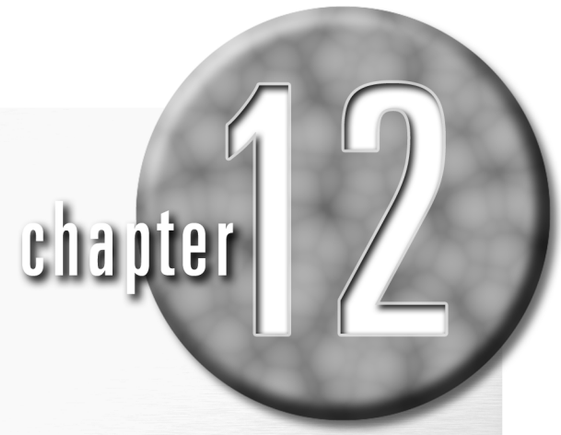


Process Diagrams

OBJECTIVES

After studying this chapter, the student will be able to:

- Review process diagram symbols.
- Describe the use of process diagrams and the information they contain.
- Draw a process flow diagram.
- Draw a process and instrument drawing.
- Describe the various process equipment relationships.

Key Terms

Electrical drawings—symbols and diagrams that depict an electrical process.

Elevation drawings—a graphical representation that shows the location of process equipment in relation to existing structures and ground level.

Equipment location drawings—show the exact floor plan for location of equipment in relation to the plan's physical boundaries.

Flow diagram—a simplified sketch that uses symbols to identify instruments and vessels and to describe the primary flow path through a unit.

Foundation drawings—concrete, wire mesh, and steel specifications that identify width, depth, and thickness of footings, support beams, and foundation.

Legends—a document used to define symbols, abbreviations, prefixes, and specialized equipment.

Process and instrument drawing (P&ID)—a complex diagram that uses process symbols to describe a process unit; also called piping and instrumentation drawing.

Types of Process Diagrams

Process diagrams can be broken down into two major categories: process **flow diagrams** (PFDs) and **process and instrument drawings (P&IDs),** sometimes called piping and instrumentation drawings. A flow diagram is a simple illustration that uses process symbols to describe the primary flow path through a unit. A process flow diagram provides a quick snapshot of the operating unit. Flow diagrams include all primary equipment and flows. A technician can use this document to trace the primary flow of chemicals through the unit. Secondary or minor flows are not included. Complex control loops and instrumentation are not included. The flow diagram is used for visitor information and new employee training.

A process and instrument drawing is more complex. The P&ID includes a graphic representation of the equipment, piping, and instrumentation. Modern process control can be clearly inserted into the drawing to provide a process technician with a complete picture of electronic and instrument systems. Process operators can look at their process and see how the engineering department has automated the unit. Pressure, temperature, flow, and level control loops are all included on the unit P&ID.

Basic Instrument Symbols

Process technicians use P&IDs to identify all of the equipment, instruments, and piping found in their units. New technicians use these drawings

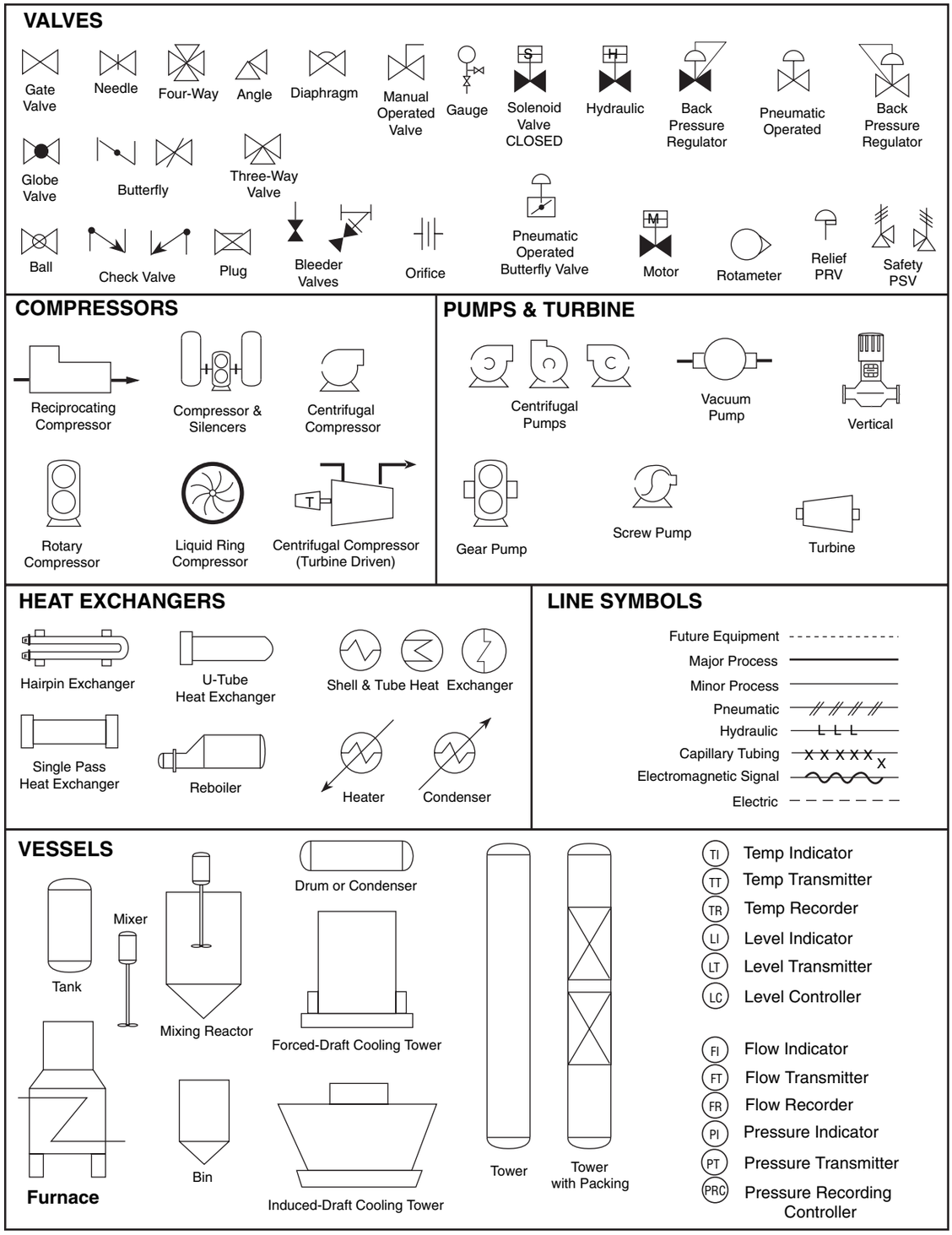


Figure 12.1a *Process and Instrument Symbols*

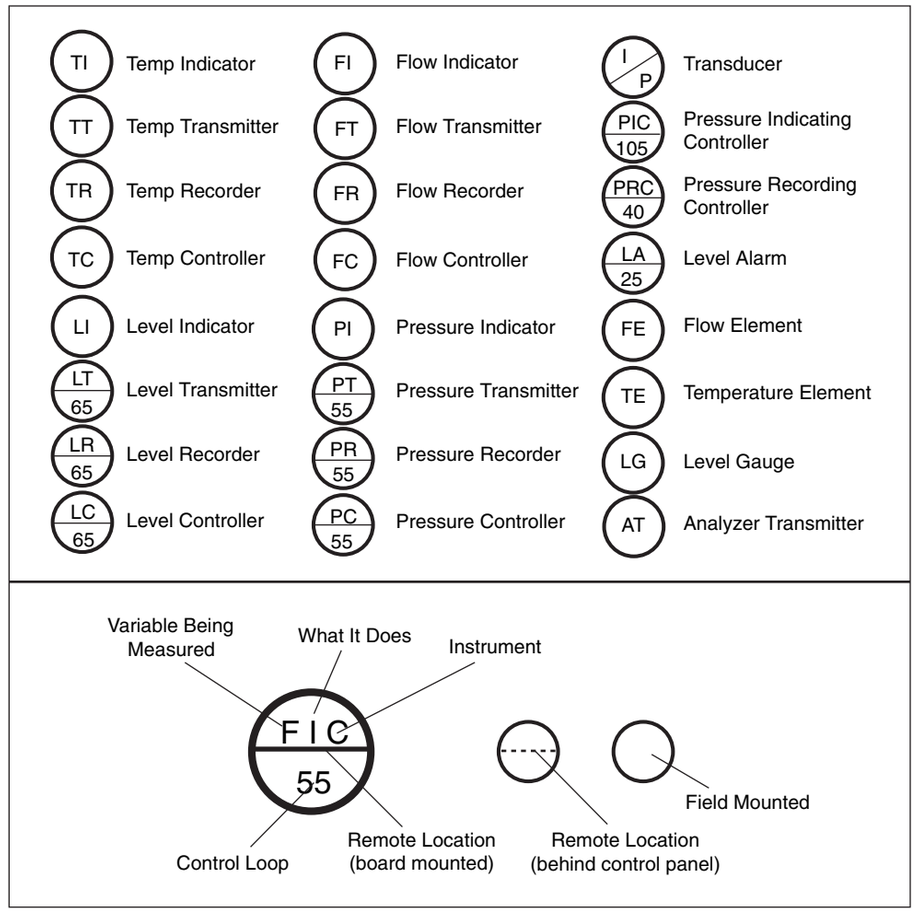


Figure 12.1b *Process and Instrument Symbols (continued)*

during their initial training period. Knowing and recognizing these symbols is important for a new technician. The chemical processing industry has assigned a symbol for each type of valve, pump, compressor, steam turbine, heat exchanger, cooling tower, basic instrumentation, reactor, distillation column, furnace, and boiler (Figure 12.1). There are symbols to represent major and minor process lines and pneumatic, hydraulic, or electric lines, and there is a wide variety of electrical symbols.

Flow Diagrams

New technicians are required to study a simple flow diagram of their assigned operating system. Process flow diagrams typically include the major equipment and piping path the process takes through the unit. As operators learn more about symbols and diagrams, they graduate to the much more complex P&IDs.

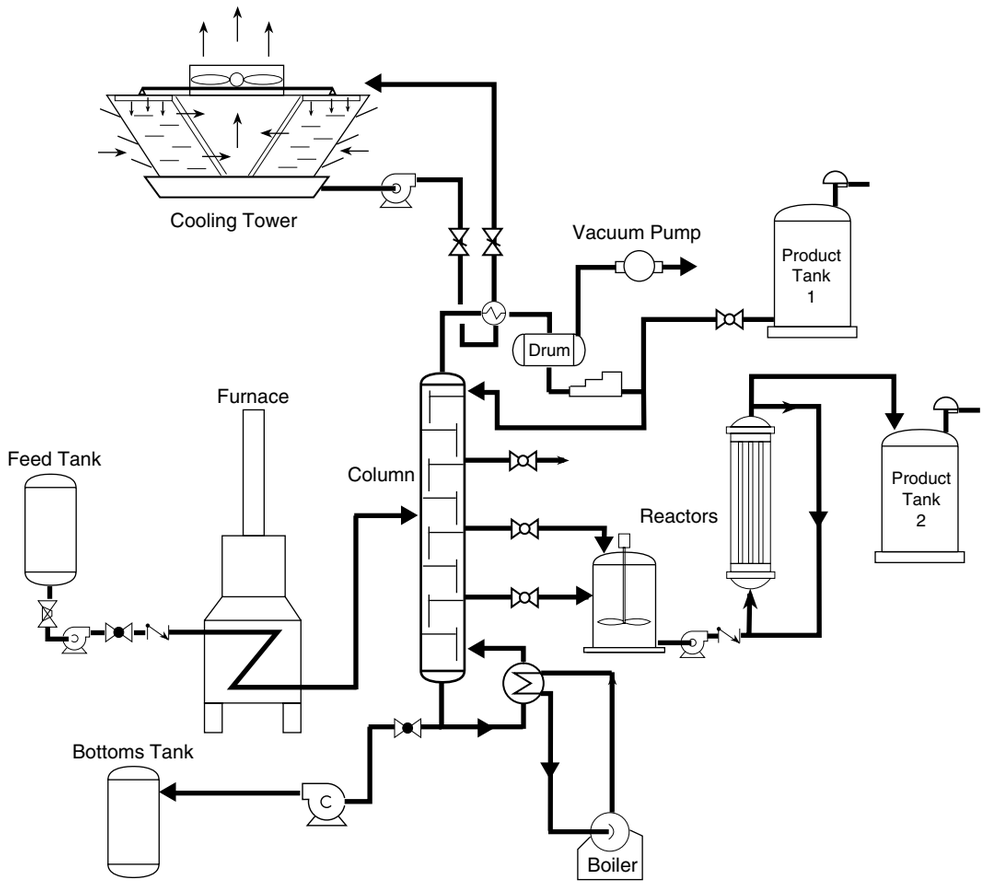


Figure 12.2 *Process Flow Diagram (PFD)*

Some symbols are common among plants; others differ from plant to plant. Some standardization of process symbols and diagrams is taking place. The symbols used in this chapter reflect a wide variety of petrochemical and refinery operations.

Figure 12.2 is a PFD that shows the basic relationships and flow paths found in a process unit. It is easier to understand a simple flow diagram if it is broken down into sections: feed, preheating, the process, and the final products. This simple left-to-right approach allows a technician to identify where the process starts and where it will eventually end. The feed section includes the feed tanks, mixers, piping, and valves. In the second step, the process flow is gradually heated for processing. This section includes heat exchangers and furnaces. In the third section, the process is included. Typical examples found in the process section could include distillation columns or reactors. The process area is a complex collection of equipment that works together to produce products that will be sent to the final section.

Process and Instrument Drawings

A P&ID is a complex representation of the various units found in a plant (Figure 12.3). It is used by people in a variety of crafts. The primary users of the document after plant startup are process technicians and instrument and electrical, mechanical, safety, and engineering personnel.

In order to read a P&ID, the technician needs an understanding of the equipment, instrumentation, and technology. The next step in using a P&ID is to memorize your plant's process symbol list. This information can be found on the process legend. Process and instrument drawings have a variety of elements, including flow diagrams, equipment locations, elevation plans, electrical layouts, loop diagrams, title blocks and **legends,** and **foundation drawings.** The entire P&ID provides a three-dimensional look at the various operating units in a plant.

Process Legend

The process legend (Figure 12.4) provides the information needed to interpret and read the P&ID. Process legends are found at the front of the P&ID. The legend includes information about piping, instrument and equipment

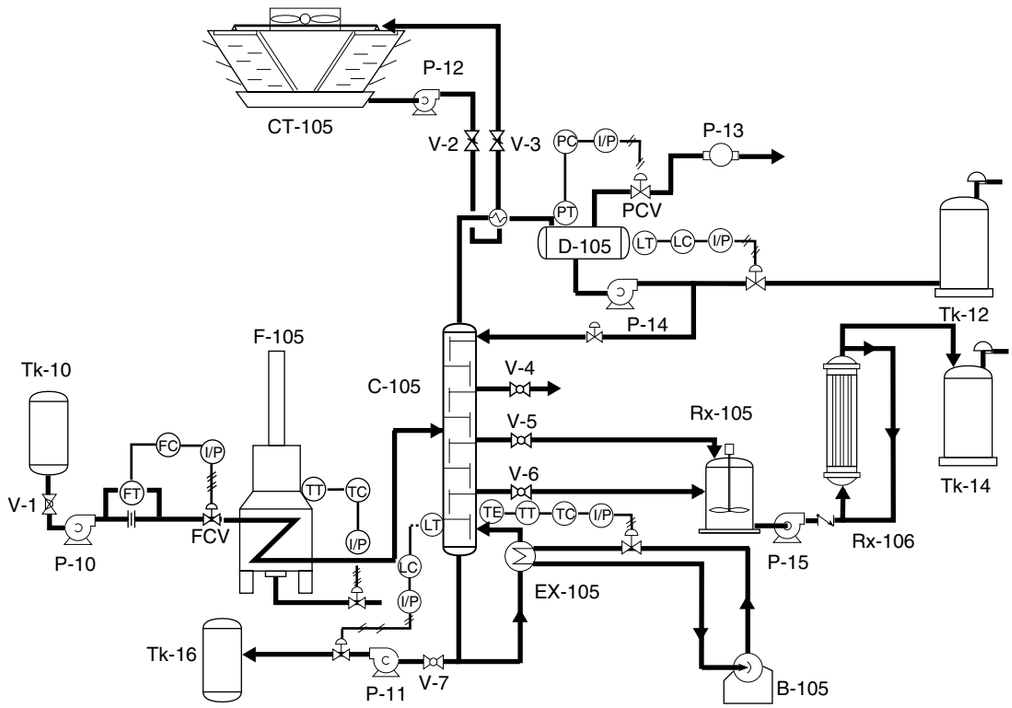


Figure 12.3 *Process and Instrument Diagram (P&ID)*

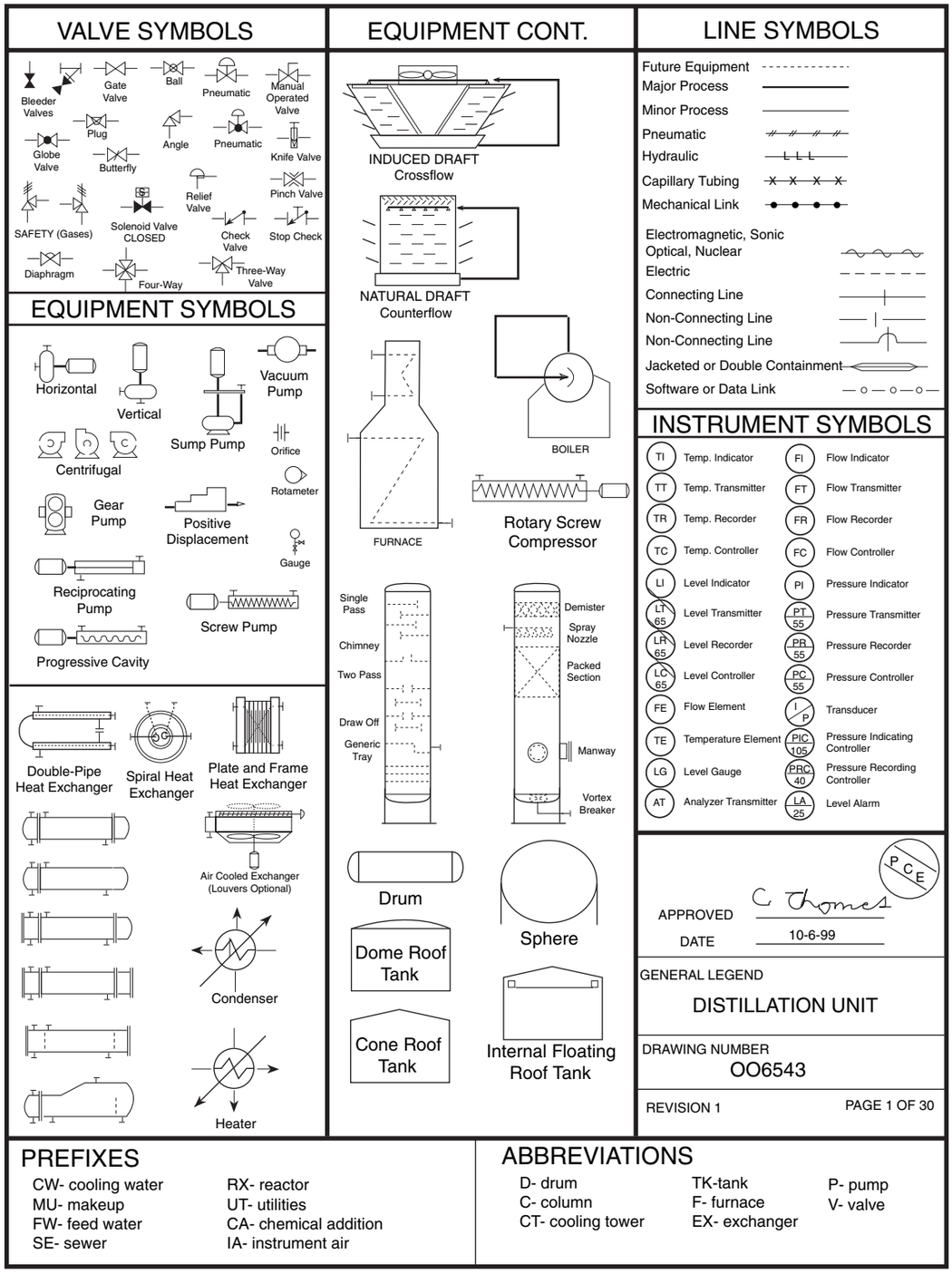


Figure 12.4 *Process Legend*

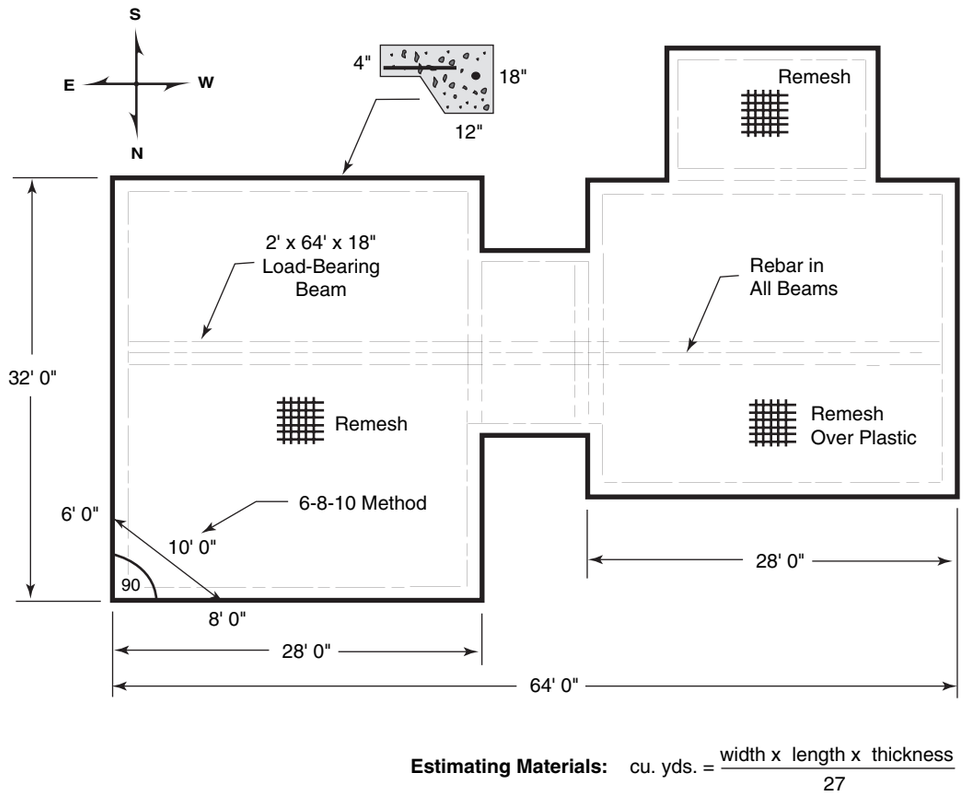


Figure 12.5 *Foundation*

symbols, abbreviations, unit name, drawing number, revision number, approvals, and company prefixes. Because symbol and diagram standardization is not complete, many companies use their own symbols in unit drawings. Unique and unusual equipment will also require a modified symbols file.

Foundation Drawing

The construction crew pouring the footers, beams, and foundation uses foundation drawings (Figure 12.5). Concrete and steel specifications are designed to support equipment, integrate underground piping, and provide support for exterior and interior walls. Process technicians do not typically use foundation drawings, but these drawings are useful when questions arise about piping that disappears under the ground and when new equipment is being added.

Elevation Drawing

Elevation drawings (Figure 12.6) show the location of process equipment in relation to existing structures and ground level. In a multistory structure, the elevation drawing provides the technician with information about

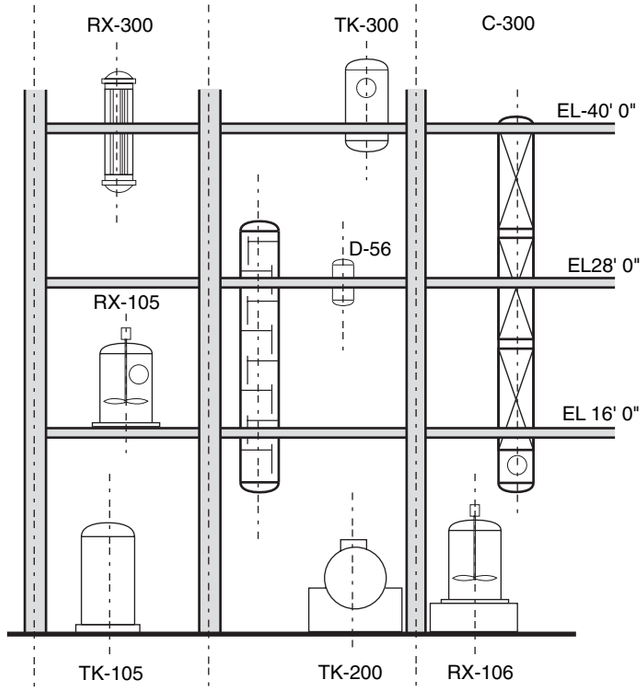


Figure 12.6
Elevation Drawing

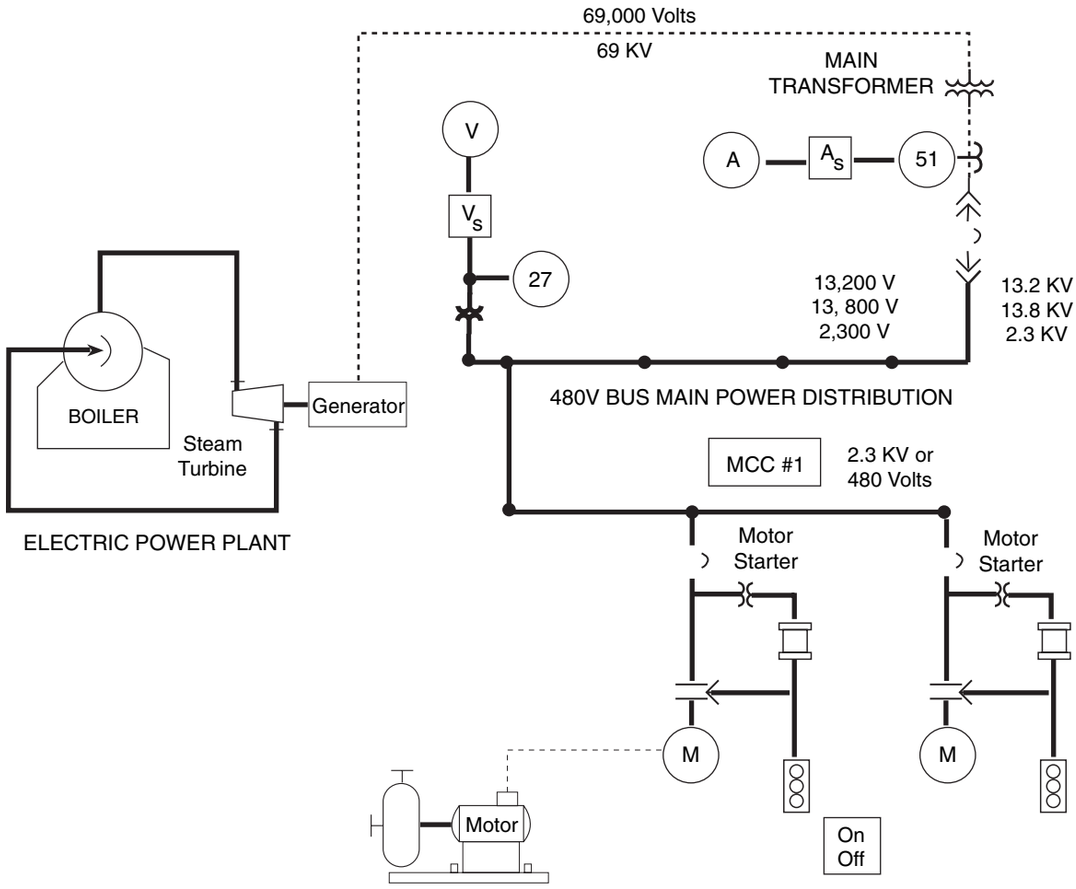
equipment location. This information is important for making rounds, checking equipment, developing checklists, catching samples, and performing startups and shutdowns.

Electrical Drawing

Electrical drawings (Figure 12.7) include symbols and diagrams that depict an electrical system. Electrical drawings show unit electricians where power transmission lines run and places where power is stepped down or up for operational purposes.

A process technician typically traces power to the unit from a motor control center (MCC). The primary components of an electrical system are the MCC, motors, transformers, breakers, fuses, switchgears, starters, and switches. Specific safety rules are attached to the operation of electrical systems. The primary safety system is the isolation of hazardous energy "lock-out, tag-out." Process technicians are required to have training in this area. Figure 12.7 shows the basic symbols and flow path associated with an electrical drawing. Electrical lines are typically run in cable trays to switches, motors, ammeters, substations, and control rooms.

A transformer is a device used by industry to convert high voltage to low voltage. The electric department always handles problems with transformers. Electric breakers are designed to interrupt current flow if design conditions are exceeded. Breakers are not switches and should not be turned on



M Motor	Fuse	MCC	Motor Control Center
V Voltmeter: measures voltage	V_S Voltmeter Switch		
27 Under Voltage Relay	Current Transformer: reduces high voltage to instrumentation.		
A Ammeter: measures electric current	A_S Ammeter switch		
50 Transformer Overcurrent Relay (Instantaneous)	Potential Transforming Symbol		
51 Transformer Overcurrent Relay (Time delay)	Power Transformer: reduces high voltage		
Circuit Breaker: a protective device that interrupts current flow through an electric circuit	Switch	Motor Circuit Contacts	

Figure 12.7 *Electrical Drawing*

or off. If a tripping problem occurs, the technician should call for an electrician. Fuses are devices designed to protect equipment from excess current. A thin strip of metal will melt if design specifications are exceeded. During operational rounds, technicians check the ammeters inside the MCC for current flow to their electrical systems. Voltmeters, electrical devices used to monitor voltage in an electrical system, are also checked during routine rounds.

Equipment Location Drawing

Equipment location drawings (plot plans) show the exact location of equipment in relation to the plant's physical boundaries (Figure 12.8). One of the most difficult concepts to explain to a new process technician is the scope and size of modern chemical processing. Most chemical plants and refineries closely resemble small cities; they have well-defined blocks and areas connected by a highway of piping and equipment. Equipment location drawings provide information about the neighborhood.

Loop Diagrams

A loop diagram traces all instrument connections between the field instrument and the control room panel. This includes instrument air lines, wiring connections at field junction boxes, and control room panels and front connections.

Electrical One-Line Diagrams

Like the piping in process systems, the wiring in a unit follows a path. Electrical diagrams show a flow path for distributing power throughout the unit and

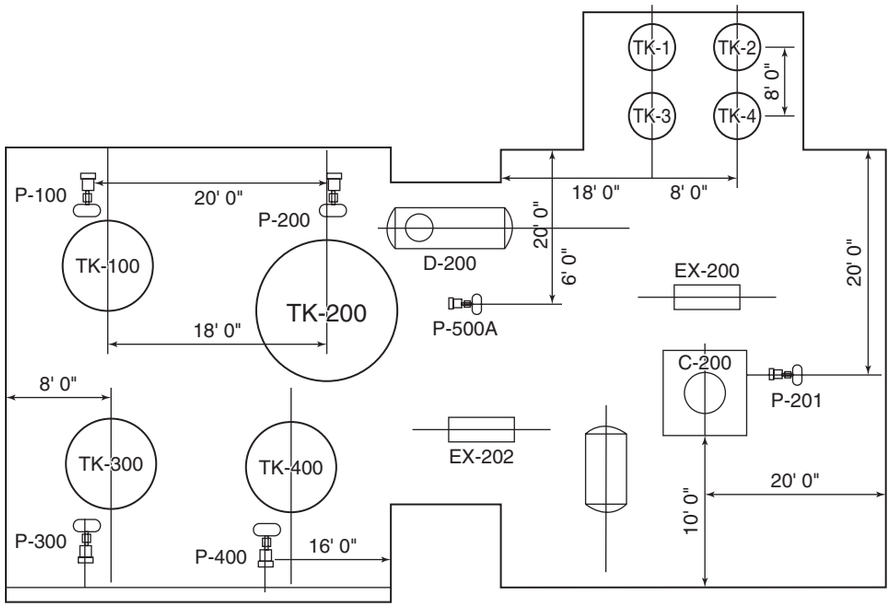


Figure 12.8
Equipment Location

to all electrical equipment. These diagrams show the different voltage levels in the unit, electrical equipment such as transformers, circuit breakers, fuses, and motors and horsepower required. It also includes start/stop switches, emergency circuits, and motor control centers. Process technicians can use these diagrams to trace a system from the power source to the load.

Review of Basic and Specialized Symbols

Piping and Valves

Each plant will have a standardized file for their piping symbols. Process technicians should carefully review the piping symbols for major and minor flows; electric, pneumatic, capillary, and hydraulic elements; and future equipment (Figure 12.9). The major flow path through a unit illustrates the

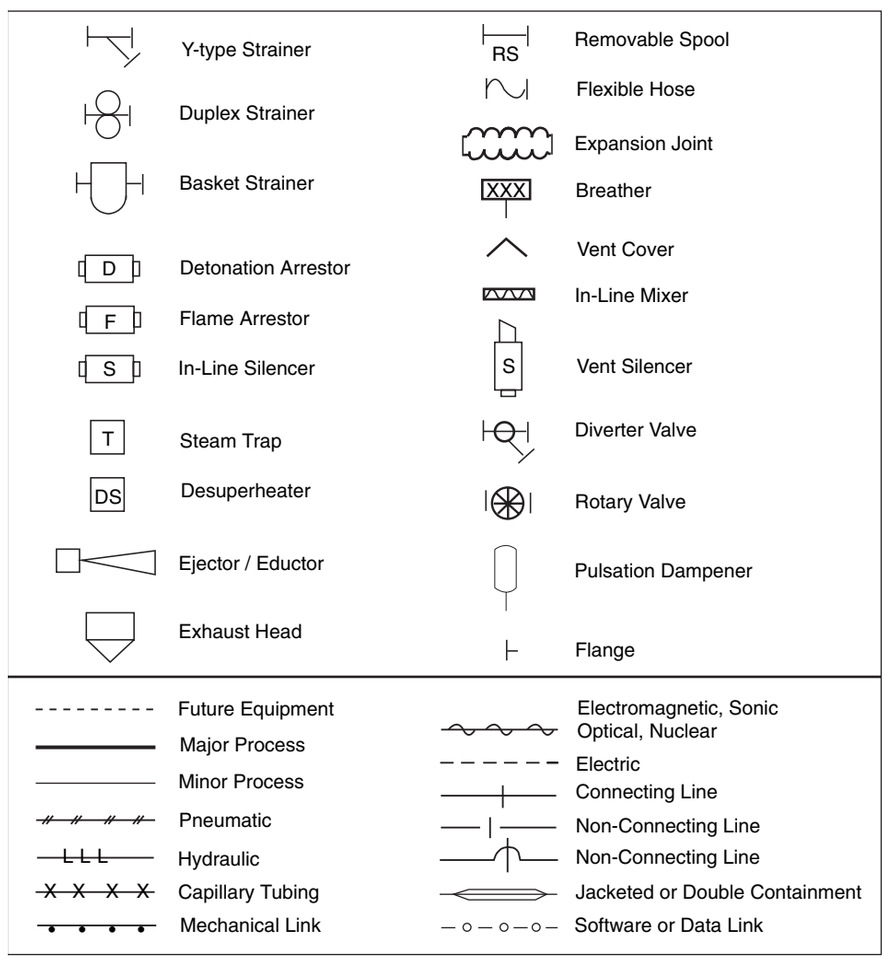


Figure 12.9
Piping Symbols

critical areas a new technician should concentrate on. A variety of other symbols are included on the piping. These include valves (Figure 12.10), strainers, filters, flanges, spool pieces, insulation, piping size, pressure rating, material codes, and steam traps.

Pumps and Tanks

Pumps and tanks come in a variety of designs and shapes. Common pump and tank symbols are shown on Figure 12.11.

Compressors, Steam Turbines, and Motors

Because compressors and pumps share a common set of operating principles and are classified as dynamic or positive displacement, the symbols for compressors may closely resemble those for pumps (compare

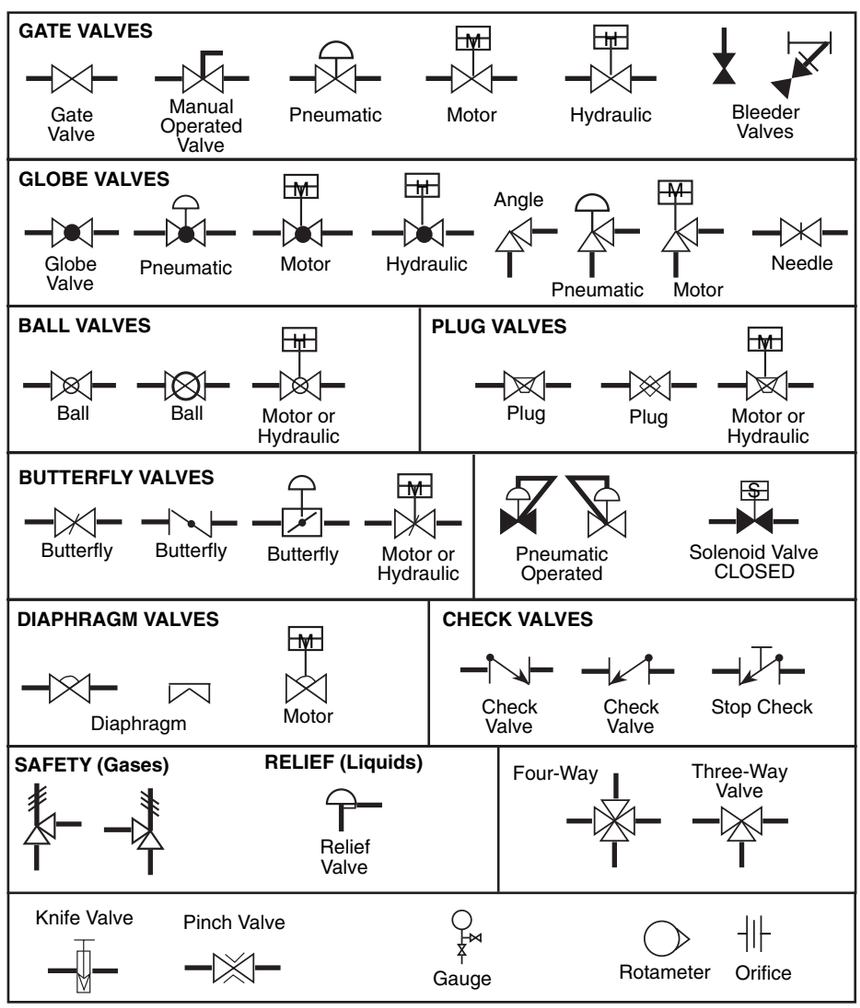


Figure 12.10
Valves

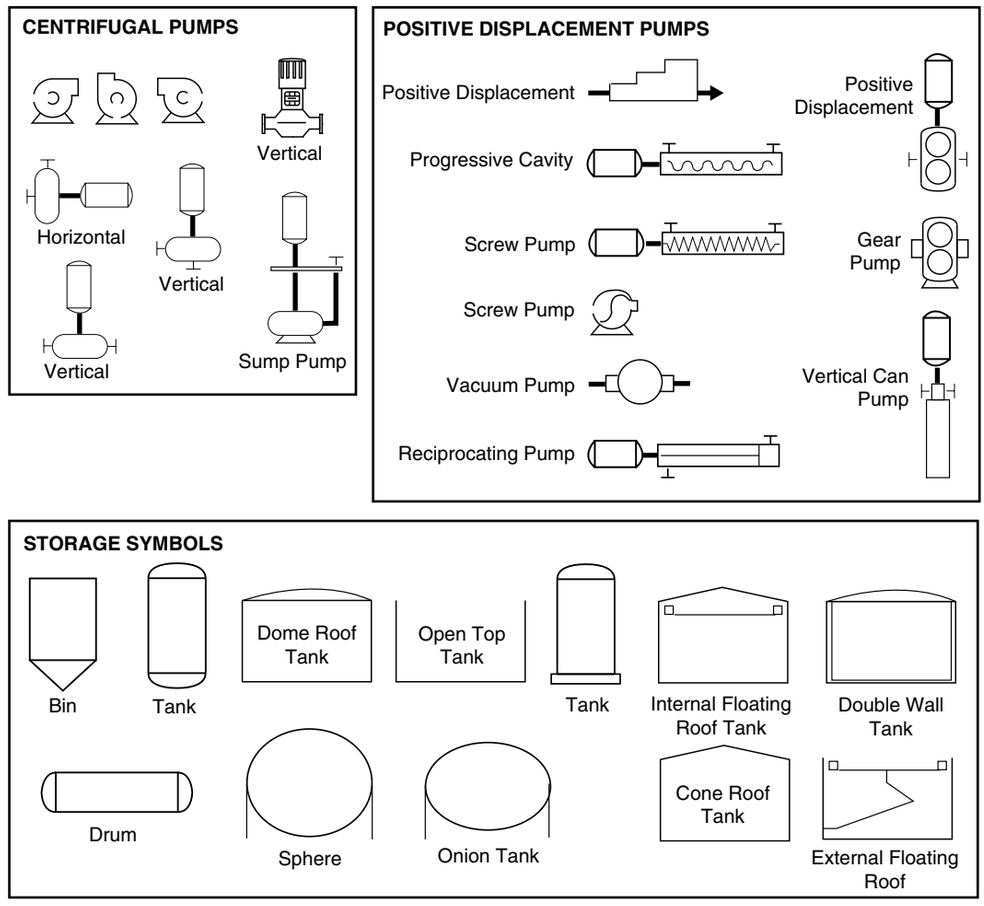


Figure 12.11 *Pumps and Tanks*

Figures 12.11 and 12.12). In most cases, the compressor symbol is slightly larger than the pump symbol.

In the multistage, centrifugal compressors, the narrowing of the symbol from left to right denotes compression of the gas before it is released. This is in sharp contrast to the steam turbine symbol, which illustrates the opposite effect as the steam expands while passing over the rotor. Modern P&IDs show the motor symbol connected to the driven equipment. This equipment may be a pump, compressor, mixer, or generator. Figure 12.12 illustrates the standardized symbols for compressors, steam turbines, and motors.

Heat Exchangers and Cooling Towers

Heat exchangers and cooling towers are two types of industrial equipment that share a unique relationship. A heat exchanger is a device used to

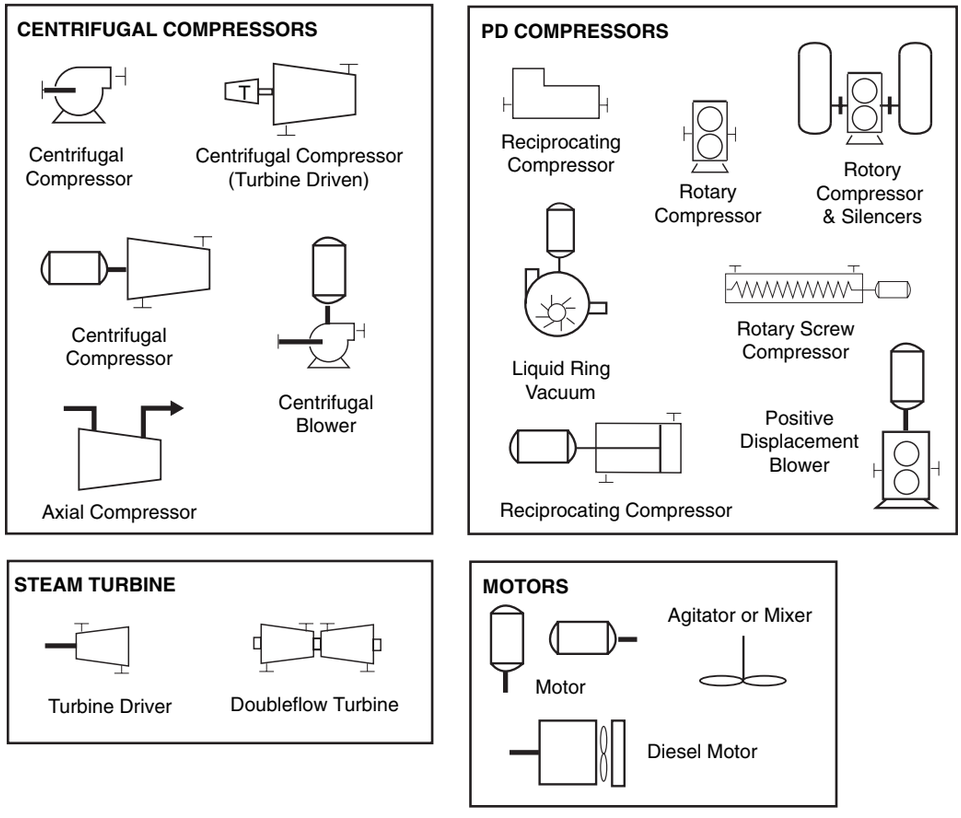


Figure 12.12 *Compressors, Steam Turbines, and Motors*

transfer heat energy between two process flows. The cooling tower performs a similar function, but cooling towers and heat exchangers use different scientific principles to operate. Heat exchangers transfer heat energy through conductive and convective heat transfer, whereas cooling towers transfer heat energy to the outside air through the principle of evaporation. Figures 12.13 and 12.14 illustrate the standard symbols used for heat exchangers and cooling towers.

The symbol for a heat exchanger clearly illustrates the flows through the device. It is important for a process technician to be able to recognize the shell inlet and outlet and the tube inlet and outlet flow paths. A heat exchanger with an arrow drawn through the body illustrates whether the tubeside flow is being used to heat or cool the shellside fluid. The downward direction indicates heating; the upward direction illustrates cooling.

Figure 12.13
Heat Exchangers

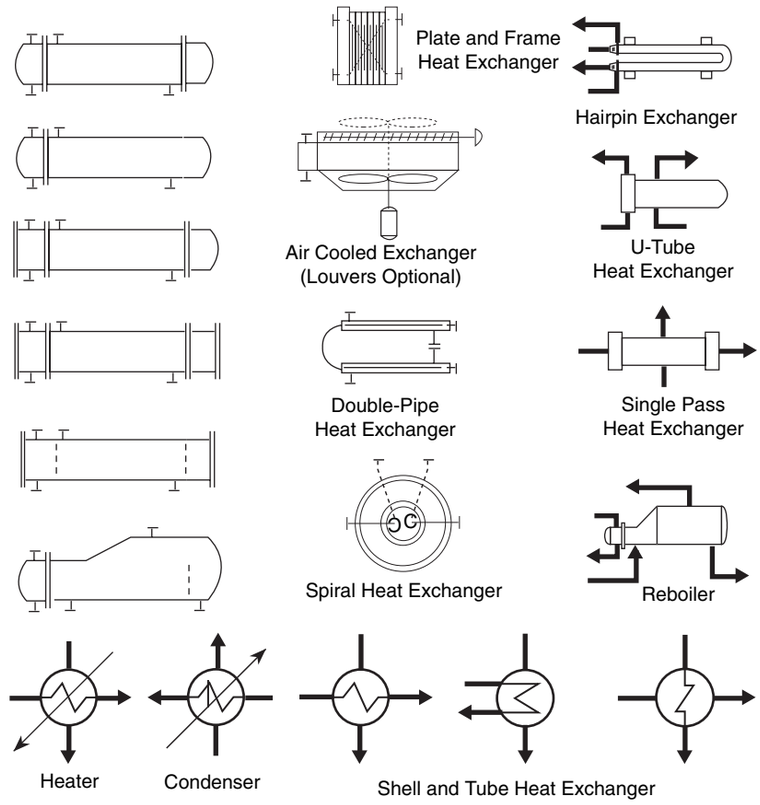
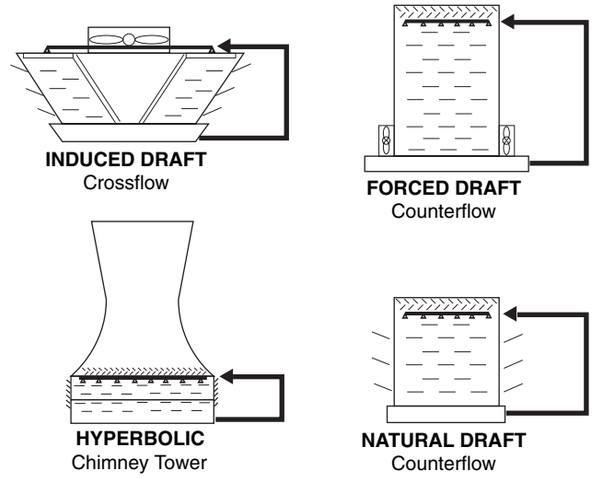


Figure 12.14
Cooling Towers



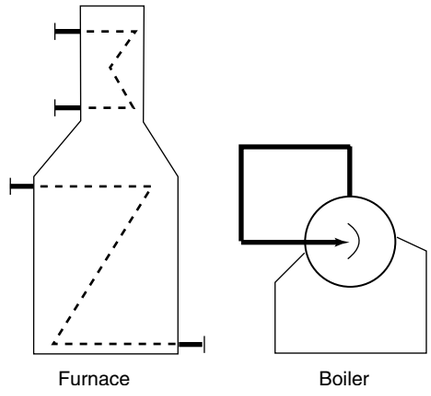


Figure 12.15
Furnace and Boiler

The symbol for a cooling tower is designed to resemble the actual device in the process unit. Cooled product flows out of the bottom of the tower and to the processing units. Hot water returns to a point located above the fill. The symbol will not show all of the various components of the cooling tower system, but it will provide a technician with a good foundation in cooling tower operation and enough information to clearly see the process.

Furnaces and Boilers

The standard symbols file for furnaces and boilers is shown in Figure 12.15. If a proprietary process includes several types of equipment not typically found on a standard symbol file, the designer will draw the device as it visually appears in the unit.

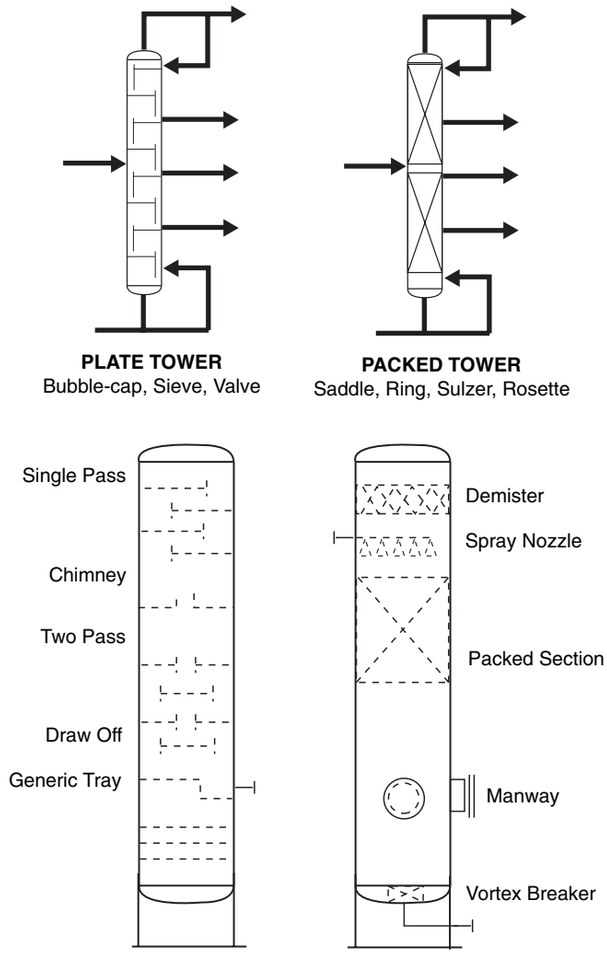
Distillation Columns

Distillation columns come in two basic designs, plate and packed (Figure 12.16). Flow arrangements vary from process to process. The symbols allow the technician to identify primary and secondary flow paths. Distillation is a process designed to separate the various components in a mixture by their boiling points. (See Chapter 15.) A distillation column is the central component of a much larger system. This system typically includes all of the equipment symbols found in this chapter. Plate distillation columns include sieve trays, valve trays, and bubble-cap trays. Packed columns are filled with packing material, rings, saddles, sulzer, and rosette.

Reactors

Reactors (Figure 12.17) are stationary vessels and can be classified as batch, semibatch, or continuous. A reactor is designed to allow chemicals to mix together under specific conditions to make chemical bonds, break chemical bonds, or make and break chemical bonds to form new products.

Figure 12.16
Distillation Symbols



Sources of Information for Process Technicians

Information used by process technicians comes from a variety of sources. Some of these sources are:

- Operating training manuals
- Process descriptions
- Process control manuals
- Equipment summaries
- Safety, health, and environment regulations
- Operating procedures
- Startup and shutdown procedures

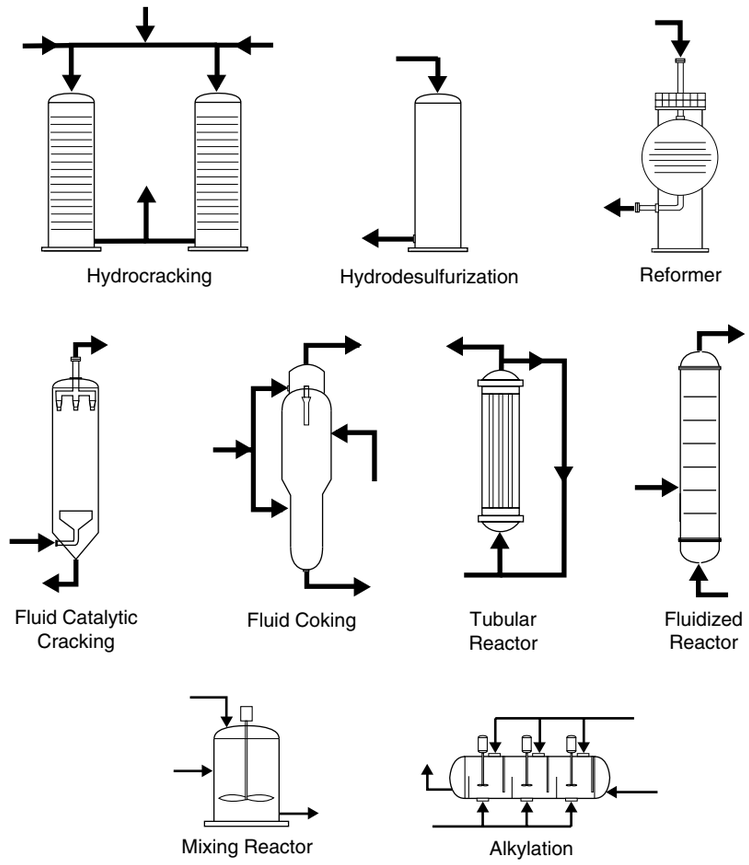


Figure 12.17
Reactor Symbols

- Emergency procedures
- Process diagrams
- Technical data books
- Detailed equipment vendor information

Summary

Process flow diagrams (PFDs) and process and instrument drawings (P&IDs) are used to outline or explain the complex flows, equipment, instrumentation, electronics, elevations, and foundations that exist in a process unit. A PFD is a simple flow diagram that describes the primary flow path through a unit. A P&ID is a complex representation of the various units found in a plant. Standardized symbols and diagrams have been developed for most pieces of industrial equipment, process flows, and instrumentation.

Review Questions

1. Describe a process flow diagram and a process and instrument drawing.
2. Draw the symbols for a gate, globe, and automatic valve.
3. Draw the symbols for a centrifugal pump and positive displacement pump.
4. Draw the symbols for a blower and a reciprocating compressor.
5. Draw the symbols for a steam turbine and centrifugal compressor.
6. Draw the symbols for a heat exchanger and a cooling tower.
7. Draw the symbols for a packed distillation column and plate distillation column.
8. Draw the symbols for a furnace and a boiler.
9. Draw a simple process flow diagram using the symbols from questions 2–8.
10. What information is obtained from a loop diagram?
11. What information is available on electrical one-line diagrams?
12. What information is contained on a plot plan drawing?