Online Continuing Education for Professional Engineers
Since 2009

Guide to Piping Diagrams (P&ID's)

PDH Credits:

3 PDH

Course No.:

CFD101

Publication Source:

US Dept. of Energy

Fundamentals Handbook – Engineering Symbology, Prints, and Drawings – Module 2

Pub. # DOE-HDBK-1016/1-93

Release Date:
Jan. 1993

1265 San Juan Dr. - Merritt Island, FL 32952
Phone: 321-501-5601

Department of Energy
Fundamentals Handbook

ENGINEERING SYMBOLOGY, PRINTS, AND DRAWINGS
Module 2
Engineering Fluid Diagrams and Prints

TABLE OF CONTENTS

LIST OF FIGURES iii

LIST OF TABLES v

REFERENCES vi

OBJECTIVES vii

ENGINEERING FLUIDS DIAGRAMS AND PRINTS 1

- Symbology 2
- Valve Symbols 3
- Valve Actuators 4
- Control Valve Designations 6
- Piping Systems 7
- Instrumentation 8
- Sensing Devices and Detectors 10
- Modifiers and Transmitters 11
- Indicators and Recorders 12
- Controllers 12
- Examples of Simple Instrument Loops 13
- Components 13
- Miscellaneous P&ID Symbols 15
- Summary 15

READING ENGINEERING P&IDs 16

- Standards and Conventions for Valve Status 16
- Summary 17

P&ID PRINT READING EXAMPLE 18

- Example 18
- Summary 22

TABLE OF CONTENTS

FLUID POWER P&IDs 23

Fluid Power Diagrams and Schematics 23
Pumps 23
Reservoirs 24
Actuator 24
Piping 26
Valves 27
Reading Fluid Power Diagrams 30
Types of Fluid Power Diagrams 33
Summary 35

LIST OF FIGURES

Figure 1 Valve Symbols 3

Figure 2 Valve Actuator Symbols 4

Figure 3 Remotely Controlled Valve 4

Figure 4 Level Control Valve 5

Figure 5 Control Valves with Valve Positioners 6

Figure 6 Control Valve Designations 6

Figure 7 Piping Symbols 7

Figure 8 More Piping Symbols 8

Figure 9 Detector and Sensing Device Symbols 10

Figure 10 Transmitters and Instruments 11

Figure 11 Indicators and Recorders 12

Figure 12 Controllers 12

Figure 13 Signal Conditioners 12

Figure 14 Instrumentation System Examples 13

Figure 15 Symbols for Major Components 14

Figure 16 Miscellaneous Symbols 15

Figure 17 Valve Status Symbols 16

Figure 18 Exercise P&ID 19

Figure 19 Fluid Power Pump and Compressor Symbols 23

Figure 20 Fluid Power Reservoir Symbols 24

Figure 21 Symbols for Linear Actuators 25

LIST OF FIGURES (Cont.)

Figure 22 Symbols for Rotary Actuators 26

Figure 23 Fluid Power Line Symbols 26

Figure 24 Valve Operation 27

Figure 25 Valve Symbol Development 28

Figure 26 Fluid Power Valve Symbols 29

Figure 27 Simple Hydraulic Power System 30

Figure 28 Line Diagram of Figure 27 30

Figure 29 Typical Fluid Power Diagram 31

Figure 30 Pictorial Fluid Power Diagram 33

Figure 31 Cutaway Fluid Power Diagram 34

Figure 32 Schematic Fluid Power Diagram 34

LIST OF TABLES

Table 1 Instrument Identifiers 9

REFERENCES

- ANSI Y14.5M - 1982, Dimensioning and Tolerancing, American National Standards Institute.
- ANSI Y32.2 - 1975, Graphic Symbols for Electrical and Electronic Diagrams, American National Standards Institute.
- Gasperini, Richard E., Digital Troubleshooting, Movonics Company; Los Altos, California, 1976.
- Jensen - Helsel, Engineering Drawing and Design, Second Ed., McGraw-Hill Book Company, New York, 1979.
- Lenk, John D., Handbook of Logic Circuits, Reston Publishing Company, Reston, Virginia, 1972.
- Wickes, William E., Logic Design with Integrated Circuits, John Wiley & Sons, Inc, 1968.
- Naval Auxiliary Machinery, United States Naval Institute, Annapolis, Maryland, 1951.
- TPC Training Systems, Reading Schematics and Symbols, Technical Publishing Company, Barrington, Illinois, 1974.
- Arnell, Alvin, Standard Graphical Symbols, McGraw-Hill Book Company, 1963.
- George Mashe, Systems Summary of a Westinghouse Pressurized Water Reactor, Westinghouse Electric Corporation, 1971.
- Zappe, R.W., Valve Selection Handbook, Gulf Publishing Company, Houston, Texas, 1968.

TERMINAL OBJECTIVE

1.0 Given an engineering print, **READ** and **INTERPRET** facility engineering Piping and Instrument Drawings.

ENABLING OBJECTIVES

1.1 **IDENTIFY** the symbols used on engineering P&IDs for the following types of valves:

a. Globe valve
b. Gate valve
c. Ball valve
d. Check valve
e. Stop check valve
f. Butterfly valve
g. Relief valve
h. Rupture disk
i. Three-way valve
j. Four-way valve
k. Throttle (needle) valve
l. Pressure regulator

1.2 **IDENTIFY** the symbols used on engineering P&IDs for the following types of valve operators:

a. Diaphragm valve operator
b. Motor valve operator
c. Solenoid valve operator
d. Piston (hydraulic) valve operator
e. Hand (manual) valve operator
f. Reach-rod valve operator

1.3 **IDENTIFY** the symbols used on engineering P&IDs for educators and ejectors.

1.4 **IDENTIFY** the symbols used on engineering P&IDs for the following lines:

a. Process
b. Pneumatic
c. Hydraulic
d. Inert gas
e. Instrument signal (electrical)
f. Instrument capillary
g. Electrical

ENABLING OBJECTIVES (cont.)

1.5 **IDENTIFY** the symbols used on engineering P&IDs for the following basic types of instrumentation:

a. Differential pressure cell
b. Temperature element
c. Venturi
d. Orifice
e. Rotometer
f. Conductivity or salinity cell
g. Radiation detector

1.6 **IDENTIFY** the symbols used on engineering P&IDs to denote the location, either local or board mounted, of instruments, indicators, and controllers.

1.7 **IDENTIFY** the symbols used on engineering P&IDs for the following types of instrument signal controllers and modifiers:

a. Proportional
b. Proportional-integral
c. Proportional-integral-differential
d. Square root extractors

1.8 **IDENTIFY** the symbols used on engineering P&IDs for the following types of system components:

a. Centrifugal pumps
b. Positive displacement pumps
c. Heat exchangers
d. Compressors
e. Fans
f. Tanks
g. Filters/strainers

ENABLING OBJECTIVES (cont.)

1.9 **STATE** how the following valve conditions are depicted on an engineering P&ID:

a. Open valve
b. Closed valve
c. Throttled valve
d. Combination valves (3- or 4-way valve)
e. Locked-closed valve
f. Locked-open valve
g. Fail-open valve
h. Fail-closed valve
i. Fail-as-is valve

1.10 Given an engineering P&ID, **IDENTIFY** components and **DETERMINE** the flowpath(s) for a given valve lineup.

1.11 **IDENTIFY** the symbols used on engineering fluid power drawings for the following components:

a. Pump
b. Compressor
c. Reservoir
d. Actuators
e. Piping and piping junctions
f. Valves

1.12 Given a fluid power type drawing, **DETERMINE** the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

ENGINEERING FLUIDS DIAGRAMS AND PRINTS

To read and understand engineering fluid diagrams and prints, usually referred to as P&IDs, an individual must be familiar with the basic symbols.

EO 1.1 IDENTIFY the symbols used on engineering P&IDs for the following types of valves:

a. Globe valve
b. Gate valve
c. Ball valve
d. Check valve
e. Stop check valve
f. Butterfly valve
g. Relief valve
h. Rupture disk
i. Three-way valve
j. Four-way valve
k. Throttle (needle) valve
l. Pressure regulator

EO 1.2 IDENTIFY the symbols used on engineering P&IDs for the following types of valve operators:

a. Diaphragm valve operator
b. Motor valve operator
c. Solenoid valve operator
d. Piston (hydraulic) valve operator
e. Hand (manual) valve operator
f. Reach rod valve operator

EO 1.3 IDENTIFY the symbols used on engineering P&IDs for educators and ejectors.

EO 1.4 IDENTIFY the symbols used on engineering P&IDs for the following lines:

a. Process
b. Pneumatic
c. Hydraulic
d. Inert gas
e. Instrument signal (electrical)
f. Instrument capillary
g. Electrical

EO 1.5 IDENTIFY the symbols used on engineering P&IDs for the following basic types of instrumentation:

- **a. Differential pressure cell**
- **b. Temperature element**
- **c. Venturi**
- **d. Orifice**
- **e. Rotometer**
- **f. Conductivity or salinity cell**
- **g. Radiation detector**

EO 1.6 IDENTIFY the symbols used on engineering P&IDs to denote the location, either local or board mounted, of instruments, indicators, and controllers.

EO 1.7 IDENTIFY the symbols used on engineering P&IDs for the following types of instrument signal modifiers:

- **a. Proportional**
- **b. Proportional-integral**
- **c. Proportional-integral-differential**
- **d. Square root extractors**

EO 1.8 IDENTIFY the symbols used on engineering P&IDs for the following types of system components:

- **a. Centrifugal pumps**
- **b. Positive displacement pumps**
- **c. Heat exchangers**
- **d. Compressors**
- **e. Fans**
- **f. Tanks**
- **g. Filters/strainers**

Symbology

To read and interpret piping and instrument drawings (P&IDs), the reader must learn the meaning of the symbols. This chapter discusses the common symbols that are used to depict fluid system components. When the symbology is mastered, the reader will be able to interpret most P&IDs.

The reader should note that this chapter is only representative of fluid system symbology, rather than being all-inclusive. The symbols presented herein are those most commonly used in engineering P&IDs. The reader may expand his or her knowledge by obtaining and studying the appropriate drafting standards used at his or her facility.

Valve Symbols

Valves are used to control the direction, flow rate, and pressure of fluids. Figure 1 shows the symbols that depict the major valve types.

It shoud be noted that globe and gate valves will often be depicted by the same valve symbol. In such cases, information concerning the valve type may be conveyed by the component identification number or by the notes and legend section of the drawing; however, in many instances even that may not hold true.

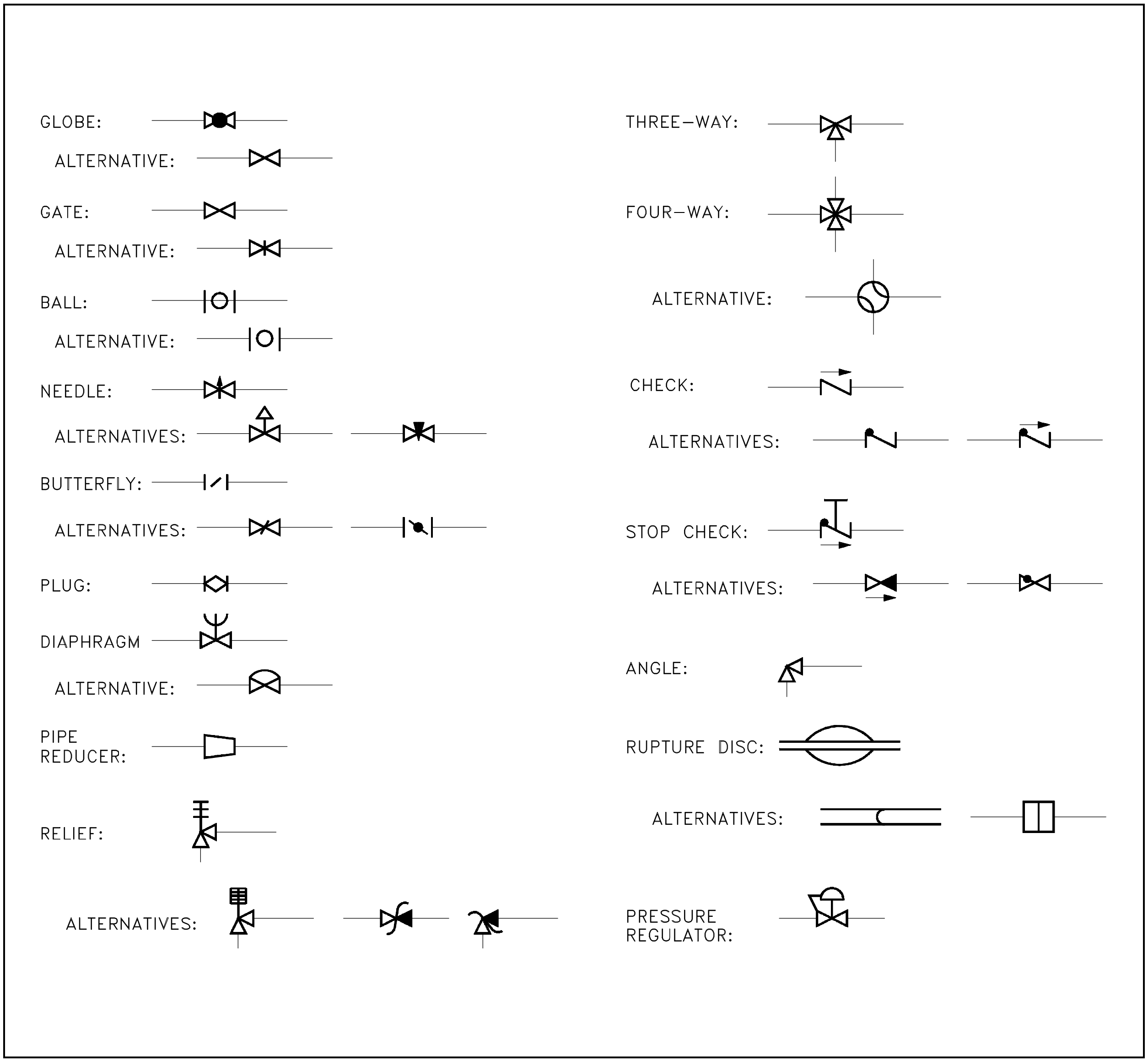


Figure 1 Valve Symbols

Valve Actuators

Some valves are provided with actuators to allow remote operation, to increase mechanical advantage, or both. Figure 2 shows the symbols for the common valve actuators. Note that although each is shown attached to a gate valve, an actuator can be attached to any type of valve body. If no actuator is shown on a valve symbol, it may be assumed the valve is equipped only with a handwheel for manual operation.

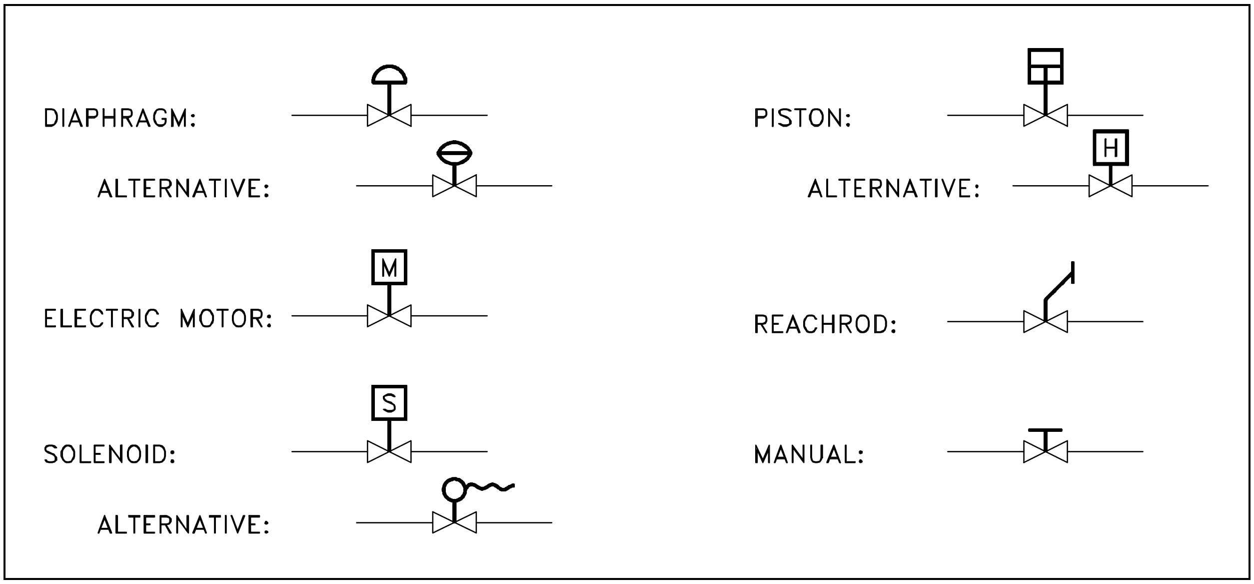


Figure 2 Valve Actuator Symbols

The combination of a valve and an actuator is commonly called a control valve. Control valves are symbolized by combining the appropriate valve symbol and actuator symbol, as illustrated in Figure 2. Control valves can be configured in many different ways. The most commonly found configurations are to manually control the actuator from a remote operating station, to automatically control the actuator from an instrument, or both.

In many cases, remote control of a valve is accomplished by using an intermediate, small control valve to operate the actuator of the process control valve. The intermediate control valve is placed in the line supplying motive force to the process control valve, as shown in Figure 3. In this example, air to the process air-operated control valve is controlled by the solenoid-operated, 3-way valve in the air supply line. The 3-way valve may supply air to the control valve's diaphragm or vent the diaphragm to the atmosphere.

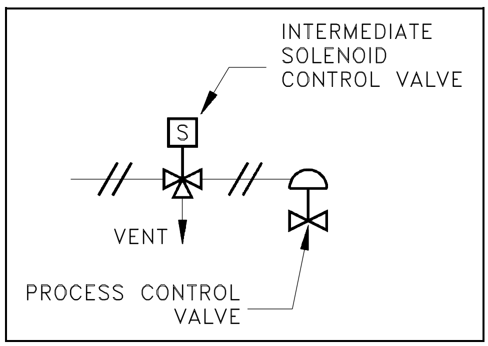


Figure 3 Remotely Controlled Valve

Note that the symbols alone in Figure 3 do not provide the reader with enough information to determine whether applying air pressure to the diaphragm opens or closes the process control valve, or whether energizing the solenoid pressurizes or vents the diaphragm. Further, Figure 3 is incomplete in that it does not show the electrical portion of the valve control system nor does it identify the source of the motive force (compressed air). Although Figure 3 informs the reader of the types of mechanical components in the control system and how they interconnect, it does not provide enough information to determine how those components react to a control signal.

Control valves operated by an instrument signal are symbolized in the same manner as those shown previously, except the output of the controlling instrument goes to the valve actuator. Figure 4 shows a level instrument (designated "LC") that controls the level in the tank by positioning an air-operated diaphragm control valve. Again, note that Figure 4 does not contain enough information to enable the reader to determine how the control valve responds to a change in level.

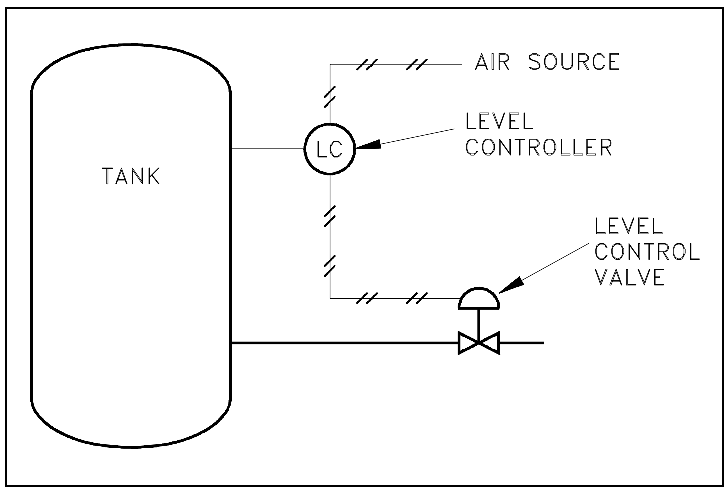


Figure 4 Level Control Valve

An additional aspect of some control valves is a valve positioner, which allows more precise control of the valve. This is especially useful when instrument signals are used to control the valve. An example of a valve positioner is a set of limit switches operated by the motion of the valve. A positioner is symbolized by a square box on the stem of the control valve actuator. The positioner may have lines attached for motive force, instrument signals, or both. Figure 5 shows two examples of valves equipped with positioners. Note that, although these examples are more detailed than those of Figure 3 and Figure 4, the reader still does not have sufficient information to fully determine response of the control valve to a change in control signal.

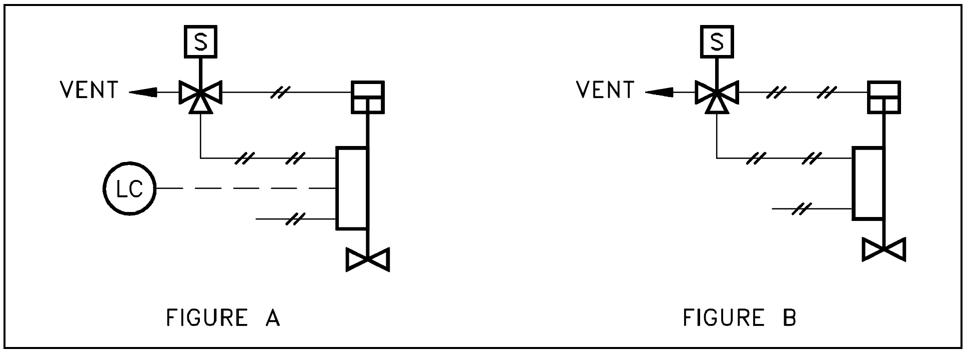


Figure 5 Control Valves with Valve Positioners

In Example A of Figure 5, the reader can reasonably assume that opening of the control valve is in some way proportional to the level it controls and that the solenoid valve provides an override of the automatic control signals. However, the reader cannot ascertain whether it opens or closes the control valve. Also, the reader cannot determine in which direction the valve moves in response to a change in the control parameter. In Example B of Figure 5, the reader can make the same general assumptions as in Example A, except the control signal is unknown. Without additional information, the reader can only assume the air supply provides both the control signal and motive force for positioning the control valve. Even when valves are equipped with positioners, the positioner symbol may appear only on detailed system diagrams. Larger, overall system diagrams usually do not show this much detail and may only show the examples of Figure 5 as air-operated valves with no special features.

Control Valve Designations

A control valve may serve any number of functions within a fluid system. To differentiate between valve uses, a balloon labeling system is used to identify the function of a control valve, as shown in Figure 6. The common convention is that the first letter used in the valve designator indicates the parameter to be controlled by the valve. For example:

F = flow
T = temperature
L = level
P = pressure
H = hand (manually operated valve)

The second letter is usually a "C" and identifies the valve as a controller, or active component, as opposed to a hand-operated valve. The third letter is a "V" to indicate that the piece of equipment is a valve.

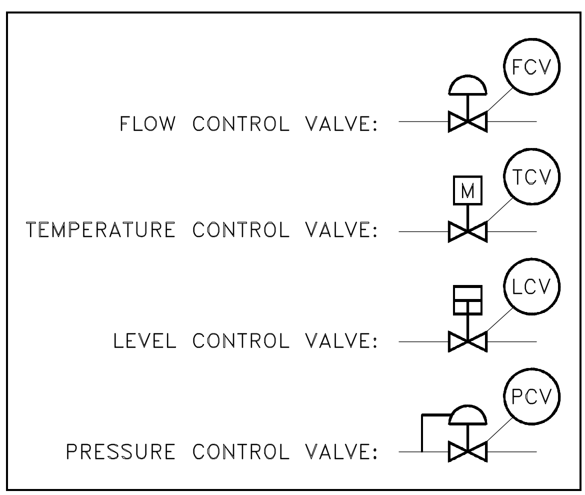


Figure 6 Control Valve Designations

Piping Systems

The piping of a single system may contain more than a single medium. For example, although the main process flow line may carry water, the associated auxiliary piping may carry compressed air, inert gas, or hydraulic fluid. Also, a fluid system diagram may also depict instrument signals and electrical wires as well as piping. Figure 7 shows commonly used symbols for indicating the medium carried by the piping and for differentiating between piping, instrumentation signals, and electrical wires. Note that, although the auxiliary piping symbols identify their mediums, the symbol for the process flow line does not identify its medium.

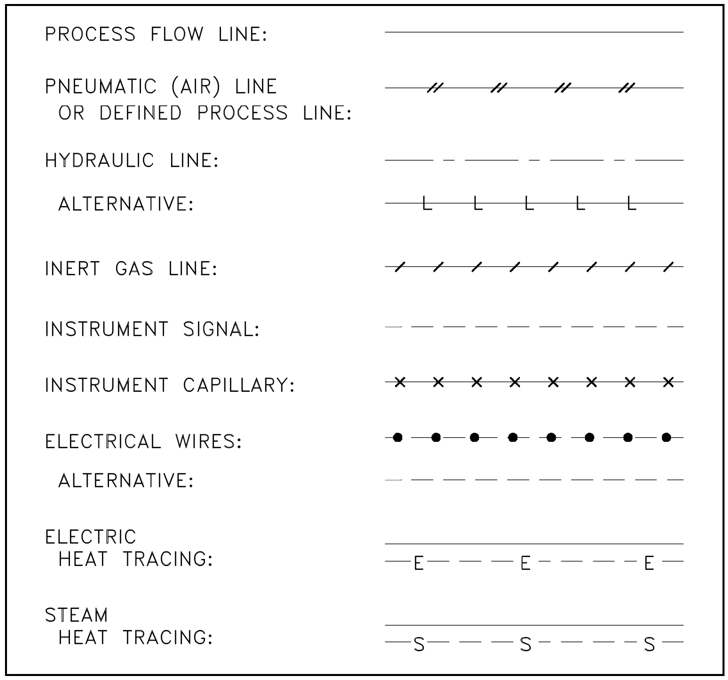


Figure 7 Piping Symbols

The diagram may also depict the individual fittings comprising the piping runs depending on its intended use. Figure 8 shows symbols used to depict pipe fittings.

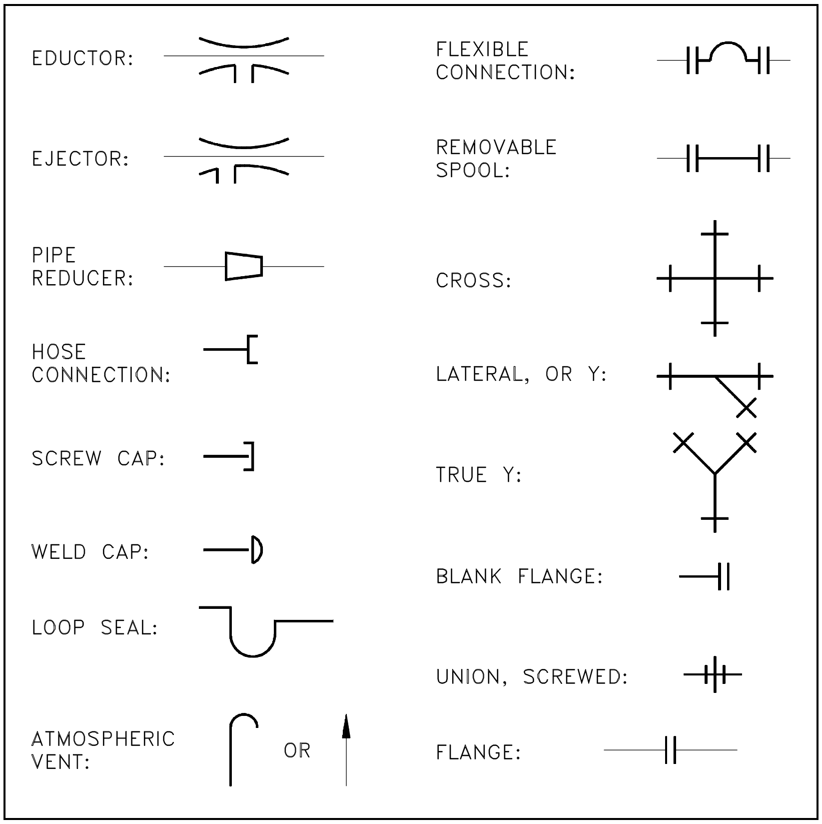


Figure 8 More Piping Symbols

Instrumentation

One of the main purposes of a P&ID is to provide functional information about how instrumentation in a system or piece of equipment interfaces with the system or piece of equipment. Because of this, a large amount of the symbology appearing on P&IDs depicts instrumentation and instrument loops.

The symbols used to represent instruments and their loops can be divided into four categories. Generally each of these four categories uses the component identifying (labeling) scheme identified in Table 1. The first column of Table 1 lists the letters used to identify the parameter being sensed or monitored by the loop or instrument. The second column lists the letters used to indicate the type of indicator or controller. The third column lists the letters used to indicate the type of component. The fourth column lists the letters used to indicate the type of signals that are being modified by a modifier.

TABLE 1
Instrument Identifiers

Sensed Parameter	Type of Indicator or Controller	Type of Component	Type of signal
F = flow T = temperature P = pressure I = current L = level V = voltage Z = position	R = recorder I = indicator C = controller	T = transmitter M = modifier E = element	I = current V = voltage P = pneumatic

The first three columns above are combined such that the resulting instrument identifier indicates its sensed parameter, the function of the instrument, and the type of instrument. The fourth column is used only in the case of an instrument modifier and is used to indicate the types of signals being modified. The following is a list of example instrument identifiers constructed from Table 1.

FIC = flow indicating controller
FM = flow modifier
PM = pressure modifier
TE = temperature element
TR = temperature recorder
LIC = level indicating controller
TT = temperature transmitter
PT = pressure transmitter
FE = flow element
FI = flow indicator
TI = temperature indicator
FC = flow controller

Sensing Devices and Detectors

The parameters of any system are monitored for indication, control, or both. To create a usable signal, a device must be inserted into the system to detect the desired parameter. In some cases, a device is used to create special conditions so that another device can supply the necessary measurement. Figure 9 shows the symbols used for the various sensors and detectors.

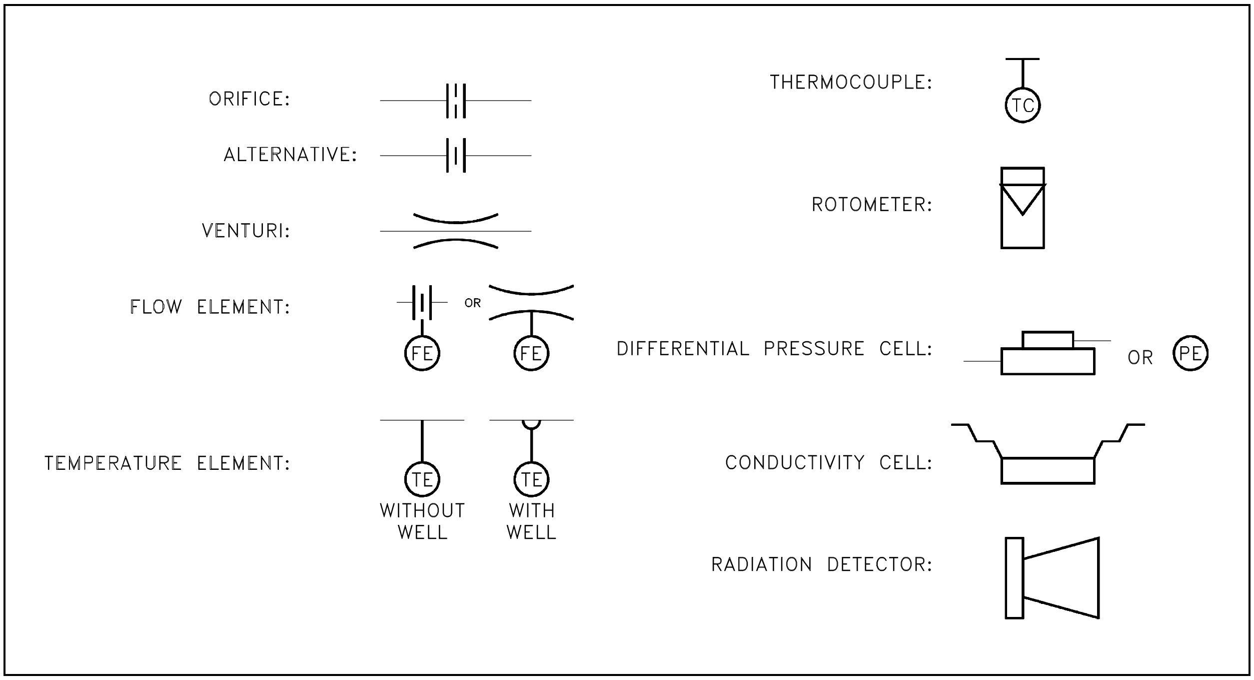


Figure 9 Detector and Sensing Device Symbols

Modifiers and Transmitters

Sensors and detectors by themselves are not sufficient to create usable system indications. Each sensor or detector must be coupled with appropriate modifiers and/or transmitters. The exceptions are certain types of local instrumentation having mechanical readouts, such as bourdon tube pressure gages and bimetallic thermometers. Figure 10 illustrates various examples of modifiers and transmitters. Figure 10 also illustrates the common notations used to indicate the location of an instrument, i.e., local or board mounted.

Transmitters are used to convert the signal from a sensor or detector to a form that can be sent to a remote point for processing, controlling, or monitoring. The output can be electronic (voltage or current), pneumatic, or hydraulic. Figure 10 illustrates symbols for several specific types of transmitters.

The reader should note that modifiers may only be identified by the type of input and output signal (such as I/P for one that converts an electrical input to a pneumatic output) rather than by the monitored parameter (such as PM for pressure modifier).

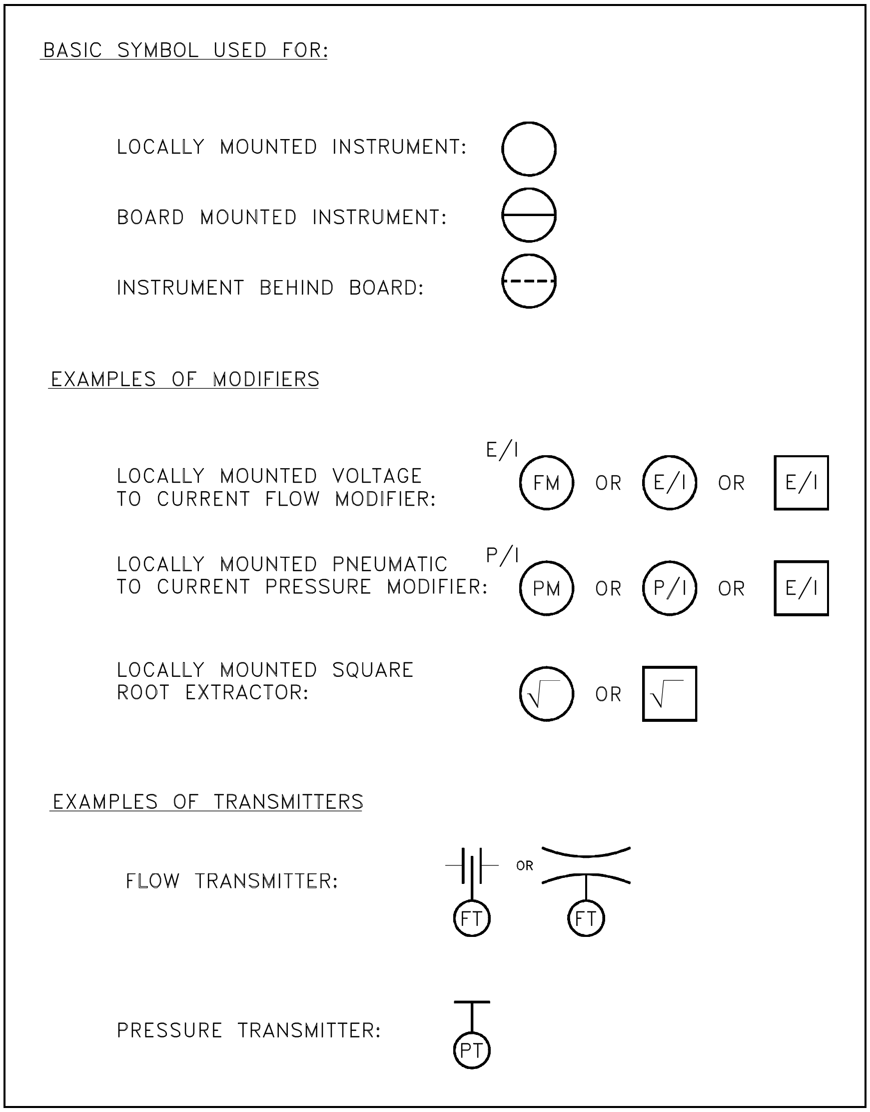


Figure 10 Transmitters and Instruments

Indicators and Recorders

Indicators and recorders are instruments that convert the signal generated by an instrument loop into a readable form. The indicator or recorder may be locally or board mounted, and like modifiers and transmitters this information is indicated by the type of symbol used. Figure 11 provides examples of the symbols used for indicators and recorders and how their location is denoted.

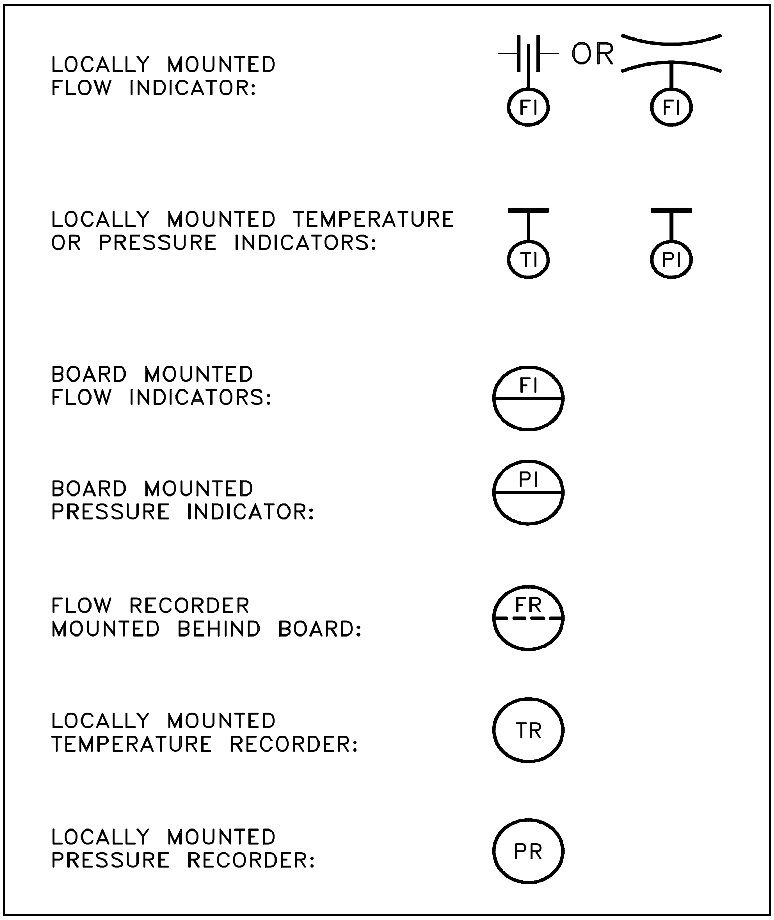


Figure 11 Indicators and Recorders

Controllers

Controllers process the signal from an instrument loop and use it to position or manipulate some other system component. Generally they are denoted by placing a "C" in the balloon after the controlling parameter as shown in Figure 12. There are controllers that serve to process a signal and create a new signal. These include proportional controllers, proportional-integral controllers, and proportional-integral-differential controllers. The symbols for these controllers are illustrated in Figure 13. Note that these types of controllers are also called signal conditioners.

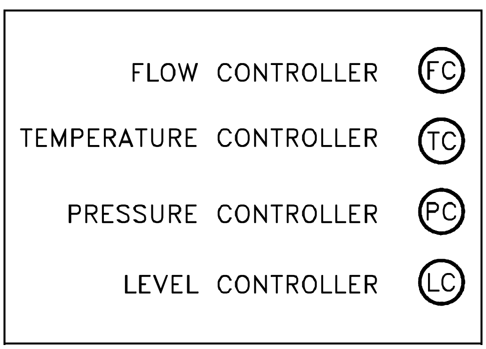


Figure 12 Controllers

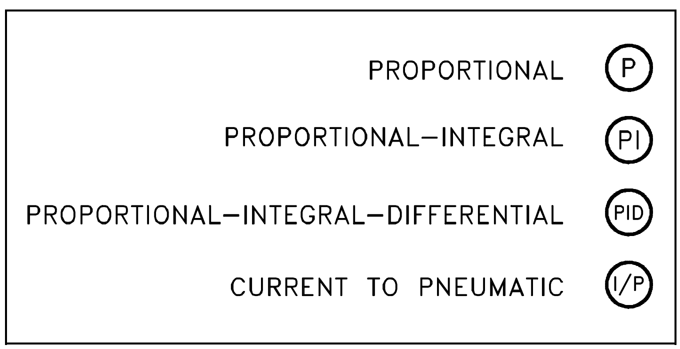


Figure 13 Signal Conditioners

Examples of Simple Instrument Loops

Figure 14 shows two examples of simple instrument loops. Figure 14 (A) shows a temperature transmitter (TT), which generates two electrical signals. One signal goes to a board-mounted temperature recorder (TR) for display. The second signal is sent to a proportional-integral-derivative (PID) controller, the output of which is sent to a current-to-pneumatic modifier (I/P). In the I/P modifier, the electric signal is converted into a pneumatic signal, commonly 3 psi to 15 psi, which in turn operates the valve. The function of the complete loop is to modify flow based on process fluid temperature. Note that there is not enough information to determine how flow and temperature are related and what the setpoint is, but in some instances the setpoint is stated on a P&ID. Knowing the setpoint and purpose of the system will usually be sufficient to allow the operation of the instrument loop to be determined.

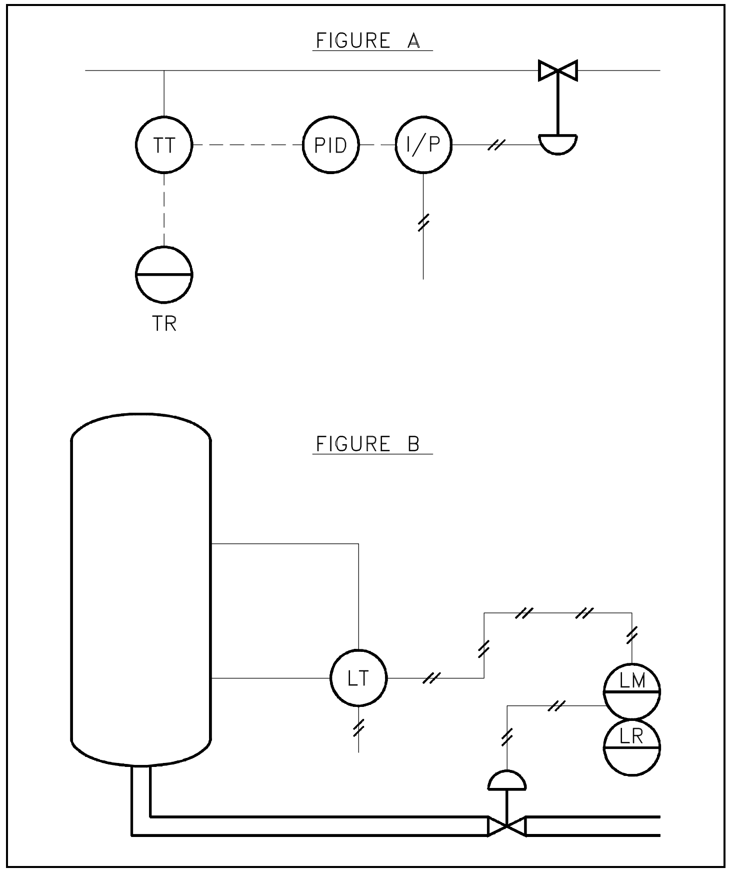


Figure 14 Instrumentation System Examples

The pneumatic level transmitter (LT) illustrated in Figure 14 (B) senses tank level. The output of the level transmitter is pneumatic and is routed to a board-mounted level modifier (LM). The level modifier conditions the signal (possibly boosts or mathematically modifies the signal) and uses the modified signal for two purposes. The modifier drives a board-mounted recorder (LR) for indication, and it sends a modified pneumatic signal to the diaphragm-operated level control valve. Notice that insufficient information exists to determine the relationship between sensed tank level and valve operation.

Components

Within every fluid system there are major components such as pumps, tanks, heat exchangers, and fans. Figure 15 shows the engineering symbols for the most common major components.

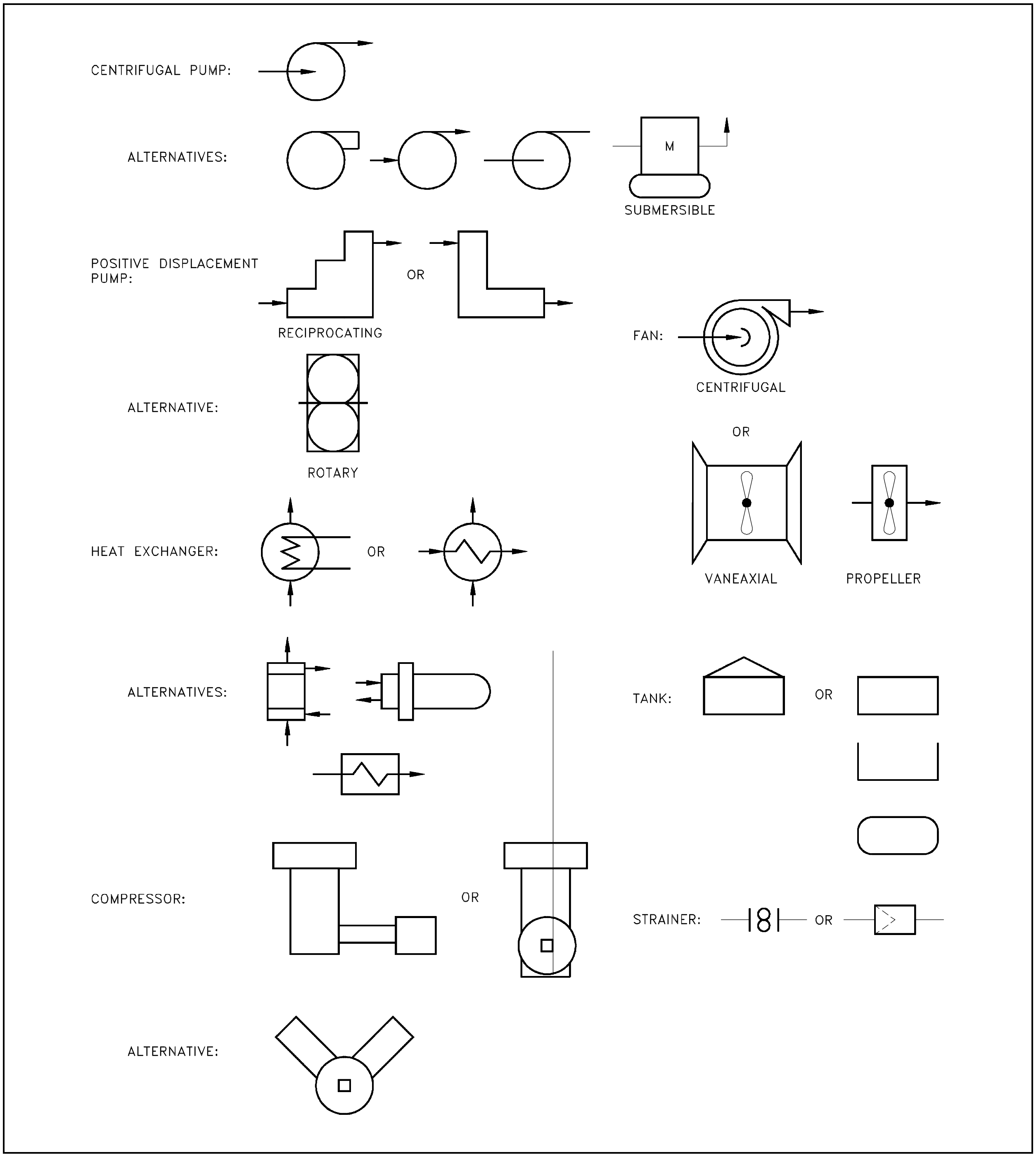


Figure 15 Symbols for Major Components

Miscellaneous P&ID Symbols

In addition to the normal symbols used on P&IDs to represent specific pieces of equipment, there are miscellaneous symbols that are used to guide or provide additional information about the drawing. Figure 16 lists and explains four of the more common miscellaneous symbols.

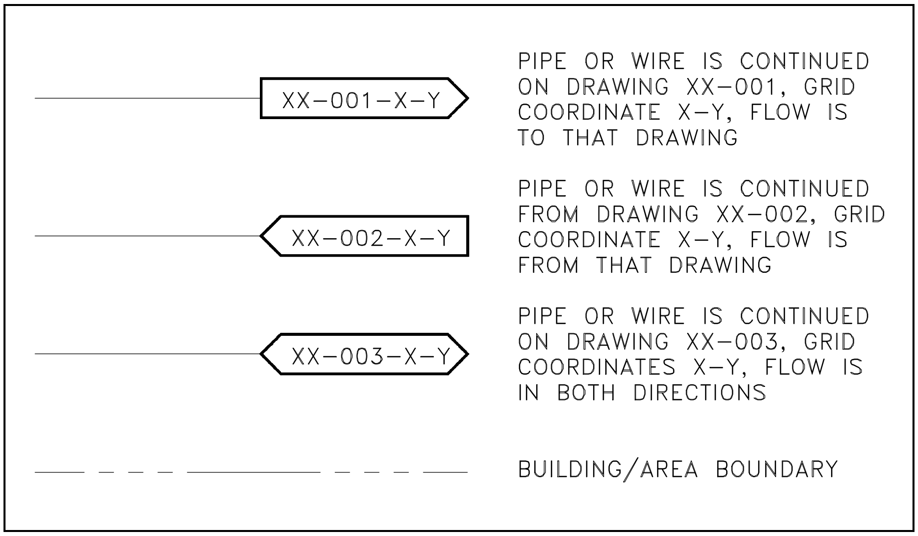


Figure 16 Miscellaneous Symbols

Summary

The important information in this chapter is summarized below.

Engineering Fluids Diagrams and Prints Summary

- In this chapter the common symbols found on P&IDs for valves, valve operators, process piping, instrumentation, and common system components were reviewed.

READING ENGINEERING P&IDs

Standards and conventions have been developed to provide consistency from drawing to drawing. To accurately interpret a drawing, these standards and conventions must be understood.

EO 1.9 STATE how the following valve conditions are depicted on an engineering P&ID drawing:

a.	**Open valve**	**e.**	**Locked-closed valve**
b.	**Closed valve**	**f.**	**Locked-open valve**
c.	**Throttled valve**	**g.**	**Fail-open valves**
d.	**Combination valves (3- or 4- way valve)**	**h.**	**Fail-closed valve**
		i.	**Fail-as-is valve**

Standards and Conventions for Valve Status

Before a diagram or print can be properly read and understood, the basic conventions used by P&IDs to denote valve positions and failure modes must be understood. The reader must be able to determine the valve position, know if this position is normal, know how the valve will fail, and in some cases know if the valve is normally locked in that position. Figure 17 illustrates the symbols used to indicate valve status. Unless otherwise stated, P&IDs indicate valves in their "normal" position. This is usually interpreted as the normal or primary flowpath for the system. An exception is safety systems, which are normally shown in their standby or non-accident condition.

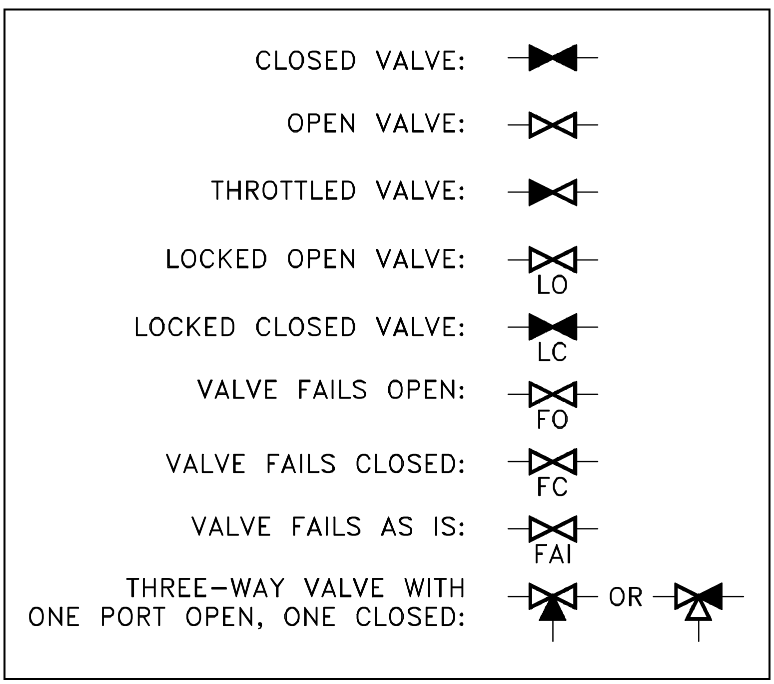


Figure 17 Valve Status Symbols

3-way valves are sometimes drawn in the position that they will fail to instead of always being drawn in their "normal" position. This will either be defined as the standard by the system of drawings or noted in some manner on the individual drawings.

Summary

The important information in this chapter is summarized below.

Reading Engineering P&IDs Summary

- This chapter reviewed the basic symbology, common standards, and conventions used on P&IDs, such as valve conditions and modes of failure. This information, with the symbology learned in the preceding chapter, provides the information necessary to read and interpret most P&IDs.

P&ID PRINT READING EXAMPLE

The ability to read and understand prints is achieved through the repetitive reading of prints.

EO 1.10 Given an engineering P&ID, IDENTIFY components and DETERMINE the flowpath(s) for a given valve lineup.

Example

At this point, all the symbols for valves and major components have been presented, as have the conventions for identifying the condition of a system. Refer to Figure 18 as necessary to answer the following questions. The answers are provided in the back of this section so that you may judge your own knowledge level.

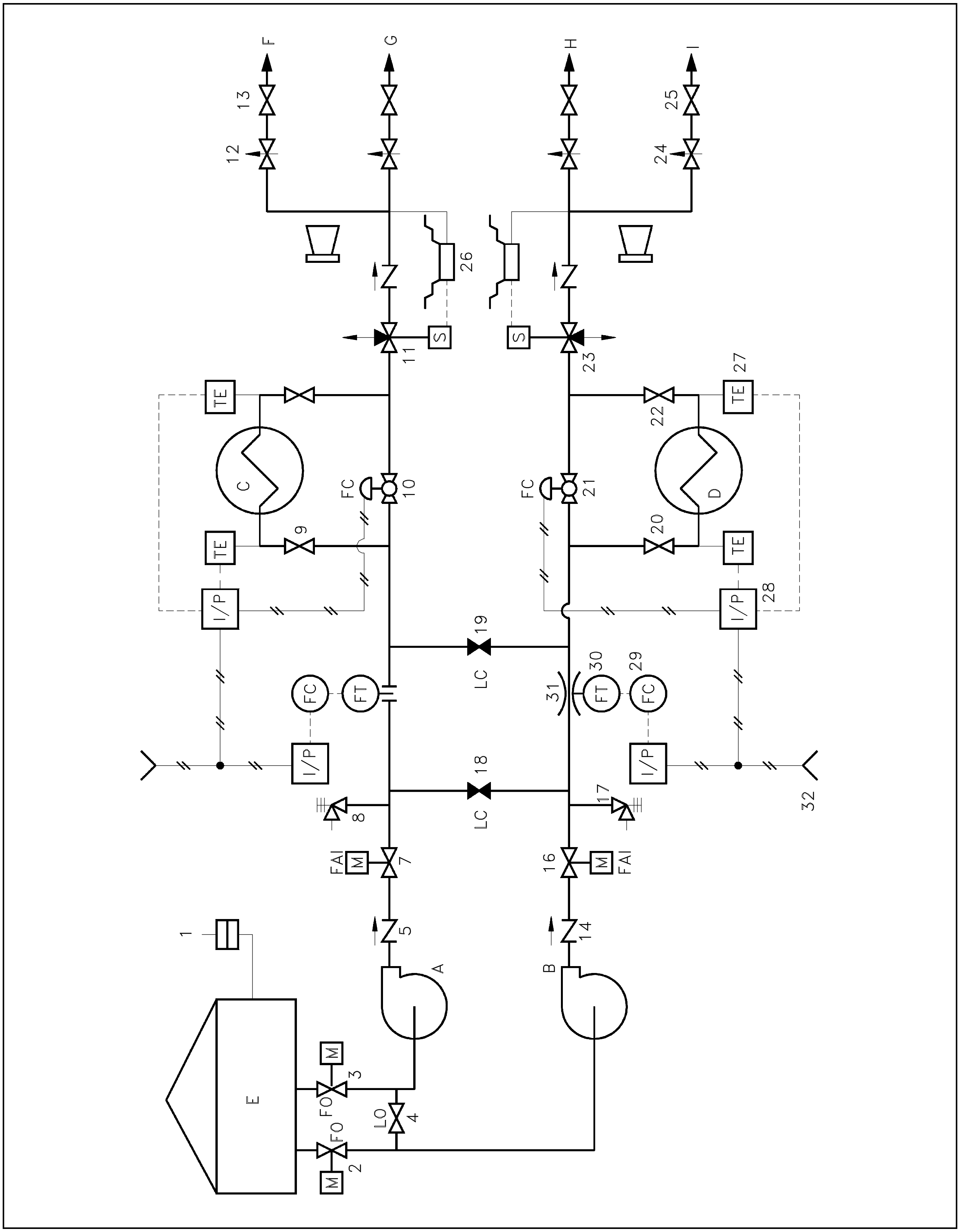


Figure 18 Exercise P&ID

1. Identify the following components by letter or number.

 ____ a. Centrifugal pump
 ____ b. Heat exchanger
 ____ c. Tank
 ____ d. Venturi
 ____ e. Rupture disc
 ____ f. Relief valve
 ____ g. Motor-operated valve
 ____ h. Air-operated valve
 ____ i. Throttle valve
 ____ j. Conductivity cell
 ____ k. Air line
 ____ l. Current-to-pneumatic converter
 ____ m. Check valve
 ____ n. A locked-closed valve
 ____ o. A closed valve
 ____ p. A locked-open valve
 ____ q. A solenoid valve

2. What is the controlling parameter for Valves 10 and 21?

3. Which valves would need to change position in order for Pump B to supply flow to only points G and H?

4. Which valves will fail open? Fail closed? Fail as is?

Answers for questions on Figure 18

1.
   a. A or B
   b. C or D
   c. E
   d. 31
   e. 1
   f. 8 or 17
   g. 2,3,7 or 16
   h. 10, 21
   i. 12 or 24
   j. 26
   k. 32
   l. 28
   m. 5 or 14
   n. 18 or 19
   o. 18 or 19
   p. 4
   q. 11 or 23

2. Temperature as sensed by the temperature elements (TE)

3. Open 18 and/or 19
   Shut 13 and 25

4. Fail Open: 2 and 3
   Fail Closed: 10 and 21
   Fail as is: 7 and 16

Summary

The important information in this chapter is summarized below.

P&ID Print Reading Example Summary

- This chapter provided the student with examples in applying the material learned in Chapters 1 and 2.

FLUID POWER P&IDs

Fluid power diagrams and schematics require an independent review because they use a unique set of symbols and conventions.

EO 1.11 IDENTIFY the symbols used on engineering fluid power drawings for the following components:

a. Pump
b. Compressor
c. Reservoir
d. Actuators
e. Piping and piping junctions
f. Valves

EO 1.12 Given a fluid power type drawing, DETERMINE the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

Fluid Power Diagrams and Schematics

Different symbology is used when dealing with systems that operate with fluid power. Fluid power includes either gas (such as air) or hydraulic (such as water or oil) motive media. Some of the symbols used in fluid power systems are the same or similar to those already discussed, but many are entirely different.

Fluid power systems are divided into five basic parts: pumps, reservoirs, actuators, valves, and lines.

Pumps

In the broad area of fluid power, two categories of pump symbols are used, depending on the motive media being used (i.e., hydraulic or pneumatic). The basic symbol for the pump is a circle containing one or more arrow heads indicating the direction(s) of flow with the points of the arrows in contact with the circle. Hydraulic pumps are shown by solid arrow heads. Pneumatic compressors are represented by hollow arrow heads. Figure 19 provides common symbols used for pumps (hydraulic) and compressors (pneumatic) in fluid power diagrams.

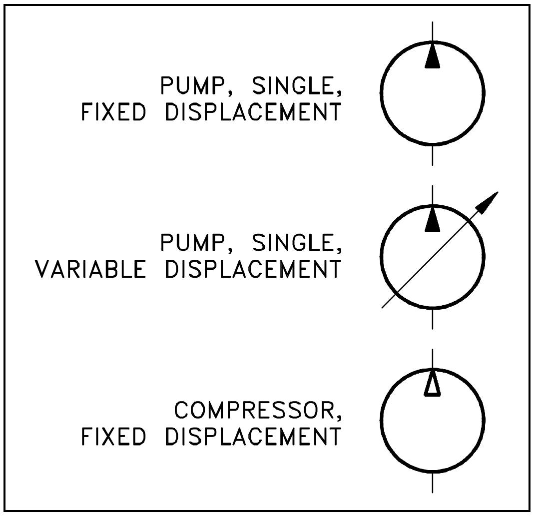


Figure 19 Fluid Power Pump and Compressor Symbols

Reservoirs

Reservoirs provide a location for storage of the motive media (hydraulic fluid or compressed gas). Although the symbols used to represent reservoirs vary widely, certain conventions are used to indicate how a reservoir handles the fluid. Pneumatic reservoirs are usually simple tanks and their symbology is usually some variation of the cylinder shown in Figure 20. Hydraulic reservoirs can be much more complex in terms of how the fluid is admitted to and removed from the tank. To convey this information, symbology conventions have been developed. These symbols are in Figure 20.

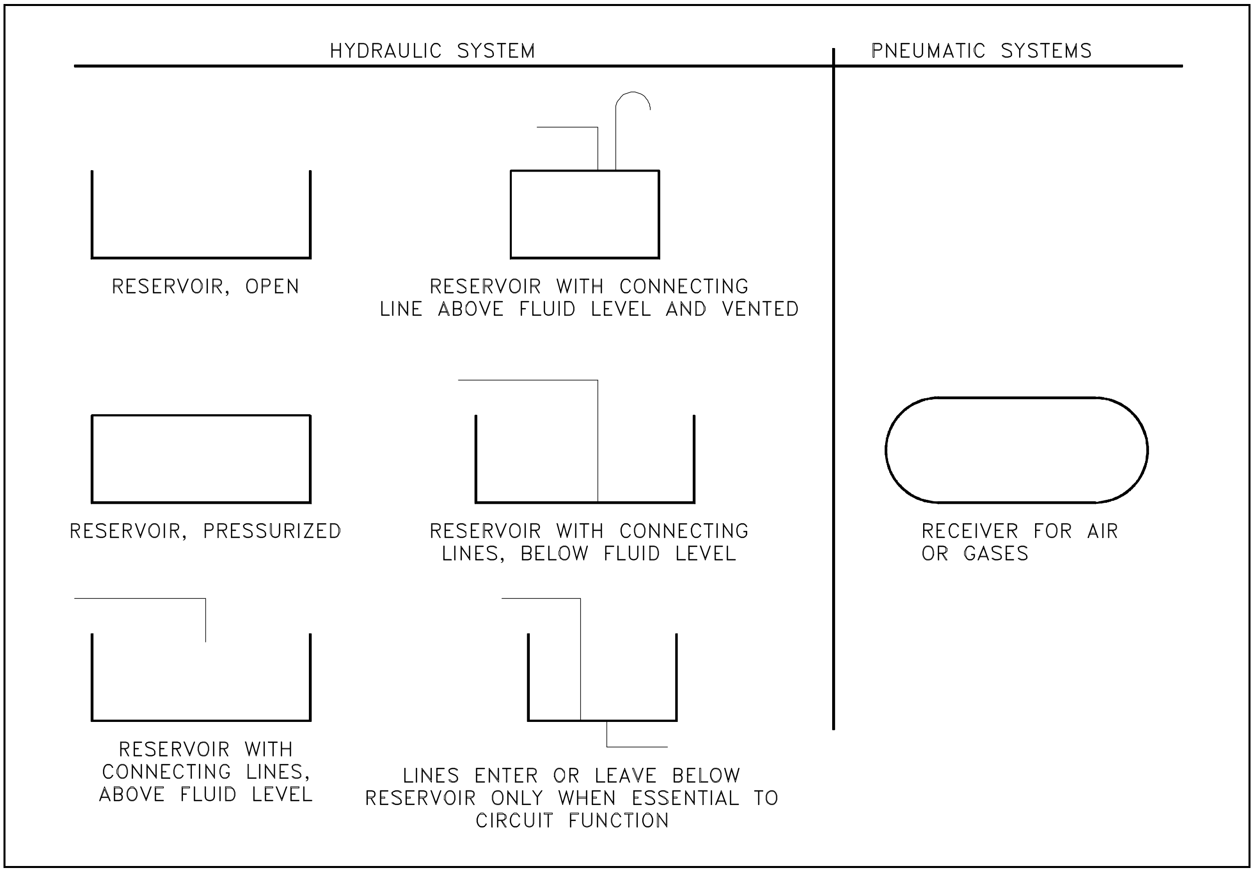


Figure 20 Fluid Power Reservoir Symbols

Actuator

An actuator in a fluid power system is any device that converts the hydraulic or pneumatic pressure into mechanical work. Actuators are classified as linear actuators and rotary actuators. Linear actuators have some form of piston device. Figure 21 illustrates several types of linear actuators and their drawing symbols.

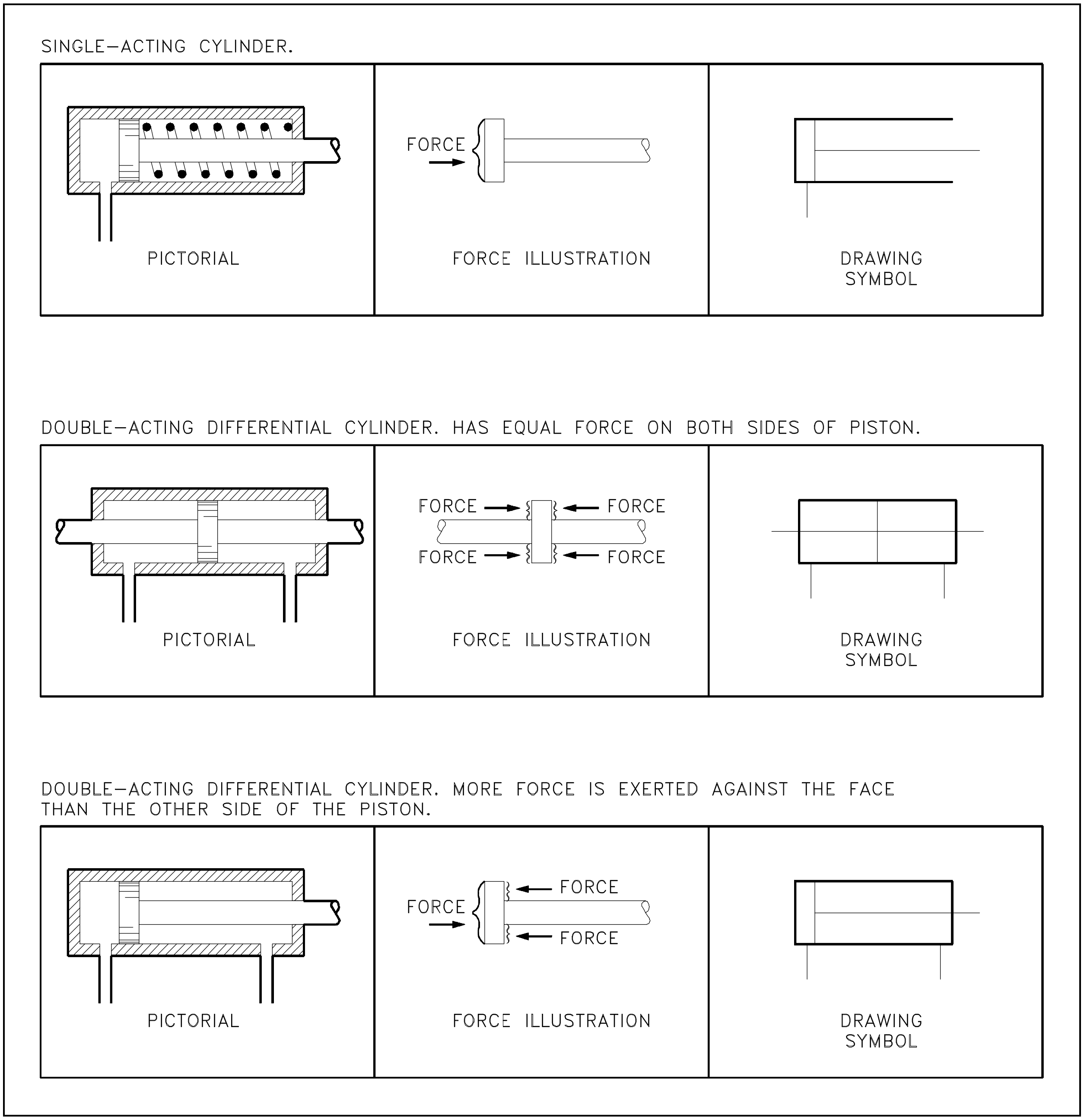


Figure 21 Symbols for Linear Actuators

Rotary actuators are generally called motors and may be fixed or variable. Several of the more common rotary symbols are shown in Figure 22. Note the similarity between rotary motor symbols in Figure 22 and the pump symbols shown in Figure 19. The difference between them is that the point of the arrow touches the circle in a pump and the tail of the arrow touches the circle in a motor.

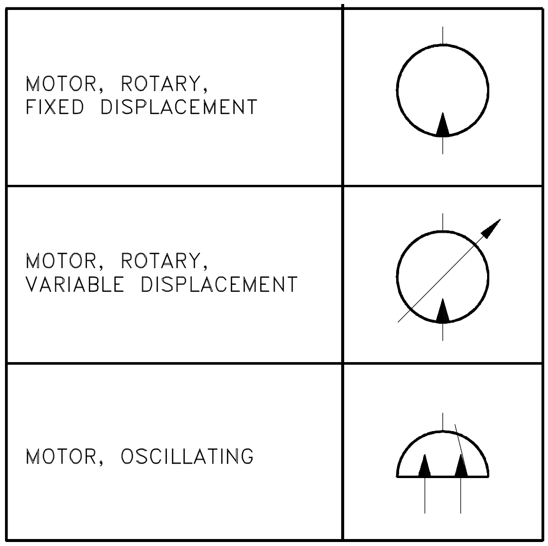


Figure 22 Symbols for Rotary Actuators

Piping

The sole purpose of piping in a fluid power system is to transport the working media, at pressure, from one point to another. The symbols for the various lines and termination points are shown in Figure 23.

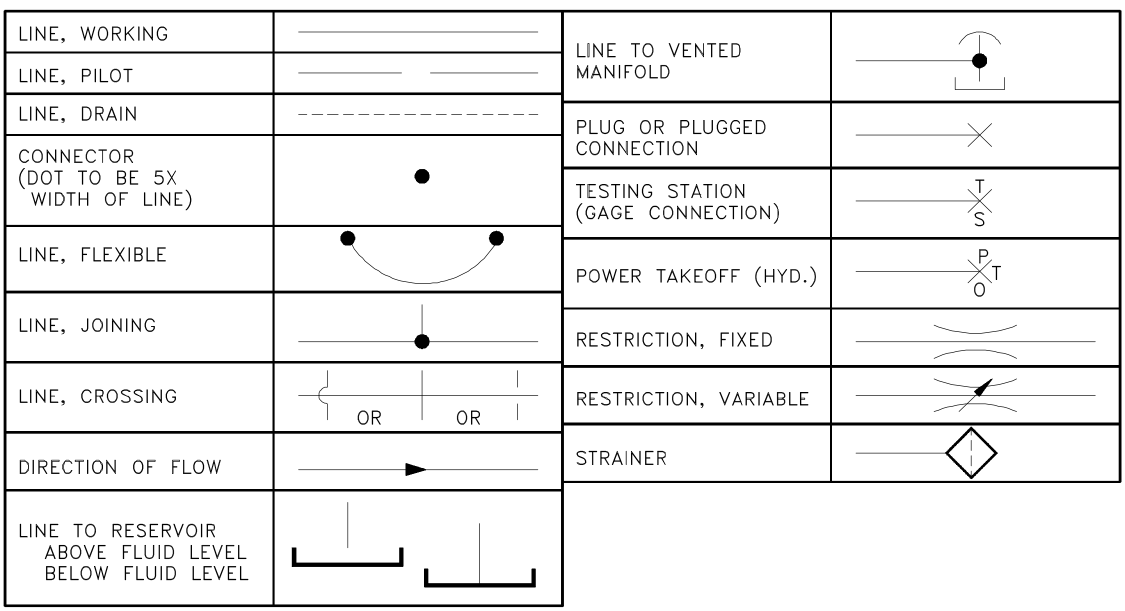


Figure 23 Fluid Power Line Symbols

Valves

Valves are the most complicated symbols in fluid power systems. Valves provide the control that is required to ensure that the motive media is routed to the correct point when needed. Fluid power system diagrams require much more complex valve symbology than standard P&IDs due to the complicated valving used in fluid power systems. In a typical P&ID, a valve opens, closes, or throttles the process fluid, but is rarely required to route the process fluid in any complex manner (three- and four-way valves being the common exceptions). In fluid power systems it is common for a valve to have three to eight pipes attached to the valve body, with the valve being capable of routing the fluid, or several separate fluids, in any number of combinations of input and output flowpaths.

The symbols used to represent fluid power valves must contain much more information than the standard P&ID valve symbology. To meet this need, the valve symbology shown in the following figures was developed for fluid power P&IDs. Figure 24, a cutaway view, provides an example of the internal complexity of a simple fluid power type valve. Figure 24 illustrates a four-way/three-position valve and how it operates to vary the flow of the fluid. Note that in Figure 24 the operator of the valve is not identified, but like a standard process fluid valve the valve could be operated by a diaphragm, motor, hydraulic, solenoid, or manual operator. Fluid power valves, when electrically operated by a solenoid, are drawn in the de-energized position. Energizing the solenoid will cause the valve to shift to the other port. If the valve is operated by other than a solenoid or is a multiport valve, the information necessary to determine how the valve operates will be provided on each drawing or on its accompanying legend print.

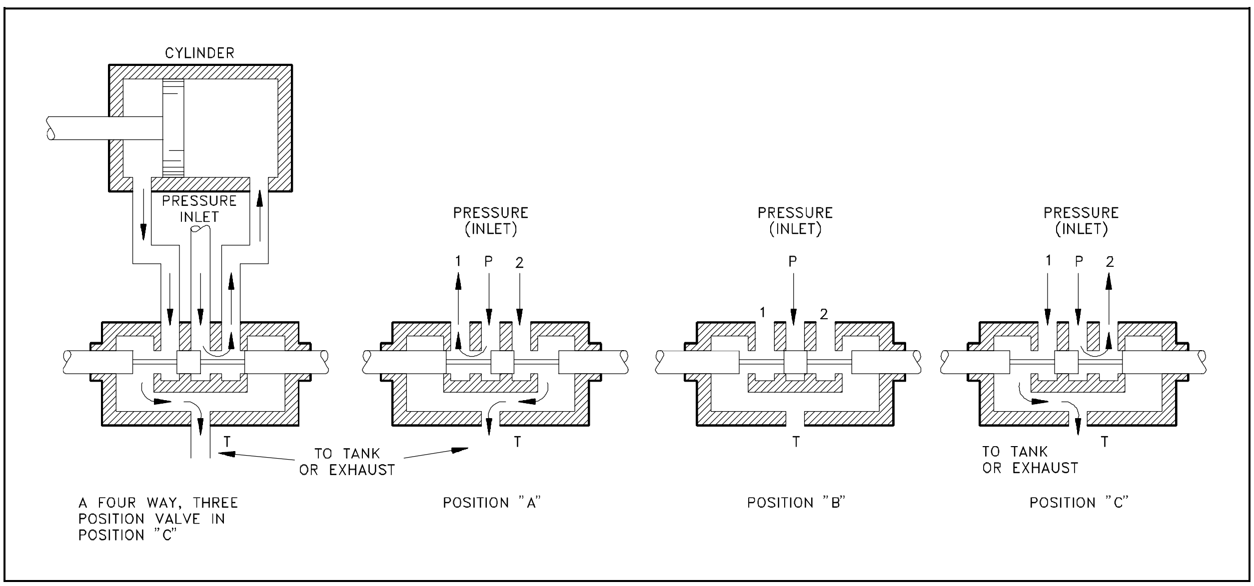


Figure 24 Valve Operation

Refer to Figure 25 to see how the valve in Figure 24 is transformed into a usable symbol.

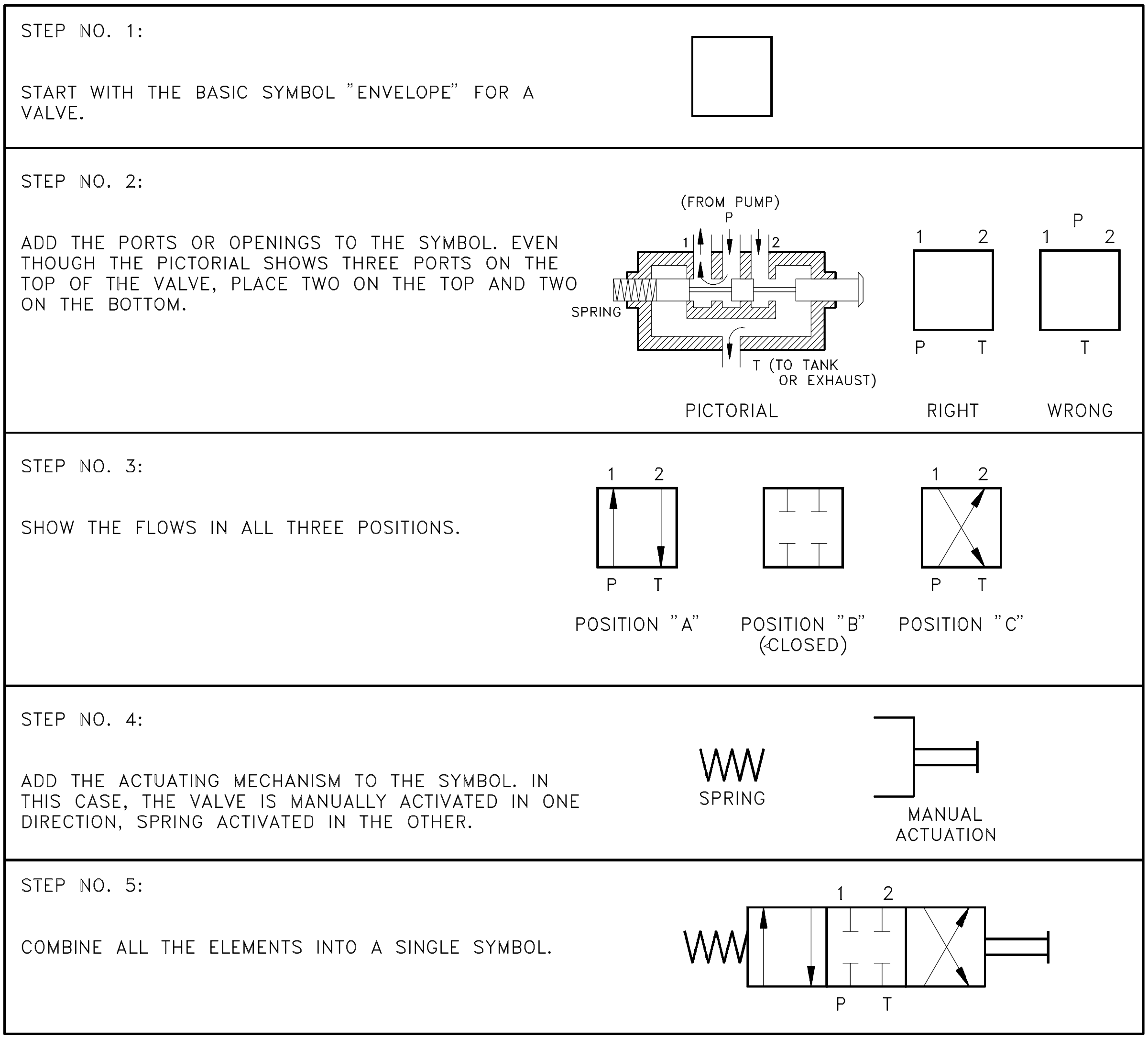


Figure 25 Valve Symbol Development

Figure 26 shows symbols for the various valve types used in fluid power systems.

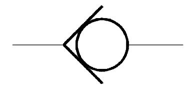
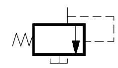
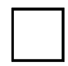
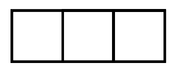
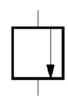
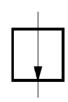
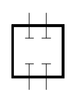
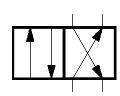
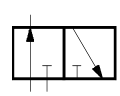
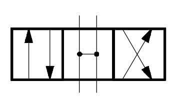
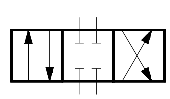
VALVE, CHECK	
VALVE, MANUAL SHUTOFF	
VALVE, MAXIMUM PRESSURE (RELIEF)	
VALVE, BASIC SYMBOL SINGLE FLOW PATH IS MODIFIED	
VALVE, BASIC SYMBOL MULTIPLE FLOW PATHS ARE CHANGED	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, MULTIPLE FLOW PATHS, BLOCKED	
VALVE, MULTIPLE FLOW PATHS, OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, DIRECTIONAL, 2 POSITION 3 CONNECTIONS	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTIONS OPEN CENTER	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTIONS CLOSED CENTER	

Figure 26 Fluid Power Valve Symbols

Reading Fluid Power Diagrams

Using the symbology previously discussed, a fluid power diagram can now be read. But before reading some complex examples, let's look at a simple hydraulic system and convert it into a fluid power diagram.

Using the drawing in Figure 27, the left portion of Figure 28 lists each part and its fluid power symbol. The right side of Figure 28 shows the fluid power diagram that represents the drawing in Figure 27.

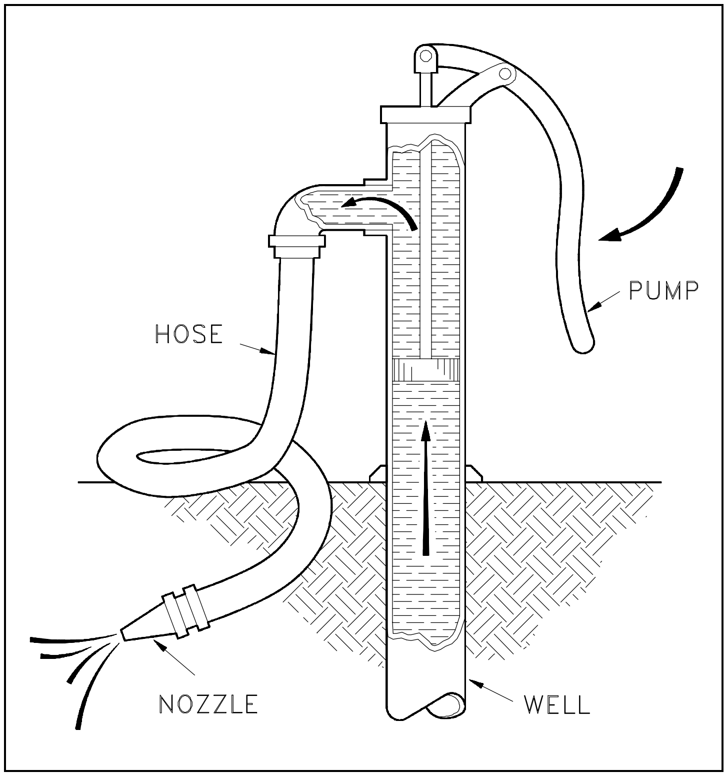


Figure 27 Simple Hydraulic Power System

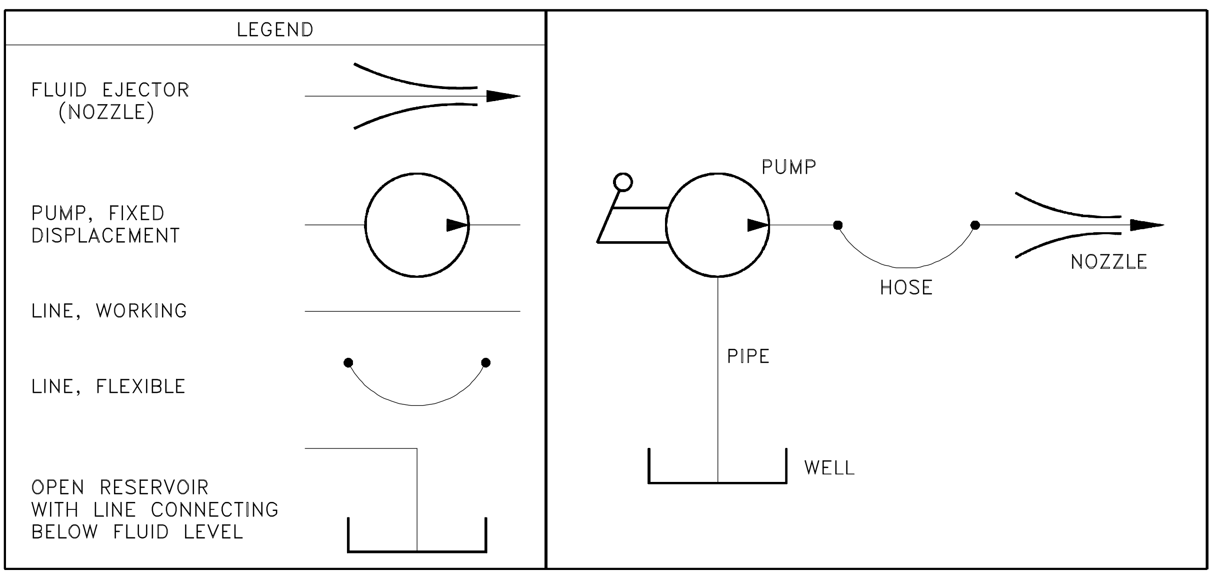


Figure 28 Line Diagram of Simple Hydraulic Power System

With an understanding of the principles involved in reading fluid power diagram, any diagram can be interpreted. Figure 29 shows the kind of diagram that is likely to be encountered in the engineering field. To read this diagram, a step-by-step interpretation of what is happening in the system will be presented.

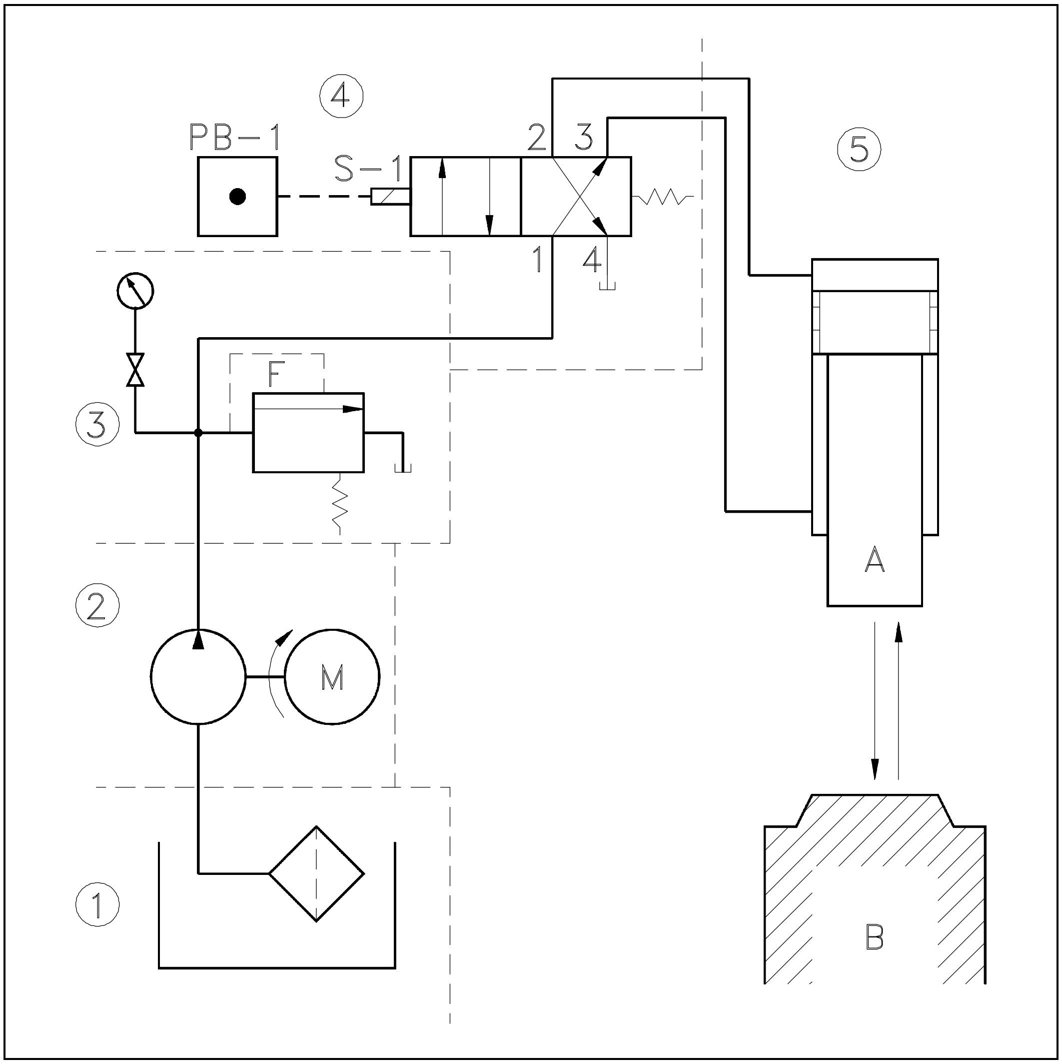


Figure 29 Typical Fluid Power Diagram

The first step is to get an overall view of what is happening. The arrows between A and B in the lower right-hand corner of the figure indicate that the system is designed to press or clamp some type of part between two sections of the machine. Hydraulic systems are often used in press work or other applications where the work piece must be held in place.

With the basic function understood, a detailed study of the diagram can be accomplished using a step-by-step analysis of each numbered local area in the diagram.

LOCAL AREA NUMBER 1

Symbol for an open reservoir with a strainer. The strainer is used to clean the oil before it enters the system.

LOCAL AREA NUMBER 2

Fixed displacement pump, electrically operated. This pump provides hydraulic pressure to the system.

LOCAL AREA NUMBER 3

Symbol for a relief valve with separate pressure gage. The relief valve is spring operated and protects the system from over pressurization. It also acts as an unloader valve to relieve pressure when the cylinder is not in operation. When system pressure exceeds its setpoint, the valve opens and returns the hydraulic fluid back to the reservoir. The gage provides a reading of how much pressure is in the system.

LOCAL AREA NUMBER 4

Composite symbol for a 4-way, 2-position valve. Pushbutton PB-1 is used to activate the valve by energizing the S-1 solenoid (note the valve is shown in the de-energized position). As shown, the high pressure hydraulic fluid is being routed from Port 1 to Port 3 and then to the bottom chamber of the piston. This drives and holds the piston in local area #5 in the retracted position. When the piston is fully retracted and hydraulic pressure builds, the unloader (relief) valve will lift and maintain the system's pressure at setpoint.

When PB-1 is pushed and S-1 energized, the 1-2 ports are aligned and 3-4 ports are aligned. This allows hydraulic fluid to enter the top chamber of the piston and drive it down. The fluid in the bottom chamber drains though the 3-4 ports back into the reservoir. The piston will continue to travel down until either PB-1 is released or full travel is reached, at which point the unloader (relief) valve will lift.

LOCAL AREA NUMBER 5

Actuating cylinder and piston. The cylinder is designed to receive fluid in either the upper or lower chambers. The system is designed so that when pressure is applied to the top chamber, the bottom chamber is aligned to drain back to the reservoir. When pressure is applied to the bottom chamber, the top chamber is aligned so that it drains back to the reservoir.

Types of Fluid Power Diagrams

Several kinds of diagrams can be used to show how systems work. With an understanding of how to interpret Figure 29, a reader will be able to interpret all of the diagrams that follow.

A pictorial diagram shows the physical arrangement of the elements in a system. The components are outline drawings that show the external shape of each item. Pictorial drawings do not show the internal function of the elements and are not especially valuable for maintenance or troubleshooting. Figure 30 shows a pictorial diagram of a system.

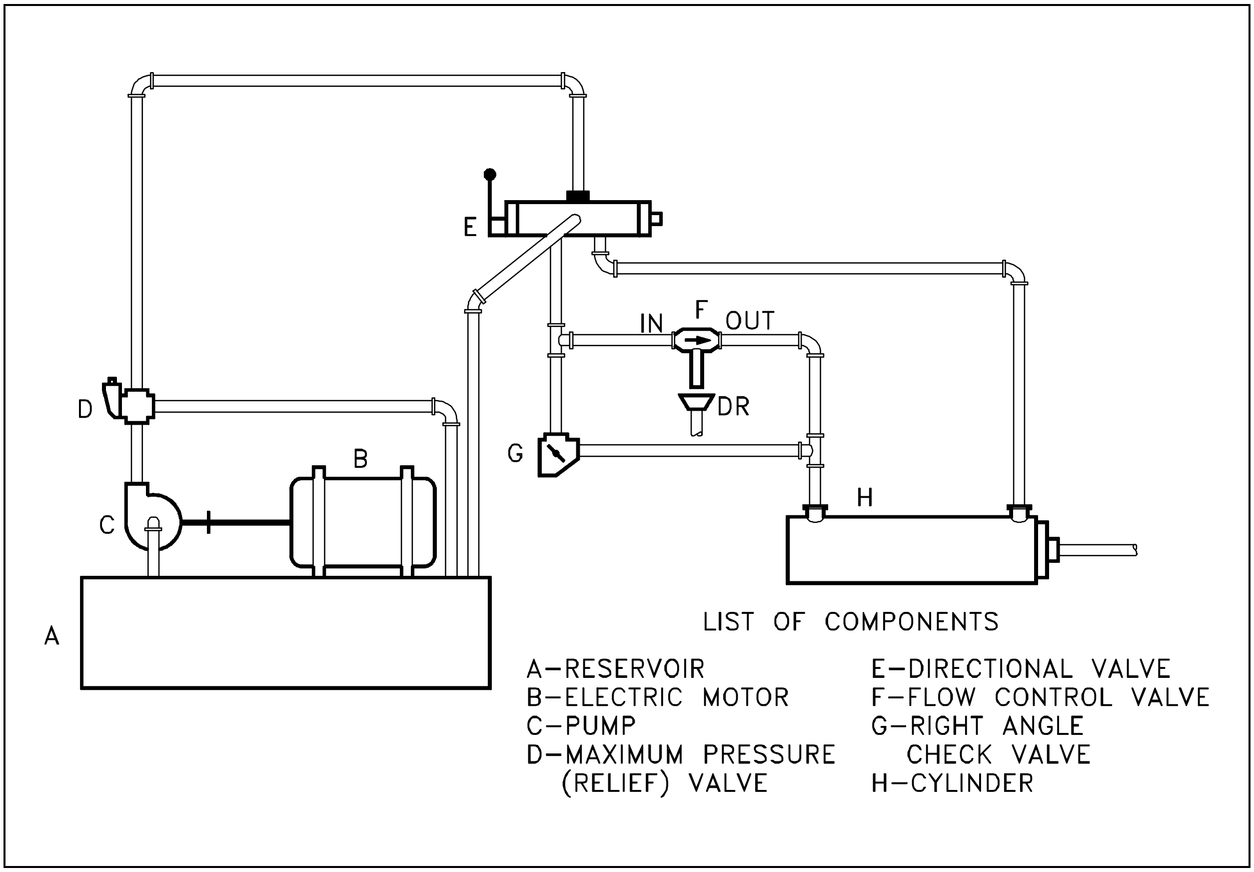


Figure 30 Pictorial Fluid Power Diagram

A cutaway diagram shows both the physical arrangement and the operation of the different components. It is generally used for instructional purposes because it explains the functions while showing how the system is arranged. Because these diagrams require so much space, they are not usually used for complicated systems. Figure 31 shows the system represented in Figure 30 in cutaway diagram format and illustrates the similarities and differences between the two types of diagrams.

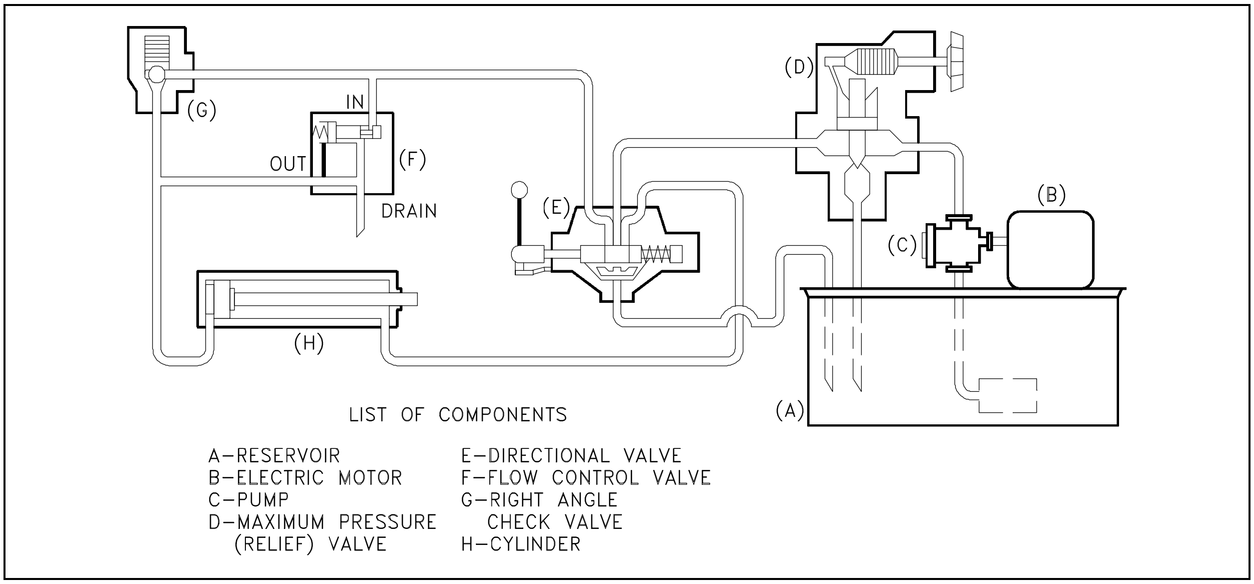


Figure 31 Cutaway Fluid Power Diagram

A schematic diagram uses symbols to show the elements in a system. Schematics are designed to supply the functional information of the system. They do not accurately represent the relative location of the components. Schematics are useful in maintenance work, and understanding them is an important part of troubleshooting. Figure 32 is a schematic diagram of the system illustrated in Figure 30 and Figure 31.

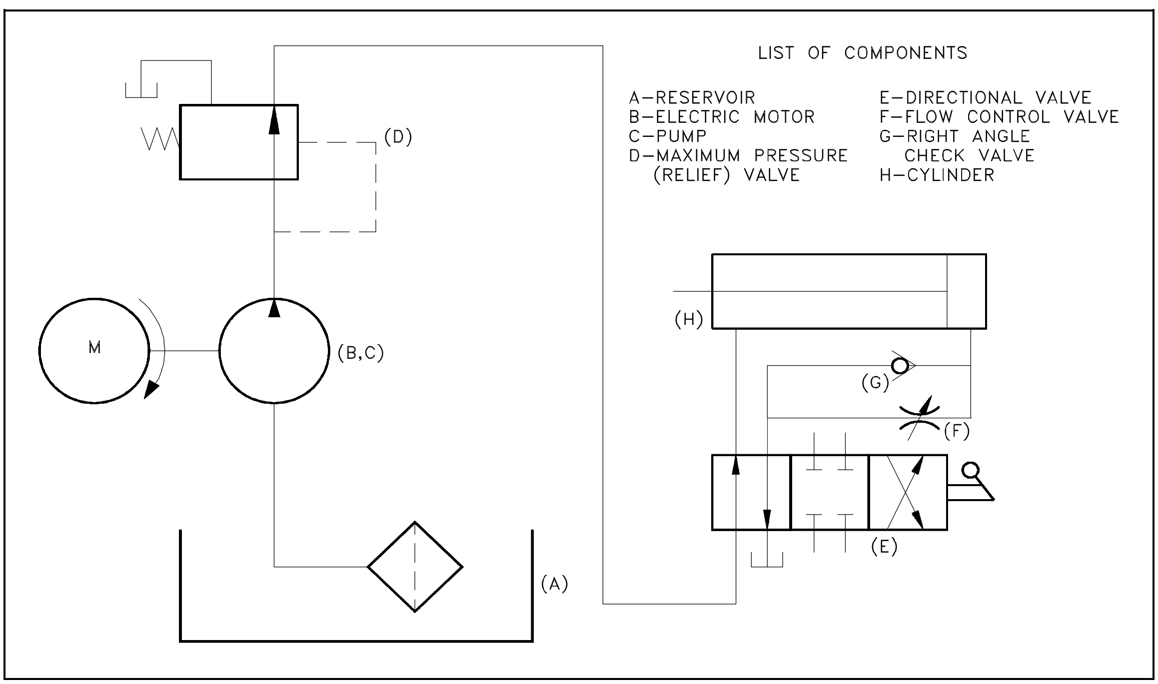


Figure 32 Schematic Fluid Power Diagram

Summary

The important information in this chapter is summarized below.

Fluid Power P&IDs Summary

- This chapter reviewed the most commonly used symbols on fluid power diagrams and the basic standards and conventions for reading and interpreting fluid power diagrams.