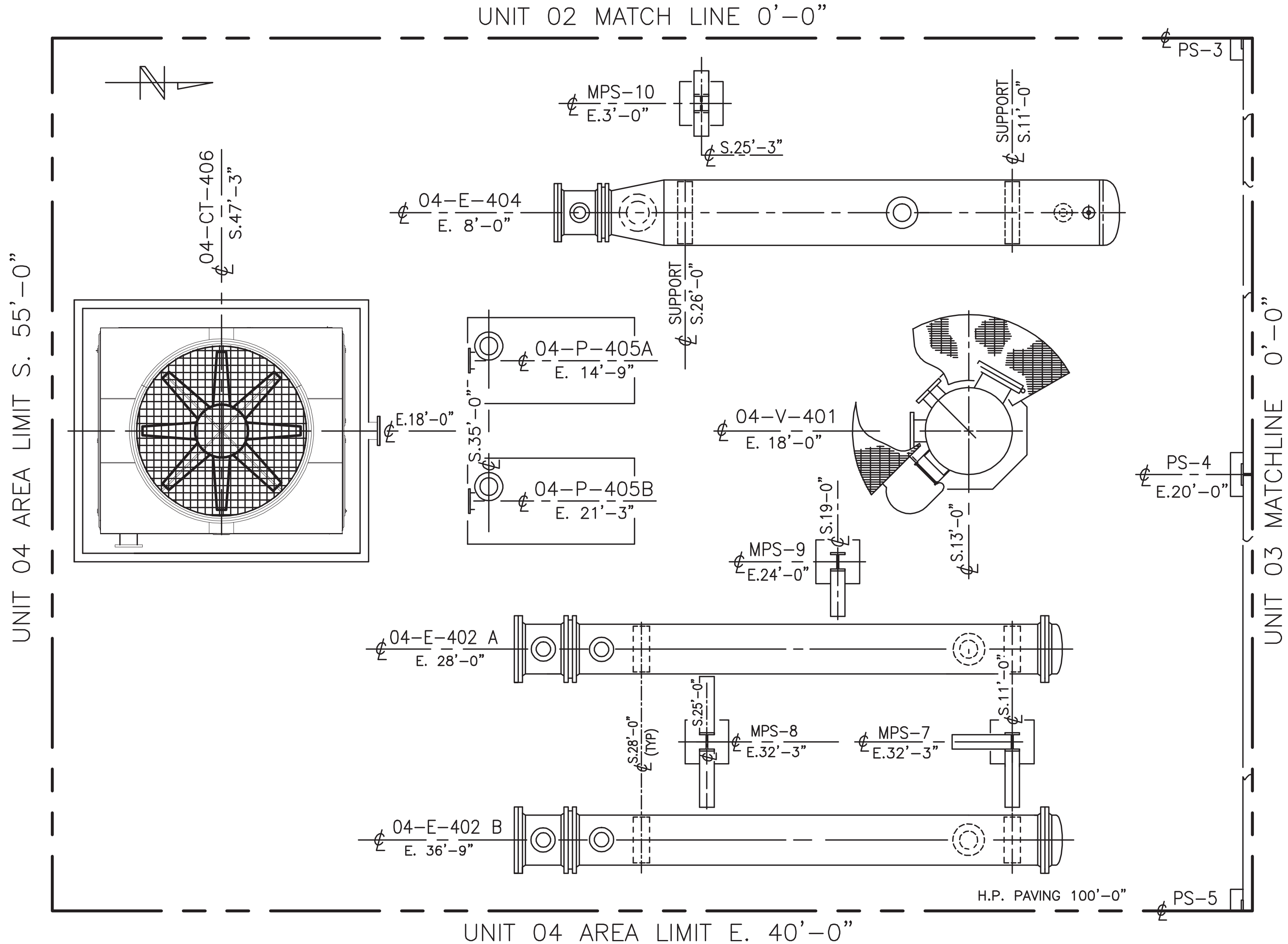


FIGURE 15.16 Unit-04: Equipment Location Plan.

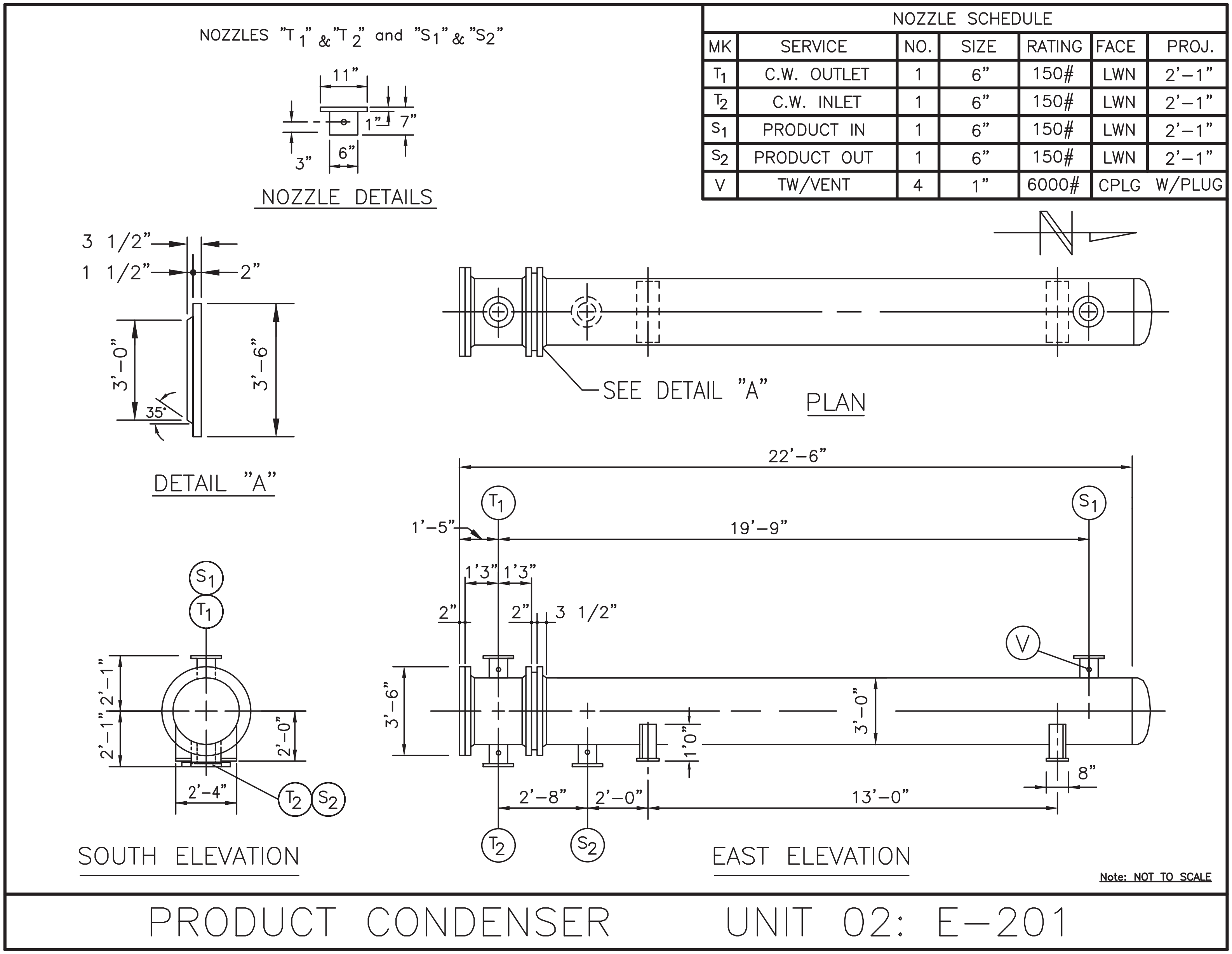
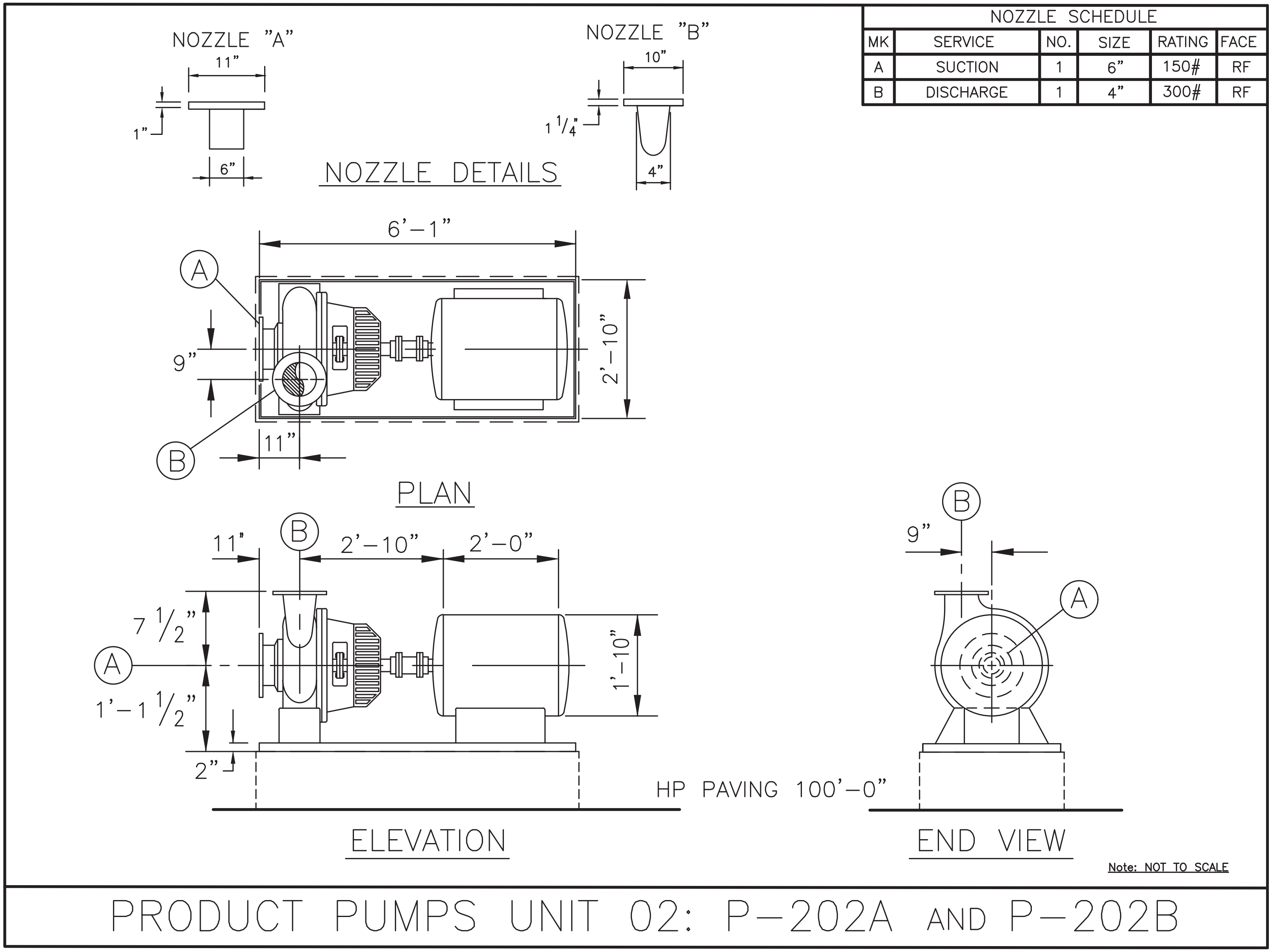


FIGURE 15.17 Unit-02: Product Condenser 02-E-201.



MK	SERVICE	NO.	SIZE	RATING	FACE
A	SUCTION	1	6"	150#	RF
B	DISCHARGE	1	4"	300#	RF

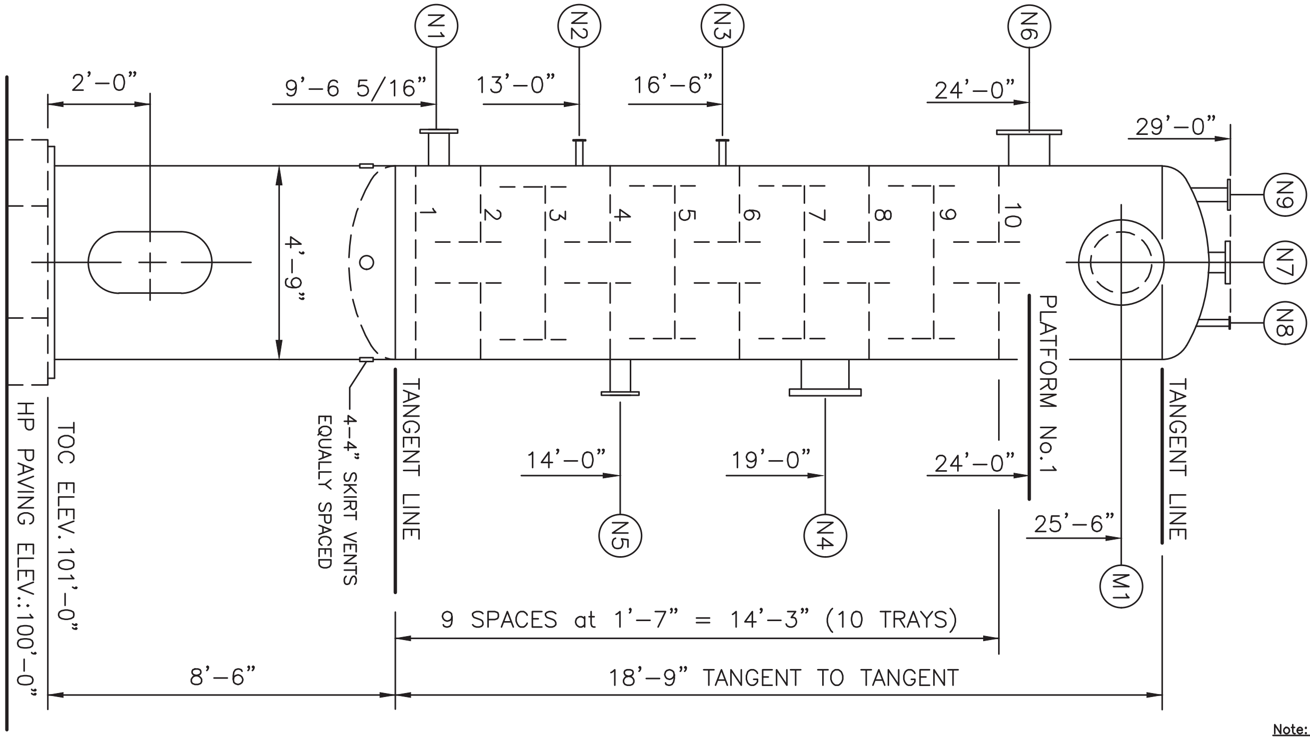
FIGURE 15.18 Unit-02: Product Pumps 02-P-202A and B.

NOTES:

1. THE TAIL DIMENSIONS SHOWN ON THIS EQUIPMENT DRAWING DO NOT INCLUDE THE 1'–0" CONCRETE PEDESTAL. TAIL DIMENSIONS ARE FROM BOTTOM OF BASE PLATE.
2. 2" THICK BASERING, 5'–9" O.D.
3. USE ASTM A–516 Gr. 60 BOILER PLATE.

NOZZLE SCHEDULE

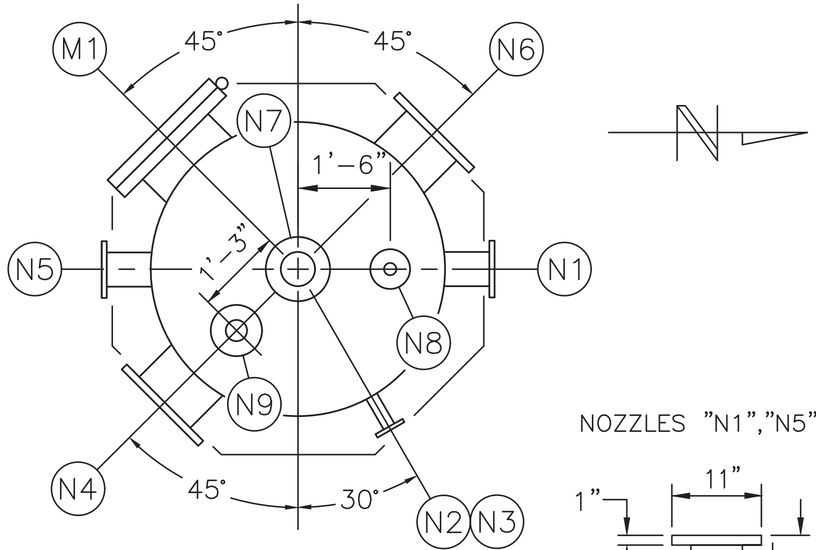
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	PHONIUM SUPPLY	1	6"	150#	RF	3'–3"
N2	L.G. CONN.	1	2"	150#	RF	3'–0"
N3	L.G. CONN.	1	2"	150#	RF	3'–0"
N4	FEED INLET	1	14"	150#	RF	3'–3"
N5	PHONIUM RETURN	1	6"	150#	RF	3'–3"
N6	PRODUCT STORAGE	1	12"	150#	RF	3'–3"
N7	REFLUX	1	6"	150#	RF	3'–3"
N8	VENT	1	2"	150#	RF	1'–9"
N9	P.S.V.	1	4"	150#	RF	1'–9"
M1	MANWAY	1	18"	150#	RF	2'–10"



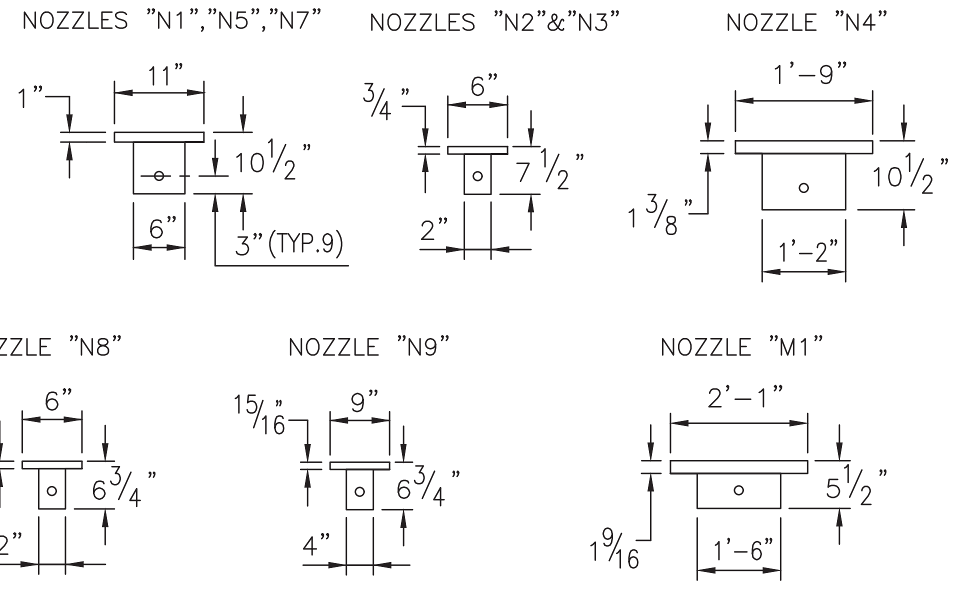
Note: NOT TO SCALE

PHONIUM COLUMN UNIT 02: V–203 1 of 2

FIGURE 15.19 Unit-02: Phonium Column 02-V-203 Sheet 1 of 2.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	PHONIUM SUPPLY	1	6"	150#	RF	3'–3"
N2	L.G. CONN.	1	2"	150#	RF	3'–0"
N3	L.G. CONN.	1	2"	150#	RF	3'–0"
N4	FEED INLET	1	14"	150#	RF	3'–3"
N5	PHONIUM RETURN	1	6"	150#	RF	3'–3"
N6	PRODUCT STORAGE	1	12"	150#	RF	3'–3"
N7	REFLUX	1	6"	150#	RF	3'–3"
N8	VENT	1	2"	150#	RF	1'–9"
N9	P.S.V.	1	4"	150#	RF	1'–9"
M1	MANWAY	1	18"	150#	RF	2'–10"



NOZZLE DETAILS

Note: NOT TO SCALE

PHONIUM COLUMN UNIT 02: V–203 2 of 2

FIGURE 15.20 Unit-02: Phonium Column 02-V-203 Sheet 2 of 2.

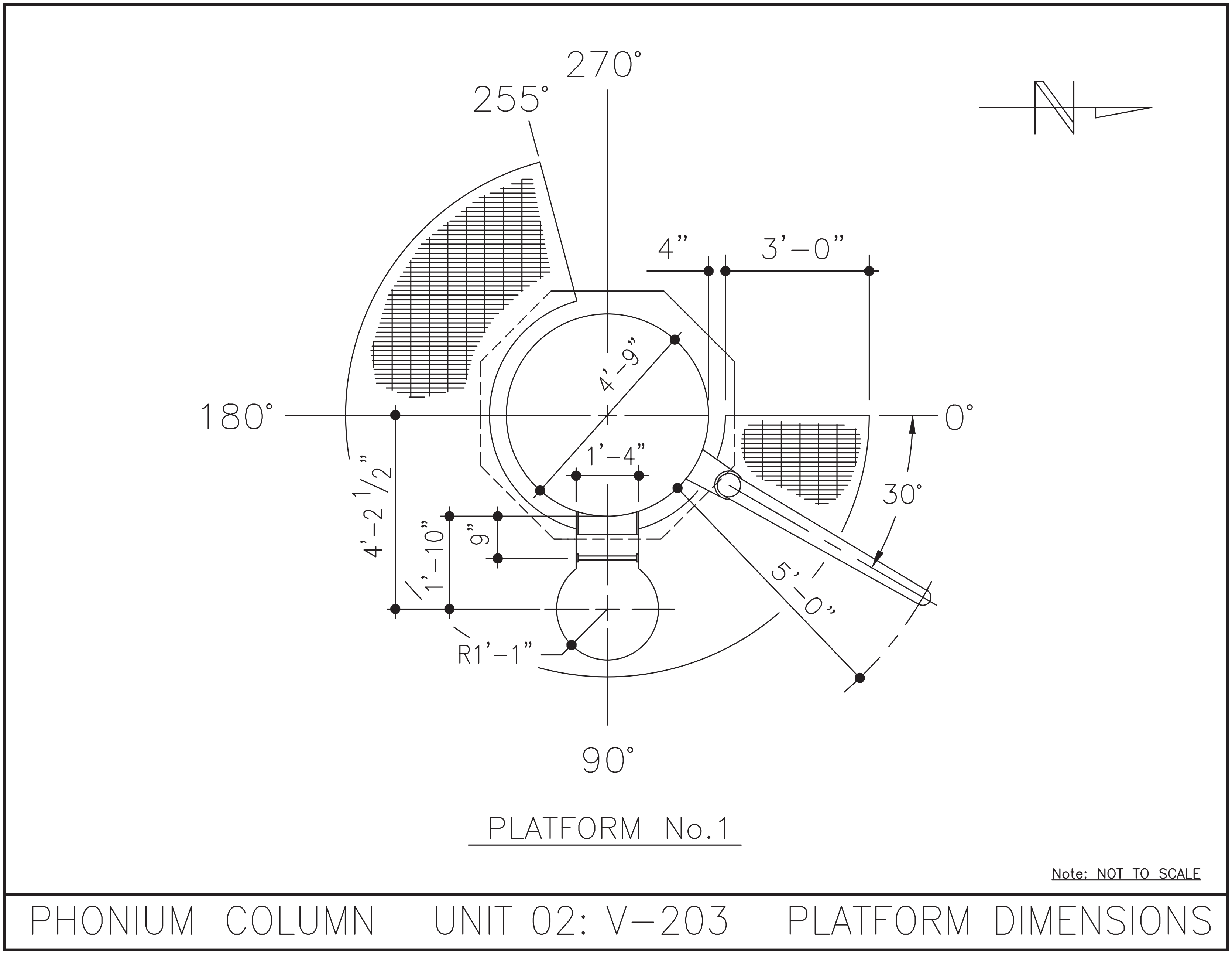
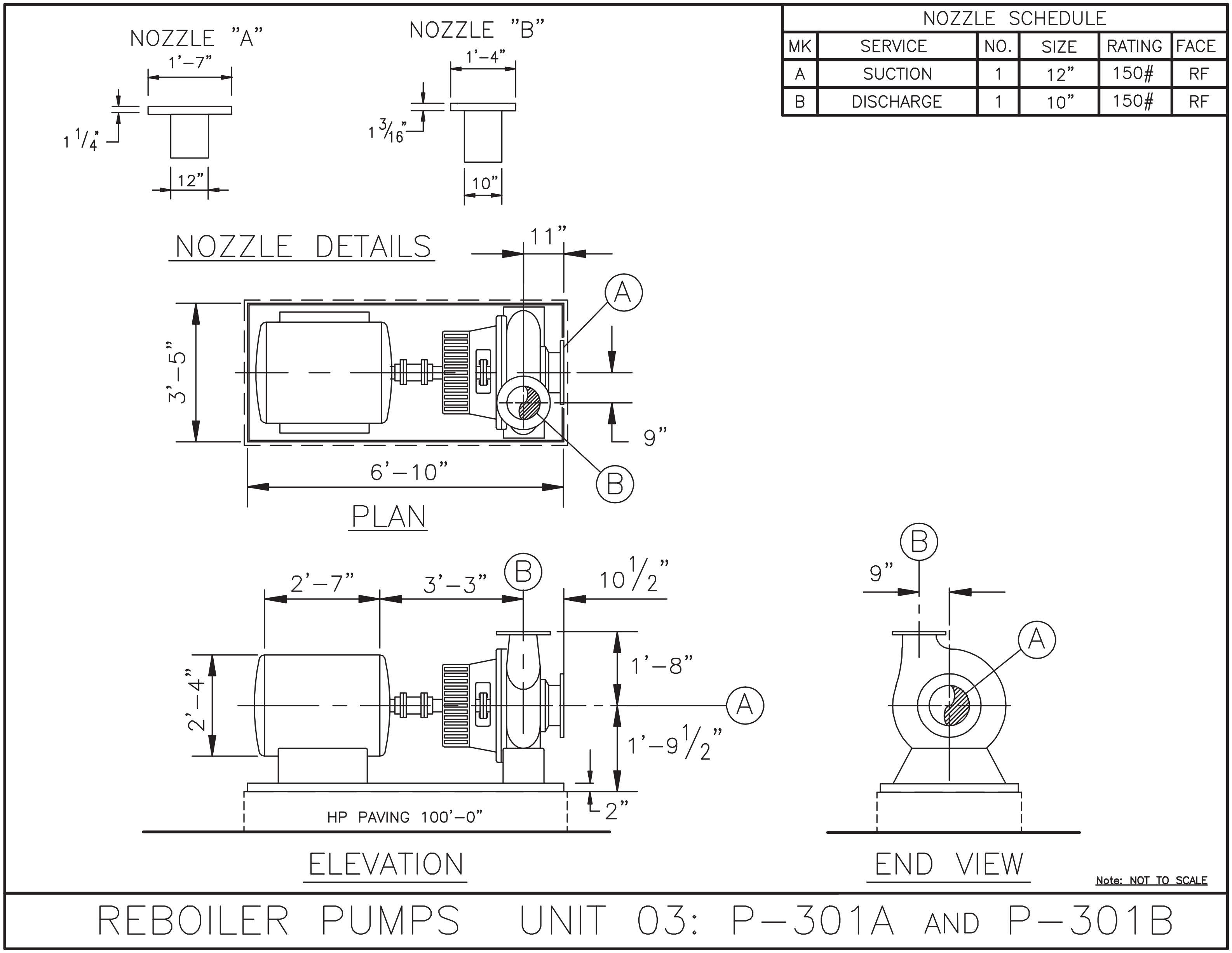
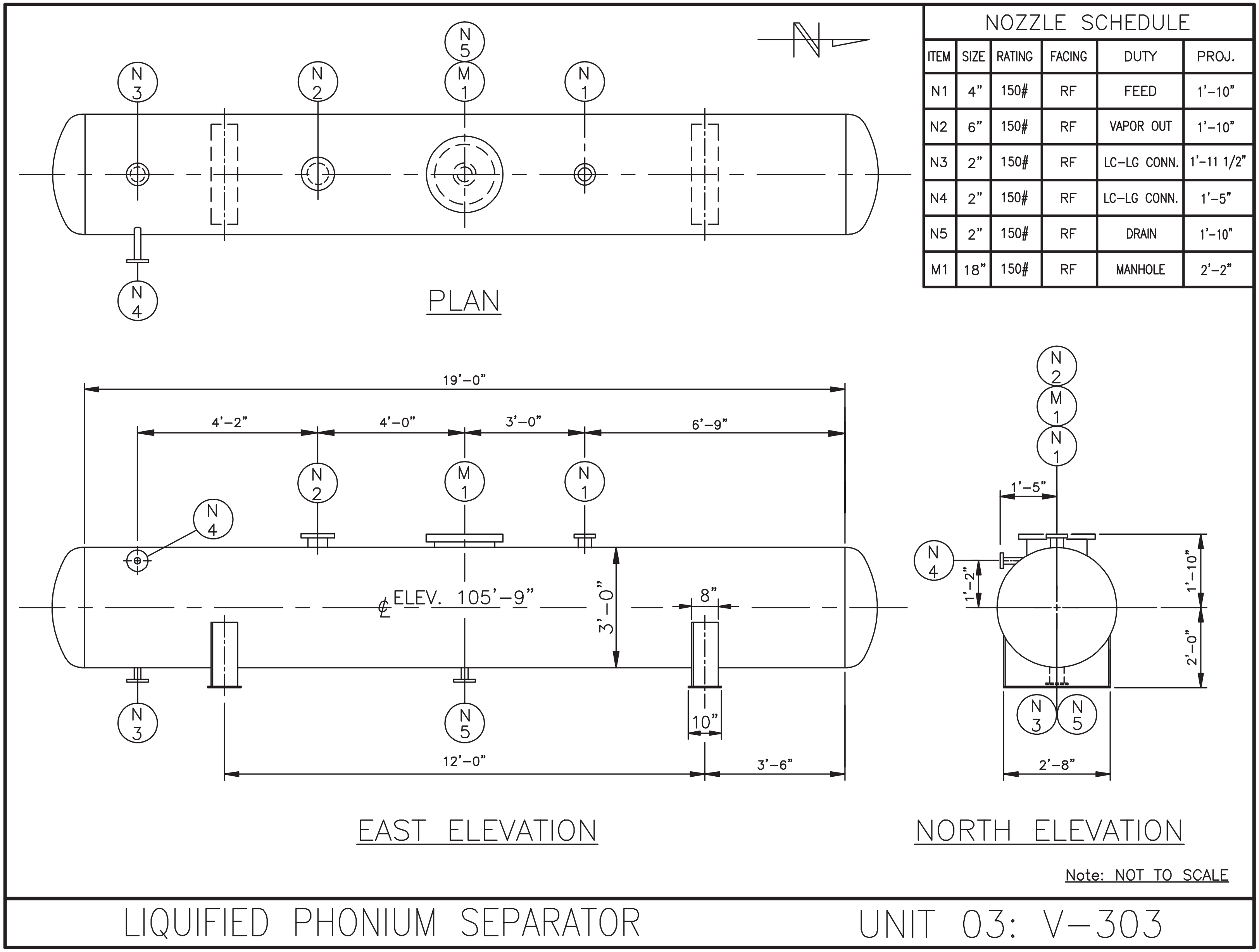


FIGURE 15.21 Unit-02: Phonium Column 02-V-203 Platform Dimensions.



NOZZLE SCHEDULE					
MK	SERVICE	NO.	SIZE	RATING	FACE
A	SUCTION	1	12"	150#	RF
B	DISCHARGE	1	10"	150#	RF

FIGURE 15.22 Unit-03: Reboiler Pumps 03-P-301A and P-301B.

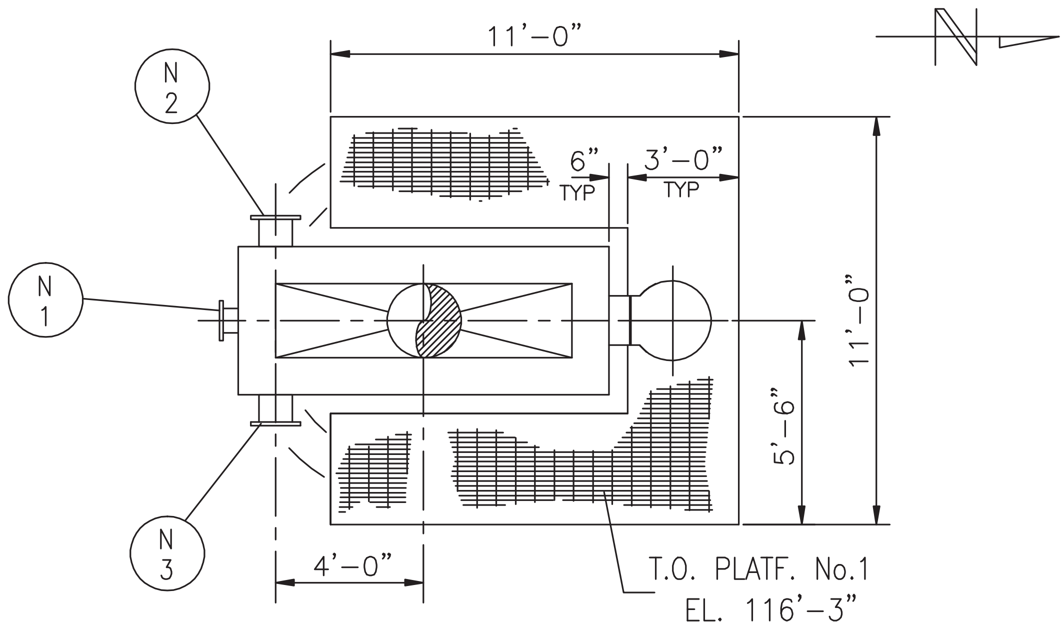


NOZZLE SCHEDULE

ITEM	SIZE	RATING	FACING	DUTY	PROJ.
N1	4"	150#	RF	FEED	1'–10"
N2	6"	150#	RF	VAPOR OUT	1'–10"
N3	2"	150#	RF	LC–LG CONN.	1'–11 1/2"
N4	2"	150#	RF	LC–LG CONN.	1'–5"
N5	2"	150#	RF	DRAIN	1'–10"
M1	18"	150#	RF	MANHOLE	2'–2"

FIGURE 15.23 Unit-03: Liquified Phonium Separator 03-V-303.

NOZZLE SCHEDULE					
ITEM	SIZE	RATING	FACING	DUTY	PROJECTION
N1	6”	150#	RF	FUEL OIL FEED	6”
N2	10”	150#	RF	HEATING OIL SUPPLY	10”
N3	12”	150#	RF	HEATING OIL RETURN	10”



PLAN

Note: NOT TO SCALE

HEATER UNIT 03: H–304 1 of 2

FIGURE 15.24 Unit-03: Heater 03-H-304 Sheet 1 of 2.

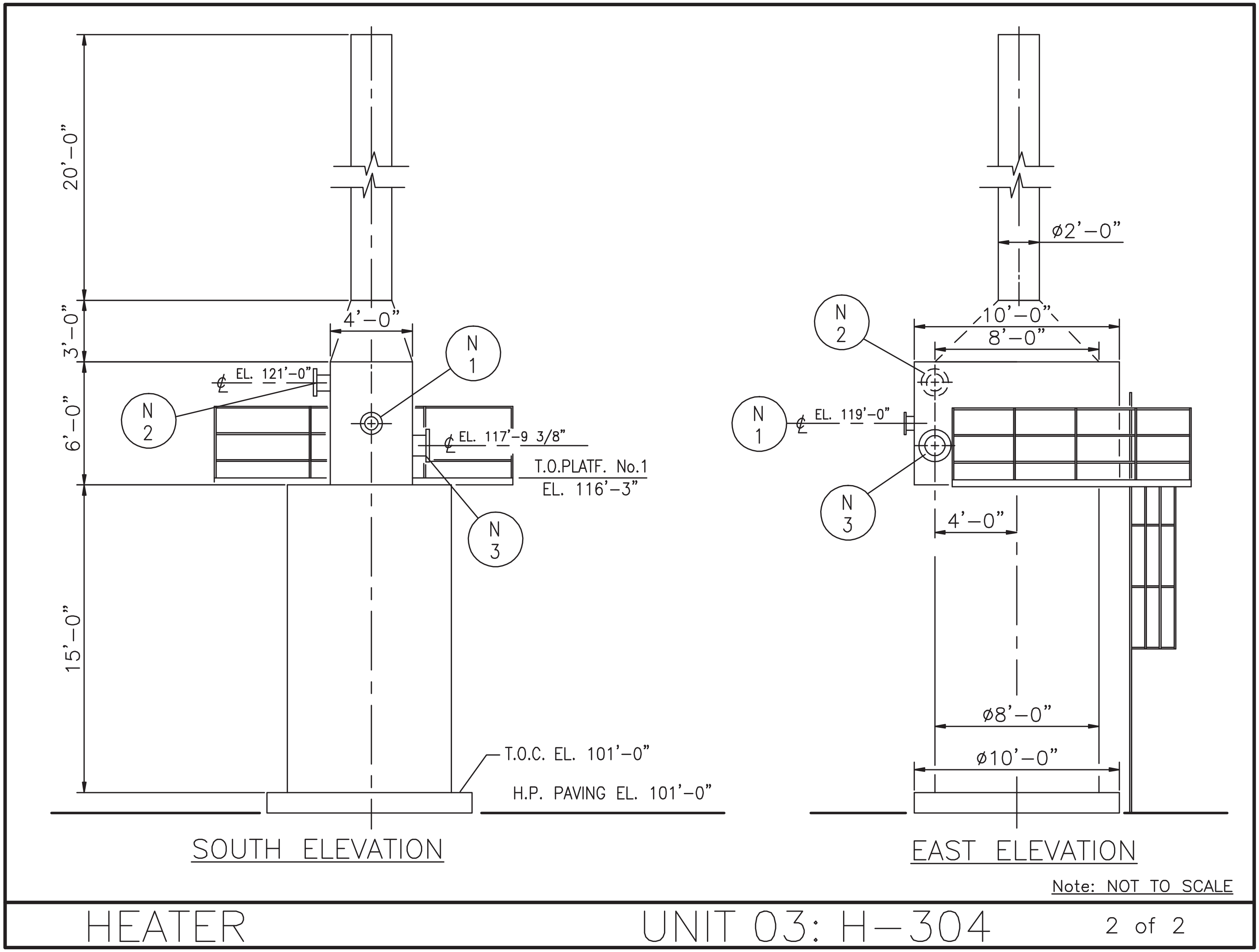


FIGURE 15.25 Unit-03: Heater 03-H-304 Sheet 2 of 2.

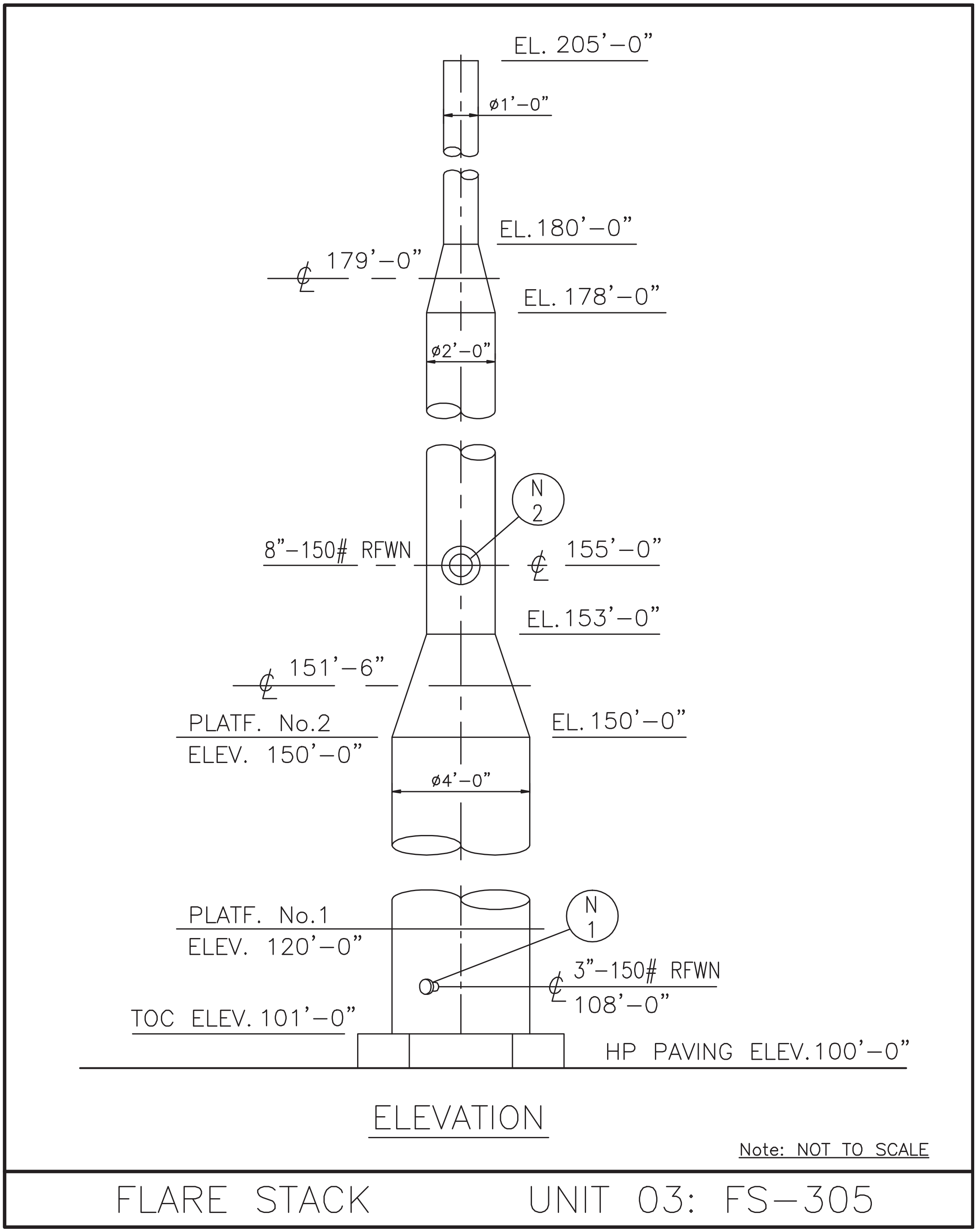


FIGURE 15.26 Unit-03: Flare Stack 03-FS-305.

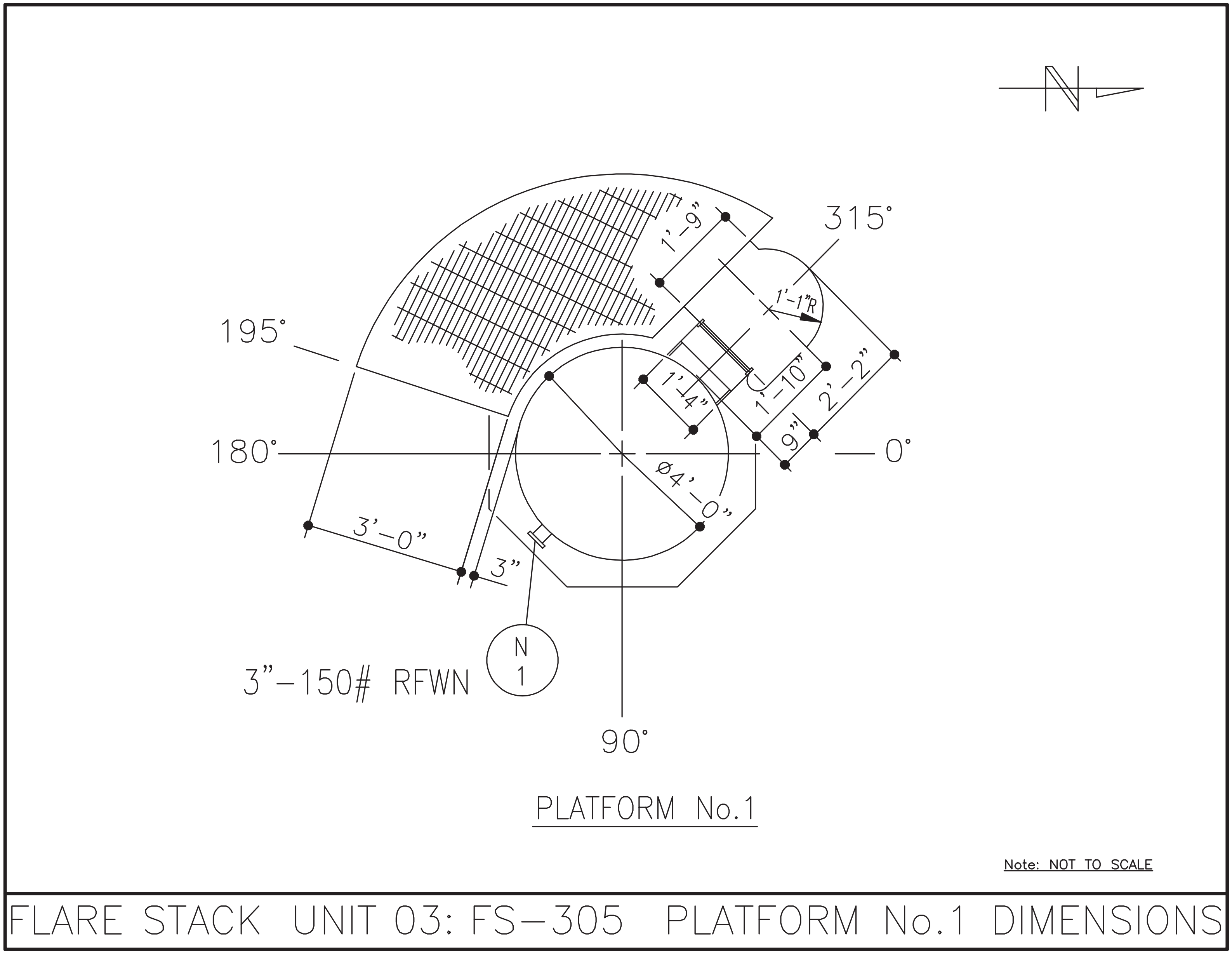
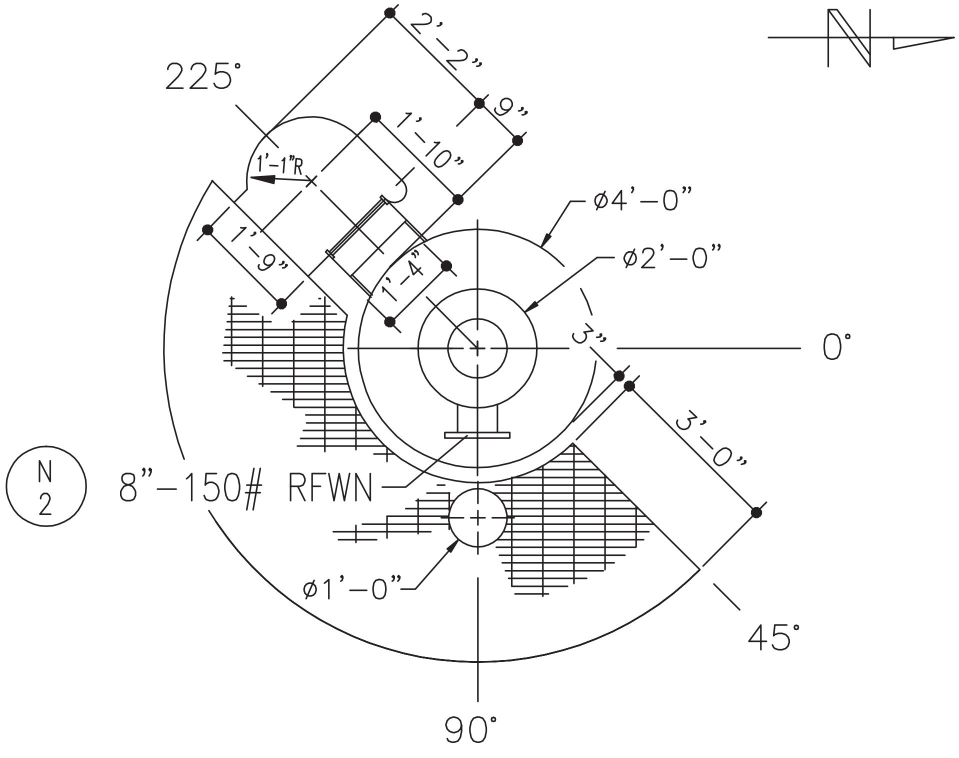


FIGURE 15.27 Unit-03: Flare Stack 03-FS-305 Platform No. 1 Dimensions.

NOZZLE SCHEDULE				
ITEM	SIZE	RATING	FACING	PROJECTION
N_1	3"	150#	RF	2'–3¾"
N_2	8"	150#	RF	1'–6"



PLATFORM No.2

Note: NOT TO SCALE

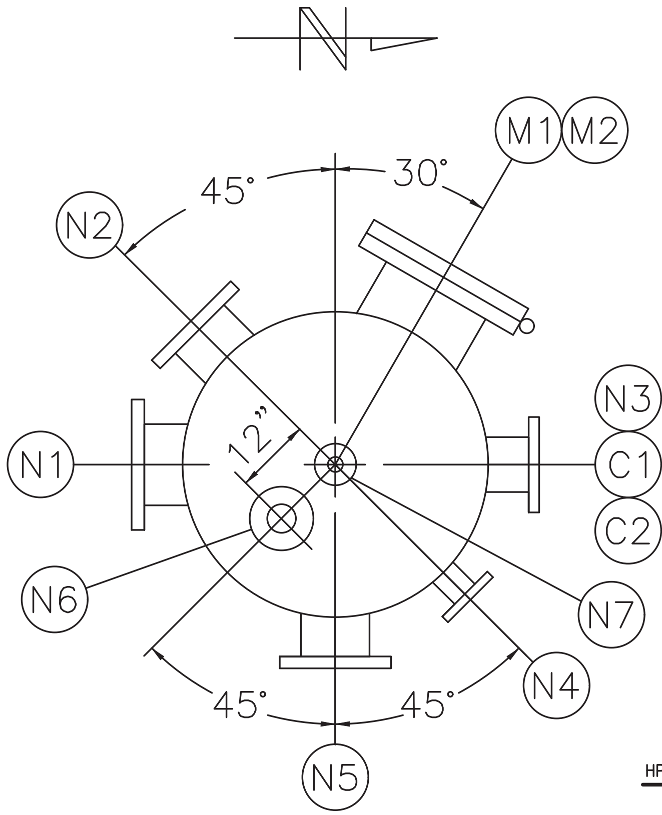
FLARE STACK UNIT 03: FS–305 PLATFORM No.2 DIMENSIONS

FIGURE 15.28 Unit-03: Flare Stack 03-FS-305 Platform No. 2 Dimensions.

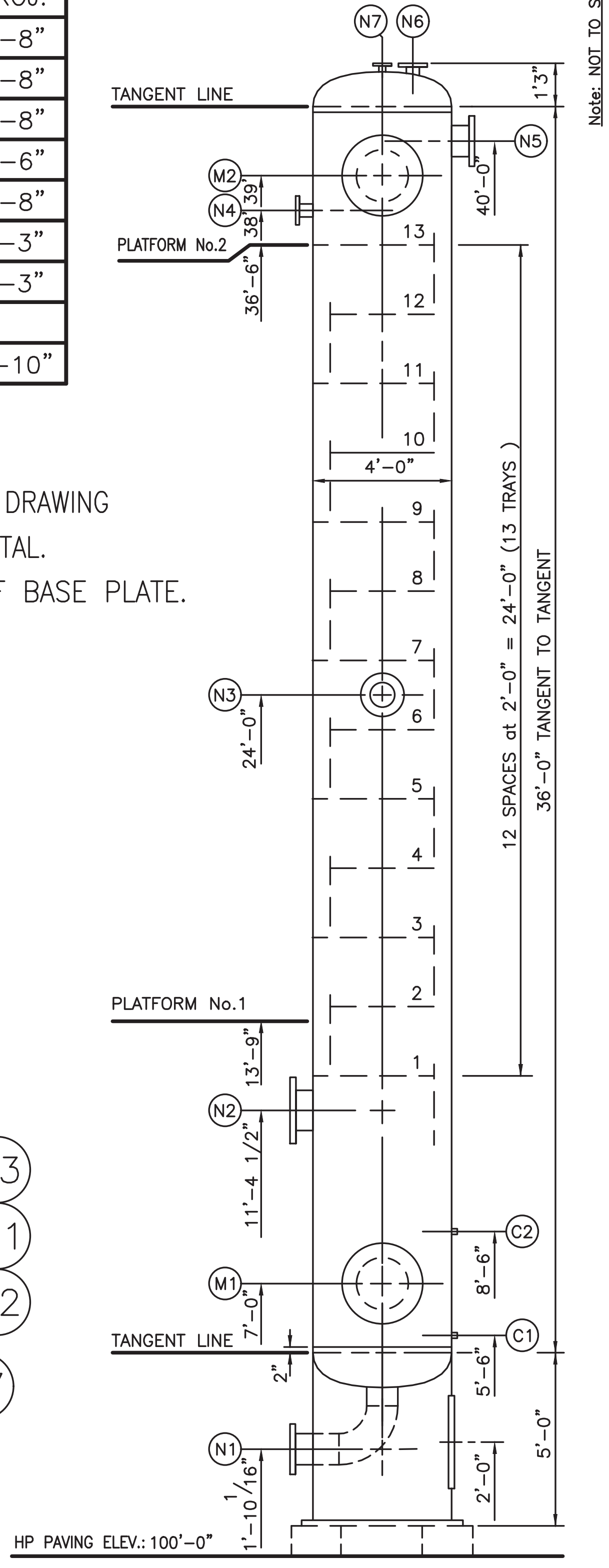
NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	BOTTOM OUT	1	12”	300#	RF	2’–8”
N2	REBOILER RETURN	1	10”	300#	RF	2’–8”
N3	FEED INLET	1	8”	300#	RF	2’–8”
N4	REFLUX	1	4”	300#	RF	2’–6”
N5	OVHD.VAPOR OUT	1	10”	300#	RF	2’–8”
N6	P.S.V.	1	4”	300#	RF	1’–3”
N7	VENT	1	2”	300#	RF	1’–3”
C1&2	L.G.CONN.	2	3/4”	3000#	CPLG	
M1&2	MANWAY	2	18”	300#	RF	2’–10”

NOTES:

1. TAIL DIMENSIONS SHOWN ON THIS EQUIPMENT DRAWING DO NOT INCLUDE 1’–0” CONCRETE PEDESTAL. TAIL DIMENSIONS ARE FROM BOTTOM OF BASE PLATE.
2. 2” THICK BASE PLATE. 4’–11” O.D.
3. USE ASTM A–516 Gr. 60 BOILER PLATE.



NOZZLE ORIENTATION



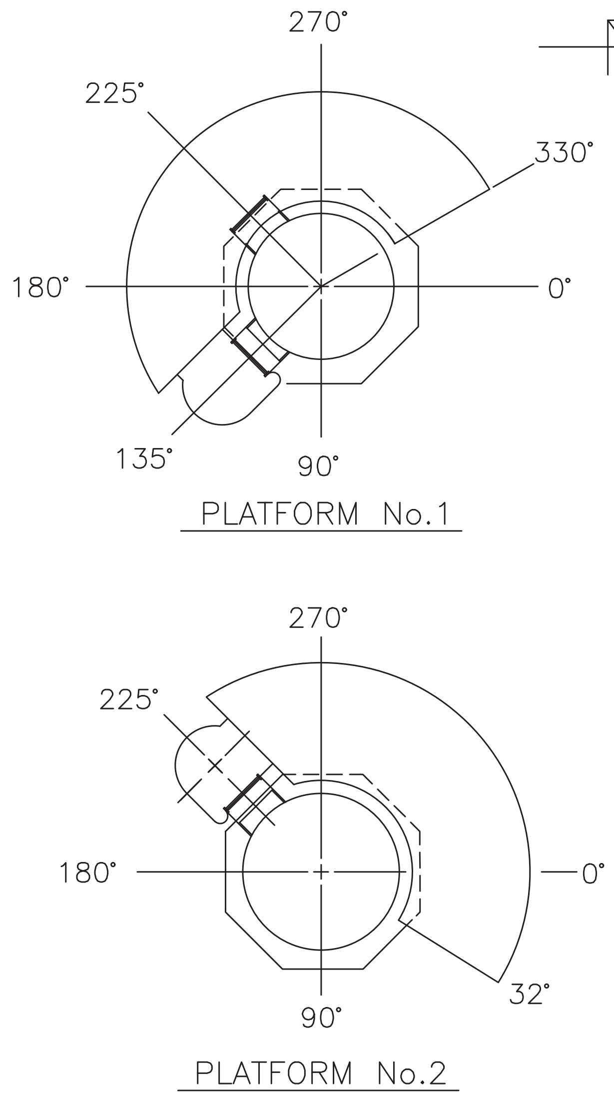
Note: NOT TO SCALE

1 of 2

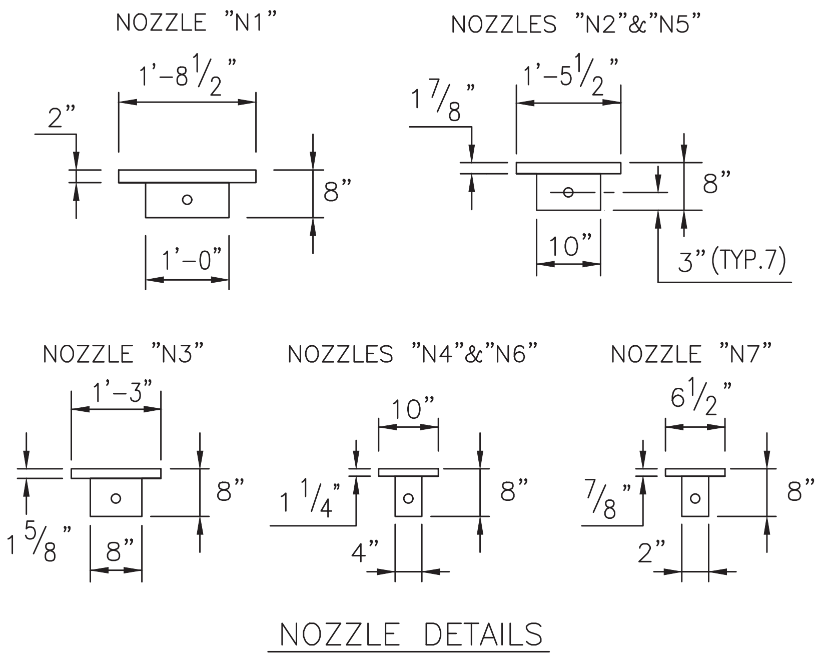
UNIT 04: V–401

COLUMN

FIGURE 15.29 Unit-04: Column 04-V-401 Sheet 1 of 2.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
N1	BOTTOM OUT	1	12"	300#	RF	2'-8"
N2	REBOILER RETURN	1	10"	300#	RF	2'-8"
N3	FEED INLET	1	8"	300#	RF	2'-8"
N4	REFLUX	1	4"	300#	RF	2'-6"
N5	OVHD.VAPOR OUT	1	10"	300#	RF	2'-8"
N6	P.S.V.	1	4"	300#	RF	1'-3"
N7	VENT	1	2"	300#	RF	1'-3"
C1&2	L.G.CONN.	2	3/4"	3000#	CPLG	
M1&2	MANWAY	2	18"	300#	RF	2'-10"



Note: NOT TO SCALE

COLUMN UNIT 04: V-401 2 of 2

FIGURE 15.30 Unit-04: Column 04-V-401 Sheet 2 of 2.

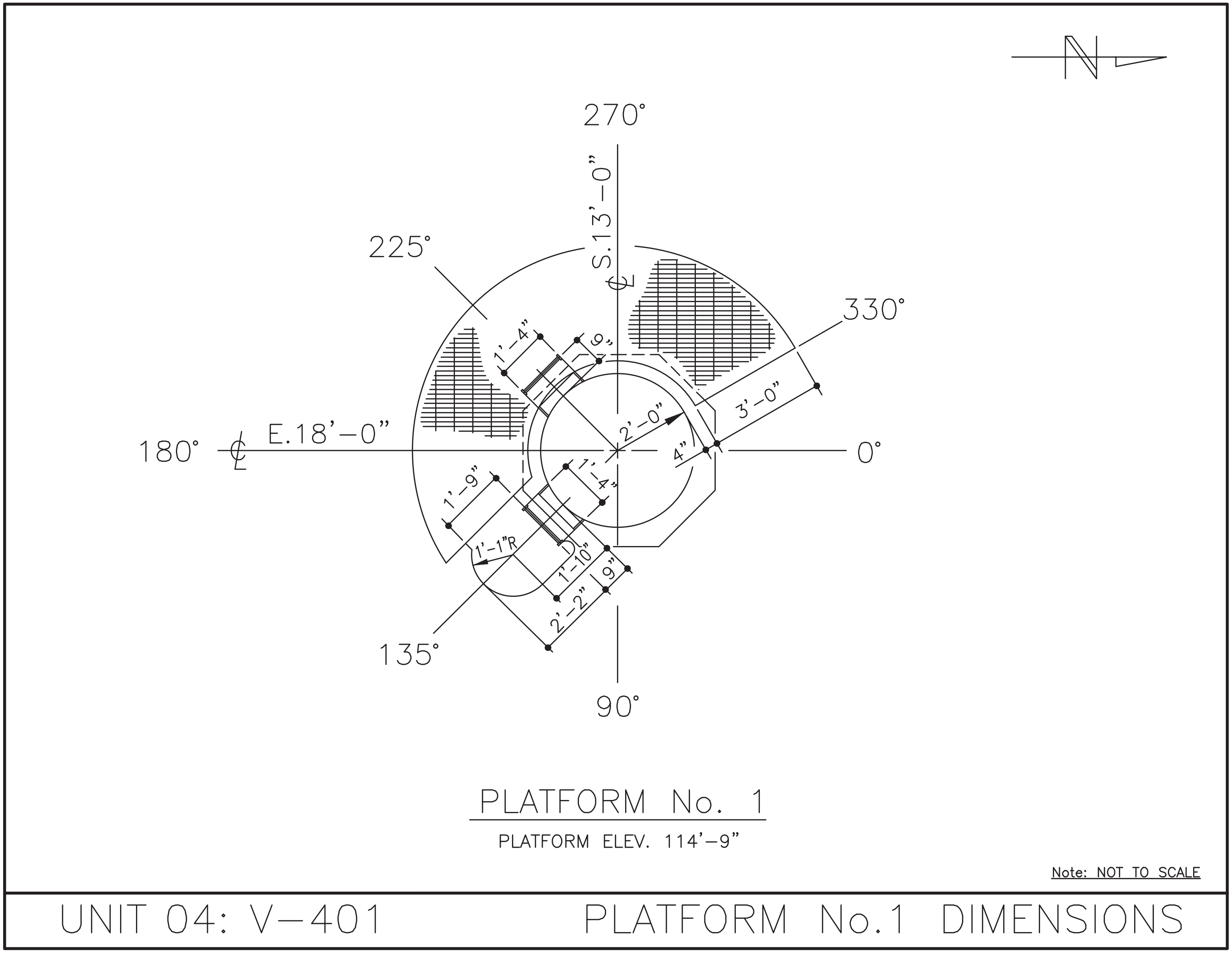


FIGURE 15.31 Unit-04: Column 04-V-401 Platform No. 1 Dimensions.

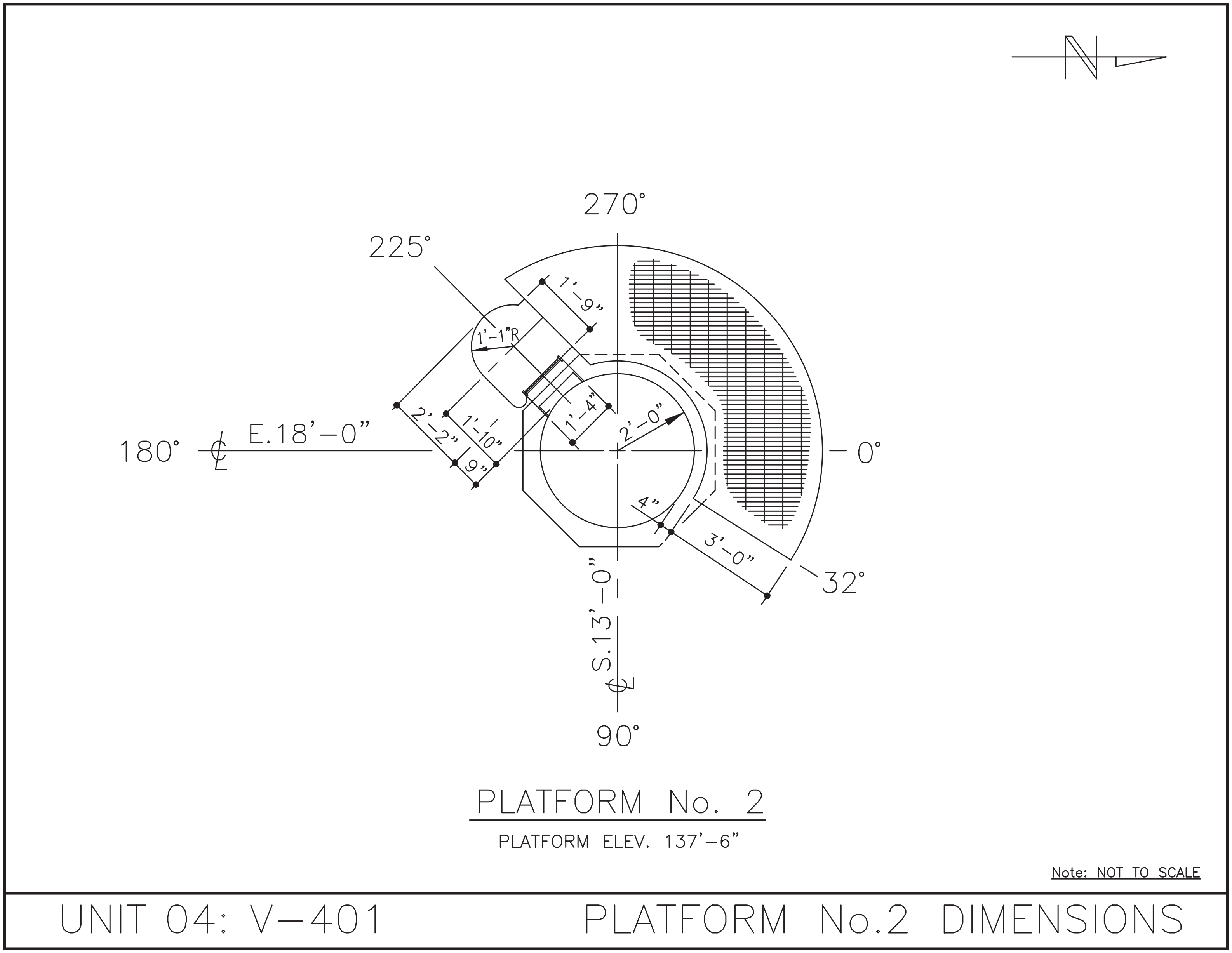
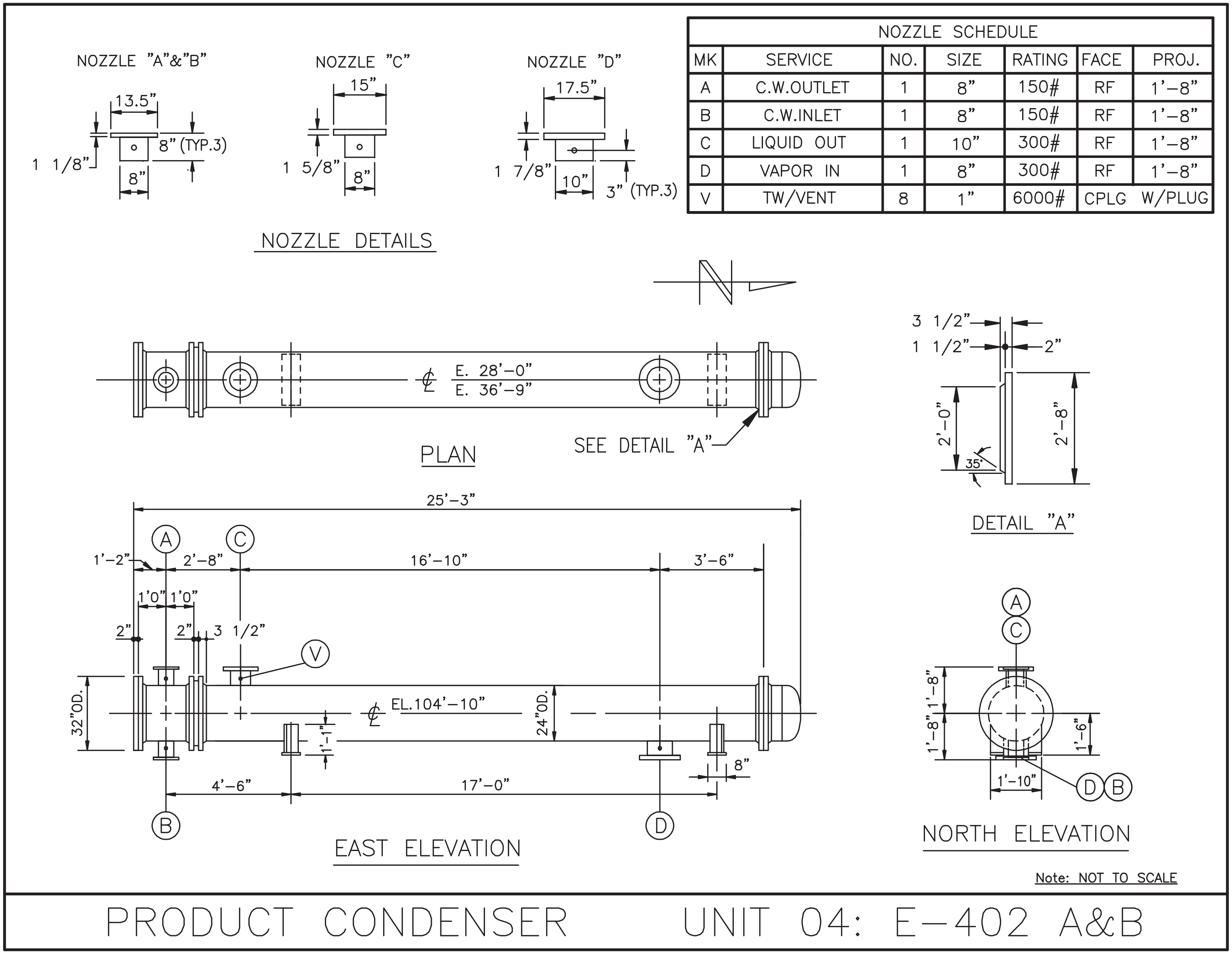


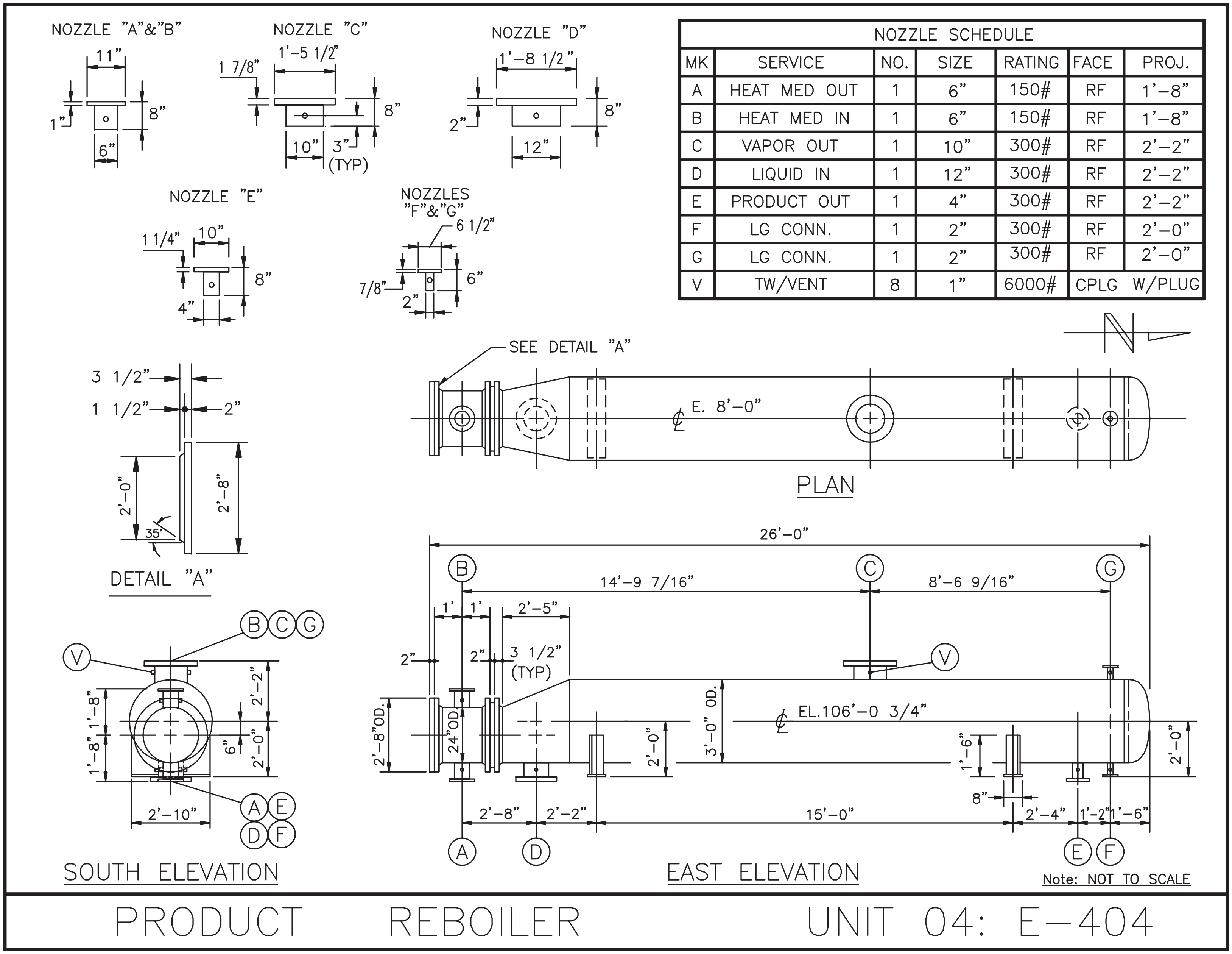
FIGURE 15.32 Unit-04: Column 04-V-401 Platform No. 2 Dimensions.



NOZZLE SCHEDULE

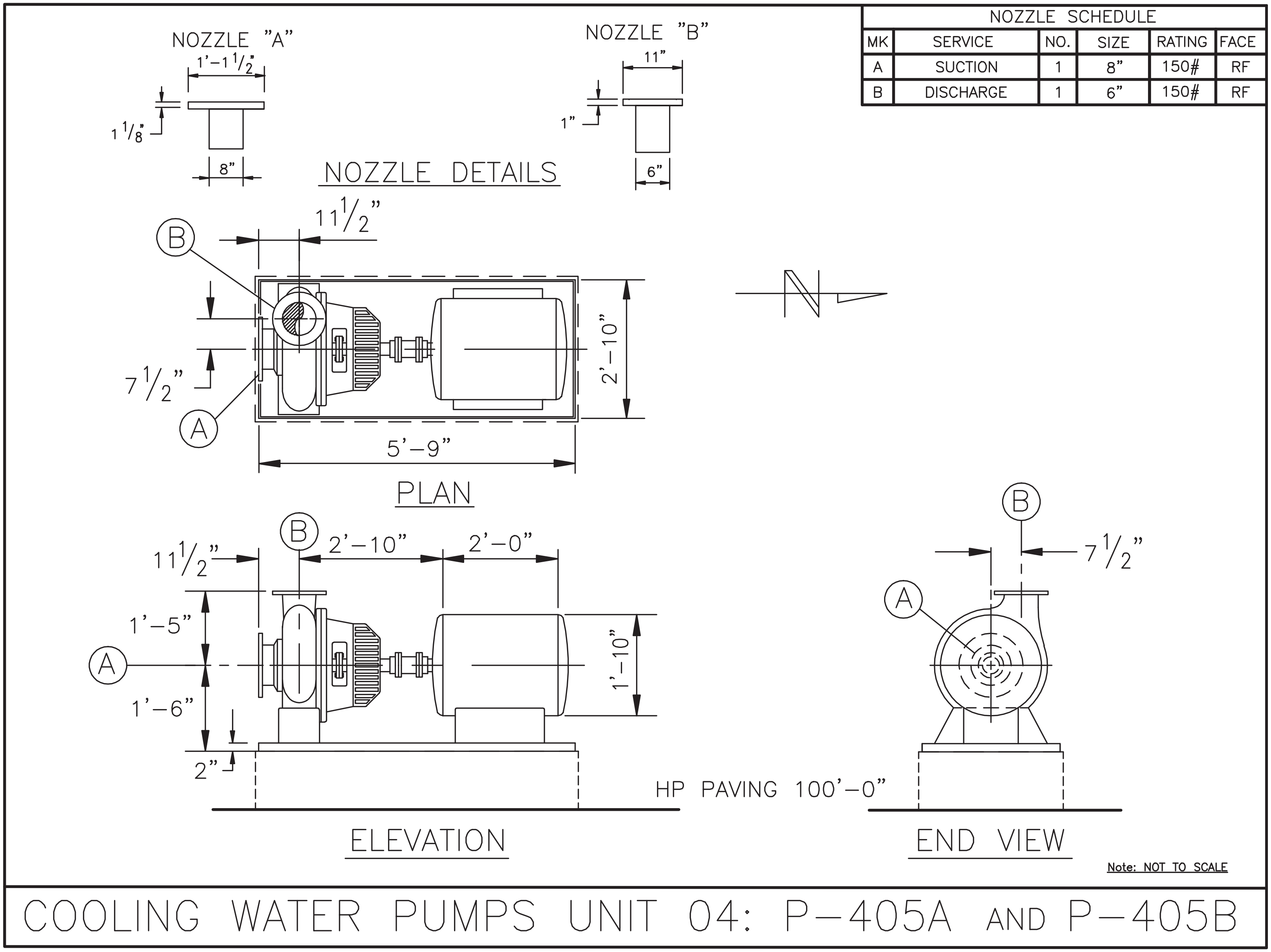
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
A	C.W.OUTLET	1	8"	150#	RF	1'–8"
B	C.W.INLET	1	8"	150#	RF	1'–8"
C	LIQUID OUT	1	10"	300#	RF	1'–8"
D	VAPOR IN	1	8"	300#	RF	1'–8"
V	TW/VENT	8	1"	6000#	CPLG W/PLUG	

FIGURE 15.33 Unit-04: Product Condenser 04-E-402 A and B.



NOZZLE SCHEDULE						
MK	SERVICE	NO.	SIZE	RATING	FACE	PROJ.
A	HEAT MED OUT	1	6"	150#	RF	1'-8"
B	HEAT MED IN	1	6"	150#	RF	1'-8"
C	VAPOR OUT	1	10"	300#	RF	2'-2"
D	LIQUID IN	1	12"	300#	RF	2'-2"
E	PRODUCT OUT	1	4"	300#	RF	2'-2"
F	LG CONN.	1	2"	300#	RF	2'-0"
G	LG CONN.	1	2"	300#	RF	2'-0"
V	TW/VENT	8	1"	6000#	CPLG W/PLUG	

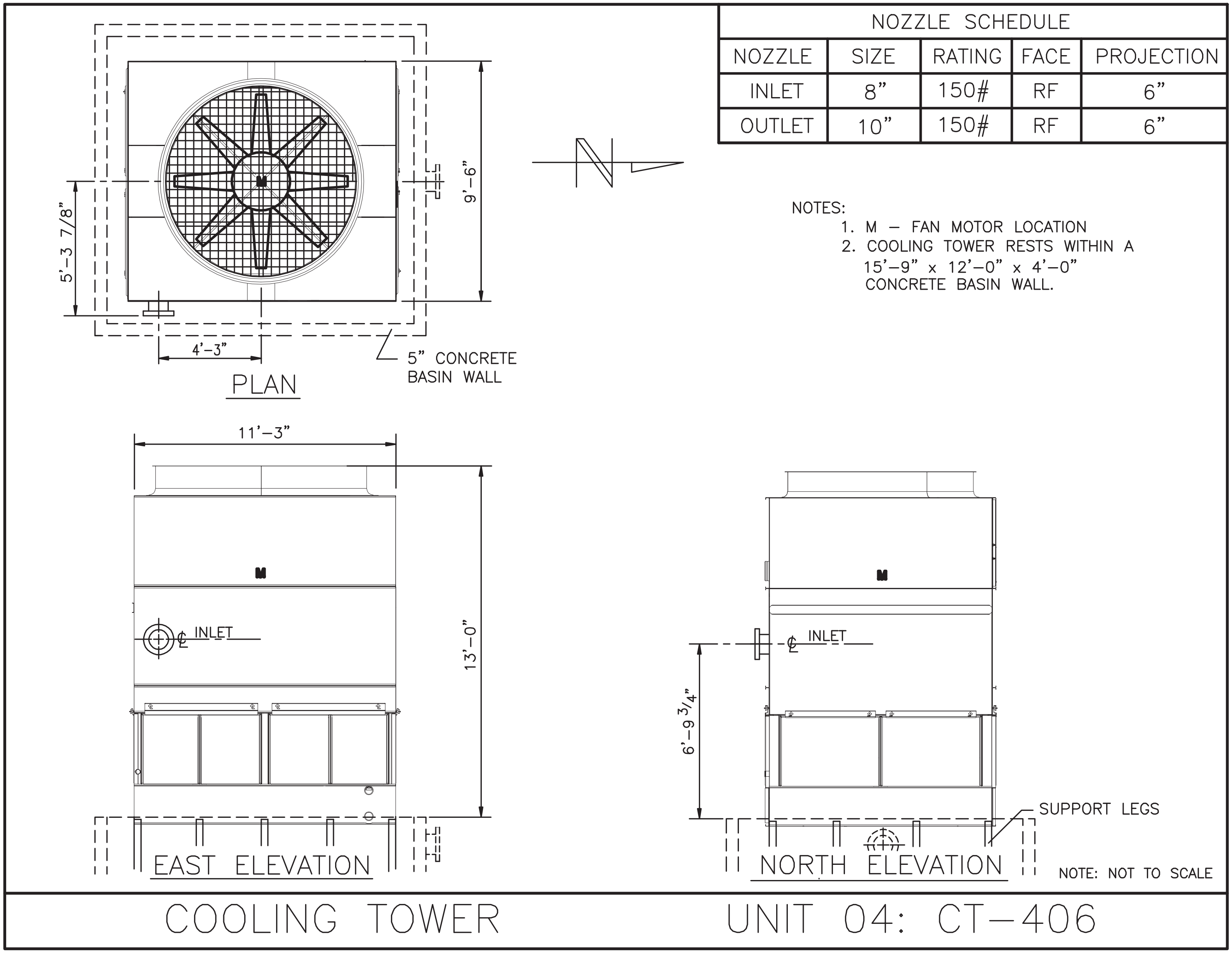
FIGURE 15.34 Unit-04: Product Reboiler 04-E-404.



NOZZLE SCHEDULE

MK	SERVICE	NO.	SIZE	RATING	FACE
A	SUCTION	1	8"	150#	RF
B	DISCHARGE	1	6"	150#	RF

FIGURE 15.35 Unit-04: Cooling Water Pumps 04-P-405A and P-405B.



NOZZLE	SIZE	RATING	FACE	PROJECTION
INLET	8"	150#	RF	6"
OUTLET	10"	150#	RF	6"

FIGURE 15.36 Unit-04: Cooling Tower 04-CT-406.

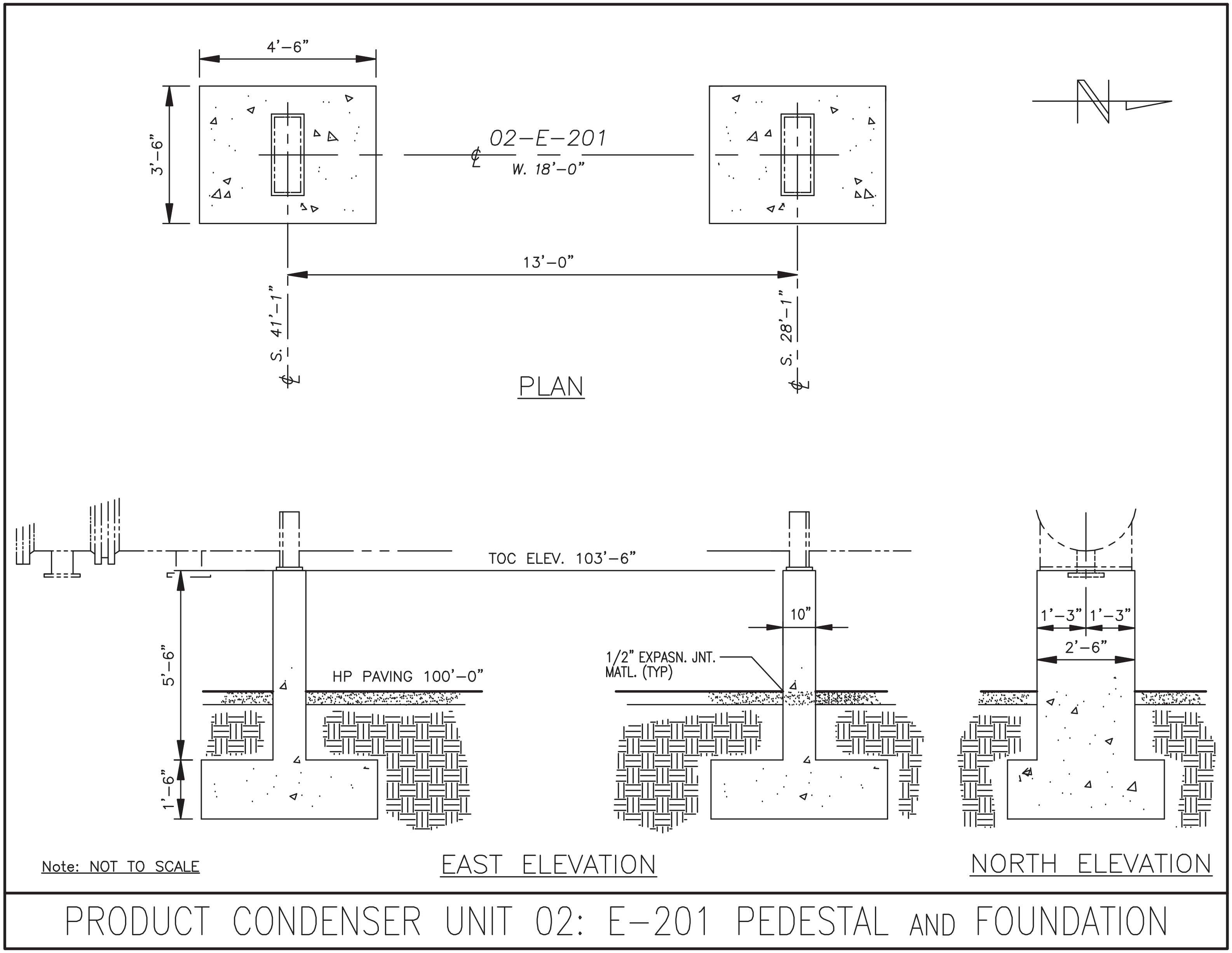


FIGURE 15.37 Unit-02: 02-E-201. Product Condenser Pedestal and Foundation.

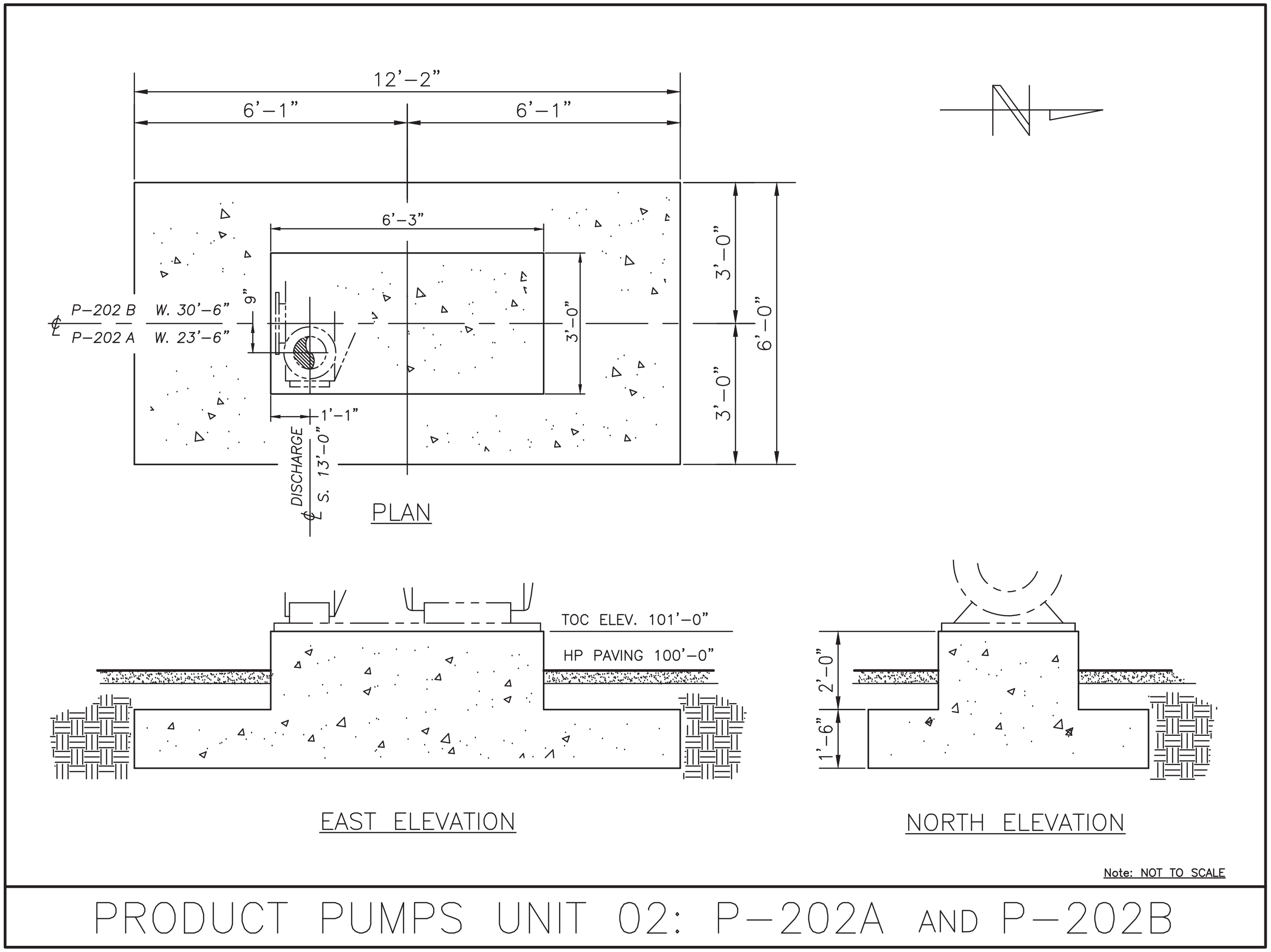


FIGURE 15.38 Unit-02: 02-P-202A and P-202B Product Pump Foundations.

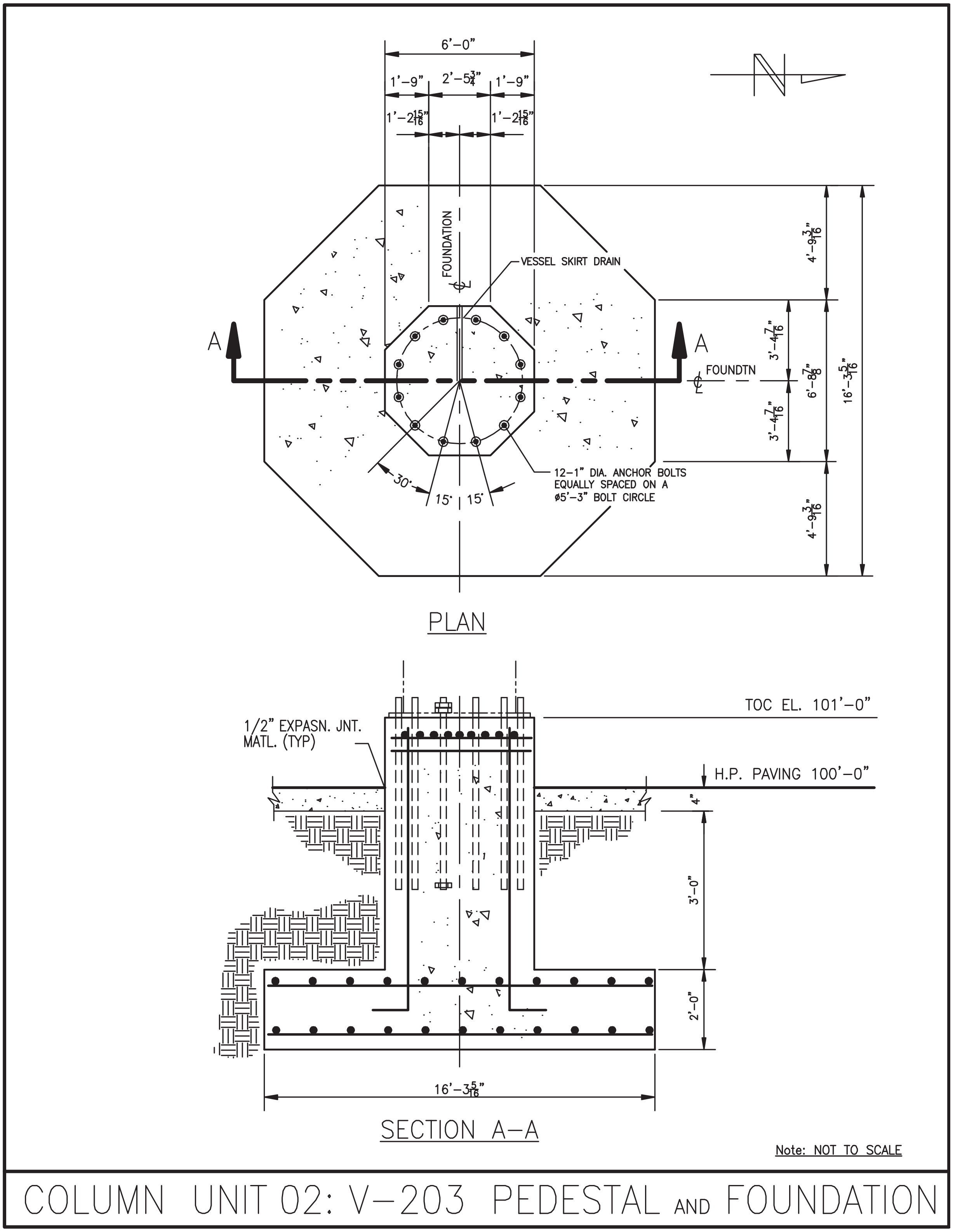


FIGURE 15.39 Unit-02: 02-V-203 Column Pedestal and Foundation.

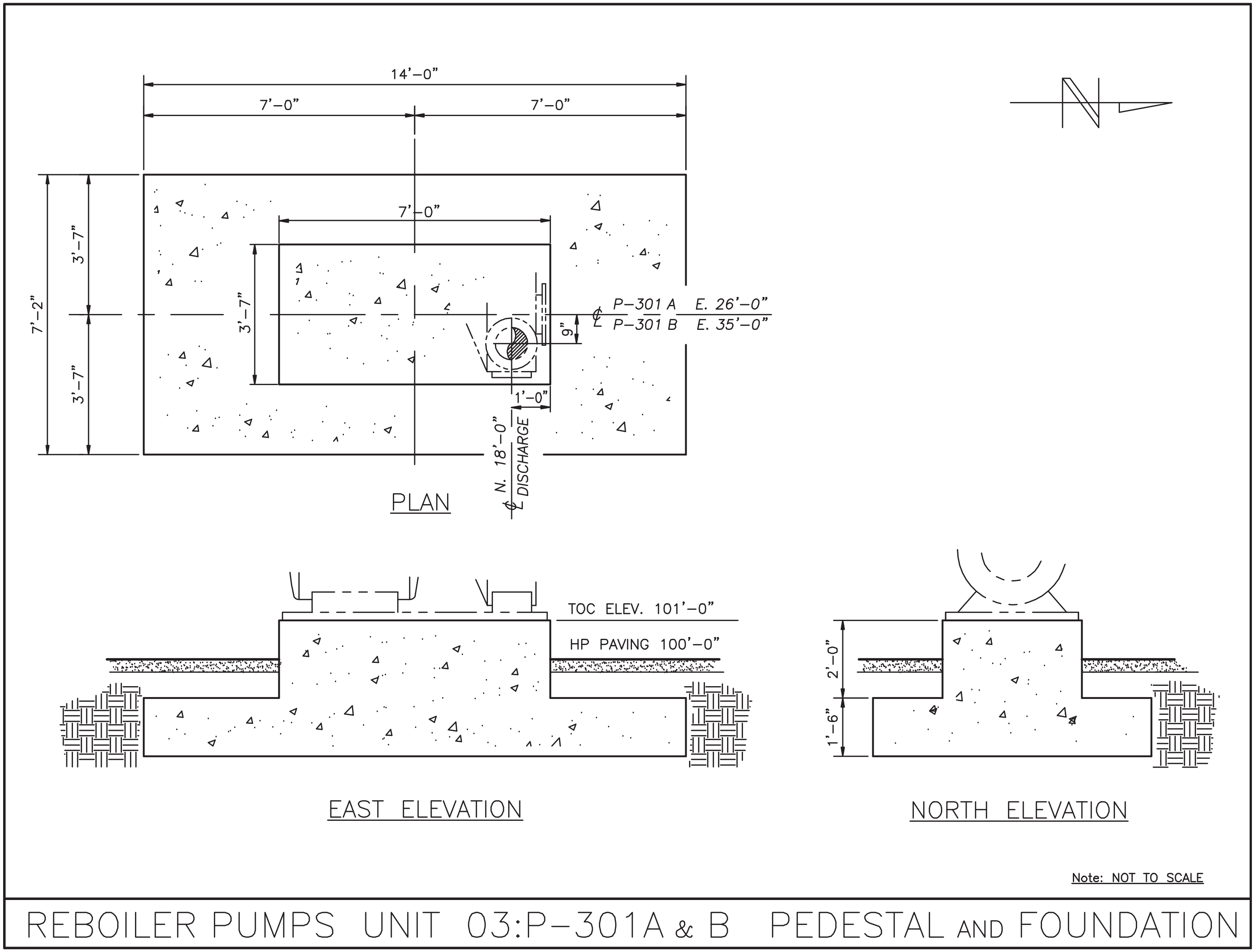


FIGURE 15.40 Unit-03: 03-P-301A and B Reboiler Pumps Pedestal and Foundation.

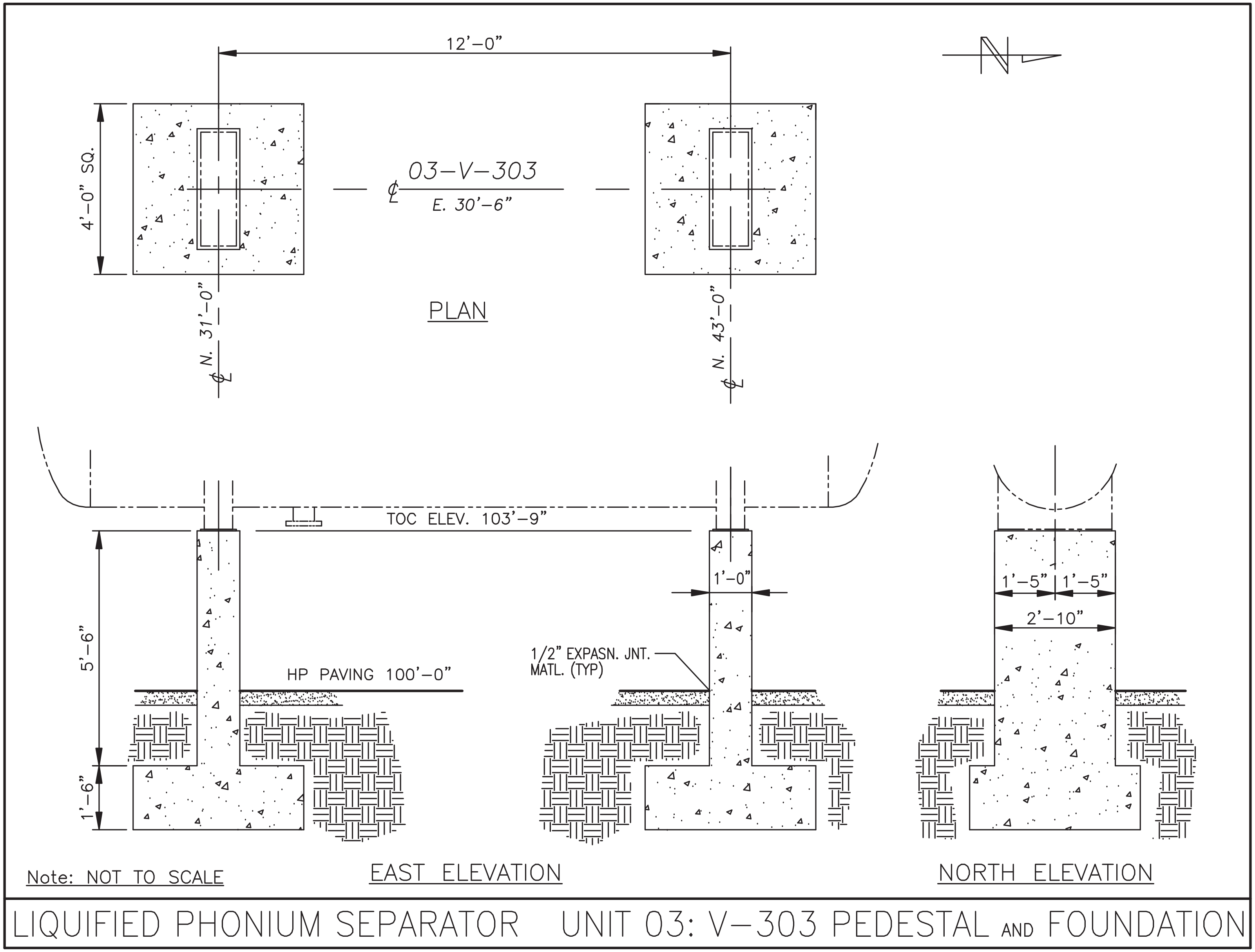


FIGURE 15.41 Unit-03: 03-V-303 Liquified Phonium Separator Pedestal and Foundation.

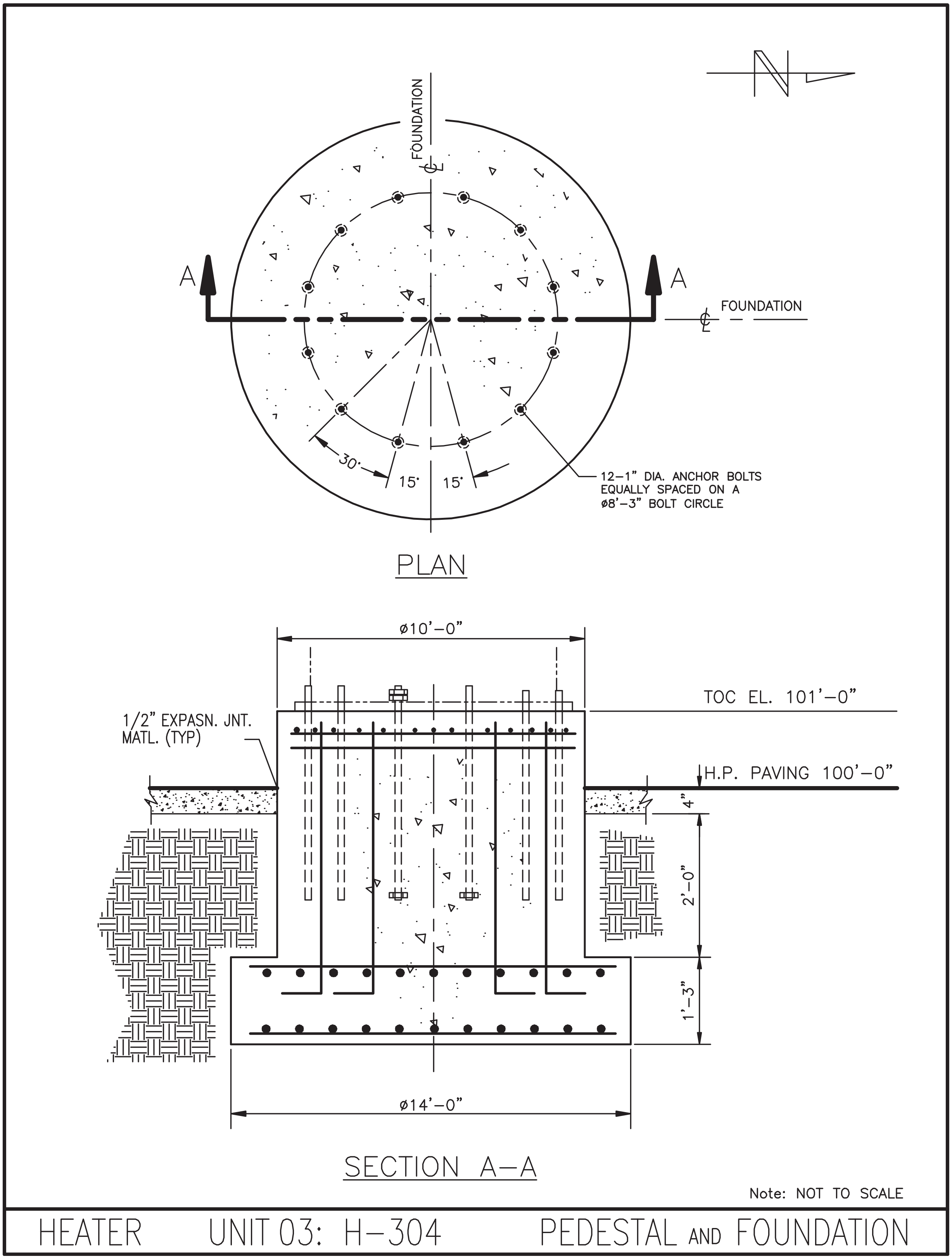


FIGURE 15.42 Unit-03: 03-H-304 Heater Pedestal and Foundation.

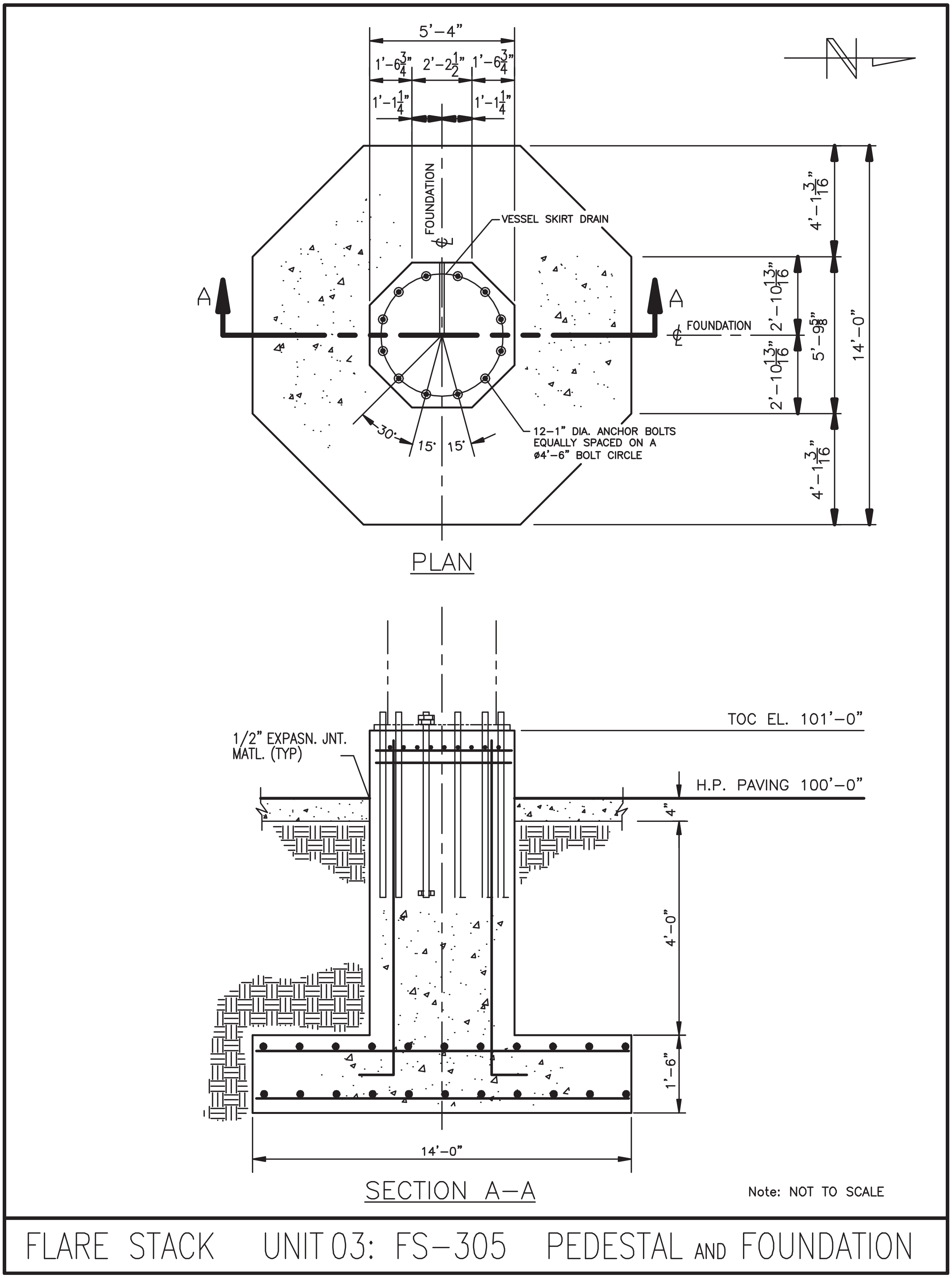


FIGURE 15.43 Unit-03: 03-FS-305 Flare Stack Pedestal and Foundation.

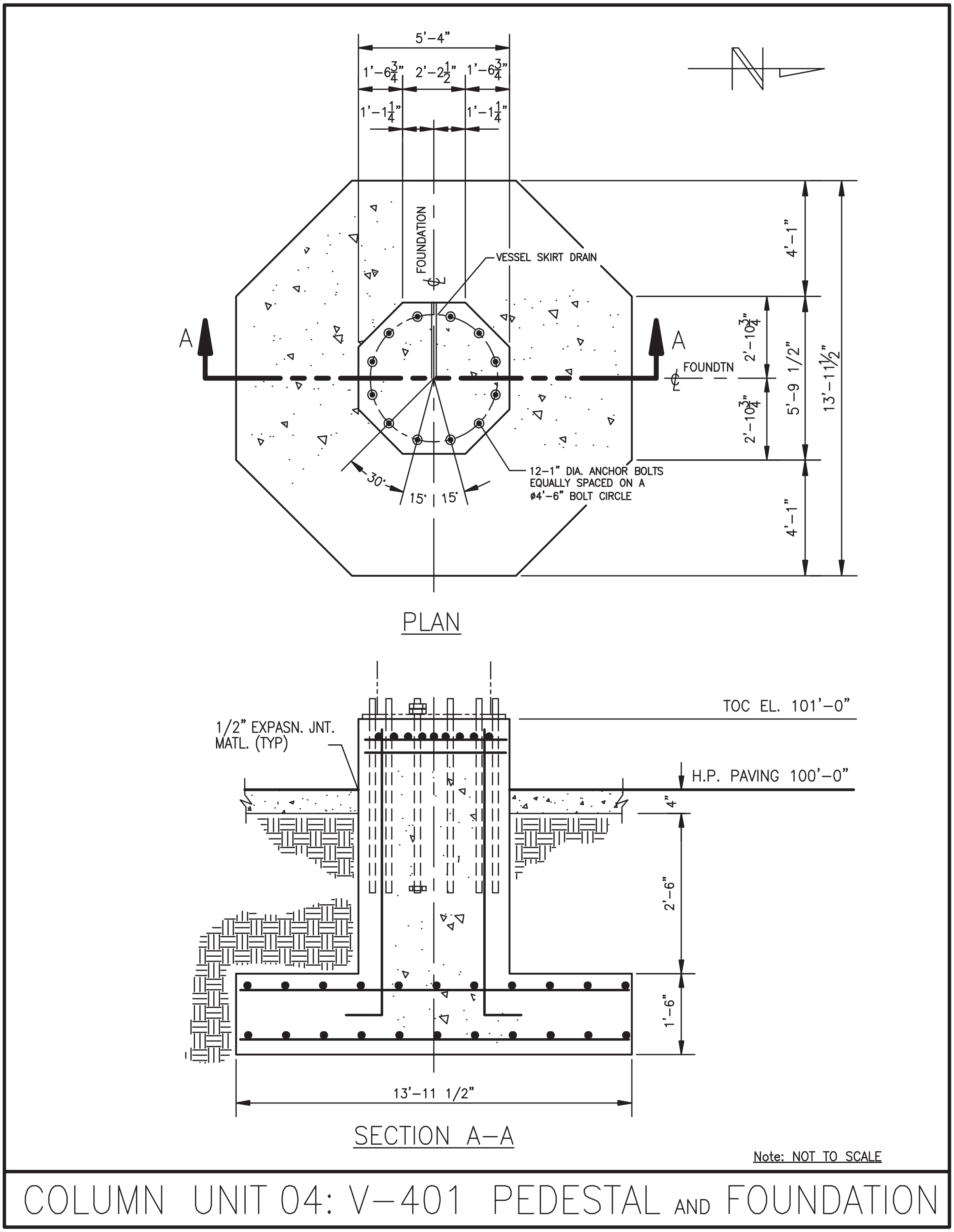


FIGURE 15.44 Unit-04: 04-V-401 Column Pedestal and Foundation.

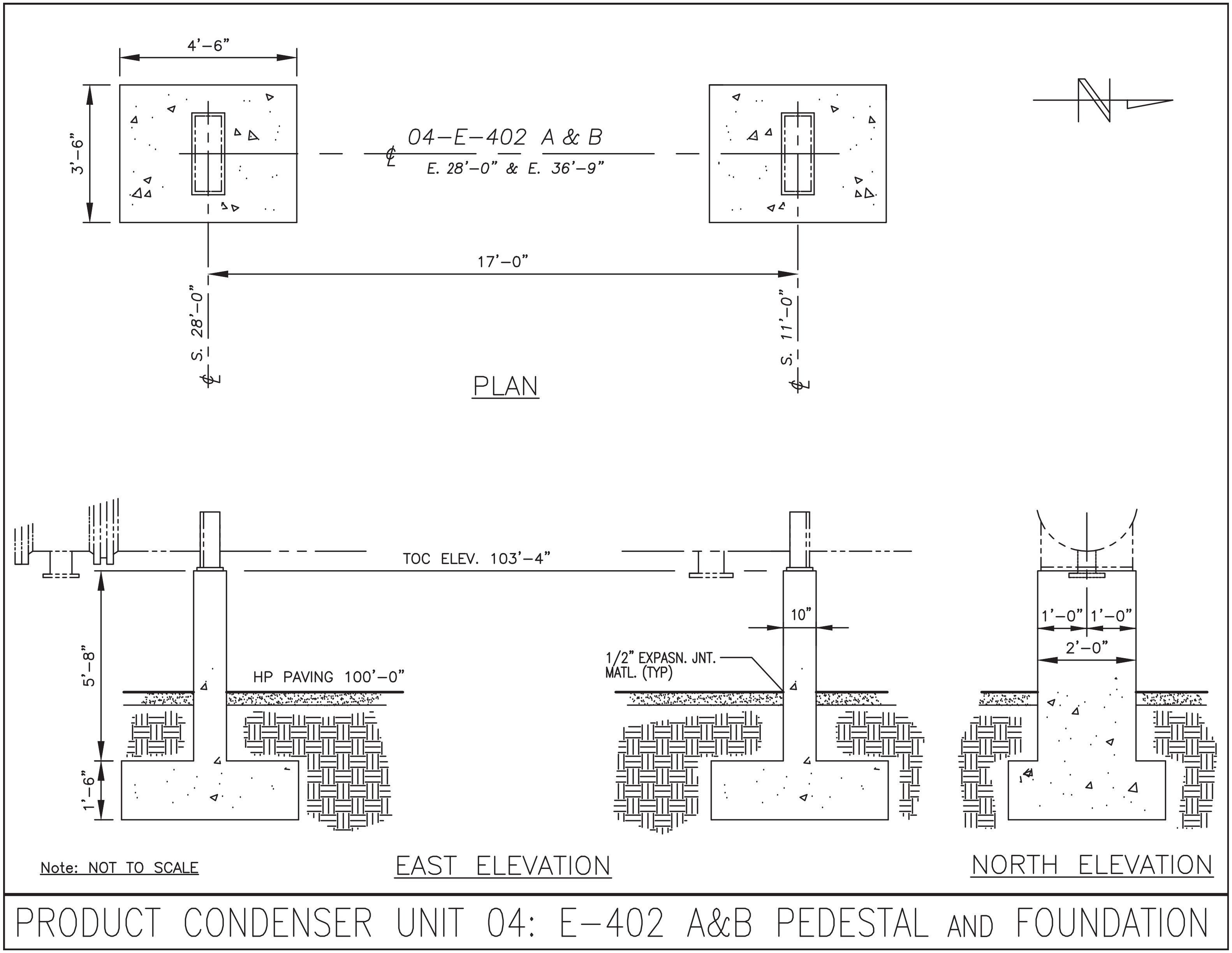


FIGURE 15.45 Unit-04: 04-E-402A and B. Product Condenser Pedestal and Foundation.

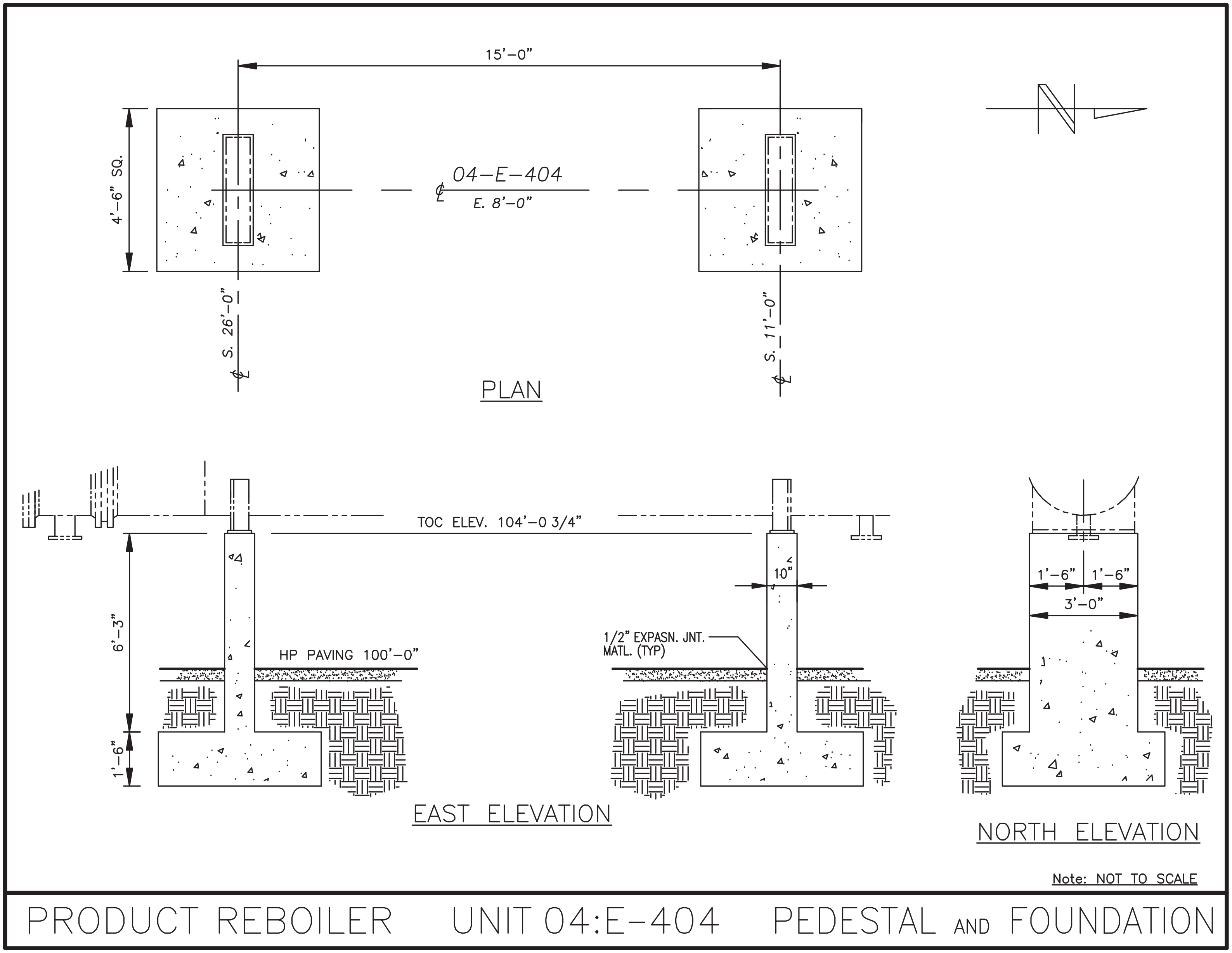


FIGURE 15.46 Unit-04: 04-E-404 Product Reboiler Pedestal and Foundation.

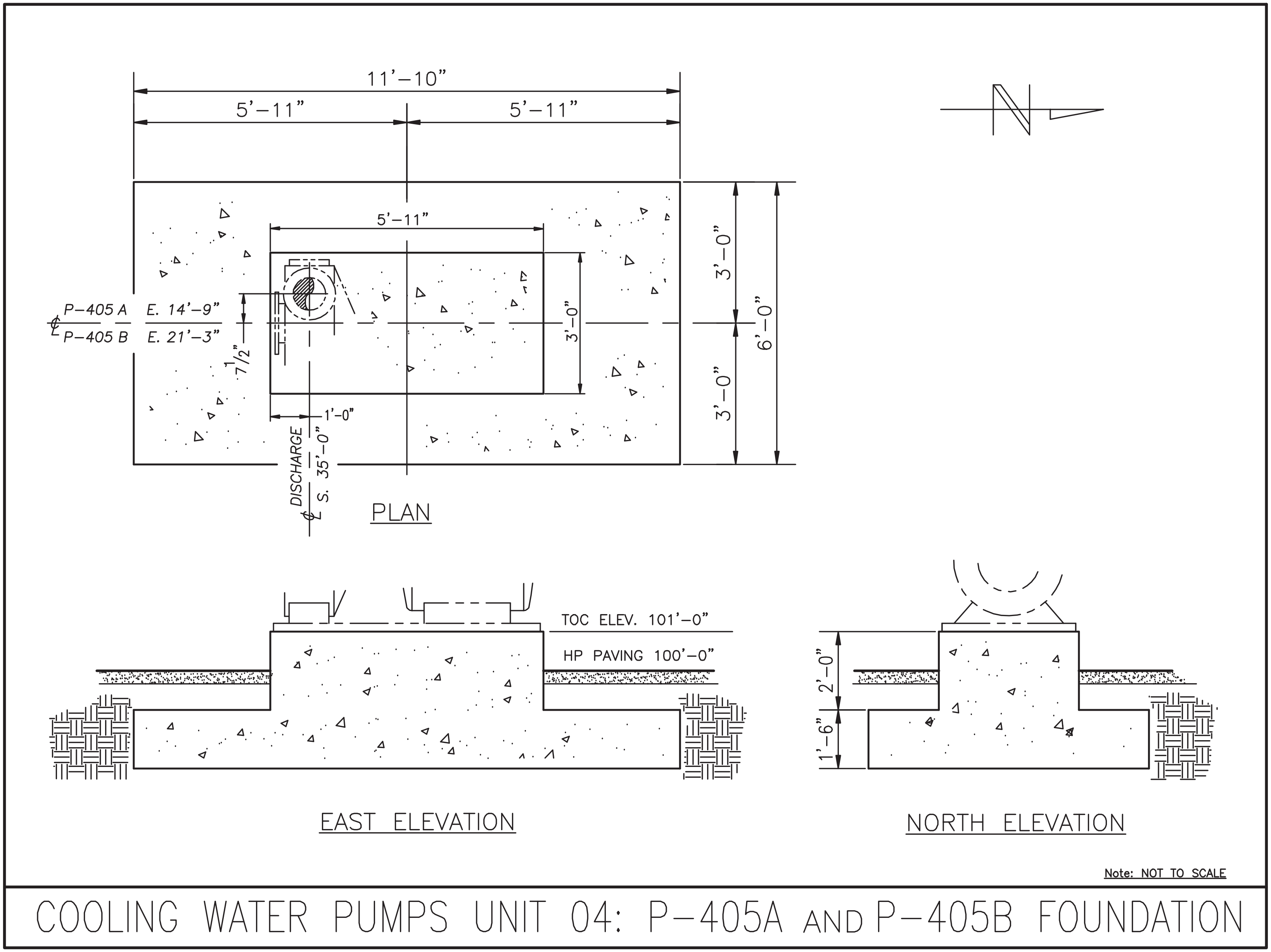


FIGURE 15.47 Unit-04: 04-P-405A and P-405B Cooling Water Pumps Foundation.

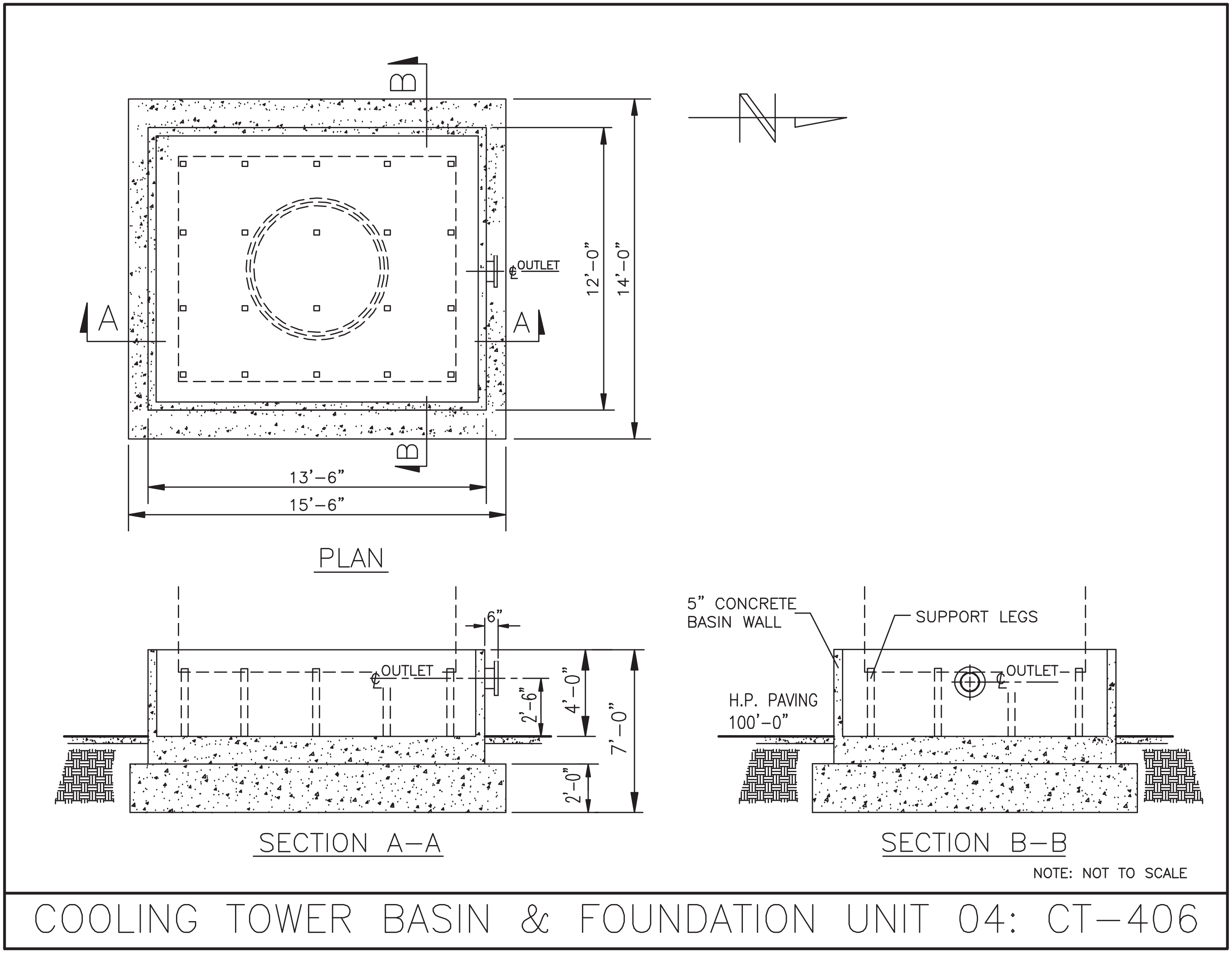


FIGURE 15.48 Unit-04: 04-CT-406 Cooling Tower Basin and Foundation.

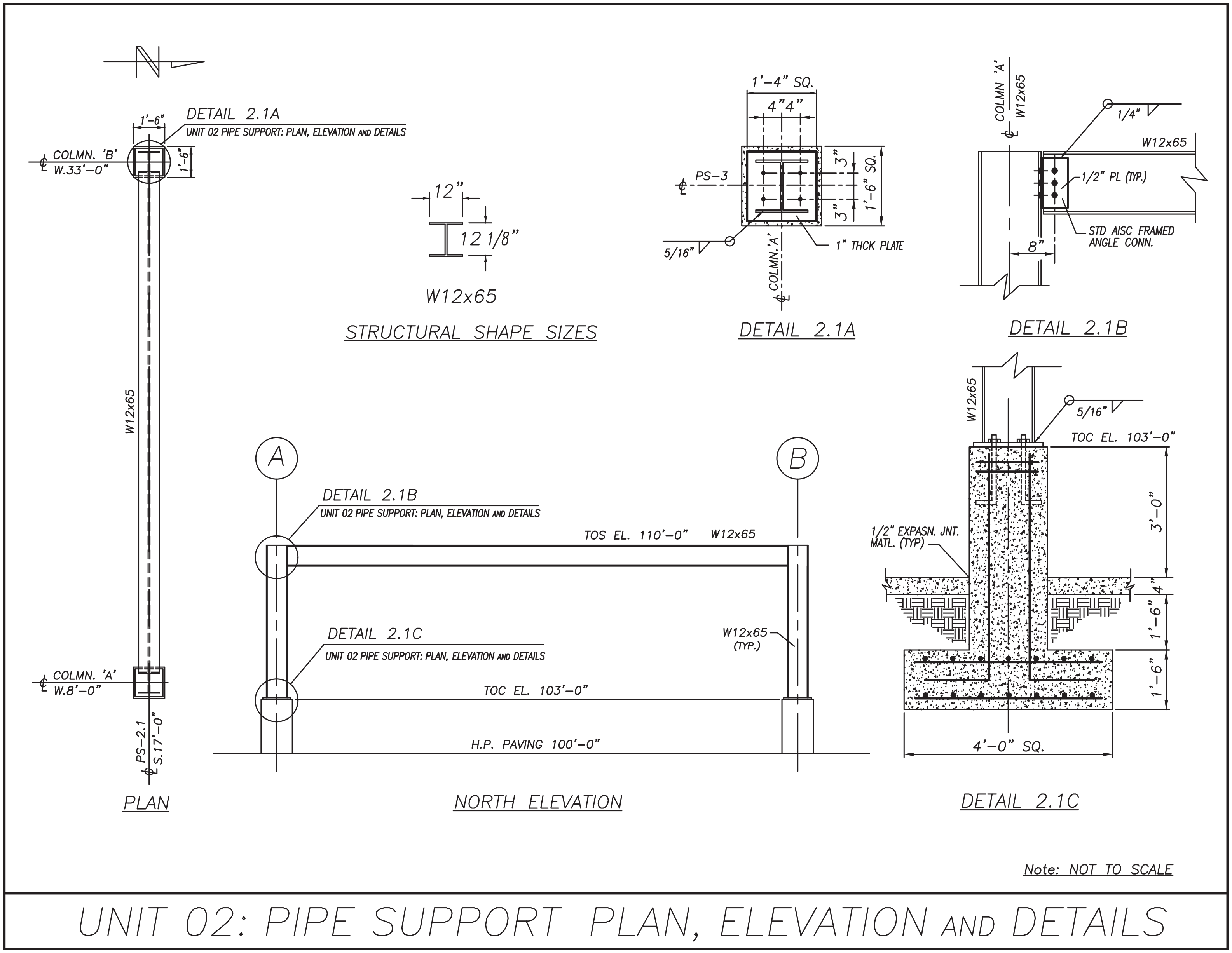


FIGURE 15.49 Unit-02: Pipe Support Plan, Elevations, and Details.

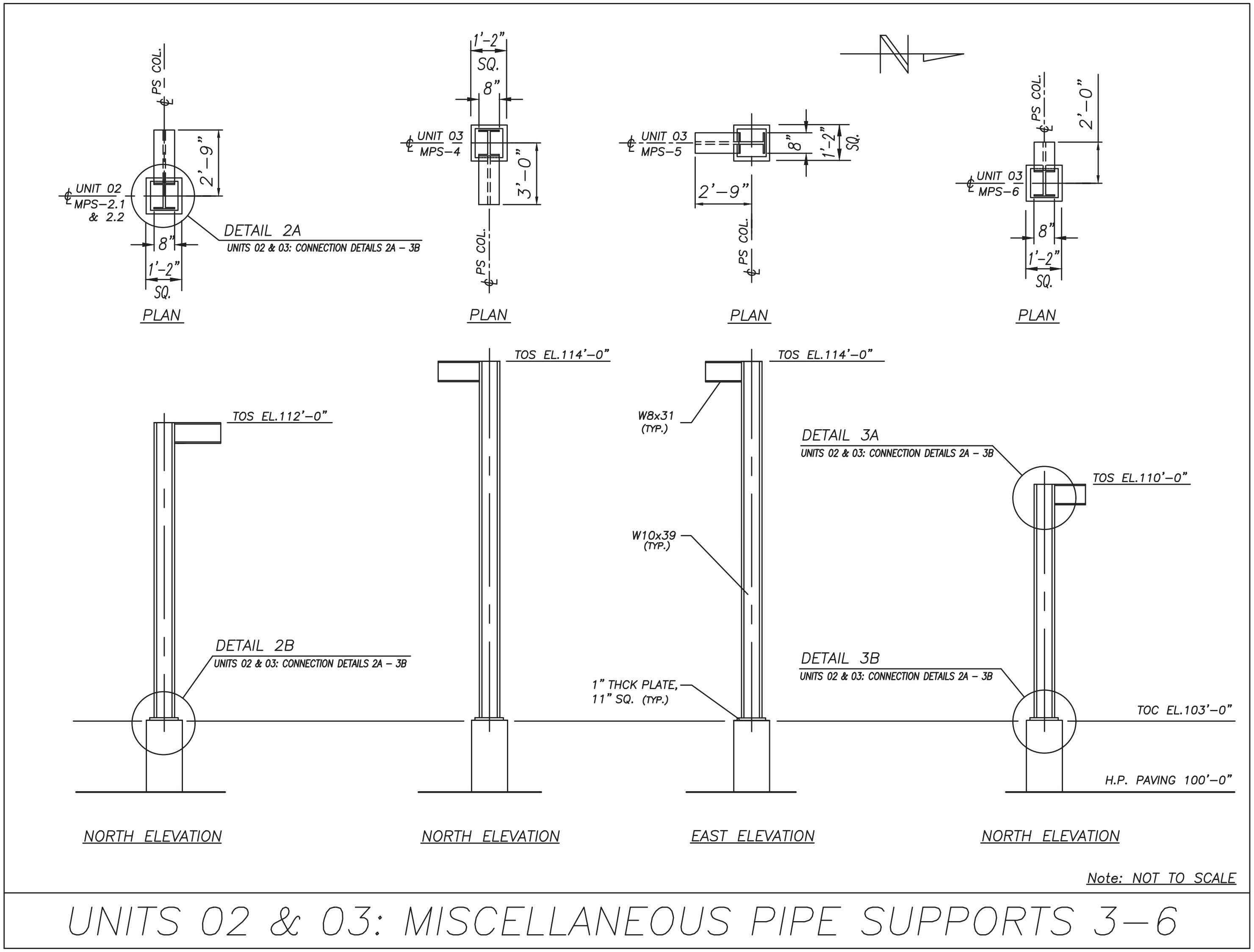


FIGURE 15.50 Units-02 and 03: Miscellaneous Pipe Supports 3–6.

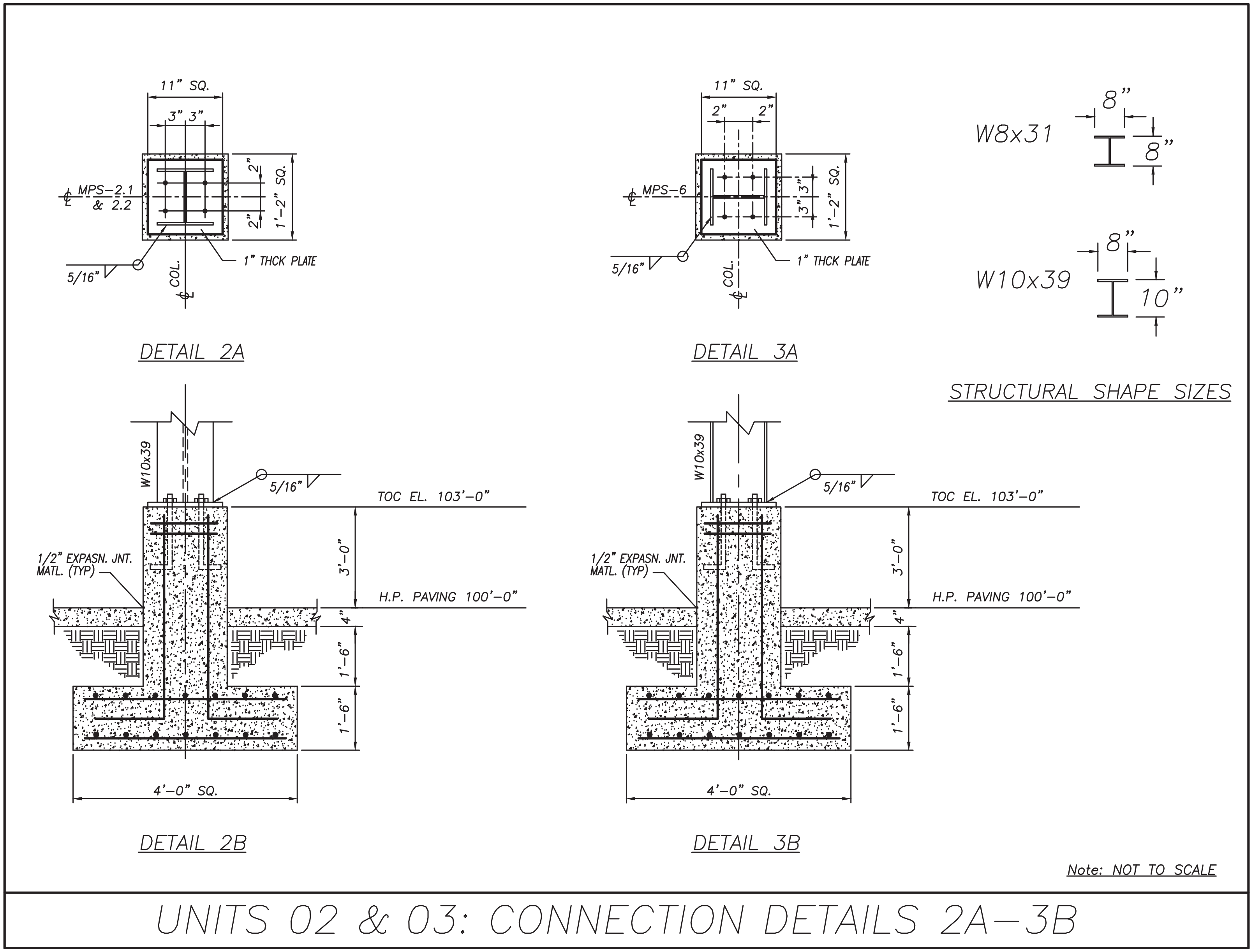


FIGURE 15.51 Units-02 and 03: Connection Details 2A–3B.

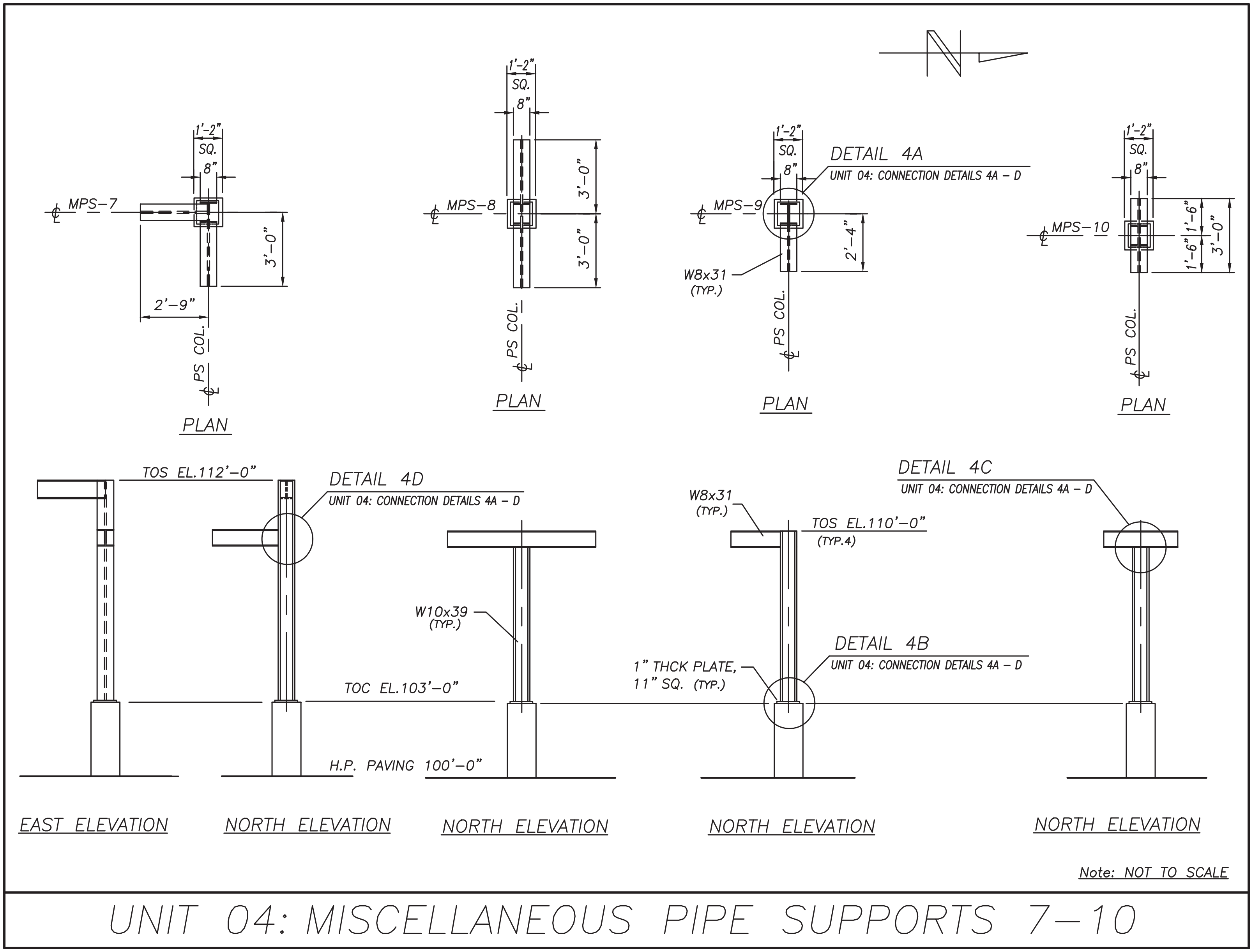


FIGURE 15.52 Unit-04: Miscellaneous Pipe Supports 7–10.

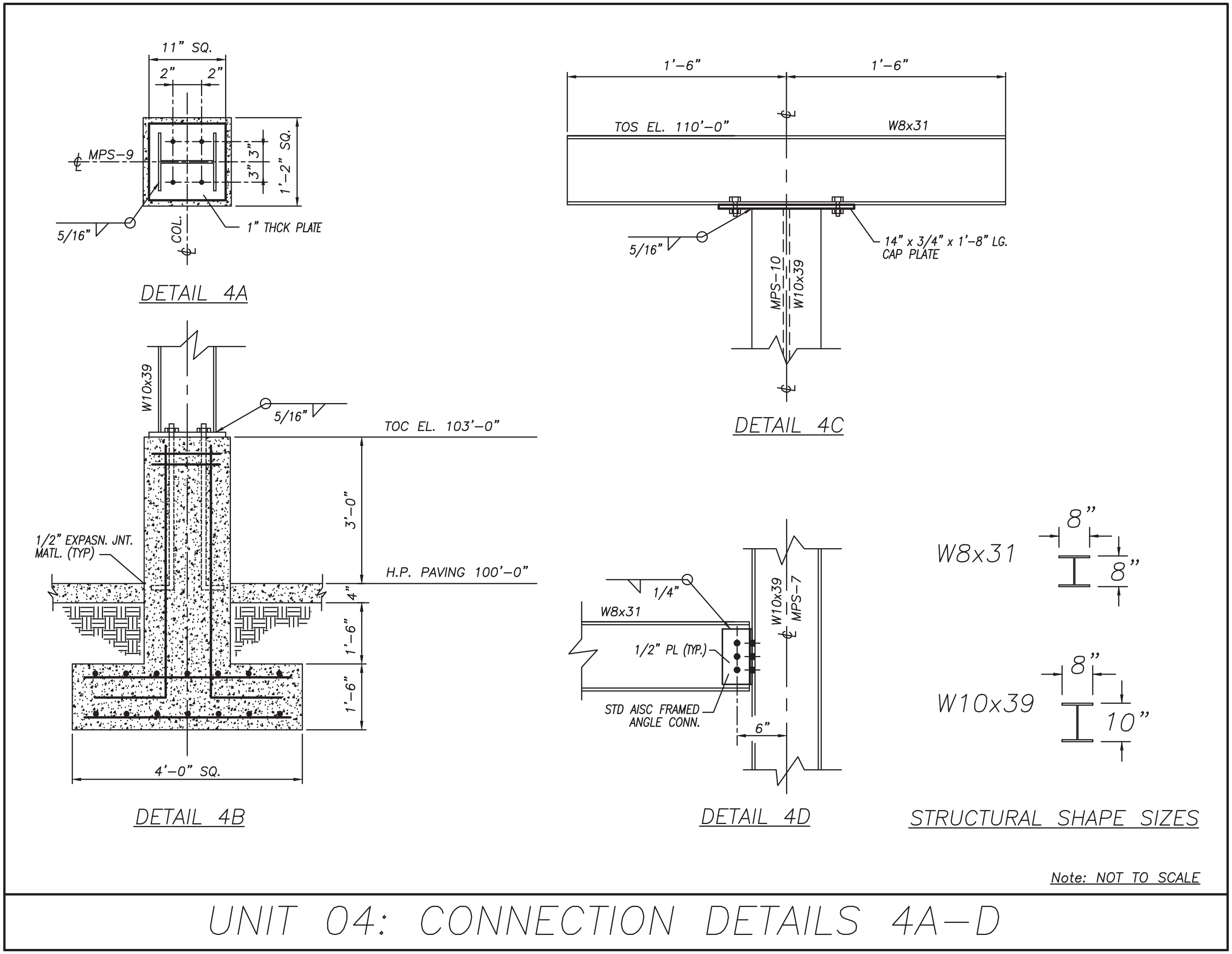


FIGURE 15.53 Unit-04: Connection Details 4A–D.

ELECTRICAL DRAWINGS: LIGHTING AND POWER SUPPLY AND GROUNDING PLAN

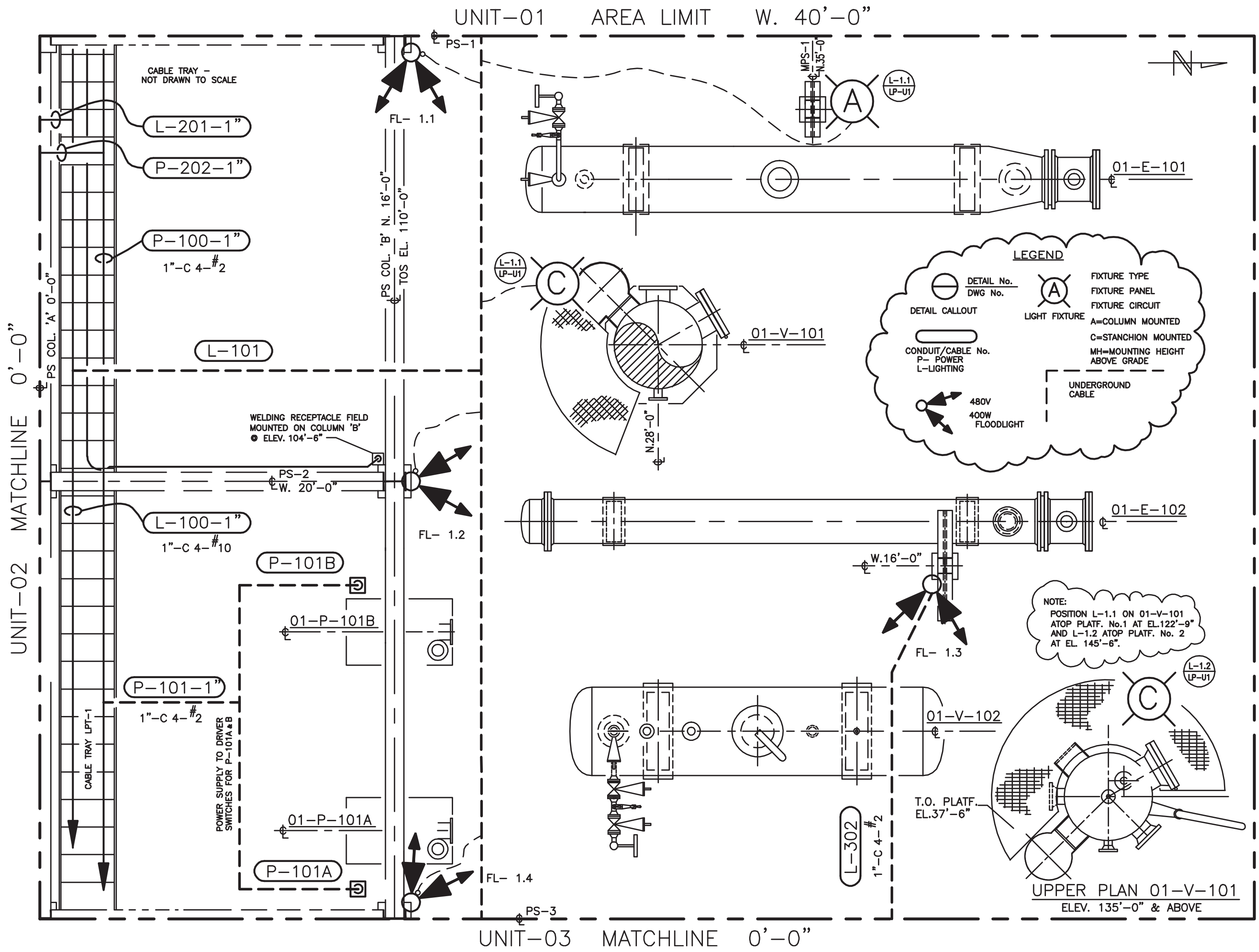


FIGURE 15.54 Unit-01: Electrical: Lighting and Power Supply.

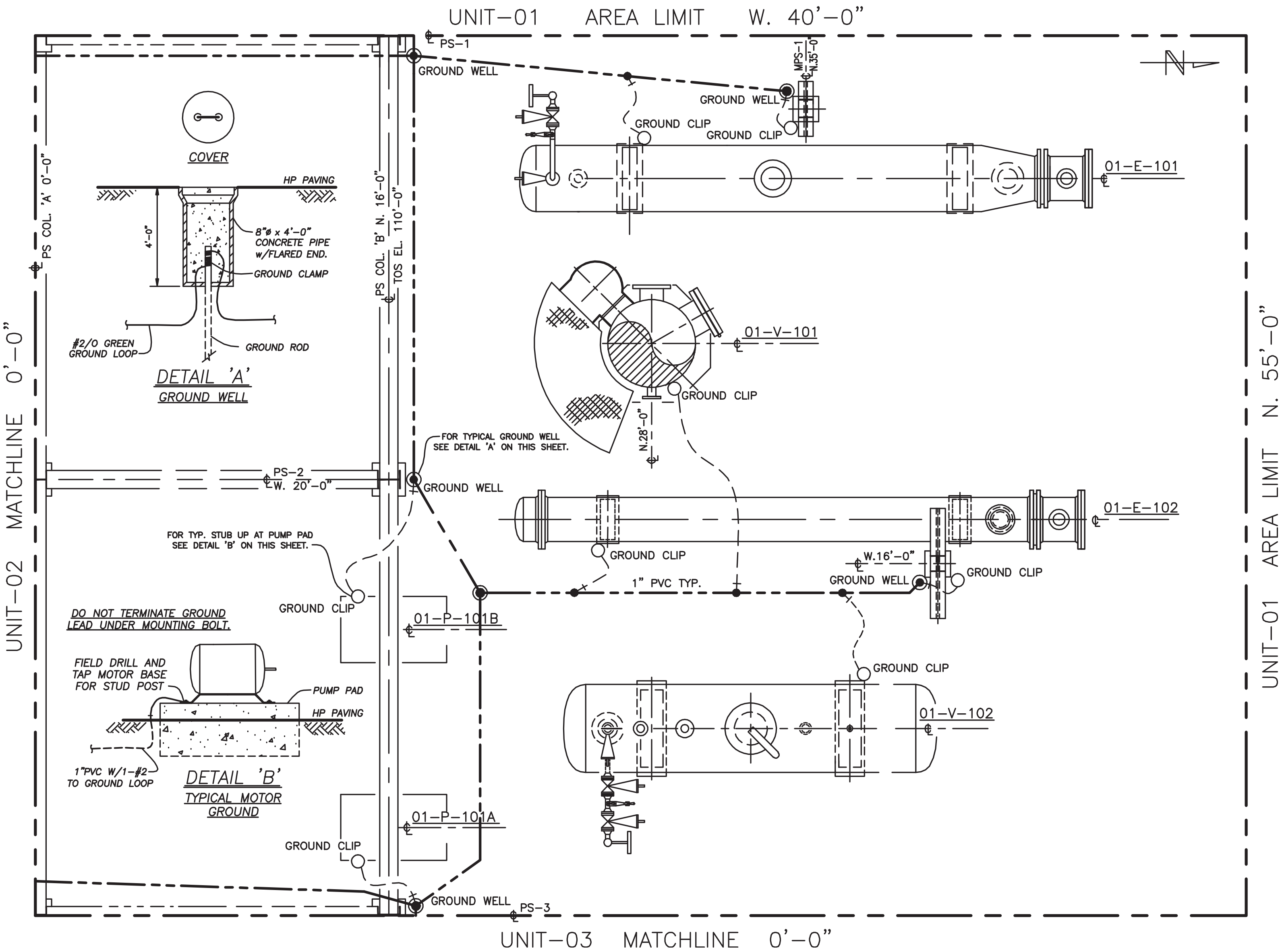


FIGURE 15.55 Unit-01: Electrical: Grounding Plan.

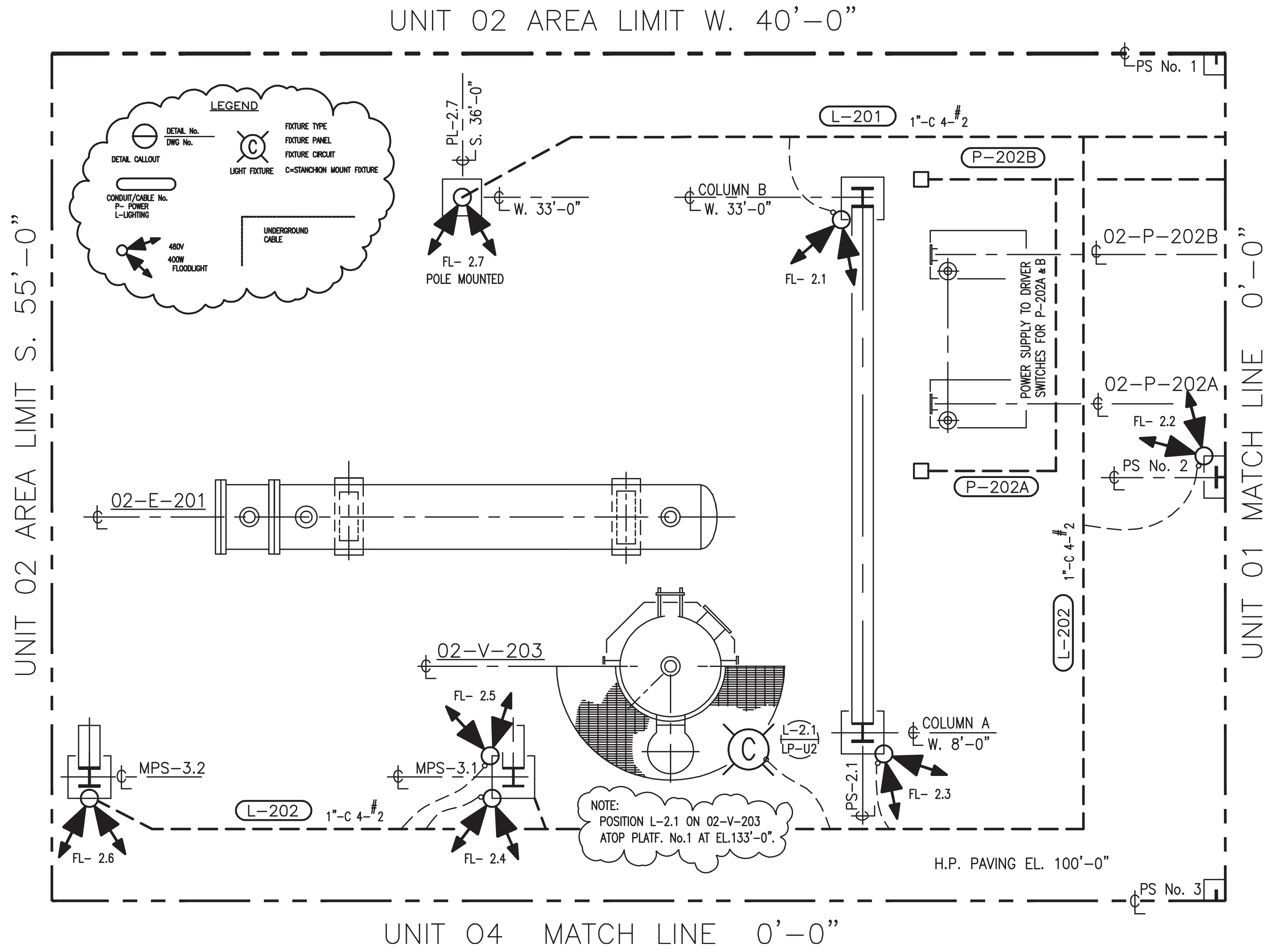


FIGURE 15.56 Unit-02: Electrical: Lighting and Power Supply.

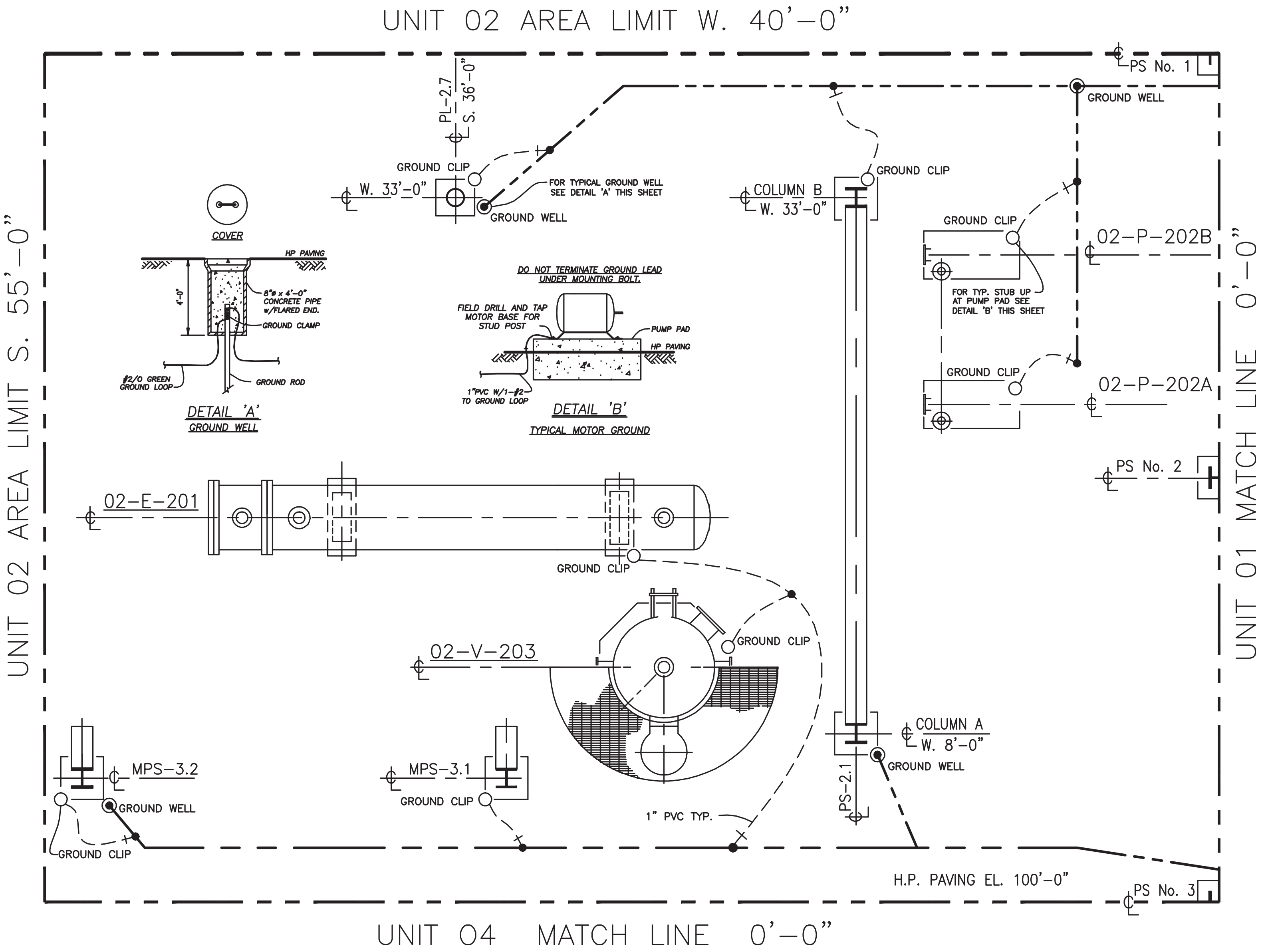


FIGURE 15.57 Unit-02: Electrical: Grounding Plan.

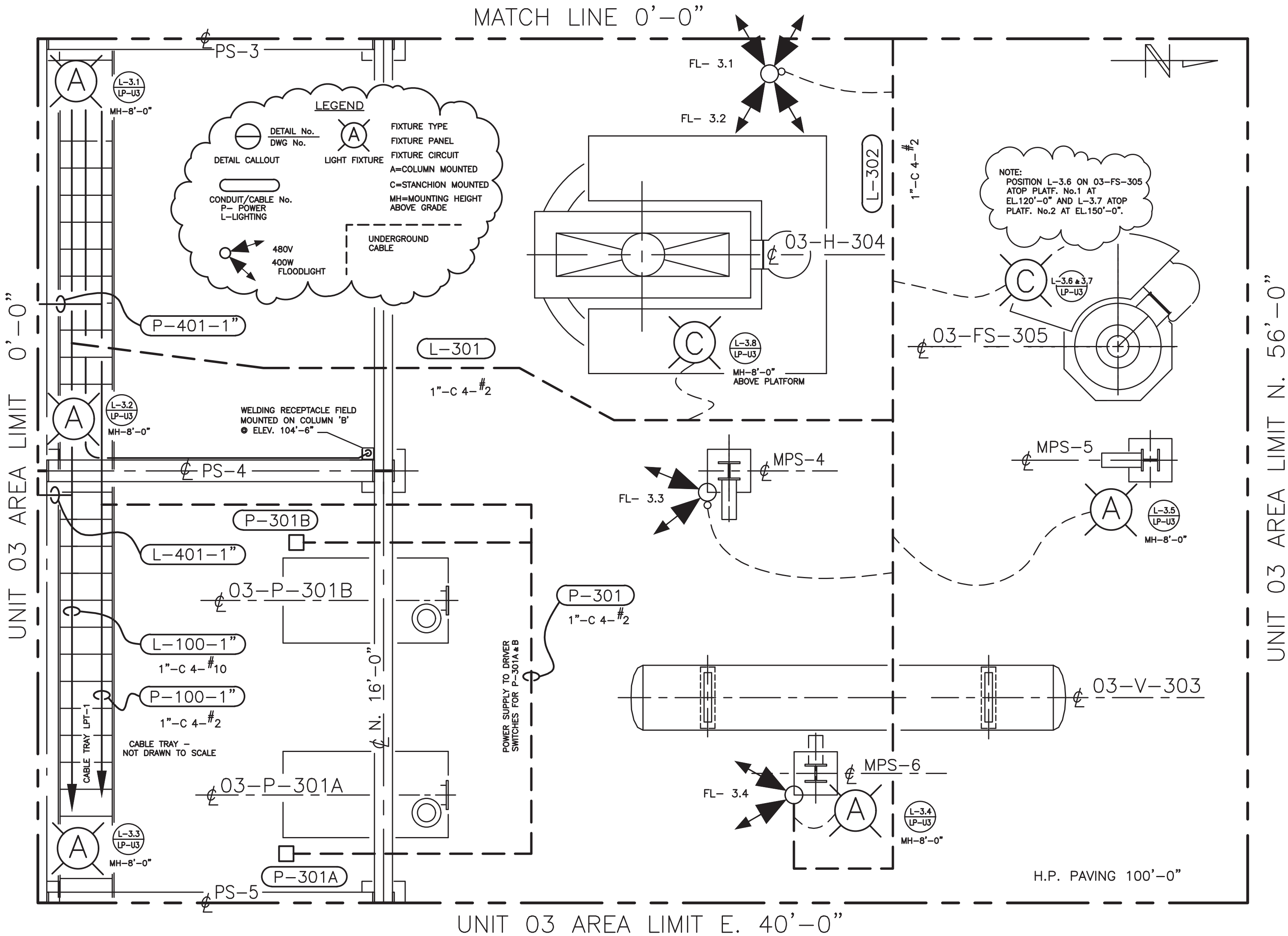


FIGURE 15.58 Unit-03: Electrical: Lighting and Power Supply.

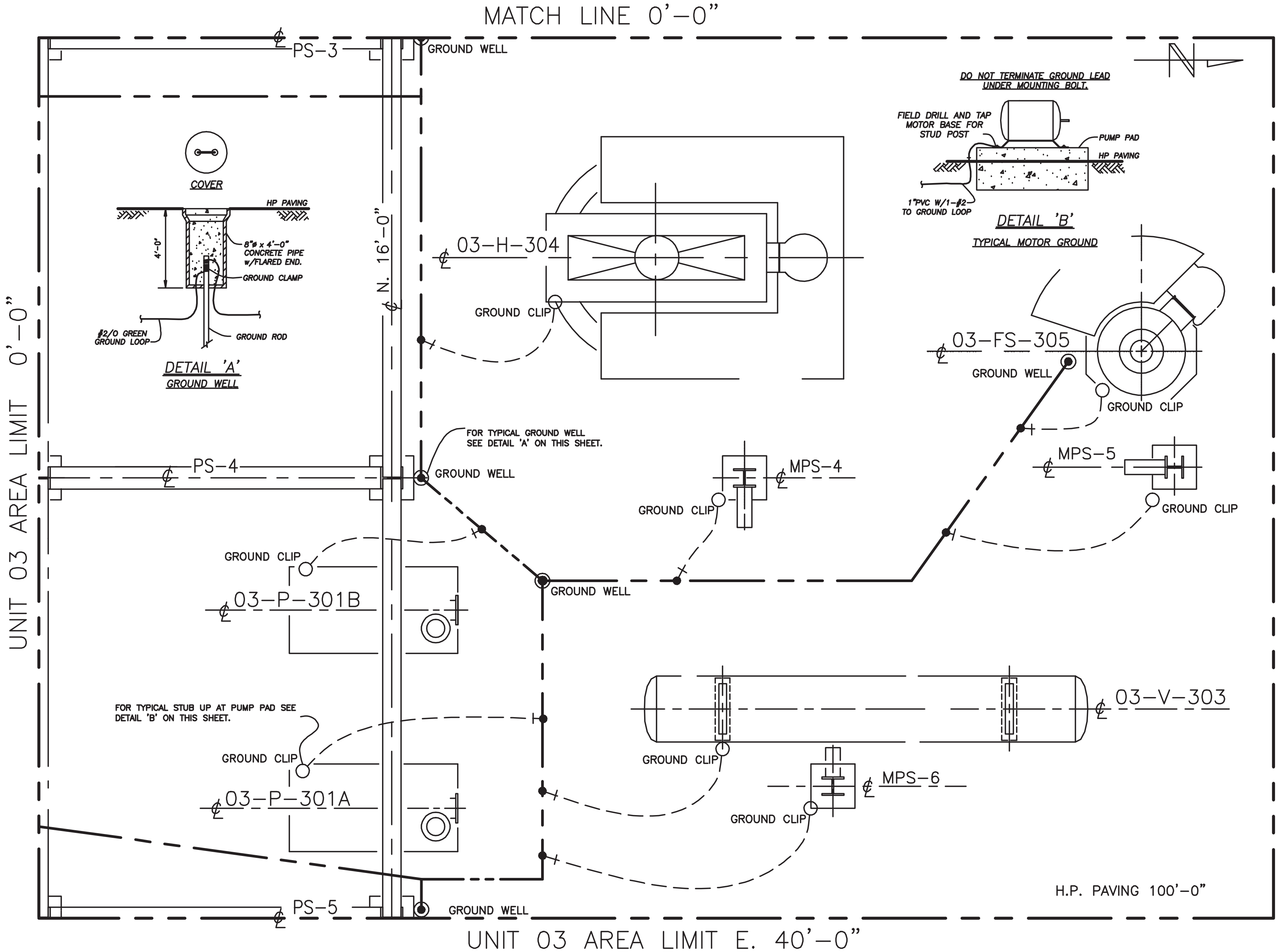


FIGURE 15.59 Unit-03: Electrical: Grounding Plan.

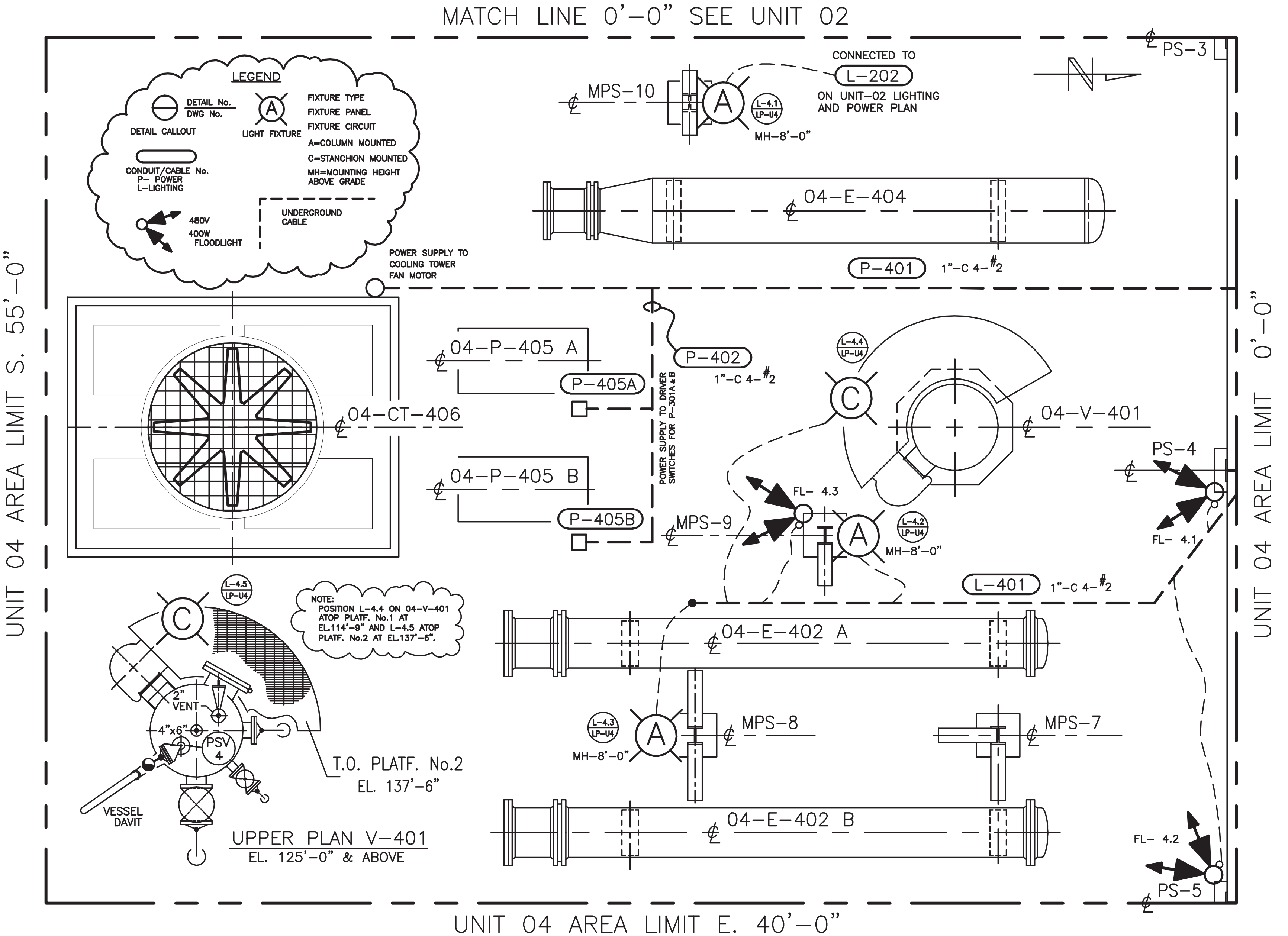


FIGURE 15.60 Unit-04: Electrical: Lighting and Power Supply.

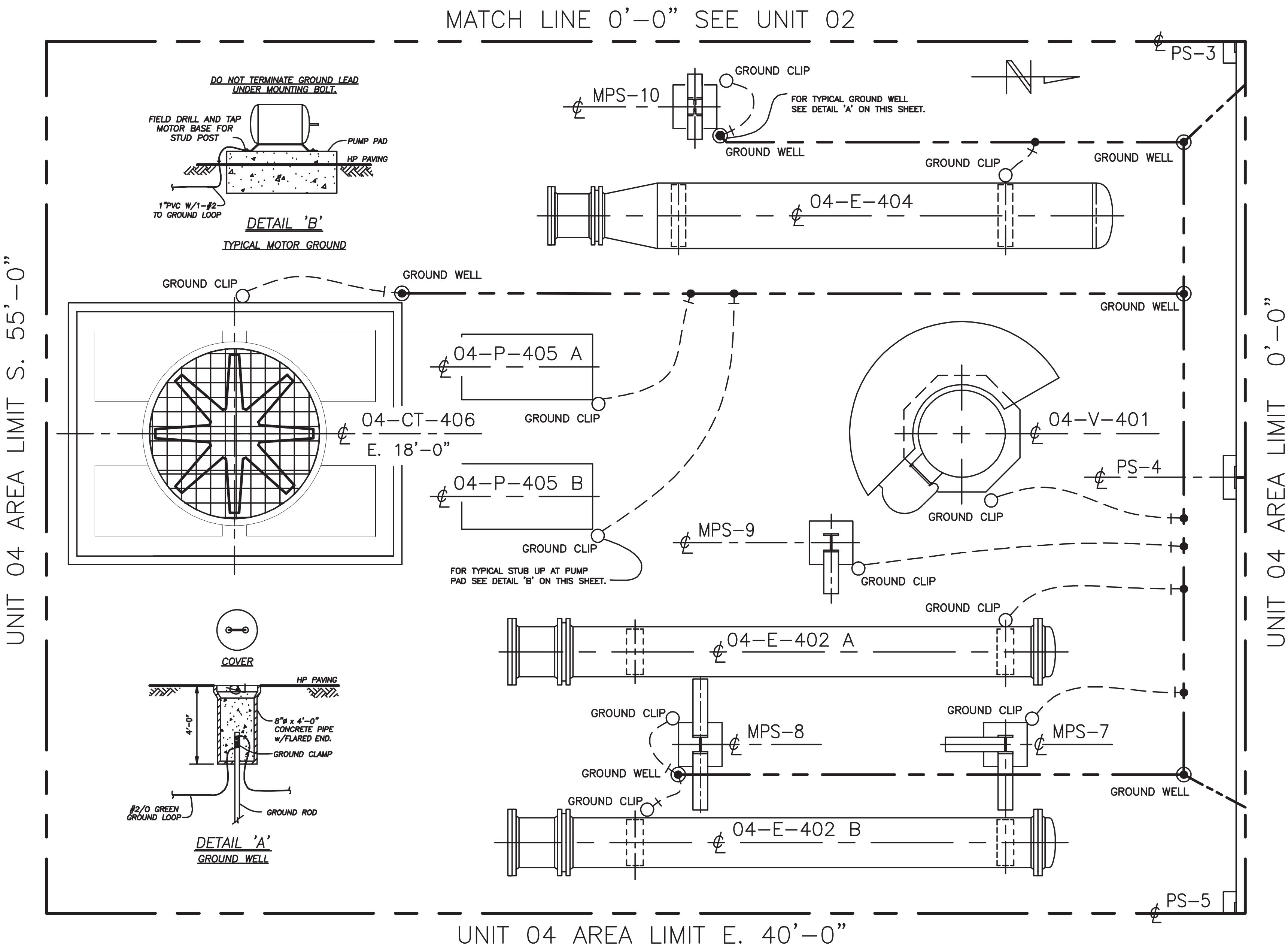


FIGURE 15.61 Unit-04: Electrical: Grounding Plan.

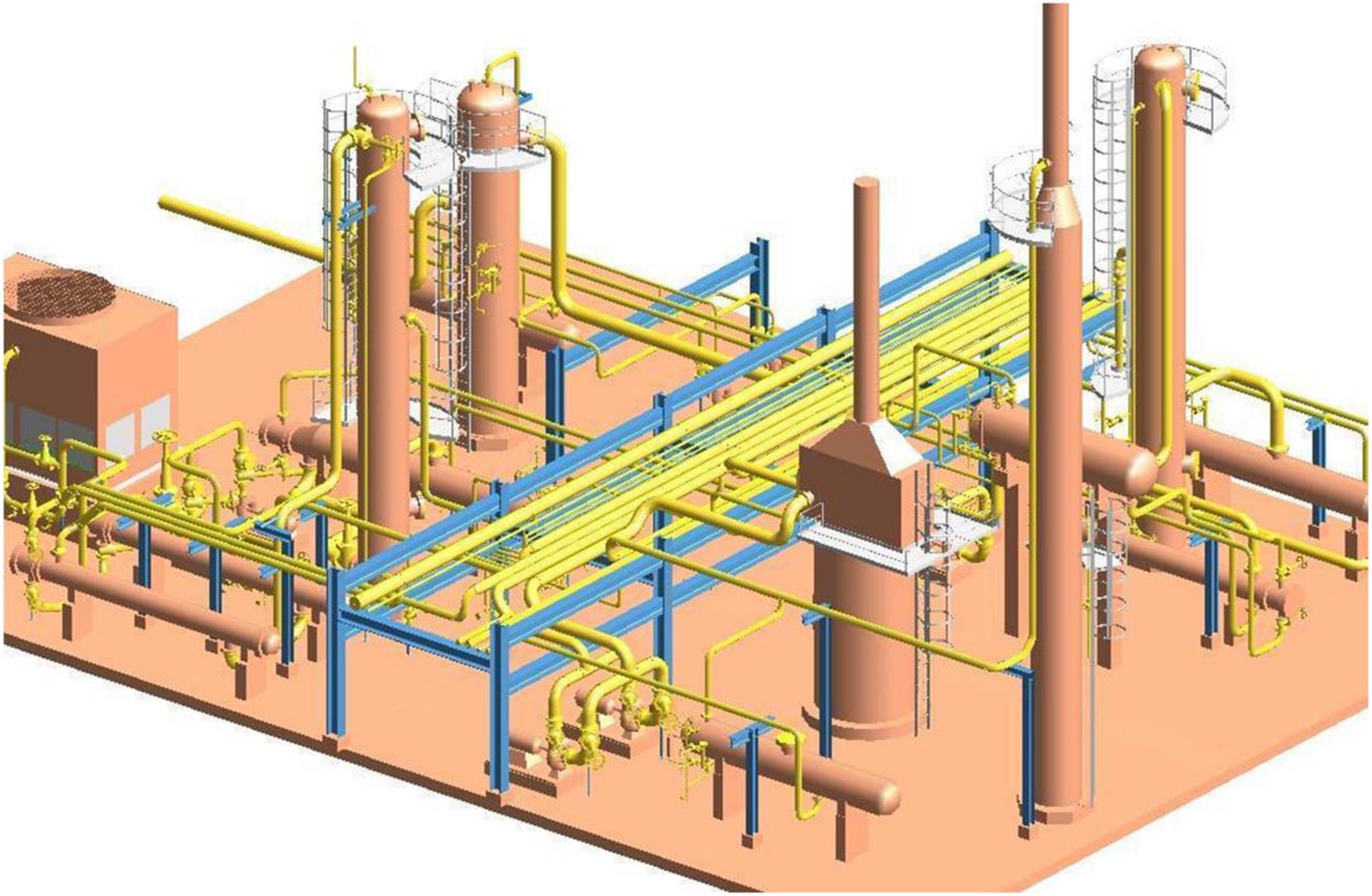


FIGURE 15.62 Northeast view of Units 01 through 04.

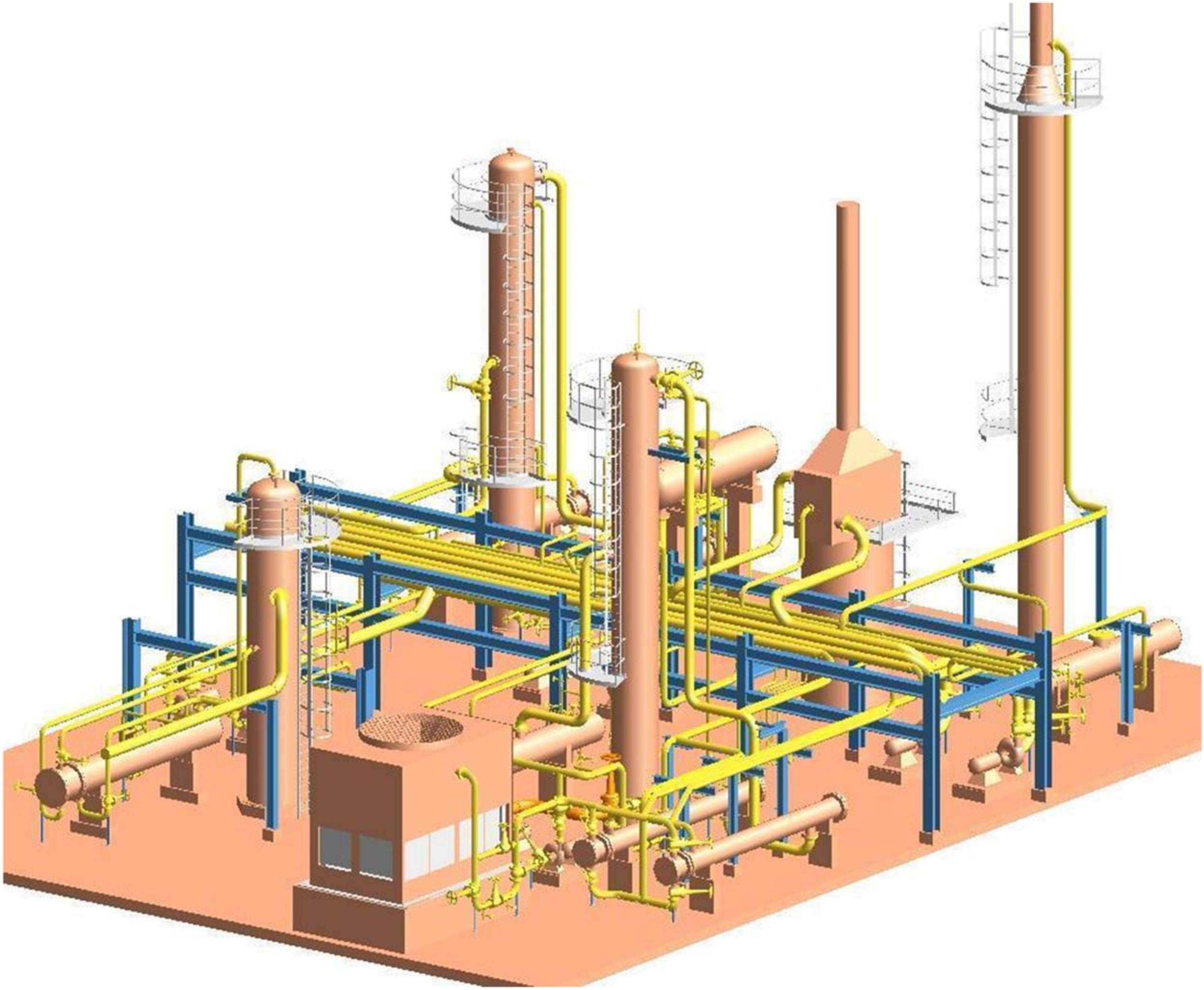


FIGURE 15.63 Southeast view of Units 01 through 04.

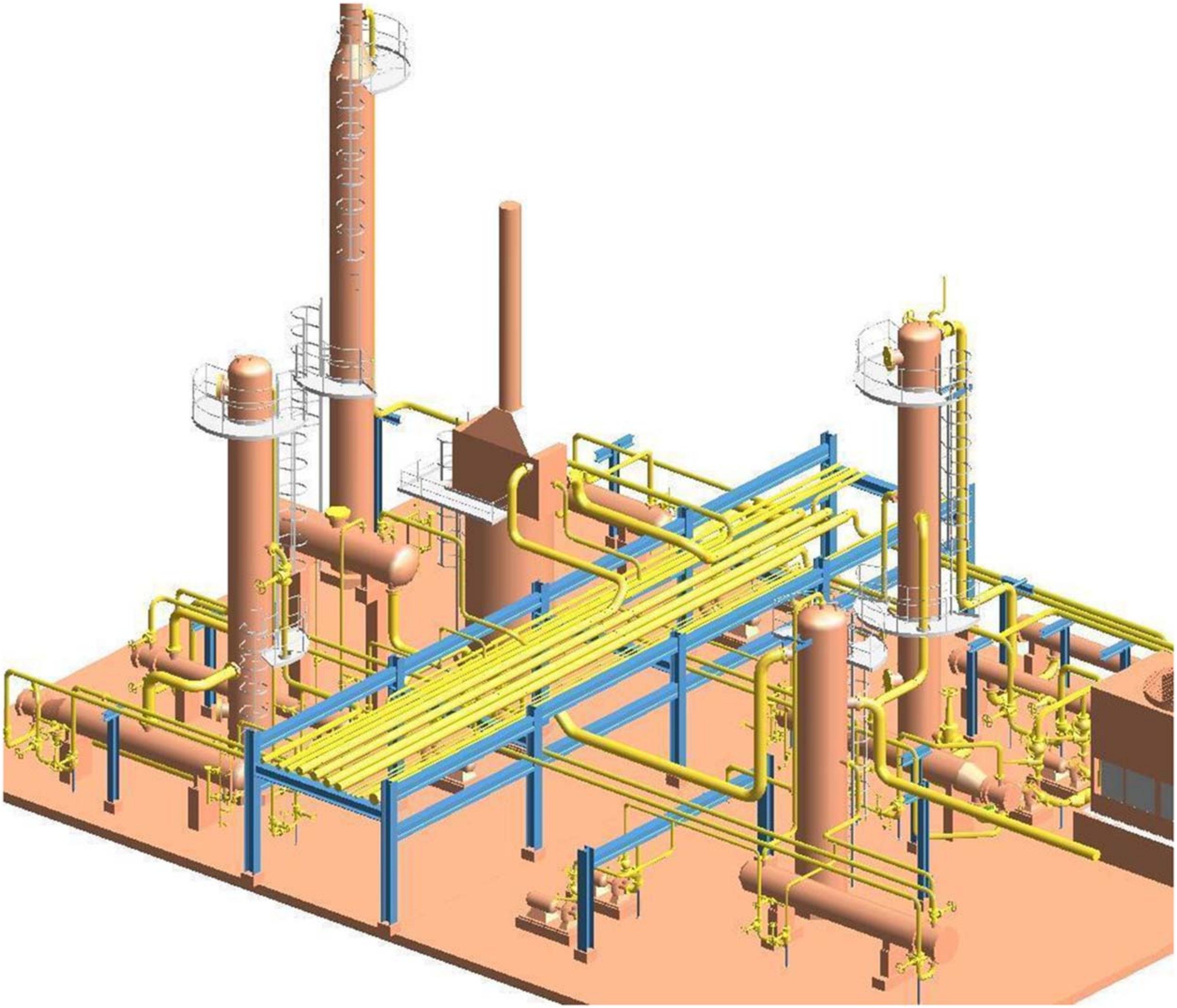


FIGURE 15.64 Southwest view of Units 01 through 04.

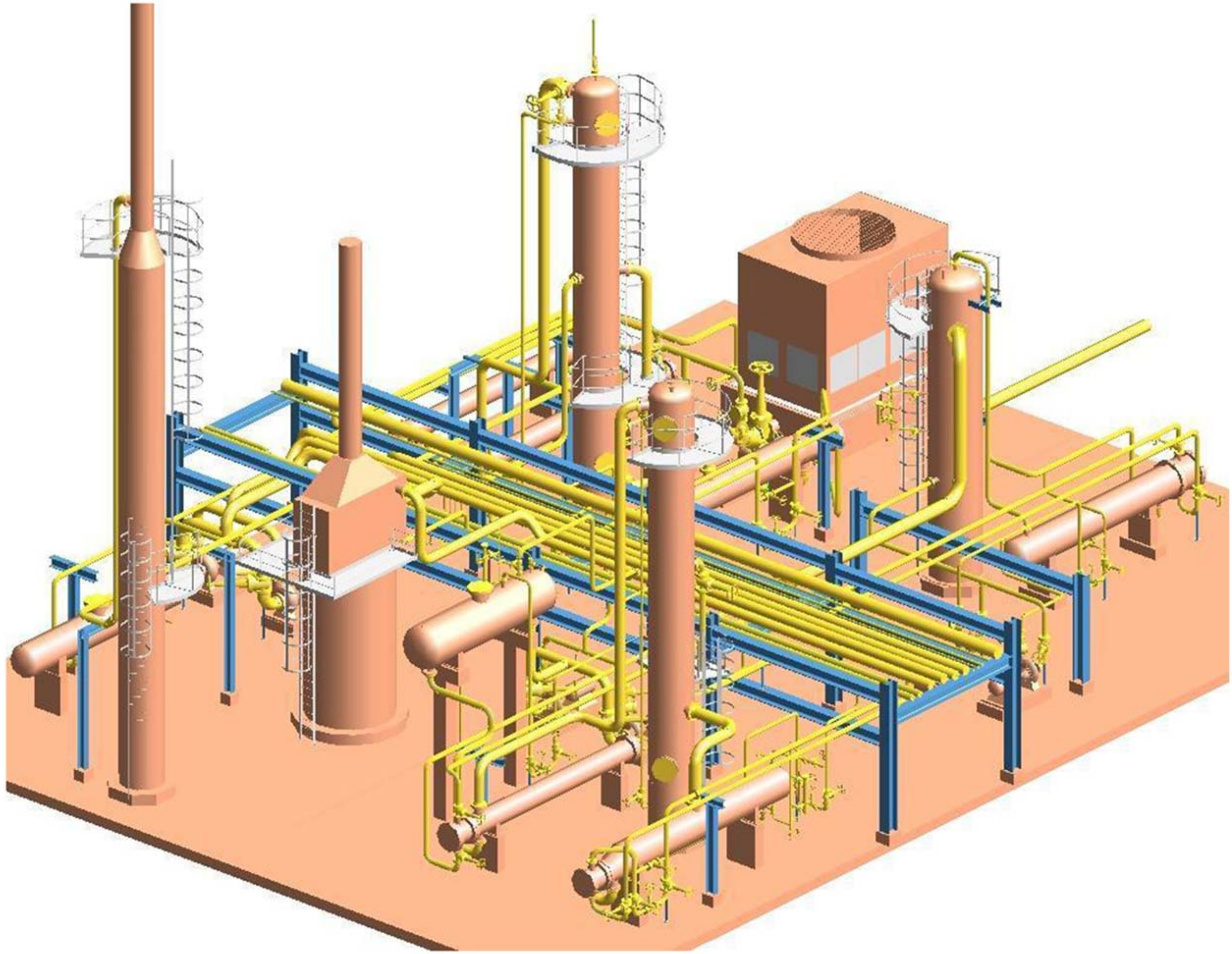


FIGURE 15.65 Northwest view of Units 01 through 04.

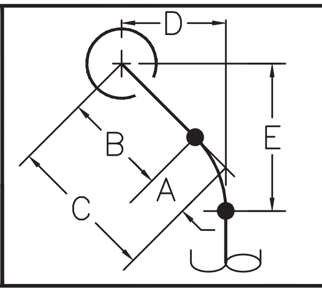
Appendix

APPENDIX A: DIMENSIONAL DATA

WELDED FITTINGS–FLANGES 150# RF

WELD FITTINGS	NOMINAL PIPE SIZE (in.)		2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
	O.D. of PIPE		2 3/8	2 7/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
	90°L.R. ELL	A	3	3 3/4	4 1/2	6	9	12	15	18	21	24	27
	45° ELL	B	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
	HALF TEE	C	2 1/2	3	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2
	REDUCER	H	3	3 1/2	3 1/2	4	5 1/2	6	7	8	13	14	15

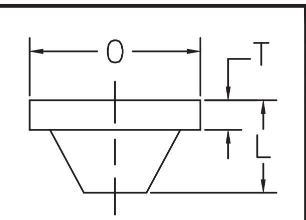
STD. 90° & 45°



STD. 90° & 45°		2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
	A	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
	B	3	3 3/4	4 1/2	6	9	12	15	18	21	24	27
	C	4 3/8	5 1/2	6 1/2	8 1/2	12 3/4	17	21 1/4	25 1/2	29 3/4	34	38 1/4
	D	3 1/8	3 7/8	4 5/8	6	9	12	15	18	21 1/16	24 1/16	27 1/16
	E	4 1/2	7 5/8	6 5/8	8 1/2	12 3/4	17	21 1/4	25 1/2	29 13/16	34 1/16	38 5/16

FITTING MAKE UP	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
90°&WN FLG	5 1/2	6 1/2	7 1/4	9	12 1/2	16	19	22 1/2	26	29	32 1/2
TEE&WN FLG	5	5 3/4	6 1/8	7 1/8	9 1/8	11	12 1/2	14 1/2	16	17	19 3/4
45°&WN FLG	3 7/8	4 1/2	4 3/4	5 1/2	7 1/4	9	10 1/4	12	13 3/4	15	18

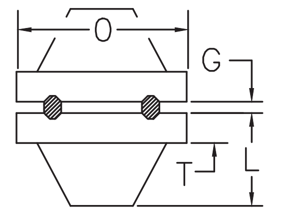
RFWN FLANGES



RFWN FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6	7	7 1/2	9	11	13 1/2	16	19	21	23 1/2	25
L	2 1/2	2 3/4	2 3/4	3	3 1/2	4	4	4 1/2	5	5	5 1/2
T	3/4	7/8	15/16	15/16	1	1 1/8	1 3/16	1 1/4	1 3/8	1 7/16	1 9/16

1/16" RAISED FACE INCLUDED ON 'L' & 'T' DIMENSIONS

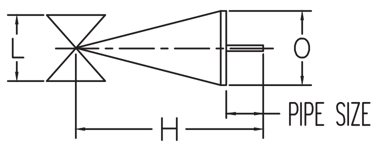
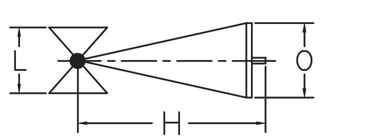
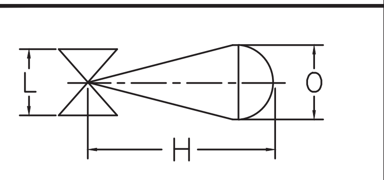
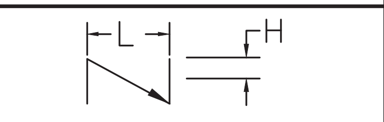
RTJ FLANGES



RTJ FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6	7	7 1/2	9	11	13 1/2	16	19	21	23 1/2	25
L	2 3/4	3	3	3 1/4	3 3/4	4 1/4	4 1/4	4 3/4	5 1/4	5 1/4	5 3/4
T	1	1 1/8	1 3/16	1 3/16	1 1/4	1 3/8	1 7/16	1 1/2	1 5/8	1 11/16	1 13/16
G	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	1/8	1/8	1/8

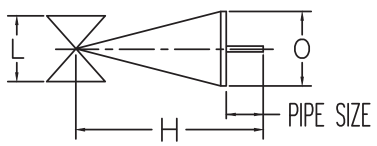
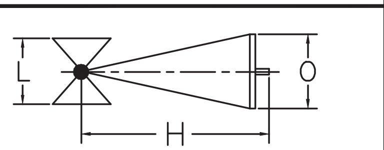
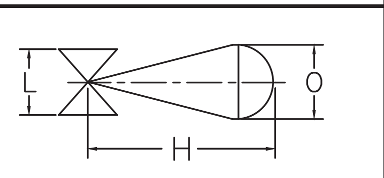
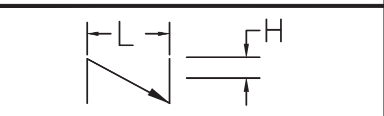
NOTE: ALL DIMENSIONS ARE IN INCHES 150#

VALVES 150#

VALVES		NOMINAL PIPE SIZES (in.)	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
		O.D. of PIPE	2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
GATE		L	7	8	9	10 1/2	11 1/2	13	14	15	16	17
		H	15 3/4	20 3/4	25 3/4	35 1/4	44	52 1/2	60 1/2	70 1/2	79 3/4	89
		O	8	9	10	14	16	18	18	22	24	27
GLOBE		L	8	9 1/2	11 1/2	16	19 1/2	*	*	*	*	*
		H	13 3/4	16 1/2	19 3/4	24 1/2	26	*	*	*	*	*
		O	8	9	10	12	16	*	*	*	*	*
CONTROL		L	10	11 3/4	13 7/8	17 3/4	21 3/8	26 1/2	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
CHECK		L	8	9 1/2	11 1/2	14	19 1/2	24 1/2	27 1/2	35	39	*
		H	5	6	7	9	10 1/4	12 1/8	13 3/4	18	20 1/2	*

NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

150# RF

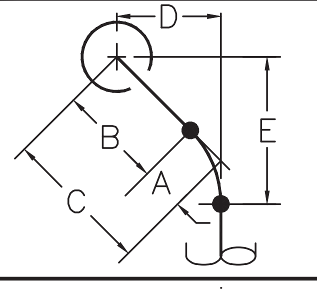
VALVES												
GATE		L	7 1/2	8 1/2	9 1/2	11	12	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2
		H	16 1/2	20 3/4	25 3/4	35 1/4	43	52 1/2	60 1/2	70 1/4	79 3/4	89
		O	8	9	10	14	14	18	18	22	24	27
GLOBE		L	8 1/2	10	12	16 1/2	20	*	*	*	*	*
		H	13 3/4	16 1/2	19 3/4	24 1/2	26	*	*	*	*	*
		O	8	9	10	12	16	*	*	*	*	*
CONTROL		L	10 1/2	12 1/4	14 3/8	18 1/4	21 7/8	27	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
CHECK		L	8 1/2	10	12	14 1/2	20	25	28	35 1/2	39 1/2	*
		H	5	6	7	9	10 1/4	12 1/8	13 3/4	18	20 1/2	*

NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

150# RTJ

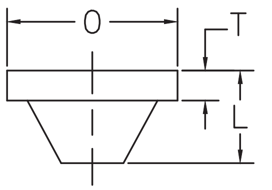
WELDED FITTINGS–FLANGES 300# RF

NOMINAL PIPE SIZE (in.)		2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
WELD FITTINGS: O.D. of PIPE		2 3/8	2 7/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
90°L.R. ELL	A	3	3 1/4	4 1/2	6	9	12	15	18	21	24	27
45° ELL	B	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
HALF TEE	C	2 1/2	3	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2
REDUCER	H	3	3 1/2	3 1/2	4	5 1/2	6	7	8	13	14	15



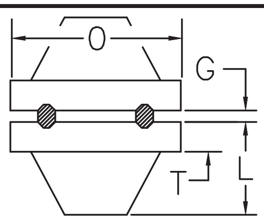
STD. 90° & 45°	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
A	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
B	3	3 3/4	4 1/2	6	9	12	15	18	21	24	27
C	4 3/8	5 1/2	6 1/2	8 1/2	12 3/4	17	21 1/4	25 1/2	29 3/4	34	38 1/4
D	3 1/8	3 7/8	4 5/8	6	9	12	15	18	21 1/16	24 1/16	27 1/16
E	4 1/2	7 5/8	6 5/8	8 1/2	12 3/4	17	21 1/4	25 1/2	29 13/16	34 1/16	38 5/16

FITTING MAKE UP	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
90°&WN FLG	5 3/4	6 3/4	7 5/8	9 3/8	12 7/8	16 3/8	19 5/8	23 1/8	26 5/8	29 3/4	33 1/4
TEE&WN FLG	5 1/2	6	6 1/2	7 1/2	9 3/8	11 3/8	13 1/8	15 1/8	16 5/8	17 3/4	19 3/4
45°&WN FLG	4 1/8	4 3/4	5 1/8	5 7/8	7 5/8	9 3/8	10 7/8	12 5/8	14 3/8	15 3/4	17 1/2



RFWN FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6 1/2	7 1/2	8 1/4	10	12 1/2	15	17 1/2	20 1/2	23	25 1/2	28
L	2 3/4	3	3 1/8	3 3/8	3 7/8	4 3/8	4 5/8	5 1/8	5 5/8	5 3/4	6 1/4
T	7/8	1	1 1/8	1 1/4	1 7/16	1 5/8	1 7/8	2	2 1/8	2 1/4	2 3/8

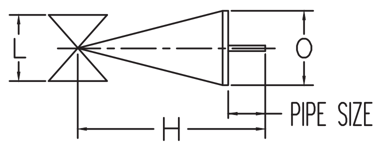
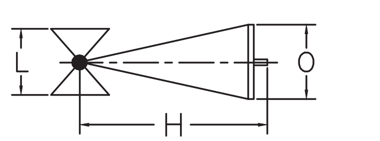
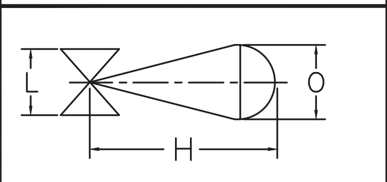
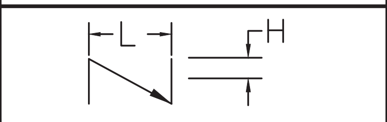
1/16" RAISED FACE INCLUDED ON 'L' & 'T' DIMENSIONS



RTJ FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6 1/2	7 1/2	8 1/4	10	12 1/2	15	17 1/2	20 1/2	23	25 1/2	28
L	3 1/16	3 5/16	3 7/16	3 11/16	4 3/16	4 11/16	4 15/16	5 7/16	5 15/16	6 1/16	6 9/16
T	1 1/8	1 1/4	1 3/8	1 1/2	1 11/16	1 7/8	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8
G	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4

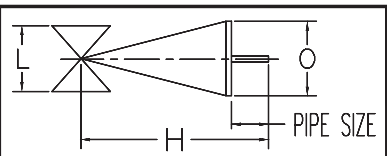
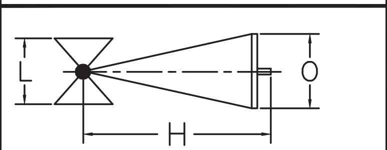
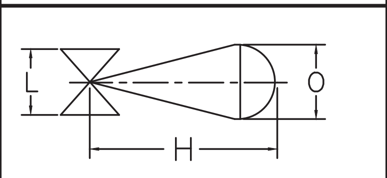
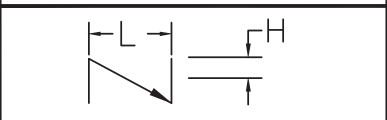
NOTE: ALL DIMENSIONS ARE IN INCHES 300#

VALVES 300#

VALVES			2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
NOMINAL PIPE SIZES (in.)			2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O.D. of PIPE			2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
GATE		L	8 1/2	11 1/8	12	15 7/8	16 1/2	18	19 3/4	30	33	36
		H	18 1/2	23 1/4	28 1/4	38 1/8	47	56 1/2	64 1/4	74 3/4	80 1/8	91
		O	8	9	10	14	16	20	20	27	27	30
GLOBE		L	10 1/2	12 1/2	14	17 1/2	22	*	*	*	*	*
		H	17 3/4	20 1/2	24 3/4	29 3/4	36 1/2	*	*	*	*	*
		O	9	10	14	18	24	*	*	*	*	*
CONTROL		L	10 1/2	12 1/2	14 1/2	18 5/8	22 3/8	27 7/8	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
CHECK		L	10 1/2	12 1/2	14	17 1/2	21	24 1/2	28	*	*	*
		H	6 3/4	8 1/2	9 3/4	11 3/4	14	15	16 3/4	*	*	*

NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

300# RF

VALVES			2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
GATE		L	9 1/8	11 3/4	12 5/8	16 1/2	17 1/8	18 5/8	20 3/8	30 5/8	33 5/8	36 5/8
		H	18 1/2	23 1/4	28 1/4	38 1/8	47	56 1/2	64 1/4	74 3/4	80 1/8	91
		O	8	9	10	14	16	20	20	27	27	30
GLOBE		L	11 1/8	13 1/8	14 5/8	18 1/8	22 5/8	*	*	*	*	*
		H	17 3/4	20 1/2	24 3/4	29 3/4	36 1/2	*	*	*	*	*
		O	9	10	14	18	24	*	*	*	*	*
CONTROL		L	11 1/8	13 1/8	15 1/8	19 1/4	23	28 1/2	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
CHECK		L	11 1/8	13 1/8	14 5/8	18 1/8	21 5/8	25 1/8	28 5/8	*	*	*
		H	6 3/4	8 1/2	9 3/4	11 3/4	14	15	16 3/4	*	*	*

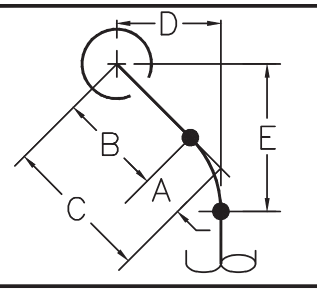
NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

300# RTJ

WELDED FITTINGS–FLANGES 600# RF

NOMINAL PIPE SIZE (in.)		2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
WELD FITTINGS: O.D. of PIPE		2 3/8	2 7/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
90° L.R. ELL	A	3	3 1/4	4 1/2	6	9	12	15	18	21	24	27
45° ELL	B	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
HALF TEE	C	2 1/2	3	3 3/8	4 1/8	5 5/8	7	8 1/2	10	11	12	13 1/2
REDUCER	H	3	3 1/2	3 1/2	4	5 1/2	6	7	8	13	14	15

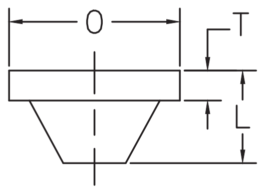
STD. 90° & 45°



		2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
STD. 90° & 45°	A	1 3/8	1 3/4	2	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4
	B	3	3 3/4	4 1/2	6	9	12	15	18	21	24	27
	C	4 3/8	5 1/2	6 1/2	8 1/2	12 3/4	17	21 1/4	25 1/2	29 3/4	34	38 1/4
	D	3 1/8	3 7/8	4 5/8	6	9	12	15	18	21 1/16	24 1/16	27 1/16
	E	4 1/2	7 5/8	6 5/8	8 1/2	12 3/4	17	21 1/4	25 1/2	29 13/16	34 1/16	38 5/16

FITTING MAKE UP	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
90° & WN FLG	6 1/8	7 1/8	8	10 1/4	13 7/8	17 1/2	21 1/4	24 3/8	27 3/4	31 1/4	34 1/2
TEE & WN FLG	5 5/8	6 3/8	6 7/8	8 3/8	10 1/2	12 1/2	14 3/4	16 3/8	17 3/4	19 1/4	22 1/2
45° & WN FLG	4 1/2	5 1/8	5 1/2	6 3/4	8 5/8	10 1/2	12 1/2	13 7/8	15 1/2	17 1/4	18 3/4

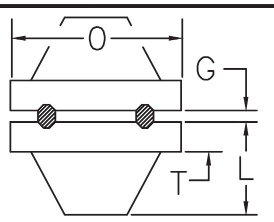
RFWN FLANGES



RFWN FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6 1/2	7 1/2	8 1/4	10 3/4	14	16 1/2	20	22	23 3/4	27	29 1/4
L	3 1/8	3 3/8	3 1/2	4 1/4	4 7/8	5 1/2	6 1/4	6 3/8	6 3/4	7 1/4	7 1/2
T	1 1/4	1 3/8	1 1/2	1 3/4	2 1/8	2 7/16	2 3/4	2 7/8	3	3 1/4	3 1/2

1/4" RAISED FACE INCLUDED ON 'L' & 'T' DIMENSIONS

RTJ FLANGES



RTJ FLANGES	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O	6 1/2	7 1/2	8 1/4	10 3/4	14	16 1/2	20	22	23 3/4	27	29 1/4
L	3 3/16	3 7/16	3 9/16	4 5/16	4 15/16	5 9/16	6 5/16	6 7/16	6 13/16	7 5/16	7 9/16
T	1 1/2	1 5/8	1 3/4	2	2 3/8	2 11/16	3	3 1/8	3 1/4	3 1/2	3 3/4
G	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16

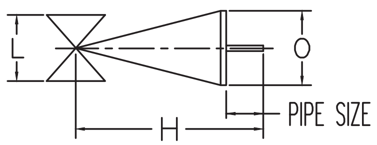
NOTE: ALL DIMENSIONS ARE IN INCHES 600#

VALVES 600#

600# RF

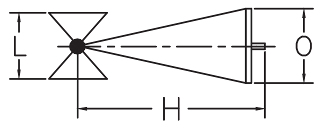
NOMINAL PIPE SIZES (in.)	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
O.D. of PIPE	2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18

VALVES – GATE



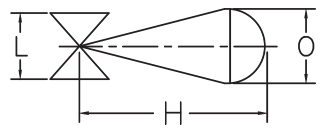
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 1/2	14	17	22	26	31	33	35	39	43
H	18 1/4	25 3/4	32	42 3/4	52 1/4	62 1/4	70	77 1/4	83 3/4	93 3/4
O	8	10	14	20	24	27	27	30	30	36

VALVES – GLOBE



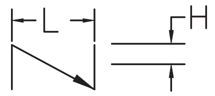
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 1/2	14	17	22	*	*	*	*	*	*
H	19	23 1/2	27 1/2	35	*	*	*	*	*	*
O	10	12	18	24	*	*	*	*	*	*

VALVES – CONTROL



	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 1/4	13 1/4	15 1/2	20	24	29	*	*	*	*
H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*

VALVES – CHECK



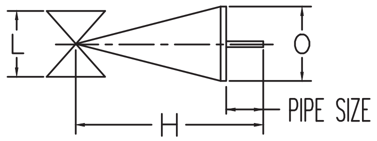
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 1/2	14	17	22	26	31	33	*	*	*
H	7	9	10 1/4	13 1/2	15 1/4	18 3/4	21 1/2	*	*	*

NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

600# RF

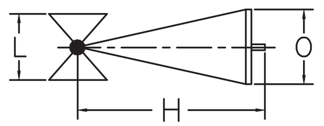
600# RTJ

VALVES – GATE



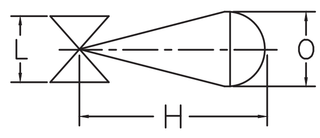
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 1/8	14 1/8	17 1/8	22 1/8	26 1/8	31 1/8	33 1/8	35 1/8	39 1/8	43 1/8
H	18 1/4	25 3/4	32	42 3/4	52 1/4	62 1/4	70	77 1/4	83 3/4	93 3/4
O	8	10	14	20	24	27	27	30	30	36

VALVES – GLOBE



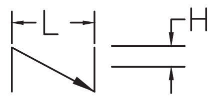
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 5/8	14 1/8	17 1/8	22 1/8	*	*	*	*	*	*
H	19	23 1/2	27 1/2	35	*	*	*	*	*	*
O	10	12	18	24	*	*	*	*	*	*

VALVES – CONTROL



	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 3/8	13 3/8	15 5/8	20 1/8	24 1/8	29 3/4	*	*	*	*
H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*

VALVES – CHECK

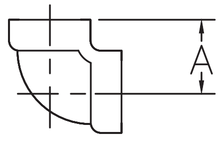
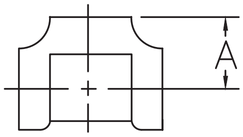
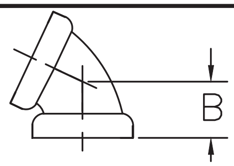
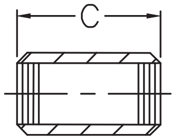
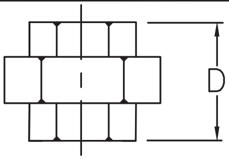
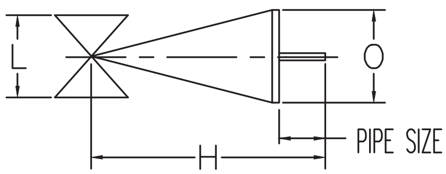
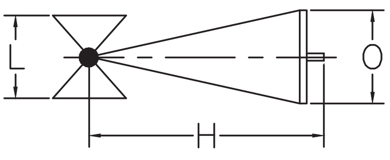
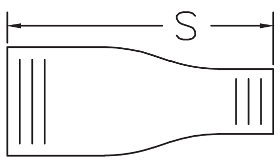


	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"
L	11 5/8	14 1/8	17 1/8	22 1/8	26 1/8	31 1/8	33 1/8	*	*	*
H	7	9	10 1/4	13 1/2	15 1/4	18 3/4	21 1/2	*	*	*

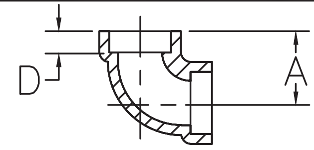
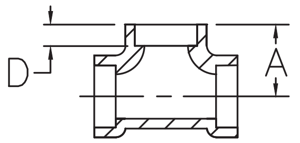
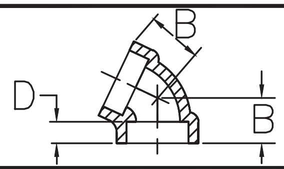
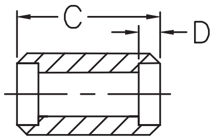
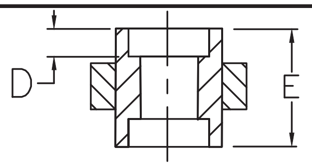
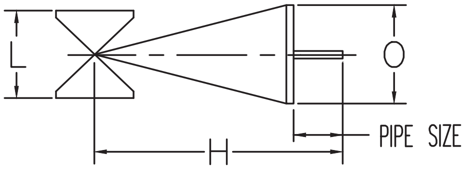
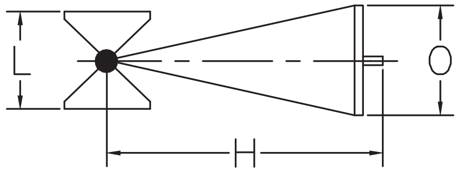
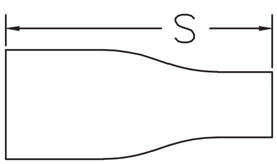
NOTE: ALL DIMENSIONS ARE IN INCHES
* = REFER TO VENDOR CATALOG

600# RTJ

THREADED FITTINGS

NOMINAL PIPE SIZE (in.)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	90° ELL 3000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	90° ELL 6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	TEE 3000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	TEE 6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	45° ELL 3000 #	B	1	1 1/8	1 5/16	1 7/16	1 11/16	2	2 1/16	2 1/2
	45° ELL 6000 #	B	1 1/8	1 5/16	1 11/32	1 11/16	1 23/32	2 1/16	2 1/2	3 1/8
	COUPLING 3000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	COUPLING 6000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	UNION 3000 #	D	1 15/16	2 1/4	2 1/2	2 13/16	3 1/16	3 7/16	4	4 5/16
	UNION 6000 #	D	2 5/16	2 1/2	2 13/16	2 3/4	2 7/8	3 11/16	3 15/16	4 5/8
NORMAL THREAD ENGAGEMENT	3000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1
	6000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1
	GATE	L	3 9/16	4 1/2	4 3/4	5	5 1/2	7	*	*
	GATE	H	6 1/2	8 1/4	9 9/16	10 7/8	11 7/16	14 1/16	*	*
	GATE	O	4	5 1/2	5 3/4	6 1/2	7	8	*	*
	GLOBE	L	3 5/8	4 5/8	6 1/4	7	7 3/4	9	*	*
	GLOBE	H	6 7/8	8 7/16	10 3/8	11 1/2	12 3/16	14 1/2	*	*
	GLOBE	O	4	4 3/4	5 3/4	8	8	8	*	*
	SWAGE	OUTLET	1/4 TO 3/8	1/4 TO 1/2	1/4 TO 3/4	1/4 TO 1	1/4 TO 1 1/4	1/4 TO 1 1/2	1/4 TO 2 1/4	1/4 TO 2 1/2
	SWAGE	S	2 3/4	3	3 1/2	4	4 1/2	6 1/2	7	8

SOCKET WELD FITTINGS

NOMINAL PIPE SIZES (in)				1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	90° ELL	3000 #	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8
		6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	TEE	3000 #	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8
		6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	45° ELL	3000 #	B	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	2	2 1/16
		6000 #	B	1	1 1/8	1 5/16	1 7/16	1 11/16	1 23/32	2 1/16	2 1/2
	COUPLING	3000 #	C	1 3/8	1 1/2	1 3/4	1 7/8	2	2 1/2	2 5/8	2 3/4
		6000 #	C	1 3/8	1 1/2	1 3/4	1 7/8	2	2 1/2	2 5/8	2 3/4
	UNION	3000 #	E	2 1/8	2 5/16	2 1/2	2 13/16	3 1/8	3 1/2	3 15/16	4 1/2
		6000 #	E	2 7/8	3 3/8	3 5/8	3 7/8	4 3/16	4 5/8	5 3/16	5 15/16
SOCKET DEPTH		3000 #	D	1/2	9/16	5/8	11/16	3/4	7/8	1 1/8	1 3/8
		6000 #	D	11/16	3/4	7/8	15/16	1	1 1/8	1 1/2	1 5/8
	GATE		L	3 9/16	4 1/2	4 3/4	5	5 1/2	7	*	*
			H	6 1/2	8 1/4	9 9/16	10 7/8	11 7/16	14 1/16	*	*
			O	4	5 1/2	5 3/4	6 1/2	7	8	*	*
	GLOBE		L	3 5/8	4 5/8	6 1/4	7	7 3/4	9	*	*
			H	6 7/8	8 7/16	10 3/8	11 1/2	12 3/16	14 1/2	*	*
			O	4	4 3/4	5 3/4	8	8	8	*	*
	SWAGE		OUTLET	1/4 TO 3/8	1/4 TO 1/2	1/4 TO 3/4	1/4 TO 1	1/4 TO 1 1/4	1/4 TO 1 1/2	1/4 TO 2 1/4	1/4 TO 2 1/2
			S	2 3/4	3	3 1/2	4	4 1/2	6 1/2	7	8

WEIGHT OF FLANGED VALVES *

VALVE TYPES	POUND RATINGS	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"
		NOMINAL PIPE SIZES										
GATE	150	55	95	140	240	400	630	830	1150	1580	1910	2350
GATE	300	75	145	215	420	700	1050	1490	2170	2800	3720	4640
GATE	400	115	194	270	530	940	1530	2000	2410	3500		
GATE	600			330	720	1220	1880	2630	3200	4230	7200	9800
GATE	900			430	900	1569	2350	3500	4680	6500		
GATE	1500			610	1410	2600						
GLOBE	150	47	80	140	250	420	598	824				
GLOBE	300	79	139	214	396	628	686					
GLOBE	400	90	160	233	476	820						
GLOBE	600	115	191	318	782	1224						
GLOBE	900	215	460	490	920							
GLOBE	1500			665	1890							
CHECK	150	34	65	100	200	390	510	775	1200	1450		
CHECK	300	62	120	180	330	620	920	1290	1650	2050	2420	
CHECK	400			200	395	680	900	1250				
CHECK	600			260	530	900	1440	1970				
CHECK	900			340	640	1180	2170					
CHECK	1500			630	1360	2100						

* APPROXIMATE WEIGHTS IN lbs. SEE MANUFACTURER'S CATALOG FOR SPECIFIC WEIGHTS.

HOT INSULATION THICKNESS CHART

Nominal Pipe Size (Inches)	Temperature Range °F: Up to 175°	176° to 225°	226° to 275°	276° to 325°	326° to 375°	376° to 425°	426° to 475°	476° to 525°	526° to 575°	576° to 625°	626° to 675°
1/2″	1″	1″	1″	1″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″
3/4″	1″	1″	1″	1″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″
1″	1″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″
1 1/2″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″
2″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″
2 1/2″	1″	1″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	2″
3″	1″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	2″
4″	1″	1″	1″	1 1/2″	1 1/2″	1 1/2″	2″	2″	2″	2″	2″
6″	1″	1″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	2″	2″	2″	2″	2 1/2″
8″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	2″	2″	2″	2″	2 1/2″	2 1/2″	2 1/2″
10″	1 1/2″	1 1/2″	1 1/2″	1 1/2″	2″	2″	2″	2 1/2″	2 1/2″	2 1/2″	3″
12″	1 1/2″	1 1/2″	1 1/2″	2″	2″	2″	2″	2 1/2″	2 1/2″	2 1/2″	3″
14″	1 1/2″	1 1/2″	2″	2″	2″	2″	2 1/2″	2 1/2″	2 1/2″	2 1/2″	3″

WEIGHT OF PIPE INSULATION
(POUNDS PER LINEAL FOOT)

NOMINAL PIPE SIZE	THICKNESS OF INSULATION 1"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"
2"	1.01	1.71	2.53	3.48	4.42	5.59	
3"	1.25	2.08	3.01	4.07	5.24	6.65	
4"	1.62	2.55	3.61	4.66	6.07	7.48	9.10
6"	2.11	3.28	4.57	6.09	7.60	9.82	11.5
8"		4.13	5.64	7.85	9.48	11.5	13.8
10"		5.20	7.07	8.93	11.0	13.2	15.5
12"		6.04	8.13	10.5	12.7	15.1	17.4
14"		6.16	8.38	10.7	13.1	15.6	18.5
16"		6.90	9.33	12.0	14.6	17.5	20.5
18"		7.73	10.4	13.3	16.3	19.3	22.6
20"		8.45	11.6	14.6	17.7	21.1	24.6

1. Based on calcium silicate weighing 11 lbs/ft^3.
2. Chart must be adjusted for other insulating compounds.
3. Chart includes banding and protective covering weights.

Pressure–Temperature Ratings for Flanges and Flanged End Valves

Temperature °F	150	300	400	600	900	1,500	2,500
	Working Pressures by Ratings (psig) *1						
-20 to 100	260	670	895	1,345	2,015	3,360	5,600
200	230	605	805	1,210	1,815	3,025	5,040
300	220	570	760	1,140	1,705	2,845	4,740
400	200	535	710	1,065	1,600	2,665	4,440
500	170	505	670	1,010	1,510	2,520	4,200
600	140	480	635	955	1,435	2,390	3,980
650	125	465	620	930	1,395	2,330	3,880
700	11	455	610	910	1,370	2,280	3,800
750	95	445	595	895	1,340	2,230	3,720
800	80	435	580	870	1,305	2,170	3,620
850	65	425	565	850	1,275	2,125	3,540
900	50	415	555	830	1,245	2,075	3,460
950	35	385	515	775	1,160	1,930	3,220
1,000	20	350	465	700	1,050	1,750	2,915
1,050	*2	335	445	665	1,000	1,665	2,770
1,100		290	390	585	875	1,460	2,430
1,150		245	330	495	740	1,235	2,060
1,200		205	275	410	620	1,030	1,715
1,250		160	215	325	485	805	1,345
1,300		120	160	240	360	600	1,000
1,350		80	105	160	235	395	660
1,400		55	75	110	165	275	460
1,450		40	50	75	115	190	315
1,500		25	30	50	70	120	200

1. Ratings are maximum allowable nonshock working pressures at the temperatures shown for the applicable material.
2. Flanged end valve ratings terminate at 1000 °F.

Commercial Wrought Steel Pipe Data

Nominal Pipe Size Inches	Outside Diameter (D) Inches	Schedule No. *See Note 1*	Wall Thickness (t) Inches	Inside Diameter (d) Inches	Area of Metal (a) Square Inches	Transverse Internal Area Square Inches	Transverse Internal Area *See Note 2* Square Feet	Moment of Inertia (I) Inches to 4th Power	Weight of Pipe Pounds per foot	Weight of Water Pounds per foot of pipe	External Surface Sq. Ft. per foot of pipe	Section Modulus $\left(2\frac{I}{D}\right)$
1/8	0.405	40s	.068	.269	.0720	.0568	.00040	.00106	.244	.025	.106	.00523
		80x	.095	.215	.0925	.0364	.00025	.00122	.314	.016	.106	.00602
1/4	0.540	40s	.088	.364	.1250	.1041	.00072	.00331	.424	.045	.141	.01227
		80x	.119	.302	.1574	.0716	.00050	.00377	.535	.031	.141	.01395
3/8	0.675	40s	.091	.493	.1670	.1910	.00133	.00729	.567	.083	.178	.02160
		80x	.126	.423	.2173	.1405	.00098	.00862	.738	.061	.178	.02554
1/2	0.840	40s	.109	.622	.2503	.3040	.00211	.01709	.850	.132	.220	.04069
		80x	.147	.546	.3200	.2340	.00163	.02008	1.087	.102	.220	.04780
		160	.187	.466	.3836	.1706	.00118	.02212	1.300	.074	.220	.05267
		...xx	.294	.252	.5043	.050	.00035	.02424	1.714	.022	.220	.05772
3/4	1.050	40s	.113	.824	.3326	.5330	.00371	.03704	1.130	.231	.275	.07055
		80x	.154	.742	.4335	.4330	.00300	.04479	1.473	.188	.275	.08531
		160	.218	.614	.5698	.2961	.00206	.05269	1.940	.128	.275	.10036
		...xx	.308	.434	.7180	.148	.00103	.05792	2.440	.064	.275	.11032
1	1.315	40s	.133	1.049	.4939	.8640	.00600	.08734	1.678	.375	.344	.1328
		80x	.179	.957	.6388	.7190	.00499	.1056	2.171	.312	.344	.1606
		160	.250	.815	.8365	.5217	.00362	.1251	2.840	.230	.344	.1903
		...xx	.358	.599	1.0760	.282	.00196	.1405	3.659	.122	.344	.2136
1 1/4	1.660	40s	.140	1.380	.6685	1.495	.01040	.1947	2.272	.649	.435	.2346
		80x	.191	1.278	.8815	1.283	.00891	.2418	2.996	.555	.435	.2913
		160	.250	1.160	1.1070	1.057	.00734	.2839	3.764	.458	.435	.3421
		...xx	.382	.896	1.534	.630	.00438	.3411	5.214	.273	.435	.4110
1 1/2	1.900	40s	.145	1.610	.7995	2.036	.01414	.3099	2.717	.882	.497	.3262
		80x	.200	1.500	1.068	1.767	.01225	.3912	3.631	.765	.497	.4118
		160	.281	1.338	1.429	1.406	.00976	.4824	4.862	.608	.497	.5078
		...xx	.400	1.100	1.885	.950	.00660	.5678	6.408	.42	.497	.5977
2	2.375	40s	.154	2.067	1.075	3.355	.02330	.6657	3.652	1.45	.622	.5606
		80x	.218	1.939	1.477	2.953	.02050	.8679	5.022	1.28	.622	.7309
		160	.343	1.689	2.190	2.241	.01556	1.162	7.440	.97	.622	.979
		...xx	.436	1.503	2.656	1.774	.01232	1.311	9.029	.77	.622	1.104
2 1/2	2.875	40s	.203	2.469	1.704	4.788	.03322	1.530	5.79	2.07	.753	1.064
		80x	.276	2.323	2.254	4.238	.02942	1.924	7.66	1.87	.753	1.339
		160	.375	2.125	2.945	3.546	.02463	2.353	10.01	1.54	.753	1.638
		...xx	.552	1.771	4.028	2.464	.01710	2.871	13.70	1.07	.753	1.997
3	3.500	40s	.216	3.068	2.228	7.393	.05130	3.017	7.58	3.20	.916	1.724
		80x	.300	2.900	3.016	6.605	.04587	3.894	10.25	2.86	.916	2.225
		160	.438	2.624	4.205	5.408	.03755	5.032	14.32	2.35	.916	2.876
		...xx	.600	2.300	5.466	4.155	.02885	5.993	18.58	1.80	.916	3.424
3 1/2	4.000	40s	.226	3.548	2.680	9.886	.06870	4.788	9.11	4.29	1.047	2.394
		80x	.318	3.364	3.678	8.888	.06170	6.280	12.51	3.84	1.047	3.140
4	4.500	40s	.237	4.026	3.174	12.73	.08840	7.233	10.79	5.50	1.178	3.214
		80x	.337	3.826	4.407	11.50	.07986	9.610	14.98	4.98	1.178	4.271
		120	.438	3.624	5.595	10.31	.0716	11.65	19.00	4.47	1.178	5.178
		160	.531	3.438	6.621	9.28	.0645	13.27	22.51	4.02	1.178	5.898
		...xx	.674	3.152	8.101	7.80	.0542	15.28	27.54	3.38	1.178	6.791
5	5.563	40s	.258	5.047	4.300	20.01	.1390	15.16	14.62	8.67	1.456	5.451
		80x	.375	4.813	6.112	18.19	.1263	20.67	20.78	7.88	1.456	7.431
		120	.500	4.563	7.953	16.35	.1136	25.73	27.10	7.09	1.456	9.250
		160	.625	4.313	9.696	14.61	.1015	30.03	32.96	6.33	1.456	10.796
		...xx	.750	4.063	11.340	12.97	.0901	33.63	38.55	5.61	1.456	12.090
6	6.625	40s	.280	6.065	5.581	28.89	.2006	28.14	18.97	12.51	1.734	8.50
		80x	.432	5.761	8.405	26.07	.1810	40.49	28.57	11.29	1.734	12.22
		120	.562	5.501	10.70	23.77	.1650	49.61	36.40	10.30	1.734	14.98
		160	.718	5.189	13.32	21.15	.1469	58.97	45.30	9.16	1.734	17.81
		...xx	.864	4.897	15.64	18.84	.1308	66.33	53.16	8.16	1.734	20.02
8	8.625	20	.250	8.125	6.57	51.85	.3601	57.72	22.36	22.47	2.258	13.39
		30	.277	8.071	7.26	51.16	.3553	63.35	24.70	22.17	2.258	14.69
		40s	.322	7.981	8.40	50.03	.3474	72.49	28.55	21.70	2.258	16.81
		60	.406	7.813	10.48	47.94	.3329	88.73	35.64	20.77	2.258	20.58
		80x	.500	7.625	12.76	45.66	.3171	105.7	43.39	19.78	2.258	24.51
		100	.593	7.439	14.96	43.46	.3018	121.3	50.87	18.83	2.258	28.14
		120	.718	7.189	17.84	40.59	.2819	140.5	60.63	17.59	2.258	32.58
		140	.812	7.001	19.93	38.50	.2673	153.7	67.76	16.68	2.258	35.65
		...xx	.875	6.875	21.30	37.12	.2578	162.0	72.42	16.10	2.258	37.56
		160	.906	6.813	21.97	36.46	.2532	165.9	74.69	15.80	2.258	38.48

continued on following page

Source: Crane Co.

Note 1: The letters s, x, and xx in the column of Schedule Numbers indicate Standard, Extra Strong, and Double Extra Strong Pipe, respectively.

Note 2: The values shown in square feet for the Transverse Internal Area also represent the volume in cubic feet per foot of pipe length.

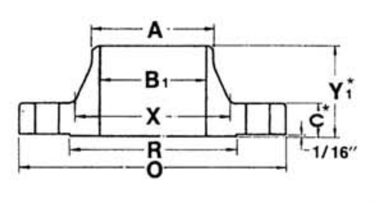
Courtesy of Crane Co.

Nominal Pipe Size Inches	Outside Diameter (D) Inches	Schedule No. *See Note 1*	Wall Thickness (t) Inches	Inside Diameter (d) Inches	Area of Metal (a) Square Inches	Transverse Internal Area Square Inches	Transverse Internal Area *See Note 2* Square Feet	Moment of Inertia (I) Inches to 4th Power	Weight of Pipe Pounds per foot	Weight of Water Pounds per foot of pipe	External Surface Sq. Ft. per foot of pipe	Section Modulus $\left(2\frac{I}{D}\right)$
10	10.750	20	.250	10.250	8.24	82.52	.5731	113.7	28.04	35.76	2.814	21.15
		30	.307	10.136	10.07	80.69	.5603	137.4	34.24	34.96	2.814	25.57
		40s	.365	10.020	11.90	78.86	.5475	160.7	40.48	34.20	2.814	29.90
		60x	.500	9.750	16.10	74.66	.5185	212.0	54.74	32.35	2.814	39.43
		80	.593	9.564	18.92	71.84	.4989	244.8	64.33	31.13	2.814	45.54
		100	.718	9.314	22.63	68.13	.4732	286.1	76.93	29.53	2.814	53.22
		120	.843	9.064	26.24	64.53	.4481	324.2	89.20	27.96	2.814	60.32
		140	1.000	8.750	30.63	60.13	.4176	367.8	104.13	26.06	2.814	68.43
		160	1.125	8.500	34.02	56.75	.3941	399.3	115.65	24.59	2.814	74.29
12	12.75	20	.250	12.250	9.82	117.86	.8185	191.8	33.38	51.07	3.338	30.2
		30	.330	12.090	12.87	114.80	.7972	248.4	43.77	49.74	3.338	39.0
		. . s	.375	12.000	14.58	113.10	.7854	279.3	49.56	49.00	3.338	43.8
		40	.406	11.938	15.77	111.93	.7773	300.3	53.53	48.50	3.338	47.1
		. . x	.500	11.750	19.24	108.43	.7528	361.5	65.42	46.92	3.338	56.7
		60	.562	11.626	21.52	106.16	.7372	400.4	73.16	46.00	3.338	62.8
		80	.687	11.376	26.03	101.64	.7058	475.1	88.51	44.04	3.338	74.6
		100	.843	11.064	31.53	96.14	.6677	561.6	107.20	41.66	3.338	88.1
		120	1.000	10.750	36.91	90.76	.6303	641.6	125.49	39.33	3.338	100.7
		140	1.125	10.500	41.08	86.59	.6013	700.5	133.68	37.52	3.338	109.9
		160	1.312	10.126	47.14	80.53	.5592	781.1	160.27	34.89	3.338	122.6
14	14.00	10	.250	13.500	10.80	143.14	.9940	255.3	36.71	62.03	3.665	36.6
		20	.312	13.376	13.42	140.52	.9758	314.4	45.68	60.89	3.665	45.0
		30s	.375	13.250	16.05	137.88	.9575	372.8	54.57	59.75	3.665	53.2
		40	.438	13.124	18.66	135.28	.9394	429.1	63.37	58.64	3.665	61.3
		. . x	.500	13.000	21.21	132.73	.9217	483.8	72.09	57.46	3.665	69.1
		60	.593	12.814	24.98	128.96	.8956	562.3	84.91	55.86	3.665	80.3
		80	.750	12.500	31.22	122.72	.8522	687.3	106.13	53.18	3.665	98.2
		100	.937	12.126	38.45	115.49	.8020	824.4	130.73	50.04	3.665	117.8
		120	1.093	11.814	44.32	109.62	.7612	929.6	150.67	47.45	3.665	132.8
		140	1.250	11.500	50.07	103.87	.7213	1027.0	170.22	45.01	3.665	146.8
		160	1.406	11.188	55.63	98.31	.6827	1117.0	189.12	42.60	3.665	159.6
16	16.00	10	.250	15.500	12.37	188.69	1.3103	383.7	42.05	81.74	4.189	48.0
		20	.312	15.376	15.38	185.69	1.2895	473.2	52.36	80.50	4.189	59.2
		30s	.375	15.250	18.41	182.65	1.2684	562.1	62.58	79.12	4.189	70.3
		40x	.500	15.000	24.35	176.72	1.2272	731.9	82.77	76.58	4.189	91.5
		60	.656	14.688	31.62	169.44	1.1766	932.4	107.50	73.42	4.189	116.6
		80	.843	14.314	40.14	160.92	1.1175	1155.8	136.46	69.73	4.189	144.5
		100	1.031	13.938	48.48	152.58	1.0596	1364.5	164.83	66.12	4.189	170.5
		120	1.218	13.564	56.56	144.50	1.0035	1555.8	192.29	62.62	4.189	194.5
		140	1.438	13.124	65.78	135.28	.9394	1760.3	223.64	58.64	4.189	220.0
		160	1.593	12.814	72.10	128.96	.8956	1893.5	245.11	55.83	4.189	236.7
18	18.00	10	.250	17.500	13.94	240.53	1.6703	549.1	47.39	104.21	4.712	61.1
		20	.312	17.376	17.34	237.13	1.6467	678.2	59.03	102.77	4.712	75.5
		. . s	.375	17.250	20.76	233.71	1.6230	806.7	70.59	101.18	4.712	89.6
		30	.438	17.124	24.17	230.30	1.5990	930.3	82.06	99.84	4.712	103.4
		. . x	.500	17.000	27.49	226.98	1.5763	1053.2	92.45	98.27	4.712	117.0
		40	.562	16.876	30.79	223.68	1.5533	1171.5	104.75	96.93	4.712	130.1
		60	.750	16.500	40.64	213.83	1.4849	1514.7	138.17	92.57	4.712	168.3
		80	.937	16.126	50.23	204.24	1.4183	1833.0	170.75	88.50	4.712	203.8
		100	1.156	15.688	61.17	193.30	1.3423	2180.0	207.96	83.76	4.712	242.3
		120	1.375	15.250	71.81	182.66	1.2684	2498.1	244.14	79.07	4.712	277.6
		140	1.562	14.876	80.66	173.80	1.2070	2749.0	274.23	75.32	4.712	305.5
		160	1.781	14.438	90.75	163.72	1.1369	3020.0	308.51	70.88	4.712	335.6
20	20.00	10	.250	19.500	15.51	298.65	2.0740	756.4	52.73	129.42	5.236	75.6
		20s	.375	19.250	23.12	290.04	2.0142	1113.0	78.60	125.67	5.236	111.3
		30x	.500	19.000	30.63	283.53	1.9690	1457.0	104.13	122.87	5.236	145.7
		40	.593	18.814	36.15	278.00	1.9305	1703.0	122.91	120.46	5.236	170.4
		60	.812	18.376	48.95	265.21	1.8417	2257.0	166.40	114.92	5.236	225.7
		80	1.031	17.938	61.44	252.72	1.7550	2772.0	208.87	109.51	5.236	277.1
		100	1.281	17.438	75.33	238.83	1.6585	3315.2	256.10	103.39	5.236	331.5
		120	1.500	17.000	87.18	226.98	1.5762	3754.0	296.37	98.35	5.236	375.5
		140	1.750	16.500	100.33	213.82	1.4849	4216.0	341.10	92.66	5.236	421.7
		160	1.968	16.064	111.49	202.67	1.4074	4585.5	379.01	87.74	5.236	458.5
24	24.00	10	.250	23.500	18.65	433.74	3.0121	1315.4	63.41	187.95	6.283	109.6
		20s	.375	23.250	27.83	424.56	2.9483	1942.0	94.62	183.95	6.283	161.9
		. . x	.500	23.000	36.91	415.48	2.8853	2549.5	125.49	179.87	6.283	212.5
		30	.562	22.876	41.39	411.00	2.8542	2843.0	140.80	178.09	6.283	237.0
		40	.687	22.626	50.31	402.07	2.7921	3421.3	171.17	174.23	6.283	285.1
		60	.968	22.064	70.04	382.35	2.6552	4652.8	238.11	165.52	6.283	387.7
		80	1.218	21.564	87.17	365.22	2.5362	5672.0	296.36	158.26	6.283	472.8
		100	1.531	20.938	108.07	344.32	2.3911	6849.9	367.40	149.06	6.283	570.8
		120	1.812	20.376	126.31	326.08	2.2645	7825.0	429.39	141.17	6.283	652.1
		140	2.062	19.876	142.11	310.28	2.1547	8625.0	483.13	134.45	6.283	718.9
		160	2.343	19.314	159.41	292.98	2.0346	9455.9	541.94	126.84	6.283	787.9

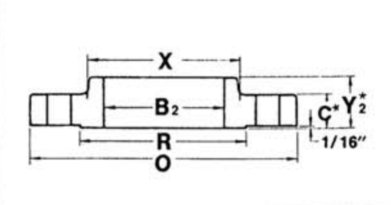
Courtesy of Crane Co.

FLANGES DIMENSIONS

WELDING NECK



SLIP-ON



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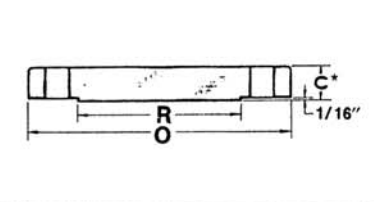
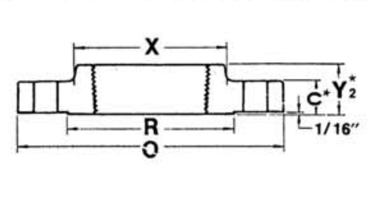
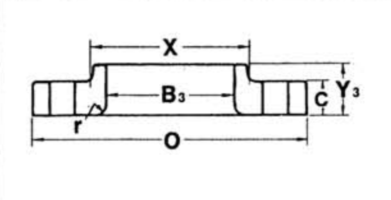


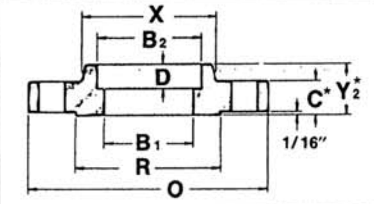
THREADED



LAP JOINT



SOCKET-WELD[3]



150-LB.

Nom. Pipe Size	Out-side Diam.	Thkn. (min.)	O.D. of Raised Face	Hub Diam.	Length thru Hub			Bore □			Depth of Socket	Approx. Weight (Lbs.)				Drilling		
					Wldg. Neck	Slip-on Thrd. Sock. W.	Lap Joint	Wldg.[2] Neck	Slip-on Sock. W.	Lap Joint		Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
	O	C	R	X	Y1	Y2	Y3	B1	B2	B3	D							
½	3½	7/16	1⅜	1 3/16	1⅞	⅝	⅝	0.62	0.88	0.90	⅜	2	1	1	1	4	⅝	2⅜
¾	3⅞	½	1 11/16	1½	2 1/16	⅝	⅝	0.82	1.09	1.11	7/16	2	2	2	2	4	⅝	2¾
1	4¼	9/16	2	1 15/16	2 3/16	11/16	11/16	1.05	1.36	1.38	½	3	2	2	2	4	⅝	3⅛
1¼	4⅝	⅝	2½	2 5/16	2¼	13/16	13/16	1.38	1.70	1.72	9/16	3	3	3	3	4	⅝	3½
1½	5	11/16	2⅞	2 9/16	2 7/16	⅞	⅞	1.61	1.95	1.97	⅝	4	3	3	4	4	⅝	3⅞
2	6	¾	3⅝	3 1/16	2½	1	1	2.07	2.44	2.46	11/16	6	5	5	5	4	¾	4¾
2½	7	⅞	4⅛	3 9/16	2¾	1⅛	1⅛	2.47	2.94	2.97	¾	8	7	7	7	4	¾	5½
3	7½	15/16	5	4¼	2¾	1 3/16	1 3/16	3.07	3.57	3.60	13/16	10	8	8	9	4	¾	6
3½	8½	15/16	5½	4 13/16	2 13/16	1¼	1¼	3.55	4.07	4.10	⅞	12	11	11	13	8	¾	7
4	9	15/16	6 3/16	5 5/16	3	1 5/16	1 5/16	4.03	4.57	4.60	15/16	15	13	13	17	8	¾	7½
5	10	15/16	7 5/16	6 7/16	3½	1 7/16	1 7/16	5.05	5.66	5.69	15/16	19	15	15	20	8	⅞	8½
6	11	1	8½	7 9/16	3½	1 9/16	1 9/16	6.07	6.72	6.75	1 1/16	24	19	19	26	8	⅞	9½
8	13½	1⅛	10⅝	9 11/16	4	1¾	1¾	7.98	8.72	8.75	1¼	39	30	30	45	8	⅞	11¾
10	16	1 3/16	12¾	12	4	1 15/16	1 15/16	10.02	10.88	10.92	1 5/16	52	43	43	70	12	1	14¼
12	19	1¼	15	14⅜	4½	2 3/16	2 3/16	12.00	12.88	12.92	1 9/16	80	64	64	110	12	1	17
14	21	1⅜	16¼	15¾	5	2¼	3⅛	13.25	14.14	14.18	1⅝	110	90	105	140	12	1⅛	18¾
16	23½	1 7/16	18½	18	5	2½	3 7/16	15.25	16.16	16.19	1¾	140	98	140	180	16	1⅛	21¼
18	25	1 9/16	21	19⅞	5½	2 11/16	3 13/16	17.25	18.18	18.20	1 15/16	150	130	160	220	16	1¼	22¾
20	27½	1 11/16	23	22	5 11/16	2⅞	4 1/16	19.25	20.20	20.25	2⅛	180	165	195	285	20	1¼	25
22	29½	1 13/16	25¼	24¼	5⅞	3⅛	4¼	21.25	22.22	22.25	2⅜	225	185	245	355	20	1⅜	27¼
24	32	1⅞	27¼	26⅛	6	3¼	4⅜	23.25	24.25	24.25	2½	260	220	275	430	20	1⅜	29½

ANSI B16.5 covers only sizes through 24″. Larger sizes as listed below have the same flange and drilling dimensions as Class 125 Cast Iron Flanges, ASA B16.1.

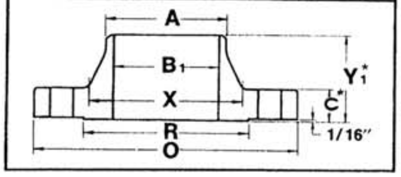
26	34¼	2	29¼	28½	5	3⅜	—	To be specified by purchaser	26.25	—	—	300	250	—	525	24	1⅜	31¾
28	36½	2 1/16	31¼	30¾	5 1/16	3 7/16	—		28.25	—	—	315	285	—	620	28	1⅜	34
30	38¾	2⅛	33¾	32¾	5⅛	3½	—		30.25	—	—	360	315	—	720	28	1⅜	36
32	41¾	2¼	35¾	35	5¼	3⅝	—		32.25	—	—	435	395	—	870	28	1⅝	38½
34	43¾	2 5/16	37¾	37	5 5/16	3 11/16	—		34.25	—	—	465	420	—	990	32	1⅝	40½
36	46	2⅜	40¼	39¼	5⅜	3¾	—		36.25	—	—	520	480	—	1125	32	1⅝	42¾
42	53	2⅝	47	46	5⅝	4	—		42.25	—	—	750	680	—	1625	36	1⅝	49½

Courtesy of Taylor Forge

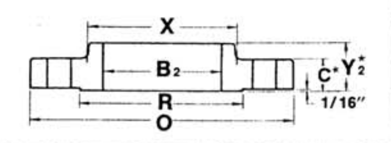
FLANGES

DIMENSIONS

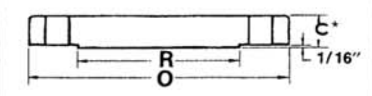
WELDING NECK



SLIP-ON



BLIND



300-lb.

Nom. Pipe Size	Out-side Diam. O	Thkn. (min.) C	O.D. of Raised Face R	Hub Diam. X	Length thru Hub: Widg. Neck Y_1	Length thru Hub: Slip-on Thrd. Sock. W. Y_2	Length thru Hub: Lap Joint Y_3	Bore □: Widg.[2] Neck B_1	Bore □: Slip-On Sock. W. B_2	Bore □: Lap Joint B_3	Depth of Sock. D	Approx. Weight (Lbs.): Widg. Neck	Approx. Weight (Lbs.): Slip-On Thrd. Sock. W.	Approx. Weight (Lbs.): Lap Joint	Approx. Weight (Lbs.): Blind	Drilling: No. Holes	Drilling: Diam. Holes	Drilling: Bolt Circle Diam.
½	3¾	9/16	1⅜	1½	2 1/16	⅞	⅞	0.62	0.88	0.90	⅜	2	2	2	2	4	⅝	2⅝
¾	4⅝	⅝	1 11/16	1⅞	2¼	1	1	0.82	1.09	1.11	7/16	3	3	3	3	4	¾	3¼
1	4⅞	11/16	2	2⅛	2 7/16	1 1/16	1 1/16	1.05	1.36	1.38	½	4	3	3	3	4	¾	3½
1¼	5¼	¾	2½	2½	2 9/16	1 1/16	1 1/16	1.38	1.70	1.72	9/16	5	4	4	4	4	¾	3⅞
1½	6⅛	13/16	2⅞	2¾	2 11/16	1 3/16	1 3/16	1.61	1.95	1.97	⅝	7	6	6	6	4	⅞	4½
2	6½	⅞	3⅝	3 5/16	2¾	1 5/16	1 5/16	2.07	2.44	2.46	11/16	9	7	7	8	8	¾	5
2½	7½	1	4⅛	3 15/16	3	1½	1½	2.47	2.94	2.97	¾	12	10	10	12	8	⅞	5⅞
3	8¼	1⅛	5	4⅝	3⅛	1 11/16	1 11/16	3.07	3.57	3.60	13/16	15	13	13	16	8	⅞	6⅝
3½	9	1 3/16	5½	5¼	3 3/16	1¾	1¾	3.55	4.07	4.10	—	18	17	17	21	8	⅞	7¼
4	10	1¼	6 3/16	5¾	3⅜	1⅞	1⅞	4.03	4.57	4.60	—	25	22	22	27	8	⅞	7⅞
5	11	1⅜	7 5/16	7	3⅞	2	2	5.05	5.66	5.69	—	32	28	28	35	8	⅞	9¼
6	12½	1 7/16	8½	8⅛	3⅞	2 1/16	2 1/16	6.07	6.72	6.75	—	42	39	39	50	12	⅞	10⅝
8	15	1⅝	10⅝	10¼	4⅜	2 7/16	2 7/16	7.98	8.72	8.75	—	67	58	58	81	12	1	13
10	17½	1⅞	12¾	12⅝	4⅝	2⅝	3¾	10.02	10.88	10.92	—	91	81	91	124	16	1⅛	15¼
12	20½	2	15	14¾	5⅛	2⅞	4	12.00	12.88	12.92	—	140	115	140	185	16	1¼	17¾
14	23	2⅛	16¼	16¾	5⅝	3	4⅜	13.25	14.14	14.18	—	180	165	190	250	20	1¼	20¼
16	25½	2¼	18½	19	5¾	3¼	4¾	15.25	16.16	16.19	—	250	190	250	295	20	1⅜	22½
18	28	2⅜	21	21	6¼	3½	5⅛	17.25	18.18	18.20	—	320	250	295	395	24	1⅜	24¾
20	30½	2½	23	23⅛	6⅜	3¾	5½	19.25	20.20	20.25	—	400	315	370	505	24	1⅜	27
22	33	2⅝	25¼	25¼	6½	4	5¾	21.25	22.22	22.25	—	465	370	435	640	24	1⅝	29¼
24	36	2¾	27¼	27⅝	6⅝	4 3/16	6	23.25	24.25	24.25	—	580	475	550	790	24	1⅝	32
MSS—SP44 Class 300** ■																ASTM A105-II		
26	38¼	3⅛	29½	28⅜	7¼	—	—	To be specified by purchaser	—	—	—	670	570	—	1050	28	1¾	34½
28	40¾	3⅜	31½	30½	7¾	—	—		—	—	—	810	720	—	1275	28	1¾	37
30	43	3⅝	33¾	32 5/16	8¼	—	—		—	—	—	930	810	—	1500	28	1⅞	39¼
32	45¼	3⅞	36	34 11/16	8¾	—	—		—	—	—	1025	890	—	1775	28	2	41½
34	47½	4	38	36⅞	9⅛	—	—		—	—	—	1200	1075	—	2025	28	2	43½
36	50	4⅛	40¼	39	9½	—	—		—	—	—	1300	1200	—	2275	32	2⅛	46
42	57	4⅝	47	45 7/16	10⅞	—	—		—	—	—	1740.	1610	—	3165	36	2⅛	52¾

400-lb.

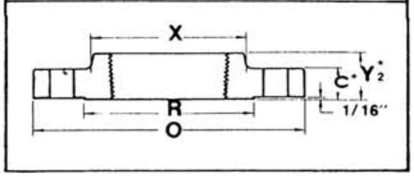
(NOTE: Sizes ½" thru 3½" are identical with 600 lb. flanges (see next page).

Nom. Pipe Size	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D	Widg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
4	10	1⅜	6 3/16	5¾	3½	2	2	To be specified by purchaser	4.57	4.60	Not manufactured in 400-lb.	35	26	25	33	8	1	7⅞
5	11	1½	7 5/16	7	4	2⅛	2⅛		5.66	5.69		43	31	29	44	8	1	9¼
6	12½	1⅝	8½	8⅛	4 1/16	2¼	2¼		6.72	6.75		57	44	42	61	12	1	10⅝
8	15	1⅞	10⅝	10¼	4⅝	2 11/16	2 11/16		8.72	8.75		89	67	64	100	12	1⅛	13
10	17½	2⅛	12¾	12⅝	4⅞	2⅞	4		10.88	10.92		125	91	110	155	16	1¼	15¼
12	20½	2¼	15	14¾	5⅜	3⅛	4¼		12.88	12.92		175	130	150	225	16	1⅜	17¾
14	23	2⅜	16¼	16¾	5⅞	3 5/16	4⅝		14.14	14.18		230	180	205	290	20	1⅜	20¼
16	25½	2½	18½	19	6	3 11/16	5		16.16	16.19		295	235	260	370	20	1½	22½
18	28	2⅝	21	21	6½	3⅞	5⅜		18.18	18.20		350	285	315	455	24	1½	24¾
20	30½	2¾	23	23⅛	6⅝	4	5¾		20.20	20.25		425	345	385	587	24	1⅝	27
22	33	2⅞	25¼	25¼	6¾	4¼	6		22.22	22.25		505	405	455	720	24	1¾	29¼
24	36	3	27¼	27⅝	6⅞	4½	6¼		24.25	24.25		620	510	570	890	24	1⅞	32
MSS—SP44 Class 400** ■																ASTM A105-II		
26	38¼	3½	29½	28⅝	7⅝	—	—		—	—		750	650	—	1125	28	1⅞	34½
28	40¾	3¾	31½	30 13/16	8½	—	—		—	—		880	780	—	1425	28	2	37
30	43	4	33¾	32 15/16	8⅝	—	—		—	—		1000	900	—	1675	28	2⅛	39¼
32	45¼	4¼	36	35	9⅛	—	—		—	—		1150	1025	—	1975	28	2⅛	41½
34	47½	4⅜	38	37 3/16	9½	—	—		—	—		1300	1150	—	2250	28	2⅛	43½
36	50	4½	40¼	39⅜	9⅞	—	—		—	—		1475	1325	—	2525	32	2⅛	46

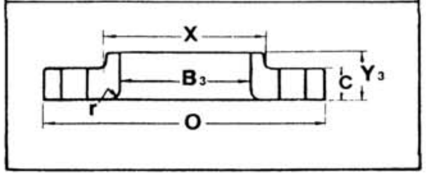
Courtesy of Taylor Forge

FLANGES DIMENSIONS

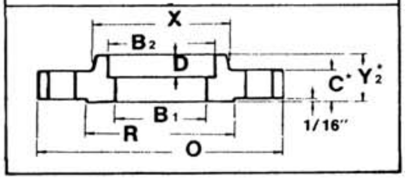
THREADED



LAP JOINT



SOCKET-WELD †



600-lb.

Nom. Pipe Size	Outside Diam.	Thkn. (min.)	O.D. of Raised Face	Hub Diam.	Length thru Hub			Bore□			Depth of Socket	Approx. Weight (Lbs.)				Drilling		
					Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Wldg. Neck	Slip-On Socket W.	Lap Joint		Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D							
½	3¾	9/16	1⅜	1½	2 1/16	⅞	⅞	To be specified by purchaser	0.88	0.90	⅜	2	2	2	2	4	⅝	2⅝
¾	4⅝	⅝	1 11/16	1⅞	2¼	1	1		1.09	1.11	7/16	4	3	3	3	4	¾	3¼
1	4⅞	11/16	2	2⅛	2 7/16	1 1/16	1 1/16		1 36	1.38	½	4	4	4	4	4	¾	3½
1¼	5¼	13/16	2½	2½	2⅝	1⅛	1⅛		1.70	1.72	9/16	6	5	5	5	4	¾	3⅞
1½	6⅛	⅞	2⅞	2¾	2¾	1¼	1¼		1.95	1.97	⅝	8	7	7	8	4	⅞	4½
2	6½	1	3⅝	3 5/16	2⅞	1 7/16	1 7/16		2.44	2.46	11/16	12	9	9	10	8	¾	5
2½	7½	1⅛	4⅛	3 15/16	3⅛	1⅝	1⅝		2.94	2.97	¾	18	13	12	15	8	⅞	5⅞
3	8¼	1¼	5	4⅝	3¼	1 13/16	1 13/16		3.57	3.60	13/16	23	16	15	20	8	⅞	6⅝
3½	9	1⅜	5½	5¼	3⅜	1 15/16	1 15/16		4.07	4.10	—	26	21	20	29	8	1	7¼
4	10¾	1½	6 3/16	6	4	2⅛	2⅛		4.57	4.60	—	42	37	36	41	8	1	8½
5	13	1¾	7 5/16	7 7/16	4½	2⅜	2⅜		5.66	5.69	—	68	63	61	68	8	1⅛	10½
6	14	1⅞	8½	8¾	4⅝	2⅝	2⅝		6.72	6.75	—	81	80	78	86	12	1⅛	11½
8	16½	2 3/16	10⅝	10¾	5¼	3	3		8.72	8.75	—	120	115	110	140	12	1¼	13¾
10	20	2½	12¾	13½	6	3⅜	4⅜		10.88	10.92	—	190	170	170	230	16	1⅜	17
12	22	2⅝	15	15¾	6⅛	3⅝	4⅝		12.88	12.92	—	225	200	200	295	20	1⅜	19¼
14	23¾	2¾	16¼	17	6½	3 11/16	5		14.14	14.18	—	280	230	250	355	20	1½	20¾
16	27	3	18½	19½	7	4 3/16	5½		16.16	16.19	—	390	330	365	495	20	1⅝	23¾
18	29¼	3¼	21	21½	7¼	4⅝	6		18.18	18.20	—	475	400	435	630	20	1¾	25¾
20	32	3½	23	24	7½	5	6½		20.20	20.25	—	590	510	570	810	24	1¾	28½
22	34¼	3¾	25¼	26¼	7¾	5¼	6⅞		22.22	22.25	—	720	590	670	1000	24	1⅞	30⅝
24	37	4	27¼	28¼	8	5½	7¼		24.25	24.25	—	830	730	810	1250	24	2	33
MSS—SP44 Class 600** ■																ASTM A105-II		
26	40	4¼	29½	29 7/16	8¾	—	—		—	—	—	1025	950	—	1525	28	2	36
28	42¼	4⅜	31½	31⅝	9¼	—	—		—	—	—	1175	1075	—	1750	28	2⅛	38
30	44½	4½	33¾	33 15/16	9¾	—	—		—	—	—	1300	1175	—	2000	28	2⅛	40¼
32	47	4⅝	36	36⅛	10¼	—	—		—	—	—	1500	1375	—	2300	28	2⅜	42½
34	49	4¾	38	38 5/16	10⅝	—	—		—	—	—	1650	1500	—	2575	28	2⅜	44½
36	51¾	4⅞	40¼	40⅝	11⅛	—	—		—	—	—	1750	1600	—	2950	28	2⅝	47

900-lb.

(NOTE: Sizes ½" thru 2½" are identical with 1500 lb. flanges (see next page).

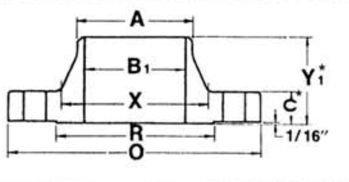
Nom. Pipe Size	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D	Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
3	9½	1½	5	5	4	2⅛	2⅛	To be specified by purchaser	3.57	3.60	—	31	26	25	29	8	1	7½
4	11½	1¾	6 3/16	6¼	4½	2¾	2¾		4.57	4.60	—	53	53	51	54	8	1¼	9¼
5	13¾	2	7 5/16	7½	5	3⅛	3⅛		5.66	5.69	—	86	83	81	87	8	1⅜	11
6	15	2 3/16	8½	9¼	5½	3⅜	3⅜		6.72	6.75	—	110	110	105	115	12	1¼	12½
8	18½	2½	10⅝	11¾	6⅜	4	4½		8.72	8.75	—	175	170	190	200	12	1½	15½
10	21½	2¾	12¾	14½	7¼	4¼	5		10.88	10.92	—	260	245	275	290	16	1½	18½
12	24	3⅛	15	16½	7⅞	4⅝	5⅝		12.88	12.92	—	325	325	370	415	20	1½	21
14	25¼	3⅜	16¼	17¾	8⅜	5⅛	6⅛		14.14	14.18	—	400	400	415	520	20	1⅝	22
16	27¾	3½	18½	20	8½	5¼	6½		16.16	16.19	—	495	425	465	600	20	1¾	24¼
18	31	4	21	22¼	9	6	7½		18.18	18.20	—	680	600	650	850	20	2	27
20	33¾	4¼	23	24½	9¾	6¼	8¼		20.20	20.25	—	830	730	810	1075	20	2⅛	29½
22	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
24	41	5½	27¼	29½	11½	8	10½		24.25	24.25	—	1500	1400	1550	2025	20	2⅝	35½
MSS—SP44 Class 900** ■																ASTM A105-II		
26	42¾	5½	29½	30½	11¼	—	—		—	—	—	1575	1525	—	2200	20	2⅞	37½
28	46	5⅝	31½	32¾	11¾	—	—		—	—	—	1850	1800	—	2575	20	3⅛	40¼
30	48½	5⅞	33¾	35	12¼	—	—		—	—	—	2150	2075	—	3025	20	3⅛	42¾
32	51¾	6¼	36	37¼	13	—	—		—	—	—	2575	2500	—	3650	20	3⅜	45½
34	55	6½	38	39⅝	13¾	—	—		—	—	—	3025	2950	—	4275	20	3⅝	48¼
36	57½	6¾	40¼	41⅞	14¼	—	—		—	—	—	3450	3350	—	4900	20	3⅝	50¾

Courtesy of Taylor Forge

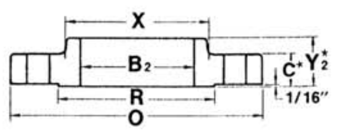
FLANGES

DIMENSIONS

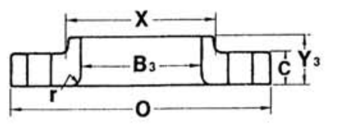
WELDING NECK



SLIP-ON



LAP JOINT



1500-lb.

Nom. Pipe Size	Out-side Diam.	Thkn. (min.)	O.D. of Raised Face	Hub Diam.	Length thru Hub			Bore□			Depth of Socket	Approx. Wgt. (Lbs.)				Drilling		
					Wldg. Neck	Slip-On Thrd. ♦ Sock. W.	Lap Joint	Wldg. Neck	Slip-on Sock. W.	Lap Joint		Wldg. Neck	Slip-On♦ Thrd. Sock. W.	Lap Joint	Blind♦	No. Holes	Diam. Holes	Bolt Circle Diam.
	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D							
1/2	4 3/4	7/8	1 3/8	1 1/2	2 3/8	1 1/4	1 1/4	To be specified by customer	0.88	0.90	3/8	5	4	4	4	4	7/8	3 1/4
3/4	5 1/8	1	1 11/16	1 3/4	2 3/4	1 3/8	1 3/8		1.09	1.11	7/16	6	5	5	6	4	7/8	3 1/2
1	5 7/8	1 1/8	2	2 1/16	2 7/8	1 5/8	1 5/8		1.36	1.38	1/2	9	8	8	8	4	1	4
1 1/4	6 1/4	1 1/8	2 1/2	2 1/2	2 7/8	1 5/8	1 5/8		1.70	1.72	9/16	10	9	9	9	4	1	4 3/8
1 1/2	7	1 1/4	2 7/8	2 3/4	3 1/4	1 3/4	1 3/4		1.95	1.97	5/8	13	12	12	13	4	1 1/8	4 7/8
2	8 1/2	1 1/2	3 5/8	4 1/8	4	2 1/4	2 1/4		2.44	2.46	11/16	25	25	25	25	8	1	6 1/2
2 1/2	9 5/8	1 5/8	4 1/8	4 7/8	4 1/6	2 1/2	2 1/2		2.94	2.97	3/4	36	36	35	35	8	1 1/8	7 1/2
3	10 1/2	1 7/8	5	5 1/4	4 5/8	2 7/8	2 7/8		3.57	3.60	—	48	48	47	48	8	1 1/4	8
3 1/2	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
4	12 1/4	2 1/8	6 3/16	6 3/8	4 7/8	3 9/16	3 9/16		4.57	4.60	—	73	73	75	73	8	1 3/8	9 1/2
5	14 3/4	2 7/8	7 5/16	7 3/4	6 1/8	4 1/8	4 1/8		5.66	5.69	—	130	130	140	140	8	1 5/8	11 1/2
6	15 1/2	3 1/4	8 1/2	9	6 3/4	4 11/16	4 11/16		6.72	6.75	—	165	165	170	160	12	1 1/2	12 1/2
8	19	3 5/8	10 5/8	11 1/2	8 3/8	5 5/8	5 5/8		8.72	8.75	—	275	260	285	300	12	1 3/4	15 1/2
10	23	4 1/4	12 3/4	14 1/2	10	6 1/4	7		10.88	10.92	—	455	435	485	510	12	2	19
12	26 1/2	4 7/8	15	17 3/4	11 1/8	7 1/8	8 5/8		12.88	12.92	—	690	580	630	690	16	2 1/8	22 1/2
14	29 1/2	5 1/4	16 1/4	19 1/2	11 3/4	—	9 1/2		—	14.18	—	940	—	890	975	16	2 3/8	25
16	32 1/2	5 3/4	18 1/2	21 3/4	12 1/4	—	10 1/4		—	16.19	—	1250	—	1150	1300	16	2 5/8	27 3/4
18	36	6 3/8	21	23 1/2	12 7/8	—	10 7/8		—	18.20	—	1625	—	1475	1750	16	2 7/8	30 1/2
20	38 3/4	7	23	25 1/4	14	—	11 1/2		—	20.25	—	2050	—	1775	2225	16	3 1/8	32 3/4
22	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
24	46	8	27 1/4	30	16	—	13		—	24.25	—	3325	—	2825	3625	16	3 5/8	39
2500-lb.																		
1/2	5 1/4	1 3/16	1 3/8	1 11/16	2 7/8	1 9/16	1 9/16	To be specified by customer	0.88	0.90	Not manufactured in 2500-lb.	7	7	7	7	4	7/8	3 1/2
3/4	5 1/2	1 1/4	1 11/16	2	3 1/8	1 11/16	1 11/16		1.09	1.11		8	8	8	8	4	7/8	3 3/4
1	6 1/4	1 3/8	2	2 1/4	3 1/2	1 7/8	1 7/8		1.36	1.38		12	11	11	11	4	1	4 1/4
1 1/4	7 1/4	1 1/2	2 1/2	2 7/8	3 3/4	2 1/16	2 1/16		1.70	1.72		17	16	16	17	4	1 1/8	5 1/8
1 1/2	8	1 3/4	2 7/8	3 1/8	4 3/8	2 3/8	2 3/8		1.95	1.97		25	22	22	23	4	1 1/4	5 3/4
2	9 1/4	2	3 5/8	3 3/4	5	2 3/4	2 3/4		2.44	2.46		42	38	37	39	8	1 1/8	6 3/4
2 1/2	10 1/2	2 1/4	4 1/8	4 1/2	5 5/8	3 1/8	3 1/8		2.94	2.97		52	55	53	56	8	1 1/4	7 3/4
3	12	2 5/8	5	5 1/4	6 5/8	3 5/8	3 5/8		3.57	3.60		94	83	80	86	8	1 3/8	9
3 1/2	—	—	—	—	—	—	—		—	—		—	—	—	—	—	—	—
4	14	3	6 3/16	6 1/2	7 1/2	4 1/4	4 1/4		4.57	4.60		145	125	120	135	8	1 5/8	10 3/4
5	16 1/2	3 5/8	7 5/16	8	9	5 1/8	5 1/8		5.66	5.69		245	210	205	225	8	1 7/8	12 3/4
6	19	4 1/4	8 1/2	9 1/4	10 3/4	6	6		6.72	6.75		380	325	315	345	8	2 1/8	14 1/2
8	21 3/4	5	10 5/8	12	12 1/2	7	7		8.72	8.75		580	485	470	530	12	2 1/8	17 1/4
10	26 1/2	6 1/2	12 3/4	14 3/4	16 1/2	9	9		10.88	10.92		1075	930	900	1025	12	2 5/8	21 1/4
12	30	7 1/4	15	17 3/8	18 1/4	10	10		12.88	12.92		1525	1100	1100	1300	12	2 7/8	24 3/8

1. Dimensions are in inches. Prices on application.
2. Standard bore will be furnished unless otherwise specified.
3. Socket Weld figs. are not mfd. in 150# type over 24", in 300# and 600# over 3", in 1500# over 2 1/2", in 400# and 2500# in any size.
4. Specifications—All Taylor Forge flanges conform to ANSI Std. B16.5 or MSS SP44 as applicable and to ASTM Spec. A181 (for 150# and 300# flanges) or A105 (for 400# and heavier flanges.
5. Welding bevel standards and tolerances.
6. Pressure—Temperature ratings.
7. Threading details.
8. Large diameter flanges.

□ Minimum bores.

*Facings: 150# and 300# flanges (except Lap Joint) furnished with 1-1/16" raised face, which is included in the thickness and hub length shown, 400# and heavier flanges (except Lap Joint) furnished with 1/4" raised face, which is not included in thickness or hub length dimensions.

**Refer to Taylor Forge Pipeline Catalog 723 for complete listings of MSS-SP44 and API 605 flanges.

■ Dimension and blind flange is same as companion flange, however, this is not true for MSS blind flanges, class 300 or heavier, 26" and larger, which have a greater thickness.

Courtesy of Taylor Forge

LINEAR CONVERSION

Fractions of an Inch
To Decimals of an Inch and to Millimeters

Fraction				Decimal	Millimeter
			1/64	.015625	0.39688
		1/32		.03125	0.79375
			3/64	.046875	1.19063
	1/16			.0625	1.58750
			5/64	.078125	1.98438
		3/32		.09375	2.38125
			7/64	.109375	2.77813
1/8				.125	3.17501
			9/64	.140625	3.57188
		5/32		.15625	3.96876
			11/64	.171875	4.36563
	3/16			.1875	4.76251
			13/64	.203125	5.15939
		7/32		.21875	5.55626
			15/64	.234375	5.95314
1/4				.25	6.35001
			17/64	.265625	6.74689
		9/32		.28125	7.14376
			19/64	.296875	7.54064
	5/16			.3125	7.93752
			21/64	.328125	8.33439
		11/32		.34375	8.73127
			23/64	.359375	9.12814
3/8				.375	9.52502
			25/64	.390625	9.92189
		13/32		.40625	10.31877
			27/64	.421875	10.71565
	7/16			.4375	11.11252
			29/64	.453125	11.50940
		15/32		.46875	11.90627
			31/64	.484375	12.30315
1/2				.5	12.70002

Fraction				Decimal	Millimeter
			33/64	.515625	13.09690
		17/32		.53125	13.49378
			35/64	.546875	13.89065
	9/16			.5625	14.28753
			37/64	.578125	14.68440
		19/32		.59375	15.08128
			39/64	.609375	15.47816
5/8				.625	15.87503
			41/64	.640625	16.27191
		21/32		.65625	16.66878
			43/64	.671875	17.06566
	11/16			.6875	17.46253
			45/64	.703125	17.85941
		23/32		.71875	18.25629
			47/64	.734375	18.65316
3/4				.75	19.05004
			49/64	.765625	19.44691
		25/32		.78125	19.84379
			51/64	.796875	20.24066
	13/16			.8125	20.63754
			53/64	.828125	21.03442
		27/32		.84375	21.43129
			55/64	.859375	21.82817
7/8				.875	22.22504
			57/64	.890625	22.62192
		29/32		.90625	23.01880
			59/64	.921875	23.41567
	15/16			.9375	23.81255
			61/64	.953125	24.20942
		31/32		.96875	24.60630
			63/64	.984375	25.00317
1				1.0	25.40005

Courtesy of Crane Co.

LINEAR CONVERSION

Inches to Millimeters

(1 inch = 25.4 millimeters)

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.8	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.5	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.2	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.9	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.3	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.8	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.5	300.0	301.6	303.2
12	304.8	306.4	308.0	309.6	311.2	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.9	325.4	327.0	328.6
13	330.2	331.8	333.4	335.0	336.6	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.3	350.8	352.4	354.0
14	355.6	357.2	358.8	360.4	362.0	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.7	376.2	377.8	379.4
15	381.0	382.6	384.2	385.8	387.4	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.1	401.6	403.2	404.8
16	406.4	408.0	409.6	411.2	412.8	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.5	427.0	428.6	430.2
17	431.8	433.4	435.0	436.6	438.2	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.9	452.4	454.0	455.6
18	457.2	458.8	460.4	462.0	463.6	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.3	477.8	479.4	481.0
19	482.6	484.2	485.8	487.4	489.0	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.7	503.2	504.8	506.4
20	508.0	509.6	511.2	512.8	514.4	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.1	528.6	530.2	531.8
21	533.4	535.0	536.6	538.2	539.8	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.5	554.0	555.6	557.2
22	558.8	560.4	562.0	563.6	565.2	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.9	579.4	581.0	582.6
23	584.2	585.8	587.4	589.0	590.6	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.3	604.8	606.4	608.0
24	609.6	611.2	612.8	614.4	616.0	617.5	619.1	620.7	622.3	623.9	625.5	627.1	628.7	630.2	631.8	633.4
25	635.0	636.6	638.2	639.8	641.4	642.9	644.5	646.1	647.7	649.3	650.9	652.5	654.1	655.6	657.2	658.8
26	660.4	662.0	663.6	665.2	666.8	668.3	669.9	671.5	673.1	674.7	676.3	677.9	679.5	681.0	682.6	684.2
27	685.8	687.4	689.0	690.6	692.2	693.7	695.3	696.9	698.5	700.1	701.7	703.3	704.9	706.4	708.0	709.6
28	711.2	712.8	714.4	716.0	717.6	719.1	720.7	722.3	723.9	725.5	727.1	728.7	730.3	731.8	733.4	735.0
29	736.6	738.2	739.8	714.4	743.0	744.5	746.1	747.7	749.3	750.9	752.5	754.1	755.7	757.2	758.8	760.4
30	762.0	763.6	765.2	766.8	768.4	769.9	771.5	773.1	774.7	776.3	777.9	779.5	781.1	782.6	784.2	785.8
31	787.4	789.0	790.6	792.2	793.8	795.3	796.9	798.5	800.1	801.7	803.3	804.9	806.5	808.0	809.6	811.2
32	812.8	814.4	816.0	817.6	819.2	820.7	822.3	823.9	825.5	827.1	828.7	830.3	831.9	833.4	835.0	836.6
33	838.2	839.8	841.4	843.0	844.6	846.1	847.7	849.3	850.9	852.5	854.1	855.7	857.3	858.8	860.4	862.0
34	863.6	865.2	866.8	868.4	870.0	871.5	873.1	874.7	876.3	877.9	879.5	881.1	882.7	884.2	885.8	887.4
35	889.0	890.6	892.2	893.8	895.4	896.9	898.5	900.1	901.7	903.3	904.9	906.5	908.1	909.6	911.2	912.8
36	914.4	916.0	917.6	919.2	920.8	922.3	923.9	925.5	927.1	928.7	930.3	931.9	933.5	935.0	936.6	938.2
37	939.8	941.4	943.0	944.6	946.2	947.7	949.3	950.9	952.5	954.1	955.7	957.3	958.9	960.4	962.0	963.6
38	965.2	966.8	968.4	970.0	971.6	973.1	974.7	976.3	977.9	979.5	981.1	982.7	984.3	985.8	987.4	989.0
39	990.6	992.2	993.8	995.4	997.0	998.5	1000.1	1001.7	1003.3	1004.9	1006.5	1008.1	1009.7	1011.2	1012.8	1014.4
40	1016.0	1017.6	1019.2	1020.8	1022.4	1023.9	1025.5	1027.1	1028.7	1030.3	1031.9	1033.5	1035.1	1036.6	1038.2	1039.8
41	1041.4	1043.0	1044.6	1046.2	1047.8	1049.3	1050.9	1052.5	1054.1	1055.7	1057.3	1058.9	1060.5	1062.0	1063.6	1065.2
42	1066.8	1068.4	1070.0	1071.6	1073.2	1074.7	1076.3	1077.9	1079.5	1081.1	1082.7	1084.3	1085.9	1087.4	1089.0	1090.6
43	1092.2	1093.8	1095.4	1097.0	1098.6	1100.1	1101.7	1103.3	1104.9	1106.5	1108.1	1109.7	1111.3	1112.8	1114.4	1116.0
44	1117.6	1119.2	1120.8	1122.4	1124.0	1125.5	1127.1	1128.7	1130.3	1131.9	1133.5	1135.1	1136.7	1138.2	1139.8	1141.4
45	1143.0	1144.6	1146.2	1147.8	1149.4	1150.9	1152.5	1154.1	1155.7	1157.3	1158.9	1160.5	1162.1	1163.6	1165.2	1166.8
46	1168.4	1170.0	1171.6	1173.2	1174.8	1176.3	1177.9	1179.5	1181.1	1182.7	1184.3	1185.9	1187.5	1189.0	1190.6	1192.2
47	1193.8	1195.4	1197.0	1198.6	1200.2	1201.7	1203.3	1204.9	1206.5	1208.1	1209.7	1211.3	1212.9	1214.4	1216.0	1217.6
48	1219.2	1220.8	1222.4	1224.0	1225.6	1227.1	1228.7	1230.3	1231.9	1233.5	1235.1	1236.7	1238.3	1239.8	1241.4	1243.0
49	1244.6	1246.2	1247.8	1249.4	1251.0	1252.5	1254.1	1255.7	1257.3	1258.9	1260.5	1262.1	1263.7	1265.2	1266.8	1268.4
50	1270.0	1271.6	1273.2	1274.8	1276.4	1277.9	1279.5	1281.1	1282.7	1284.3	1285.9	1287.5	1289.1	1290.6	1292.2	1293.8

Courtesy of Crane Co.

LINEAR CONVERSION

Decimals of an Inch to Millimeters

(0.10 inch = 2.54 millimeters)

Inches	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	Inches
0.00	0.00	0.25	0.51	0.76	1.02	1.27	1.52	1.78	2.03	2.29	0.00
.10	2.54	2.79	3.05	3.30	3.56	3.81	4.06	4.32	4.57	4.83	.10
.20	5.08	5.33	5.59	5.84	6.10	6.35	6.60	6.86	7.11	7.37	.20
.30	7.62	7.87	8.13	8.38	8.64	8.89	9.14	9.40	9.65	9.91	.30
.40	10.16	10.41	10.67	10.92	11.18	11.43	11.68	11.94	12.19	12.45	.40
.50	12.70	12.95	13.21	13.46	13.72	13.97	14.22	14.48	14.73	14.99	.50
.60	15.24	15.49	15.75	16.00	16.26	16.51	16.76	17.02	17.27	17.53	.60
.70	17.78	18.03	18.29	18.54	18.80	19.05	19.30	19.56	19.81	20.07	.70
.80	20.32	20.57	20.83	21.08	21.34	21.59	21.84	22.10	22.35	22.61	.80
.90	22.86	23.11	23.37	23.62	23.88	24.13	24.38	24.64	24.89	25.15	.90

Millimeters to Inches

(1 millimeter = 0.03937 inch)

Millimeters	0	1	2	3	4	5	6	7	8	9	Millimeters
0	0.00	0.039	0.079	0.118	0.157	0.197	0.236	0.276	0.315	0.354	0
10	0.39	0.43	0.47	0.51	0.55	0.59	0.63	0.67	0.71	0.75	10
20	0.79	0.83	0.87	0.91	0.94	0.98	1.02	1.06	1.10	1.14	20
30	1.18	1.22	1.26	1.30	1.34	1.38	1.42	1.46	1.50	1.54	30
40	1.57	1.61	1.65	1.69	1.73	1.77	1.81	1.85	1.89	1.93	40
50	1.97	2.01	2.05	2.09	2.13	2.17	2.20	2.24	2.28	2.32	50
60	2.36	2.40	2.44	2.48	2.52	2.56	2.60	2.64	2.68	2.72	60
70	2.76	2.80	2.83	2.87	2.91	2.95	2.99	3.03	3.07	3.11	70
80	3.15	3.19	3.23	3.27	3.31	3.35	3.39	3.43	3.46	3.50	80
90	3.54	3.58	3.62	3.66	3.70	3.74	3.78	3.82	3.86	3.90	90
100	3.94	3.98	4.02	4.06	4.09	4.13	4.17	4.21	4.25	4.29	100
110	4.33	4.37	4.41	4.45	4.49	4.53	4.57	4.61	4.65	4.69	110
120	4.72	4.76	4.80	4.84	4.88	4.92	4.96	5.00	5.04	5.08	120
130	5.12	5.16	5.20	5.24	5.28	5.31	5.35	5.39	5.43	5.47	130
140	5.51	5.55	5.59	5.63	5.67	5.71	5.75	5.79	5.83	5.87	140
150	5.91	5.94	5.98	6.02	6.06	6.10	6.14	6.18	6.22	6.26	150
160	6.30	6.34	6.38	6.42	6.46	6.50	6.54	6.57	6.61	6.65	160
170	6.69	6.73	6.77	6.81	6.85	6.89	6.93	6.97	7.01	7.05	170
180	7.09	7.13	7.17	7.20	7.24	7.28	7.32	7.36	7.40	7.44	180
190	7.48	7.52	7.56	7.60	7.64	7.68	7.72	7.76	7.80	7.83	190
200	7.87	7.91	7.95	7.99	8.03	8.07	8.11	8.15	8.19	8.23	200
210	8.27	8.31	8.35	8.39	8.43	8.46	8.50	8.54	8.58	8.62	210
220	8.66	8.70	8.74	8.78	8.82	8.86	8.90	8.94	8.98	9.02	220
230	9.06	9.09	9.13	9.17	9.21	9.25	9.29	9.33	9.37	9.41	230
240	9.45	9.49	9.53	9.57	9.61	9.65	9.69	9.72	9.76	9.80	240
250	9.84	9.88	9.92	9.96	10.00	10.04	10.08	10.12	10.16	10.20	250
260	10.24	10.28	10.31	10.35	10.39	10.43	10.47	10.51	10.55	10.59	260
270	10.63	10.67	10.71	10.75	10.79	10.83	10.87	10.91	10.94	10.98	270
280	11.02	11.06	11.10	11.14	11.18	11.22	11.26	11.30	11.34	11.38	280
290	11.42	11.46	11.50	11.54	11.57	11.61	11.65	11.69	11.73	11.77	290
300	11.81	11.85	11.89	11.93	11.97	12.01	12.05	12.09	12.13	12.17	300
310	12.20	12.24	12.28	12.32	12.36	12.40	12.44	12.48	12.52	12.56	310
320	12.60	12.64	12.68	12.72	12.76	12.80	12.83	12.87	12.91	12.95	320
330	12.99	13.03	13.07	13.11	13.15	13.19	13.23	13.27	13.31	13.35	330
340	13.39	13.43	13.46	13.50	13.54	13.58	13.62	13.66	13.70	13.74	340
350	13.78	13.82	13.86	13.90	13.94	13.98	14.02	14.06	14.09	14.13	350
360	14.17	14.21	14.25	14.29	14.33	14.37	14.41	14.45	14.49	14.53	360
370	14.57	14.61	14.65	14.69	14.72	14.76	14.80	14.84	14.88	14.92	370
380	14.96	15.00	15.04	15.08	15.12	15.16	15.20	15.24	15.28	15.31	380
390	15.35	15.39	15.43	15.47	15.51	15.55	15.59	15.63	15.67	15.71	390

(continued on next page)

Courtesy of Crane Co.

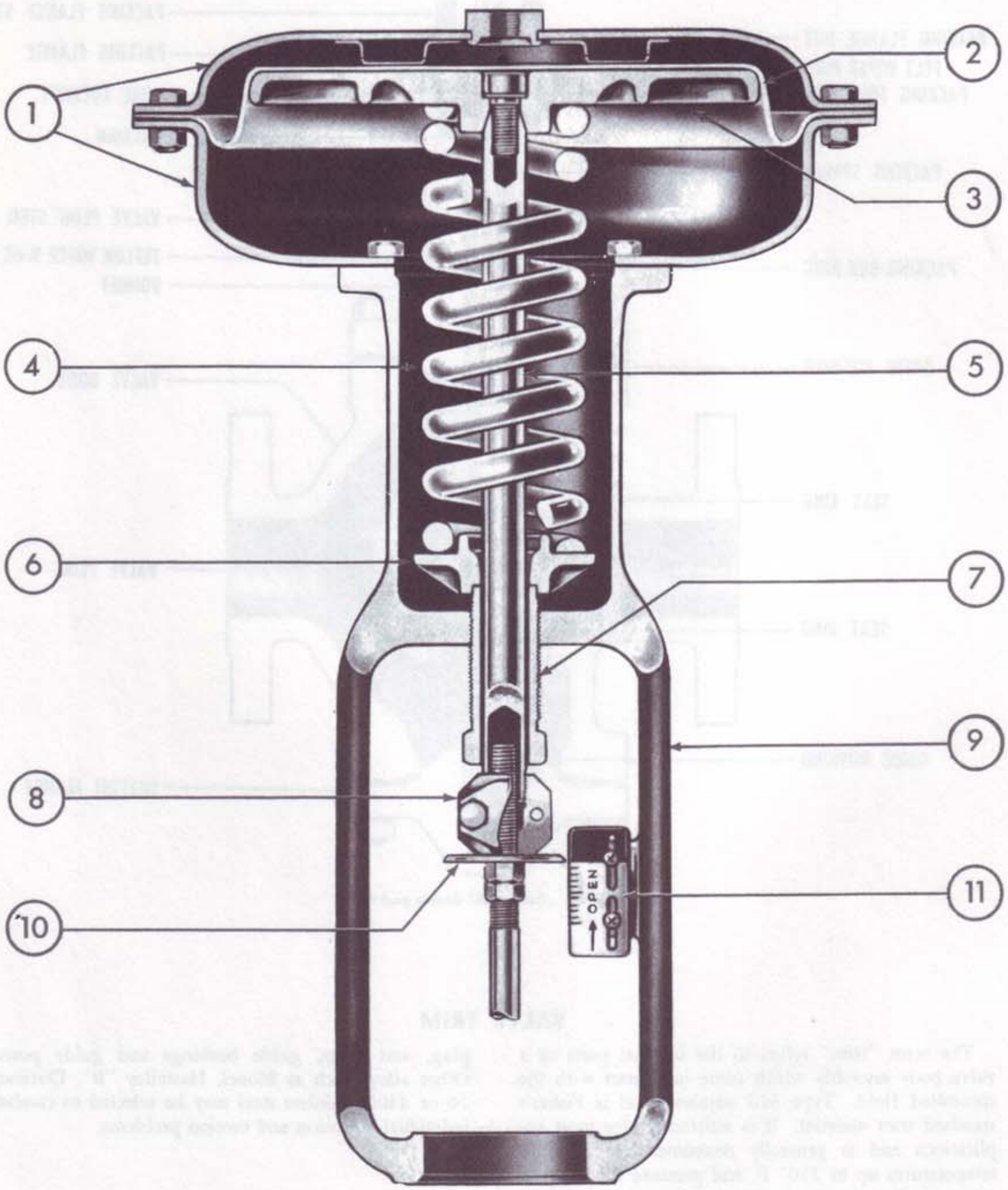
LINEAR CONVERSION
Millimeters to inches—cont.

Millimeters	0	1	2	3	4	5	6	7	8	9	Millimeters
400	15.75	15.79	15.83	15.87	15.91	15.94	15.98	16.02	16.06	16.10	400
410	16.14	16.18	16.22	16.26	16.30	16.34	16.38	16.42	16.46	16.50	410
420	16.54	16.57	16.61	16.65	16.69	16.73	16.77	16.81	16.85	16.89	420
430	16.93	16.97	17.01	17.05	17.09	17.13	17.17	17.20	17.24	17.28	430
440	17.32	17.36	17.40	17.44	17.48	17.52	17.56	17.60	17.64	17.68	440
450	17.72	17.76	17.80	17.83	17.87	17.91	17.95	17.99	18.03	18.07	450
460	18.11	18.15	18.19	18.23	18.27	18.31	18.35	18.39	18.43	18.46	460
470	18.50	18.54	18.58	18.62	18.66	18.70	18.74	18.78	18.82	18.86	470
480	18.90	18.94	18.98	19.02	19.06	19.09	19.13	19.17	19.21	19.25	480
490	19.29	19.33	19.37	19.41	19.45	19.49	19.53	19.57	19.61	19.65	490
500	19.69	19.72	19.76	19.80	19.84	19.88	19.92	19.96	20.00	20.04	500
510	20.08	20.12	20.16	20.20	20.24	20.28	20.31	20.35	20.39	20.43	510
520	20.47	20.51	20.55	20.59	20.63	20.67	20.71	20.75	20.79	20.83	520
530	20.87	20.91	20.94	20.98	21.02	21.06	21.10	21.14	21.18	21.22	530
540	21.26	21.30	21.34	21.38	21.42	21.46	21.50	21.54	21.58	21.61	540
550	21.65	21.69	21.73	21.77	21.81	21.85	21.89	21.93	21.97	22.01	550
560	22.05	22.09	22.13	22.17	22.20	22.24	22.28	22.32	22.36	22.40	560
570	22.44	22.48	22.52	22.56	22.60	22.64	22.68	22.72	22.76	22.80	570
580	22.83	22.87	22.91	22.95	22.99	23.03	23.07	23.11	23.15	23.19	580
590	23.23	23.27	23.31	23.35	23.39	23.43	23.46	23.50	23.54	23.58	590
600	23.62	23.66	23.70	23.74	23.78	23.82	23.86	23.90	23.94	23.98	600
610	24.02	24.06	24.09	24.13	24.17	24.21	24.25	24.29	24.33	24.37	610
620	24.41	24.45	24.49	24.53	24.57	24.61	24.65	24.68	24.72	24.76	620
630	24.80	24.84	24.88	24.92	24.96	25.00	25.04	25.08	25.12	25.16	630
640	25.20	25.24	25.28	25.31	25.35	25.39	25.43	25.47	25.51	25.55	640
650	25.59	25.63	25.67	25.71	25.75	25.79	25.83	25.87	25.91	25.94	650
660	25.98	26.02	26.06	26.10	26.14	26.18	26.22	26.26	26.30	26.34	660
670	26.38	26.42	26.46	26.50	26.54	26.57	26.61	26.65	26.69	26.73	670
680	26.77	26.81	26.85	26.89	26.93	26.97	27.01	27.05	27.09	27.13	680
690	27.17	27.20	27.24	27.28	27.32	27.36	27.40	27.44	27.48	27.52	690
700	27.56	27.60	27.64	27.68	27.72	27.76	27.80	27.83	27.87	27.91	700
710	27.95	27.99	28.03	28.07	28.11	28.15	28.19	28.23	28.27	28.31	710
720	28.35	28.39	28.43	28.46	28.50	28.54	28.58	28.62	28.66	28.70	720
730	28.74	28.78	28.82	28.86	28.90	28.94	28.98	29.02	29.06	29.09	730
740	29.13	29.17	29.21	29.25	29.29	29.33	29.37	29.41	29.45	29.49	740
750	29.53	29.57	29.61	29.65	29.68	29.72	29.76	29.80	29.84	29.88	750
760	29.92	29.96	30.00	30.04	30.08	30.12	30.16	30.20	30.24	30.28	760
770	30.31	30.35	30.39	30.43	30.47	30.51	30.55	30.59	30.63	30.67	770
780	30.71	30.75	30.79	30.83	30.87	30.91	30.94	30.98	31.02	31.06	780
790	31.10	31.14	31.18	31.22	31.26	31.30	31.34	31.38	31.42	31.46	790
800	31.50	31.54	31.57	31.61	31.65	31.69	31.73	31.77	31.81	31.85	800
810	31.89	31.93	31.97	32.01	32.05	32.09	32.13	32.17	32.20	32.24	810
820	32.28	32.32	32.36	32.40	32.44	32.48	32.52	32.56	32.60	32.64	820
830	32.68	32.72	32.76	32.80	32.83	32.87	32.91	32.95	32.99	33.03	830
840	33.07	33.11	33.15	33.19	33.23	33.27	33.31	33.35	33.39	33.43	840
850	33.46	33.50	33.54	33.58	33.62	33.66	33.70	33.74	33.78	33.82	850
860	33.86	33.90	33.94	33.98	34.02	34.06	34.09	34.13	34.17	34.21	860
870	34.25	34.29	34.33	34.37	34.41	34.45	34.49	34.53	34.57	34.61	870
880	34.65	34.68	34.72	34.76	34.80	34.84	34.88	34.92	34.96	35.00	880
890	35.04	35.08	35.12	35.16	35.20	35.24	35.28	35.31	35.35	35.39	890
900	35.43	35.47	35.51	35.55	35.59	35.63	35.67	35.71	35.75	35.79	900
910	35.83	35.87	35.91	35.94	35.98	36.02	36.06	36.10	36.14	36.18	910
920	36.22	36.26	36.30	36.34	36.38	36.42	36.46	36.50	36.54	36.57	920
930	36.61	36.65	36.69	36.73	36.77	36.81	36.85	36.89	36.93	36.97	930
940	37.01	37.05	37.09	37.13	37.17	37.20	37.24	37.28	37.32	37.36	940
950	37.40	37.44	37.48	37.52	37.56	37.60	37.64	37.68	37.72	37.76	950
960	37.80	37.83	37.87	37.91	37.95	37.99	38.03	38.07	38.11	38.15	960
970	38.19	38.23	38.27	38.31	38.35	38.39	38.43	38.46	38.50	38.54	970
980	38.58	38.62	38.66	38.70	38.74	38.78	38.82	38.86	38.90	38.94	980
990	38.98	39.02	39.06	39.09	39.13	39.17	39.21	39.25	39.29	39.33	990
1000	39.37	39.41	39.45	39.49	39.53	39.57	39.61	39.65	39.68	39.72	1000

Courtesy of Crane Co.

DIAPHRAGM AND PISTON ACTUATORS

DIAPHRAGM ACTUATORS



1	Diaphragm Case	4	Actuator Spring	7	Spring Adjustor	10	Travel Indicator
2	Diaphragm	5	Actuator Stem	8	Stem Connector	11	Travel Indicator Scale
3	Diaphragm Plate	6	Spring Seat	9	Yoke		

Figure 1.1 Type 657 direct acting diaphragm actuator.

Courtesy of Fisher Controls

VALVE BODIES

VALVE TRIM

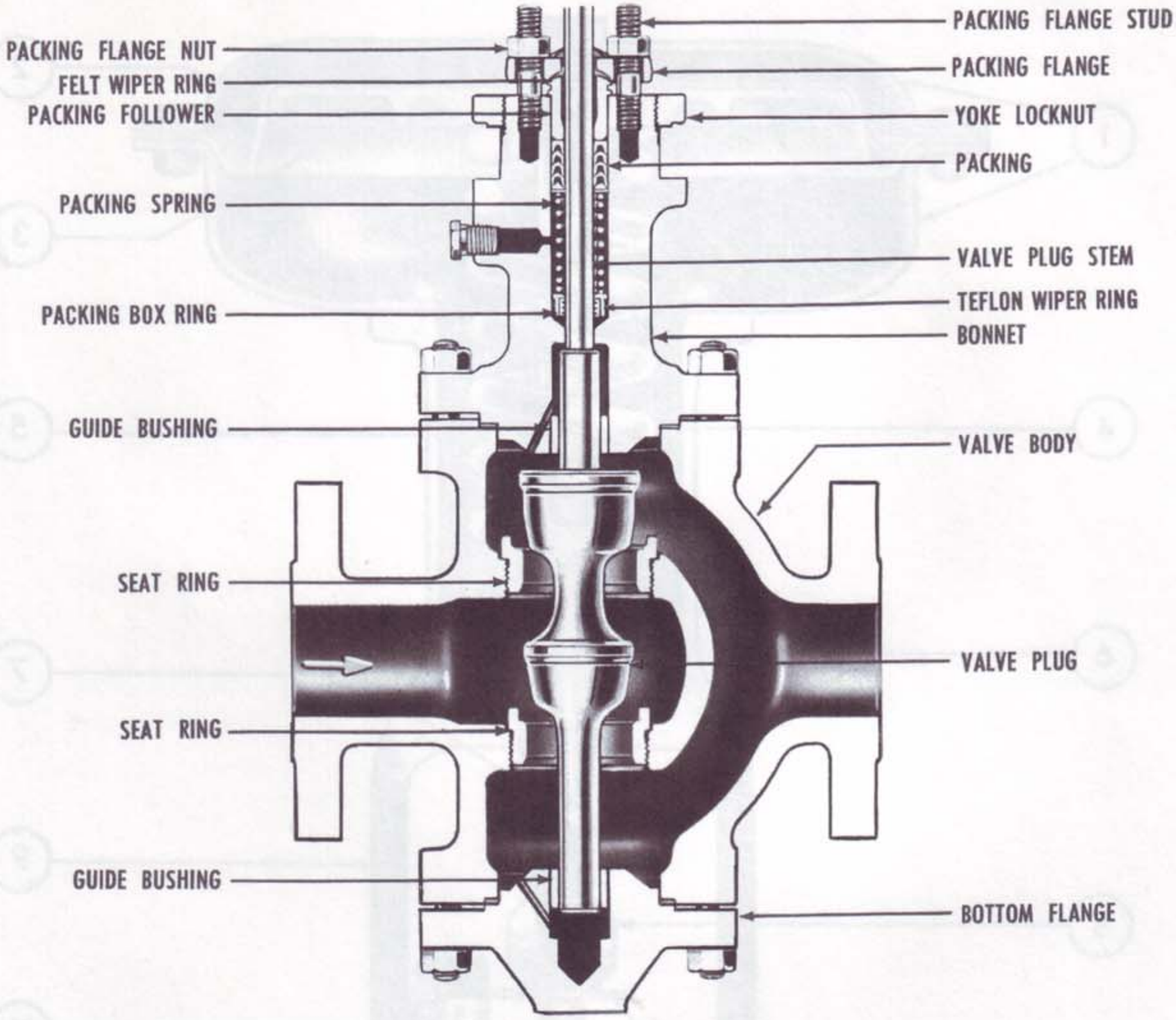


Figure 2-1. Design "A" double port body.

VALVE TRIM

The term "trim" refers to the internal parts of a valve body assembly which come in contact with the controlled fluid. Type 316 stainless steel is Fisher's standard trim material. It is satisfactory for most applications and is generally recommended for fluid temperatures up to 750° F. and pressure drops up to 150 psi. For very high pressure drops or high temperature conditions, a hard surfacing alloy such as Stellite can be used on the wearing parts of the valve plug, seat rings, guide bushings and guide posts. Other alloys such as Monel, Hastelloy "B", Durimet 20 or 440C stainless steel may be selected to combat individual corrosion and erosion problems.

Courtesy of Fisher Controls

CONTROL VALVE SELECTION

CONTROL VALVES WITH DESIGN "A" BODIES

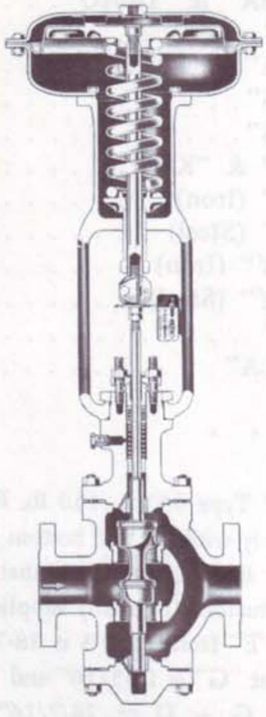


Figure 3-1. Type 657-A control valve with double port, top, and bottom guided V-pup valve plug.

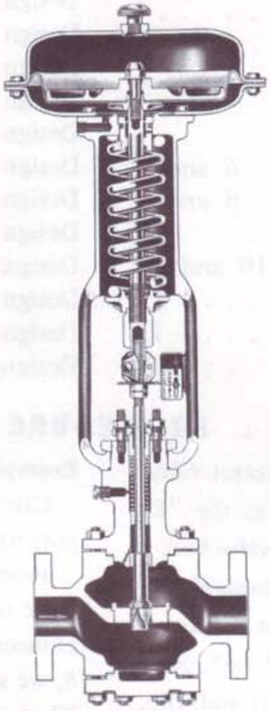


Figure 3-2. Type 667-A control valve with single port, top, and port guided Micro-Flute valve plug.

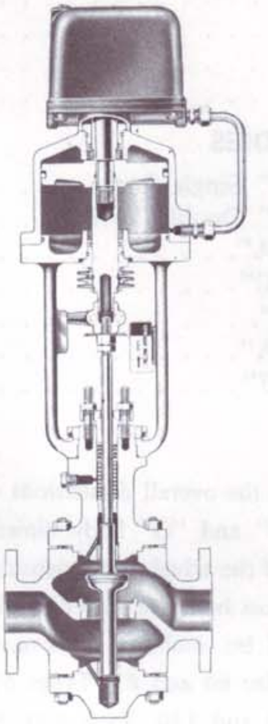
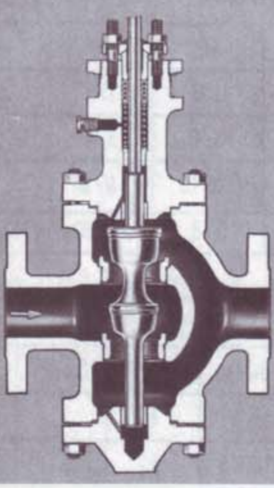


Figure 3-3. Type 470-A control valve with single port, top, and bottom guided Throttle Plug valve plug.

Figure 3-4.Double port Design "A" body with top and bottom throttle Plug valve plug.



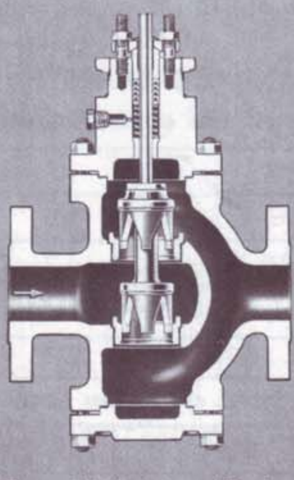
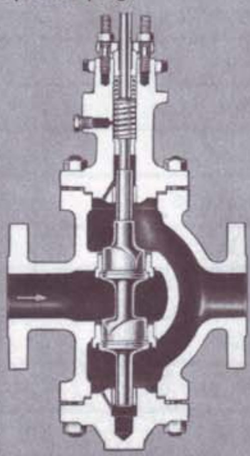


Figure 3-5. Double port Design "A" body with port guided V-Port valve plug.

Figure 3-6. Double port Design "AR" body with reverse acting V-Pup valve plug.



Courtesy of Fisher Controls

. . . PROCEDURE . . .

To obtain the overall dimensions of a control valve, add the "D" and "G" body dimensions to the "E" dimension of the actuator. Dimensions for valve bodies with a 5″ boss head are so indicated and these dimensions should be combined with one of the following actuators: Size 80 and 87, Types 657 and 667; Sizes 80, 86, 100 and 130, Type 470; Sizes 80 and 100, Types 472 and 473. Similarly, dimensions for valve bodies that can be furnished with a 1¼″ boss head are so indicated and these dimensions should be combined with the dimensions of the Type 513 or the Type 470, Size 23, actuators.

Example:

Given: 6″ Type 657-A, 150 lb. RF flanged, double port steel body with top and bottom guided valve plug.

From the table below, note that a Size 50 or 60 Type 657 actuator is normally supplied with a 6″ valve. Dimension "E" from Page 3 is 28-7/16″. From Page 8, we see that "G" is 13-5/16″ and "D" is 14-15/16″. Thus, E + G + D = 28-7/16″ + 13-5/16″ + 14-15/16″ = 56-11/16″.

NOTE: When using a valve plug requiring a top guide but not a bottom guide, such as Micro-Form valve plug, use dimension "D" under top and bottom guided and dimension "G" under skirt guided.

. . . STANDARD CONSTRUCTIONS . . .

SERIES 657 AND 667 DIAPHRAGM ACTUATORS

Actuator Size	30	34	40	45	50	60	70	80	87
Effective Area, Sq. In.	46	69	69	105	105	156	220	283	220
Stem Size, In.	3/8	3/8	1/2	1/2	3/4	3/4	3/4	1, 1-1/4	1
Yoke Boss Size, In.	2-1/8	2-1/8	2-13/16	2-13/16	3-9/16	3-9/16	3-9/16	5	5
Body Size, In.	1/2 - 1-1/2	1/2 - 1-1/2	2 - 4	2 - 4	5 - 8	5 - 8	10 - 16	10 - 16	10 - 16

SERIES 470 PISTON ACTUATORS

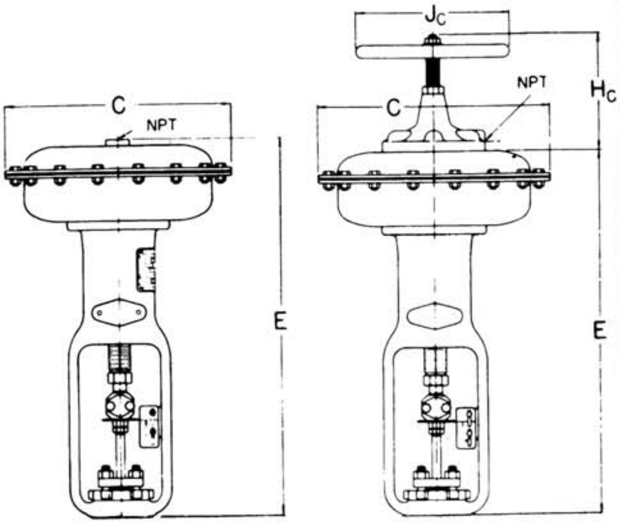
Actuator Size	23	30	40	43	60	63	64	80	86	100	130
Cylinder Dia., In.	4-3/4	4-3/4	6-1/8	4-3/4	8-1/2	4-3/4	6-1/8	10-3/4	8-1/2	13	17
Stem Size, In.	3/8	3/8	1/2	1/2	3/4	3/4	3/4	1	1	1-1/4	1-1/4
Yoke Boss Size, In.	1-1/4	2-1/8	2-13/16	2-13/16	3-9/16	3-9/16	3-9/16	5	5	5	5
Body Size, In.	1/2 - 2*	1/2 - 1-1/2	2 - 4	2 - 4	5 - 8	5 - 8	5 - 8	10 - 16	10 - 16	10 - 16	10 - 16

*Design "GS," "B" and "BA" bodies only.

Courtesy of Fisher Controls

ACTUATOR DIMENSIONS

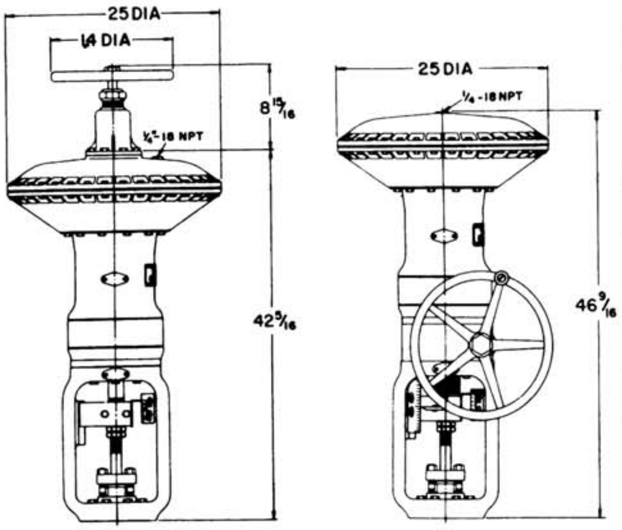
TYPE 657 DIAPHRAGM ACTUATOR



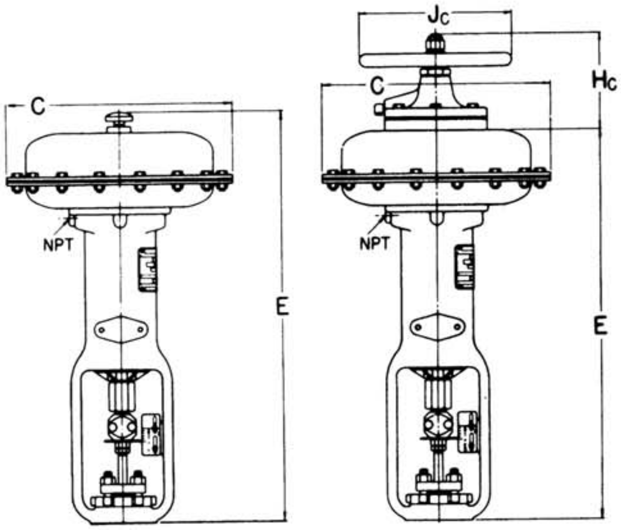
SIZE	E	C	Jc	Hc	NPT
30	17 5/16	11 3/8	6 3/4	4 3/4	1/4 – 18
34	19 5/8	13 1/8	8 3/4	6 7/16	1/4 – 18
40	21 9/16	13 1/8	8 3/4	6 7/16	1/4 – 18
45	25 15/16	16	8 3/4	7 15/16	1/4 – 18
50	28 7/16	16	8 3/4	7 15/16	1/4 – 18
60	28 7/16	18 5/8	8 3/4	7 15/16	1/4 – 18
70	33 1/16	21 1/8	14	12 5/16	1/2 – 14
87	36 15/16	21 1/8	14	12 5/16	1/2 – 14

SIZE 87 HAS A 5" BOSS

TYPE 657 - SIZE 80
(5" YOKE BOSS)



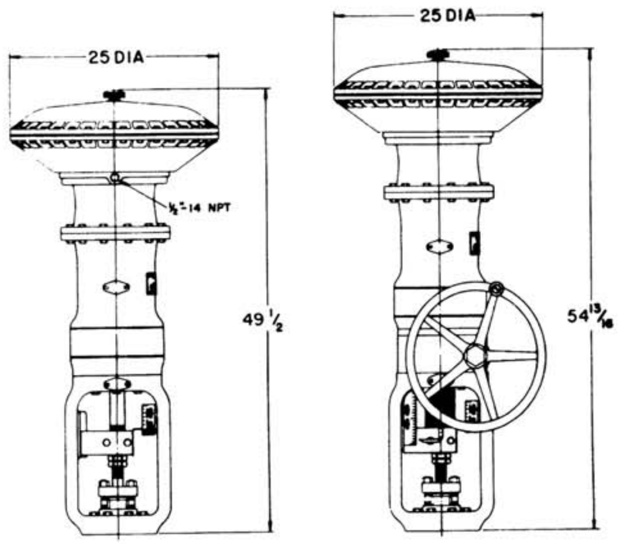
TYPE 667 DIAPHRAGM ACTUATOR



SIZE	E	C	Jc	Hc	NPT
30	18 13/16	11 3/8	6 3/4	4 11/16	1/4 – 18
34	22 5/16	13 1/8	8 3/4	4 3/4	1/4 – 18
40	23 3/8	13 1/8	8 3/4	5 3/8	1/4 – 18
45	30 1/4	16	8 3/4	6 1/4	1/4 – 18
50	30 7/8	16	8 3/4	6 5/8	1/4 – 18
60	30 7/8	18 5/8	8 3/4	6 5/8	1/4 – 18
70	36 3/4	21 1/8	14	11 1/4	1/2 – 14
87	39 1/2	21 1/8	14	11 1/4	1/2 – 14

SIZE 87 HAS A 5" BOSS

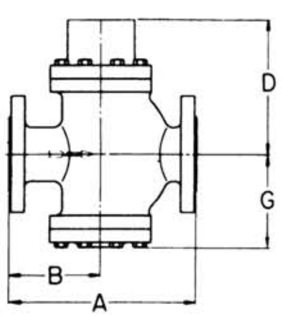
TYPE 667 - SIZE 80
(5" YOKE BOSS)



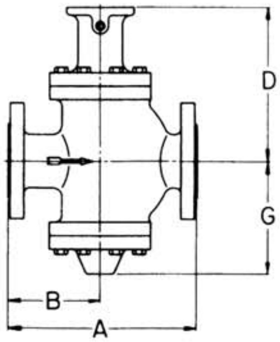
Courtesy of Fisher Controls

DESIGN "A" DOUBLE PORT IRON BODIES

PLAIN BONNET



PORT GUIDED



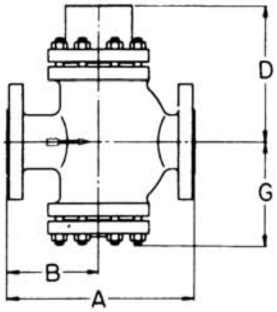
TOP AND BOTTOM GUIDED

SIZE	A SCRD	A 125 FF	A 250 RF	B SCRD	B 125 FF	B 250 RF	G PORT GUIDED	D PORT GUIDED	G T&B GUIDED	D T&B GUIDED
1	6	7 1/4	7 3/4	2 11/16	3 5/8	3 7/8	3 7/8	5 3/16	4 3/16	6
1 1/4	6	7 7/8	8 3/8	2 11/16	3 15/16	4 3/16	3 7/8	5 3/16	4 3/16	6
1 1/2	7 3/4	8 3/4	9 1/4	3 3/4	4 3/8	4 5/8	4 11/16	6 3/16	5 3/4	7
2	9 1/8	10	10 1/2	3 7/8	4 7/8	5 1/8	5 1/4	7 1/2	6 5/16	8 5/8
2 1/2		10 7/8	11 1/2		5 1/16	5 3/8	5 13/16	7 5/8	7 5/8	9 7/8
3		11 3/4	12 1/2		5 3/8	5 3/4	6 9/16	8 3/16	8 7/16	10 5/8
4		13 7/8	14 1/2		6 3/16	6 1/2	8 3/8	9 13/16	9 3/4	11 1/2
5		15 7/8	16 3/4		7	7 7/16	8 13/16	10 3/16	11 5/16	13 5/8
6		17 3/4	18 5/8		7 7/8	8 5/16	11 3/16	12 3/16	13 1/8	14 15/16
8		21 3/8	22 3/8		9 5/8	10 1/8	12 5/8	13 5/8	14 1/8	15 15/16
10		26 1/2	27 7/8		11 1/8	11 13/16	15 1/4	16	18 13/16	20 7/16

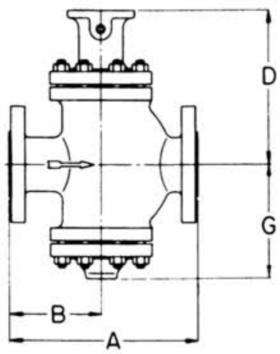
ABBREVIATIONS USED ABOVE: SCRD = SCREWED ENDS
FF = FLAT FACE, RF = RAISED FACE
FLANGE SPECIFICATION REFERENCE: 125 LB - USAS B16.1
250 LB - USAS B16b

DESIGN "A" DOUBLE PORT STEEL BODIES

PLAIN BONNET

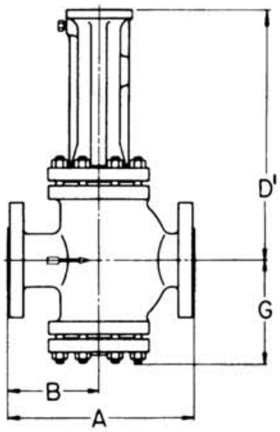


PORT GUIDED

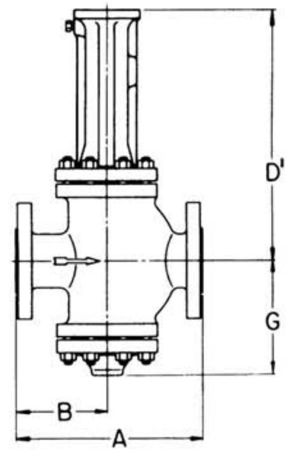


TOP AND BOTTOM GUIDED

EXTENSION BONNET



PORT GUIDED



TOP AND BOTTOM GUIDED

SIZE	A SCRD	A 150 RF	A 150 RTJ	A 300 RF	A 300 RTJ	A 400 RF	A 400 RTJ	A 600 RF	A 600 RTJ
1	6	7 1/4	7 3/4	7 3/4	8 1/4	*	†	8 1/4	8 1/4
1 1/4	6	7 7/8	8 3/8	8 3/8	8 7/8	*	†	9	9
1 1/2	7 3/4	8 3/4	9 1/4	9 1/4	9 3/4	*	†	9 7/8	9 7/8
2	9 1/8	10	10 1/2	10 1/2	11 1/8	*	†	11 1/4	11 3/8
2 1/2		10 7/8	11 3/8	11 1/2	12 1/8	*	†	12 1/4	12 3/8
3		11 3/4	12 1/4	12 1/2	13 1/8	*	†	13 1/4	13 3/8
4		13 7/8	14 3/8	14 1/2	15 1/8	15 1/4	15 3/8	15 1/2	15 5/8
5		15 7/8	16 3/8	16 3/4	17 3/8	17 1/2	17 5/8	18	18 1/8
6		17 3/4	18 1/4	18 5/8	19 1/4	19 1/2	19 5/8	20	20 1/8
8		21 3/8	21 7/8	22 3/8	23	23 3/8	23 1/2	24	24 1/8
10		26 1/2	27	27 7/8	28 1/2	28 7/8	29	29 5/8	29 3/4

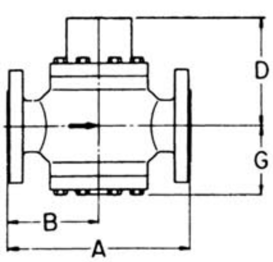
SIZE	B SCRD	B 150 RF	B 150 RTJ	B 300 RF	B 300 RTJ	B 400 RF	B 400 RTJ	B 600 RF	B 600 RTJ	G PORT GUIDED	D PORT GUIDED	G T&B GUIDED	D T&B GUIDED	D' EXT.
1	2 11/16	3 5/8	3 7/8	3 7/8	4 1/8	*	†	4 1/8	4 1/8	4 5/16	5 1/4	4 1/4	6	8 9/16
1 1/4	2 11/16	3 15/16	4 3/16	4 3/16	4 7/16	*	†	4 1/2	4 1/2	4 5/16	5 1/4	4 1/4	6	8 9/16
1 1/2	3 3/4	4 3/8	4 5/8	4 5/8	4 7/8	*	†	4 15/16	4 15/16	5 3/8	6 3/16	5 7/8	7	9 1/2
2	3 7/8	4 7/8	5 1/8	5 1/8	5 7/16	*	†	5 1/2	5 9/16	5 15/16	7 5/8	6 7/16	8 5/8	14 1/16
2 1/2		5 1/16	5 5/16	5 3/8	5 11/16	*	†	5 3/4	5 13/16	6 5/8	7 5/8	7 3/4	9 7/8	14 1/2
3		5 3/8	5 5/8	5 3/4	6 1/16	*	†	6 1/8	6 3/16	7 9/16	8 3/16	8 7/16	10 5/8	15 1/4
4		6 3/16	6 7/16	6 1/2	6 13/16	6 7/8	6 15/16	7	7 1/16	9 3/8	9 13/16	9 15/16	11 1/2	17
5		7	7 1/4	7 7/16	7 3/4	7 13/16	7 7/8	8 1/16	8 1/8	9 13/16	10 3/16	12 1/8	13 5/8	16 5/8
6		7 7/8	8 1/8	8 5/16	8 5/8	8 3/4	8 13/16	9	9 1/16	11 15/16	12 3/16	13 5/16	14 15/16	18 3/4
8		9 5/8	9 7/8	10 1/8	10 7/16	10 5/8	10 11/16	10 15/16	11	13 3/4	13 5/8	14 1/8	15 15/16	20 3/16
10		11 1/8	11 3/8	11 13/16	12 1/8	12 5/16	12 3/8	12 11/16	12 3/4	16 3/16	16	18 13/16	20 7/16	22 13/16

ABBREVIATIONS USED ABOVE: SCRD = SCREWED ENDS, RF = RAISED FACE, RTJ = RING TYPE JOINT
FLANGE SPECIFICATION REFERENCE: 150-300-400-600 LB USAS B16.5
* DIMENSIONALLY THE SAME AS 600 LB RF
† DIMENSIONALLY THE SAME AS 600 LB RTJ

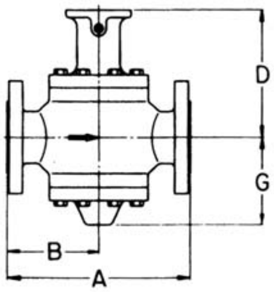
Courtesy of Fisher Controls

DESIGN "A" SINGLE PORT IRON BODIES

PLAIN BONNET



PORT GUIDED



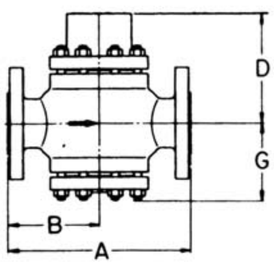
TOP AND BOTTOM GUIDED

SIZE	A			B			G	D	G	D
	SCRD	125 FF	250 RF	SCRD	125 FF	250 RF	PORT GUIDED		T & B GUIDED	
1/2	6		7 1/2	3		3 3/4	3 1/8	4 7/16	3 7/16	5 1/4
3/4	6	7 3/8	7 5/8	3	3 11/16	3 13/16	3 1/8	4 7/16	3 7/16	5 1/4
1	6 1/2	7 1/4	7 3/4	3 1/4	3 5/8	3 7/8	3 3/8	4 11/16	3 11/16	5 1/2
1 1/4	6 1/2	7 7/8	8 3/8	3 1/4	3 15/16	4 3/16	3 3/8	4 11/16	3 11/16	5 1/2
1 1/2	8	8 3/4	9 1/4	4	4 3/8	4 5/8	3 5/16	5 7/16	5	6 1/4
2	9 1/4	10	10 1/2	4 5/8	5	5 1/4	3 15/16	6 3/16	5	7 5/16
2 1/2		10 7/8	11 1/2		5 7/16	5 3/4	4 11/16	6 1/2	6 1/2	8 3/4
3		11 3/4	12 1/2		5 7/8	6 1/4	5 1/4	6 7/8	7 1/8	9 5/16
4		13 7/8	14 1/2		6 15/16	7 1/4	6 7/16	7 7/8	7 13/16	9 9/16
5		15 7/8	16 3/4		7 15/16	8 3/8	7 5/8	9	10 3/4	12 7/16
6		17 3/4	18 5/8		8 7/8	9 5/16	8 9/16	9 5/8	10 1/2	12 5/16
8		21 3/8	22 3/8		10 11/16	11 3/16	9 13/16	10 13/16	11 5/16	13 1/8
10		26 1/2	27 7/8		13 1/4	13 15/16	12 7/16	13 3/16	16	17 5/8

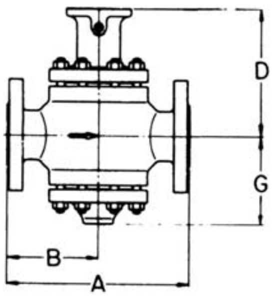
ABBREVIATIONS USED ABOVE: SCRD = SCREWED ENDS
FF = FLAT FACE, RF = RAISED FACE
FLANGE SPECIFICATION REFERENCE: 125 LB. - USAS B16.1
250 LB. - USAS B16.b

DESIGN "A" SINGLE PORT STEEL BODIES

PLAIN BONNET

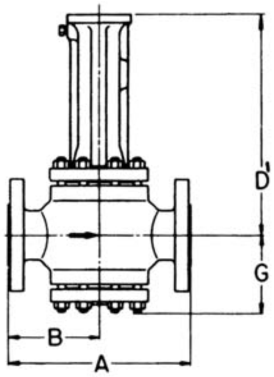


PORT GUIDED

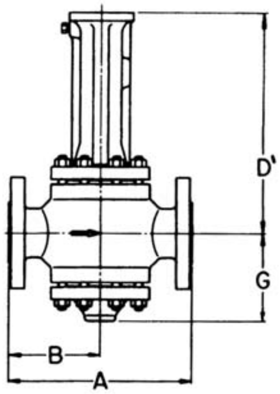


TOP AND BOTTOM GUIDED

EXTENSION BONNET



PORT GUIDED



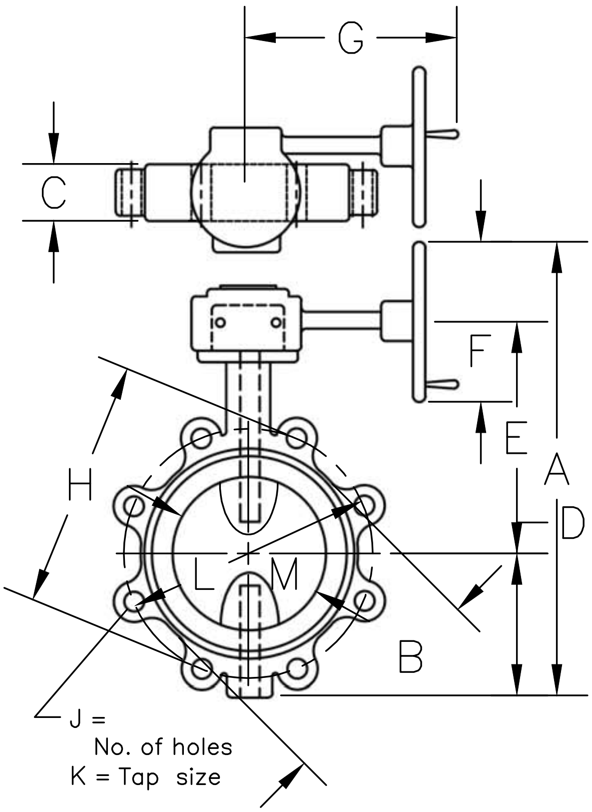
TOP AND BOTTOM GUIDED

SIZE	A								
	SCRD	150 RF	150 RTJ	300 RF	300 RTJ	400 RF	400 RTJ	600 RF	600 RTJ
1/2	6			7 1/2	7 15/16	*	†	8	7 15/16
3/4	6	7 3/8		7 5/8	8 1/8	*	†	8 1/8	8 1/8
1	6 1/2	7 1/4	7 3/4	7 3/4	8 1/4	*	†	8 1/4	8 1/4
1 1/4	6 1/2	7 7/8	8 3/8	8 3/8	8 7/8	*	†	9	9
1 1/2	8	8 3/4	9 1/4	9 1/4	9 3/4	*	†	9 7/8	9 7/8
2	9 1/4	10	10 1/2	10 1/2	11 1/8	*	†	11 1/4	11 3/8
2 1/2		10 7/8	11 3/8	11 1/2	12 1/8	*	†	12 1/4	12 3/8
3		11 3/4	12 1/4	12 1/2	13 1/8	*	†	13 1/4	13 3/8
4		13 7/8	14 3/8	14 1/2	15 1/8	15 1/4	15 3/8	15 1/2	15 5/8
5		15 7/8	16 3/8	16 3/4	17 3/8	17 1/2	17 5/8	18	18 1/8
6		17 3/4	18 1/4	18 5/8	19 1/4	19 1/2	19 5/8	20	20 1/8
8		21 3/8	21 7/8	22 3/8	23	23 3/8	23 1/2	24	24 1/8
10		26 1/2	27	27 7/8	28 1/2	28 7/8	29	29 5/8	29 3/4

SIZE	B									G	D	G	D	D'
	SCRD	150 RF	150 RTJ	300 RF	300 RTJ	400 RF	400 RTJ	600 RF	600 RTJ	PORT GUIDED		T & B GUIDED		EXT.
1/2	3			3 3/4	3 31/32	*	†	4	3 31/32	3 9/16	4 1/2	3 1/2	5 1/4	7 13/16
3/4	3	3 11/16		3 13/16	4 1/16	*	†	4 1/16	4 1/16	3 9/16	4 1/2	3 1/2	5 1/4	7 13/16
1	3 1/4	3 5/8	3 7/8	3 7/8	4 1/8	*	†	4 1/8	4 1/8	3 13/16	4 3/4	3 3/4	5 1/2	8 1/16
1 1/4	3 1/4	3 15/16	4 3/16	4 3/16	4 7/16	*	†	4 1/2	4 1/2	3 13/16	4 3/4	3 3/4	5 1/2	8 1/16
1 1/2	4	4 3/8	4 5/8	4 5/8	4 7/8	*	†	4 15/16	4 15/16	4 5/8	5 7/16	5 1/8	6 1/4	8 3/4
2	4 5/8	5	5 1/4	5 1/4	5 9/16	*	†	5 5/8	5 11/16	4 5/8	6 5/16	5 1/8	7 5/16	12 3/4
2 1/2		5 7/16	5 11/16	5 3/4	6 1/16	*	†	6 1/8	6 3/16	5 1/2	6 1/2	6 5/8	8 3/4	13 3/8
3		5 7/8	6 1/8	6 1/4	6 9/16	*	†	6 5/8	6 11/16	6 1/4	6 7/8	7 1/8	9 5/16	13 15/16
4		6 15/16	7 3/16	7 1/4	7 9/16	7 5/8	7 11/16	7 3/4	7 13/16	7 7/16	7 7/8	8	9 9/16	15 1/16
5		7 15/16	8 3/16	8 3/8	8 11/16	8 3/4	8 13/16	9	9 1/16	8 5/8	9	10 5/16	12 7/16	15 7/16
6		8 7/8	9 1/8	9 5/16	9 5/8	9 3/4	9 13/16	10	10 1/16	9 5/16	9 9/16	10 11/16	12 5/16	16 1/8
8		10 11/16	10 15/16	11 3/16	11 1/2	11 11/16	11 3/4	12	12 1/16	10 15/16	10 13/16	11 5/16	13 1/8	17 3/8
10		13 1/4	13 1/2	13 15/16	14 1/4	14 7/16	14 1/2	14 13/16	14 7/8	13 3/8	13 3/16	16	17 5/8	20

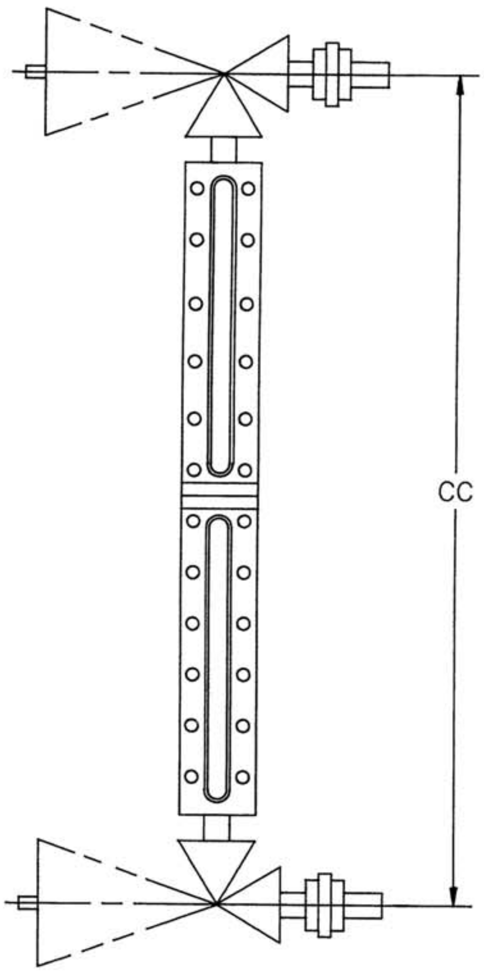
ABBREVIATIONS USED ABOVE: SCRD = SCREWED ENDS, RF = RAISED FACE, RTJ = RING TYPE JOINT
FLANGE SPECIFICATION REFERENCE: 150-300-400-600 LB. USAS B16.5
* DIMENSIONALLY THE SAME AS 600 LB. RF
† DIMENSIONALLY THE SAME AS 600 LB. RTJ

BUTTERFLY VALVE – Full lug style
150 lb

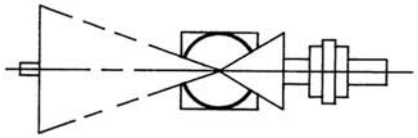


Size	2	2-1/2	3	4	5	6	8	10	12
A	9-3/8	10-3/16	10-11/16	13	14	15-3/16	17-3/4	20-1/2	23-1/2
B	4-1/4	4-15/16	5-7/8	6-15/16	7-3/4	8-3/4	11	13-3/8	16
C	1-3/4	1-7/8	1-7/8	2-1/8	2-1/4	2-1/4	2-1/2	2-13/16	3-1/8
D	3	3-1/4	3-11/16	4-13/16	5-1/4	5-7/8	6-15/16	8-3/8	9-13/16
E	5-3/8	5-15/19	6	7	7-9/16	7-15/16	9-3/16	10-1/2	12-1/16
F	6	6	6	6	6	6	10	10	10
G	8	8	8	11	11	11	16	16	16
H	6	7	7-1/2	9-1/8	10	11-1/4	13-3/4	16	19
J	4	4	4	8	8	8	8	12	12
K	5/8-11 UNC	5/8-11 UNC	5/8-11 UNC	5/8-11 UNC	3/4-10 UNC	3/4-10 UNC	3/4-10 UNC	7/8-9 UNC	7/8-9 UNC
L	4-3/4	5-1/2	6	7-1/2	8-1/2	9-1/2	11-3/4	14-1/4	17
M	2	2-1/2	3	4	5	6	8	10	12

Courtesy of Penberthy



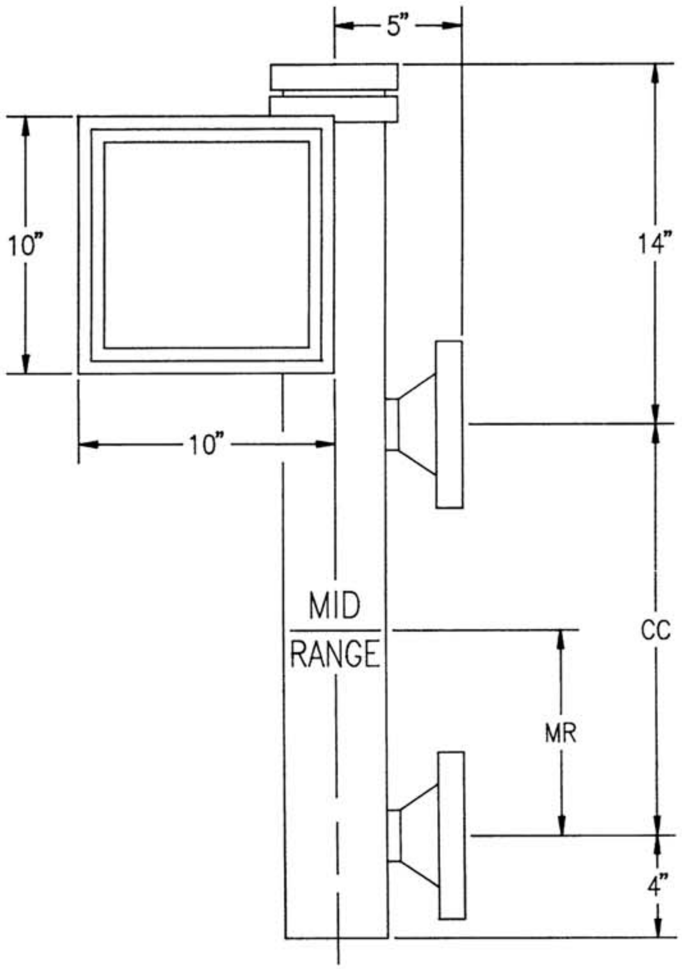
ELEVATION



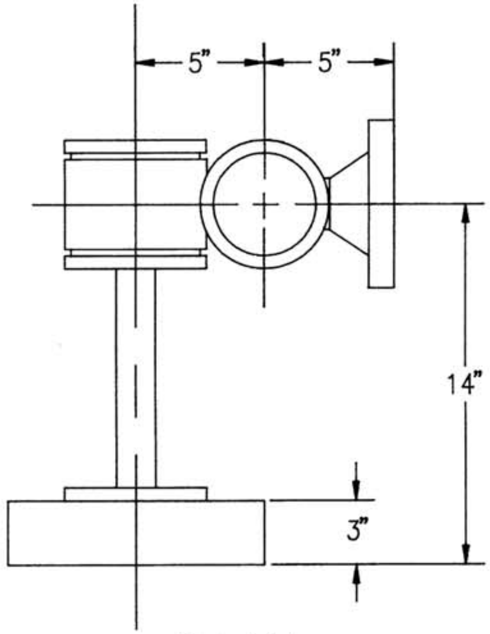
PLAN

NUMBER OF SECTIONS	VISIBLE GLASS	UNION CONNECTION CC
2	15	22
2	18	25
2	21	28
2	24	31
2	27	34
3	30	37
3	33	40
3	36	43
3	39	46
4	41	49
4	44	52
4	47	55

LIQUID LEVEL GAGE LG 1,2 & 3



ELEVATION



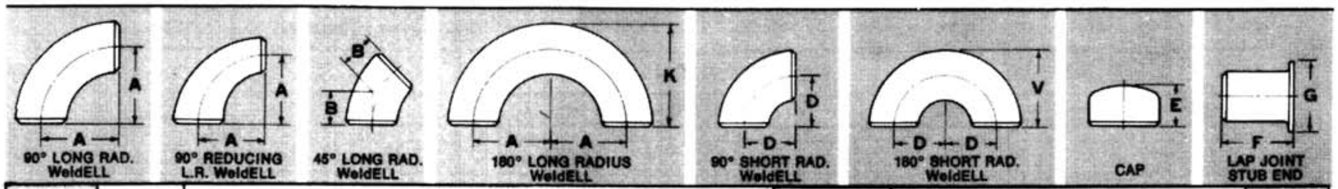
PLAN

RANGE	CC	MR
14	14	7
24	24	12
34	34	17
44	44	22
54	54	27

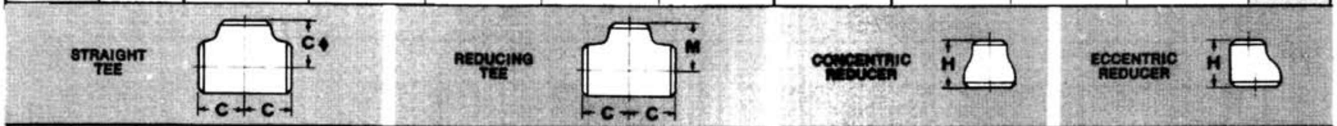
LEVEL CONTROLLER LC 1&2

Courtesy of Penberthy

DIMENSIONS



Nom. Pipe Size	Pipe O.D.	WeldELL A	WeldELL B	WeldELL D	WeldELL K	WeldELL V	CAPS* E	STUB ENDS F ANSI Std.	STUB ENDS G O.D. of Lap	STUB ENDS Corner Radius	Nom. Pipe Size
½	.840	1½	⅝	–	1⅞	–	1	3	1⅜	⅛	½
¾	1.050	1⅛	7/16	–	1 11/16	–	1	3	1 11/16	⅛	¾
1	1.315	1½	⅞	1	2 3/16	1⅝	1½	4	2	⅛	1
1¼	1.660	1⅞	1	1¼	2¾	2 1/16	1½	4	2½	3/16	1¼
1½	1.900	2¼	1⅛	1½	3¼	2 7/16	1½	4	2⅞	¼	1½
2	2.375	3	1⅜	2	4 3/16	3 3/16	1½	6	3⅝	5/16	2
2½	2.875	3¾	1¾	2½	5 3/16	3 15/16	1½	6	4⅛	5/16	2½
3	3.500	4½	2	3	6¼	4¾	2	6	5	⅜	3
3½	4.000	5¼	2¼	3½	7¼	5½	2½	6	5½	⅜	3½
4	4.500	6	2½	4	8¼	6¼	2½	6	6 3/16	7/16	4
5	5.563	7½	3⅛	5	10 5/16	7¾	3	8	7 5/16	7/16	5
6	6.625	9	3¾	6	12 5/16	9 5/16	3½	8	8½	½	6
8	8.625	12	5	8	16 5/16	12 3/16	4	8	10⅝	½	8
10	10.750	15	6¼	10	20⅜	15⅜	5	10	12¾	½	10
12	12.750	18	7½	12	24⅜	18⅜	6	10	15	½	12
14	14.000	21	8¾	14	28	21	6½	12	16¼	½	14
16	16.000	24	10	16	32	24	7	12	18½	½	16
18	18.000	27	11¼	18	36	27	8	12	21	½	18
20	20.000	30	12½	20	40	30	9	12	23	½	20
24	24.000	36	15	24	48	26	10½	12	27½	½	24
30	30.000	45	18½	30	60	45	10½	–	–	–	30
36	36.000	54	22¼	36	–	–	12	–	–	–	36
42	42.000	63	26	42	–	–	12	–	–	–	42
48	48.000	72	29⅞	48	–	–	13½	–	–	–	48



Nom. Pipe Size	Outlet	C	M	H
¾	¾	1⅛	...	...
	½	1⅛	1⅛	1½
1	1	1½	...	...
	¾	1½	1½	2
	½	1½	1½	2
1¼	1¼	1⅞	...	...
	1	1⅞	1⅞	2
	¾	1⅞	1⅞	2
	½	1⅞	1⅞	2
1½	1½	2¼	...	...
	1¼	2¼	2¼	2½
	1	2¼	2¼	2½
	¾	2¼	2¼	2½
	½	2¼	2¼	2½
2	2	2½	...	...
	1½	2½	2⅜	3
	1¼	2½	2¼	3
	1	2½	2	3
	¾	2½	1¾	3
2½	2½	3	...	...
	2	3	2¾	3½
	1½	3	2⅝	3½
	1¼	3	2½	3½
	1	3	2¼	3½
3	3	3⅜	...	...
	2½	3⅜	3¼	3½
	2	3⅜	3	3½
	1½	3⅜	2⅞	3½
	1¼	3⅜	2¾	3½

Nom. Pipe Size	Outlet	C	M	H
3½	3½	3¾	...	...
	3	3¾	3⅝	4
	2½	3¾	3½	4
	2	3¾	3¼	4
	1½	3¾	3⅛	4
4	4	4⅛	...	...
	3½	4⅛	4	4
	3	4⅛	3⅞	4
	2½	4⅛	3¾	4
	2	4⅛	3½	4
	1½	4⅛	3⅜	4
5	5	4⅞	...	...
	4	4⅞	4⅝	5
	3½	4⅞	4½	5
	3	4⅞	4⅜	5
	2½	4⅞	4¼	5
	2	4⅞	4⅛	5
6	6	5⅝	...	...
	5	5⅝	5⅜	5½
	4	5⅝	5⅛	5½
	3½	5⅝	5	5½
	3	5⅝	4⅞	5½
	2½	5⅝	4¾	5½
8	8	7	...	...
	6	7	6⅝	6
	5	7	6⅜	6
	4	7	6⅛	6
	3½	7	6	6

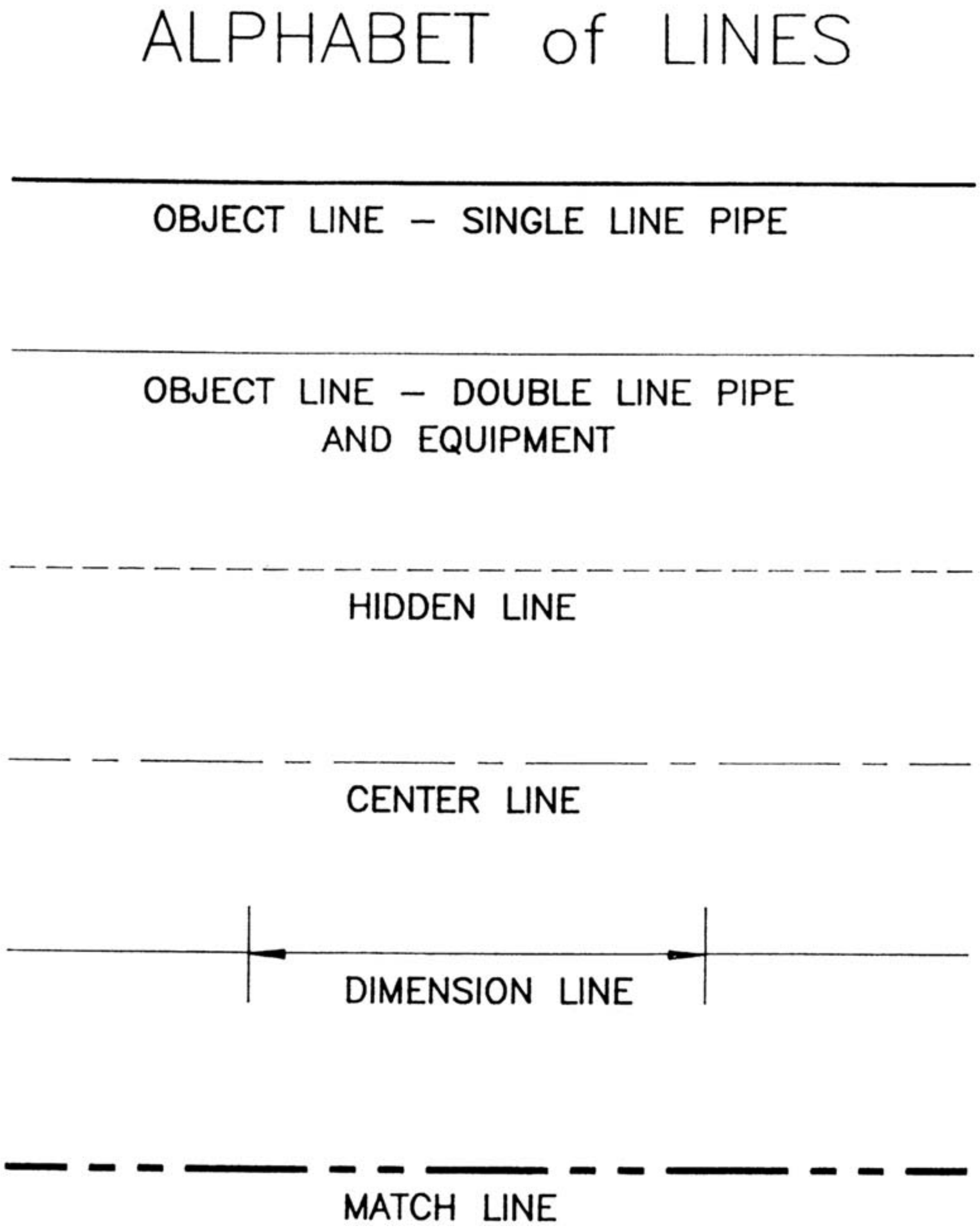
Nom. Pipe Size	Outlet	C	M	H
10	10	8½	...	...
	8	8½	8	7
	6	8½	7⅝	7
	5	8½	7½	7
	4	8½	7¼	7
12	12	10	...	...
	10	10	9½	8
	8	10	9	8
	6	10	8⅝	8
	5	10	8½	8
14	14	11	...	...
	12	11	10⅝	13
	10	11	10⅛	13
	8	11	9¾	13
	6	11	9⅜	13
16	16	12	...	...
	14	12	12	14
	12	12	11⅝	14
	10	12	11⅛	14
	8	12	10¾	14
	6	12	10⅜	14
18	18	13½	...	...
	16	13½	13	15
	14	13½	13	15
	12	13½	12⅝	15
	10	13½	12⅛	15
	8	13½	11¾	15

Nom. Pipe Size	Outlet	C	M	H
20	20	15	...	...
	18	15	14½	20
	16 & 14	15	14	20
	12	15	13⅝	20
	10	15	13⅛	20
	8	15	12¾	20
24	24	17	...	...
	20	17	17	20
	18	17	16½	20
	16 & 14	17	16	20
	12	17	15⅝	20
	10	17	15⅛	20
30	30	22	...	...
	24	22	21	24
	20	22	20	24
	18	22	19½	24
	16 & 14	22	19	24
36	36	26½	...	...
	30	26½	25	24
	24	26½	24	24
	20	26½	23	24
	18	26½	22½	24
	16	26½	22	24
42	42	30	28	...
	36 & 30	30	28	24
	24 & 20	30	26	24
48	48	35	33	...
	42	35	32	28
	36	35	31	28
	30	35	30	28
	24	35	29	28

♦ See M dimensions for branch height of 42" or 48" full branch tee. All dimensions are in inches.
See ANSI B16.9 for cap lengths when wall thicknesses are greater than x-stg.

Courtesy of Taylor Forge

APPENDIX B: ALPHABET OF LINES*



APPENDIX C: REVIEW OF MATH*

ADDITION and SUBTRACTION of FRACTIONS

$\frac{1}{16}''$

$\frac{2}{16}'' = \frac{1}{8}''$

$\frac{3}{16}''$

$\frac{4}{16}'' = \frac{2}{8}'' = \frac{1}{4}''$

$\frac{5}{16}''$

$\frac{6}{16}'' = \frac{3}{8}''$

$\frac{7}{16}''$

$\frac{8}{16}'' = \frac{4}{8}'' = \frac{2}{4}'' = \frac{1}{2}''$

$\frac{9}{16}''$

$\frac{10}{16}'' = \frac{5}{8}''$

$\frac{11}{16}''$

$\frac{12}{16}'' = \frac{6}{8}'' = \frac{3}{4}''$

$\frac{13}{16}''$

$\frac{14}{16}'' = \frac{7}{8}''$

$\frac{15}{16}''$

$\frac{16}{16}'' = \frac{8}{8}'' = \frac{4}{4}'' = \frac{2}{2}'' = 1''$

ADDITION

(1)

$$\begin{aligned} 2\tfrac{3}{4}'' &= 2\tfrac{6}{8}'' \\ 4\tfrac{5}{8}'' &= 4\tfrac{5}{8}'' \\ +3\tfrac{1}{2}'' &= 3\tfrac{4}{8}'' \\ \hline & 9\tfrac{15}{8}'' = 10\tfrac{7}{8}'' \end{aligned}$$

CHANGE FRACTIONS TO THE LEAST COMMON DENOMINATOR BEFORE ADDING

REDUCE ANSWER TO THE LOWEST TERMS

(2)

$$\begin{aligned} 12\tfrac{3}{16}'' &= 12\tfrac{3}{16}'' \\ 10\tfrac{7}{8}'' &= 10\tfrac{14}{16}'' \\ +9\tfrac{1}{4}'' &= 9\tfrac{4}{16}'' \\ \hline & 31\tfrac{21}{16}'' = 2'\text{-}8\tfrac{5}{16}'' \end{aligned}$$

SUBTRACTION

(3)

$$\begin{aligned} 7\tfrac{5}{8}'' &= 7\tfrac{5}{8}'' \\ -3\tfrac{1}{2}'' &= 3\tfrac{4}{8}'' \\ \hline & 4\tfrac{1}{8}'' \end{aligned} \qquad \begin{aligned} 12\tfrac{5}{16}'' &= 12\tfrac{5}{16}'' \\ -6\tfrac{1}{4}'' &= 6\tfrac{4}{16}'' \\ \hline & 6\tfrac{1}{16}'' \end{aligned}$$

(4)

$$\begin{aligned} 17\tfrac{5}{8}'' &= 17\tfrac{10}{16}'' = \overset{16+\frac{16}{16}}{\cancel{17}}\tfrac{10}{16}'' = 16\tfrac{10}{16}'' + \tfrac{16}{16}'' = \tfrac{26}{16}'' \\ -\ 11\tfrac{11}{16}'' &= 11\tfrac{11}{16}'' = 11\tfrac{11}{16}'' = 11 \qquad \tfrac{11}{16}'' \\ \hline & 5\tfrac{15}{16}'' \end{aligned}$$

(5)

$$\begin{aligned} 24'\text{-}3\tfrac{3}{4}'' &= 24'\text{-}3\tfrac{6}{8}'' = \overset{23+12''}{\cancel{24}}'\text{-}3\tfrac{6}{8} = 23'\text{-}15\tfrac{6}{8} \\ -17'\text{-}8\tfrac{3}{8}'' &= 17'\text{-}8\tfrac{3}{8}'' = 17'\text{-}8\tfrac{3}{8} = 17'\text{-}\ 8\tfrac{3}{8} \\ \hline & 6'\text{-}\ 7\tfrac{3}{8}'' \end{aligned}$$

CONVERSION from FEET and INCHES to DECIMALS of a FOOT

(1) 1'–4 5/16"

[5] [÷] [16] [=]
0.3125 [+] [4] [=]
4.3125 [÷] [12] [=]
0.3594 [+] [1] [=]
1.3594 FT.

(2) 0'–7 5/8"

[5] [÷] [8] [=]
0.6250 [+] [7] [=]
7.6250 [÷] [12] [=]
0.6354 [+] [0] [=]
0.6354 FT.

(3) 2'–9 7/8"

[7] [÷] [8] [=]
0.8750 [+] [9] [=]
9.8750 [÷] [12] [=]
0.8229 [+] [2] [=]
2.8229 FT.

(4) 4'–0 1/4"

1 [÷] [4] [=]
0.2500 [+] [0] [=]
0.2500 [÷] [12] [=]
0.0208 [+] [4] [=]
4.0208 FT.

(5) 7'–5 9/16"

[9] [÷] [16] [=]
0.5625 [+] [5] [=]
5.5625 [÷] [12] [=]
0.4635 [+] [7] [=]
7.4635 FT.

(6) 3'–10 1/2"

1 [÷] [2] [=]
0.5000 [+] [10] [=]
10.500 [÷] [12] [=]
0.8750 [+] [3] [=]
3.8750 FT.

CONVERSION from DECIMALS of a FOOT to FEET and INCHES

(1) 1.3594'

1.3594 [−] [1] [=] (1')
0.3594 [×] [12] [=]
4.3128 [−] [4] [=] (4")
0.3128 [×] [16] [=]
5.0048 [=] (5/16") [=] **1'-4 5/16"**

(2) 0.6354'

0.6354 [−] [0] [=] (0')
0.6354 [×] [12] [=]
7.6248 [−] [7] [=] (7")
0.6248 [×] [16] [=]
9.9968 [=] (10/16") [=] **0'-7 5/8"**

(3) 2.8229'

2.8229 [−] [2] [=] (2')
0.8229 [×] [12] [=]
9.8748 [−] [9] [=] (9")
0.8748 [×] [16] [=]
13.9968 [=] (14/16") [=] **2'-9 7/8"**

(4) 4.0208'

4.0208 [−] [4] [=] (4')
0.0208 [×] [12] [=]
0.2496 [−] [0] [=] (0")
0.2496 [×] [16] [=]
3.9936 [=] (4/16") [=] **4'-0 1/4"**

(5) 7.4635'

7.4635 [−] [7] [=] (7')
0.4635 [×] [12] [=]
5.5620 [−] [5] [=] (5")
0.5620 [×] [16] [=]
8.9920 [=] (9/16") [=] **7'-5 9/16"**

(6) 3.8750'

3.8750 [−] [3] [=] (3')
0.8750 [×] [12] [=]
10.500 [−] [10] [=] (10")
0.5000 [×] [16] [=]
8.0000 [=] (8/16") [=] **3'-10 1/2"**

CONVERSION from DEGREES, MINUTES and SECONDS to DECIMAL DEGREES

1 17°30'45"

45 [÷] [60] [=]

0.7500 [+] [30] [=]

30.750 [÷] [60] [=]

0.5125 [+] [17] [=]

17.5125°

2 21°38'13"

13 [÷] [60] [=]

0.2166 [+] [38] [=]

38.2166 [÷] [60] [=]

0.6369 [+] [21] [=]

21.6369°

CONVERSION from DECIMAL DEGREES to DEGREES, MINUTES and SECONDS

1 17.5125°

17.5125 [–] [17] [=] (17°)

0.5125 [×] [60] [=]

30.7500 [–] [30] [=] (30')

0.7500 [×] [60] [=]

45.0000 [=] (45") [=]

17°30'45"

2 21.6369°

21.6369 [–] [21] [=] (21°)

0.6369 [×] [60] [=]

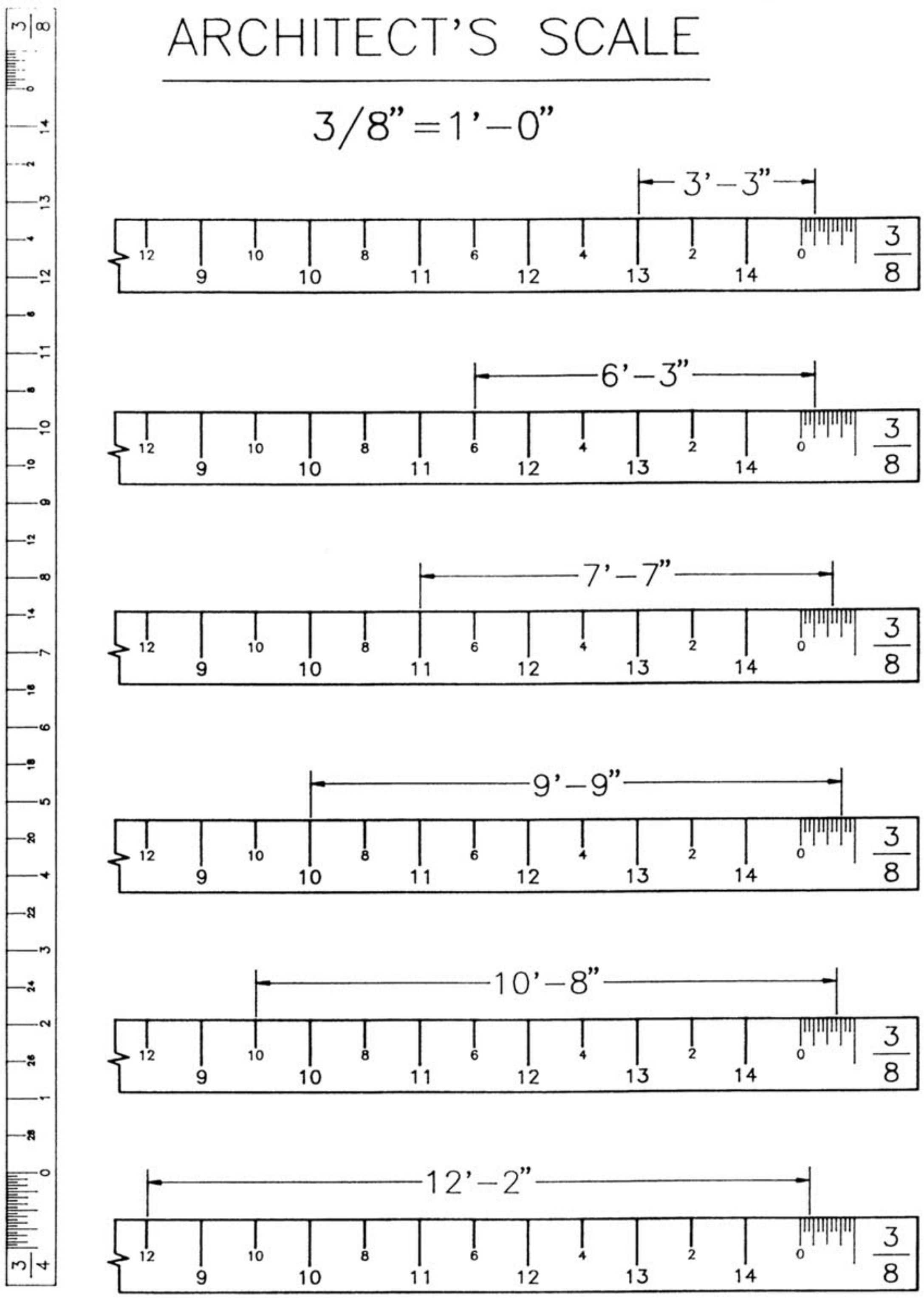
38.2140 [–] [38] [=] (38')

0.2140 [×] [60] [=]

12.8400 [=] (13") [=]

21°38'13"

APPENDIX E: ARCHITECT'S SCALE*



Glossary

A

Accumulator Temporary storage tank for liquids and vapors.

Actuator A hydraulic or pneumatic apparatus which will operate a valve by remote control.

Air, compressed Any air with pressure greater than atmospheric pressure.

Air, instrument Compressed air free of contaminants which is used to operate pneumatic control devices.

Air, plant Compressed air used to drive pneumatic hand tools.

Air cooler Large fan-type coolers placed above or below a pipe rack, which draws air across the pipes in the pipe rack to cool them.

Alarm Signals, via lights or horn, used to indicate whether the liquid level, temperature, or pressure inside a vessel is too high or too low or whether there is no flow or reverse flow.

Anchor Stationary support designed to restrict the movement of a pipe caused by vibration, turbulence, expansion, or other external forces.

Anchor bolts Bolts which have been positioned in concrete prior to curing. Used to secure equipment, buildings, tanks, or other items to a concrete foundation.

Area limit Boundary identifying the extents of the unit being drawn.

B

Back-up ring A 1/8″-thick, washer-like ring placed between two pieces of pipe to prevent the build-up of weld icicles inside the pipe during the welding process.

Ball valve Valve having a ball with a hole through it which allows straight-through flow. A 90° turn of the wrench opens/closes the valves.

Base plate Flat, metal plate welded to a vessel or other piece of equipment allowing it to be secured to a concrete foundation via anchor bolts.

Battery limit Lines placed on a drawing to identify the perimeter limits of a unit.

Bent One section of a pipe rack containing two vertical columns and one or more horizontal connecting members.

Beveled end Any piping component having a tapered end used in butt-welding.

Billet Near-molten, steel bar from which seamless pipe is formed.

Bill of materials A detailed listing of components required to fabricate a run of pipe.

Blind flange A flanged plate-like device used to terminate the end of a run of pipe, valve, or vessel opening.

Blowdown Commodity discharged from a relief valve.

Boiler Vessel used to convert water into superheated steam.

Box heater Vessel used to raise the temperature of a feed before it begins fractional distillation. *See* vertical heater.

Branch A connecting tie-in of the same or smaller pipe size.

Briddle A screwed or socket-weld piping configuration containing instruments which measures the liquid level in horizontal or vertical vessels.

Bubble caps Small valve-like controls on a tray in a fractionating column which allows rising vapors to pass through.

Butt-weld Weld made when two beveled ends are butted together and welded.

Bypass valve Valve connecting the upstream and downstream sides of a control set which allows the control valve to be removed for repair or replacement.

By-product Liquid fraction of raw crude.

C

Cage Metal enclosure surrounding a ladder providing worker safety.

Cap Butt-weld fitting used to close the end of a pipe run.

Carbon steel Chief manufacturing material of pipe and fittings used in industrial piping applications.

Catalyst Compound used to induce a chemical reaction.

Centrifugal "Center-fleeing" action caused by a spinning impeller.

Charge The initial feed used in a fractional distillation process.

Check valve Valve used to prevent backflow.

Chemical plant Facility which converts semirefined products into usable consumer products.

Chiller one of the many types of exchangers used to reduce the temperature of a process commodity.

Codes A collection of regulations and procedures for design, construction, and operation of a facility.

Coefficient of expansion The numerical factor of expansion/contraction of a substance based on a change in temperature.

Column *See* fractionation column. Also, a vertical steel or concrete member which supports structures, pipe racks, buildings, etc.

Companion flange Mating flange of the same size and pound rating as the nozzle, valve, or fitting to which it is bolted.

Compressor Mechanical device used to compress gases or vapors.

Concentric Reducer or swage having a common centerline.

Condensate The liquid which has been removed from a gas or vapor.

Condenser Mechanical apparatus which cools a gas or vapor to the point of condensing.

Conduit Protective covering around electrical wires and cables.

Control building Building from which monitoring and operation of remotely installed instruments are made.

Control panel A cabinet or desk-type housing containing monitoring instruments.

Control station A U-shaped series of valves and fittings which allows for the monitoring, control, and regulation of flow or pressure through a piping system.

Control valve Typically having a globe valve body, this valve provides a method to automatically and remotely control the fluid flow and pressure through a pipe.

Controller A device used to maintain a specified liquid level, temperature, or flow inside a vessel or piping system.

Cooler Mechanical apparatus used to reduce the temperature of a liquid commodity.

Cooling tower A mechanical device which dissipates heat by evaporation of water sprayed into a forced-air tower.

Cooling water Water used in any cooling process which will lower the temperature of a commodity.

Coordinates Intersecting north—south and east—west lines used to position foundations, equipment, supports, buildings, etc., on a drawing.

Corrosion The dissolving of surface material by chemical reaction.

Corrosion allowance The amount of surface material allowed to be eroded by the commodity within a pipe while permitting the pipe to remain usable for the specific service for which it was installed.

Coupling Fitting used to join two lengths of screwed pipe together. Also used as a branch connection on pipe or a nozzle connection on equipment.

Crude oil The natural state of unrefined oil product. Primary source of fractionated hydrocarbon by-products.

D

Davit Crane-like device made of steel pipe or structural steel which allows replacement parts, tools, and small machinery to be raised and lowered from the tops of vertical vessels.

Debutanizer A distillation column which receives the bottoms residue from a depropanizer whose overhead product is a mixture of normal and iso-butane. Its bottoms residue is a C_5+ mixture (pentane).

Deethanizer The first in a series of three distillation columns whereby heavier gaseous molecule hydrocarbons or NGL (Natural Gas Liquids) are fractionated. The deethanizer distillation column's overhead product is ethane gas. Its bottoms residue is routed to a depropanizer for further processing.

***Deiso*-butanizer** A distillation column which fractionates butane. Iso-butane is a refrigerant which is used to replace ozone layer-depleting gases.

Demethanizer A fractionating column in a cryogenic low-temperature distillation process whereby lighter gaseous molecule hydrocarbons (methane) are fractionated from raw natural gas.

Depropanizer A distillation column which receives the bottoms residue from a deethanizer whose overhead product is propane. Its bottom residue is routed to a debutanizer.

Diameter, inside The circumference measured around the interior wall of a pipe.

Diameter, nominal The name given to a particular size of pipe.

Diameter, outside The circumference measured around the outer wall of a pipe.

Dike Typically, an earthen dam or concrete wall surrounding tanks creating a containment area in case of accidental discharge or rupture.

Discharge Outgoing flow, typically with increased pressure as in the case of pumps or compressors.

Distillation The process of extracting and separating molecular compounds from a supply product.

Double extra strong Category of thick-walled pipe.

Double line Drawings used to represent piping systems 14″ in diameter and larger.

Double pipe exchanger Exchanger having a small diameter pipe inserted into a large diameter pipe.

Double random length Length of manufactured pipe, typically 35′—40′ long.

Downcomer Opening adjacent to a tray which allows overflowing liquids to fall to the tray below and begin refractionation.

Drain Typically, an underground piping system which transfers water runoff or waste materials to a processing facility for disposal or treatment. *See* O.W.S.

Drain funnel Often a reducer fitting placed at the opening of a drainage pipe which aids in the collection of disposable materials.

Drift The amount of water lost during the aeration and evaporation sequence in a cooling tower.

Dummy leg A length of pipe or structural steel welded to the outside of a pipe which provides support for the line.

E

Eccentric Reducer or swage having offset centerlines.

Elbow Fitting used to make changes in direction of pipeline.

Elbow, long radius Ninety-degree elbow having a radius equal to one and one-half times the pipe's nominal size.

Elbow, short radius Ninety-degree elbow having a radius equal to the pipe's nominal size.

Electric traced Electric leads coiled around a pipe to maintain a desired temperature.

Elevation Sectional view of a facility showing vertical height dimensions.

Extra strong Pipe and fittings having measurements equivalent to schedule 80.

F

Face The mating surface of flanged fittings or valves.

Face-to-face Measurement from the mating surface on one end of a flanged valve to the mating surface on the other end.

Feed The initial fluid material used in the fractional distillation process.

Feed, boiler Water piped through a boiler to produce steam.

Female thread Internal thread grooves cut into pipes, fittings, or valves.

Field pipe A run of pipe configured, cut, and pieced together at the time of installation.

Filter Basket-type strainer used to collect solid waste and contaminants circulating through the piping system.

Fin-fan *See* air cooler.

Fired heater Mechanical device used to elevate circulating liquids to extreme temperatures.

Fire proofing Generally brick, concrete, or gunite, applied around vessel skirts or structural columns to prevent damage in case of fire.

Fitting Generic name for components used to make turns, branches, or reductions in a run of pipe.

Flange Ring-shaped device which is welded or screwed on the end of a pipe which permits the pipe to be attached to other similarly prepared piping components.

Flare stack Vertical column which uses an open flame to burn waste gases.

Flash zone The position in a fractionation column where the incoming feed separates into vapor and liquid states.

Flat face Flange facing which has no raised surfaces.

Floating roof The type of storage tank roof which is suspended by the commodity being stored. The floating prevents the collection of harmful gases and vapors in tanks which store flammable liquids.

Flow diagram Schematic drawing depicting the equipment, piping, and instrumentation of a piping facility.

Flow displacement meter Instrument installed within a piping configuration which measures the flow rate of the commodity within the pipe.

Flow element Set of orifice flanges used with test equipment which measures rates.

Flow indicator A local or board mounted instrument which registers flow rates.

Flow meter A device used to indicate or record the amount of commodity flowing through a pipe.

Flow rate The amount of flow passing a given point in a pipe for a predetermined amount of time, for example, gph and gpm.

Flow ratio recording controller A combination of control valve and recorder which records the flow within a pipe then controls the flow as required.

Flow recorder Instrument which makes a permanent record of flow measurement.

Flow recording controller A control valve which records measurements of flow through a pipe.

Foundation Grade-level concrete support for buildings, equipment, and structural members.

Foundation location plan Plan drawing depicting the coordinate location of buildings, equipment, and structural concrete supports.

Fraction By-products of a feed supply.

Fractional distillation The chemical process of separating a feed supply into its various molecular components (by-products).

Fractionation column A vertical vessel having internal plates, called trays, which aid in the separation and collection of the various molecular compounds of a feed stock (fractional distillation).

Fuel oil Combustible material used as a heat source for fired equipment in a process facility.

G

G-fin A U-shaped exchanger having a pipe within a pipe. Also known as a "hair pin" or "double pipe" exchanger.

Gas The physical state of matter having the ability to diffuse readily and distribute uniformly throughout the container to which it is confined.

Gasket Any of a wide variety of materials placed between mating surfaces to prevent leaks.

Gate valve Valve designed for on or off control of a commodity flowing through a pipe.

Gauge Instruments which measure the liquid level inside a vessel or the temperature and/or pressure in a piping system.

Globe valve Valve designed to allow for the throttling of commodities flowing through a pipe.

Grade The true or predetermined elevation of the ground-supported surface of a piping facility.

Grade beam Structural member used to support grating or other flooring material at ground (grade) level.

Gravity flow system Piping system constructed of sloped pipes which uses gravity as a means of moving the commodity inside.

Grout A concrete mixture poured on the tops of equipment foundations to provided final leveling.

Guide Type of pipe support which permits longitudinal but not lateral movement.

H

Hand rail Protective railing around platforms. Typically, 3′−6″ tall.

Hanger Pipe support used on horizontal pipes which will suspend the pipe from a stationary object from above.

Head The end enclosure of a vessel.

Header The main run of pipe from which branches are connected.

Headroom Vertical measurement which provides overhead clearances.

Heater Piping equipment which uses a combustible material to increase the temperature of a commodity.

Heat exchanger Piping equipment used to transfer heat from one fluid source to another without the two fluids mixing together.

Hydrocarbon Any solid, liquid, or gaseous compound whose molecular structure is made exclusively of hydrogen and carbon molecules.

I

Impeller Rotating device in a pump which forces the incoming commodity to be expelled at a greater pressure.

Indicator A device used to indicate the liquid level, temperature, pressure, or flow rate inside a piping system.

Instrument One of many monitoring devices which can sense, measure, transmit, or control.

Instrument air Piping system containing clean air used to operate instrumentation throughout a piping facility.

Instrumentation The use of monitoring instruments to perform duties not permissible by human workers.

Insulation Exterior covering on pipe or equipment which maintains a constant temperature. Also protection for workers from high-temperature surfaces.

Insulation rings Continuous circular rings welded to the exterior of a vertical vessel which support a vessel's insulation. Typically spaced on 12′−0″ centers.

K

Knockout drum Used to collect any liquids present in the waste stream prior to entering a flare system, especially important if substantial cooling of heavy liquids is necessary.

L

Ladder Climbing apparatus which allows access to piping components at extreme elevations.

Level Alarm Instrument which detects high or low liquid levels within a vessel and alerts plant operators with an audible or visual signal.

Level gauge (glass) A vertical transparent tube connected to the external surface of a vessel which allows visual inspection of internal liquid levels.

Level indicating controller Instrument which indicates the liquid level of a vessel and can control the liquid level by transmitting signals to a control valve.

Level recorder Makes a permanent record of liquid level in a vessel.

Level recording controller Instrument which records the liquid level of a vessel and can control the liquid level by transmitting signals to a control valve.

Lifting lugs Donut-shaped rings welded to the vessel's shell or head which allow the vessel to be raised and positioned during installation.

Line Generic name given to reference a completed piping configuration.

Liquid The physical state of matter possessing flow characteristics and minimal compressibility.

M

Malleable iron Cast iron which has been heat-treated to improve its tensile strength.

Mandrel A long, pointed shaft used to pierce molten steel billets to form seamless pipe.

Manhole Similar to large nozzles which allow workers entry points into a vessel. Generally 18″ ID.

Manhole hinge A hinge which creates a pivot point allowing the blind flange attached to the manhole to be easily removed for worker entrance.

Manifold A main pipeway having numerous branch connections.

Manway *See* manhole.

Match line Lines used to divide the plot plan into small drawing areas.

Material takeoff The gathering of descriptions, quantities, and prices for various components of the piping system, that is, pipe, flanges, fittings, valves, bolts, and gaskets.

Meter run A clear run of pipe having a set of orifice flanges which is used to measure flow rate through the pipe.

Mixer Device used to combine liquid, semiliquid, or bulk materials needed in the refining process.

N

Naphtha Colorless, flammable by-product of crude petroleum used in the manufacture of gasoline.

Nipple A short length of pipe used to connect screwed or socket-weld fittings to one another.

Nozzle The connecting point of the piping configuration to the vessel or equipment. Nozzles are provided in locations where a commodity is either introduced or removed from a vessel or piece of equipment.

Nozzle arrangement The positioning of nozzles on a piece of piping equipment.

Nozzle orientation Plan drawing depicting the location of nozzles around the perimeter of a vessel using angular measurements from 0°.

O

Octagon An eight-sided concrete foundation placed below vertical vessels which distributes the vessel's load over a broader area.

O-lets Any of several fittings used to make branch connections for welded, screwed, or socket-weld pipe.

Operator Device used to activate valving.

Orifice flange Flange with a hole tapped into the flange face perpendicular to the pipe which permits testing equipment to be inserted.

Orifice flange union Pair of orifice flanges, orifice plate, bolts, nuts, jackscrews, and gaskets. Primary components of a meter run.

Orifice plate Metal plate with a hole of predetermined size sandwiched between orifice flanges.

O.W.S. (Oily water sewer) An underground piping system used to collect and transfer contaminated discharge to a treatment facility.

P

P&ID Piping and instrumentation diagram.

Pedestal *See* foundation.

Pipe guide *See* guide.

Pipe hanger *See* hanger.

Pipe rack Structural framework consisting of a series of vertical columns connected with horizontal members. Major thoroughfare for pipes traveling in a process facility.

Pipe support Structural member which carries the weight of a piping configuration.

Piping Generic term used to describe pipes, fittings, flanges, and valves in a facility.

Piping drawing index Created from the plot plan, the index uses match lines to divide the piping facility into small drawing areas. These areas are assigned drawing numbers and distributed to drafters/designers for creation.

Plain end Any piping component having square ends used for socket-weld connections.

Platform An elevated walkway around a vessel or other piping equipment.

Plot plan A master drawing showing the locations of all buildings, structures, and equipment in a piping facility.

Plug Screwed fitting having external threads which terminates a piping configuration.

Plug valve A particular valve having a rectangular shaped hole through a tapered plug. Uses one-quarter turn of a handle to align the hole with the valve port.

Pressure alarm Instrument designed to signal dramatic changes in internal pressure.

Pressure controller A control valve which regulates internal pressure of a pipe or vessel after receiving a signal from a transmitter.

Pressure differential recording controller Controls the pressure differential between two pipes or vessels by means of a control valve.

Pressure indicator Dial instrument which indicates internal pressure of a pipe or vessel.

Pressure indicating controller Control valve with an indicating transmitter which controls internal pressure on a pipe or vessel.

Pressure recorder A recording instrument which makes a permanent record of internal pressures within a pipe or vessel.

Pressure recording controller Instrument similar to a pressure recorder and having the capability to transmit a signal to a control valve.

Pressure safety valve An automatic pressure-relieving device actuated by excessive internal pressure of a pipe or vessel.

Process equipment Piping equipment having the capability to alter the chemical makeup of the commodity it contains.

Pump Mechanical device used to move fluids under pressure from one location to another.

Purge The act of removing foreign matter from the internal surfaces of a pipe or vessel.

R

Raised face Type of flange facing used with flat ring gaskets. 150# and 300# raised face flanges have a $^{1}/_{16}''$ raised face, and 400# and above flanges have a $^{1}/_{4}''$ raised face.

Reactors Change the chemical composition of a commodity through the introduction of a reagent or catalyst.

Rebar Short form of *reinforcing bar*. A metal rod used in the reinforcement of concrete.

Reciprocating pump Piping equipment with parts similar to a piston or plunger which moves back and forth to create pressure.

Recorder A device used to record the liquid level, temperature, pressure, or flow rate inside a vessel or piping system throughout a specified period of time.

Reducer A pipe fitting with one end larger than the other which allows reductions in the diameter of a run of pipe.

Refinery Process facility which breaks crude petroleum down into usable by-products such as butane, propane, fuel oil, and lubricants.

Reflux A liquid product returned to a fractionation column which aids in the fractionation process.

Reinforcing pad A plate contoured to the shape of a vessel shell. It is positioned around nozzles to provide additional strength in the areas where metal was removed from the shell.

Restriction orifice Standard orifice union assembly including spectacle blind used to create smooth flow.

Ring-type joint Flange face which uses a steel ring rather than flat or full ring gasket.

Root gap The $^{1}/_{16}''$ space between two butt-weld fittings prior to welding.

Rotary pump Displacement-type pump using pistons, gears, or screws to discharge a commodity.

Run Generic name for any length of pipe.

Rung Horizontal member of a ladder.

S

Saddle U-shaped structural support welded to horizontal vessels and exchangers. Saddles are bolted to concrete foundations and create a craddle-like support in which the vessel can rest.

Schedule Wall thickness of pipe.

Scrubber Used to separate contaminants from gases during the refining process.

Seal pan Installed below the bottom tray in a vessel to prevent liquids from bypassing the trays.

Seamless Pipe manufactured without any resulting welded connection.

Separator Any collection-type vessel used to separate liquids from gases or other liquids during the refining process.

Shape roller Mechanical apparatus which sizes and shapes rolled plate to form pipe.

Shell The cylindrical walls of a vessel.

Shell and tube Type of heat exchanger having tube bundles contained within an outer vessel shell.

Shoe Structural member welded to the bottom side of a pipe having insulation. Designed to prevent the insulation from being crushed when the pipe rests on a steel support.

Skelp Plate which has been rolled and shaped into the form of a pipe.

Skirt A cylinder-shaped support for a vertical vessel. One end is welded to the base plate allowing it to rest on the foundation, and the other end is welded to the bottom head of a vertical vessel.

Skirt access opening An 18″ ID hole 2′−16″ above the foundation which allows workers entrance for inspection and maintenance.

Skirt fireproofing Brick or granite material applied to the interior and occasionally exterior surfaces of a vessel skirt to prevent damage in the event of a fire.

Skirt vents Equally spaced holes approximately 3″−4″ in diameter bored near the top of the vessel skirt which allow toxic and explosive gases to escape.

Sleeper Near grade-level structural support used to support horizontal piping runs.

Slip-on flange Flange with a low hub which allows pipe to be inserted prior to welding.

Slotted anchor Saddle or other support having elongated bolt holes which allows for movement due to heat expansion.

Specifications Guidelines established by governmental agencies, standards associations, and vendors, for plant design and construction.

Spectacle blind A figure 8-shaped plate placed within an orifice flange assembly. One end has a hole through which flow can pass to create smooth flow for accurate instrument readings.

Spiral weld Type of pipe formed by twisting metal plate in spiral shapes then welding.

Spool Type of isometric or orthographic drawing containing dimensions and callouts for fabrication.

Spring hanger Pipe hanger using a coil spring to absorb movement within a pipe.

Steam The vapor phase of water.

Steam, dry Steam which is devoid of suspended water particles.

Steam, saturated Steam which exceeds boiling point temperature for an equivalent pressure.

Steam traced Tubing coiled around a pipe containing steam to help maintain a desired temperature.

Steam turbine Pump or generator driver using high pressure steam to power the turbine's impeller.

Stem Threaded shaft within a valve which raises and lowers the valve wedge or disc by rotating the handwheel.

Stub-in Branch connection made on a run of pipe without the use of a fitting.

Suction The inlet or incoming side of a pump or compressor.

Swage Typically a screwed or socket-weld type of fitting used to make a reduction in the diameter of the size of pipe.

T

Tank Storage vessel used for the collection of process materials.

Tank farm Area within a process facility where several storage tanks reside.

Tee Three-way fitting used to make branch connections on a run of pipe.

Temperature alarm Instrument designed to signal dramatic changes in internal temperature.

Temperature controller A control valve which regulates internal temperature of a pipe or vessel after receiving a signal from a transmitter.

Temperature control valve Valve using fluctuations in temperature to make adjustments in commodity flow.

Temperature element Thermocouple which allows portable test equipment to be inserted to measure the temperature of the commodity within a pipe or vessel.

Temperature indicator Instrument which indicates temperature of the commodity in a pipe or vessel (thermometer).

Temperature recorder A recording instrument which makes a permanent record of temperature within a pipe or vessel.

Temperature recording controller Instrument which provides simultaneous recording and regulation of the temperature within a pipe or vessel by sending a signal to a control valve and recorder.

Temperature well (Thermowell) Inserted into a coupling to protect the temperature instrument bulb.

Thermal expansion Growth of pipe due to the application of heat.

Threaded end Any piping component having internal or external threads.

Threads, external Pipe component having screw threads cut into the exterior surface (male threads).

Threads, internal Pipe component having screw threads cut into the interior surface (female threads).

Tower Vertical vessel or column.

Tower, cooling Equipment which dissipates heat gain in cooling water by evaporating specific amounts of water which has been aerated.

Transmitter Instrument which sends signals to indicating, controlling, or recording devices.

Trapeze Pipe hanger consisting of two vertical rods connected with a horizontal support member.

Tray Flat metal plates spaced approximately 30″ apart inside a vertical vessel which aid in the fractionation of crude petroleum into by-products.

Tube bundle Removable section of an exchanger containing internal tubes.

Tube sheet Vertical plate separating the shell side from the channel end of an exchanger.

Turbulence Uneven flow produced by directional changes or obstructions within the pipe.

U

Union A three-piece fitting placed within a screwed or socket-weld configuration which permits quick disassembly of the configuration.

Utility One of many plant services required for the efficient operation of the facility, for example, air, water, steam, sewer, and flares.

Utility air Compressed air used to drive pneumatic tools, clean equipment, and perform other maintenance services.

V

Valve Device used to control the flow of a commodity through a pipe.

Vapor The gaseous state of any substance which is liquid or solid under ordinary circumstances.

Vapor lock Trapped air or vapor in a pipe which prevents the flow of a commodity through the pipe.

Vendor A third-party supplier of parts, equipment, or other components of the piping facility.

Vendor drawing A drawing or rendering which depicts descriptive information pertaining to the equipment or piping component which a supplier or manufacturer delivers to the piping facility.

Vertical heater Device used to raise the temperature of a commodity to the point at which it can be used in a process system.

Vessel Generic term used to describe any closed container housing liquid, vapor, or gaseous commodity.

W

Wedge Sealing component of a gate valve.

Weir Dam-like plate welded on a tray which allows a fractionated by-product to collect and be extracted by a nozzle.

Welding ring *See* back-up ring.

Weld neck flange Flange with a tapered neck for butt-welding to other bevel-end piping components.

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Pipe Drafting and Design

Fourth Edition

Roy A. Parisher and Robert A. Rhea

Pipe Drafting and Design*, *Fourth Edition, is a tried and trusted guide to the terminology, drafting methods, and applications of pipe, fittings, flanges, valves, and more. Those new to this subject will find no better introduction on the topic, with detailed explanations of piping system components including mechanical equipment, easy step-by-step instructions, exercises, review questions, hundreds of clear illustrations, explanations of drawing techniques, methodology and symbology used in the creation of piping and instrumentation diagrams, piping arrangement drawings, sections and elevations, and piping isometric drawings. This fully updated and expanded new edition also explains procedures for building 3D models and gives examples of a complete field-scale project including flow diagrams, civil drawings, structural steel drawings, vendor data drawings, project specifications, and other relevant piping drawings and documents used in the real world.

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About the Authors

Roy A. Parisher is a professor and former department chair of the Engineering Design Graphics department at San Jacinto College in Pasadena, Texas, USA, where he has taught for over 40 years. He also taught at the University of Houston Downtown's Summer Piping Institute.
Robert A. Rhea is a retired associate professor of engineering technology at the University of Houston Downtown, Houston, Texas, USA.

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