PROCESS CONTROL SYSTEMS

5

LEARNING ACTIVITY PACKET

FINAL CONTROL ELEMENTS

IST™

AMATROL

INTEGRATED SYSTEMS TECHNOLOGY

B270-XD

LEARNING ACTIVITY PACKET 5

FINAL CONTROL ELEMENTS

INTRODUCTION

Final control elements are the devices that receive the output signal from the controller and adjust accordingly to maintain the process at the setpoint. The most common final control element is the proportional valve.

This LAP covers the proportional valve and how it is used to control processes. It also covers the current-to-pressure (I/P) converter, which is a signal conditioning device used with proportional valves.

ITEMS NEEDED

Amatrol Supplied

1 T5552 Process Control Learning System

School Supplied

1 Water (10 Gallons)
1 Compressed Air Supply
1 Digital Multimeter
1 Loop Calibrator (Optional)
1 1/4" Open End Wrench

FIRST EDITION, LAP 5, REV. A

Amatrol,Inc., P.O. Box 2697, Jeffersonville, IN 47131 USA, Ph 812-288-8285, FAX 812-283-1584 www.amatrol.com

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SEGMENT 1

I/P CONVERTER OPERATION

OBJECTIVE 1 DESCRIBE THE FUNCTION OF A CURRENT-TO-AIR PRESSURE (I/P) CONVERTER

Read This

An I/P converter is a signal conditioner that receives an electrical analog signal and converts it to a pneumatic analog signal.

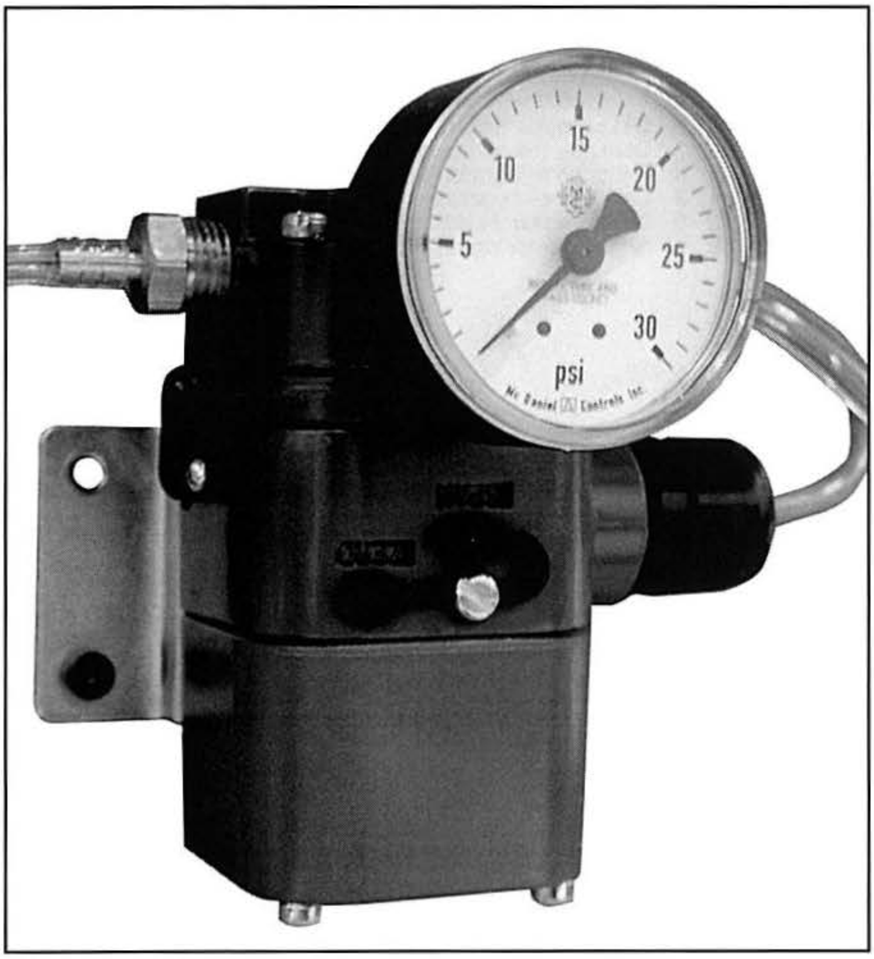

Figure 1. An I/P Converter

One common application of an I/P converter is to interface an electronic loop controller to a pneumatic diaphragm valve, as shown in figure 2. Pneumatic valves are often used instead of electrical valves because they are less expensive and safer if the process fluid is flammable. In this application, the I/P converter converts a 4-20 mA electrical signal from the controller to a 3-15 psi pneumatic signal to the valve.

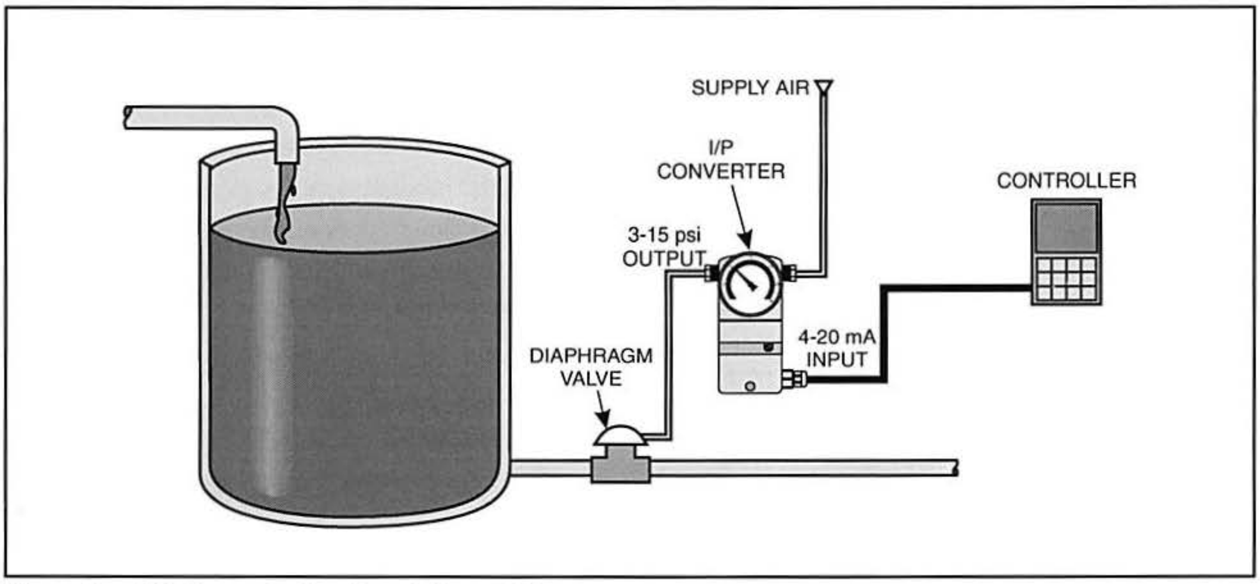

Figure 2. I/P Converter in a Level Control Process

OBJECTIVE 2 DESCRIBE THE CONSTRUCTION OF AN I/P CONVERTER

Read This

Most parts of an I/P converter are contained within its enclosure. However, the parts of an I/P converter that are externally visible are:

- **Protective Enclosure** - Protects internal components of the I/P converter.
- **Electrical Conduit Connection** - Receives the signal wiring from the controller.
- **Input Air Connection** - Connects to regulated air supply.
- **Span Adjustment** - Sets the maximum output pressure.
- **Zero Adjustment** - Sets the minimum output pressure.
- **Output Air Connection** - Sends pneumatic output signal to the control valve.
- **Pressure Gauge** - Indicates the output pressure.

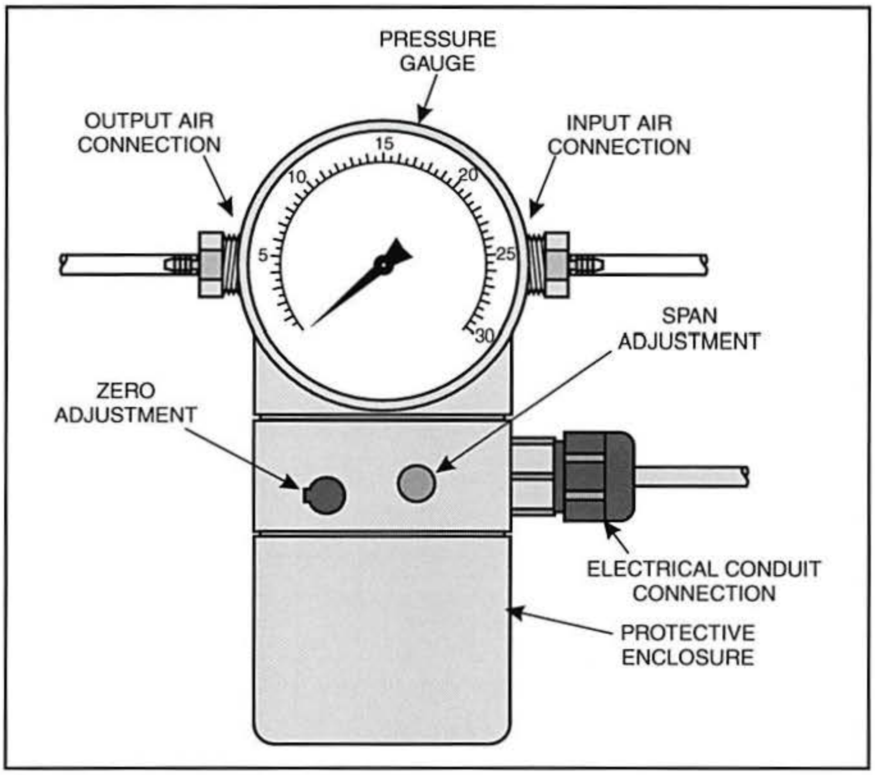

Figure 3. External Parts of an I/P Converter

The internal parts which are not visible externally are shown in figure 4. They include:

- **Coil Assembly** - The coil assembly includes the electrical terminals, permanent magnet, coil, and the beam. The electrical terminals accept the electrical input signal and are connected to wires that wrap around a magnetic coil. As the signal travels through the coil, it creates an electromagnetic field that causes the beam to deflect towards or away from an air nozzle.
- **Diaphragm/Valve Assembly** - The diaphragm/valve assembly includes the air nozzle, diaphragm assembly, and the valve. The components work together to create a balanced pressure on both sides of the internal diaphragm.
- **Input/Output Pressure Channels –** Allow the transport of supply and output air, respectively.
- **Zero Adjustment/Zero Spring –** Sets the minimum output pressure by adjusting the spring to deflect the beam towards or away from the air nozzle.
- **Span Adjustment/Magnetic Shunt –** Sets the maximum output pressure by using the shunt to adjust the strength of the magnetic field.

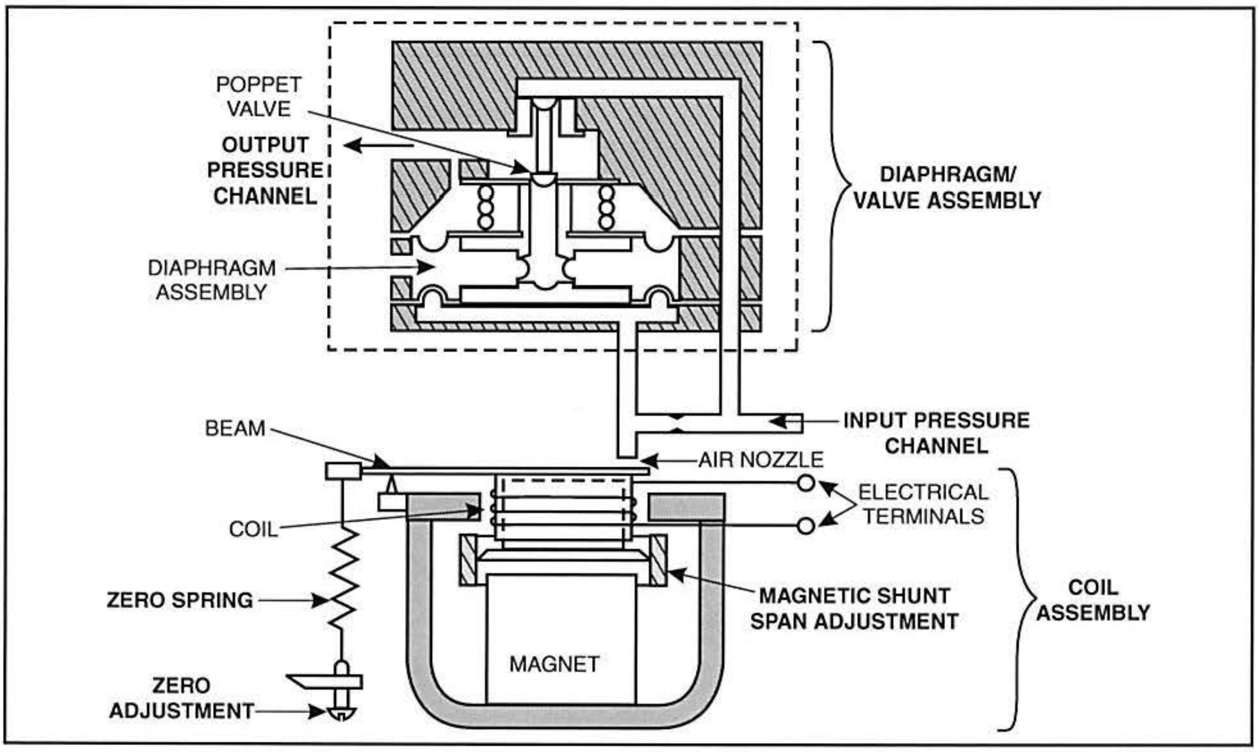

Figure 4. Internal Parts of an I/P Converter

OBJECTIVE 3 DESCRIBE THE OPERATION OF AN I/P CONVERTER

Read This

Many I/P converters accept a 4-20 mA electrical input signal and deliver a 3-15 psi pneumatic output signal, as shown in figure 5.

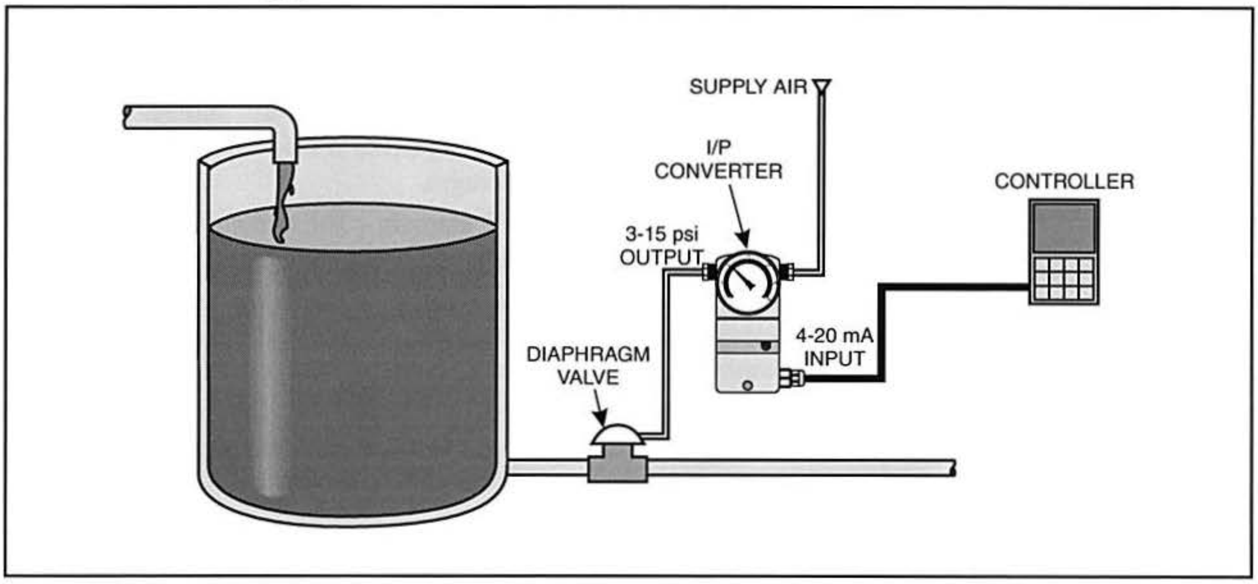

Figure 5. I/P Converter Operation

The relationship between the input and output of an I/P converter is linear, as shown in figure 6. For example, a 4 mA input signal results in a 3 psi air pressure output signal, while a 20 mA input signal results in a 15 psi air pressure output signal. Therefore, a 12 mA input signal causes the I/P converter to output 9 psi.

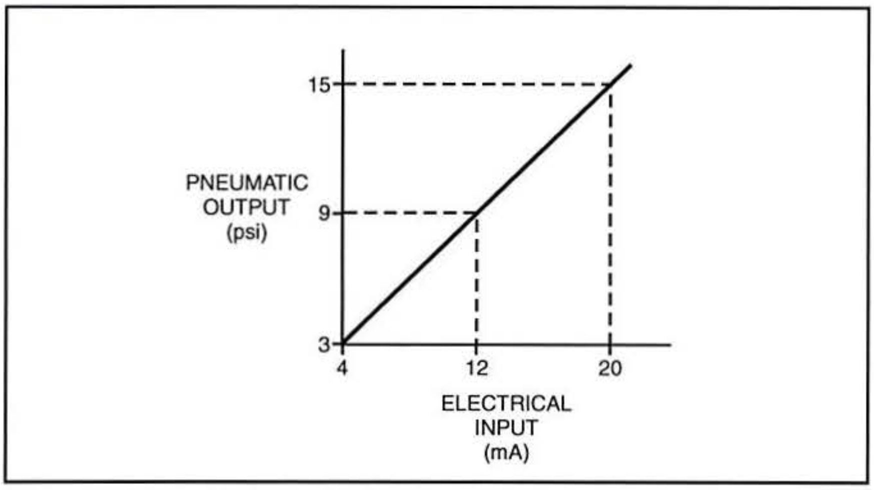

Figure 6. Linear Relationship Between I/P Converter Input/Output

To understand how an I/P converter works, examine figure 7. Figure 7 shows the state of the I/P converter when the input signal is at a minimum (i.e. 4mA). The strength of the electromagnetic field is weak because of the low current. Therefore, the beam only deflects a small amount toward the nozzle. As a result, the supply air is able to escape through the air nozzle, little pressure builds up on the diaphragm, and the poppet valve only opens enough to allow the minimum output pressure (3 psi).

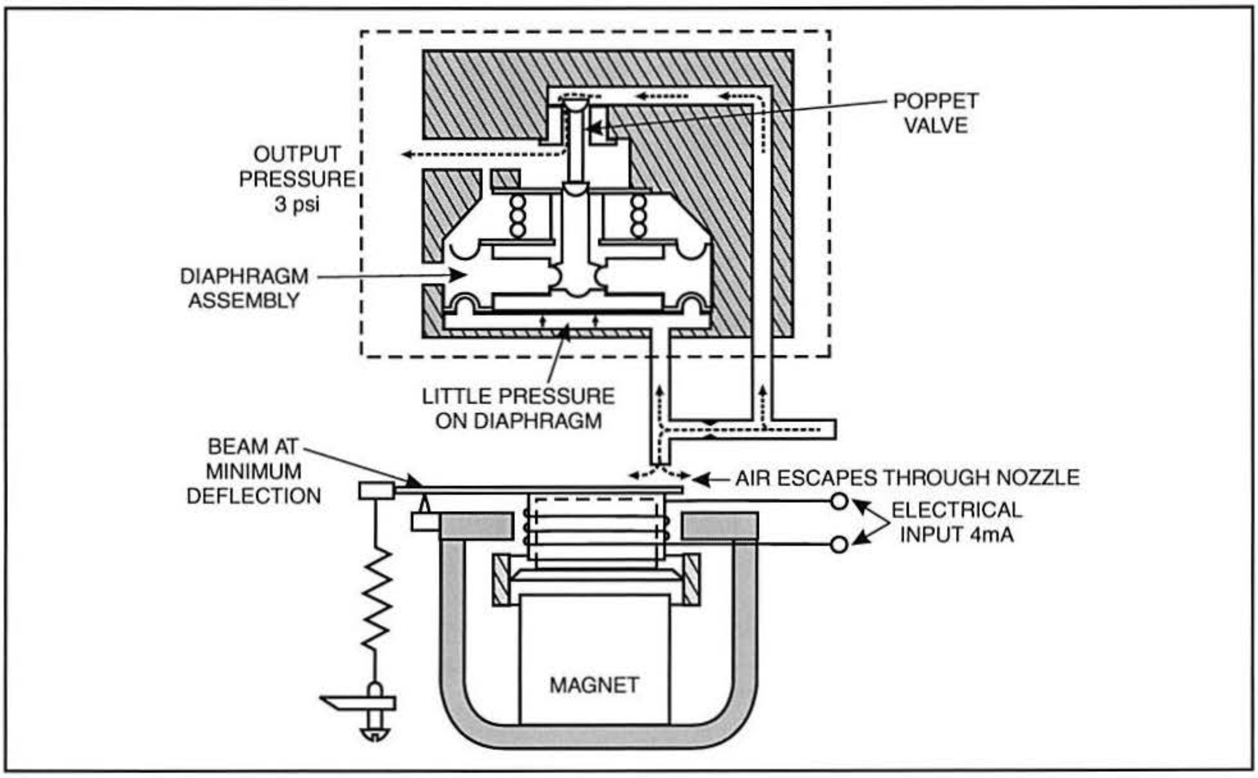

Figure 7. I/P Converter with Minimum Current Input

If the current increases to 12 mA, the magnetic field strengthens and the beam deflects more, as shown in figure 8. This results in more pressure on the diaphragm, which causes the poppet valve to open more. This action creates an output pressure (of 9 psi) which is equal to half the total pressure range of the converter (3-15 psi).

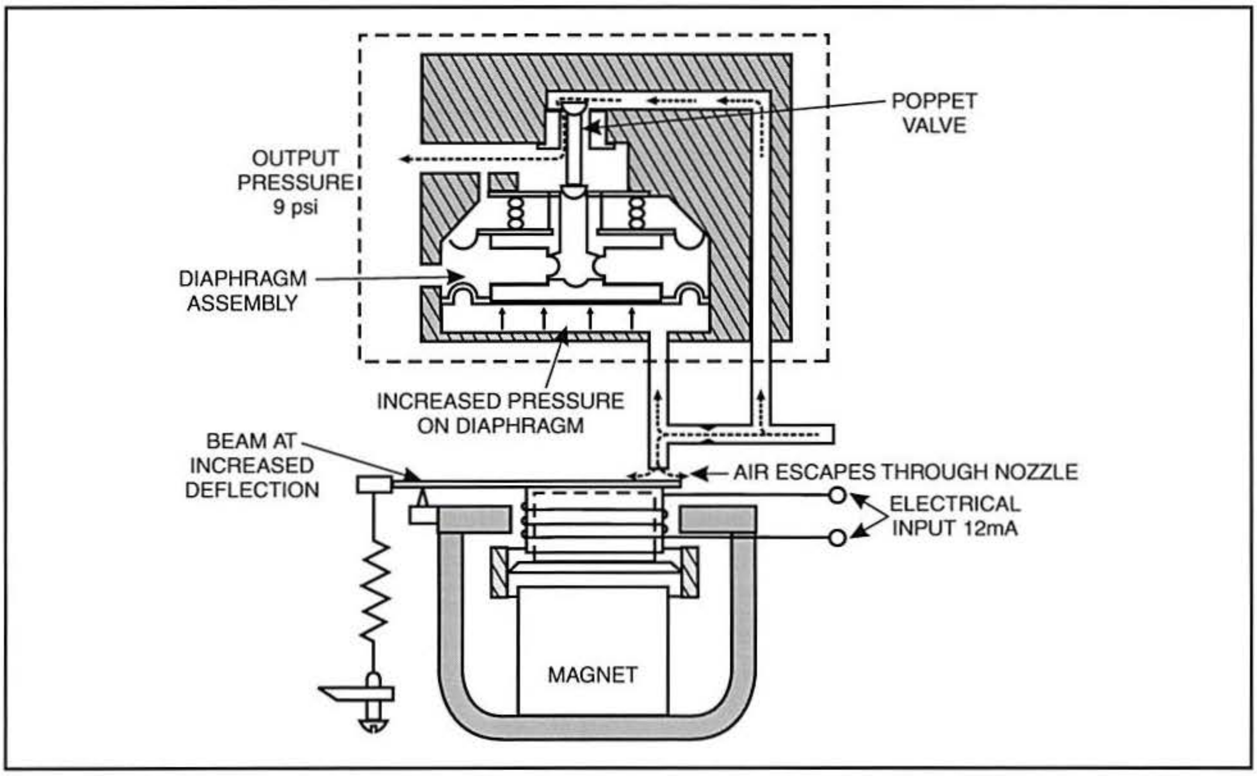

Figure 8. I/P Converter with a 50% Current Input

When the current is at a maximum, there is maximum pressure on the diaphragm and the poppet valve fully opens. This creates the maximum output pressure, which is 15 psi.

The zero and span adjustments shown in figure 9 set the range for the I/P converter. The zero adjustment determines the output air pressure when the input current is at a minimum (the lower point of the range). Changing the zero adjustment changes the angle of the beam across the pivot point, which causes the amount of pressure on the diaphragm to change as the beam moves closer to or farther from the air nozzle.

The span adjustment sets the maximum output air pressure when the input current is at a maximum (the upper point of the range) by using a magnetic shunt to vary the strength of the magnetic field. The span of the I/P converter is proportional to the strength of the magnetic field.

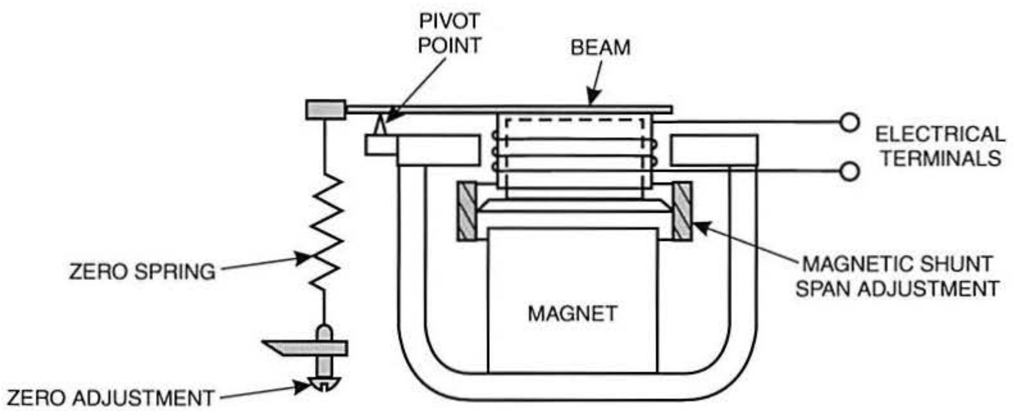

Figure 9. Zero and Span Adjustments

I/P converters can be direct acting or reverse acting. Direct acting I/P converters increase the output pressure as the current increases. Reverse acting I/P converters decrease the output pressure as current increases. Reversing the polarity of the electrical input signal often changes the I/P converter from direct acting to reverse acting.

An I/P converter is typically connected to the analog output of a control device, such as the PID controller in figure 10. This analog output is typically a 4-20 mA signal, which requires two wires.

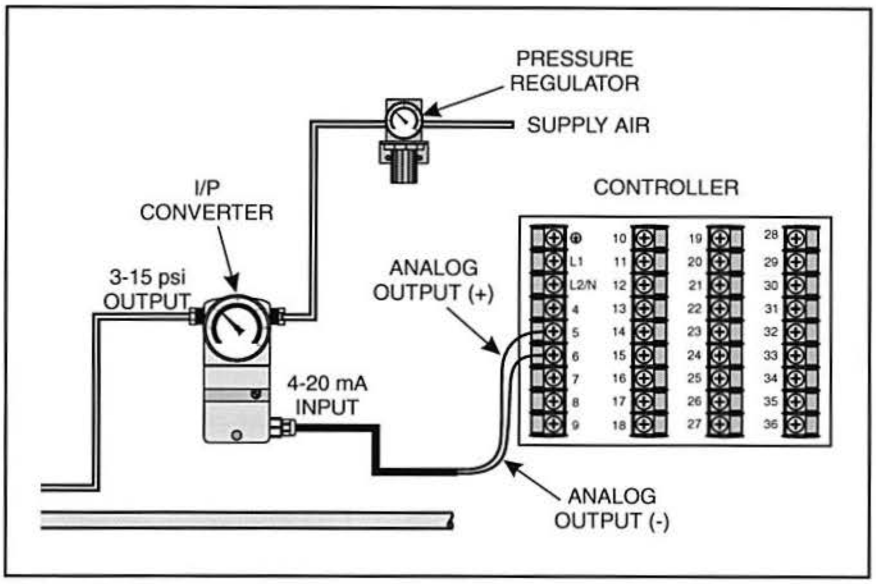

Figure 10. Wiring Connections for I/P Converter

SKILL 1 CONNECT AND OPERATE AN I/P CONVERTER

Procedure Overview

In this procedure, you will make the connections from a Honeywell controller to an I/P converter on the T5552 system using plug-in connectors. Then you will operate the I/P converter and compare the current input signal to the pressure output signal. You should observe that there is a linear relationship between input and output.

Do This

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 11.

A. Connect the air supply line to the T5552.

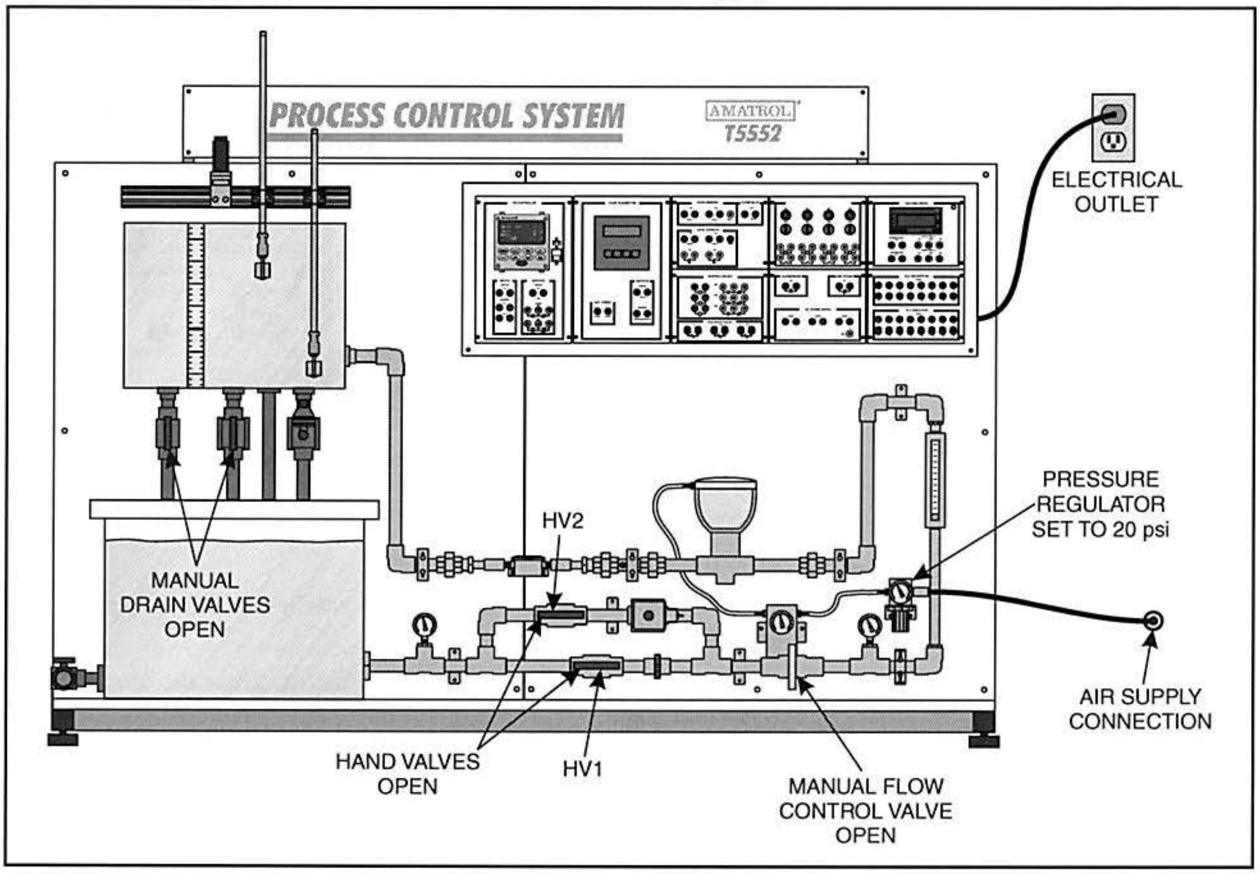

Figure 11. T5552 Set Up

B. Set the pressure regulator to 20 psi.

C. Fill the reservoir tank with water.

D. Open (fully counterclockwise) the two manual process tank drain valves.

E. Open (fully counterclockwise) the manual flow control valve.

F. Connect the circuit shown in figure 12.

Set the DMM to measure DC current in milliamps. Make sure the meter probes are connected to the proper jacks for measuring current. This circuit allows you to adjust and measure the output from the Honeywell controller and observe the change in the pressure output signal from the I/P converter.

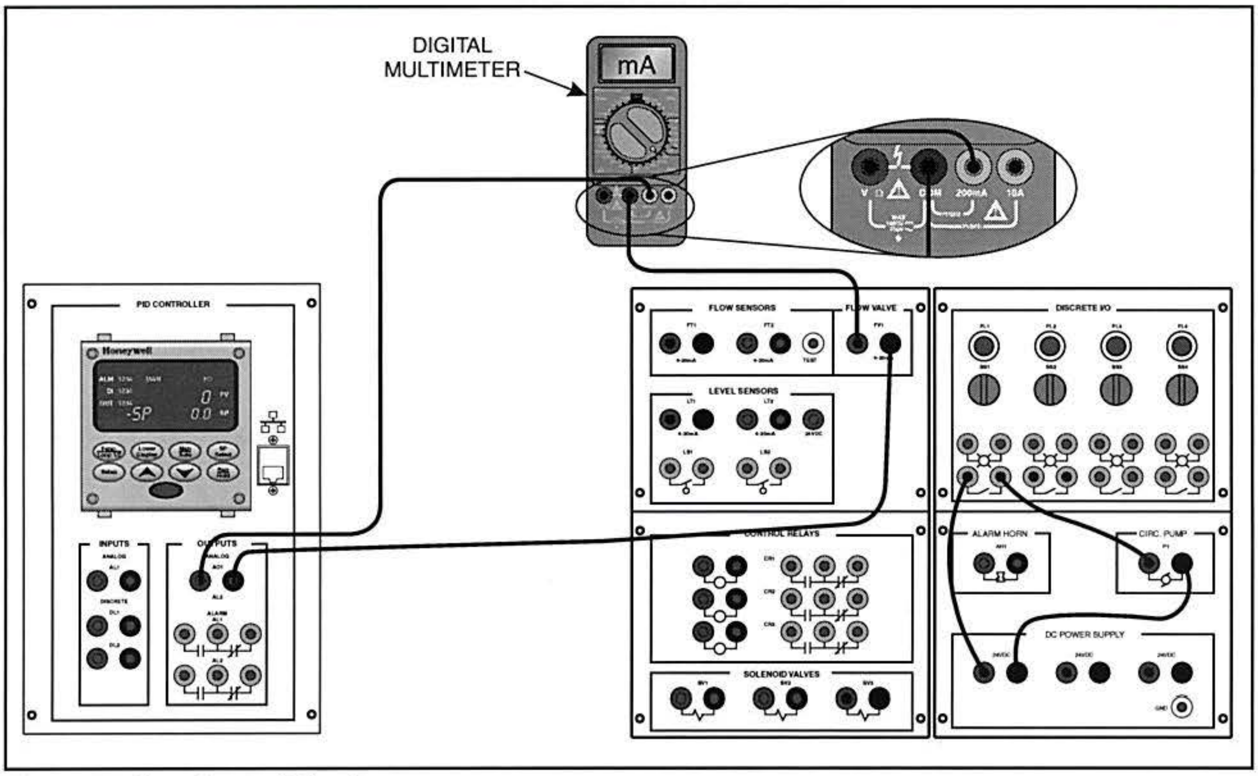

Figure 12. Flow Control Circuit

- ❑ 3. Remove the lockout/tagout.
- ❑ 4. Turn on the main circuit breaker.
- ❑ 5. Perform the following substeps to configure the controller for manual operation.

A. If necessary, press the **Man/Auto** key to place the controller in manual mode.

B. Press the **Lower Display** key repeatedly until the controller output is displayed in the lower display area.

C. Press the up ▲ and down ▼ keys until the output reads 0%.

The output is displayed as a percentage where 0% represents the minimum current output (4 mA) and 100% represents the maximum current output (20 mA).

❑ 6. Turn on selector switch **SS1** to start the pump. Then observe the process trainer to determine if there is flow.

Flow into the process tank ________________________(Yes/No)

You should find that water flows into the process tank because the manual flow valves are open. You should also notice that the water empties into the reservoir tank because the manual drain valves are also open.

❑ 7. Perform the following substeps to compare the current input signal to the pressure output signal.

A. Use the up ▲ and down ▼ keys to adjust the controller output to each value listed in the table in figure 13. For each controller output percentage, record the corresponding current value as indicated on the digital multimeter and the pressure indicated on the I/P converter pressure gauge.

I/P CONVERTER CURRENT INPUT VS. PRESSURE OUTPUT		
CONTROLLER OUTPUT (%)	**CONTROLLER OUTPUT (mA)**	**PRESSURE OUTPUT (psi)**
0		
25		
50		
75		
100		

Figure 13. Table Listing Current Input Values and Pressure Output Values

You should find that the current values should be approximately 4, 8, 12, 16, and 20 mA for each percentage value from 0-100, respectively. The pressure values should be approximately 3, 6, 9, 12, and 15 psi for each percentage value from 0 – 100, respectively. However, the pressure values may vary slightly because the I/P converter may not be properly calibrated.

B. Use the values you recorded in the table in figure 13 to plot the pressure versus the current on the graph sheet in figure 14. The controller output in mA is scaled along the horizontal axis and the I/P converter output in psi is scaled along the vertical axis.

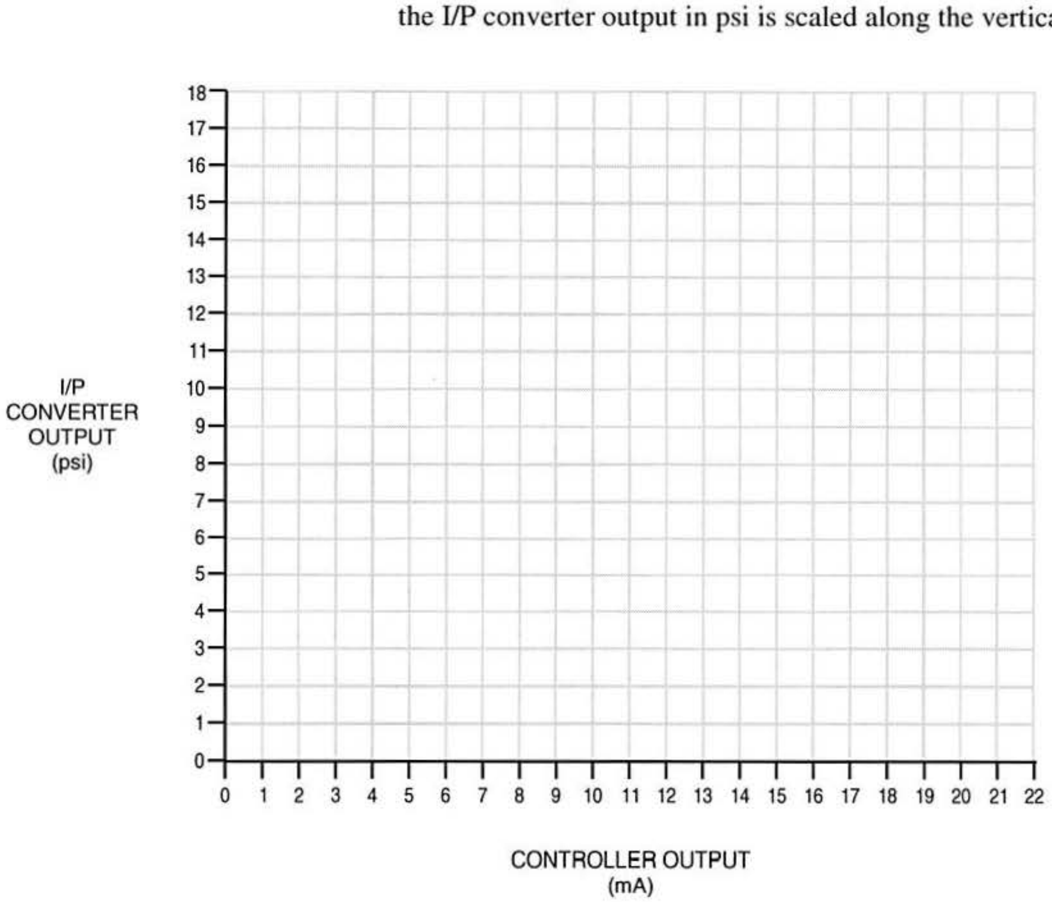

Figure 14. Graph of Controller Output vs. I/P Converter Pressure Output

Your graph should resemble the graph in figure 15. The values may not exactly match if the I/P converter is not calibrated.

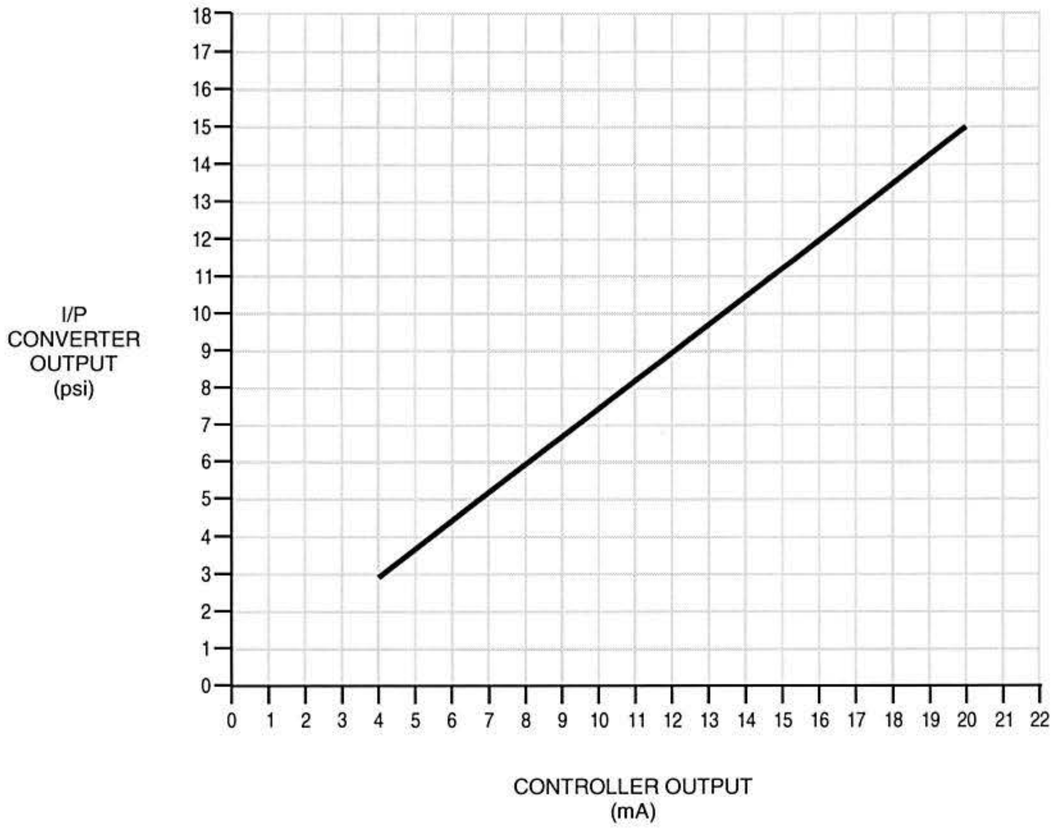

Figure 15. Ideal Graph of Controller Output vs. I/P Converter Pressure Output

C. Determine the type of relationship between the I/P converter current input and the I/P converter pressure output.

Relationship________________________(Linear/NonLinear)

You should find that there is a linear relationship between the current input and the pressure output of the I/P converter.

D. Press the down ▼ key repeatedly to gradually decrease the controller output.

E. Determine if the I/P converter output pressure increases or decreases as the controller output (i.e. I/P converter current input) decreases.

I/P converter pressure output __________(Increases/Decreases)

You should find that the I/P converter pressure output decreases as the current input decreases, indicating that the I/P converter is direct-acting.

❑ 9. Perform the following substeps to shut down the T5552.

A. Turn off selector switch **SS1** to turn off the circulation pump.

B. Close the manual flow control valve.

C. Close the manual drain valves.

D. Turn off the main circuit breaker.

E. Perform a lockout/tagout

F. Disconnect the circuit.

G. Remove the lockout/tagout.

If this is your last activity for the day, return the lockout/tagout equipment to the instructor. Otherwise, continue.

SEGMENT 1

SELF REVIEW

1. An I/P converter converts an electrical signal to a ____________ signal.

2. A pressure _________ is usually added to an I/P converter so that an operator can quickly determine the output pressure.

3. Many I/P converters accept a _____________ input range.

4. Direct-acting I/P converters ________ the output pressure as the input current increases.

5. Reverse-acting I/P converters ____________ the output pressure as the input current increases.

6. The span of the I/P converter is proportional to the strength of the __________________ field.

7. The _______ adjustment on an I/P converter sets the minimum output pressure.

SEGMENT 2

I/P CONVERTER CALIBRATION

OBJECTIVE 4 DESCRIBE THE FUNCTION OF CONTROL LOOP COMPONENT CALIBRATION AND EXPLAIN ITS IMPORTANCE

Read This

Calibration is the process of adjusting the reading or output of a component so that it matches the actual measured or controlled variable. Calibration procedures commonly include setting the desired output when the input is at its minimum and maximum values and comparing the output graph of a measuring device to the output graph of a calibrated device or accepted standard. Figure 16 shows an I/P converter being calibrated.

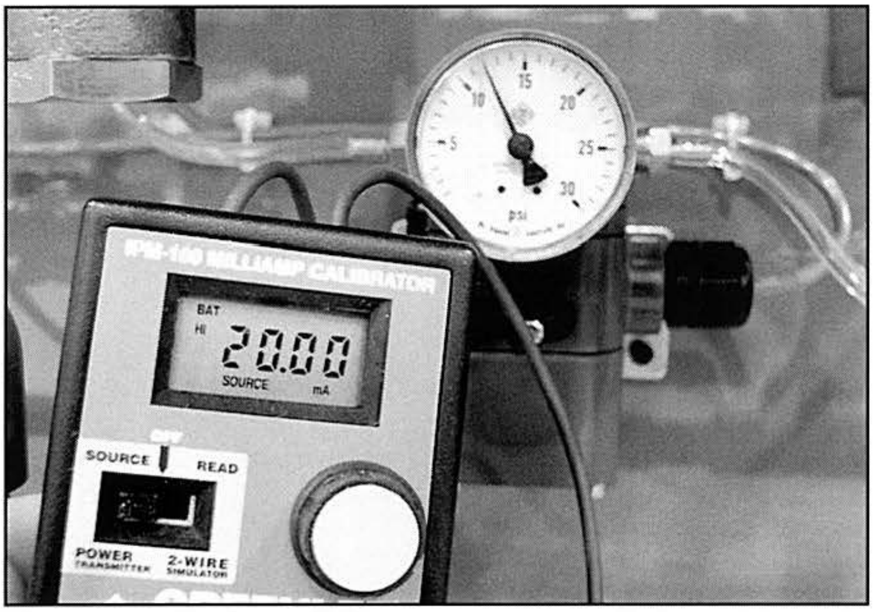

Figure 16. Calibrating an I/P Converter

Proper calibration of the components in a process is important because it helps to ensure the actual output of the process matches the desired output. Without calibration, the desired output cannot be guaranteed. For example, if an I/P converter is not properly calibrated, it may not be able to fully open or close a control valve as necessary to control flow.

Any devices used as a reference for calibration should be traceable to the National Institute of Standards & Technology (NIST). This means that a calibration device is checked against an accepted standard and is certified. Figure 17 shows an example of a certificate of conformity for a calibration device.

Certificate of Conformity

10794019

Greenlee Textron products are manufactured in accordance with the international ISO 9000 (1994) series of Quality Management Systems.

The instrument enclosed has been checked and/or calibrated using equipment that is checked and calibrated to standards that are traceable to the National Institute for Standards and Technology (NIST).

This instrument is covered by a Lifetime Limited Warranty against manufacturing defects and materials for their useful life, excepting normal wear and abuse.

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Figure 17. Certificate of Conformity for a Calibration Device

OBJECTIVE 5 DESCRIBE HOW TO CALIBRATE AN I/P CONVERTER

Calibrating an I/P converter usually involves the following three steps:

Step 1 Connect a current source and meter
Step 2 Set the zero adjustment
Step 3 Set the span adjustment

Step 1. Connect a Current Source and Meter

To calibrate an I/P converter, a reliable current source is required to simulate the transmitter output. Most I/P converters accept a 4-20 mA input signal. Therefore, the current source should be able to output this range.

The instrument most often used as a current source is a loop calibrator. Loop calibrators are used because they are certified calibration instruments that function as a power source and a meter. They can also be easily moved from one component to another. Figure 18 shows a loop calibrator sending a 4 mA signal to an I/P converter.

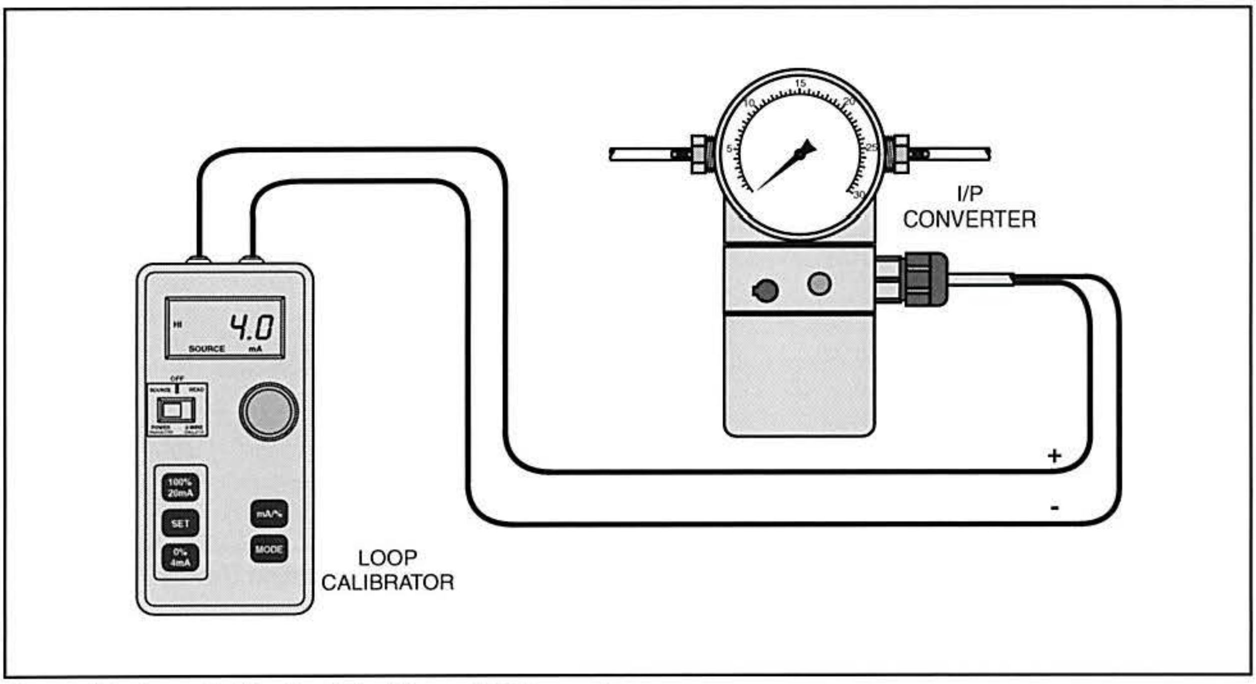

Figure 18. Loop Calibrator Wired to an I/P Converter

If a loop calibrator is unavailable, the output from an electronic controller or sensor can also serve as the current source. In this case, a multimeter is required to measure the output of the controller/sensor. The multimeter indicates the output from the controller and is monitored to make sure the output remains stable.

The multimeter, the controller, and the I/P converter should be placed in series with each other, as shown in figure 19, to perform calibration.

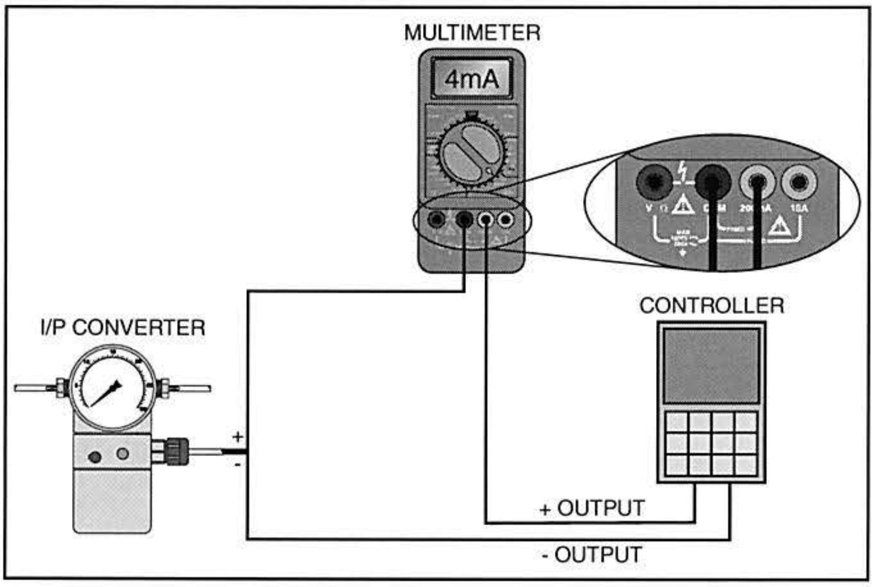

Figure 19. I/P Converter, Multimeter, and Electronic Controller Output in Series

This method is less accurate than using a loop calibrator because the output from the controller may change slightly from the desired value. Therefore, you must constantly watch the meter display to make sure the output is correct. Loop calibrators function as a source by design. Therefore, they are able to maintain a steady value.

Step 2. Set the Zero Adjustment

The zero adjustment sets the component output to the desired value when the process variable (the input) is at a minimum. It is usually the first adjustment made in the calibration process. For most I/P converters, the minimum input current is 4 mA and the desired output is 3 psi. A small slotted screwdriver is often used to adjust the zero adjustment screw on the converter.

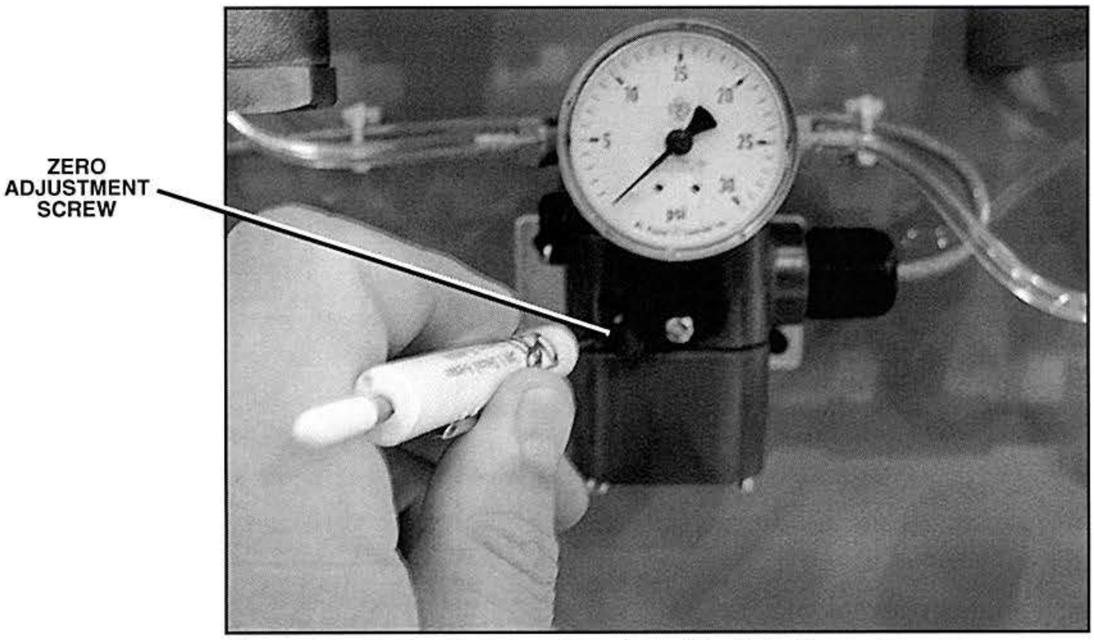

Figure 20. Setting the Zero Adjustment by Adjusting a Screw

The following steps describe how to set the zero adjustment on an I/P converter:

- **Apply the minimum current input** - Use a loop calibrator or another current source to deliver the minimum input current to the converter.
- **Set the desired pressure output -** Use a small slotted screwdriver to adjust the zero adjustment screw. Turn the screw to the left to increase the output pressure and to the right to decrease the output pressure.

Step 3. Set the Span Adjustment

The span represents the numerical difference between the minimum and maximum values (i.e. the range) of the process variable. Therefore, setting the span adjustment sets the output to the desired value when the input is at a maximum. For the I/P converter, the maximum input current is 20 mA and the desired output is 15 psi. Like the zero adjustment, a screw is adjusted using a small slotted screwdriver to change the span, as shown in figure 21.

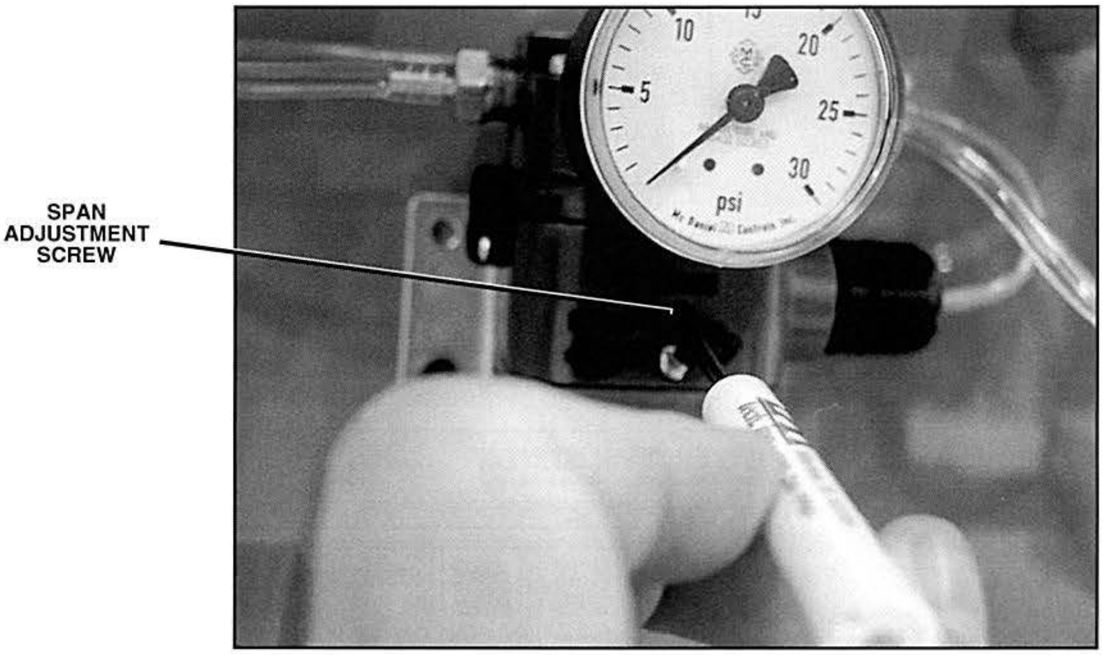

Figure 21. Setting the Span Adjustment by Adjusting a Screw

The following steps describe how to set the span adjustment on an I/P converter:

- **Apply the maximum current input -** Use a loop calibrator or another current source to deliver the maximum input current to the converter.
- **Set the desired pressure output -** Use a small slotted screwdriver to adjust the span adjustment screw. Turn the screw to the right to decrease the output pressure and to the left to increase the output pressure.

SKILL 2 CALIBRATE AN I/P CONVERTER USING A MULTIMETER OR LOOP CALIBRATOR

Procedure Overview

In this procedure, you will calibrate an I/P converter by adjusting the zero and span adjustments. You will need a 4 mA output to set the zero adjustment and a 20 mA output to set the span adjustment. If you have a loop calibrator, you will use it to supply the 4 mA and 20 mA signals. If you do not have a loop calibrator, you can use the PID controller in the manual mode to supply the 4 mA and 20 mA signals.

Do This

- ❑ 1. Perform a lockout/tagout.
- ❑ 2. Perform the following substeps to set up the T5552, as shown in figure 22.

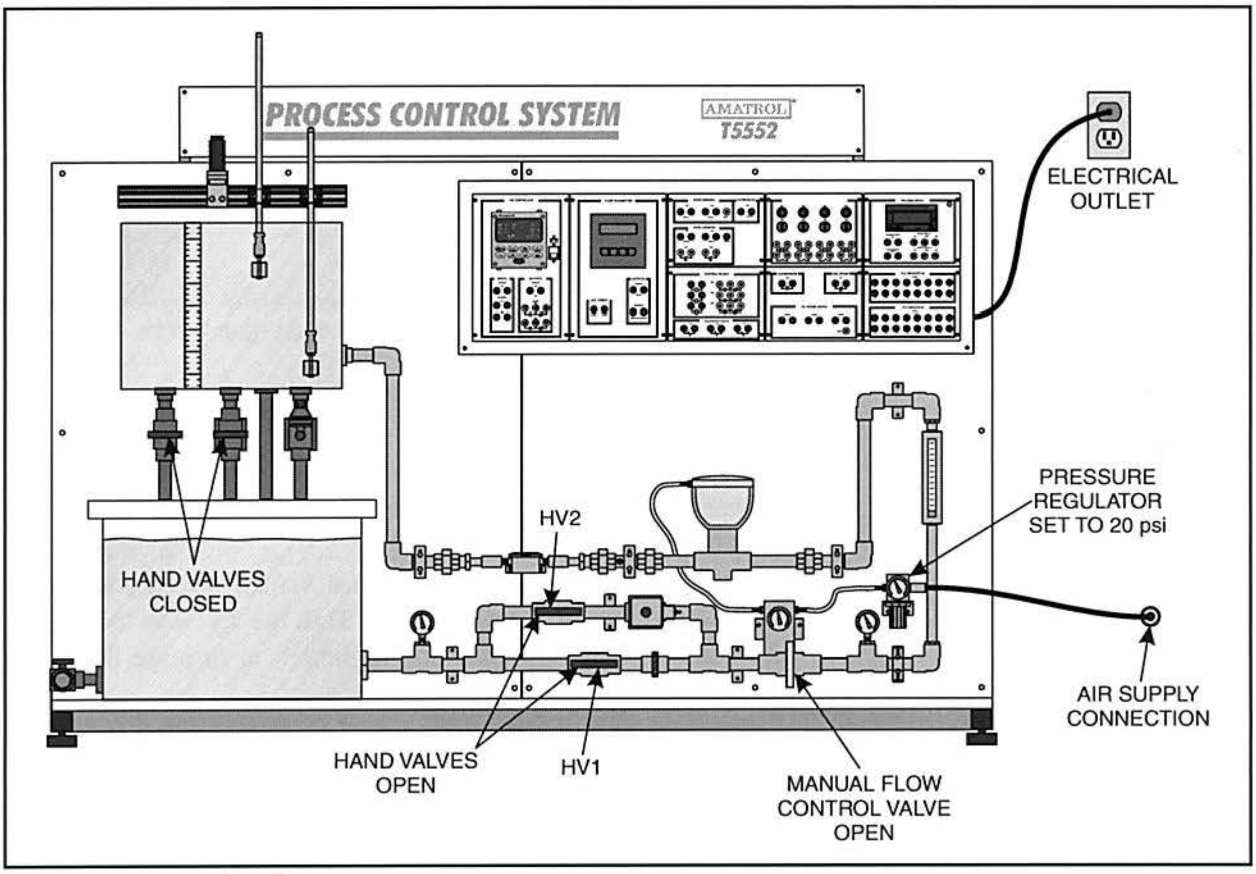

Figure 22. T5552 Set Up

A. Connect the T5552 to the air supply line and set the pressure regulator to 20 psi.

B. Fill the reservoir tank with water.

C. Close the process tank manual drain valves.

D. Fully open the manual flow control valve.

❑ 3. If you have a loop calibrator, connect the circuit shown in figure 23. If you do not have a loop calibrator, connect the circuit shown in figure 24.

The circuit in figure 23 allows you to use the loop calibrator to supply current to the I/P converter.

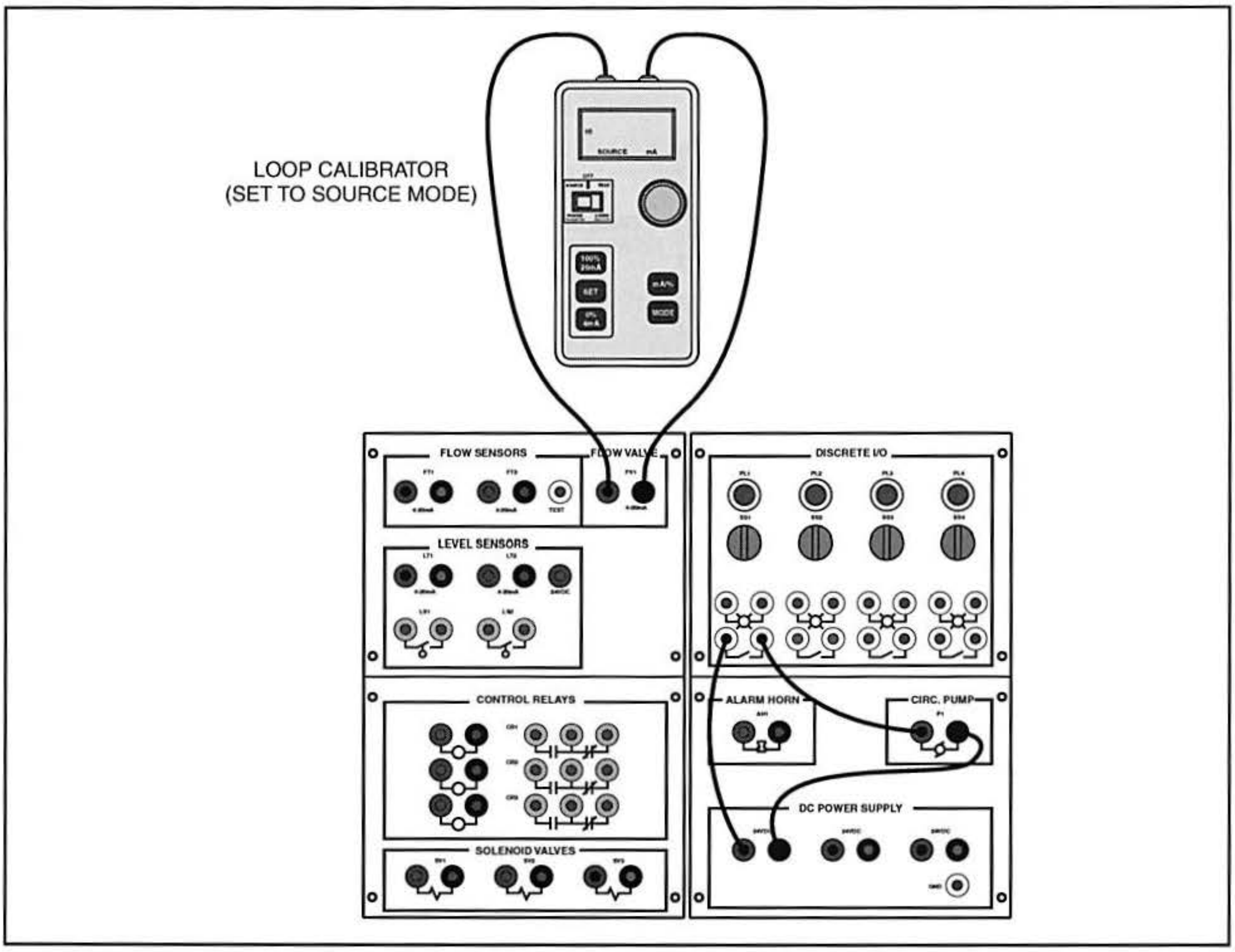

Figure 23. Loop Calibrator Connected to Supply the I/P Converter

The circuit in figure 24 allows you to supply the current to the I/P converter using the PID controller in the manual mode. The multimeter (set to measure DC mA) allows you to measure the output current from the controller.

NOTE

It is important to make sure the leads are connected with the polarity as shown in figure 24. If the polarity is reversed, the I/P converter becomes reverse acting, giving a maximum output with a 4 mA input signal and a minimum output with a 20 mA input signal.

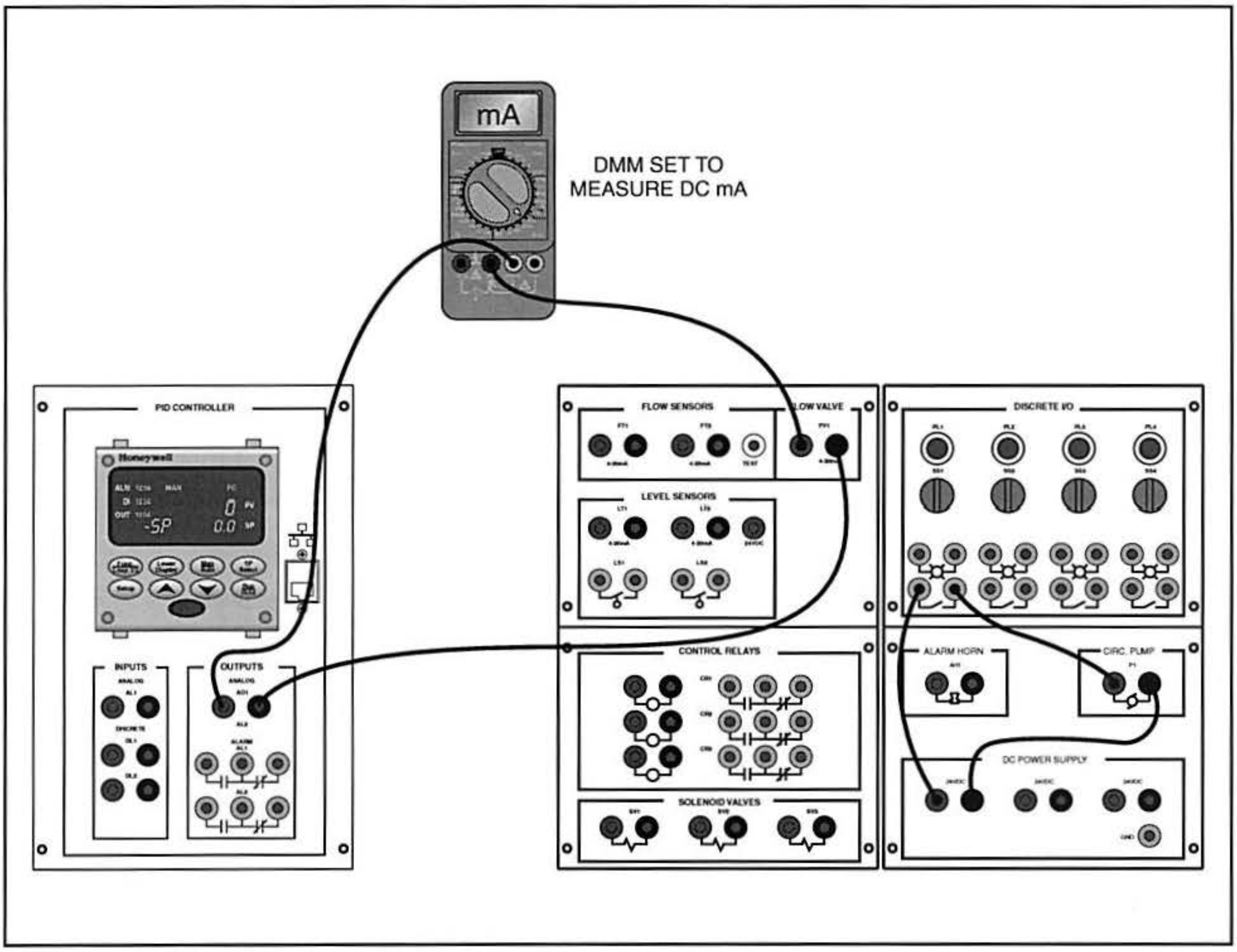

Figure 24. PID Controller Connected to Supply the I/P Converter

❑ 4. Perform the following substeps to set the zero adjustment on the I/P converter.

A. If you are using a loop calibrator, set the calibrator to the **SOURCE** mode and set it to output 4mA (if you have the optional Greenlee calibrator supplied with the T5552, press the **0% / 4mA** button). Then, skip to substep B.

If you are using the PID controller, remove the lockout/tagout and turn on the main circuit breaker. Then, with the controller in the manual mode, adjust the output using the up/down keys (▲/▼) until the multimeter indicates 4mA.

B. Locate the zero adjustment screw on the I/P converter, as shown in figure 25.

The zero adjustment screw is located beneath a protective rubber cap.

C. Remove the protective cap that conceals the zero adjustment screw.

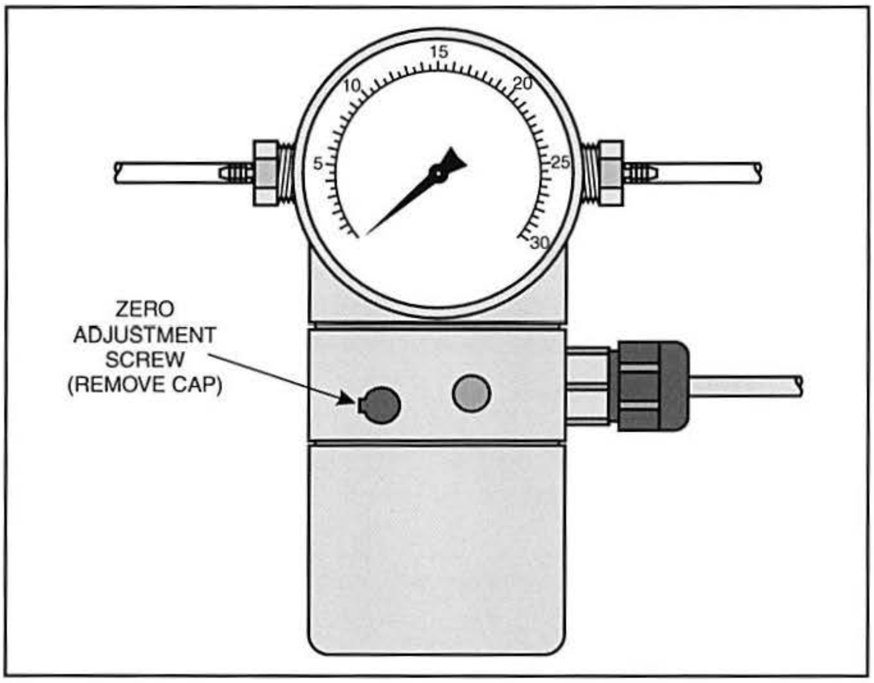

Figure 25. The Zero Adjustment Screw

D. Use a small slotted screwdriver to adjust the zero adjustment screw until the gauge on the I/P converter indicates 3 psi, as figure 26 shows.

This causes the I/P converter to output a pressure of 3 psi for an input of 4mA. An output of 3 psi from the I/P converter causes the diaphragm-actuated valve to be fully opened (maximum flow).

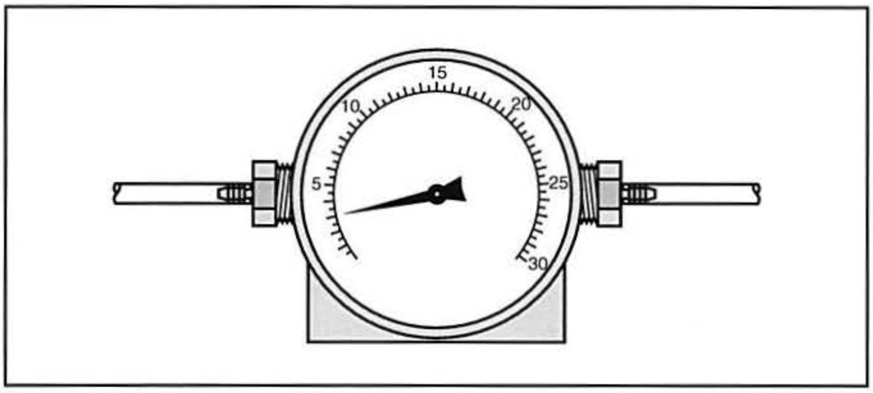

Figure 26. Adjust Zero Adjustment until Gauge Indicates 3 psi (Outside Scale)

E. Now, locate the span adjustment screw on the I/P converter, as shown in figure 27.

A rubber cap also conceals this screw, as figure 27 also shows.

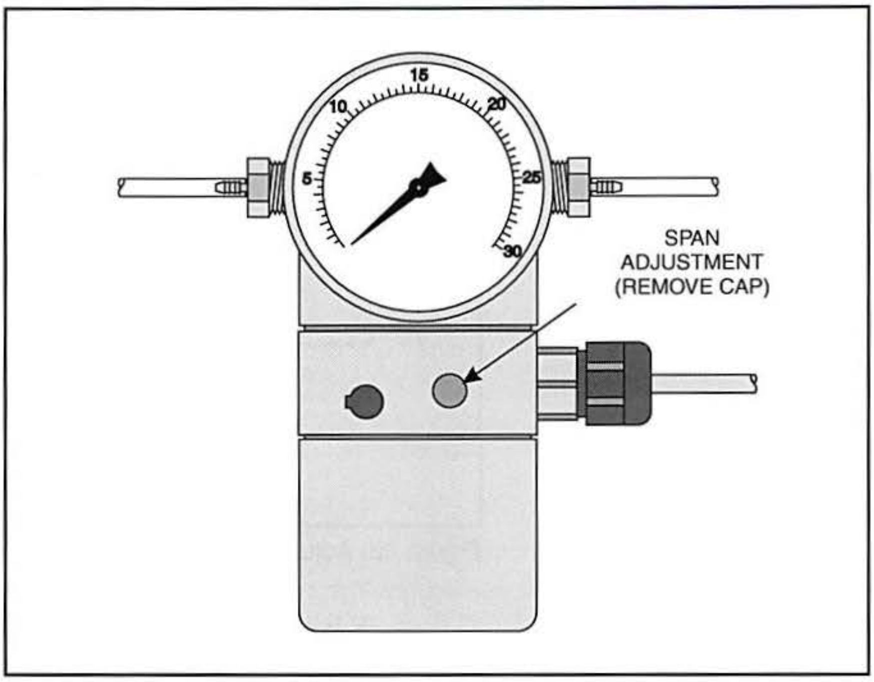

Figure 27. The Span Adjustment Screw

F. Remove the cap that conceals the span adjustment screw.

G. If you are using a loop calibrator, make sure it is set to the **SOURCE** mode and is set to output 20 mA (if you have the optional Greenlee calibrator supplied with the T5552, press the **100% / 20 mA** button). Then skip to substep H.

If you are using the PID controller, make sure the controller is in the manual mode and adjust the output until the multimeter indicates 20 mA.

H. Use the small slotted screwdriver to adjust the span adjustment screw until the gauge on the I/P converter indicates 15 psi, as figure 28 shows.

This causes the I/P converter to output a pressure of 15 psi for an input of 20 mA (this sets the upper limit of the range). An output of 15 psi from the I/P converter causes the diaphragm-actuated valve to close (minimum flow).

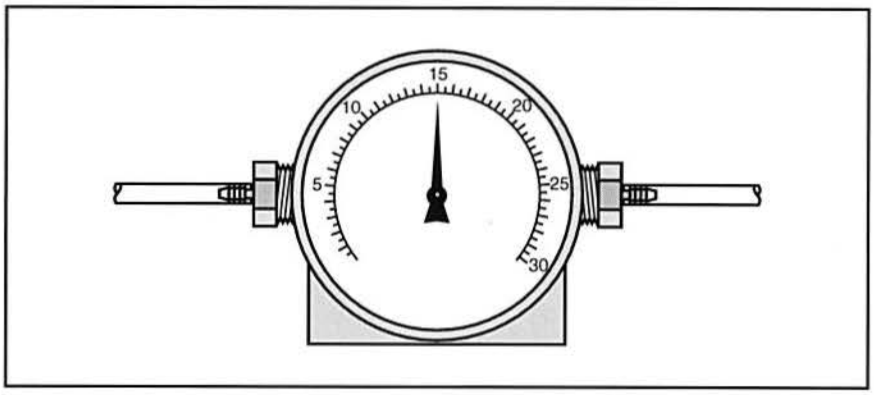

Figure 28. Adjust Span Adjustment until Gauge Indicates 15 psi

It is a good practice to go back and check the zero adjustment after you set the span adjustment.

I. Supply 4mA to the I/P converter and check the gauge on the I/P converter.

If the gauge indicates 3 psi, do not adjust the zero adjustment. If the gauge indicates anything other than 3 psi, adjust the zero adjustment until the gauge indicates 3 psi.

J. Recheck the span adjustment (supply 20mA to the I/P converter) and make adjustments if necessary.

❑ 5. Remove the lockout/tagout, if necessary.

You will only need to do this if you are using a loop calibrator.

❑ 6. Perform the following substeps to test the operation of the I/P converter.

A. Turn on the main circuit breaker, if necessary.

B. Turn on selector switch **SS1** to start the circulation pump.

C. Supply 4 mA to the I/P converter.

D. Determine the flow rate by observing the rotameter.

Flow Rate ______________________________(gpm)

The output from the I/P converter should be 3 psi for a 4mA input. Therefore, the diaphragm-actuated control valve should be fully opened, which should result in a flow rate of 1.2 gpm or greater.

If the flow rate is not what is expected, check the manual flow control valve to be sure it is not closed.

E. Supply 20 mA to the I/P converter.

F. Determine the flow rate.

The output from the I/P converter should be 15 psi for a 20 mA input. Therefore, the diaphragm-actuated control valve should be fully closed (flow rate of 0 gpm).

G. Repeat substeps C-F and observe the operation of the diaphragm-actuated valve.

You should see that the valve moves from fully open to fully closed based on whether the I/P converter receives a 4 mA or 20 mA signal.

The I/P converter can now control the position of the diaphragm-actuated valve in a range from fully open to fully closed, based on the output signal from the controller. For example, an output of 12 mA (50%) from the controller should result in the valve opening halfway.

❑ 7. Perform the following substeps to shut down the T5552.

A. Shut off the circulation pump by turning off **SS1**.

B. If necessary, open the manual process tank drain valves to drain the tank. Then, close the drain valves.

C. Turn off the main circuit breaker.

D. Disconnect the circuit.

SEGMENT 2

SELF REVIEW

1. The process of adjusting the reading or output of a component is called ______________.

2. The __________ represents the numerical difference in the range of the process variable.

3. A ______________________ or the output from a controller or sensor in series with a multimeter can be used as the current source to calibrate an I/P converter.

4. Usually, the first adjustment made in the calibration process is the __________ adjustment.

5. Certified calibration devices should be traceable to the ______________.

6. The span adjustment sets the output to the desired value when the input is at a ___________.

SEGMENT 3

PROPORTIONAL CONTROL VALVES

OBJECTIVE 6 DESCRIBE TWO TYPES OF PROPORTIONAL VALVES AND GIVE AN APPLICATION OF EACH

Read This

Proportional valves control fluid flow by opening to a degree that is proportional to the input signal (e.g. electrical or pneumatic) that it receives. Two commonly used types of proportional valves are diaphragm actuator valves and electric actuator valves.

Figure 29 shows an example of a diaphragm actuator valve, which is controlled by a pneumatic input signal.

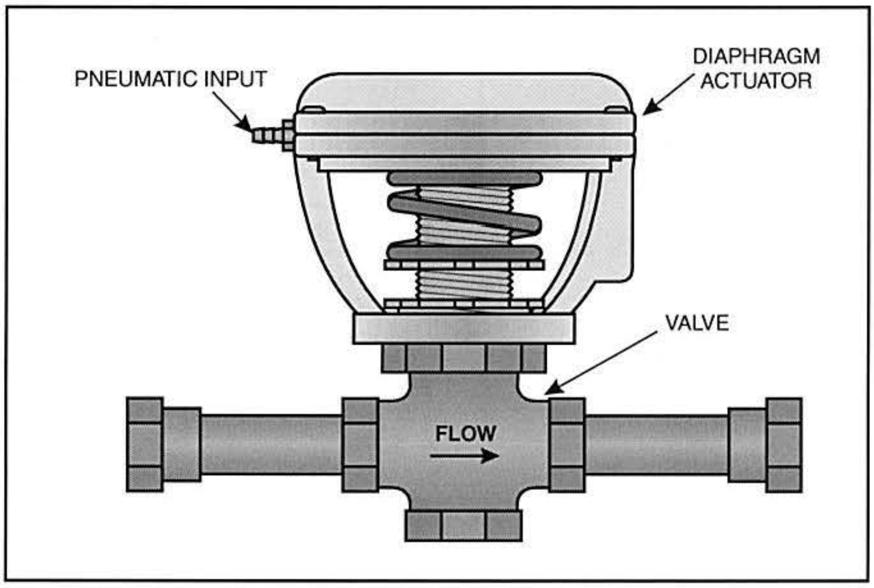

Figure 29. Diaphragm Actuator Valve

Diaphragm actuator valves are used in various flow control applications including petroleum, other combustible fluids and water treatment. They are used more often than electric actuator valves because they are less expensive and usually operate faster.

Figure 30 shows an example of an electric actuator valve that is controlled by an electrical signal delivered to a motor. Electric actuator valves commonly operate using a motor-driven gear train to cause stem movement.

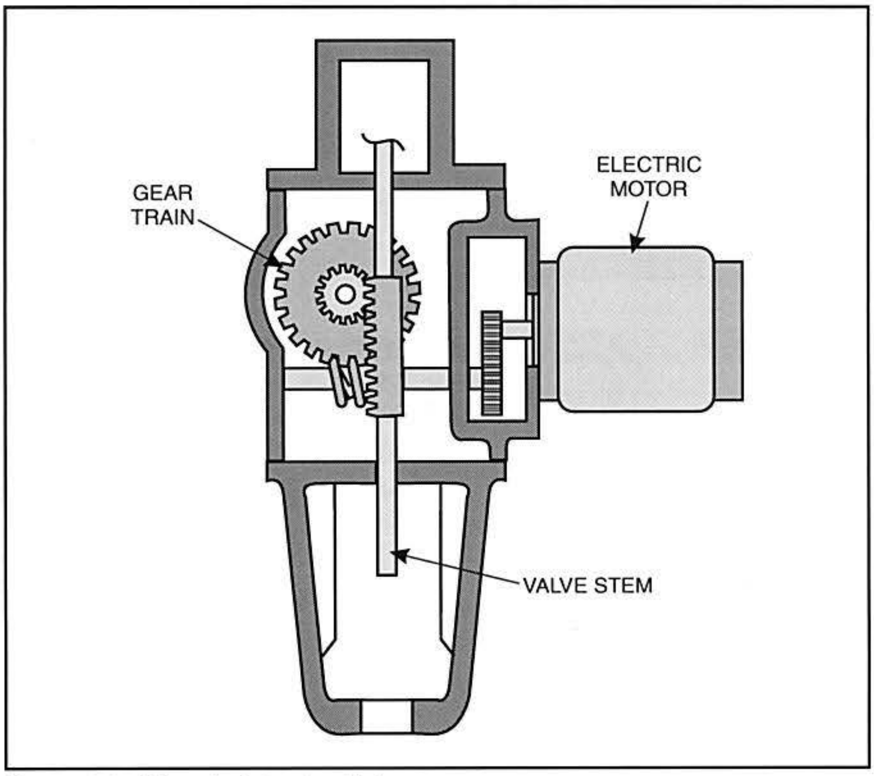

Figure 30. Electric Actuator Valve

Electric actuator valves are generally used in applications where a pneumatic supply is unavailable or in cases where high torque is required to move the valve stem.

OBJECTIVE 7 DESCRIBE THE OPERATION OF A DIAPHRAGM ACTUATOR PROPORTIONAL VALVE

Read This

Diaphragm actuator proportional valves use pneumatic pressure to open or close the valve by an amount that is proportional to the air pressure. These valves consist of three main components: a diaphragm actuator, a yoke, and a valve body, shown in figure 31.

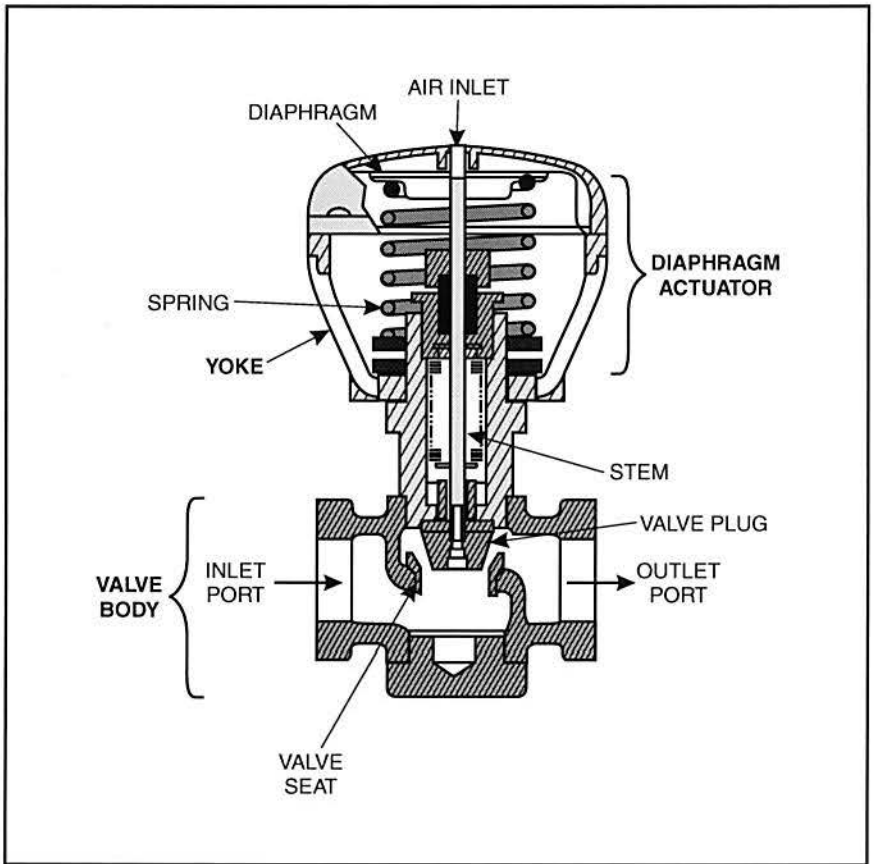

Figure 31. Construction of a Diaphragm Actuator Proportional Valve

The diaphragm actuator consists of a diaphragm, usually made out of synthetic rubber or stainless steel, that flexes according to the input pressure signal, a calibrated spring that opposes the movement of the diaphragm through its compression, and a stem that moves up and down according to the movement of the diaphragm.

The yoke is a support brace, usually made of metal, that attaches the diaphragm actuator to the valve body.

The valve body includes the valve plug, valve seat, and the inlet and outlet ports. The valve plug moves up and down in the flow path to control the flow. When the valve is completely closed, the valve plug rests on the valve seat. Fluid enters the valve at the inlet port and exits at the outlet port.

Figure 32 shows the state of an air-to-close diaphragm actuator valve when it receives a 3 psi pneumatic signal. An air-to-close diaphragm actuator valve requires increasing pressure to close the valve. The 3 psi signal does not place enough pressure on the diaphragm to overcome the spring compression, so the valve is fully open, allowing full flow.

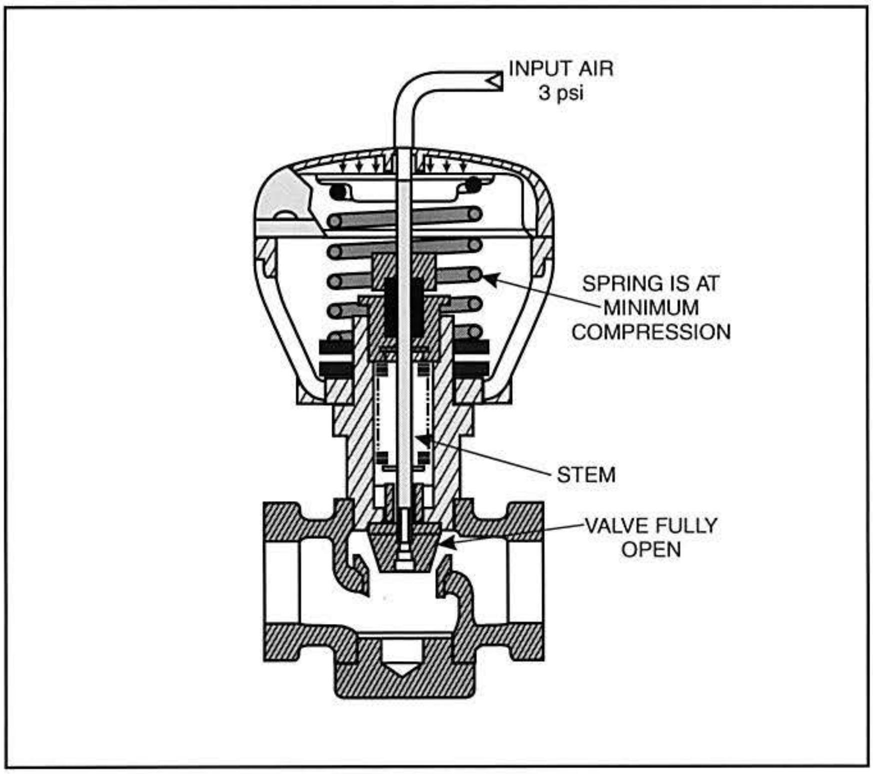

Figure 32. Air-to-Close Diaphragm Actuator Valve Receiving a 3 psi Signal

If the pressure signal increases to 9 psi, as shown in figure 33, the air pressure on the diaphragm causes the spring to compress halfway. This results in downward stem movement, which causes the valve to close halfway and decrease the flow.

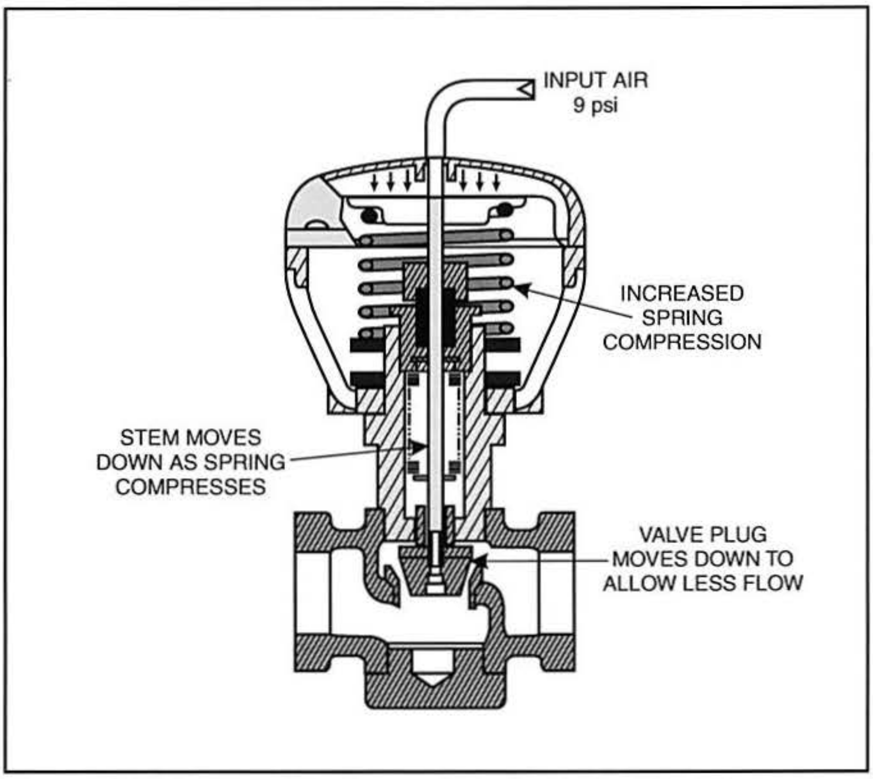

Figure 33. Air-to-Close Diaphragm Actuator Valve Receiving a 9 psi Signal

When the valve receives a 15 psi signal, the pressure on the diaphragm compresses the spring further and causes the stem to close the valve completely.

An air-to-open diaphragm valve operates in a similar manner to the air-to-close valve, except an air-to-open diaphragm valve requires increasing pressure to open (decreasing pressure to close). The valve is closed when the pressure signal is at a minimum (3 psi). As the pressure increases, the valve begins to open. When the pressure signal is at its maximum, the valve is fully open.

OBJECTIVE 8 DESCRIBE TWO TYPES OF DIAPHRAGM ACTUATOR VALVE CONFIGURATIONS AND GIVE AN APPLICATION OF EACH

Read This

Diaphragm actuator valves can be configured as either direct acting or reverse acting, depending on the action of the valve as the pressure signal increases. Manufacturers often define a valve as direct acting if the valve closes as the air pressure signal increases. Figure 34 shows an example of a directing acting (air-to-close) diaphragm actuator valve.

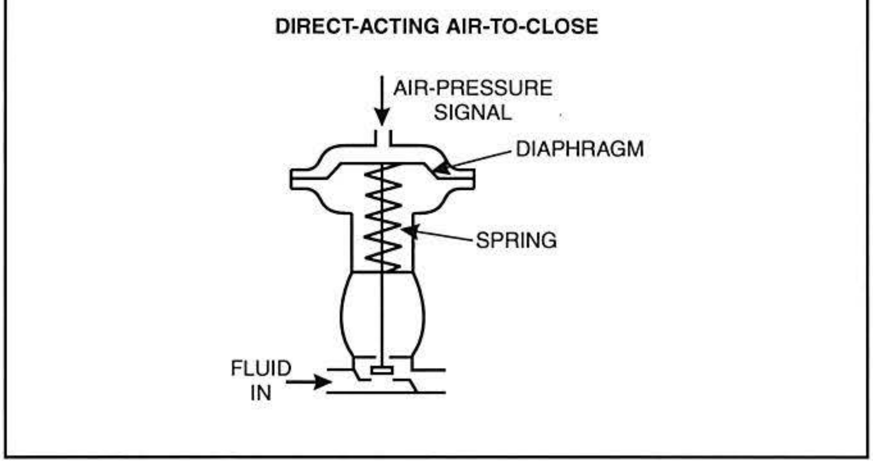

Figure 34. Direct-Acting Air-to-Close Diaphragm Actuator Valve

Reverse acting valves open as the air pressure signal increases. Figure 35 shows an example of a reverse acting (air-to-open) diaphragm actuator valve.

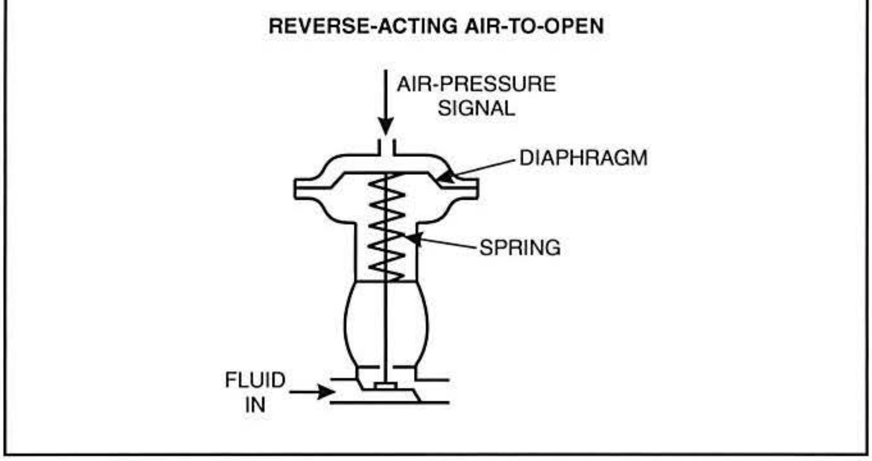

Figure 35. Reverse-Acting (Air-to-Open) Diaphragm Actuator Valve

Direct and reverse acting valves both serve the same function, which is to control flow. They are both used in the same applications, which include wastewater treatment, flow control of petroleum and oils, temperature control, and ratio control processes. The type of valve selected for a process depends on what the valve should do in the event of power loss.

A direct-acting valve is used if the process will be safer if the valve opens when a power loss occurs, while a reverse-acting type is used if the valve should go closed when a power loss occurs. An example is a liquid level system where the valve controls the outlet flow, as shown in figure 36.

If the inlet flow could continue after power loss, a direct-acting valve might be chosen so that the tank does not overflow. If, however, the inlet flow would always stop after a power loss, the designers might choose to use a reverse-acting valve to avoid losing the batch in the tank.

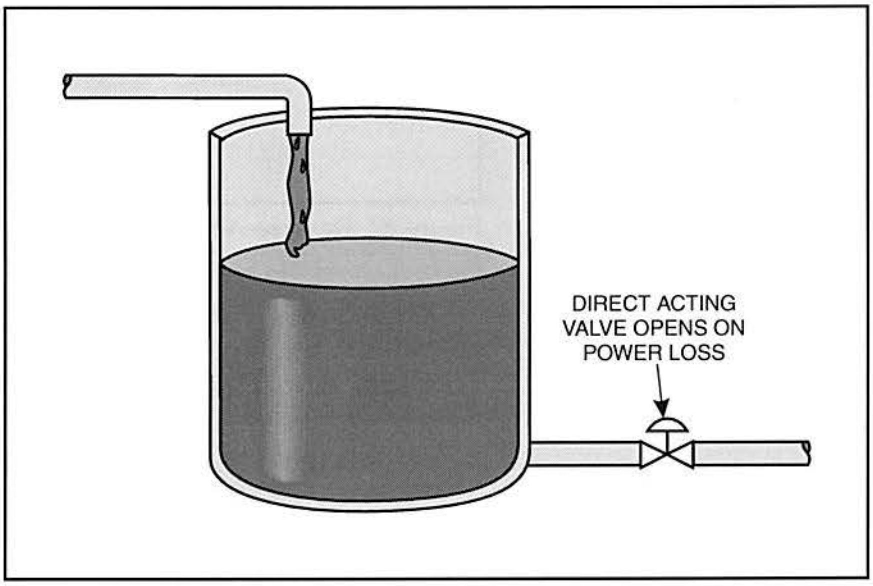

Figure 36. Level Control System

Valve Construction

The diaphragm actuator valves shown in figures 34 and 35 are constructed with the spring below the diaphragm. This construction is the most common. However, many textbooks show diaphragm actuator valves with the spring above the diaphragm and define this type of construction as reverse acting. For example, figure 37 shows an example of a reverse acting air-to-close diaphragm actuator valve.

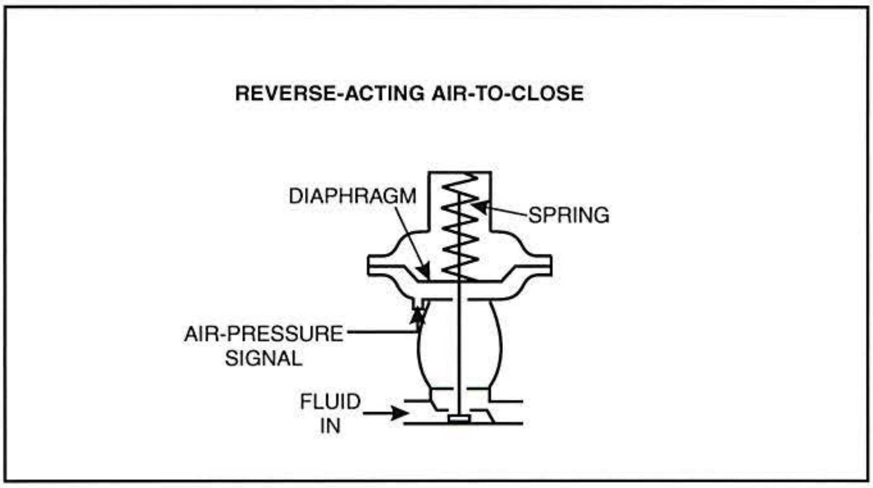

Figure 37. Reverse-Acting (Air-to-Close) Diaphragm Actuator Valve

These types of valves distinguish between reverse and direct acting by the location of the spring. If the spring is located below the diaphragm, the valve is direct acting. If it is above the diaphragm, the valve is reverse acting. The action of the valve is still considered, but it is a separate specification. It is termed air-to-open or air-to-close. Therefore, it is important to read the manufacturer's specifications to determine how they define direct and reverse acting.

SKILL 3 CONNECT AND OPERATE A DIAPHRAGM ACTUATOR PROPORTIONAL VALVE

Procedure Overview

In this procedure, you will make the connections from an I/P converter to a diaphragm actuator valve and a Honeywell controller on the T5552 system. You will then control the diaphragm actuator proportional valve by adjusting the output from the Honeywell controller to observe the effects on the flow rate when it opens and closes.

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 38.

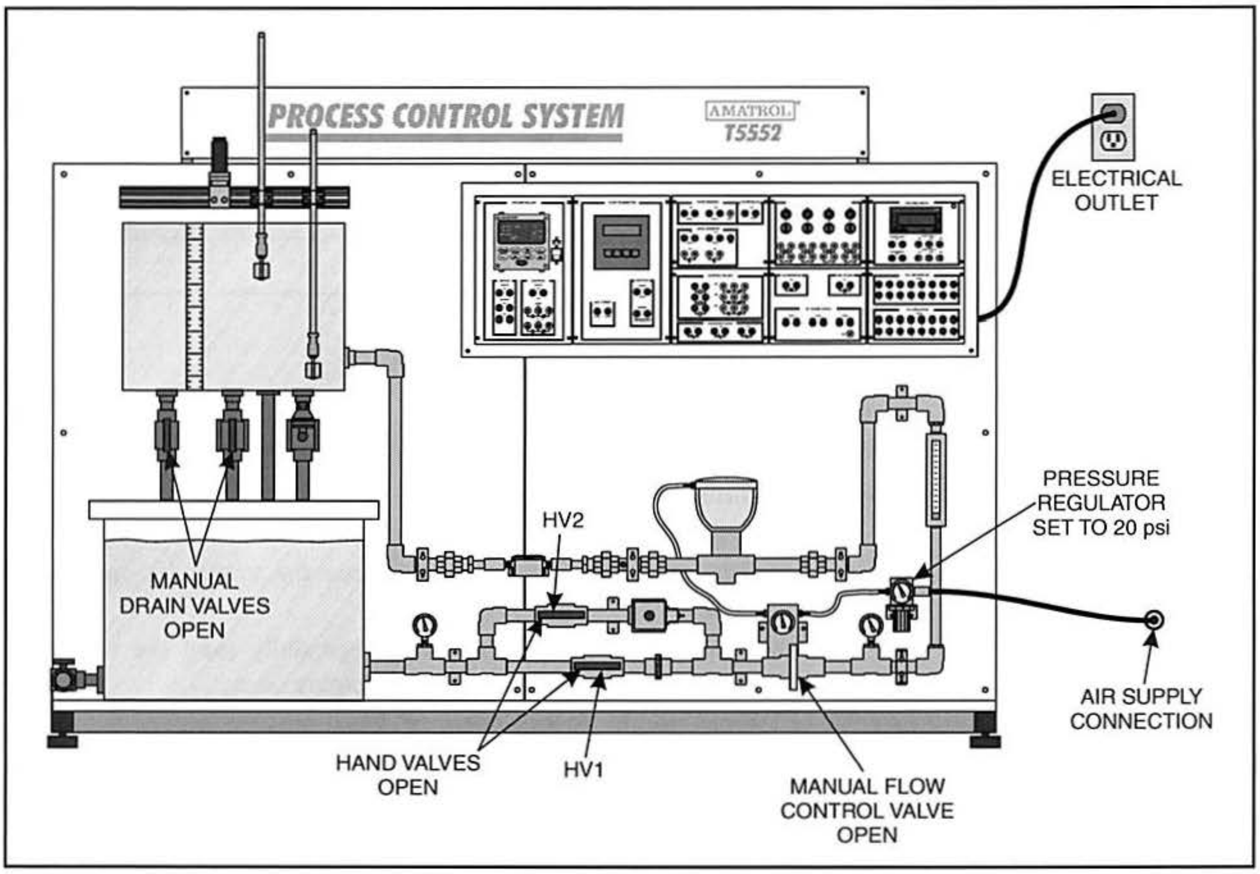

Figure 38. T5552 Set Up

A. Connect the air supply line to the T5552.

B. Set the pressure regulator to 20 psi.

C. Fill the reservoir tank with water.

D. Open (fully counterclockwise) the two manual process tank drain valves.

E. Open (fully counterclockwise) the manual flow control valve.

F. Connect the circuit shown in figure 39.

This circuit allows you to adjust and measure the output from the Honeywell controller and observe the change in the pressure output signal from the I/P converter. The output of the I/P converter controls the position of the diaphragm actuator valve.

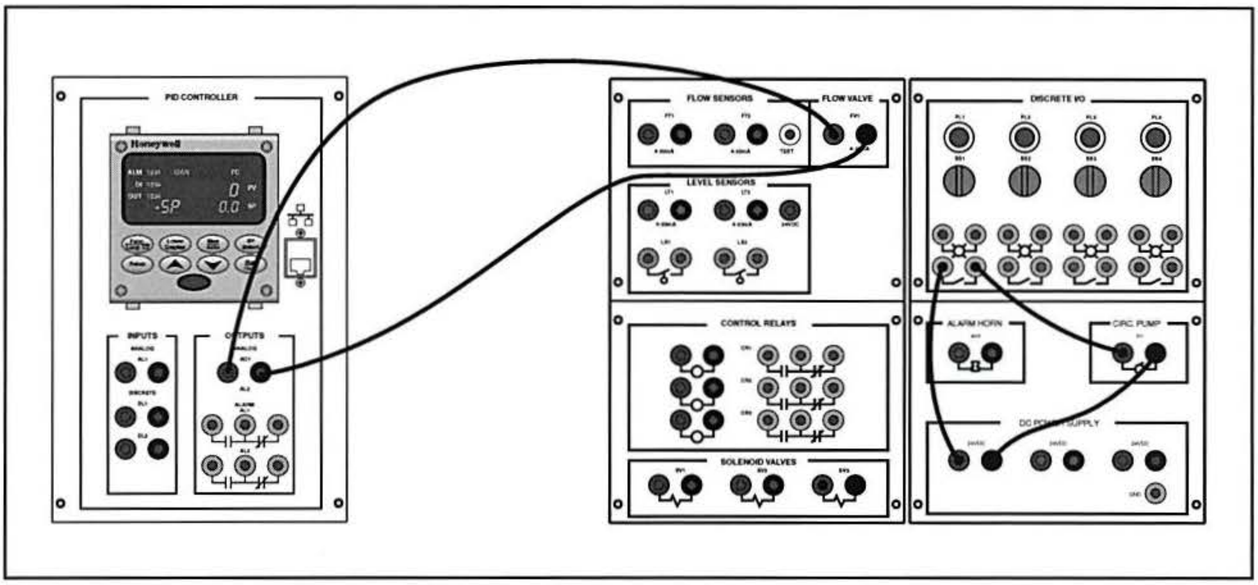

Figure 39. Flow Control Circuit

❑ 3. Remove the lockout/tagout.

❑ 4. Turn on the main circuit breaker.

❑ 5. Perform the following substeps to configure the controller for manual operation.

A. Press the **Man/Auto** key to place the controller in manual mode.

B. Press the **Lower Display** key repeatedly until the controller output is displayed in the lower display area.

C. Press the up ▲ and down ▼ keys until the output reads 0%. The output is displayed as a percentage where 0% represents the minimum current output (4 mA) and 100% represents the maximum current output (20 mA).

❑ 6. Turn on selector switch **SS1** to start the pump.

Is there flow into the process tank? ________________(Yes/No)

What is the condition of the
diaphragm actuator valve? ____________________(Open/Closed)

You should find that water flows into the process tank because the manual flow valves are open. This indicates that the diaphragm actuator valve is also open. You should also notice that the water empties into the reservoir tank because the manual drain valves are open.

❑ 7. Perform the following substeps to compare the pressure output signal to the flow rate.

A. Use the up ▲ and down ▼ keys to adjust the controller output to each value listed in the table in figure 40. For each controller output percentage record the corresponding pressure as indicated on the I/P converter pressure gage and the flow rate as indicated on the rotameter.

I/P CONVERTER CURRENT INPUT VS. PRESSURE OUTPUT		
CONTROLLER OUTPUT (%)	PRESSURE OUTPUT (psi)	FLOW RATE (gpm)
0		
25		
50		
75		
100		

Figure 40. Table Listing Pressure Output Values and Flow Rate

B. Record below if the valve opens or closes as the pressure output increases.

Valve Action____________________________(Opens/Closes)

You should find that the valve closes as the pressure output from the I/P converter (pressure input to the valve) increases. This indicates that the valve is air-to-close. You can determine this by noting that the flow rate decreases as the I/P converter pressure output increases.

C. Use the values you recorded in the table in figure 41 to plot the I/P converter output pressure versus the flow rate on the graph sheet in figure 41. The pressure output in psi is scaled along the horizontal axis and the flow rate in gpm is scaled along the vertical axis.

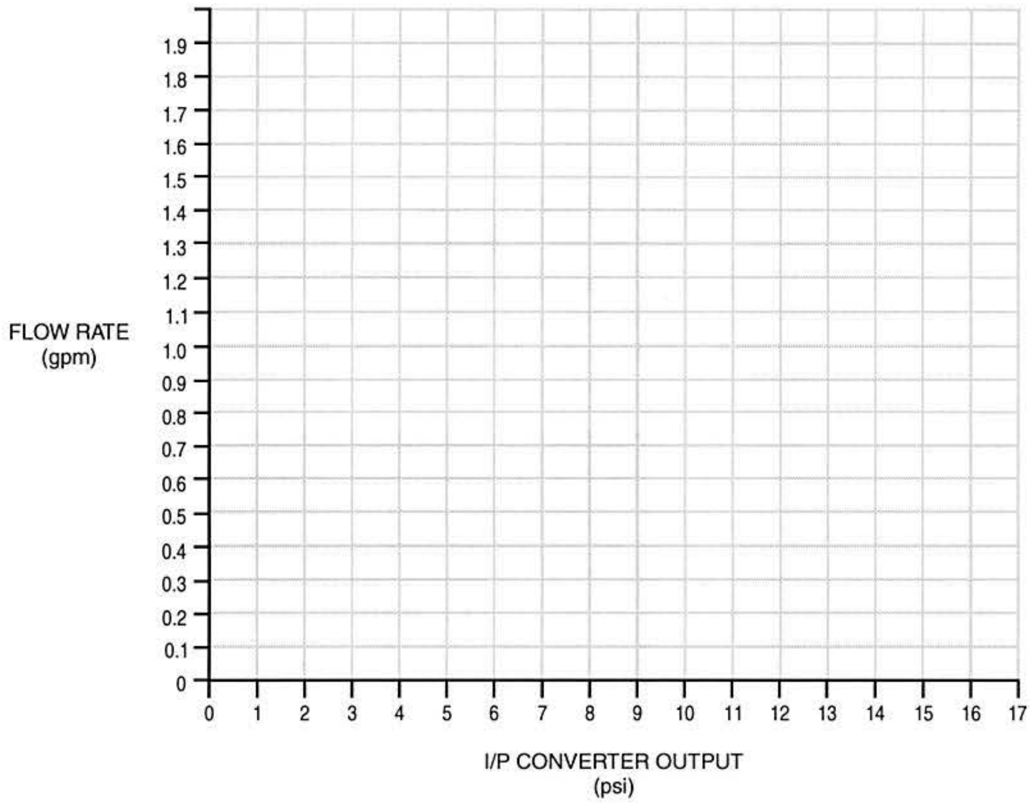

Figure 41. Graph of I/P Converter Pressure Output vs. Flow Rate

Your graph should resemble the graph in figure 42. The values may not exactly match because the spring on the diaphragm actuator valve may not be adjusted to the same compression.

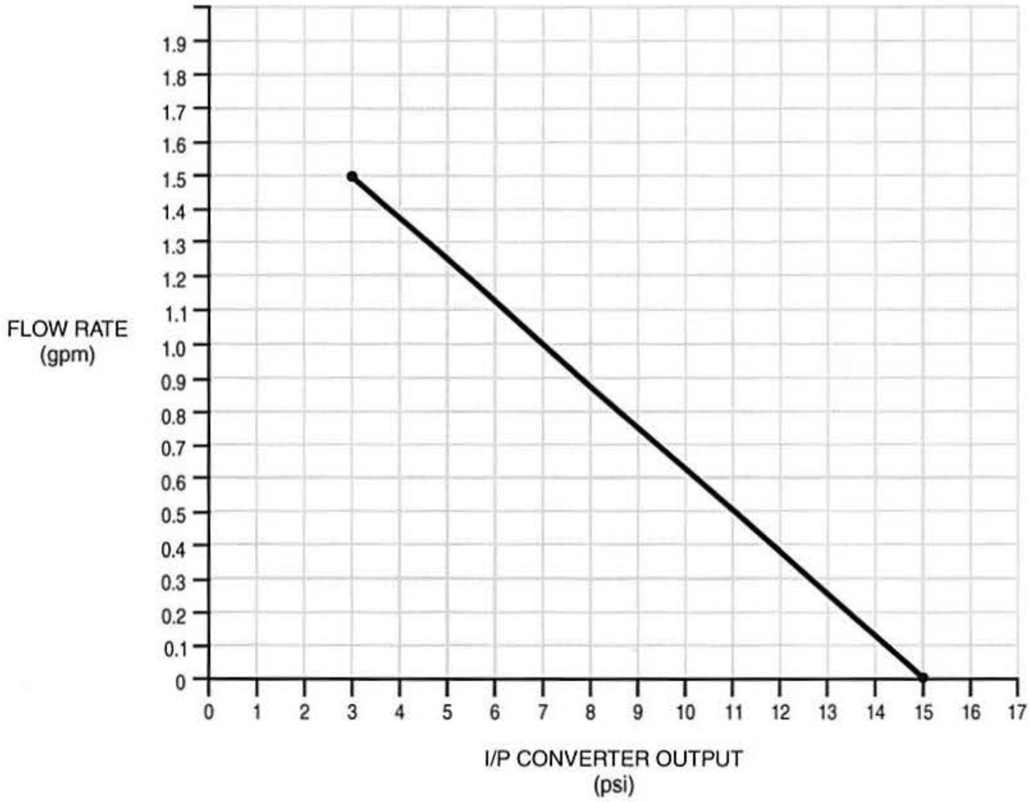

Figure 42. Ideal Graph of Controller Output vs. I/P Converter Pressure Output

D. Determine the type of relationship between the I/P converter pressure output and the flow rate.

Relationship ________________________(Linear/Nonlinear)

You should find that there is a linear relationship between the pressure output and the flow rate. This indicates that there is also a linear relationship between the valve position and the flow rate. For example, when the flow rate is at 50%, the valve is approximately halfway open, and when the flow rate is at a maximum (i.e. 100%) the valve is fully open.

E. Press the down ▼ key repeatedly to gradually decrease the controller output and the I/P converter pressure output.

❑ 8. Perform the following substeps to shut down the T5552.

A. Turn off selector switch **SS1** to turn off the circulation pump.

B. Close the manual flow control valve.

C. Close the manual drain valves.

D. Turn off the main circuit breaker.

E. Disconnect the circuit.

OBJECTIVE 9 DESCRIBE HOW TO ADJUST THE SPRING OF A DIAPHRAGM ACTUATOR PROPORTIONAL VALVE

The spring adjustment on a diaphragm actuator valve allows full valve travel over the pressure range. Generally, the manufacturer sets the spring for the input signal (e.g. 3-15 psi, 3-30 psi, etc.) that the valve receives. However, due to shipping, mishandling, or actual pressure differences, the spring may require readjustment.

The spring is adjusted using a spring adjustor, like the one shown in figure 43. The spring adjustor changes the compression of the spring, which determines the amount of air pressure that must be applied to the diaphragm to fully open or close the valve.

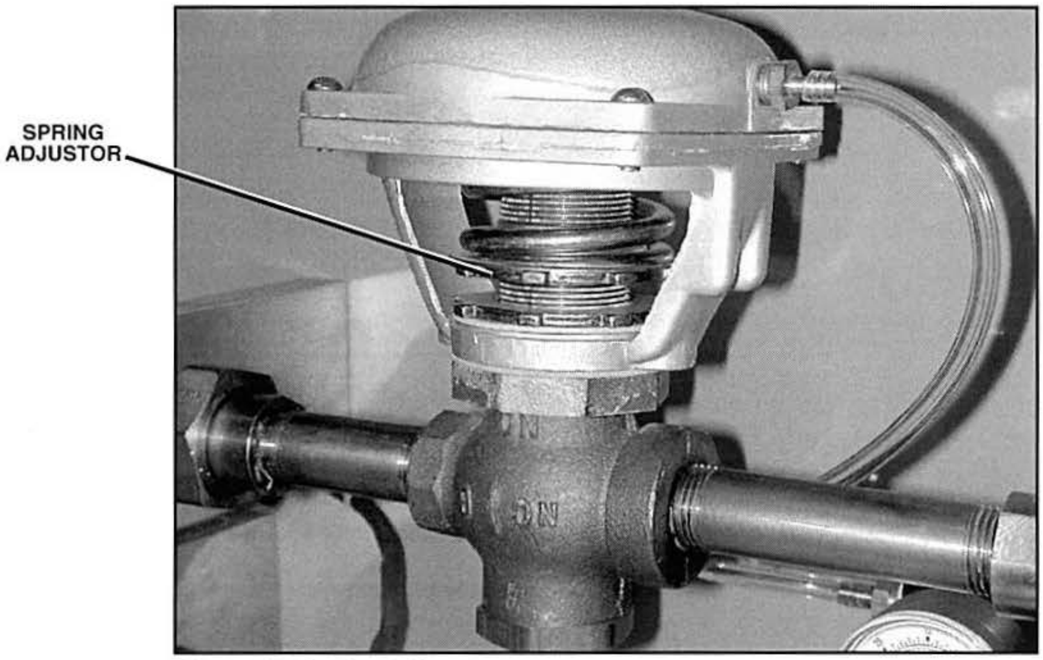

Figure 43. Spring Adjustor

To adjust the spring, relieve air pressure inside the valve either by turning off the pressure regulator or simply disconnecting the pressure line that feeds the valve. You should then be able to turn the spring adjustor using your hands or a small open-ended wrench, as shown in figure 44. Turn the spring adjustor to the right to increase spring compression and to the left to decrease spring compression.

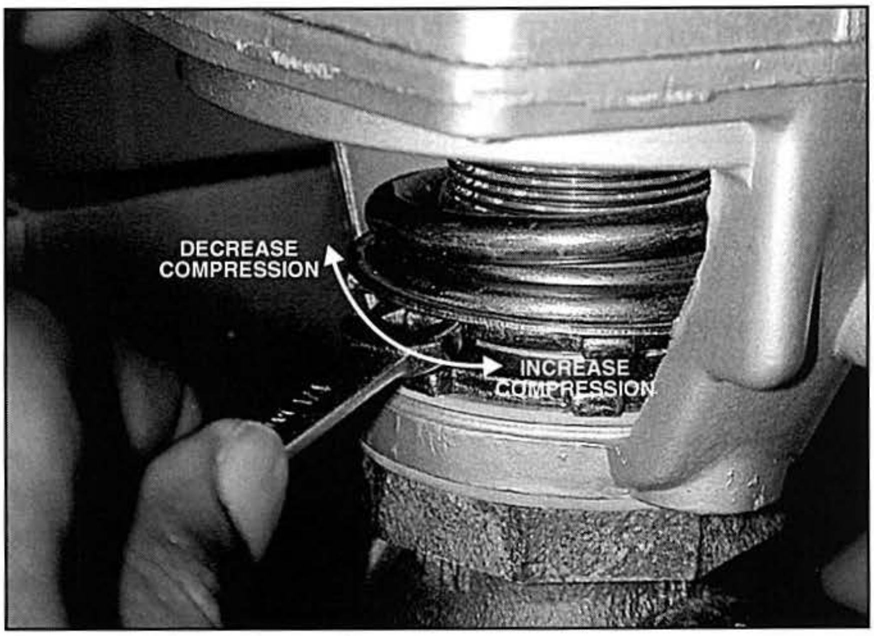

Figure 44. Spring Adjustment

For a direct acting, air-to-close diaphragm actuator valve, increasing the spring compression means that more air pressure has to be applied to the diaphragm to fully close the valve. Decreasing the spring compression means that less air pressure has to be applied to the diaphragm for the valve to close. The opposite is true for a reverse acting diaphragm actuator valve.

Many diaphragm actuator proportional valves are not positive shut-off valves (i.e. valves that ensure no leakage when closed). This is because many diaphragm actuators valves are used simply to control flow. For example, in the flow system shown in figure 45, the diaphragm actuator valve is receiving a 15 psi signal. However, the 15 psi is not enough to completely overcome the tension in the spring. This results in leakage.

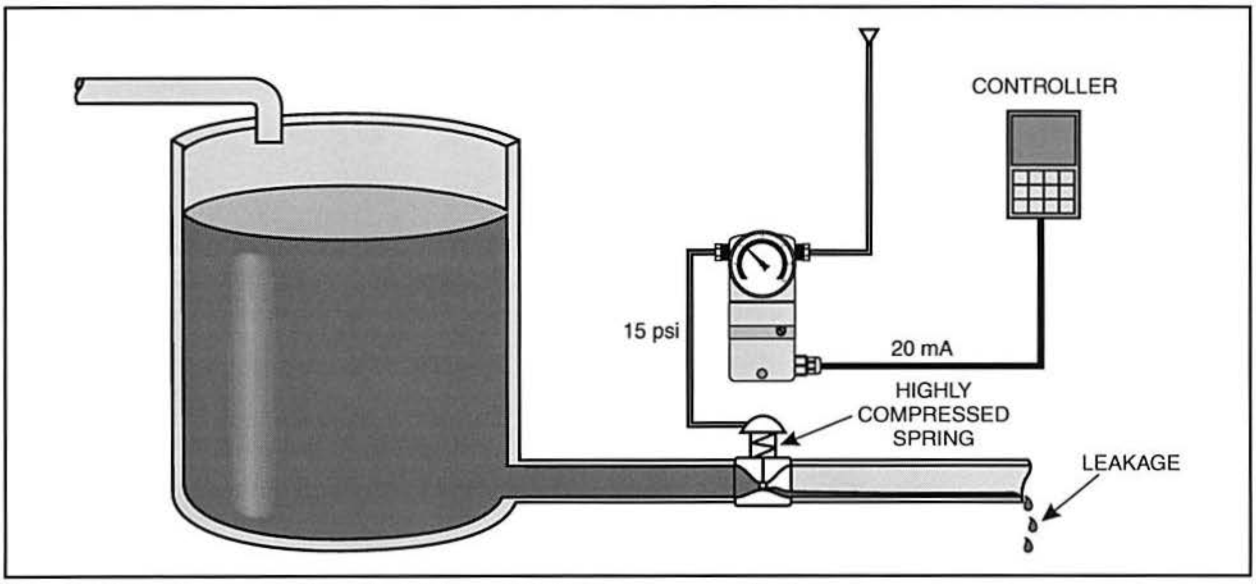

Figure 45. Leakage as a Result of Using a Highly Compressed Spring

If the spring is adjusted so that there is no leakage when the input signal is at its maximum value, the flow rate is likely to be too low when the input signal is at its minimum value. By the same logic, if the spring is adjusted so that the flow rate is very high when the input signal is at its minimum value, the system is likely to have a large amount of leakage when the input is at its maximum value. Often times, spring adjustment is a compromise between the desired maximum flow rate and the maximum leakage allowed.

The following steps describe how to adjust a diaphragm actuator valve for a 3-15 psi pressure signal:

Step 1: Calibrate the I/P converter - This ensures that the output pressure is 3 psi for a 4 mA input and 15 psi for a 20 mA input.

Step 2: Apply 3 psi to the diaphragm in the control valve - Send a 4 mA signal to the I/P converter to do this.

Step 3: Allow the maximum flow through the valve - Fully open any other valves or restrictions that will be open during normal operation so you can determine the maximum flow.

Step 4: Determine the flow rate - Use a flow meter of some type to determine the flow rate at maximum flow.

Step 5: Apply 15 psi to the diaphragm - Send a 20 mA signal to the I/P converter to apply 15 psi to the diaphragm.

Step 6: Determine the flow rate - Use a flow meter to determine the flow rate at minimum flow.

Step 7: Adjust the spring to allow the desired range of flow if necessary - Now that you have determined the minimum and maximum flow rates, you can adjust the spring if necessary to fit the process. If the valve opens sufficiently at minimum pressure and closes sufficiently at maximum pressure in steps 1-6, then you do not need to adjust the spring.

Recall that if you increase the spring compression, it is harder for the diaphragm to push down on the spring and close the valve. Therefore, the more the spring is compressed, the higher the flow rate. However, this also means that there is more leakage because 15 psi is not enough pressure to completely overcome the spring compression and close the valve.

Leakage is not a major concern in many processes because the valve controls the flow at a set point. Therefore, positive shut-off is not necessary. However, if leakage is a concern, you can open the line downstream of the valve or install pressure gages to check for leakage. If the process line is open downstream and the valve is not fully closed, you can see the liquid draining out the open end. A pressure gage placed downstream of a fully closed valve indicates zero pressure.

SKILL 4 ADJUST THE SPRING OF A DIAPHRAGM ACTUATOR PROPORTIONAL VALVE

Procedure Overview

In this procedure, you will set up a circuit to control the flow in the process tank. You will then adjust the spring of a diaphragm actuator proportional valve so that the valve stem moves over the entire pressure range. You will need a small open-ended wrench to perform this skill.

- ❑ 1. Perform a lockout/tagout.
- ❑ 2. Perform the following substeps to set up the T5552, as shown in figure 46.

NOTE

The diaphragm actuator valve is not a positive shut off valve. Therefore, there may still be some leakage when the valve is closed.

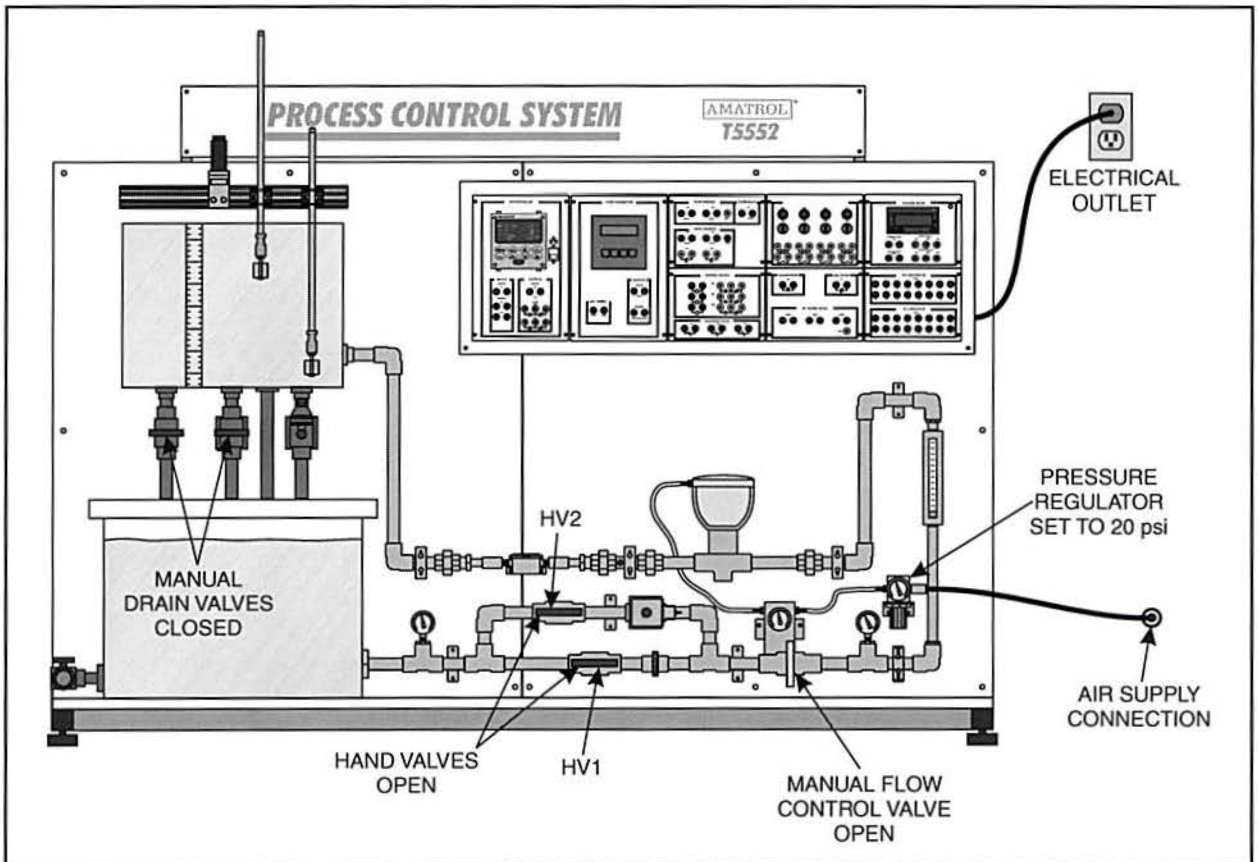

Figure 46. T5552 Set Up

A. Connect the air supply line to the T5552.

B. Set the pressure regulator to 20 psi.

C. Fill the reservoir tank with water.

D. Close (fully clockwise) the two manual process tank drain valves.

E. Close the manual flow control valve.

F. Connect the circuit shown in figure 47.

This circuit will allow you to measure, display, and control the flow into the process tank.

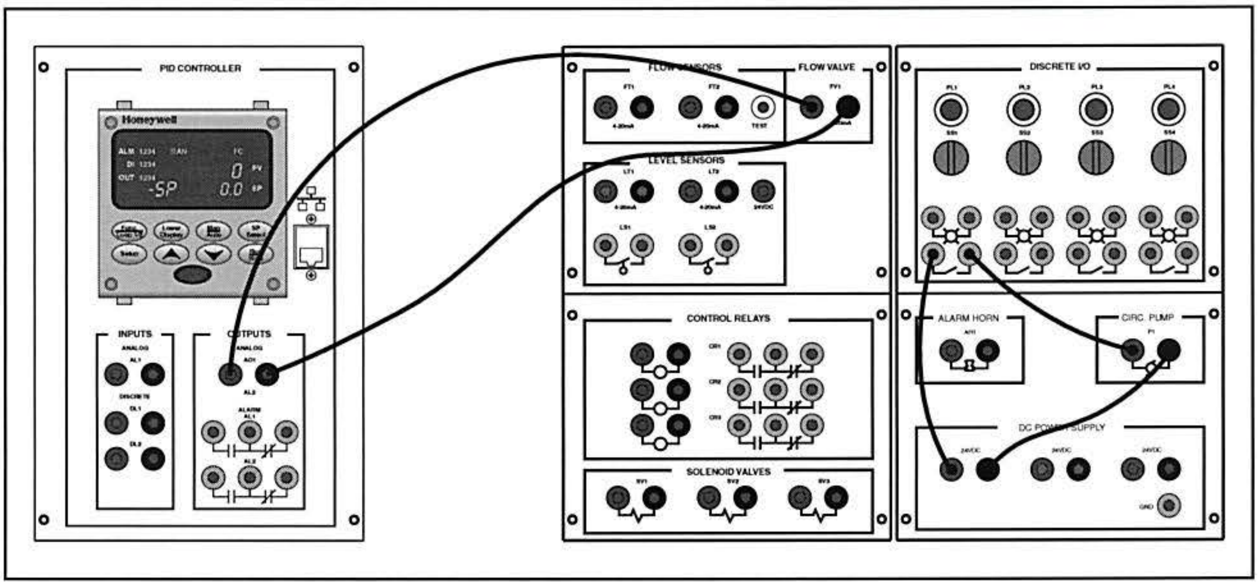

Figure 47. Flow Circuit

❑ 3. Remove the lockout/tagout.

❑ 4. Turn on the main circuit breaker.

❑ 5. If necessary, press the **Man/Auto** key to place the controller in manual mode.

❑ 6. If the controller output is not displayed on the screen, press the **Lower Display** key repeatedly until the output is displayed.

❑ 7. Disconnect the pressure line from the air pressure regulator, as shown in figure 48.

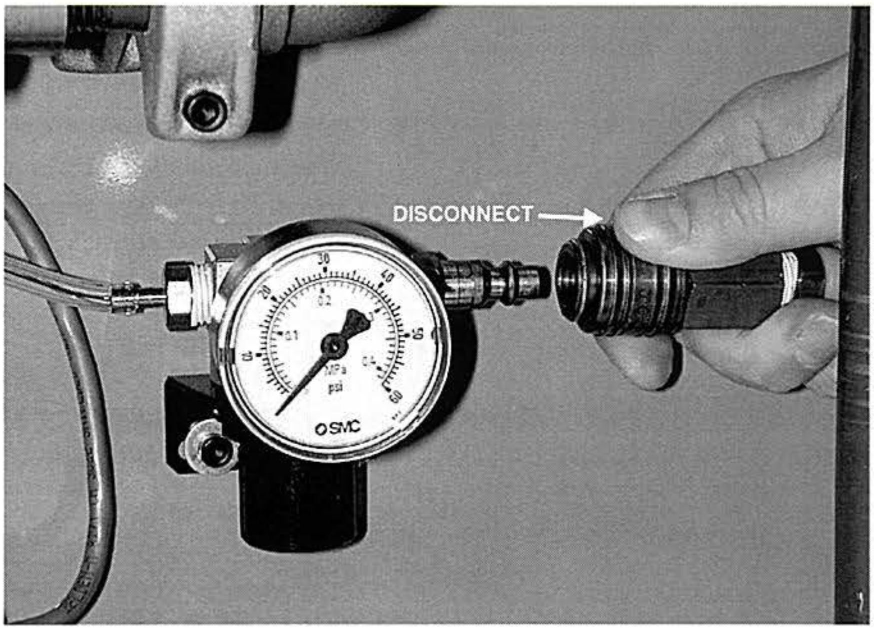

Figure 48. Disconnected Pressure Line

❑ 8. Fully open (counterclockwise) the process tank drain valves.

❑ 9. Fully open the manual flow control valve.

❑ 10. Turn on selector switch **SS1** to start the pump.

❑ 11. Determine the flow rate using the rotameter.

What is the flow rate through the system? _____________ (gpm)

You should find that the flow rate with no air pressure to the valve is fairly high (i.e. between 1.2 and 1.8 gpm). The actual value is determined by the current compression of the spring and the calibration of the I/P converter.

❑ 12. Turn off selector switch **SS1** to stop the pump.

❑ 13. Use your hand or a 1/4-inch wrench to rotate the spring adjustor completely to the left, as shown in figure 49. This places spring compression at its minimum level.

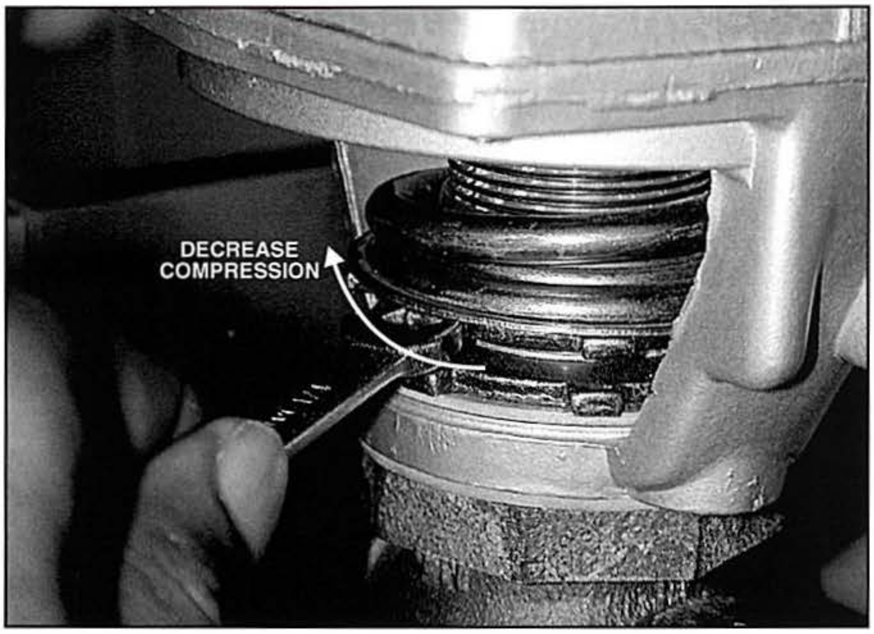

Figure 49. Spring Adjustment

❑ 14. Reconnect the pressure line to the air pressure regulator.

❑ 15. Turn on selector switch **SS1** to start the pump.

❑ 16. Use the up ▲ and down ▼ keys to adjust the output from the controller to **0.0** (0%).

Recall that when the output is zero, the controller is sending a 4 mA signal to the I/P converter, which converts the 4 mA signal to a 3 psi signal.

❑ 17. Determine the flow rate.

Flow Rate ____(gpm)

You should find that the flow rate is considerably lower than in step 11. The flow rate has decreased a large amount because there is very little tension in the spring. This means that only a small amount of air pressure on the diaphragm is required to close the valve. Therefore, even the 3 psi pressure input that is present when the controller output is 4 mA is enough to almost fully close the valve.

❑ 18. Use the up ▲ and down ▼ keys to adjust the output from the controller to **100.0** (100%).

☐ 19. Determine the flow rate.

Flow Rate ________________________________(gpm)

You should find that the controller indicates that there is no flow through the system. You should also notice that there is little to no leakage into the process tank from the piping network. When the controller output is at 100.0 (i.e. 100%), 15 psi of air pressure is exerted on the diaphragm. Because there is very little tension in the spring, the valve closes very easily.

☐ 20. Turn off selector switch **SS1** to stop the pump.

☐ 21. Disconnect the pressure line from the air pressure regulator.

☐ 22. Using your hand or a 1/4-inch wrench, turn the spring adjustor to the right until there is approximately a 1/2-inch gap between the spring adjustor and the yoke, as shown in figure 50.

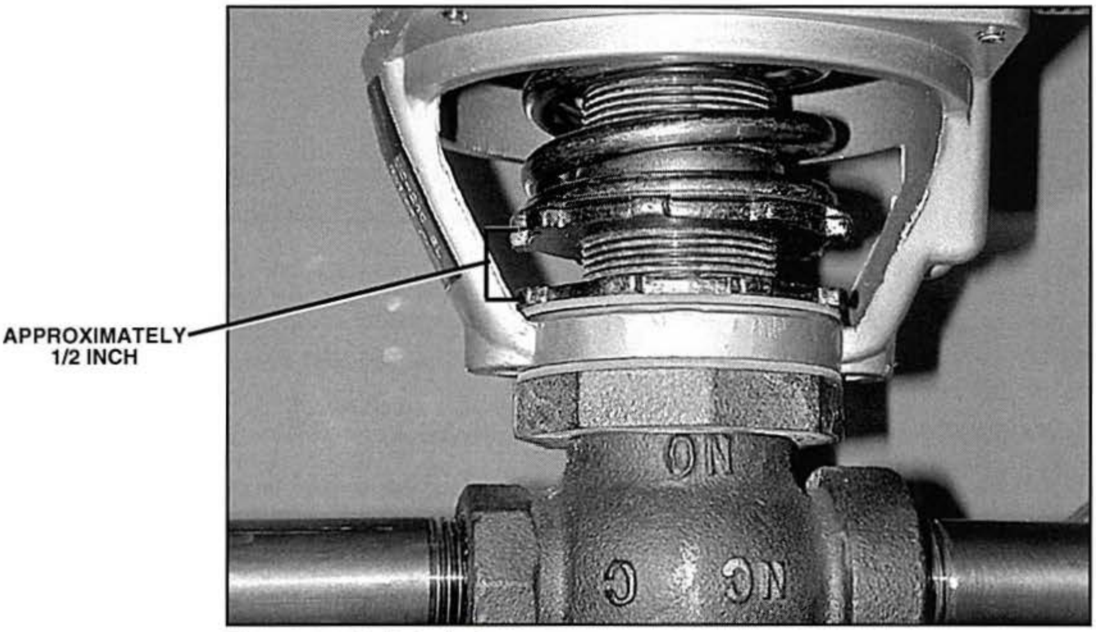

Figure 50. Half-Inch Gap

☐ 23. Reconnect the pressure line to the air pressure regulator.

☐ 24. Turn on selector switch **SS1** to start the pump.

The controller output should still be at 100.0.

☐ 25. Determine the flow rate.

Flow Rate ________________________________(gpm)

❑26. Determine the pressure output of the I/P converter.

You can determine this by observing the pressure gauge on the I/P converter.

Output Pressure ______________________________ (psi)

The output pressure of the I/P converter should be 15 psi. You should also notice that there is still flow into the process tank. The controller is sending a 20 mA signal to the I/P converter, which is converting that signal to a 15 psi pressure signal. However, the spring is so compressed that 15 psi is not enough air pressure to overcome that tension. Therefore the valve does not fully close.

❑27. Use the up ▲ and down ▼ keys to adjust the output from the controller to **0.0** and determine the flow rate.

Flow Rate ______________________________ (gpm)

You should find that the flow rate has increased a large amount because the spring is compressed. This means that with a small amount of air pressure (e.g. 3 psi) the valve remains almost completely open. Therefore, adjusting the spring to the proper tension level is a balance between having a high enough flow rate when the valve is completely open and the amount of leakage that is allowed when the valve is closed.

❑28. Turn off selector switch **SS1** to stop the pump.

❑29. Disconnect the pressure line from the air pressure regulator.

❑30. Adjust the spring adjustor until the rotameter indicates that the flow rate through the system is 1.20 gpm when the controller's output is 0.0. This requires you to adjust the spring to the left a small amount, replace the air pressure line, start the pump, and check the flow rate.

❑31. With the flow rate at 1.20 gpm when the controller output is 0.0, adjust the controller output to **100.0** and determine the flow rate.

Flow Rate ______________________________(gpm)

You should find that the flow rate through the system is 0.0 gpm. However, if you look closely where the water enters the process tank, you may notice a small amount of leakage. Recall that the diaphragm actuator proportional valve is a flow control valve and does not have positive shut off. Therefore, a small amount of leakage is normal.

❑32. Perform the following substeps to shut down the T5552.

A. Turn off selector switch **SS1** to stop the circulation pump.

B. Close the manual flow control valve.

C. Allow the process tank to drain. When the tank is completely drained, close the tank drain valves.

D. Turn off the main circuit breaker.

E. Disconnect the circuit.

SELF REVIEW

1. Two types of proportional valves are electric actuator valves and ____________ actuator valves.

2. Most air-to-close diaphragm actuator valves require a _______ psi input signal to fully close.

3. In direct acting diaphragm actuator valves, the calibrated spring is located _________ the diaphragm.

4. The ______________ usually sets the calibrated spring for the input signal the valve will receive.

5. Calibrated springs on diaphragm actuator valves are adjusted to allow full travel over the ___________ range.

6. The three main components of a diaphragm actuator valve are the diaphragm actuator, the valve body, and the ________.