

# **ANALYTICAL PROCESS CONTROL**

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**3**

**LEARNING  
ACTIVITY  
PACKET**

**PIPING AND  
INSTRUMENTATION  
DIAGRAMS**



B33303-AB03AEN

# **PIPING AND INSTRUMENTATION DIAGRAMS**

## **INTRODUCTION**

Piping and instrumentation diagrams (P&IDs) provide a visual representation of the overall function of a process as well as specific information. This information can include the type of signal being sent to a device (e.g. pneumatic, electrical) and the types of control and sensing elements in the process.

This LAP covers the symbols for sensors and control elements, as well as the line symbols used in P&IDs. It also covers the instrument index, which is a valuable tool used to help operators and technicians organize the many process documents.

## **ITEMS NEEDED**



### Amatrol Supplied

- 1 T5554 Analytical Process Control Learning System

### School Supplied

- 1 Municipal Water Supply
- 1 120VAC Electrical Supply

FIRST EDITION, LAP 3, REV. A

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## SEGMENT 1

### LINE SYMBOLS

#### OBJECTIVE 1

#### DESCRIBE THE FUNCTION OF A P&ID



Piping and Instrumentation Diagrams (P&ID), like the one in figure 1, are drawings that show the layout of an entire process or a section of a process. P&IDs (also called flow diagrams) include things such as:

- Process flow
- Major components within the system
- Different types of signals within the process
- Interconnection between components

P&IDs do not show the physical location of devices, the spatial distance between devices, or the size of each device. In addition, not all components within the system appear on a P&ID. Only the major components affecting the process are shown.

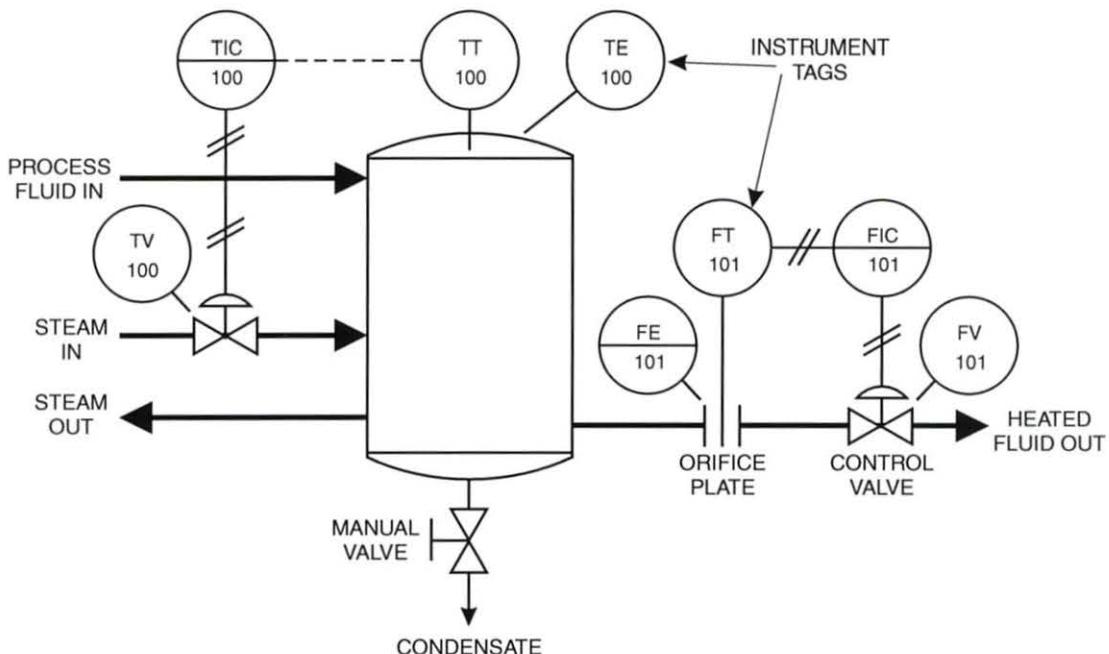


Figure 1. Flow Diagram (P&ID)

## OBJECTIVE 2

## DESCRIBE THE FUNCTION OF A LOOP DIAGRAM



P&IDs often consist of several control loops. Typically, P&IDs are broken into smaller diagrams which show each loop of the process individually. These individual diagrams are called loop diagrams or loop sheets. Loop diagrams are often helpful when performing setup, calibration, and troubleshooting.

Figure 2 shows an example of a loop diagram. In this example, loop 401 controls the flow of the process fluid.

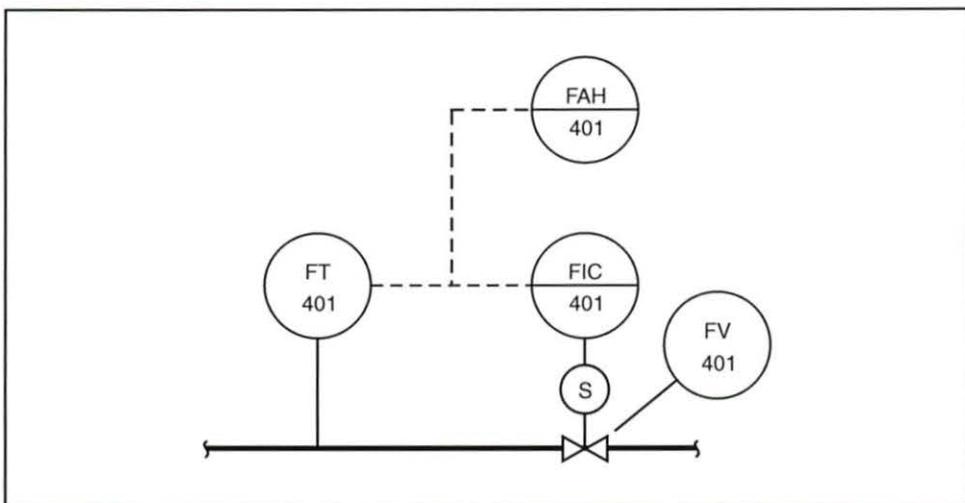


Figure 2. Loop Diagram



The line symbols used in P&IDs identify process piping, connections to the process, and the method used to transfer signals from instrument to instrument within the loop. P&IDs differentiate between the various lines because one diagram typically includes multiple types of signals.

Ten common line symbols used on P&IDs are displayed in figure 3.

—————	PROCESS PIPING
—————	PROCESS CONNECTION
## — ##	PNEUMATIC LINE
/// — // OR - - - -	ELECTRIC LINE
L — L	HYDRAULIC LINE
X — X	CAPILLARY TUBE
~~~~~	ULTRASONIC WAVES (GUIDED)
~~~	ULTRASONIC WAVES (UNGUIDED)
—○—	INTERNAL SYSTEM LINK
—○—	MECHANICAL LINK

Figure 3. P&ID Line Symbols

### Process Piping

The first type of line symbol is a bold dark line that represents the process piping. The process piping is the main flow line that carries the process materials (i.e. fluids, chemicals, etc).

### Process Connection

A solid line that is not bold indicates the line is a process connection. A process connection line is any line that taps into the main process piping. An instrument line that connects to the process piping to monitor the status of the material in the process piping is an example of a process connection.

## Pneumatic Line

Pneumatic signals are frequently used to control a process. The symbol for a line that carries a compressed gas is a solid line with two slashes through it.

## Electric Line

An electric line appears as either a line with three slashes through it or, more commonly, as a dashed line from device to device.

## Hydraulic Line

A hydraulic line appears as a line with a series of Ls drawn through it.

## Capillary Tubes

Capillary tubes are small diameter tubes used for signal transmission. An example of a capillary tube is the copper tubing connected to an alcohol-filled thermometer. The symbol for a capillary tube is a fine line with a series of Xs through it.

## Ultrasonic Waves (Guided)

The use of ultrasonic waves in instrumentation is becoming more common. Ultrasonic waves are high frequency waves that cannot be seen or heard. Typically, these waves are used in one of two fashions: guided or unguided.

Guided waves are transmitted through a device called a waveguide, which is typically a metal container. The line symbol for a guided wave is a line with sine waves drawn on it.

## Ultrasonic Waves (Unguided)

Unguided ultrasonic waves are transmitted through the air. The line symbol for an unguided ultrasonic wave is sine waves without the line in the middle.

## Internal System Link

Many modern processes use computer software to replace field devices. If software emulates a device, the connections to the other devices in the loop will be shown with the internal system link symbol, which is a line with open circles.

## Mechanical Link

The mechanical system link symbol is used when a signal is transmitted by a mechanical connection. It consists of a line and circles with a dot inside each circle.

## OBJECTIVE 4

## DESCRIBE HOW TO REPRESENT BINARY SIGNALS IN A P&ID



To aid in the identification of the nature of line symbols, backslashes are sometimes added to denote that the signal being transmitted is binary, as shown in figure 4. If a device is considered binary, it has only two operating conditions: On (1) or Off (0).

If a device is understood to be binary, such as the case with a solenoid valve, backslashes through its line symbol may be used. However, it is not mandatory.

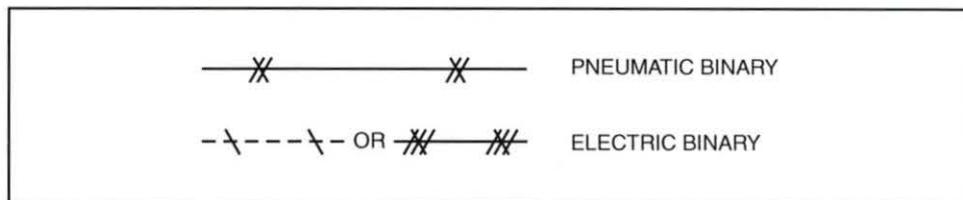


Figure 4. Binary Line Symbols

**Procedure Overview**

In this procedure, you will identify line symbols used to represent various types of process connections on a P&ID so that you can increase your ability to read P&IDs.



- 1. Identify the line symbol shown in figure 5.

Line Symbol \_\_\_\_\_



Figure 5. Line Symbol

You should find that the symbol indicates a pneumatic binary line because the symbol shows a horizontal line with double forward slashes and a superimposed backslash along the line.

- 2. Identify the line symbol shown in figure 6.

Line Symbol \_\_\_\_\_



Figure 6. Line Symbol

You should find that the symbol indicates a hydraulic line because the symbol shows a horizontal line with an L through it.

- 3. Identify the line symbol shown in figure 7.

Line Symbol \_\_\_\_\_



Figure 7. Line Symbol

You should find that the symbol indicates guided ultrasonic waves because the symbol shows a horizontal line with a sinusoidal wave along it.

4. Identify the line symbol shown in figure 8.

Line Symbol \_\_\_\_\_



Figure 8. Line Symbol

You should find that the symbol indicates a mechanical link because the symbol shows a horizontal line with a small circle that has a dot in the center along it.

5. Identify the line symbol shown in figure 9.

Line Symbol \_\_\_\_\_



Figure 9. Line Symbol

You should find that the symbol indicates a binary electrical line because the symbol shows a horizontal line with three forward slashes and a superimposed backslash along it.

6. Identify the line symbol shown in figure 10.

Line Symbol \_\_\_\_\_



Figure 10. Line Symbol

You should find that the symbol indicates unguided ultrasonic waves because the symbol shows sinusoidal waves that are not along a line.

7. Identify the line symbol shown in figure 11.

Line Symbol \_\_\_\_\_



Figure 11. Line Symbol

You should find that the symbol indicates an electrical binary line because the symbol shows a dashed horizontal line with a backslash.

8. Identify the line symbol that each letter indicates.

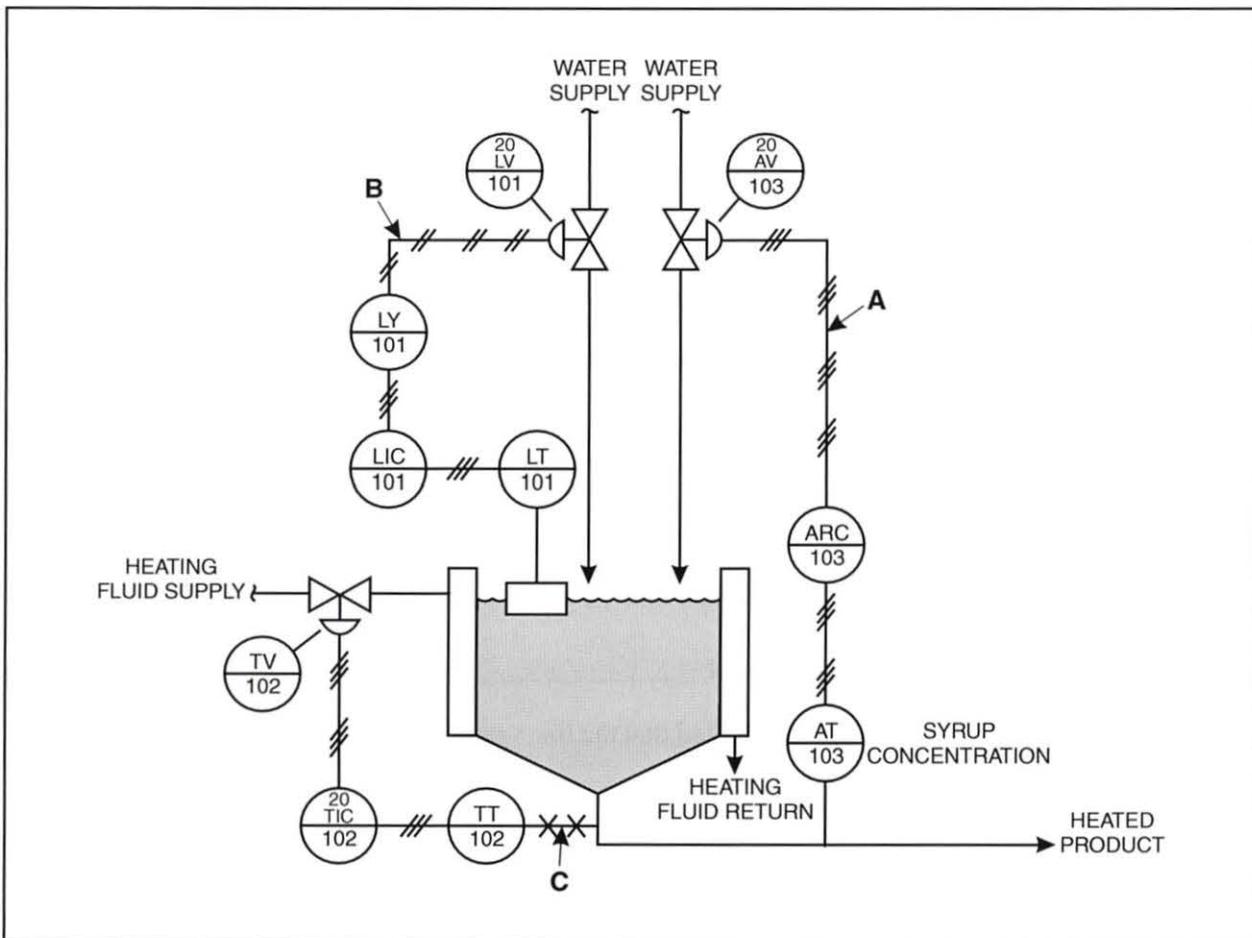


Figure 12. Heating and Mixing System P&ID

A. Line Symbol \_\_\_\_\_

You should find that the line symbol indicates an electrical line.

B. Line Symbol \_\_\_\_\_

You should find that the line symbol indicates a pneumatic line.

C. Line Symbol \_\_\_\_\_

You should find that the line symbol indicates a capillary tube.

9. Identify the line symbol that each letter indicates.

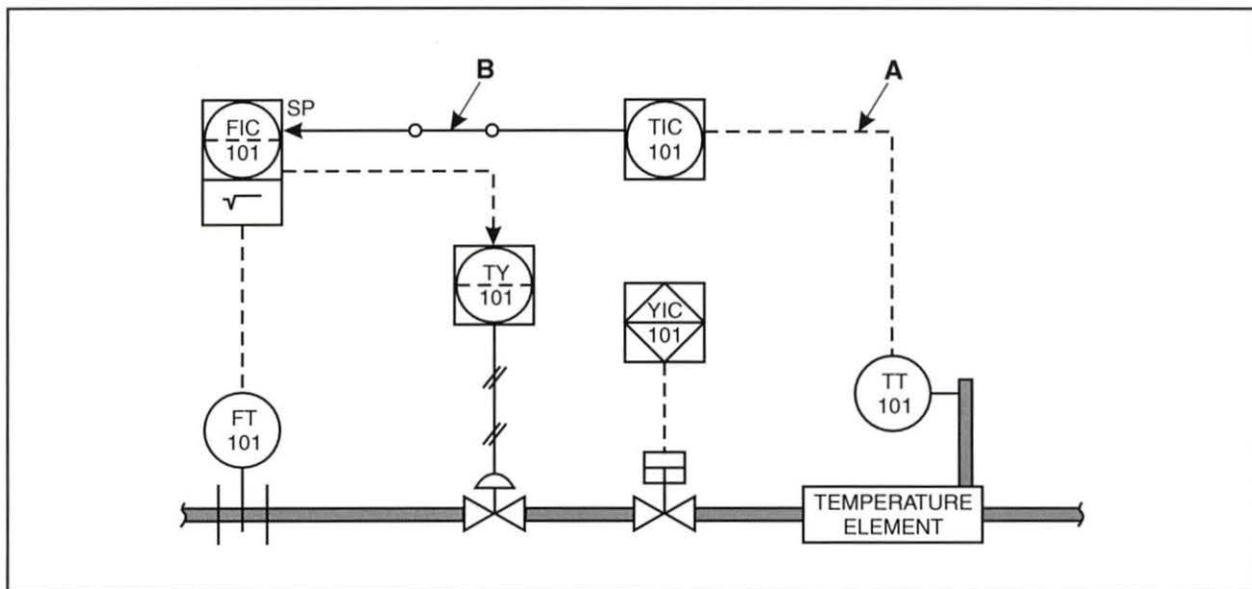


Figure 13. Temperature Control P&ID

A. Line Symbol \_\_\_\_\_

You should find that the line symbol indicates an electrical line.

B. Line Symbol \_\_\_\_\_

You should find that the line symbol indicates an internal system link.



1. A(n) \_\_\_\_\_, is a diagram that shows the layout of an entire process or section of a process.
2. When a P&ID shows a single loop within a process, it is called a(n) \_\_\_\_\_.
3. A line with two slashes through it represents a(n) \_\_\_\_\_ line on a flow diagram.
4. A dashed line on a flow diagram represents a(n) \_\_\_\_\_ line.
5. P&IDs do not indicate the physical location of a device, the spatial distance between devices, or the \_\_\_\_\_ of each device.
6. A line with a backslash through it represents a(n) \_\_\_\_\_ signal.

## SEGMENT 2

### VALVE AND PUMP SYMBOLS

#### OBJECTIVE 5

#### DESCRIBE 11 P&ID VALVE SYMBOLS



The majority of final control elements in a process control system are either pumps or valves. There are many types of valves, like the one in figure 14, that can be used to control a process. Each type of valve has unique operating characteristics and therefore requires a unique symbol to identify it in a P&ID.

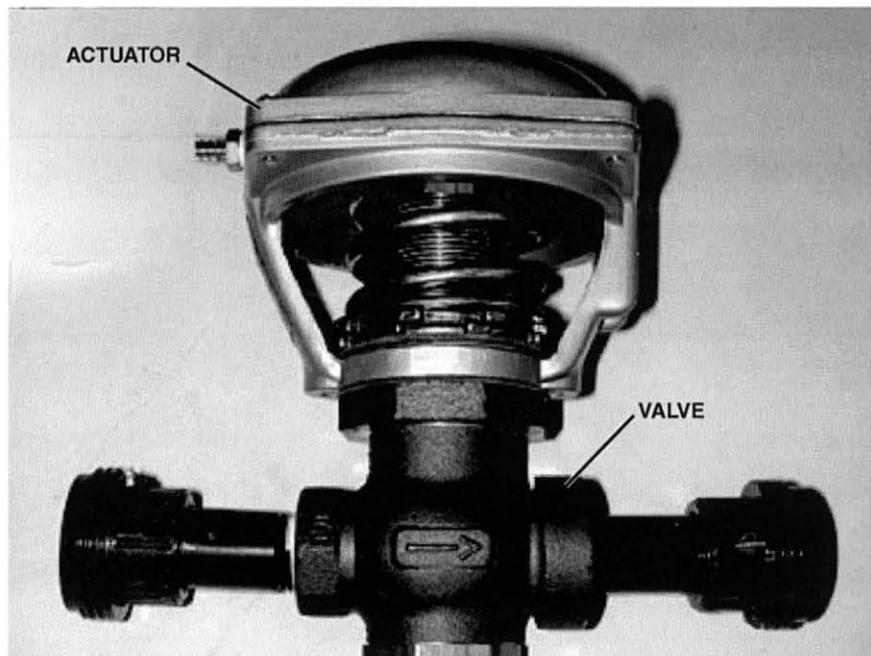


Figure 14. Valve with Actuator

The most common symbol used to represent a valve in a P&ID is two triangles with their points touching in the middle, as shown in figure 15. This symbol is often called the bowtie.

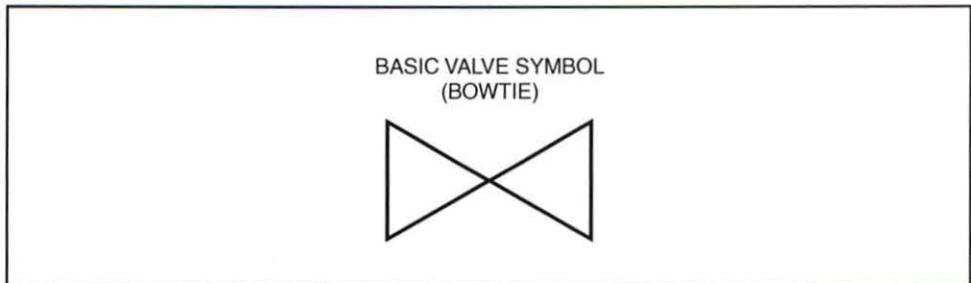


Figure 15. Basic Valve Symbol

The valve symbol can be drawn differently to represent other commonly used valves such as an angle valve, a diaphragm valve, a pinch valve, and a four-way valve. In addition, some special-purpose valves have symbols that are unique to that particular valve. Figure 16 shows examples of these different valve symbols.

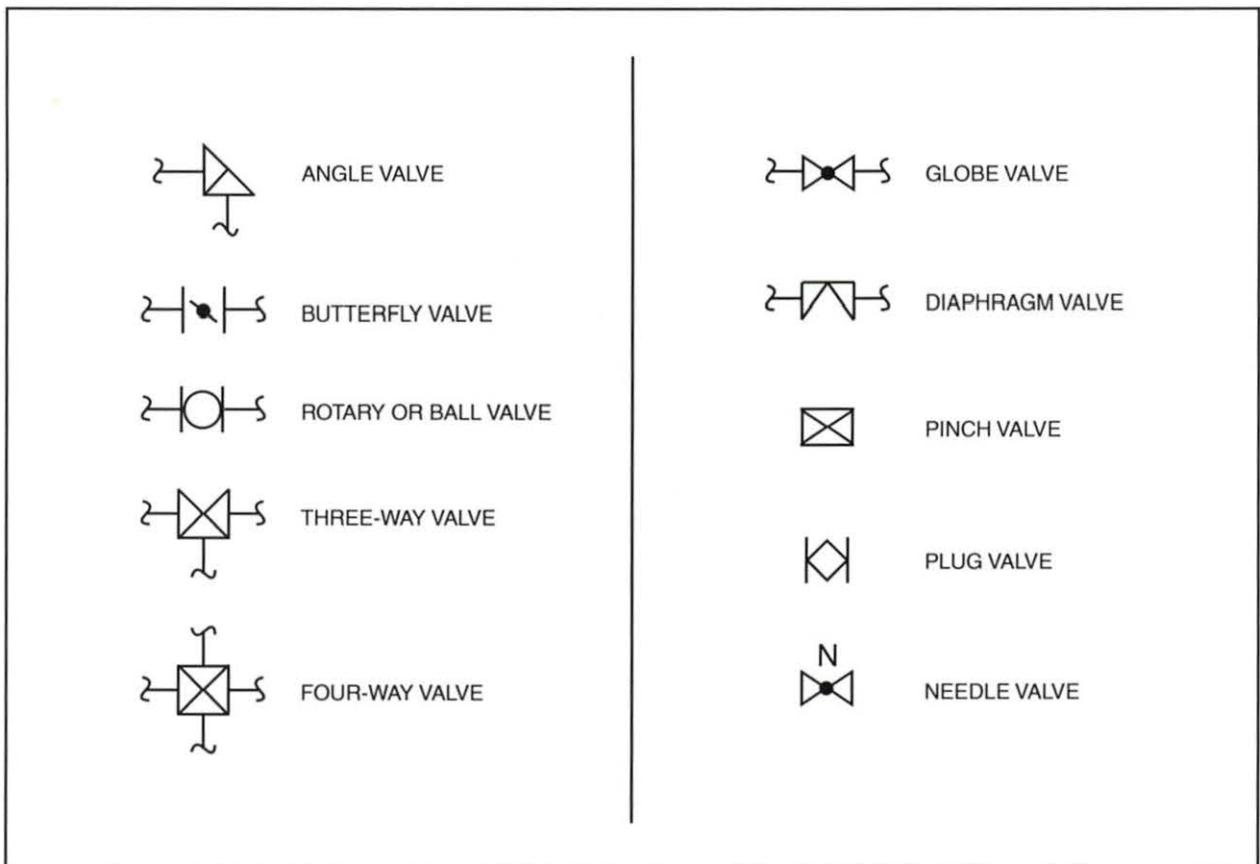


Figure 16. Valve Symbols



The part of the valve that controls the valve stem position is called an actuator. There are many types of actuators available and each has a unique symbol. The actuator symbol is attached to the top of the valve symbol, as shown in figure 17.

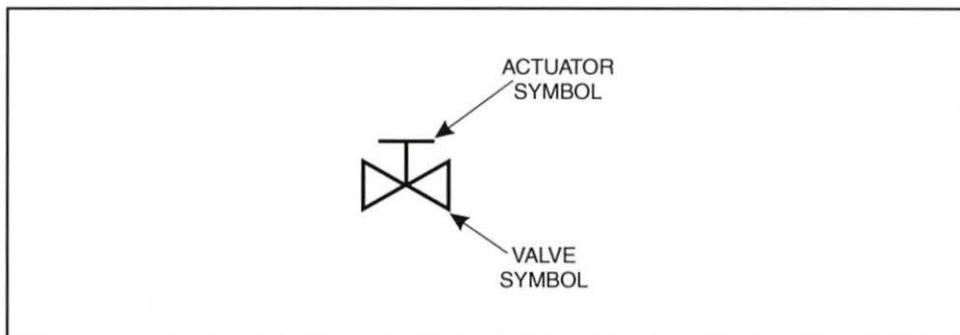


Figure 17. Location of Actuator Symbol

The most basic valve actuator is the hand-actuator, as shown in figure 18. This type of actuator requires a person to manually operate the valve. Notice that the hand-actuator symbol is the shape of a T and looks similar to a handle.

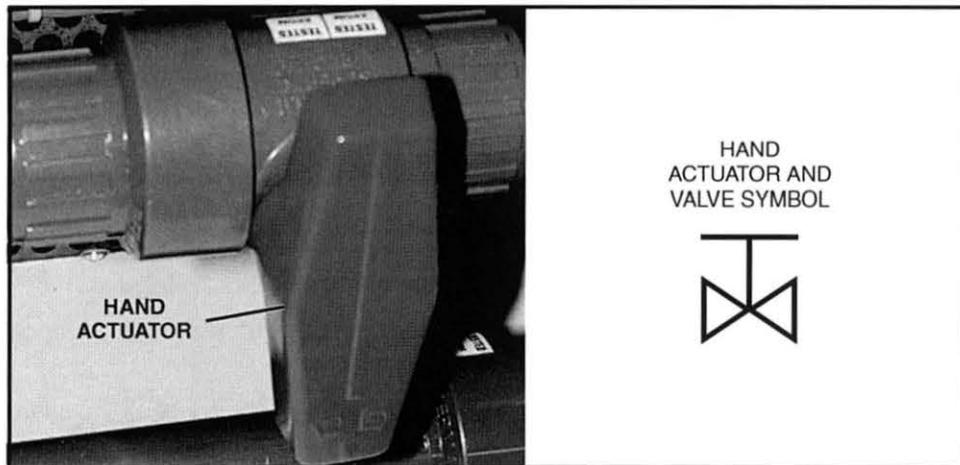


Figure 18. A Hand Valve Actuator and Its Symbol

One of the most common valve actuators in closed loop control is the diaphragm actuator, as shown in figure 19. Diaphragm actuators use compressed air to press on a diaphragm. Notice that the symbol for a diaphragm actuator includes a dome.

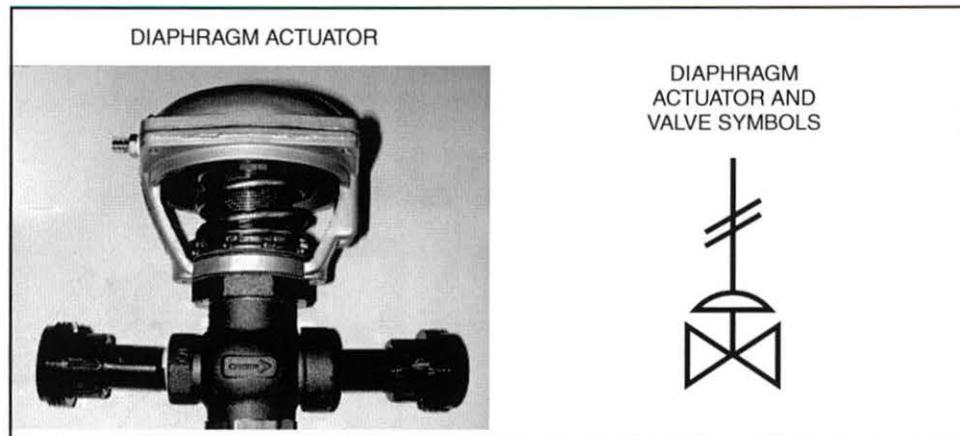


Figure 19. A Diaphragm Valve Actuator and Its Symbol

Another common type of valve actuator is the solenoid valve actuator, as shown in figure 20. Notice that a solenoid actuator symbol is a square that contains an S for solenoid.

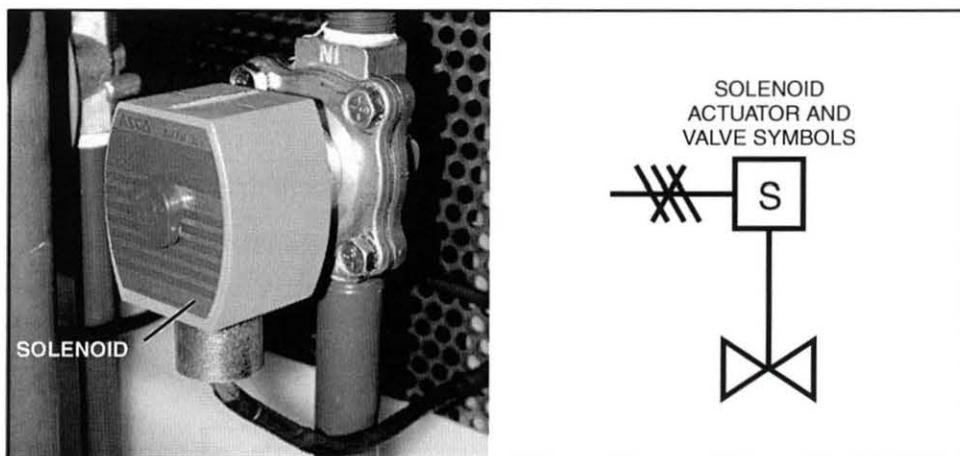


Figure 20. A Solenoid Valve Actuator and Its Symbol

For large valves requiring higher torque to open and close, an electric motor may actuate the valve, as figure 21 shows. The symbol for a motor valve actuator is a circle that contains an M for motor.

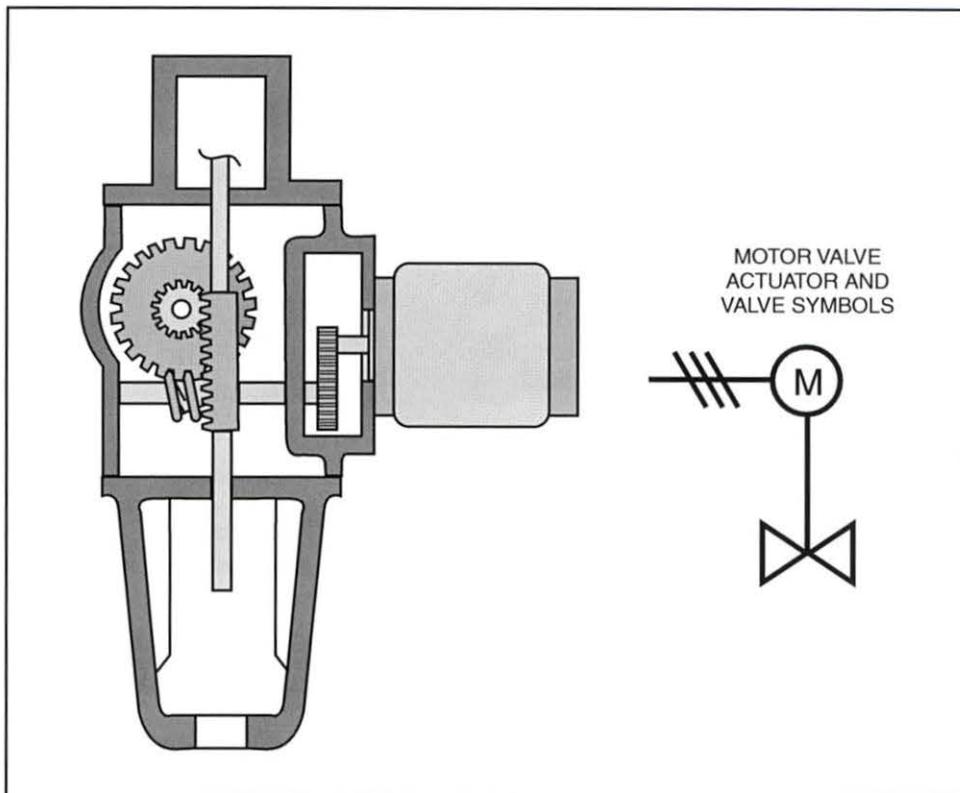


Figure 21. Motor Valve Actuator and Its Symbol

Some valves also have positioners. A positioner is a device that controls the movement of an actuator. For example, figure 22 shows the symbol for a diaphragm valve actuator with a positioner.

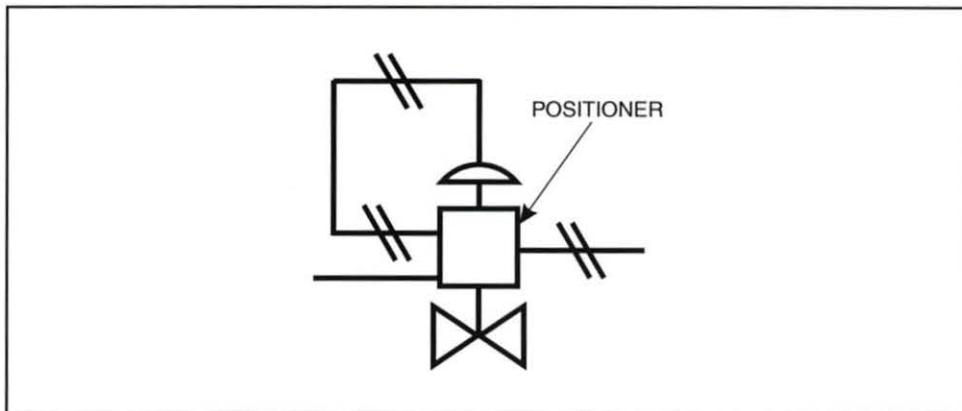


Figure 22. Diaphragm Valve Actuator With a Positioner

**Procedure Overview**

In this procedure, you will identify flow diagram valve and actuator symbols.



1. Determine the type of valve or actuator symbol depicted in figure 23.

Symbol \_\_\_\_\_

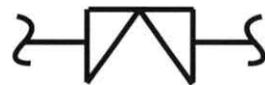


Figure 23. Valve Symbol

You should find that the symbol indicates a diaphragm valve.

2. Determine the type of valve or actuator symbol depicted in figure 24.

Symbol \_\_\_\_\_



Figure 24. Valve Symbol

You should find that the symbol indicates a plug valve because the tag shows two parallel lines with a diamond between them.

3. Determine the type of valve or actuator symbol depicted in figure 25.

Symbol \_\_\_\_\_

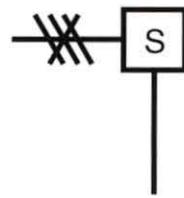


Figure 25. Actuator Symbol

You should find that the symbol indicates a solenoid actuator valve. Recall that the S in the square stands for solenoid.

4. Determine the type of valve or actuator symbol depicted in figure 26.

Symbol \_\_\_\_\_



Figure 26. Valve Symbol

You should find that the symbol indicates a butterfly valve.

5. Determine the type of valve or actuator symbol depicted in figure 27.

Symbol \_\_\_\_\_

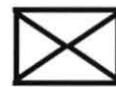


Figure 27. Valve Symbol

You should find that the symbol indicates a pinch valve because the tag shows two intersecting bowtie symbols that form a square with an X in the center. You should also notice that there are no connections extending from the sides of the square.

6. Determine the type of valve or actuator symbol depicted in figure 28.

Symbol \_\_\_\_\_

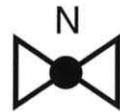


Figure 28. Valve Symbol

You should find that the symbol indicates a needle valve. The N in the symbol identifies it as a needle valve. If the N were not present, it would be a globe valve symbol.

7. Determine the type of valve or actuator symbol depicted in figure 29.

Symbol \_\_\_\_\_

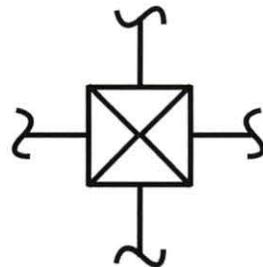


Figure 29. Valve Symbol

You should find that the symbol indicates a four-way valve because the tag shows a square with an X in the center and a connection extending from each side.

8. Determine the type of valve or actuator symbol depicted in figure 30.

Symbol \_\_\_\_\_

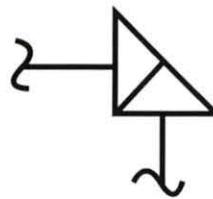


Figure 30. Valve Symbol

You should find that the symbol indicates an angle valve.

9. Determine the type of valve or actuator symbol depicted in figure 31.

Symbol \_\_\_\_\_



Figure 31. Valve Symbol

You should find that the symbol indicates a rotary valve because the tag shows two parallel lines with a circle between them.

10. Determine the type of valve or actuator symbol depicted in figure 32.

Symbol \_\_\_\_\_

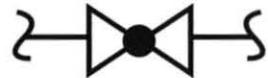


Figure 32. Valve Symbol

You should find that the symbol indicates a globe valve. Notice that the tag is a bowtie symbol with a large dot (which you can think of as a globe) at the point of intersection. You should also notice that there is a connection extending from each side.

□ 11. Identify the valve and valve actuator symbols indicated by the letters.

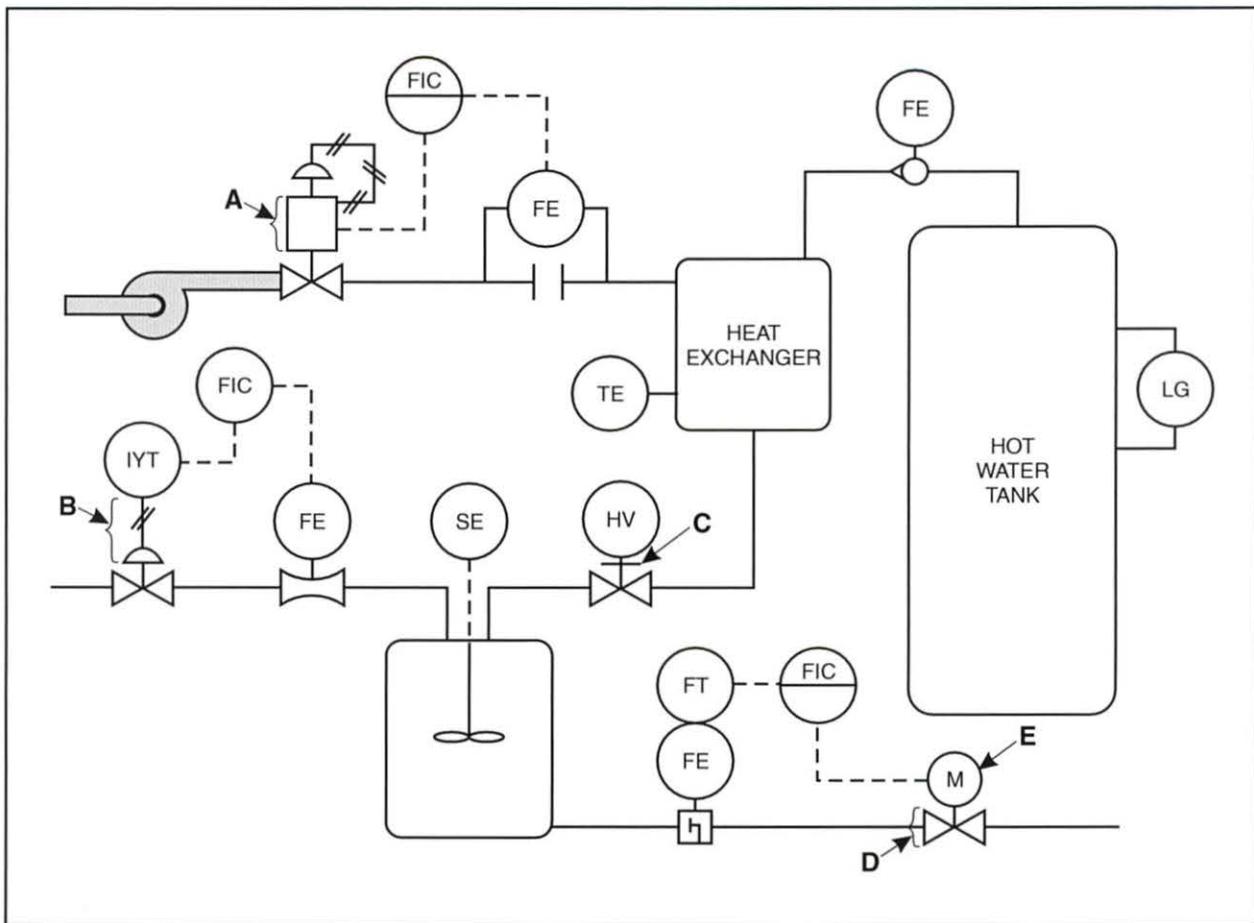


Figure 33. Valve and Valve Actuator Symbols on a P&ID

A. Symbol \_\_\_\_\_

You should find that the symbol indicates a positioner.

B. Symbol \_\_\_\_\_

You should find that the symbol indicates a diaphragm actuator.

C. Symbol \_\_\_\_\_

You should find that the symbol indicates a hand valve actuator.

D. Symbol \_\_\_\_\_

You should find that the symbol indicates a valve.

E. Symbol \_\_\_\_\_

You should find that the symbol indicates a motor valve actuator.



Pumps are one of several types of final control elements in process systems, moving the process fluid from point to point. Figure 34 shows the symbol for three common types of pumps.

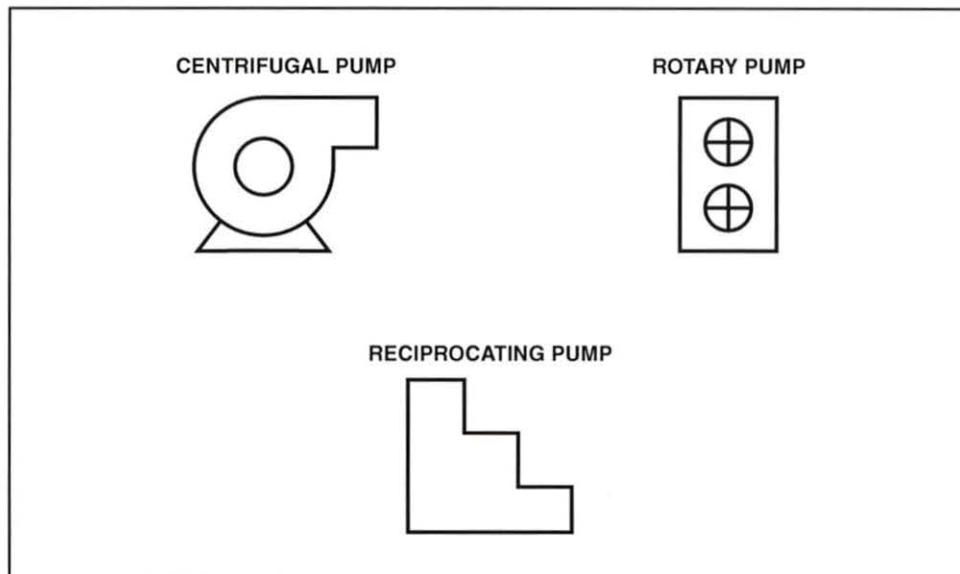


Figure 34. P&ID Symbols for Centrifugal, Rotary, and Reciprocating Pumps

**Procedure Overview**

In this procedure, you will examine a P&ID and identify the different pumps used in the system.



- 1. Identify the pump symbol that each letter indicates.

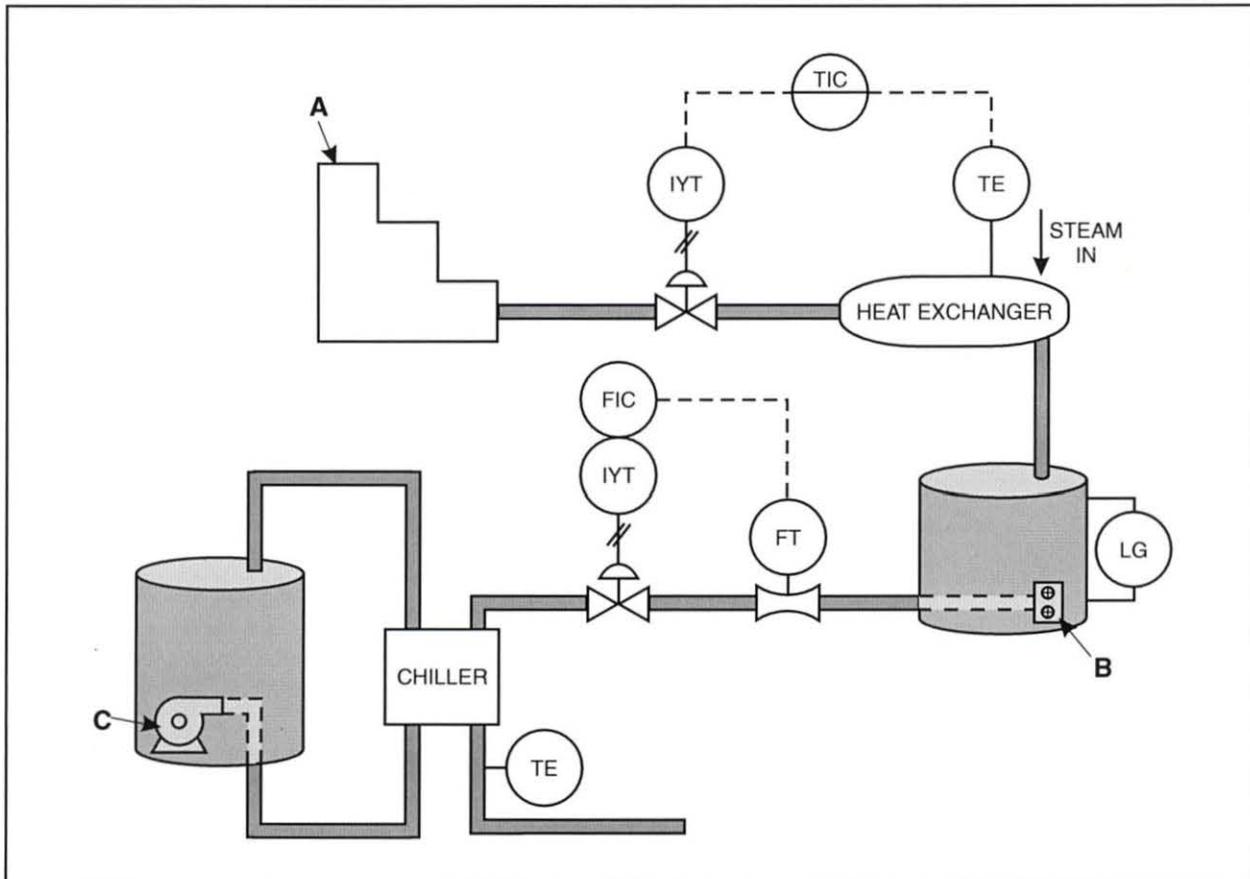


Figure 35. P&ID of Liquid Heating and Cooling Process

A. Pump Symbol \_\_\_\_\_

You should find that the symbol indicates a reciprocating pump.

B. Pump Symbol \_\_\_\_\_

You should find that the symbol indicates a rotary pump.

C. Pump Symbol \_\_\_\_\_

You should find that the symbol indicates a centrifugal pump.



1. The basic valve symbol is often referred to as a(n) \_\_\_\_\_ because of its shape.
2. The most basic valve actuator is the \_\_\_\_\_ actuator, which requires a person to manually operate the valve.
3. A(n) \_\_\_\_\_ valve actuator symbol is represented by a square with the letter S inside.
4. A(n) \_\_\_\_\_ is a device that controls the movement of an actuator.
5. The most common types of final control elements are valves and \_\_\_\_\_.
6. The three most common types of pumps are reciprocating, centrifugal, and \_\_\_\_\_ pumps.

## SEGMENT 3

### LEVEL AND FLOW SENSING ELEMENT SYMBOLS

#### OBJECTIVE 8

#### DESCRIBE 10 P&ID LIQUID LEVEL SENSING ELEMENT SYMBOLS

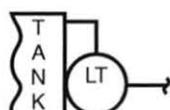


Figure 36 shows 10 common liquid level element symbols used in P&IDs. Notice that some of the symbols indicate how the device is mounted and some indicate the method the device uses to transmit data to the control loop. This information helps determine the principle on which the device operates.

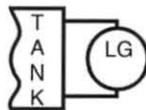
#### P & ID LEVEL ELEMENT SYMBOLS



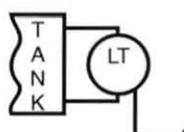
GAUGE GLASS,  
MOUNTED ON TANK



LEVEL TRANSMITTER,  
DIFFERENTIAL PRESSURE TYPE,  
MOUNTED ON TANK



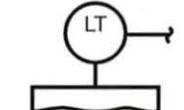
GAUGE GLASS  
EXTERNALLY CONNECTED



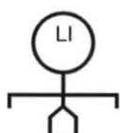
LEVEL TRANSMITTER,  
DIFFERENTIAL PRESSURE TYPE,  
WITH TWO CONNECTIONS



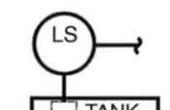
LEVEL INDICATOR,  
WITH TWO CONNECTIONS



LEVEL TRANSMITTER,  
CAPACITANCE OR  
DIELECTRIC TYPE



LEVEL INDICATOR,  
FLOAT TYPE



LEVEL SWITCH,  
PADDLE WHEEL OR  
LEVER TYPE



LEVEL TRANSMITTER,  
ONE CONNECTION

Figure 36. P&ID Level Element Symbols

**Procedure Overview**

In this procedure, you will identify level sensing element symbols.



1. Determine which type of level sensing element symbol is shown in figure 37.

Symbol \_\_\_\_\_

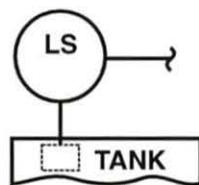


Figure 37. Level Sensing Element Symbol

You should find that the symbol indicates a level switch.

2. Determine which type of level sensing element symbol is shown in figure 38.

Symbol \_\_\_\_\_

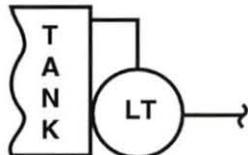


Figure 38. Level Sensing Element Symbol

You should find that the symbol indicates a mounted differential pressure level transmitter.

3. Determine which type of level sensing element symbol is shown in figure 39.

Symbol \_\_\_\_\_

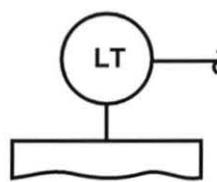


Figure 39. Level Sensing Element Symbol

You should find that the symbol indicates a capacitance level transmitter.

4. Determine which type of level sensing element symbol is shown in figure 40.

Symbol \_\_\_\_\_

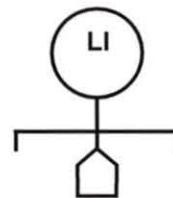


Figure 40. Level Sensing Element Symbol

You should find that the symbol indicates a level float indicator.

5. Determine which type of level sensing element symbol is shown in figure 41.

Symbol \_\_\_\_\_



Figure 41. Level Sensing Element Symbol

You should find that the symbol indicates a gauge glass mounted on the tank.

6. Determine which type of level sensing element symbol is shown in figure 42.

Symbol \_\_\_\_\_

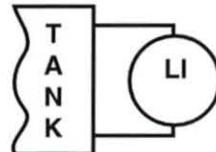


Figure 42. Level Sensing Element Symbol

You should find that the symbol indicates a level indicator with two connections.

7. Determine which type of level sensing element symbol is shown in figure 43.

Symbol \_\_\_\_\_

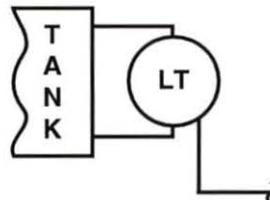


Figure 43. Level Sensing Element Symbol

You should find that the symbol indicates a differential pressure level transmitter with two connections.

8. Determine which type of level sensing element symbol is shown in figure 44.

Symbol \_\_\_\_\_

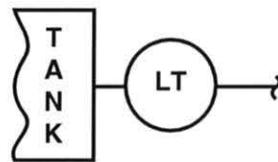


Figure 44. Level Sensing Element Symbol

You should find that the symbol indicates a level transmitter with one connection.

9. Determine which type of level sensing element symbol is shown in figure 45.

Symbol \_\_\_\_\_

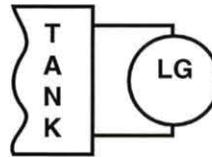


Figure 45. Level Sensing Element Symbol

You should find that the symbol indicates a gauge glass, externally connected.



Figure 46 shows 11 symbols used to represent various types of flow sensing devices.

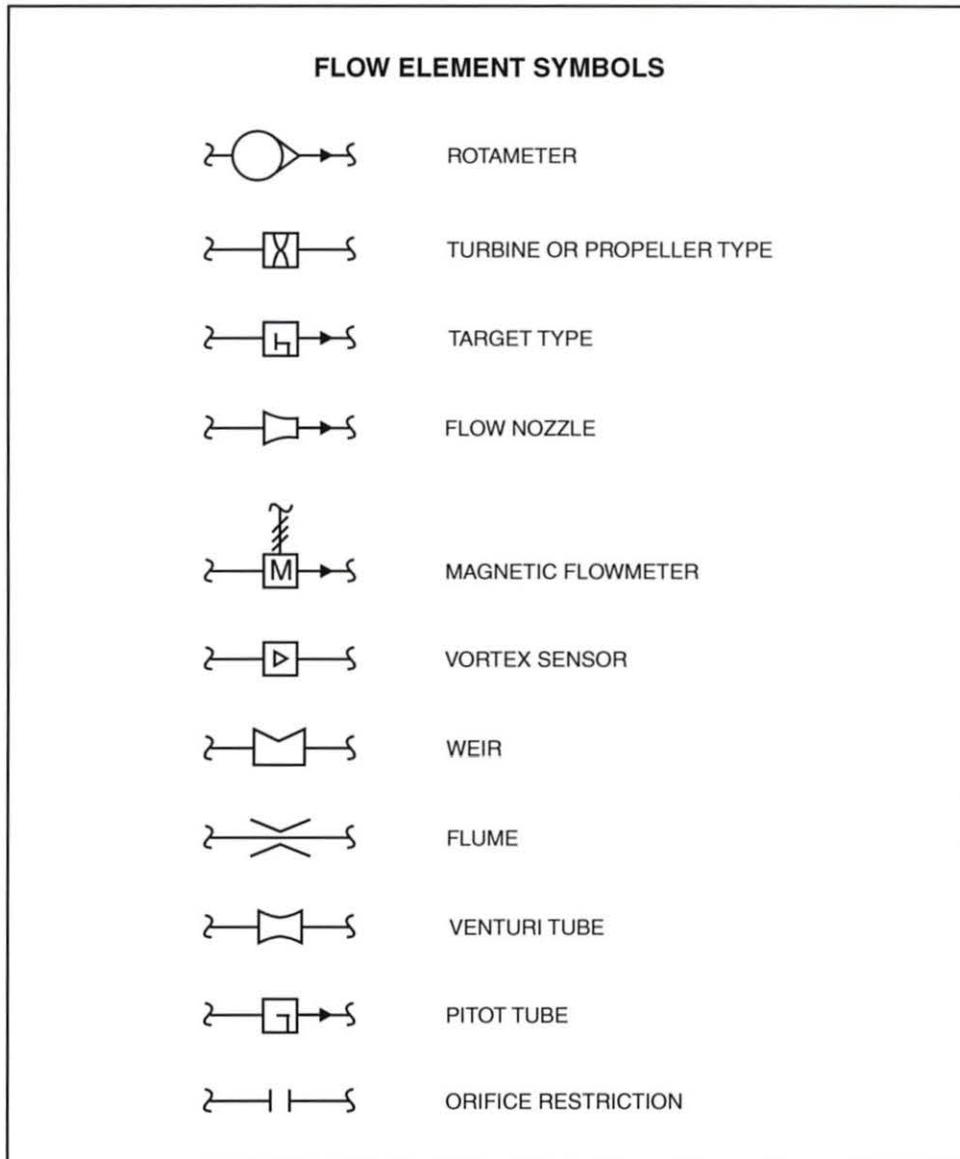


Figure 46. Flow Element Symbols

---

**Procedure Overview**

In this procedure, you will identify the flow sensing element symbols.

---



- ❑ 1. Determine which type of flow sensing element symbol is shown in figure 47.  
Symbol \_\_\_\_\_

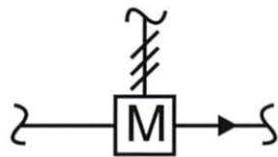


Figure 47. Flow Sensing Element Symbol

You should find that the symbol indicates a magnetic flow meter.

- ❑ 2. Determine which type of flow sensing element symbol is shown in figure 48.  
Symbol \_\_\_\_\_

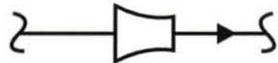


Figure 48. Flow Sensing Element Symbol

You should find that the symbol indicates a flow nozzle.

- ❑ 3. Determine which type of flow sensing element symbol is shown in figure 49.  
Symbol \_\_\_\_\_



Figure 49. Flow Sensing Element Symbol

You should find that the symbol indicates a vortex sensor.

4. Determine which type of flow sensing element symbol is shown in figure 50.

Symbol \_\_\_\_\_

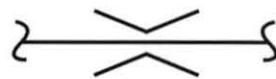


Figure 50. Flow Sensing Element Symbol

You should find that the symbol indicates a flume.

5. Determine which type of flow sensing element symbol is shown in figure 51.

Symbol \_\_\_\_\_

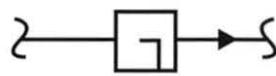


Figure 51. Flow Sensing Element Symbol

You should find that the symbol indicates a pitot tube.

6. Determine which type of flow sensing element symbol is shown in figure 52.

Symbol \_\_\_\_\_



Figure 52. Flow Sensing Element Symbol

You should find that the symbol indicates a weir.

7. Determine which type of flow sensing element symbol is shown in figure 53.

Symbol \_\_\_\_\_



Figure 53. Flow Sensing Element Symbol

You should find that the symbol indicates a turbine-type flow meter.

8. Identify the flow sensing elements that each letter indicates.

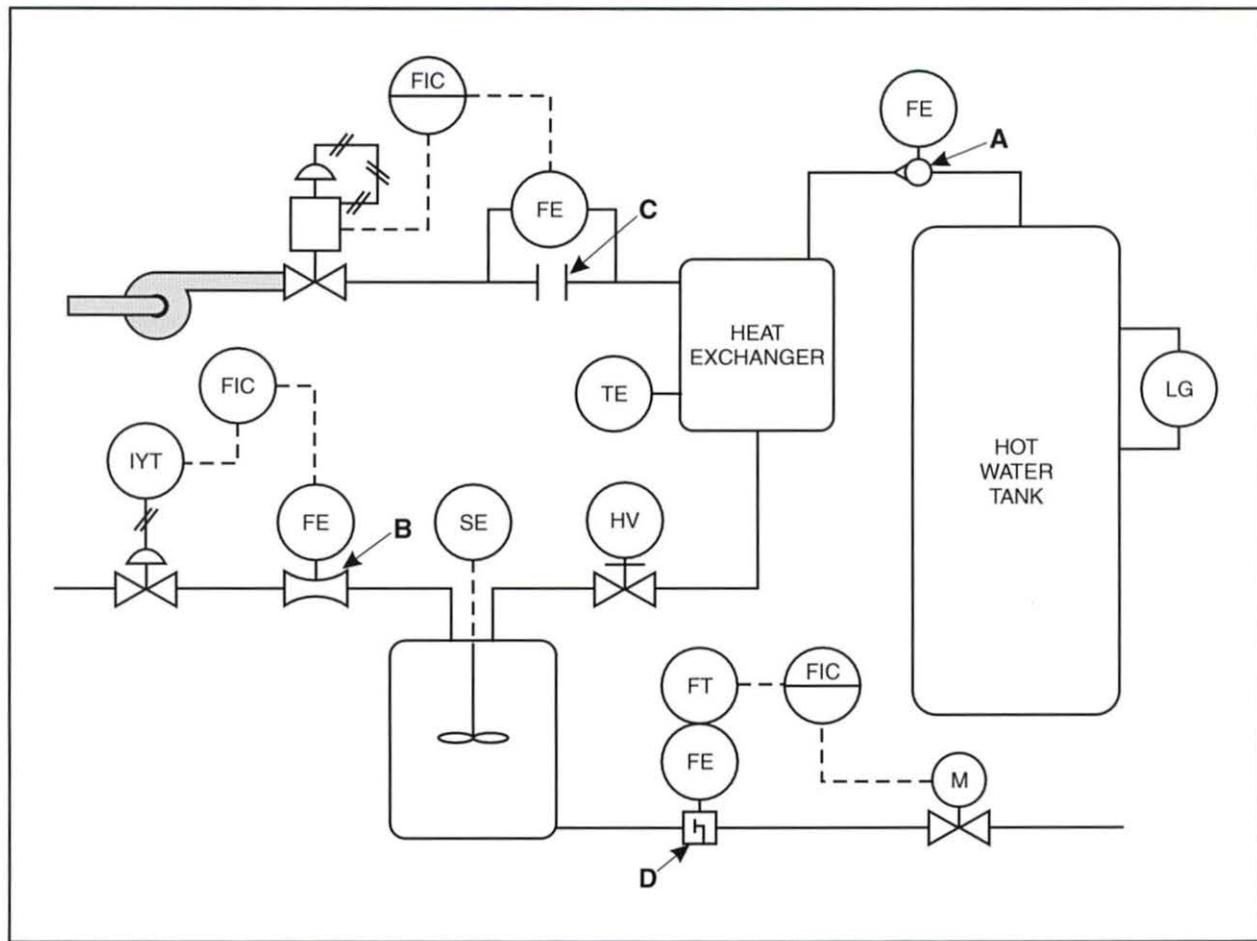


Figure 54. Sample P&ID

A. Symbol \_\_\_\_\_

You should find that the symbol indicates a rotameter.

B. Symbol \_\_\_\_\_

You should find that the symbol indicates a Venturi tube.

C. Symbol \_\_\_\_\_

You should find that the symbol indicates an orifice restriction.

D. Symbol \_\_\_\_\_

You should find that the symbol indicates a target flow sensor.



1. A rotameter is an example of a(n) \_\_\_\_\_ sensing element.
2. A bubble with the identifiers LG inside it represents a(n) \_\_\_\_\_, either mounted on the tank or externally connected.
3. Some \_\_\_\_\_ sensing element symbols indicate the method the device uses to transmit data to the control loop.
4. A square with an X in the center indicates a(n) \_\_\_\_\_ type flow sensor.
5. A square with an arrowhead pointing to the right indicates a(n) \_\_\_\_\_ flow sensor.

## SEGMENT 4

### PRESSURE, TEMPERATURE, AND pH SENSING ELEMENT SYMBOLS

#### OBJECTIVE 10

#### DESCRIBE TWO P&ID PRESSURE SENSING ELEMENT SYMBOLS



Pressure elements are represented by a standard symbol tag, as figure 55 shows.

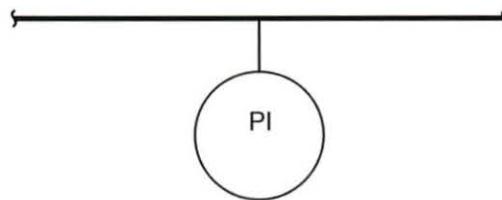


Figure 55. Standard Pressure Sensing Element Symbol

While most pressure elements don't have special symbols to represent them, they do use components that help isolate the device from the system. One example is a diaphragm.

Diaphragms are devices that can be used to isolate the sensing element from the process or they can be used to separate two transmission mediums from each other. An example of this is an application where an air signal is converted to a liquid signal. A diaphragm is used to separate the liquid from the air.

The symbol for a diaphragm is shown in figure 56.

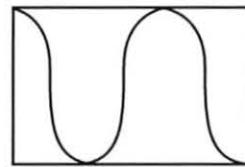


Figure 56. Symbol for a Diaphragm

Figure 57 shows a pressure element connected to the process line through a diaphragm.

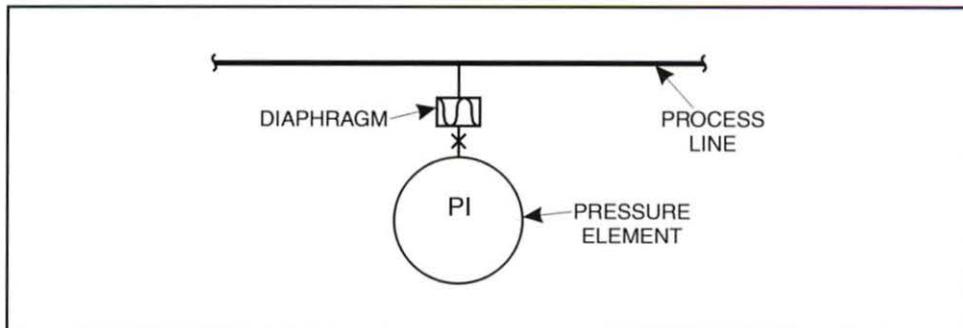


Figure 57. Pressure Element Connected to Process Line Through a Diaphragm

## OBJECTIVE 11

## DESCRIBE TWO P&ID TEMPERATURE SENSING ELEMENT SYMBOLS



A standard symbol tag also represents temperature elements, as shown in figure 58.

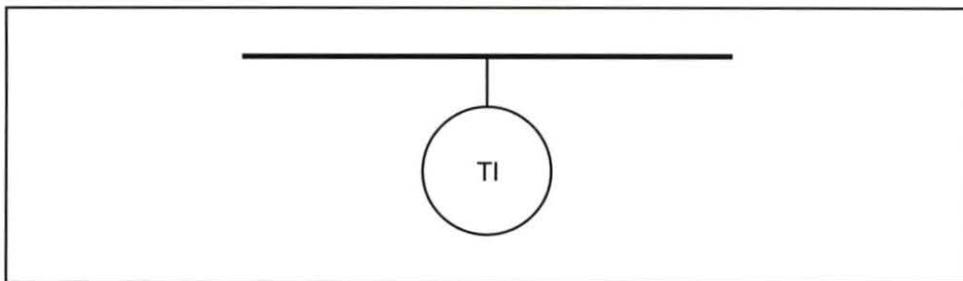


Figure 58. Temperature Sensing Element Symbol

Many temperature element symbols also indicate how the element is connected to the process. For example, if the connection line for a temperature element is drawn with a circle around it, the element is separated from the process by a device called a thermocouple well (often referred to as a thermowell), as shown in figure 59.

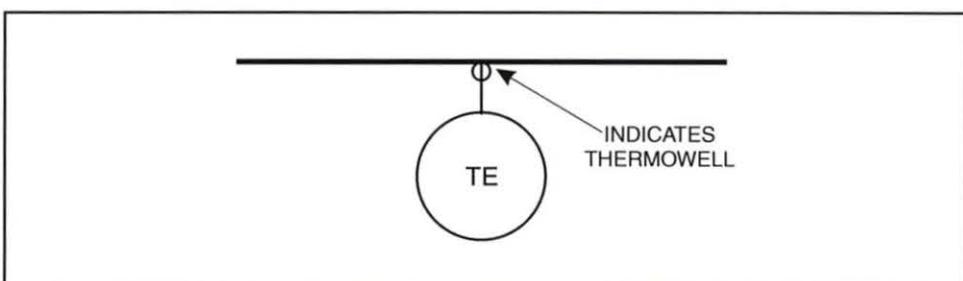


Figure 59. Symbol for Temperature Sensing Element in a Thermowell

Thermowells are hollow tubes in which the temperature element is placed to protect the temperature element from the process, as figure 60 shows. This is useful when the device must sense the temperature of a caustic fluid that would adversely react with the materials that make up the temperature element.

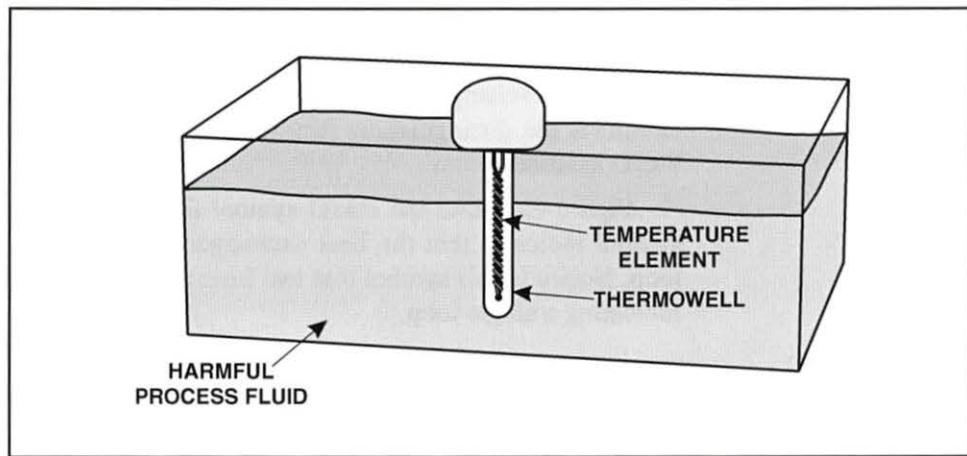


Figure 60. A Temperature Element in a Thermowell

Another type of temperature element connection is a surface-mount, where the temperature element is mounted to the outer surface of the vessel or piping that contains the process fluid. The symbol for this is a connection line that spreads out to form a T on the process piping, as shown in figure 61.

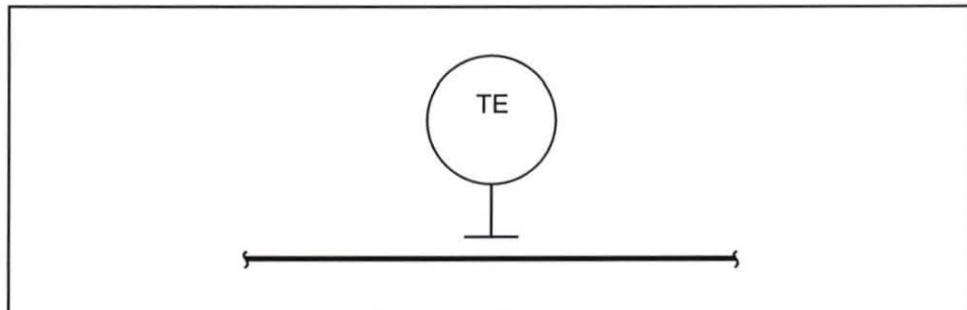


Figure 61. Surface Mounted Temperature Element Symbol



Heat exchangers are designed for single circuit or dual circuit operation. Single circuit heat exchangers are used when the system requires one heating or cooling loop. Systems that have more than one heating or cooling loop often use dual circuit heat exchangers. The design of the heat exchanger (i.e. single circuit or dual circuit) is the distinguishing factor between two commonly used heat exchanger P&ID symbols.

Figure 62 shows the P&ID symbol for a single circuit heat exchanger. This symbol indicates that the heat exchanger is heating or cooling fluid in a single loop. Notice in this symbol that two lines extend from only one side of the circle, indicating a single loop.

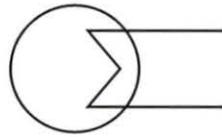


Figure 62. Single Circuit Heat Exchanger

Figure 63 shows the P&ID symbol for a dual circuit heat exchanger. This symbol indicates that the heat exchanger is heating or cooling fluid in two loops. Notice that two lines extend from both sides of the circle. In addition, a line down the middle of the circle indicates two independent loops.

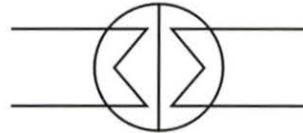


Figure 63. Dual Circuit Heat Exchanger



A standard symbol tag is used to represent a pH sensing element, just like temperature and pressure sensing elements. The only difference is the letters used to indicate a pH sensor, as shown in figure 64.

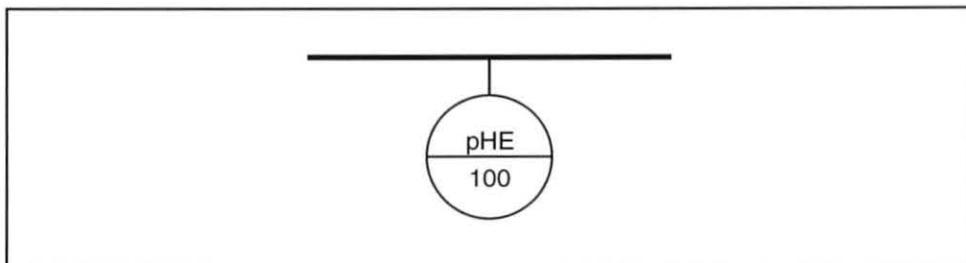


Figure 64. Flow Sensing Element Symbol

**Procedure Overview**

In this procedure, you will identify pressure, temperature, and pH sensing element symbols.



1. Determine which type of pressure sensing element symbol is shown in figure 65.

Symbol \_\_\_\_\_

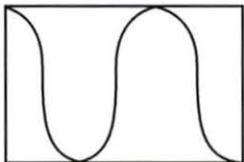


Figure 65. Sensing Element Symbol

You should find that the symbol indicates a diaphragm.

2. Determine which type of temperature sensing element symbol is shown in figure 66.

Symbol \_\_\_\_\_

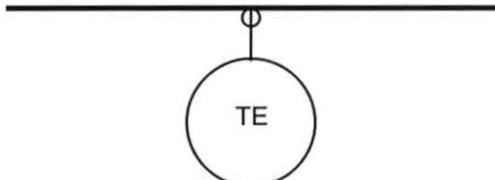


Figure 66. Sensing Element Symbol

You should find that the symbol indicates a temperature element with a thermowell.

3. Determine which type of pressure sensing element symbol is shown in figure 67.

Symbol \_\_\_\_\_

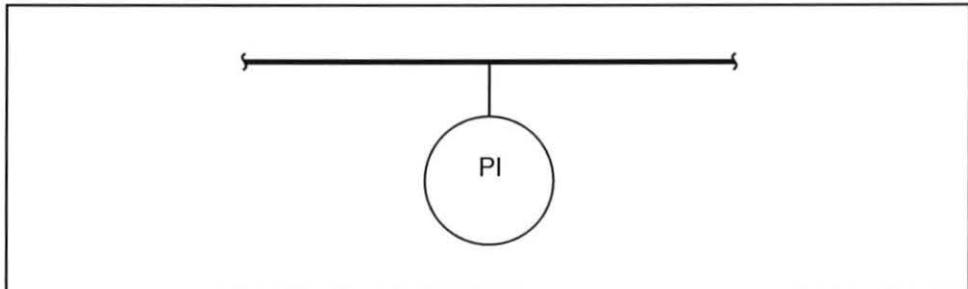


Figure 67. Sensing Element Symbol

You should find that the symbol indicates a standard pressure symbol.

4. Determine which type of temperature sensing element symbol is shown in figure 68.

Symbol \_\_\_\_\_

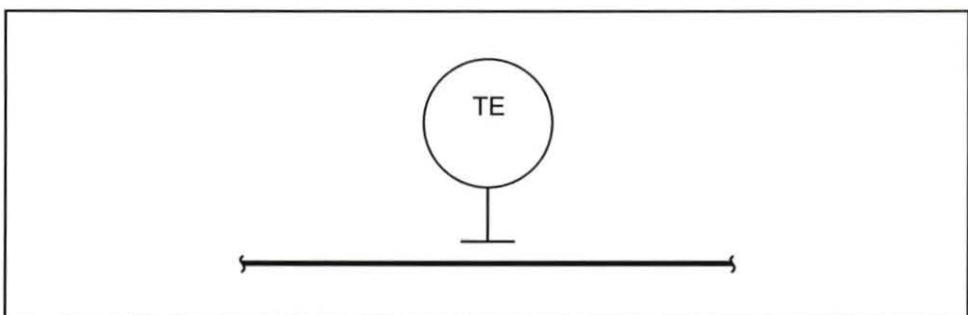


Figure 68. Sensing Element Symbol

You should find that the symbol indicates a surface-mounted temperature sensing element.

5. Determine which type of pressure sensing element symbol is shown in figure 69.

Symbol \_\_\_\_\_

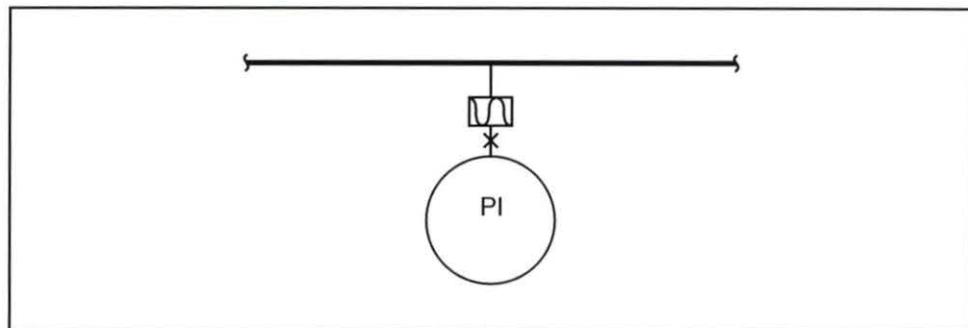


Figure 69. Sensing Element Symbol

You should find that the symbol indicates a standard pressure element connected through a diaphragm.

6. Determine which type of component symbol is shown in figure 70.

Symbol \_\_\_\_\_

Configuration \_\_\_\_\_

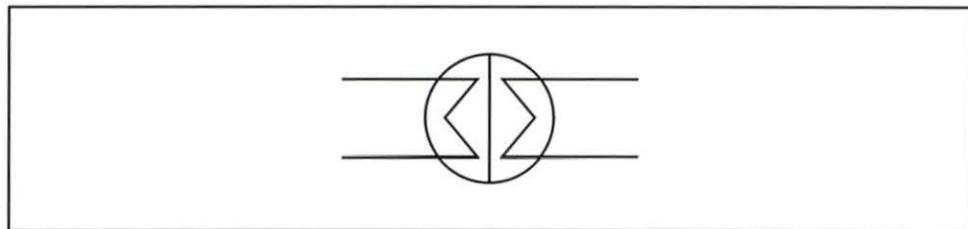


Figure 70. Thermal System Component

You should find that the symbol indicates a dual circuit heat exchanger.

7. Determine which type of component symbol is shown in figure 71.

Symbol \_\_\_\_\_

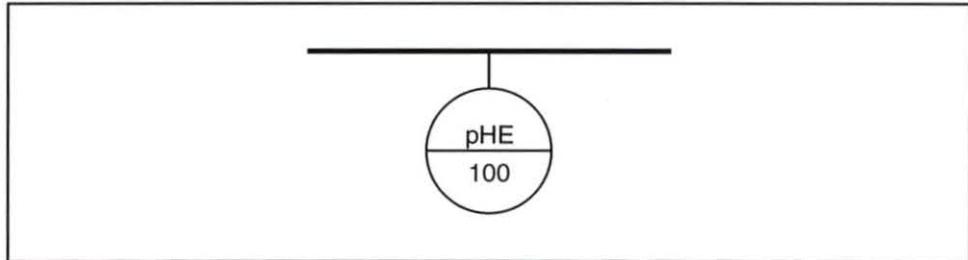


Figure 71. Sensing Element Symbol

You should find that the symbol indicates a pH sensing element.

---

### Procedure Overview

In this procedure, you will draw a P&ID for a given process control system. This process is similar to drawing a schematic diagram for an electrical or fluid power circuit.

---



- 1. Draw a P&ID based on the following description. Draw your diagram on a separate piece of paper.

**Description:**

- The system is a level control loop that controls the level of a liquid in a tank.
- The tank uses two level sensors, one for the high level and the other for the low level.
- These sensors send electrical signals to an electronic level controller, which is mounted in the control room and is accessible to the operator.
- The controller includes a digital display.
- The controller controls the flow into and out of the tank by controlling two solenoid valves, one in the input line and one in the output line. The control loop number is 100.

Your diagram should be similar to the one in figure 72. The instrument tag of the high level sensor should read LSH-100. The instrument tag of the low level sensor should read LSL-100. The instrument tag of the level controller should read LIC-100 and should have a single line through the center (primary location and accessible). The instrument tags for the solenoid valves should read FV-100. However, you might also label them LV-100, since they are being used to control the level in the tank.

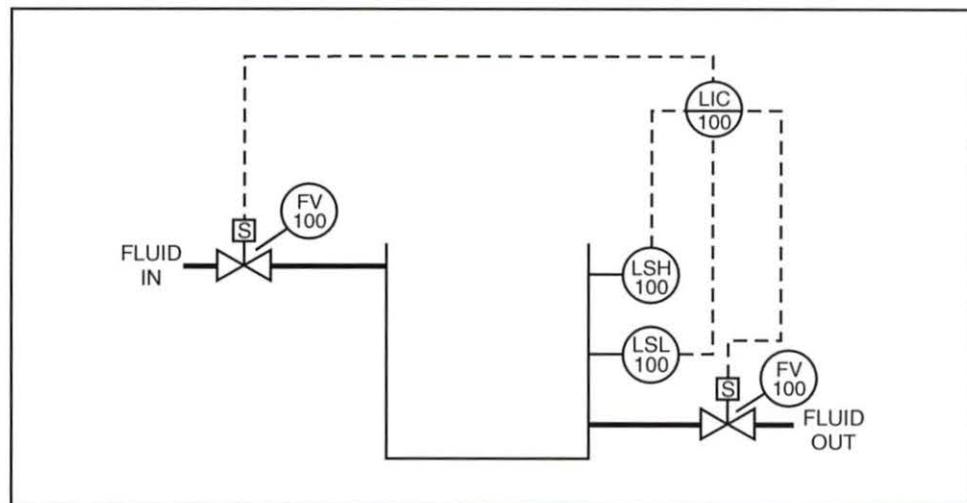


Figure 72. P&ID for Level Control Loop

2. Draw a P&ID based on the following description. Draw your diagram on a separate piece of paper.

**Description:**

- The system is a pressure control loop that controls the pressure of nitrogen in a tank.
- An electronic pressure controller monitors the pressure in the tank based on feedback transmitted by a pressure sensor that measures the pressure inside the tank.
- The pressure controller is located in a remote control panel away from the control room, but is accessible.
- The controller controls the flow of nitrogen into the tank through a diaphragm-actuated valve.
- Since the output of the controller is an electrical signal, a transducer is needed to convert the electrical signal to a pneumatic signal.
- The controller also controls the venting of gas to the atmosphere through a solenoid valve.
- The control loop number is 50.

3. Draw a P&ID based on the following description. Draw your diagram on a separate piece of paper.

**Description:**

- The system is a temperature control loop that controls the temperature of the process fluid from a heat exchanger.
- A PLC controls the temperature of the outgoing process fluid based on temperature feedback from a temperature sensor.
- The temperature sensor is enclosed in a thermowell.
- Based on the temperature of the outgoing fluid, the PLC controls the flow of steam into the heat exchanger through a motor-actuated valve.
- The in flow of the process fluid is controlled by another loop.
- A hand-actuated valve is also used to vent steam when necessary.
- The control loop number is 250.

4. Draw a P&ID based on the following description. Draw your diagram on a separate piece of paper.

**Description:**

- The system is a flow control loop that controls the flow of two liquids into a mixing tank.
- The controller must maintain an exact ratio of the two fluids.
- The controller, a computer located in the control room, controls the flow of each fluid into the tank using motor-actuated valves.
- The flow of the two liquids is measured using venturi tubes with flow transmitters connected to them.
- The flow transmitters, which provide feedback to the controller, are located in primary location but are inaccessible.
- The controller controls the flow of the mixture out of the tank using a diaphragm-actuated valve.
- A transducer is needed to convert the electrical signal from the controller to a pneumatic signal.
- The control loop number is 600.

□ 5. Draw a P&ID for the T5554.

Figure 73 shows a drawing of the T5554 that you can use for reference.

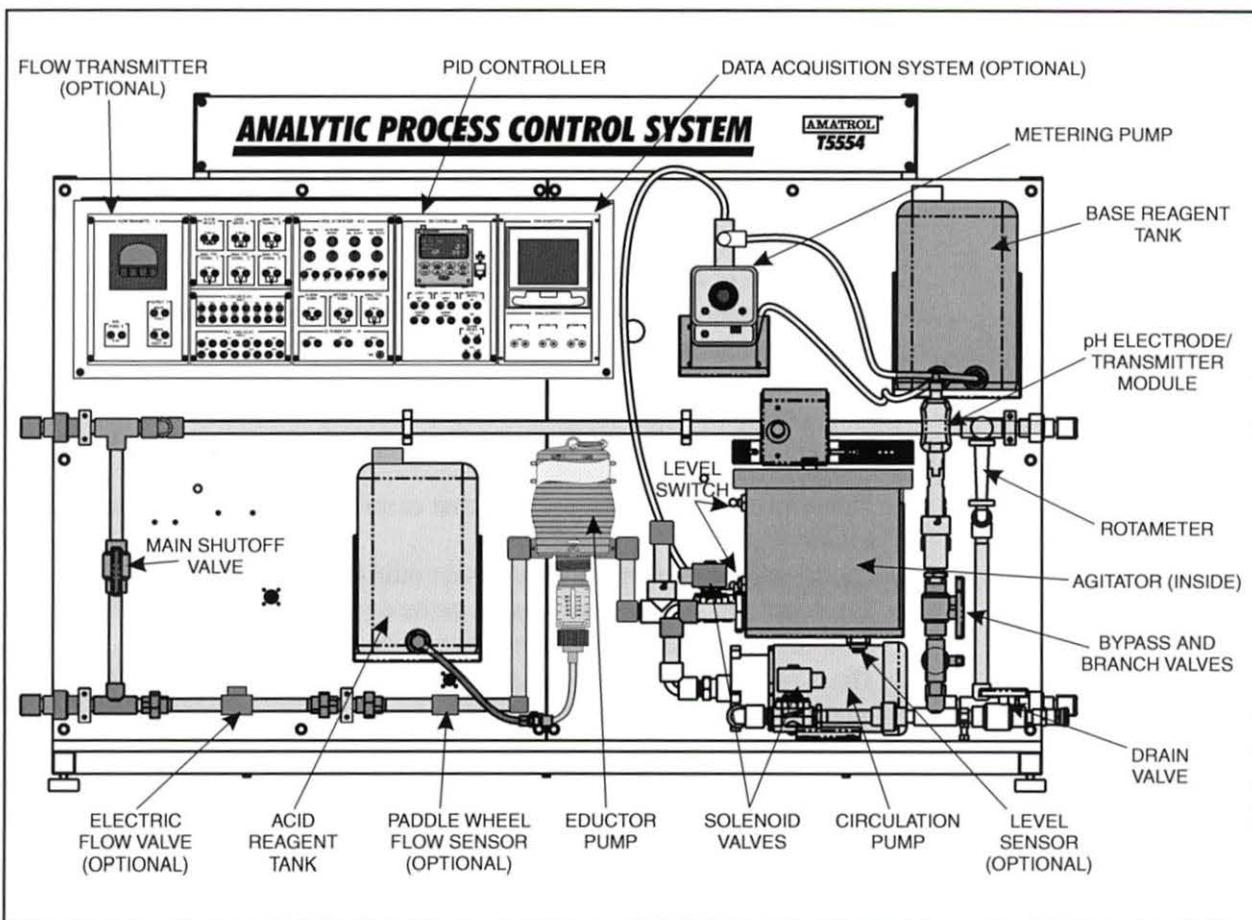


Figure 73. The Amatrol T5554 Analytical Process Control System

Your P&ID should include the following components:

- Reactor Tank
- Circulation Pump
- All Hand Valves
- Rotameter
- Flow Transmitter (optional)
- Level Switches (in reactor tank)
- Reagent Tanks
- Reactor Tank Inlet and Outlet Solenoid Valves
- Data Acquisition System (optional)
- Reactor Tank Agitator
- Agitator Speed Control
- Electric Flow Valve (optional)
- Eductor Pump
- Metering Pump
- pH Electrode/Transmitter Module
- Level Sensor (optional)
- Paddle Wheel Flow Sensor (optional)

Ask your instructor if you have any questions about the location of any of the components listed.



1. On pressure elements, a(n) \_\_\_\_\_ is used to separate the liquid from the air.
2. Temperature and pressure elements are represented by a(n) \_\_\_\_\_ symbol tag.
3. \_\_\_\_\_ are hollow tubes in which the temperature element is placed to protect it from the process.
4. If the temperature element connection line spreads out to form a T on the process piping, the temperature element is \_\_\_\_\_.
5. A connection line on a temperature element symbol that has a(n) \_\_\_\_\_ around it indicates that the element is inside a thermocouple well.
6. Heat exchangers are designed for single circuit or \_\_\_\_\_ circuit operation.
7. A standard symbol tag is used to represent a(n) \_\_\_\_\_ sensing element, just like temperature and pressure sensing elements.

## SEGMENT 5

### INSTRUMENT INDEX

#### OBJECTIVE 14

#### DESCRIBE THE FUNCTION OF AN INSTRUMENT INDEX



An instrument index is a document that lists every instrument in the process by tag number and the numbers of the drawings on which it can be found. A typical process system has a number of documents associated with it. These include P&IDs, installation drawings, and instrument specifications. An instrument index brings all of this information together so that you can quickly locate the documents you need. Figure 74 shows a typical instrument index.

AREA PREFIX	SERVICE	LOCATION	MFR	SPEC SHEET NO.	P & I DWG NO.	LOOP-SHEET DWG NO.	LOCATION & ROUTING DRAWING NO.	INSTL DETAIL DWG NO.	PIPING DWG NO.	ELECT DWG NO	VENDOR DWG NO	NOTES
TAG NO.												
LAH-1	Cooling Tower Level	PV	ACME	03-LA-1	03-P-100	03-L-1	-----	-----	-----	-----	-----	P.O. NO. 249-126
LAL-1	Cooling Tower Level	PV	ACME	03-LA-1	03-P-100	03-L-1	-----	-----	-----	-----	-----	P.O. NO. 249-126
LIC-1	Cooling Tower Level	L	Jones	03-C-2	03-P-100	03-L-1	03-I-600	65-I-502	-----	-----	-----	P.O. NO. 249-290
LSH-1	Cooling Tower Level	L	US Inst.	03-LS-1	03-P-100	03-L-1	03-I-600	-----	-----	-----	-----	P.O. NO. 249-423
LT-1	Cooling Tower Level	F	Smith	03-LT-1	03-P-100	03-L-1	03-I-600	03-I-600	03-P-200	-----	-----	P.O. NO. 249-612
LV-1	Cooling Tower Level	F	Honey	0V-V-2	03-P-100	03-L-1	03-I-600	65-I-523	03-P-200	-----	-----	P.O. NO. 249-612
PC-1	Cooling Tower Recirculation Water Pressure	F	Fisher	03-V-005	03-P-100	03-P-002	03-I-600	65-I-502 65-I-540A	03-P-200	-----	-----	P.O. NO. 249-083

				LOCATION LEGEND A- ANALOG SOFTWARE B- BACK OF PANEL D- DIGITAL SOFTWARE E- EXISTING F- FIELD L- LOCAL PANEL P- FRONT OF PANEL B- BACK V- VENDOR PACKAGE	DRAWN BY: WORD PROCESS.	DATE 4/26/92	A B & C ENGINEERING	NO. 2 COOLING TOWER			ABC-249	
					DESIGNED BY	DATE 3/29/92						
					CHECKED BY	DATE 5/05/92						
					APPROVED BY	DATE						
					RELEASED BY	DATE 5/07/92						
1	8/5/92	ADDED HEAT TRACE I.D.										
0	5/7/92	RELEASED FOR CONSTRUCTION										
NO.	DATE	REVISIONS	DSGN	CKD								INSTRUMENT INDEX

Figure 74. An Instrument Index

## OBJECTIVE 15

## DESCRIBE HOW TO INTERPRET THE INFORMATION CONTAINED IN AN INSTRUMENT INDEX



An instrument index can be organized in several ways depending on the process system it documents. The items labeled in figure 75 represent information commonly found on an instrument index. These items are described as follows:

**Item 1: Tag Number/Area Prefix** – Lists the tag number and area number (if applicable) of every instrument.

**Item 2: Service** – Describes the type of process where the instrument is installed and/or how the instrument functions in terms of measuring the process.

ITEM 1 AREA PREFIX TAG NO.	ITEM 2 SERVICE	ITEM 3A LOCATION	ITEM 4 MFR	ITEM 5 SPEC SHEET NO.	P & I DWG NO.	LOOP-SHEET DWG NO.	LOCATION & ROUTING DRAWING NO.	INSTL DETAIL DWG NO.	PIPING DWG NO.	ELECT DWG NO.	VENDOR DWG NO.	ITEM 7 NOTES	
LAH-1	Cooling Tower Level	PV	ACME	03-LA-1	03-P-100	03-L-1	-----	-----	-----	-----	-----	P.O. NO. 249-126	
LAL-1	Cooling Tower Level	PV	ACME	03-LA-1	03-P-100	03-L-1	-----	-----	-----	-----	-----	P.O. NO. 249-126	
LIC-1	Cooling Tower Level	L	Jones	03-C-2	03-P-100	03-L-1	03-I-600	65-I-502	-----	-----	-----	P.O. NO. 249-290	
LSH-1	Cooling Tower Level	L	US Inst.	03-LS-1	03-P-100	03-L-1	03-I-600	-----	-----	-----	-----	P.O. NO. 249-423	
LT-1	Cooling Tower Level	F	Smith	03-LT-1	03-P-100	03-L-1	03-I-600	03-I-600	03-P-200	-----	-----	P.O. NO. 249-612	
LV-1	Cooling Tower Level	F	Honey	0V-V-2	03-P-100	03-L-1	03-I-600	65-I-523	03-P-200	-----	-----	P.O. NO. 249-612	
PC-1	Cooling Tower Recirculation Water Pressure	F	Fisher	03-V-005	03-P-100	03-P-002	03-I-600	65-I-502 65-I-540A	03-P-200	-----	-----	P.O. NO. 249-083	
PCV-2	Cooling Tower Recirculation Water Pressure	F	Fisher	03-V-005	03-P-100	03-P-002	03-I-600	65-I-524	03-P-200	-----	-----	P.O. NO. 249-083	
VAH-3A	Cooling Tower Fan Vibration	PV	Roberts	03-VA-1	03-P-100	66-I-301	-----	-----	-----	-----	-----	P.O. NO. 249-016	
VT-3A	Cooling Tower Fan Vibration	PV	Roberts	03-VA-1	03-P-100	03-V-003	03-I-600	-----	-----	-----	-----	P.O. NO. 249-016	
VAH-3B	Cooling Tower Fan Vibration	PV	Roberts	03-VT-1	03-P-100	66-I-301	-----	-----	-----	-----	-----	P.O. NO. 249-018	
VT-3B	Cooling Tower Fan Vibration	PV	Roberts	03-VS-1	03-P-100	03-V-002	03-I-600	-----	-----	-----	-----	P.O. NO. 249-018	
					LOCATION LEGEND	DRAWN BY: WORD PROCESS.	DATE 4/26/92	A B & C ENGINEERING	NO. 2 COOLING TOWER				
					A- ANALOG SOFTWARE	DESIGNED BY	DATE 3/29/92						
					B- BACK OF PANEL	CHECKED BY	DATE 5/05/92						
					D- DIGITAL SOFTWARE	APPROVED BY	DATE						
					E- EXISTING	RELEASED BY	DATE 5/07/92						
					F- FIELD								
					L- LOCAL PANEL								
					P- FRONT OF PANEL								
1	8/5/92	ADDED HEAT TRACE I.D.			B- BACK								
0	5/7/92	RELEASED FOR CONSTRUCTION											
NO.	DATE	REVISIONS	DSGN	CKD	V- VENDOR PACKAGE								
					ITEM 8	ITEM 3B	ITEM 9	ITEM 10					

Figure 75. Instrument Index

**Items 3A & 3B: Location/Location Legend** – The location where the instrument is installed is often represented as a letter or several letters. The legend at the bottom of the index indicates the meaning of the location letters.

**Item 4: Manufacturer** – Lists the manufacturer of the instrument. A technician needs to know the manufacturer of an instrument to request specifications and order new parts.

**Item 5: Specification Sheet Number** – Lists the specification sheet number of the instrument. These sheets detail the physical characteristics of the instrument.

**Item 6: Drawing Numbers** – An instrument can list several types of drawings for an instrument. These include:

- P&I Drawing Number lists the piping and instrument drawing number on which the instrument appears.
- Loop Sheet Drawing Number lists the loop drawing number on which the instrument appears.
- Location & Routing Drawing Number lists the location or panel drawing number on which the instrument appears.
- Installation Detail Drawing Number lists the installation drawing number on which the instrument appears. These drawings describe how to install the instrument.
- Piping Drawing Number these drawings show the piping line where the instrument is installed.
- Electrical Drawing Number these drawings show the electrical connections of the instrument.
- Vendor Drawing Number lists any vendor drawings that relate to the instrument.

**Item 7: Notes** – Lists any additional information about the instrument (e.g. purchase order number).

**Item 8: Revisions** – List any revisions made to the instrument index. This includes when and by whom.

**Item 9: Signoffs** – List several signoffs on the instrument index to ensure accuracy.

**Item 10: Additional Information** – This section can contain a variety of extra information (e.g. the name of the company that created the instrument index, sheet number, etc.)

### Procedure Overview

In this procedure, you will examine an instrument index for the T5554 Analytical Process Control System. You will use the instrument index to determine as much information as possible about various devices on the T5554.

- 1. Examine the partial instrument index for the T5554, as shown in figure 76.



T5554 ANALYTICAL PROCESS INSTRUMENT INDEX DRAWING NO. A050201-1-4							
TAG NO.	SERVICE	LOCATION	MFR.	MFR. PART NO.	DESCRIPTION	SPEC SHEET NO.	P&ID DWG NO.
FCV-1200*	Process Feed Liquid Flow		ASCO	SD8202G076V	Electric Modulating Valve, Proportional Flow Control, 24 VDC	A050201-1-3	
FCV-1200A*	Process Feed Liquid Flow		ASCO	8908A001	Control Module, Electric Modulating Valve	A050201-1-3	
FE-1200*	Process Feed Liquid Flow		GF Signet	3-2000-21	Paddlewheel Flow Sensor, 0.3-3.2 GPM	A050201-1-3	
FIC-1200A*	Process Feed Liquid Flow		Honeywell	DC3500-OE-0000-200-00000-00-0	Flow Indicating PID Controller, Single-Loop	A050201-1-3	
FIC-1200B*	Process Feed Liquid Flow		Honeywell	DC3500-CE-3C20-210-00000-00-0	Flow Indicating PID Controller, Dual-Loop	A050201-1-3	
FIT-1200*	Process Feed Liquid Flow		GF Signet	3-8550-1P	Flow Indicating Transmitter, 4-20 mA	A050201-1-3	
HV-1200	Process Feed Liquid Flow	Colonial	V07191N		Hand Valve, Ball, 1/2", PVC, Socket Type	A050201-1-3	
SV-1200	Process Feed Liquid Flow		ASCO	8210G035	Solenoid Valve, 3/4", 120 VAC	A050201-1-3	
LET-1300*	Reactor Tank Level	Setra	673-1		Level Pressure Sensor/Transmitter, 1 PSI	A050201-1-3	
LSH-1300	Reactor Tank Level	Dwyer	F7-HPS-1		Level Switch, High	A050201-1-3	
LSL-1300	Reactor Tank Level	Dwyer	F7-HPS-1		Level Switch, Low	A050201-1-3	
pHE-1300A*	Reactor Tank pH Batch Control	Honeywell	DL1-772-0000		Durafet II pH Electrode	A050201-1-3	
pHE-1300B*	Reactor Tank pH Batch Control	Honeywell	DL2-770-0000		Meridian II Glass pH Electrode	A050201-1-3	
pHIT-1300*	Reactor Tank pH Batch Control	Honeywell	DL421-E-0-A-0000		pH Directline Transmitter	A050201-1-3	
RT-1300	Reactor Tank	US Plastics	6299		Tank, Polyethylene, 6 Gal.	A050201-1-3	
SC-1300	Reactor Tank Agitator	Grainger/Dayton	4X796		Speed Control, 5A	A050201-1-3	
SZ-1300	Reactor Tank Agitator	Grainger/Dayton	2M033		Agitator Motor, 1/15 HP, AC/DC	A050201-1-3	
FCP-1400	Process Discharge Liquid Flow	Shertech	CMSV1X		Centrifugal Pump	A050201-1-3	
FI-1400	Process Discharge Liquid Flow	Blue-White	F-44376LE-A-8		Rotameter Flow Indicator, 0.2-2 GPM	A050201-1-3	
FV-1400	Process Discharge Liquid Flow	Blue-White	Part of FI-1400		Flow Control Valve, Manual	A050201-1-3	
HV-1400	Process Discharge Liquid Flow	Colonial	V07191N		Hand Valve, Ball, 1/2", PVC, Socket Type	A050201-1-3	
SV-1400	Process Discharge Liquid Flow	ASCO	8210G035		Solenoid Valve, 3/4", 120 VAC	A050201-1-3	
HV-1500	Acidic pH Control	US Plastics	22264		3-Way Ball Valve, PVC	A050201-1-3	
pHE-1500A*	Acidic pH Control	Honeywell	DL1-772-0000		Durafet II pH Electrode	A050201-1-3	
pHE-1500B*	Acidic pH Control	Honeywell	DL2-770-0000		Meridian II Glass pH Electrode	A050201-1-3	
pHEP-1500	Acidic pH Control	Dosmatic	112600		Eductor Pump, MiniDOS, 3/4" NPT	A050201-1-3	
pHIT-1500*	Acidic pH Control	Honeywell	DL421-E-0-A-0000		pH Directline Transmitter	A050201-1-3	
pHST-1500	Acidic pH Control	US Plastics	74093		Acid Storage Tank, 2.5 Gal, Carboy	A050201-1-3	
CKV-1600	Alkaline pH Control	Pulsefeeder	Supplied with pHMP-1600		Check Valve	A050201-1-3	
HV-1600A	Alkaline pH Control	Pulsefeeder	Supplied with pHMP-1600		Hand Valve, 3-Way	A050201-1-3	
HV-1600B	Alkaline pH Control	Colonial	V07191N		Hand Valve, Ball, 1/2", PVC, Socket Type	A050201-1-3	
HV-1600C	Alkaline pH Control	Colonial	V07191N		Hand Valve, Ball, 1/2", PVC, Socket Type	A050201-1-3	
HV-1600D	Alkaline pH Control	Colonial	V07191N		Hand Valve, Ball, 1/2", PVC, Socket Type	A050201-1-3	
pHE-1600A	Alkaline pH Control	Honeywell	DL1-772-0000		Durafet II pH Electrode	A050201-1-3	
pHE-1600B*	Alkaline pH Control	Honeywell	DL2-770-0000		Meridian II Glass pH Electrode	A050201-1-3	
pHIC-1600A*	Alkaline pH Control	Honeywell	DC3500-OE-0000-200-00000-00-0		pH PID Indicating Controller, Single-Loop	A050201-1-3	
pHIC-1600B*	Alkaline pH Control	Honeywell	DC3500-CE-3C20-210-00000-00-0		pH PID Indicating Controller, Dual-Loop	A050201-1-3	
pHIR-1600A*	Alkaline pH Control	Honeywell	TVEZQX-30-000-22-0-0000-00000-000		pH Recorder, 3-Channel	A050201-1-3	
pHIT-1600	Alkaline pH Control	Honeywell	DL421-E-0-A-0000		pH Directline Transmitter	A050201-1-3	
pHMP-1600	Alkaline pH Control	Pulsefeeder	LPE4MA-PTC1		pH Metering Pump, 4-20 mA, 240 GPD	A050201-1-3	
pHST-1600	Alkaline pH Control	US Plastics	74093		Alkaline Storage Tank, 2.5 Gal, Carboy	A050201-1-3	

\* Optional Equipment

Figure 76. Partial Instrument Index for the T5554

- 2. Locate the device with a tag number of LSH-1300.
- 3. Determine the following information for the selected device.

Service \_\_\_\_\_

Manufacturer \_\_\_\_\_

Part Number \_\_\_\_\_

Description \_\_\_\_\_

The device is used in the Reactor Tank Level service. The manufacturer of the device is Dwyer. The part number is F7-HPS-1. The description is a level switch, high.

- 4. Locate the device with a tag number of FI-1400 on the instrument index. Record the information for the device.

Service \_\_\_\_\_

Manufacturer \_\_\_\_\_

Part Number \_\_\_\_\_

Description \_\_\_\_\_

The device is used in the Process Discharge Flow service. The manufacturer of the device is Blue-White. The part number is F-44376LEA-8. The description indicates the device is a rotameter.

- 5. Locate the device with a tag number of pHEP-1500 on the instrument index. Record the information for the device.

Service \_\_\_\_\_

Manufacturer \_\_\_\_\_

Part Number \_\_\_\_\_

Description \_\_\_\_\_

The device is used for the Acidic pH Control service. The manufacturer of the device is Dosomal. The part number is 112600. The description indicates the device is an eductor pump.

6. Locate the device with a tag number of SV-1200 on the instrument index. Record the information for the device.

Service \_\_\_\_\_

Manufacturer \_\_\_\_\_

Part Number \_\_\_\_\_

Description \_\_\_\_\_

The device is used for the Process Feed Flow service. The manufacturer is ASCO. The part number is 8210G035. The description indicates the device is a solenoid valve.

7. Locate the device with a tag number of SC-1300 on the instrument index. Record the information for the device.

Service \_\_\_\_\_

Manufacturer \_\_\_\_\_

Part Number \_\_\_\_\_

Description \_\_\_\_\_

The device is used for the Reactor Tank Agitator service. The manufacturer is Grainger/Dayton. The part number is 4X796. The description indicates the device is a speed control.

8. Repeat step 7 for the devices listed in the following table.

DEVICE TAG NO.	SERVICE	MANUFACTURER	PART NO.	DESC.
pHE-1300A				
SZ-1300				
FCP-1400				
pHST-1500				
pHMP-1600				
HV-1600A				



1. A(n) \_\_\_\_\_ is a document that lists every instrument in the process by tag number.
2. It is important to know the \_\_\_\_\_ of an instrument in case you need specifications on it or need to order a new one.
3. The \_\_\_\_\_ data in an instrument index describes the type of process where the instrument is installed.
4. A location legend is sometimes included at the \_\_\_\_\_ of an instrument index.
5. The \_\_\_\_\_ number indicates on which document information about the physical characteristics of the instrument can be found.