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Department of Electrical and Electronics Skills

STUDENT HANDBOOK

Control Valves Operation & Maintenance

INCT 1428

2020

Prepared by

Industrial Instrumentation & Control Skills Team

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Unit 1: Introduction of control valve

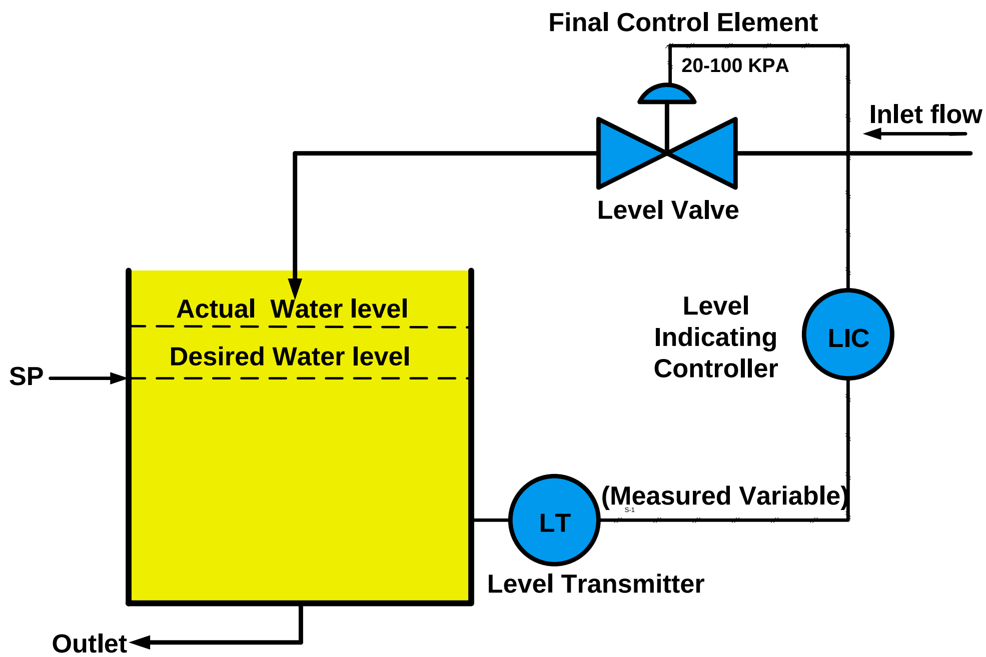


Figure 1: Open Tank Control

Control valves are widely used in process control systems as final control elements. A control valve acts as a final control element by modulating and throttling the flow of process fluid. Control valves differ from other valves in that they usually operate automatically.

A control valve works with other components in a control loop to control the process. The sensor senses changes in the value of the measured variable. In this simplified example, the water level in the tank has risen above the desired level. The sensor detects this change and sends a signal to the transmitter.

The transmitter changes the sensed value of the measured variable into a standard signal that is sent to the controller. The controller compares the value of the measured variable with the desired value. If there is a difference between the two values, as in this case, the controller sends a signal to the control valve, which is the final control element.

What is a Control Valve?

A Control valve is the final control element, which directly changes the value of the manipulated variable by changing the rate of control agent.

Control valve consists of an actuator and valve body. The actuator provides the power to vary the valve plug inside the body. The plug is connected to the actuator by a stem, which slides through a stuffing box. The increasing air signal from the controller is applied above the diaphragm. An increasing signal will push the actuator stem downwards against the force exerted by the spring on the diaphragm plate. The plug is adjusted in such a way that the plug starts moving when **3 psi** is applied to the diaphragm. Thus an increase in air pressure will close the valve. Hence the name **"air to close".** Another type is **"air to open"**, such that **3 psi** in the diaphragm, the valve is closed and **15 psi** air signal it is fully open.

Figure 1a: Typical example of Control Valves showing the actuator and valve body:

Why does a control valve operate at 15 psi?

On higher pressure the actuator size become bigger in area. The actual force produced by the actuator, F= Pressure X Area

= 15 psi X Area

If area = 25 in^2. Force produce = 15 psi X 25 in^2 = 375 pounds
Actual force acting on a control valve = *375 pounds*

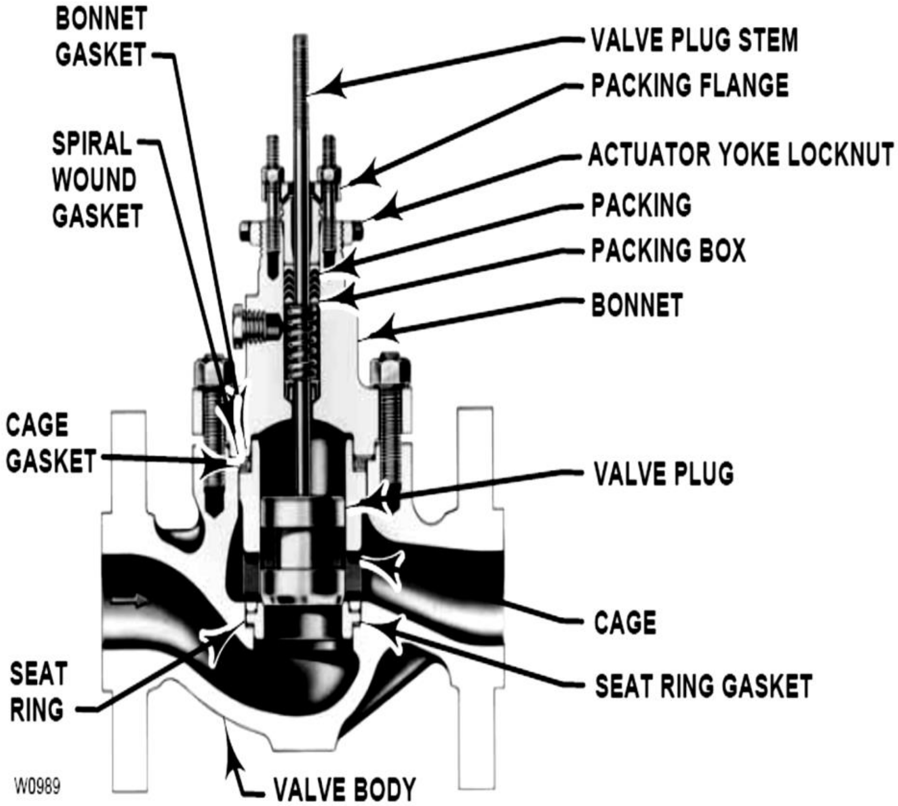


Figure 1b: Major Components of Typical Sliding Stem Valve Assemblies

Control Valve Characteristics

Various types of flow characteristics are available. This tutorial discusses the three main types used in water and steam flow applications: fast opening, linear and equal percentage flow; how they compare, and how (and why) they should be matched to the application in which they are used.

Flow characteristics

All control valves have an inherent flow characteristic that defines the relationship between 'valve opening' and flowrate under constant pressure conditions. Please note that 'valve opening' in this context refers to the relative position of the valve plug to its closed position against the valve seat. It does not refer to the orifice pass area. The orifice pass area is sometimes called the 'valve throat' and is the narrowest point between the valve plug and seat through which the fluid passes at any time. For any valve, however it is characterized, the relationship between flowrate and orifice pass area is always directly proportional.

Valves of any size or inherent flow characteristic which are subjected to the same volumetric flowrate and differential pressure will have exactly the same orifice pass area. However, different valve characteristics will give different 'valve openings' for the same pass area. Comparing linear and equal percentage valves, a linear valve might have a 25% valve opening for a certain pressure drop and flowrate, while an equal percentage valve might have a 65% valve opening for exactly the same conditions. The orifice pass areas will be the same.

The physical shape of the plug and seat arrangement, sometimes referred to as the valve 'trim', causes the difference in valve opening between these valves. Typical trim shapes for spindle operated globe valves are compared in Figure 1c.

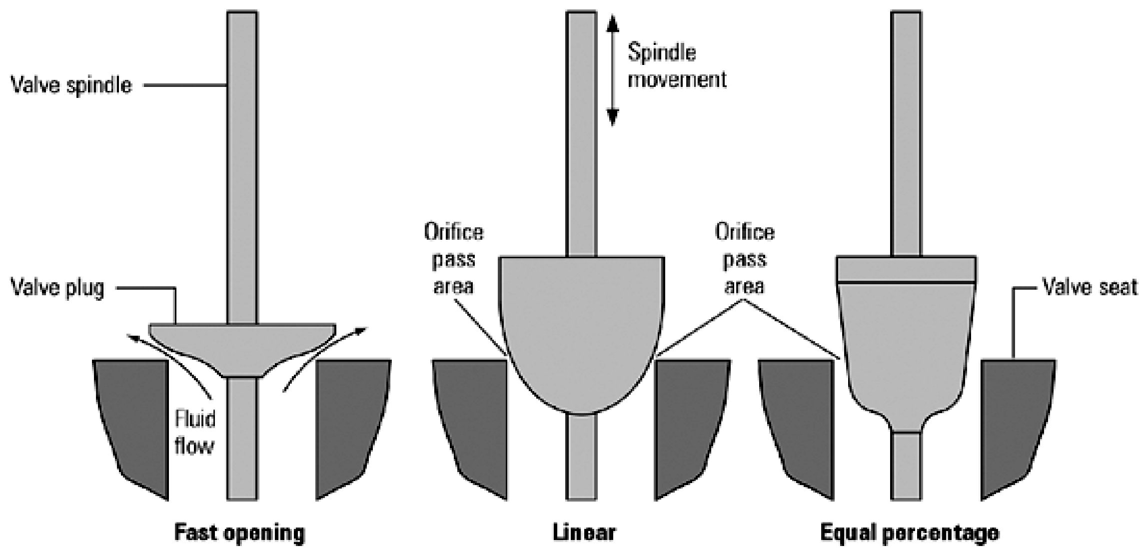


Fig. 1c: The shape of the trim determines the valve characteristic

The term 'valve lift' is used to define valve opening, whether the valve is a globe valve (up and down movement of the plug relative to the seat) or a rotary valve (lateral movement of the plug relative to the seat).

Rotary valves (for example, ball and butterfly) each have a basic characteristic curve, but altering the details of the ball or butterfly plug may modify this. The inherent flow characteristics of typical globe valves and rotary valves are compared in Figure 1d.

Globe valves may be fitted with plugs of differing shapes, each of which has its own inherent flow/opening characteristic. The three main types available are usually designated:

- Fast opening.
- Linear.
- Equal percentage.

Examples of these and their inherent characteristics are shown in Figures 1c and Figure1d.

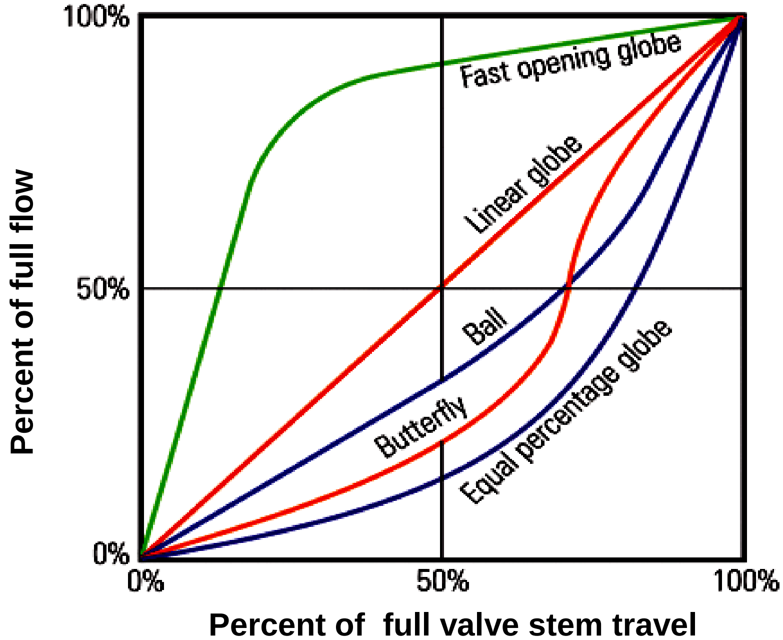


Fig. 1.d: Inherent flow characteristics of typical globe valves and rotary valves

Fast opening characteristic

The fast opening characteristic valve plug will give a large change in flowrate for a small valve lift from the closed position. For example, a valve lift of 50% may result in an orifice pass area and flowrate up to 90% of its maximum potential. A valve using this type of plug is sometimes referred to as having an 'on / off' characteristic.

Unlike linear and equal percentage characteristics, the exact shape of the fast opening curve is not defined in standards. Therefore, two valves, one giving a 80% flow for 50% lift, the other 90% flow for 60% lift, may both be regarded as having a fast opening characteristic.

Fast opening valves tend to be electrically or pneumatically actuated and used for 'on / off' control.

The self-acting type of control valve tends to have a plug shape similar to the fast opening plug in Figure 6.5.1. The plug position responds to changes in liquid or vapour pressure in the control system. The movement of this type of valve plug can be extremely small relative to small changes in the controlled condition, and consequently the valve has an inherently high rangeability. The valve plug is therefore able to reproduce small changes in flowrate, and should not be regarded as a fast opening control valve.

Linear characteristic

The linear characteristic valve plug is shaped so that the flowrate is directly proportional to the valve lift (H), at a constant differential pressure. A linear valve achieves this by having a linear relationship between the valve lift and the orifice pass area (see Figure 1e).

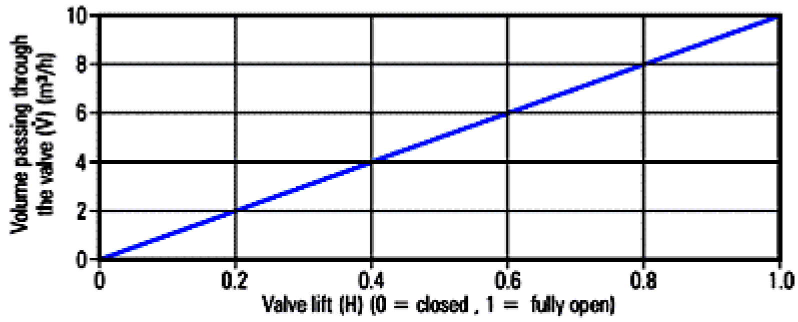


Fig. 1e: Flow / lift curve for a linear valve

For example, at 40% valve lift, a 40% orifice size allows 40% of the full flow to pass.

Equal percentage characteristic (or logarithmic characteristic)

These valves have a valve plug shaped so that each increment in valve lift increases the flowrate by a certain percentage of the previous flow. The relationship between valve lift and orifice size (and therefore flowrate) is not linear but logarithmic.

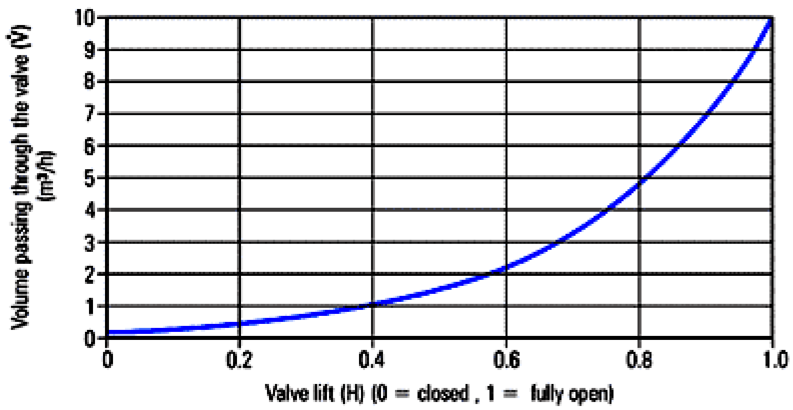


Fig. 1f: Flowrate and valve lift for an equal percentage characteristic with constant differential pressure

A few other inherent valve characteristics are sometimes used, such as parabolic, modified linear or hyperbolic, but the most common types in manufacture are fast opening, linear, and equal percentage.

Lesson 1.1: Types of control valves

1) Globe valves – single or double seated.
2) Angle valves
3) Butterfly valves
4) Three way valves
5) Gate valves
6) Plug valves
7) Check valves
8) Ball Valves
9) Solenoid valves
10) Pressure Reducer

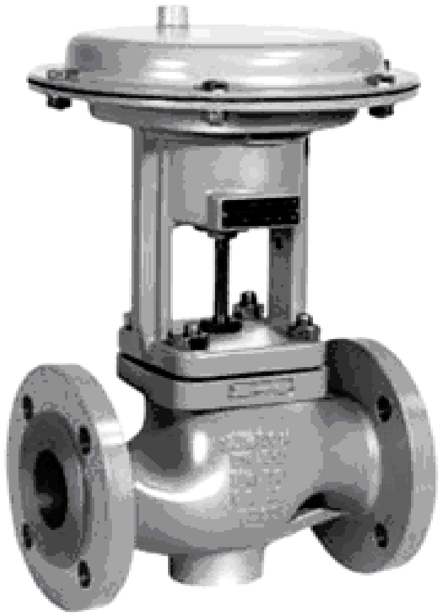
1) Globe Valve:

Operation:

The actuator of a globe valve moves in response to signals received from the controller. This movement in turn, causes the valve stem and plug to move, affecting the flow of process fluid through the valve.

For example, when the actuator of a single-seated globe valve receives a signal indicating that the volume of flow of the process fluid should be decreased, the actuator stem moves down. These forces the valves stem and plug to move toward the valve seat. As the stem and plug move toward the seat, the opening between the plug and the seat narrows. As a result, less process fluid can flow through the opening. When the plug rests firmly against the seat, the valve is fully closed. In the fully closed position, no usable amount of process fluid should be able to flow through the valve. When the actuator receives a signal indicating that the process flow should be increased, the actuator stem moves up. The valve stem and plug also move up and the valve opening widens. As a result, more, process fluid can flow through the opening. When the plug is retracted as far from the seat as possible, the valve is fully opened. In this position, the maximum amount of process fluid can flow through the valve.
One commonly used type of control valve is called a **single-seated globe valve.**

Application: The single seated valve is used in smaller sizes and in valves of larger sizes where an absolute shut off is required. The use of single seated valve is limited by pressure drop across the valve in the closed or almost close position.



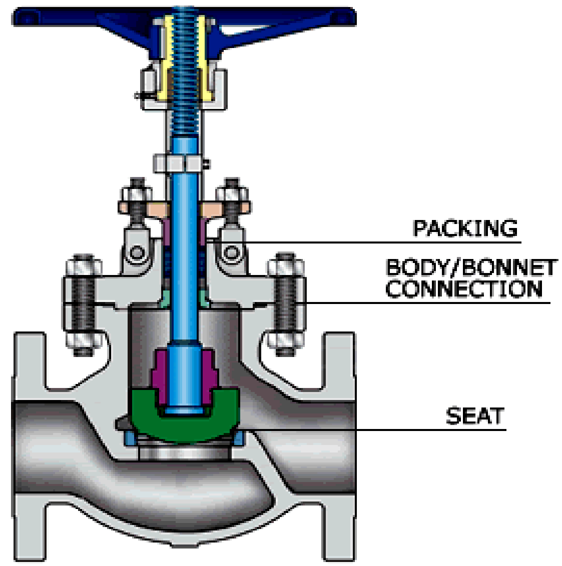


Figure 1.1a: Globe Control Valve **Figure 1.1b: Manual Globe Vale**

Arrow-head marking on the valve body indicating the flow direction.

A typical single-seated globe valve has-the following basic parts.

- **<u>The body</u>** – is part of the outer casing of the valve. Globe valve bodies come in a variety of designs and sizes. They are usually round in shape and are made of metal, such as bronze, steel, or brass. The body of the valve is connected to the process piping.

- **<u>Bonnet</u>** – The bonnet is also part of the outer casting. This part is connected to the top of the valve body and to the actuator.

- **<u>Actuator</u>** – The actuator is the device that provides the force to open and close the valve. Although actuators operate in various ways, most actuators have a stem that connects to and moves the valve stem.

- **<u>Stem</u>** – The stem in a globe valve is usually a rod that extends through the valve. One end of the stem is connected to the actuator stem; the other end is attached to the plug.

- **<u>Bushing</u>** – The bushing helps to guide the stem as it moves through the valve.

- **<u>Plug</u>** – The plug is the closure mechanism for the valve. It is attached to the end of the stem. Plugs are designed for various flow and fluid characteristics. The exact shape and size of the plug will vary, depending on the design the valve and requirements of the system.

- **Seat** – The seat is the part of the valve that the plug contacts to close the valve. The seat in a globe valve is usually a circular, cup-like part, called the seat ring. Some seat rings are designed to be threaded into an opening in the valve body. Other seat rings, such quick change seat rings, are simply inserted into the valve body.

- **Stuffing box** – The stuffing box is a hollow, cylindrical cavity inside the valve bonnet. It is filled with packing material that is used to provide a seal against leakage and to guide the stem.

- **Packing** – Packing material is used to fill the stuffing box. Packing is usually a material that can be compressed to fill spaces around the stem.

- **Spacer** – Spacers are usually used when it is not necessary to completely fill the stuffing box with packing. This spacer is usually a hollow, cylindrical piece of metal that fits into the stuffing box.

- **Packing follower** – The packing follower fits on top of the packing and serves to compress the packing and hold it in place. This part is sometimes called the gland follower.

- **Packing flange** – The packing flange holds the other parts of the packing assembly inside the stuffing box and is used to adjust the compression of the packing. This part is usually bolted into place.

Double–Seated Globe Valves

Another type of globe valve is called a double-seated globe valve. This type of valve has two plugs attached to the valve stem and two seats in the valve body. The type of valve shown here is a double-seated V-port valve.

Double-seated globe valves are usually top and bottom guided. In a top and bottom guided globe valve, another bushing is provided in the lower part of the valve. This bushing works with the parts of the packing assembly and the bushing in the top of the valve to help guide the stem.

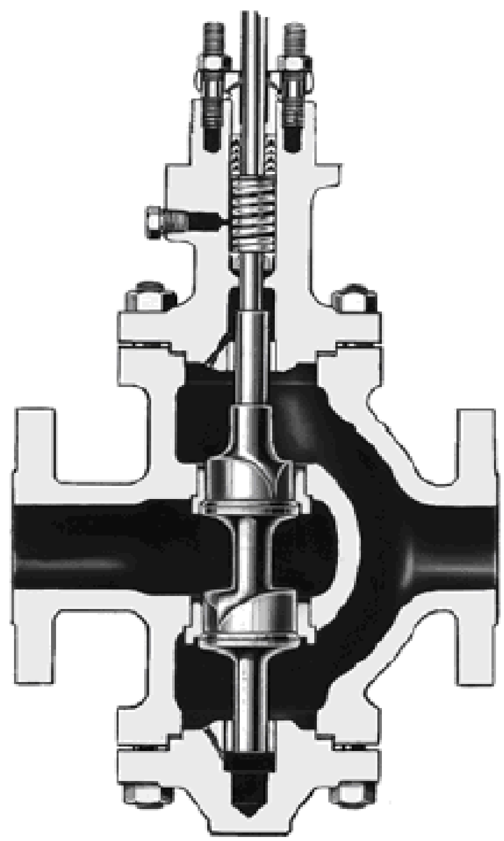


Figure 1.1c: Reverse Double – Ported Globe Style Valve body

Application: It is generally used on bigger size valves and high pressure systems actuator forces required are less i.e. a small size actuator.

2) Angle Valve:

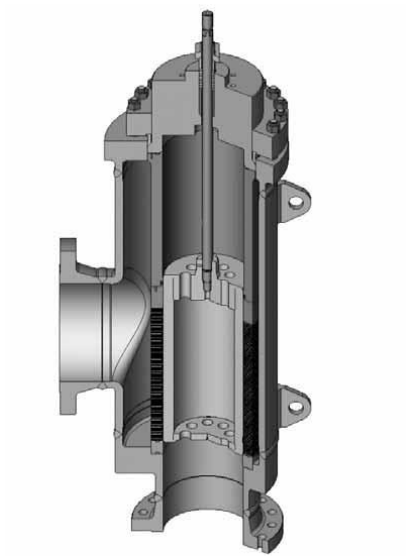


Fig.1.2a: Cut away of Angle style valve: Control Valve:

Fig. 1.2b: Angle style control valve:

Application: Angle valves are used where very high pressure drops are required under very severe conditions, where the conventional type of valve would be damaged by erosion.

3) Butterfly Valve:

Figure 1.3a: Contoured Disk Butterfly Valve

Application: Butterfly valves are used only in system where a small pressure drops across the valve is allowed. The butterfly valve is fully open when the disc rotates 90˚C. A drawback of this valve is that even a very small angular displacement produces a big change in flow.

4) Three Way Valve:

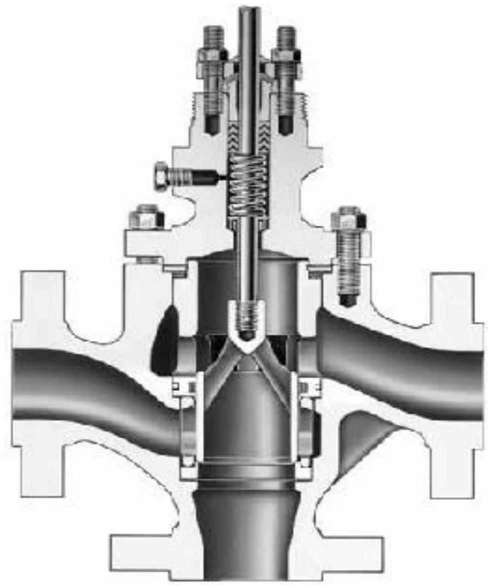


Figure 1.4a: Cutaway of 3-way Valve **Figure 1.4b: 3-Way Control Valve**

Application: Three ways control valves are only used for a special system where dividing or mixing of flows according to a controlled ratio is required.

5) Gate Valve: A gate valve is a valve that opens by lifting a round or rectangular gate out of the path of the fluid. In gate valve the plug moves parallel to seat. The plug is plate or a disk which touches fluid in closed position.

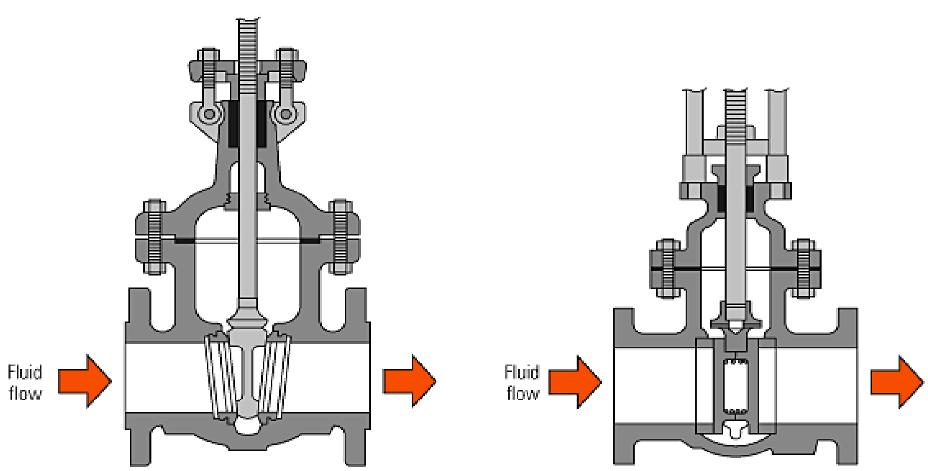


Figure 1.5a: Cutaway View of Gate Vale

Application: Used in Industry to control the fluids. But, the drawback is that the gate erodes unevenly and after sometime the gate will not completely stop the flow when it is closed.

In gate valve, gate moves up and down and the direction of flow will be straight and due to the pressure and friction on the gate, the gate erodes unevenly. After a period of time in use, the gate will not completely stop the flow when it is closed.

6) Plug Valve: Another type of valve used in industrial piping is the plug valve. The plug is located in the body of the valve and has an opening of the valve, flow can exist. The plug valve is quick shutoff or opening valve.

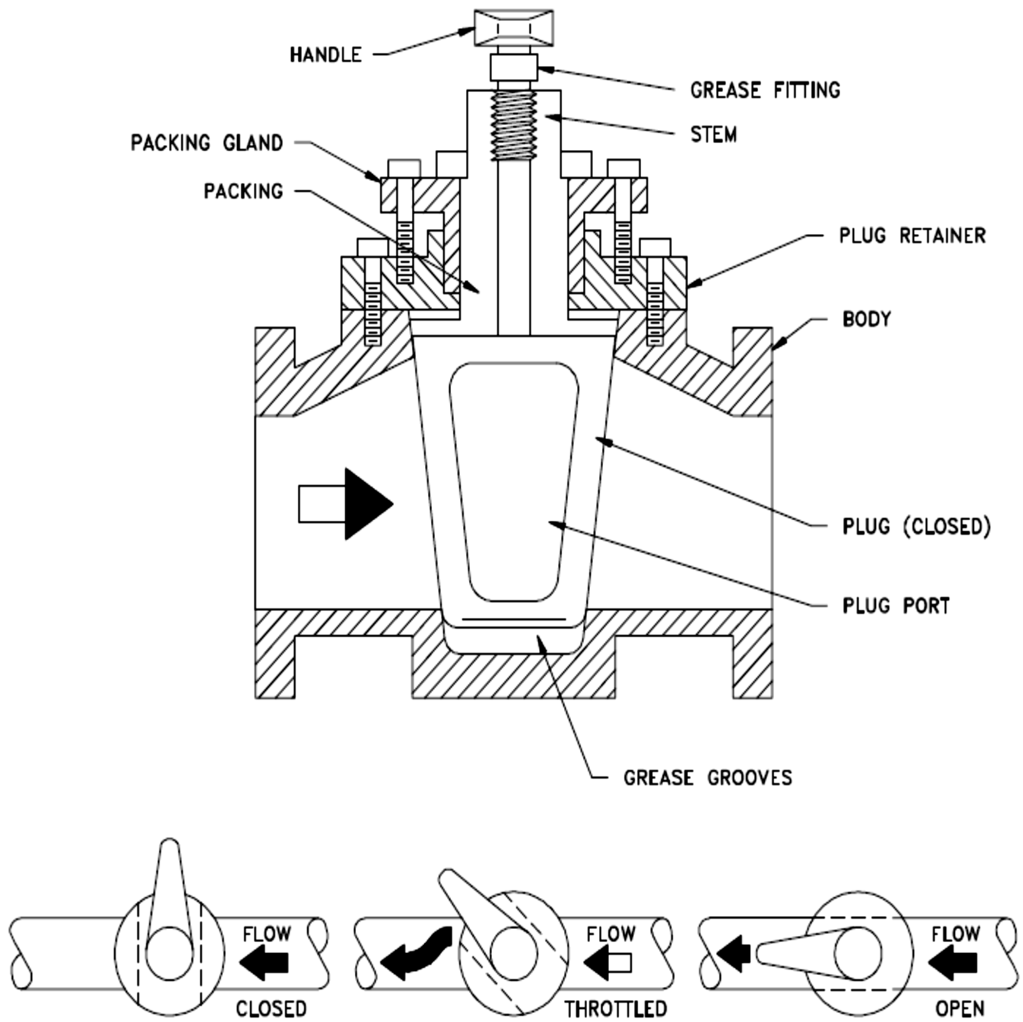


Figure 1.6a Cutaway View of Plug Valve

Application: Used in Industrial Piping for quick opening/closing operation.

7) Check Valve:

Applications

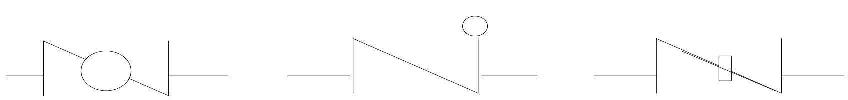
Check valves are often used with some types of pumps. Piston-driven and diaphragm pumps such as metering pumps and pumps for chromatography commonly use inlet and outlet ball check valves. These valves often look like small cylinders attached to the pump head on the inlet and outlet lines. Many similar pump-like mechanisms for moving volumes of fluids around use check valves such as ball check valves.

Check valves are used in many fluid systems such as those in chemical and power plants, and in many other industrial processes.

Check valves are also often used when multiple gases are mixed into one gas stream. A check valve is installed on each of the individual gas streams to prevent mixing of the gases in the original source. For example, if a fuel and an oxidizer are to be mixed, then check valves will normally be used on both the fuel and oxidizer sources to ensure that the original gas cylinders remain pure and therefore nonflammable.

Some types of irrigation sprinklers and drip irrigation emitters have small check valves built into them to keep the lines from draining when the system is shut off.

Symbol:



a. Ball type   b. Lift or swing type   c. Piston type

7-a. A **ball check valve** is a check valve in which the disc, the movable part to block the flow, is a spherical ball. In some (but not all) ball check valves, the ball is spring-loaded to help keep it shut. For those designs without a spring, reverse flow is required to move the ball toward the seat and create a seal. The interior surface of the main seats of ball check valves are more or less conically-tapered to guide the ball into the seat and form a positive seal when stopping reverse flow.

Ball check valves are often very small, simple, and cheap. They are commonly used in liquid or gel minipump dispenser spigots, spray devices, some rubber bulbs for pumping air, etc., manual air pumps and some other pumps, and refillable dispensing syringes. Although the balls are most often made of metal, they can be made of other materials, or in some specialized cases out of artificial ruby. High pressure HPLC pumps and similar applications commonly use small inlet and outlet ball check valves with balls made of artificial ruby and seats made of artificial sapphire, both for hardness and chemical resistance. After prolonged use, such check valves can eventually wear out or the seat can develop a crack, requiring replacement. Therefore, such valves are made to be replaceable, sometimes placed in a small plastic body tightly-fitted inside a metal fitting which can withstand high pressure and which is screwed into the pump head.

There are similar check valves where the disc is not a ball, but some other shape, such as a poppet energized by a spring. Ball check valves should not be confused with ball valves, which is a different type of valve in which a ball acts as a controllable rotor to stop or direct flow.

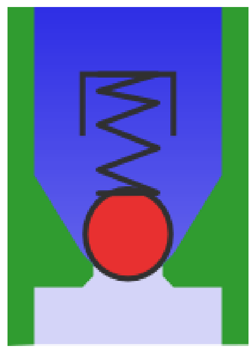


Figure 1.7a: Ball Check Valve

7-b. A **swing check valve** is a butterfly-style check valve in which the disc, the movable part to block the flow, swings on a hinge or trunnion, either onto the seat to block reverse flow or off the seat to allow forward flow. The seat opening cross-section may be perpendicular to the centerline between the two ports or at an angle. Although swing check valves can come in various sizes, large check valves are often swing check valves.

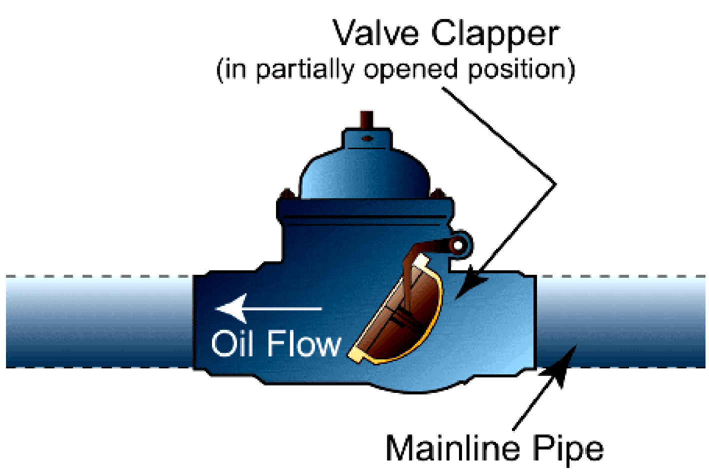


Figure 1.7b: Typical example of Lift or Swing Type Check Valve

7-c. Piston Type Check Valve

Figure 1.7c: Typical Example of Piston Type Check Valves

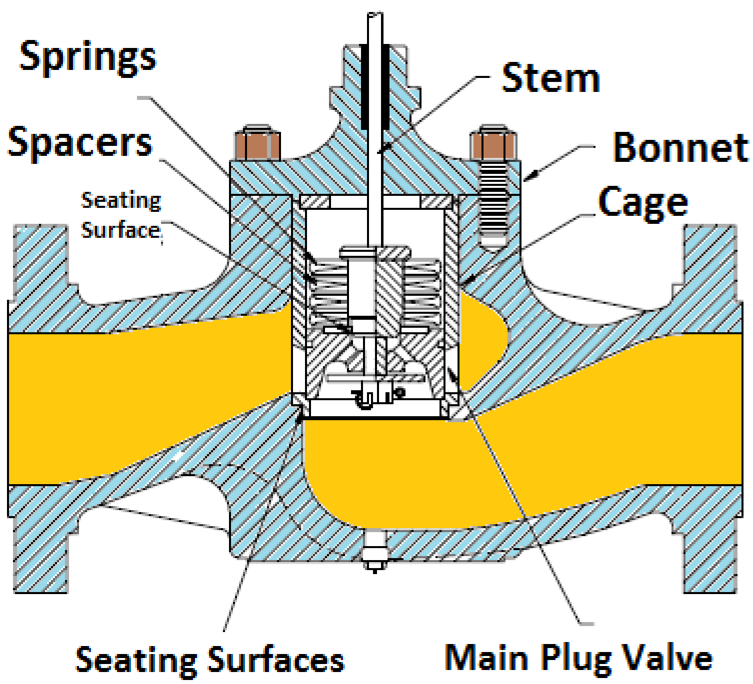


Figure 1.7d: Typical Example of internals of Piston Check Valves

Application: commonly used for instrumentation piping and pneumatic circuits especially for the Safety of equipments. It controls the direction of the flow. It works like a one way door.

8) Ball valve: The Segmented Ball Valve Pneumatic Rotary Actuator. The control valve is used for both throttling and on-off services in process engineering and plants with industrial requirements.

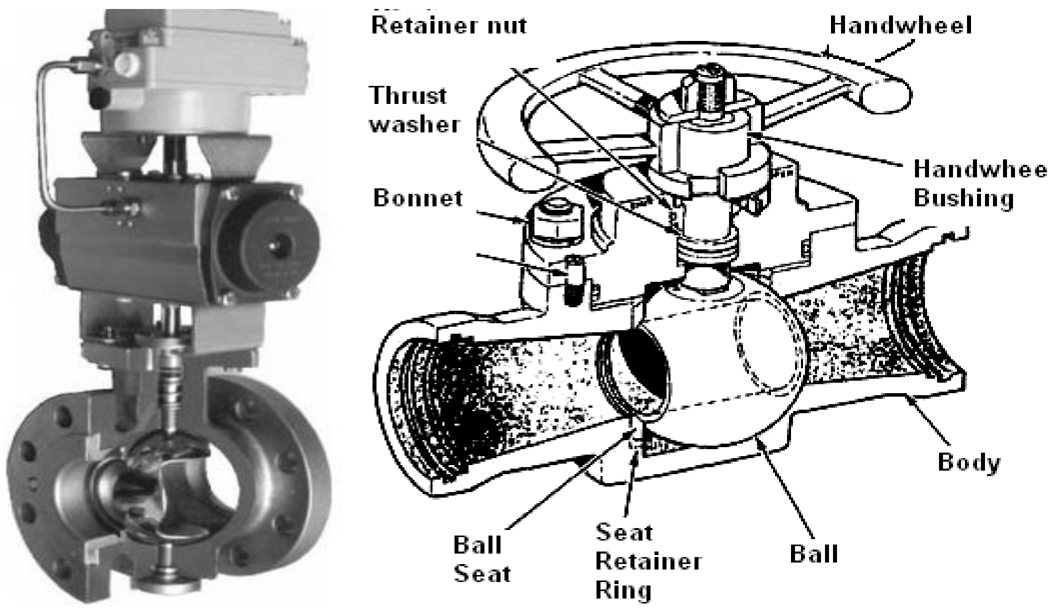
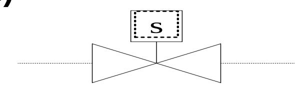


Figure 1.8a: Cut away of ball valve

Application: It is suitable for liquids, vapors and gases within a temperature range of −29 to 220 °C.

9) Solenoid Valve: A Solenoid Valve will open & close when an electrical signal is sent to it. (i.e. it provides on/off capability)

(**Symbol)**



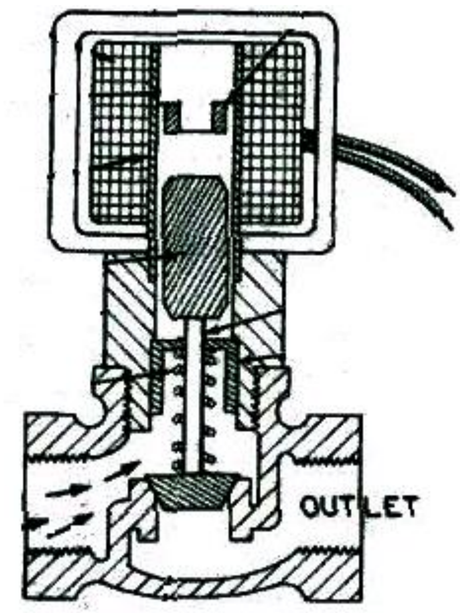


Figure 1.9a: De-Energized

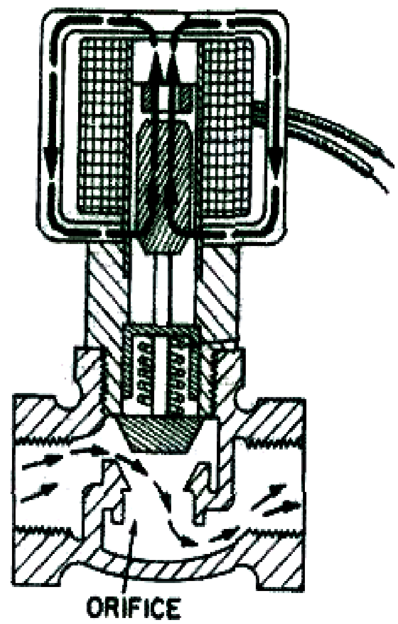
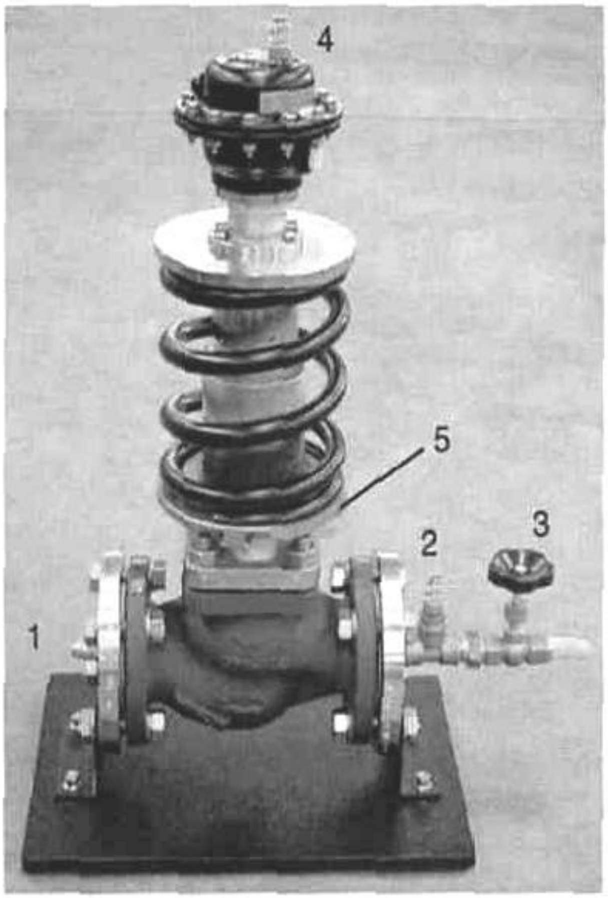


Figure 1.9b: Energized

Application: one application for a solenoid operated valve would be to interrupt airflow to a pneumatic final control element.

10) Pressure Reducer: Pressure Regulator is direct acting, proportional regulator self operated valve which regulates a high upstream pressure to a smaller downstream pressure.



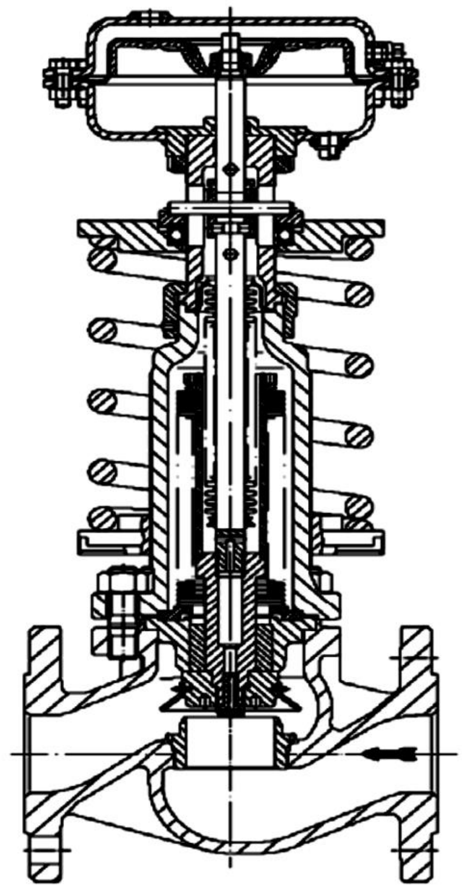


Figure 1.10a: Pressure Reducer

Figure 1.10b: Pressure Reducer (Internal parts)

<u>Application</u>: To regulate steam, natural gases and vapors in industry.

Exercise 1: Basic Operation & Testing of Butterfly Valve

Introduction:

A butterfly valve typically has a round body that is relatively thin. Therefore a butterfly valve takes up considerably less space in piping than many other types of valves.

Butterfly valves may be used for a variety of purposes in an industrial facility. For example, a butterfly valve may be used in a low pressure gas line, or to control the flow of water in a cooling system.

Some of the major parts of a butterfly valve are shown in figure below. The parts shown include the body, the disc, the seat and the actuator. The relatively thin disc has a slightly smaller diameter than the inside of the piping in which the valve is installed. When the valve is fully open, the thin disc offers little resistance to flow, so there is minimal pressure drop across the valve. The seating surface of the valve may be covered with a type of resilient material, such as plastic. This material provides a tight seal when the disc closes on the circular seat. In some butterfly valves, the outer edge of the disc, instead of the seat, may be covered with a resilient material.

a.) Typical example of automated Butterfly valve:

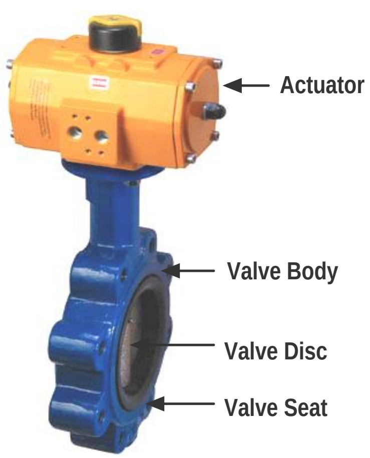


Figure 1-1a: Automated Butterfly Valve

b.) Typical example of manual Butterfly valve:

Figure 1-1a: Manual Butterfly Valve.

Equipment List:

- Butterfly valve assembly
- Regulated air supply
- ¼” O.D. plastic tubing & Fittings

Procedure:

1. Connect the air regulator to the actuator inlet port.

2. Apply regulated air supply to the actuator (0-2 bar pressure, or refer to the actuator specifications). The valve disc must rotate 90 degrees from fully close to its fully open direction. “Air to open spring to close”.

3. Release air pressure to zero, the valve disc must return to its close position. If not, check for possible wear on its seat ring.

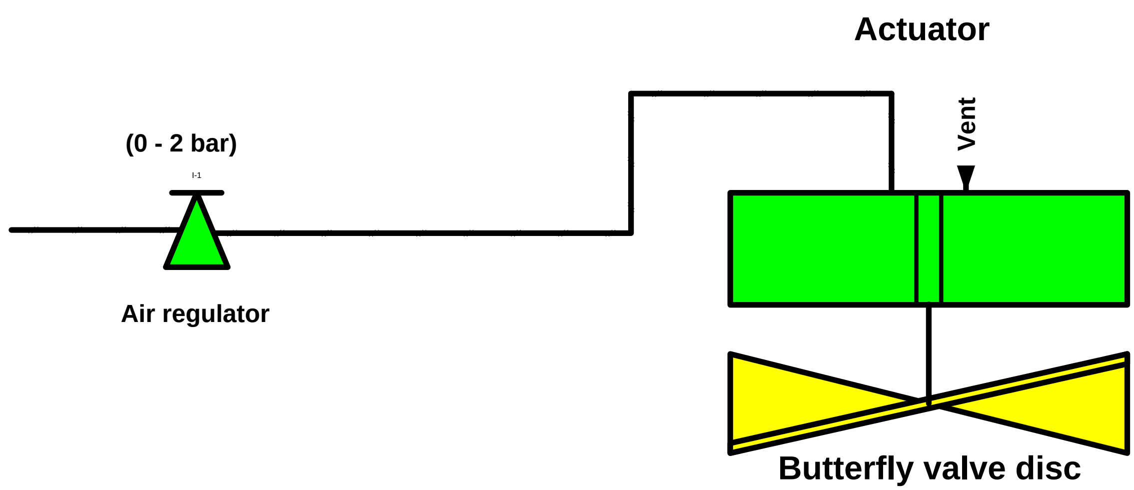


Figure 1-1b: Testing Hook up of Butterfly Valve

Questions:

1. How will you change the rate of fluid flow through a butterfly valve?

2. What are the applications of butterfly valves in the industry?

3. What is a butterfly valve?

Exercise 2: Basic Operation & Testing of Piston Type Check Valve

Introduction:

Check valves are used in fluid circuits in applications similar to those in which diodes are used in electrical circuits. Reduced to simplest terms, the duty of most
Check valves is to allow flow in one direction and to prevent flow in the reverse direction. The ideal check would have zero resistance to flow in the normal flow direction and infinite resistance to flow (leakage) in the reverse direction. Of course, the ideal check valve should also be perfectly reliable and should require
no maintenance.

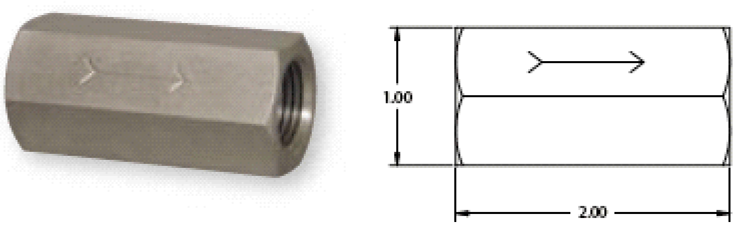


Figure 2-1: Series Check Valve

Maximum Operating Pressure — 5 000 psi
Maximum Operating Temperature — 180°F
3/8 Check Seat Area Open Diameter — .302

Design Considerations

The 014 Series Check Valve incorporates a guided poppet and large flow area design for full flow with minimum pressure loss. The 014 Check Valve is designed for High Pressure, up to 5,000 psi. The stainless poppet seals on the stainless seat with minimal back pressure.

Options

Material Options	316 Stainless Body, Poppet and Retainer
	316 Stainless Spring
	15-7 Stainless Retaining Ring
End Options	3/8 Female NPT Inlet x 3/8 Female NPT Outlet
Spring Options	1 psi, No Spring

Equipment List:

- Piston type check valve, size: ¼” FNPT x ¼” FNPT
- Regulated air supply
- Air regulator
- ¼” tubing and fittings ¼” MNPT x ¼” CTC
- Pressure gauge

Procedure:

1. Connect the tubing and connect the air regulator output to the inlet side of piston check valve. Note: Observe arrow direction.

2. Connect the pressure gauge to the outlet side of the piston check valve, close the vent valve.

3. Apply regulated air supply (0 – 2.0 bar) pressure and observe output gauge, must read 2.0 bar pressure.

4. Connect the tubing and connect the air regulator output to the outlet side of piston check valve.

5. Connect the pressure gauge to the inlet side of the piston check valve, close the vent valve.

6. Apply regulated air supply (0 – 2.0 bar) pressure and observe out put gauge, must read zero.

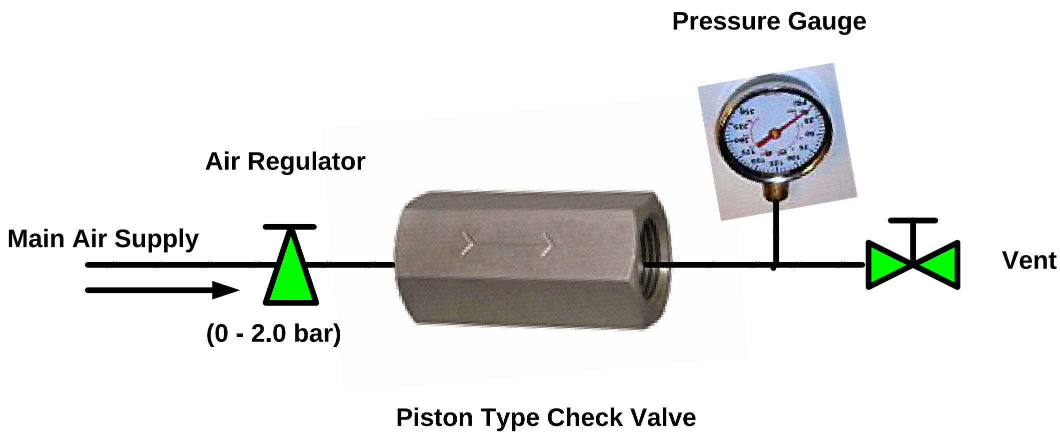


Figure 2-2: Testing Hook up of Piston Type Check Valve

Questions:

1. Explain the working principles of a check valve.

2. What are the three commonly used types of check valves?

3. What is the application of check valves in the process industry?

4. Draw the symbol of a piston type check valve.

Exercise 3: Basic Operation & Testing of Normally Open Solenoid Valve

Objective: To be able to know the basic principle of operation of the normally open solenoid valve.

Principle of Operation

A solenoid valve involves two main functional units: a solenoid (electromagnet) with its core and a valve body containing the fluid inlet(s) and outlet(s). When the solenoid is energized, the orifice controlling the airflow is either opened or closed. In most valves, the solenoid is mounted on top of the valve body allowing for a compact configuration. There are 3 main principles of operation for solenoid valves:

Direct Acting Valves: When the coil is energized, the diaphragm is lifted directly by the moving core and the orifice on the valve body will either open or close. These valves will operate at pressures from 0 psi up to each different valve's rated maximum pressure.

Internally Pilot Operated Valves: These valves use inner line pressure for operation. In addition to the opening and closing procedure from the Direct Acting Valve, they use inner line pressure to improve the tightness of the closed position. Pilot operated solenoid valves consist of two chambers, separated by the diaphragm which is not directly coupled to the core (sometimes called indirect acting) see Fig 3.1

The upper chamber is connected to upstream through a compensation hole or pilot hole in either the cover or diaphragm. The pressure of the media is acting on the upper side of the diaphragm, this keeping the valve closed. When the coil is energized the core lifts off the orifice seat allowing the operating chamber to de-pressurize. In this condition the thrust of the upstream pressure under the diaphragm prevails and the diaphragm lifts, thus opening the valve.

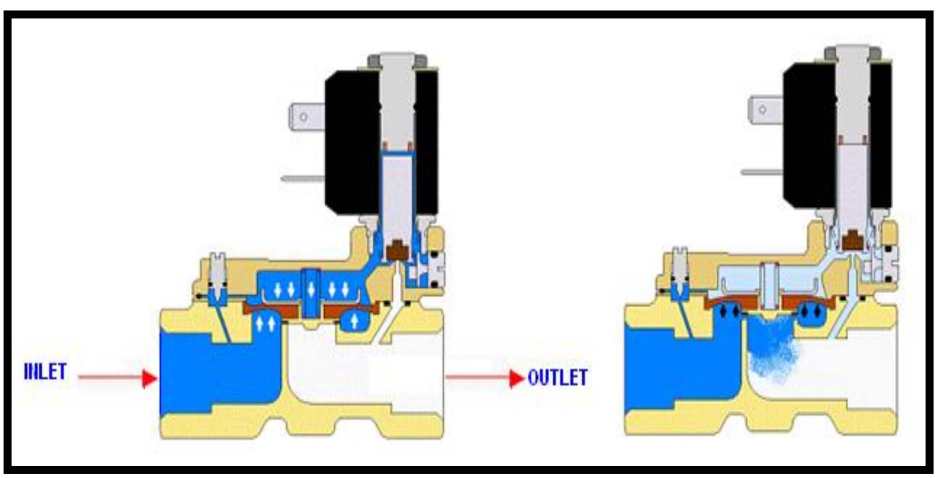


Fig. 3.1 Pilot operated solenoid valves

Manual Reset Valves: These must be manually latched into position.

Circuit Function of flow valve

Normally open: The orifice is open when the valve is de-energized and closes when the valve is energized.

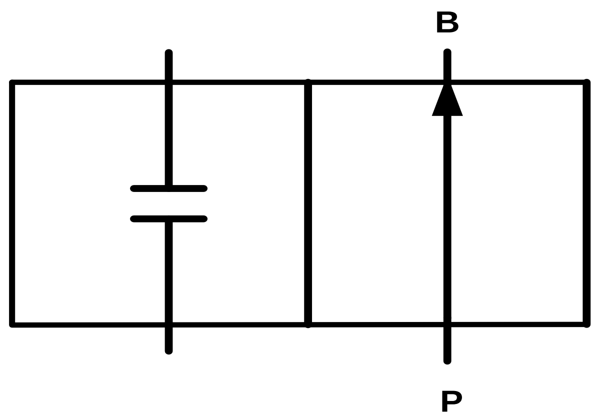


Figure 3-2:2/2-way valve; normally open

Equipment List:

- 2/2-way solenoid valve (Normally open)
- On-Off Switch
- Air supply
- 24VDC supply
- Receiver gauge
- ¼ O.D. tube

Procedure:

1- Connect the 24VDC power supply to the solenoid coil in series with the on/off switch.

2- Connect the air supply tubing to the inlet port of the solenoid and connect the outlet port to the receiver gauge.

3- Apply air supply (regulated) to the solenoid valve and operate the on-off switch. The valve must energize and verify the pressure reading at the receiver gauge, must read zero or minimum.

4- Release the on-off switch, the valve must de-energize and the receiver gauge must read equal to the inlet pressure.

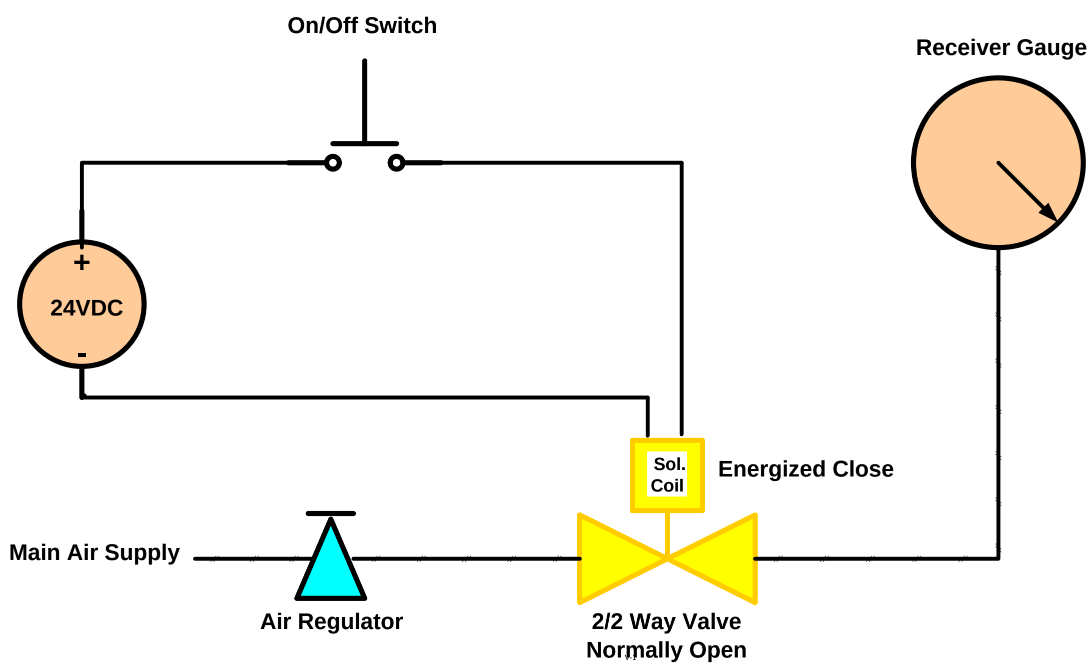


Figure 3-3: Testing Hook up of normally open solenoid valve

Questions:

1. What is the orifice status if the solenoid valve is energized?

2. What is the application of the normally open solenoid valve?

3. What does it mean by 2/2-way solenoid valve?

4. Explain the circuit function of the flow valve.

Exercise 4: Basic Operation & Testing of Normally Close Solenoid Valve

Objective: To be able to know the basic principle of operation of the normally close solenoid valve.

<u>Principle of operation</u>: (Please refer to exercise number 3)

Circuit function of flow valve: The circuit function of a valve indicates the functions which can achieved. The circuit function defines whether a valve shut off or allows the fluid flow, whether all the parts are shut-off in the de-energized position, or whether some ports are closed and others left open.

Normally close: The orifice is closed when the valve is de-energized and opens when the valve is energized.

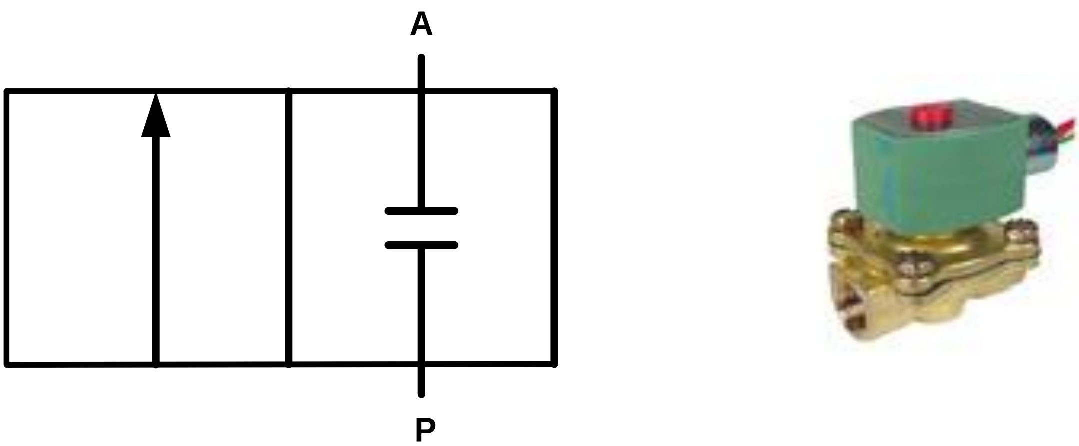


Figure 4-1: <u>2/2-way valve: normally closed</u>

Equipment List:

- 24VDC supply
- Solenoid valve (normally close)
- Receiver gauge
- On/Off Switch

Procedure:

1- Connect the 24VDC power supply to the solenoid coil in series with the on/off switch.
2- Connect the air supply tubing to the inlet port of the solenoid and connect the outlet port to the receiver gauge.
3- Apply air supply (regulated) to the solenoid valve and operate the on-off switch. The valve must energize and verify the pressure reading at the receiver gauge, must read equal to the inlet pressure.
4- Release the on-off switch, the valve must de-energize and the receiver gauge must read zero or minimum.

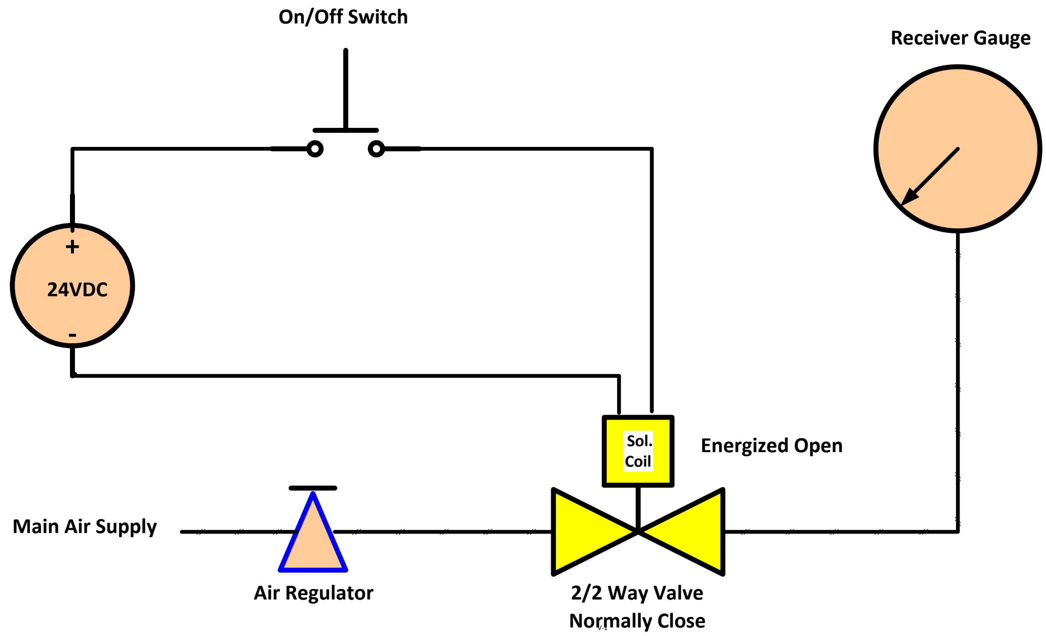


Figure 4-2: Testing hook up of normally close solenoid valve

Questions:

1. What is the orifice status if the solenoid valve is energized?

2. What is the application of the normally close solenoid?

3. Explain the circuit function for the normally close solenoid Valve?

Exercise 5: Basic Operation & Testing of Pressure Reducing Valve.

Objective: To be able to know the principle of operation of the pressure reducing valve and its application to process industries.

Introduction:

The pressure reducing valve is a normally open valve and it remains fully open while outlet pressure is lower than the valve preset pressure. When the preset pressure is reached, the valve control member (spool, ball, poppet, etc ;) is force off its stop and starts closing the orifice, thus trying to maintain outlet pressure at the preset level. Any further increase in the outlet pressure causes the control member to close the orifice even more until the point when the orifice is fully closed. The pressure increase that is necessary to close the valve is referred to as regulation range.

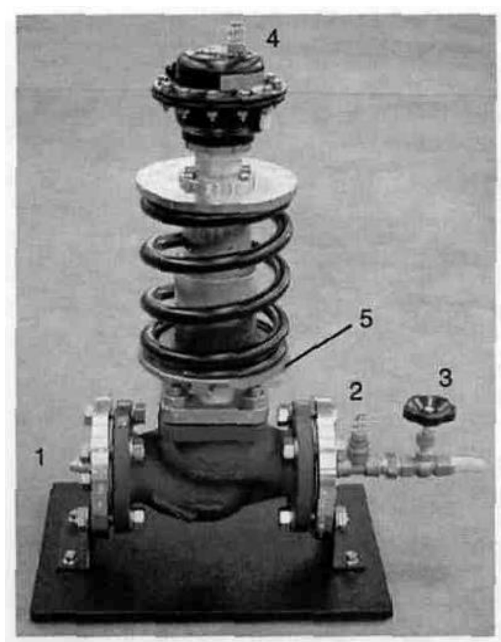


Figure 5-1: Pressure Reducing Valve

Equipment List:

- Reducing valve assembly
- Regulated air supply (0-3.5 bar)
- Preset pressure (0-2 bar)
- Pressure gauge
- ¼ O.D. Tube

Procedure:

1- Connect the regulated air supply (0-3.5 bar) to the reducing valve actuator.

2- Connect tubing to the inlet side of the valve and apply preset pressure (0-2 bar)

3- Slowly increase air pressure to the actuator up to 3.5 bars. At zero bar pressure the valve must be fully open and at 3.5 bar pressure the valve must be fully close.

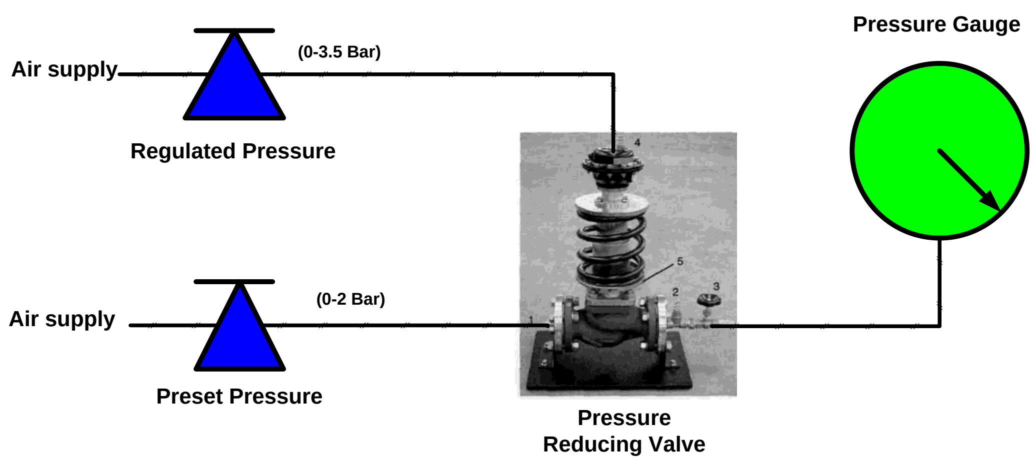


Figure 5-2: Testing Hook Up of Pressure Reducing Valve

Questions:

1. What is pressure reducing valve?

2. What is the application of pressure reducing valve?

3. How do you test a pressure reducing valve?

Unit 2: Introduction of actuator

An actuator is a device that controls the operation of a final control element, usually a control valve. The actuator moves the valve stem and plug to the position required by the process conditions. For automatic adjustment, manipulating devices require actuator that can set every desired position reliably and stably under the prevailing conditions. Power is required to lift valve cones or to turn valves and cocks. The auxiliary power used can be pneumatic, electrical or hydraulic.

Auxiliary power	Advantage	Disadvantage
Electrical	Easy negotiation or long distances	Extra protective measures required
	High setting accuracy	Auxiliary power failure results in safety problems
	Cheaply available	
	Fast	
Pneumatic	No extra protective measures required	Slow positioning signal, influences loop layout
	Auxiliary power failure causes no problems	Expensive to provide
Hydraulic	No extra protective measures required	Transmission line problematic due to high pressures
	High adjusting forces and speeds	Expensive to provide

Lesson 2.1 Types of actuators:

a) Pneumatic actuator
b) Diaphragm actuator
c) Piston actuator
d) Solenoid actuator
e) Electric motor actuator

a) Pneumatic Actuator

Pneumatic actuator use air pressure to position a control valve. The controller sends a pneumatic signal to the actuator. The actuator then converts the pneumatic signal into movement to position the control valves stem and plug, the valve stem and plug may be opened, closed, or positioned at some point between opened and closed.

Operation of a Pneumatic Actuator

When the controller sends a signal to the actuator, input air pressure causes the diaphragm to flex. The movement of the diaphragm is transferred through the diaphragm plate to the actuator stern. The change in pressure on the diaphragm causes the actuator stem assembly to move. This, in turn, causes the valve stem and plug to move.

b) Diaphragm Actuator

One type of pneumatic actuator is a diaphragm actuator. This type of actuator uses a flexible diaphragm to convert the pneumatic signal from the controller to movement to position the control valve.

Most diaphragm actuators have the following basic parts.

- Diaphragm – a flexible piece of material that flexes in response to the pneumatic signal from the controller.
- Diaphragm plate – a plate attached to the diaphragm that transmits force to the actuator stem.
- Upper and lower housings – casings that enclose the diaphragm and form two pressure chambers, one above and one below the diaphragm.
- Range spring – a spring that opposes the air pressure force on the diaphragm.
- Spring adjustor – a fitting that is used to adjust the compression of the range spring.
- Spring seat – a seat that holds the range spring in position and provides a contact surface for the spring adjustor.
- Actuator stem – usually a rod attached to the diaphragm plate on one end and the valve stem on the other end.
- Stem connector – a clamp that locks the connection between the actuator stem and the valve stem.

- Yoke – the part of the actuator that connects the actuator to the valve body.

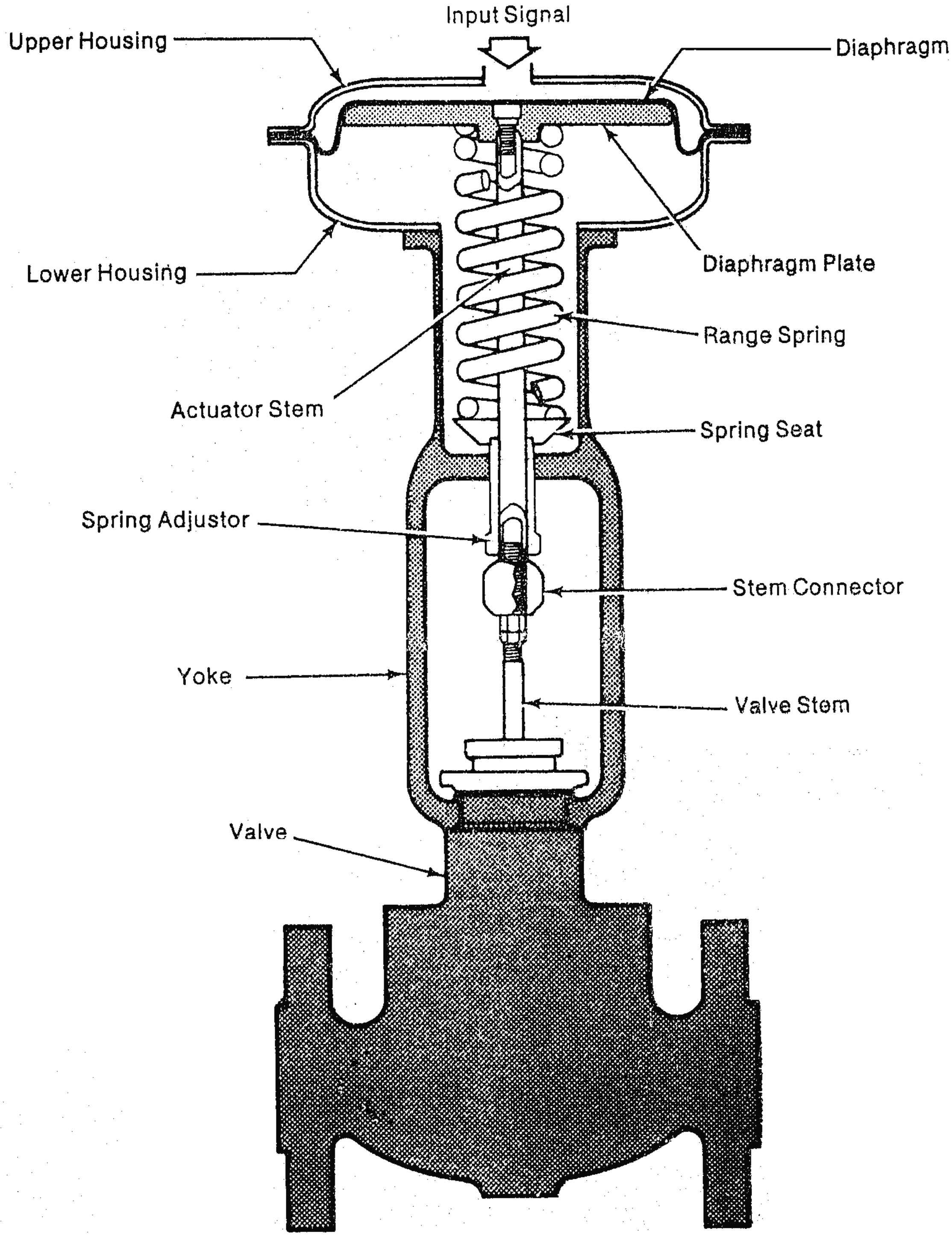


Figure 2.1b: Typical Example of Diaphragm Actuator

c) <u>Piston Actuators</u>

Another type of pneumatic actuator is a piston actuator. This type of actuator uses a piston stead of a diaphragm to convert the output signal from the controller to movement to position the valve.

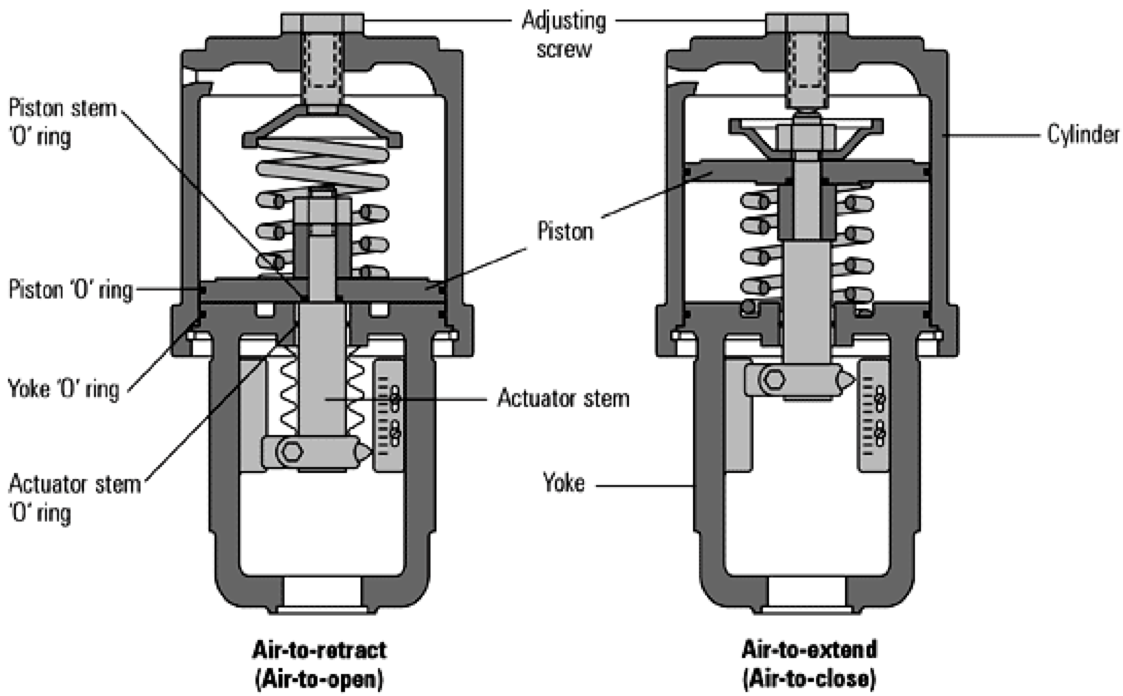


Figure 2.1c: Typical example of piston type actuator

Piston actuators are often used in industrial processes that operate at high process pressures. The piston actuator makes it possible to use much higher air pressure to position a valve. This higher air pressure compensates for strong upward pressure effects of fluids underneath the valve plug, and also helps to overcome friction that may be present in the valve trim.

Many piston actuators are used with an accessory device, called a positioner. The positioner receives the signal from the controller_and compares the signal with the actual valve position. The output signal from the positioner goes to the piston actuator, which moves the valve stem and plug to the required position: The positioner helps to obtain quick and accurate positioning of the valve stem and plug. This usually results in faster and better control of the process variable.

In a piston actuator, the piston rod moves the valve stem and plug to the required position. Some piston actuators also have a spring that opposes the input pressure on the piston in the same way that the range spring in a diaphragm actuator opposes the input to the diaphragm. The spring provides a fail-safe capability; in case of air failure, the spring will move the piston rod to the correct fail-safe position for the valve. Other piston actuators may not have a spring. Actuators of this design depend on the positioner to provide the fail-safe capability.

Other components of a piston actuator may include the cover, or outer casing, and several O-ring seals.

Operation of a Piston Actuator

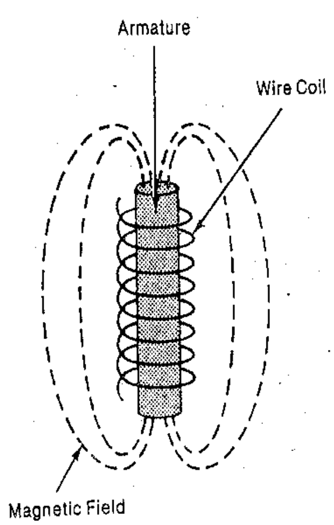
Piston actuators usually operate with a positioner. The positioner constantly compares the control valve position with the controller signal. The output signal from the controller enters a pilot valve assembly inside the positioner. The pneumatic pressure from the pilot valve causes the piston to move to meet process requirements. The piston continues to move until the forces inside the positioner balance the force of the actuator spring or the pressure under the piston. When the forces are equal, the positioner output pressure stabilizes to maintain the piston, and the control valve, in the correct position.

In a single-acting piston actuator, the piston moves in one direction in response to the input signal from the positioner. It is moved in the opposite direction by a spring. Other actuators are double-acting. This means that the piston will move upward and down- ward in response to pneumatic input signals. It is important to determine whether a piston actuator is single-acting or double-acting before maintenance is performed on the actuator.

d) Solenoid Actuators

Actuators can also be powered by electricity. Electric actuators are often used when on-off capability of the valve is all that is required by the process.

Electric actuators may be used when instrument air is not available, in isolated locations, or as a backup emergency supply if air supply failure occurs.



One type of electric actuator is a solenoid. A solenoid is a mechanism that operates by the principle of electromagnetism. A solenoid consists of a wire coil that generates a magnetic field when an electric current passes through it. When the coil is energized, a metal bar, called the armature, is attracted by the magnetic field and is drawn up inside the coil. When the current is turned off, the magnetic field collapses and the armature is pushed back out of the coil by a spring. Coils may be provided with two sets of windings to allow use with either 115 V ac or 230 V ac.

Figure 2.1d: Solenoid(Internal)

When a solenoid is used as an actuator, it is usually mounted on top of a valve. The armature in the solenoid is connected to the valve stem. When current goes through the coil, the solenoid opens or closes the valve as the armature moves into and out of the coil.

Solenoids provide only on-off, open-closed capability. One application for a solenoid-operated valve would be to interrupt airflow to a pneumatic final control, element.

Solenoids can be designed for use in explosive atmospheres and are contained in explosion-proof bodies or housings.

If excessive hum is noted in a solenoid valve, a possible cause may be a dirty armature. The valve and actuator unit should be checked for buildup of dirt oil or process residues that could cause the valve to stick or prevent it from opening and closing fully. Another cause of excessive hum could be improper voltage through the coil.

If a solenoid-operated valve chatters, the valve might be stuck. This would require servicing or the solenoid and valve unit. Another problem may be an over-heated coil. This might indicate that the solenoid may be used in the wrong application for its design. For example, the coil may not be designed to be energized 100% of the time, but 100% is required for the particular process in which it is being used." If this were the case, a different solenoid or another type of electric actuator may lie needed. Chatter could also be caused by improper voltage.

Replacing a Solenoid Coil

Maintenance on solenoids usually involves replacement of the coil. The new coil must then be tested to determine whether it energizes when electric current is applied.

The solenoid and valve unit can be mounted in the shop for maintenance, or the valve can be isolated and tagged out and the solenoid replaced in the field.

- Disassemble the coil from the valve by removing the locknut, the manufacturer's nameplate, and any small parts such as protective metal sleeves that fit around the armature.
- Remove and discard the defective coil.
- Install the new coil by placing it over the armature.
- Replace the metal sleeves and other small parts.
- Tighten the locknut.

e) <u>Electric Motor Actuators</u>

Another kind of electric actuator is a <u>motor actuator</u>. This type also opens and closes control valves. Motor actuators require electrical power to the motor and an electrical input signal from the controller. The motor moves the valve through a gear train. The gear train usually includes protective devices, such as limit switches, to provide travel limits in both the open and closed valve positions. When the valve reaches the end of its travel, open or closed, the limit switch breaks the electrical circuit and the motor stops. Another electrical input signal from the controller drives the motor back in the opposite direction, and a second limit switch stops the motor again when the valve has moved fully through its stroke.

If a motor actuator is not driving the valve properly, one possible cause may be that the limit switches are not adjusted properly. These switches are connected to cams that can be positioned as required to permit interrupting the electrical circuit to stop the motor at any point. The cams should be adjusted so that the limit switch stops the motor when the valve is fully opened or closed. If the motor continued to drive past the end of the valve's travel, damage to the valve could result or the motor might overheat and bum out.

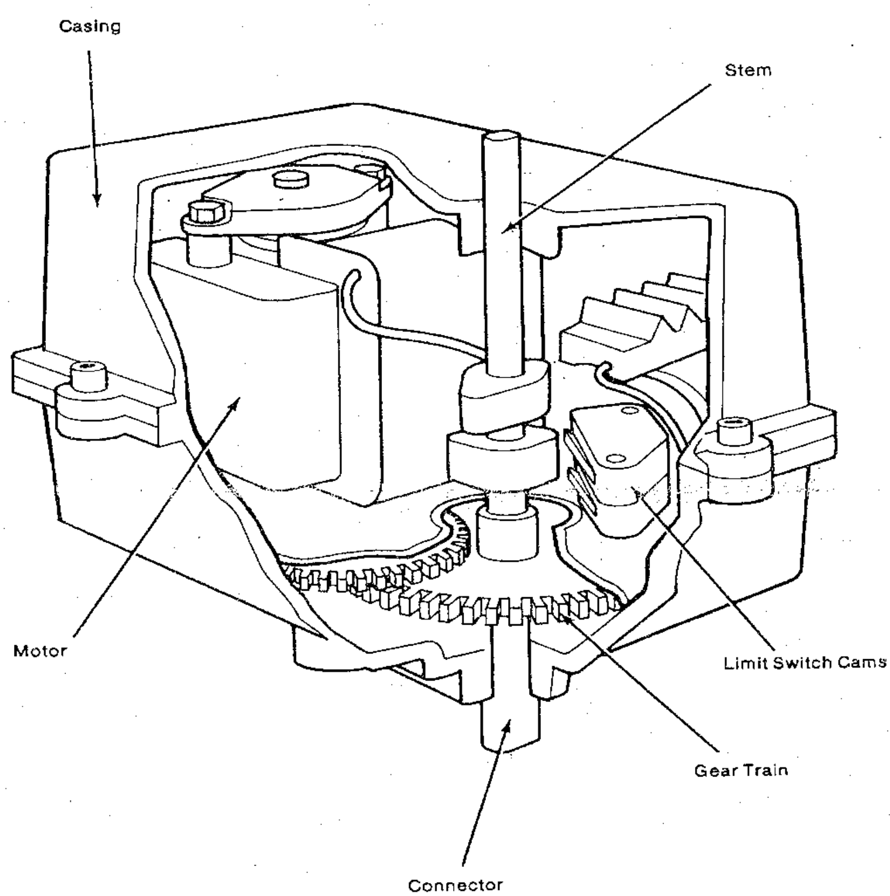


Figure 2.1e: Cutaway View of Electric Motor Actuator

Exercise 6: Basic Operation & Testing of Diaphragm Actuator

Objective: To be able to know the basic principles of operation of a diaphragm type actuator.

Actuator Operation:

Pneumatically operated diaphragm actuators use air supply from controller, positioner, or other source.

Various styles include: direct acting (increasing air pressure pushes down diaphragm and extends actuator stem, figure 6-1); reverse-acting (increasing air pressure pushes up diaphragm and retracts actuator stem, figure 6-2)

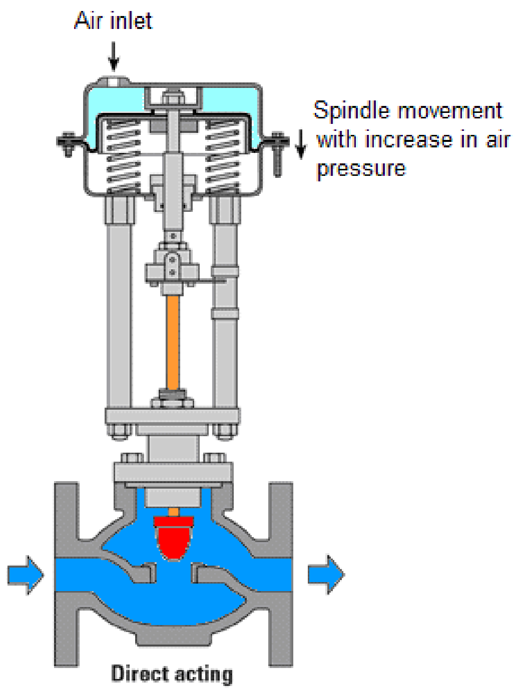


Figure 6-1: Direct acting

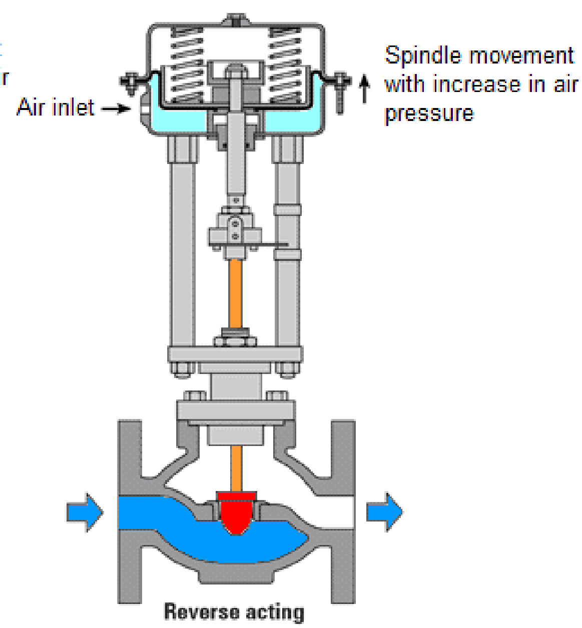


Figure 6-2: Reverse Acting

Cutaway view of diaphragm actuators

Equipment List:

- Diaphragm Actuator
- Regulated Air signal 3-15 psi or .2- 1.0 bar pressure
- ¼" Tubing and Fittings

Procedure:

1. Connect Instrument signal tube from regulated signal pressure to the inlet port of the diaphragm actuator.

2. Apply .2 bar signal pressure to the actuator, the valve travel position must be fully closed for the “air fail closed” valve and fully open for the “air fail open” valve.

3. Apply 1.0 bar signal pressure to the actuator, the valve travel position must be fully open for the **“air fail closed”** valve, and fully closed for the **“air fail open”** valve.

4. Check valve linearity travel position from 0%, 25%, 50%, 75% and 100% stroke.

5. Use sample data shown below.

“Air to open”

Signal input (bar)	Valve Travel indication
0.2 bar	0% Fully close
0.4 bar	25% open
0.6 bar	50% open
0.8 bar	75% open
1.0 bar	100% Fully open

“Air to close”

Signal input (bar)	Valve Travel indication
0.2 bar	100% fully open
0.4 bar	75% open
0.6 bar	50% open
0.8 bar	25% open
1.0 bar	0% fully close

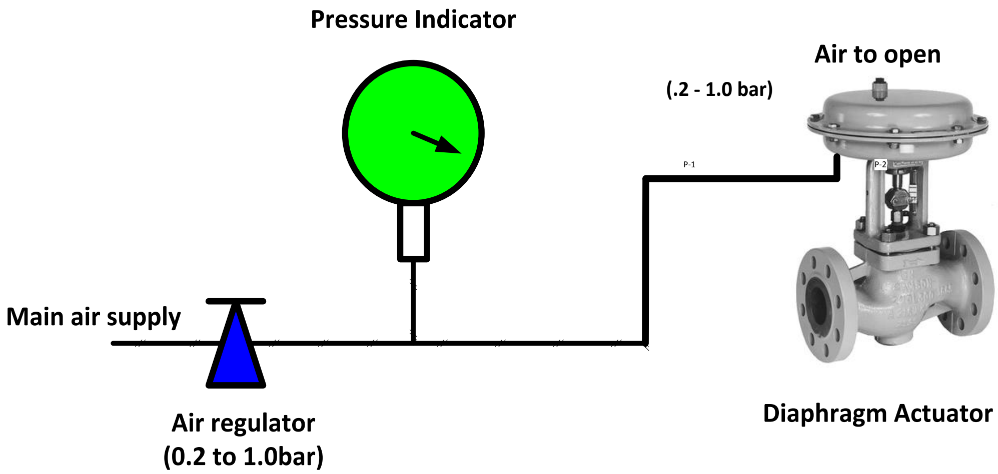


Figure 6-2: Testing Hook up of Diaphragm Actuator

Questions:

1. Describe the principles of operation of a diaphragm type actuator?

2. What does it mean by “Air fail close” and “air fail open”?

3. Enumerate the basic parts of a typical diaphragm actuator?

4. What is the material used as a diaphragm of the actuator?

Exercise 7: Basic Operation & Testing of Single Acting Pneumatic Actuator

Objective: To be able to know the principle of operation of the single acting pneumatic actuator and how it works.

Introduction:

<u>Single Acting (Fail Close) Single Acting Fail Open)</u>

Single actuators convert pneumatic energy into mechanical energy to produce work. This is usually only carried out during the forward stroke movement of the actuator. The actuators force (lbs) which is exerted via the piston and the piston rod which increases in accordance with the piston area expressed in (in^2) and the air pressure in the actuators chamber. Usually the force to return the piston is a mechanical spring: this is normally accomplished when air is exhausted from the actuator. However, in some pneumatic applications when using pneumatic single-acting actuators the spring may be place on the piston end to allow the actuator to snap into place, example shot pins, when air is shut off. This usually occurs when emergence “E”-stops application are energized on the machinery.

<u>Single Acting – General Principle:</u>

- Normally used in on/off applications
- Valves open or close (Predetermined) in case of power or air failure.
- Fail safe position: close/open as pre-determined (depending upon customer requirements)
- Only one air inlet port.
- 3/2 Solenoid Valve is used for air supply.
- Air to open/ Spring to close.
- Air to port A forces the piston outwards causing the springs to compress: the pinion turns counter clockwise while air is exhausted from port B.
- In the event of loss of air pressure on port A, the stored energy in the springs forces the piston inwards. The piston turns clockwise while air is exhausted from port A.

Figure 7-1: Single acting Actuator

Equipment List:

- Pneumatic actuator
- Solenoid valve 3/2-way
- 24VDC Supply
- Start push button switch (momentary)
- ¼ O.D. tubing & fittings
- Hand tools

Procedure:

1- Connect air supply tubing to the solenoid valve input and connect the output to the pneumatic actuator port.

2- Connect 24VDC supply to the solenoid valve coil in series with the ON/OFF switch.

3- Apply desired air supply to the solenoid valve and operate the ON/OFF switch.

4- Record your observations during the solenoid energize and de-energize condition.

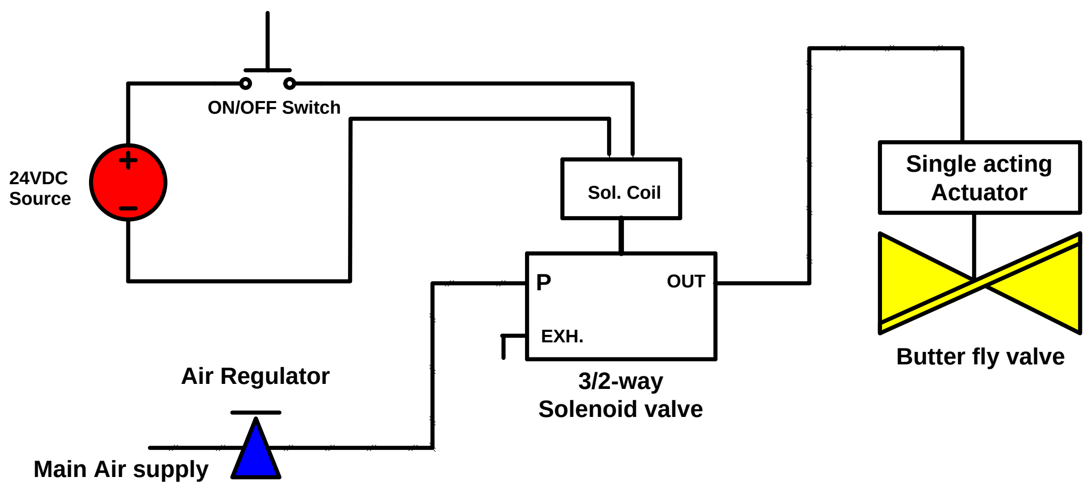


Figure 7-2: Testing hook up of Single Acting Pneumatic Actuator

Sample data:

Solenoid status	Valve position status
Energize	
De-energize	

Questions:

1. How do you identify a single acting actuator?

2. What is the type of solenoid used for single acting actuators?

3. What is the valve fail position if the air supply is disconnected?

4. What is a single acting pneumatic actuator?

Exercise 8: Basic Operation & Testing of Double Acting Pneumatic Actuator

Objective: To be able to know the basic principles of the double acting pneumatic actuator and how it works.

Introduction:

In double acting actuators, compressed air is applied to the inlet port which is fed via a large bore support rod into the centre chamber. This forces the pistons apart and turns the actuator's output drive anti-clockwise for valve opening, simultaneously venting the air in the end chamber via a second support rod through the outlet port. The operation can be reverse by reversing the air supply to the inlet and outlet ports, this will provide clockwise rotation for valve closing.

Figure 8-1: Double acting pneumatic actuator

Equipment List:

- Pneumatic actuator
- Solenoid valve 4/2-way or 5/2-way
- 24VDC Supply
- Start push button switch (momentary)
- ¼ O.D. tubing
- Hand tools

Procedure:

1. Connect air supply tubing to the solenoid valve inlet (P) and connect the output 1 and output 2 to the pneumatic actuator port A & port B.
2. Connect 24VDC supply to the solenoid valve coil in series with the on/off switch.
3. Apply desired air supply to the solenoid valve and operate the on/off switch.
4. Record your observations during the solenoid energize and de-energize condition.

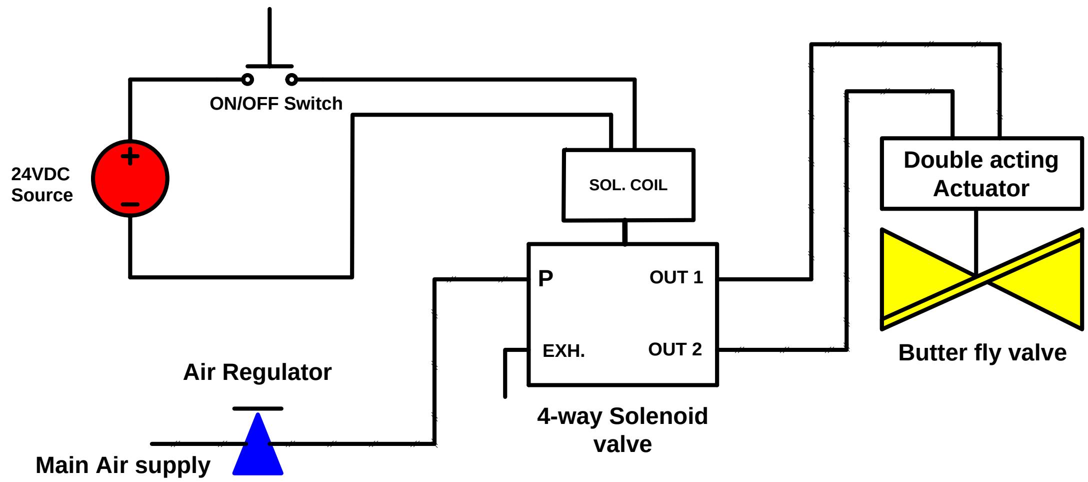


Figure 8-2: Testing Hook up of a Double Acting Pneumatic Actuator

Sample data:

Solenoid status	Valve position status (%)
Energize	
De-energize	

Questions:

1. How do you identify a double acting actuator?

2. What is the type of solenoid used to test the double acting actuator?

3. What is the valve last fail position if the air supply is isolated?

4. What is a double acting pneumatic actuator?

Exercise 9: Basic Operation & Testing of Motor Operated Actuator (MOV)

Objective: To be able to know the basic principles of operation of the motor operated actuator.

Introduction:

Electric Motor Actuators

Electric motors permit manual, semi-automatic, and automatic operation of the valve. Motors are used mostly for open-close functions, although they are adaptable to positioning the valve to any point opening. The motor is usually a, reversible, high speed type connected through a gear train to reduce the motor speed and thereby increase the torque at the stem. Direction of motor rotation determines direction of disk motion. The electrical actuation can be semi-automatic, as when the motor is started by a control system. A hand wheel, which can be engaged to the gear train, provides for manual operating of the valve. Limit switches are normally provided to stop the motor automatically at full open and full closed valve positions. Limit switches are operated either physically by position of the valve or torsionally by torque of the motor.

Equipment List:

- Motor operated valve assembly
- 4-20 ma simulator
- 24VAC Supply
- Hand tools

Procedure:

1- Open actuator top cover and connect 24VAC supply for MOV at terminal no. 54 and no. 1.

2- Connect 4-20 ma current simulator at input terminal no. 57 & 59.

3- Refer to MOV wiring configuration on **Figure 9-1**.

4- Turn on 24VAC supply and apply 4ma signal, the valve should be fully close. Apply 20ma signal, the valve should be fully open.

5- Verify MOV linear calibration from 0%, 25%, 50%, 75% & 100%. And record your observation below sample table.

Note: This valve is factory set and calibrated, may not require adjustment.

Sample Table:

Input signal (ma)	Valve status (%)
4 ma	
8 ma	
12 ma	
16 ma	
20 ma	

WIRING CONFIGURATION FOR MOTOR OPERATED VALVE TYPE: SM65/60-6
MFR: SAMSON

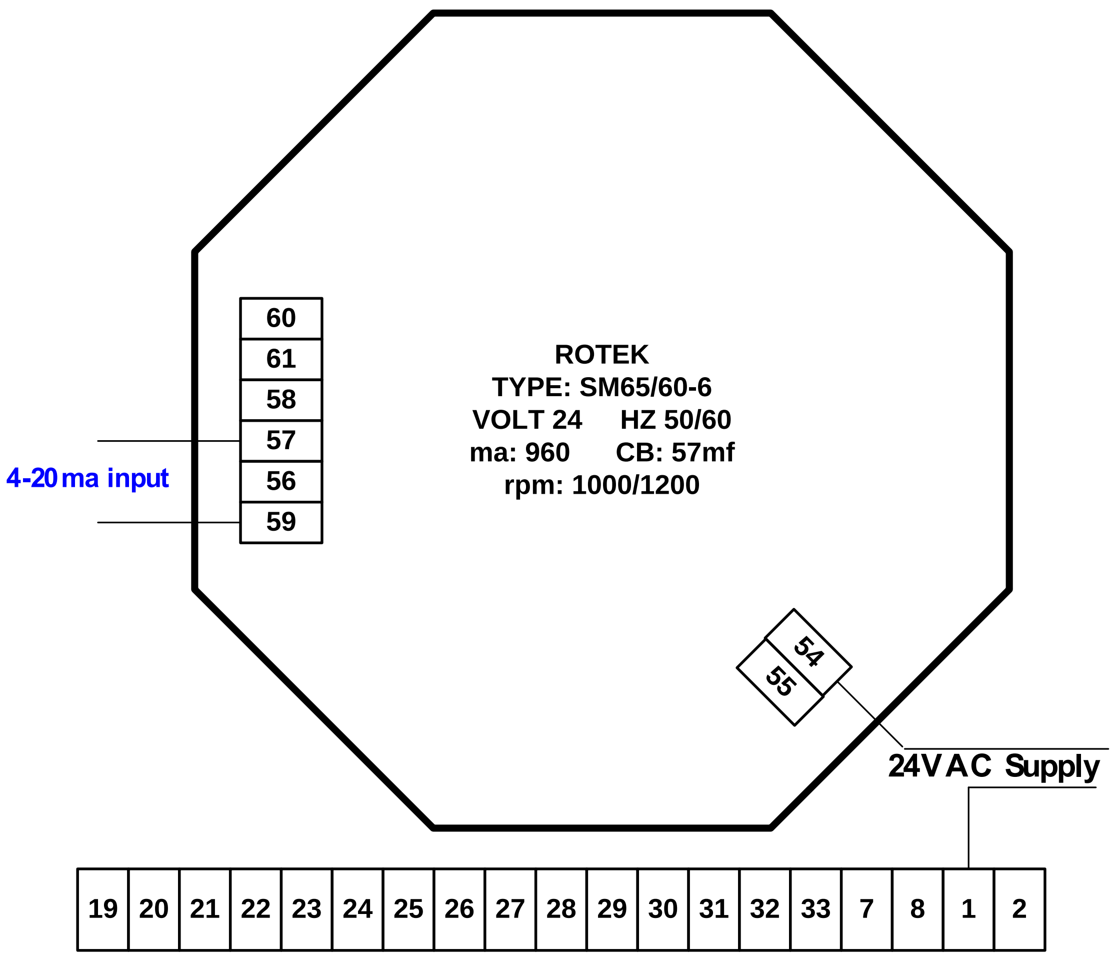


Figure 9-1

Questions:

1. What is the application of electric motor actuator or MOV’s?

2. What does it mean by MOV?

3. What is the purpose of limit switches installed on MOV’s?

4. Motor operated valves is driven by
    a. air signal
    b. hydraulic fluid
    c. electric motor
    d. solenoid valve

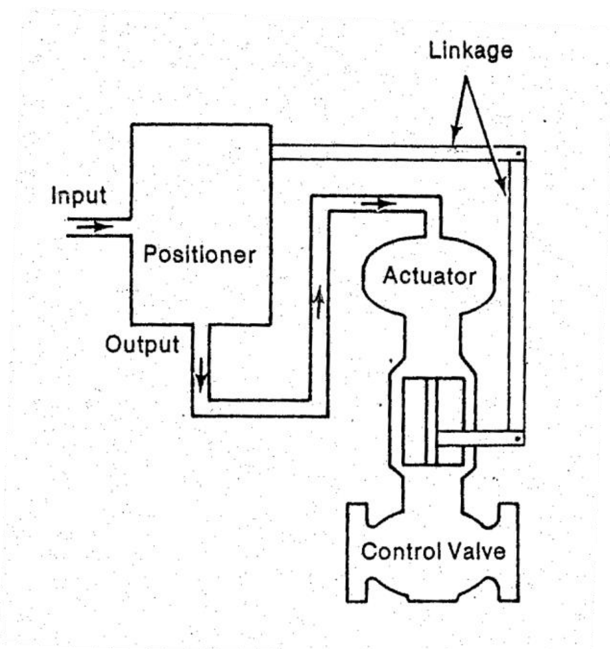
Unit 3: Introduction of Valve Positioner

Positioners are accessory devices to actuators. Positioners work with actuators to accurately control the position of a control valve. Positioners compare the control valve stem position with the signal from the controller. If the control valve is not correctly positioned, the positioner changes the valve position by increasing or decreasing the signal to the actuator.

Positioners function as pressure-to-position converters. The process controller sends a low volume pneumatic signal to a positioner. The positioner boosts the signal volume and sends the signal to the actuator which positions the valve.
A positioner's output signal may not be equal to its input signal. This is because the positioner compares the input signal to the actual valve position. The value of the output signal changes to move the valve to the required position. The positioner, actuator, and control valve form a feedback loop. The linkage between the positioner and the valve often includes a cam and a lever arrangement.

Components of Force-Balance Positioners

Positioners operate on the principle of force-balance or motion balance. The first positioner shown on the figure is a force-balance positioner. The components of a force-balance positioner are usually arranged so that two forces oppose each other. One force is created by the input signal from the controller. The other force is created by the feedback from the control valve, indicating the valve position.



The following parts are common to many force- balance positioners. Check the manufacturer's instructions for the parts specific to your positioner.

- Cam – rotates and transmits motion from the linkage to the follower wheel.
- Follower wheel – transmits motion to the lever.
- Lever – moves the feedback spring.
- Feedback spring – pushes against the diaphragm.

- Diaphragm – moves in response to force from the feedback_spring and in response to the input signal from the controller. The two forces oppose each other.

- Pilot valve – moves in response to the positioner diaphragm. The position of the pilot valve controls the value of the input signal to the actuator.

The signal from the positioner causes the actuator stem and the control valve stem to move. The position of the control valve is fed back to the positioner through the mechanical linkage. As the linkage moves, it causes the cam to rotate. As the cam rotates, the follower wheel moves the lever. The lever moves the feedback spring by changing its compression. The spring pushes against the diaphragm. The pressure from the spring opposes the force of the pneumatic signal from the controller. When the forces on the diaphragm are equal, the control valve should be in the proper position. The feedback loop is complete. When the input signal from the controller changes or if the control valve position changes as a result of process conditions, the positioner sends a pneumatic signal to the actuator to correct the control valve position.

Positioners usually have a bypass valve that permits the positioner to be isolated from the actuator for maintenance. When the bypass valve is in the bypass position, the input signal from the controller goes directly to the actuator. When the bypass valve is in the "positioner" position, the input signal from the controller goes to the positioner.

Positioners usually have three gages:

- Output gage – indicates the output signal pressure to the actuator.
- instrument gage – indicates the instrument signal pressure to the positioner, and
- Supply gage – indicates supply pressure to the positioner.

Figure 3: Example of valve positioner with three gauges

When Positioners are used with actuators to position control valves. They are used in process applications that require additional control capabilities.

Positioners can be used to provide:

- Rapid responses to changes in process conditions – The faster response capability can speed reduce the response of a control valve. This can be the lag effect of long important when the controller is located at a considerable distance from the valve. The further the distance of the controller to the valve, the longer it will take for the actuator to respond to changes in process conditions. A positioner can speed this response.

A positioner can reduce the lag effect of long transmission times.

- Compensation – for, the pressure effects of process fluids under the valve plug that could affect the valve position.

- Compensation for friction in the valve trim.

- Split-range operation – In split-range operation, one valve operates over part of the output signal range of the controller and a second valve operates over another part of the output signal range. The positioner permits more than one by a single controller valve to stroke fully in response to specified portions of the input signal range from the controller.

Split-range operation is the staggered operation of two or more control valves by a single controller.

- Amplification of the controller output signal – A positioner can amplify a signal pressure may be required by the actuator to position the valve.

Positioner amplification is often used to increase the shutoff rating of single-seated valves.

- A change in control valve flow characteristic – Cams inside some positioners can determine the valve's flow characteristic.

Summary of Application: The valve positioner is used for the following reasons:

1) Quick action of control valve
2) Valve hysteresis
3) Valves use in viscous fluids
4) Split range
5) Line pressure changes on valve
6) Valve bench set not standard
7) Reversing valve operation

Motion–Balance Positioners

In the preceding segments, we worked on a positioner that operated by the force-balance principle. Other positioners operated by the forced-balance principle. Other positioners operate by the motion-balance positioners principles. Control valve positions are also fed back to the positioner through a series of linkages to a cam.

In motion-balance positioners, the input signal from the controller goes to a pressure-to-position converter. In the positioner shown on the figure, the converter was a bellows. The graphic on the opposite page shows the position of the bellows. The input signal causes the bellows to expand, pushing against one end of a beam. There is a flapper attached to the beam that moves in relation to a nozzle as the beam moves. Backpressure in the nozzle provides the input to a small relay. The relay output is fed to the actuator, causing the actuator stem to move and reposition the control valve.

Movement of the control valve is fed back to the positioner through a linkage and a cam. The cam pushes against the other end' .of the beam and re-positions the flapper in relation to the nozzle. The motion caused by this force opposes the motion caused by the bellows. The two motions balance each other and equilibrium is established.

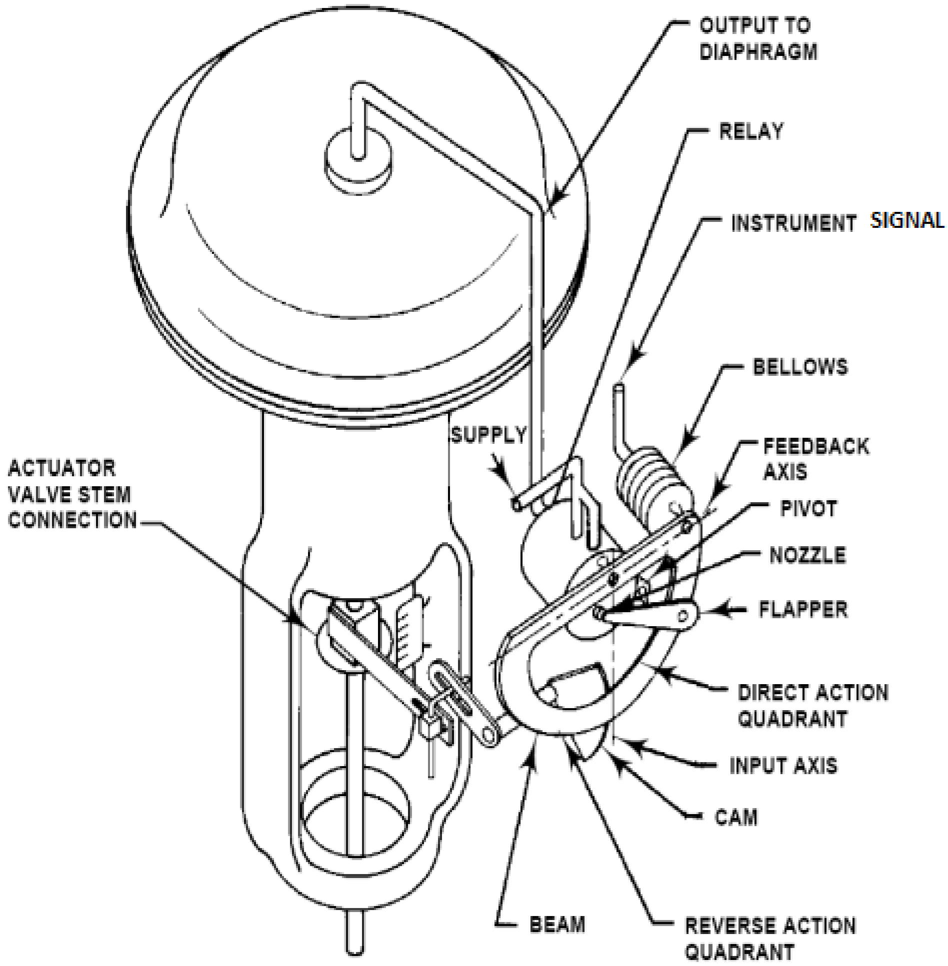


Figure 3a: Positioner Schematic for Diaphragm Actuator

Lesson 3.1: Pneumatic Positioner

Principles of Operation:

The pneumatic valve positioner receives a pneumatic input signal from a control device and modulates the supply pressure to the control valve actuator, providing an accurate valve stem position that is proportional to the pneumatic input signal.

Fig.3.1a: 4700P-4700E Pneumatic Positioners Camflex type

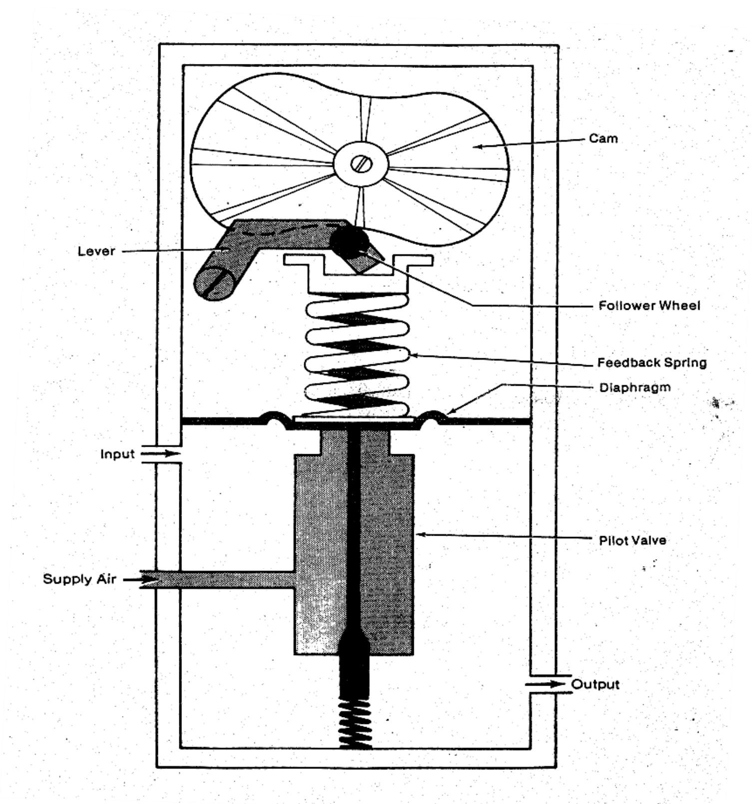


Fig. 3.1b: Schematic view of 4700P Pneumatic Positioner Camflex Type

Exercise 10: Calibration of Control Valve with Pneumatic Positioner

Objective:

- To study the principle of operation of pneumatic positioner
- To be able to know how to calibrate the control valve with pneumatic positioner.

Introduction:

Pneumatic valve positioners have diaphragms or bellows to sense the incoming signal from the controller and feed back devices from the valve stem. The unit may be position balanced or force balanced. Any error in the two signals causes a proportional change in the output of a pilot valve.

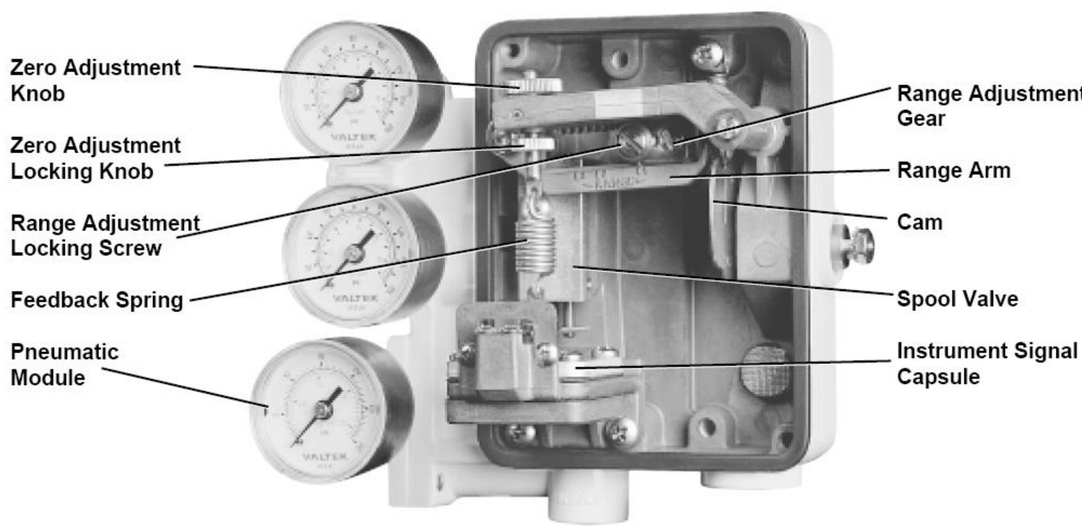


Figure 10-1: Cutaway of Valtek Beta Positioner-Pneumatic

Equipment List:

- Control Valve
- Pneumatic Positioner
- ¼ O.D tubing
- Process Calibrator
- Hand tools

Procedure:

1- Connect the tubing and apply required air supply to the valve positioner supply port. (see valve specification sheets for details)

2- Connect the process calibrator to the valve positioner input and apply the standard pneumatic signal (3-15psi) or (.2 – 1.0 bar).

3- For **"Air to Close"** valve action, at 3psi the valve should be fully open and at 15psi the valve should be fully close. If not, adjust zero and span. Likewise for **"Air to Open"** valve action, at 3psi the valve should be fully close and at 15psi the valve should be fully open. If not, adjust zero and span.

4- Verify control valve linear calibration from 0%, 25%, 50%, 75% & 100%. Record your observation using sample valve calibration sheet provided.

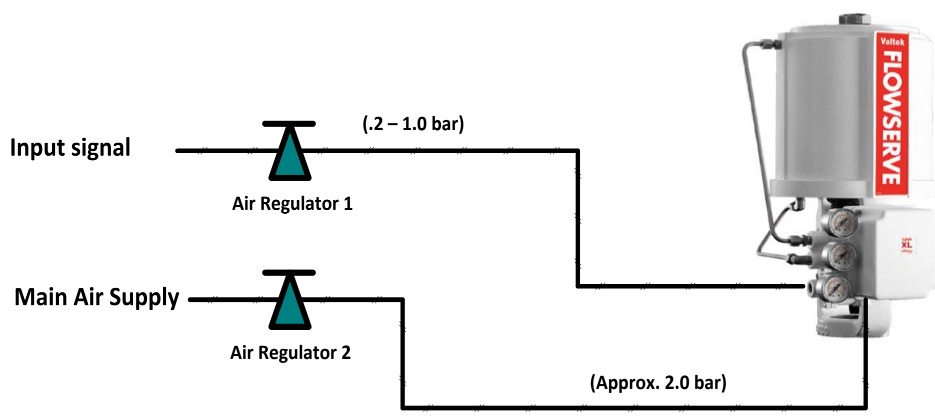


Figure 10-2: Calibration Hook up of Pneumatic Positioner

SAMPLE CONTROL VALVE CALIBRATION SHEET

Tag No. ___________ **"Air to close"**

Input signal	Valve Position % (as found)	Valve Position % (as left)
0.2bar		
0.4bar		
0.6bar		
0.8bar		
1.0bar		

Calibrated by: ______________
Date: __________

Tag No._____________ **"Air to open"**

Input signal	Valve Position % (as found)	Valve Position % (as left)
0.2bar		
0.4bar		
0.6bar		
0.8bar		
1.0bar		

Calibrated by: ______________
Date: __________

Questions:

1. How do you calibrate a valve with pneumatic positioner?

2. What is the input signal required for pneumatic positioner?

3. How will you change the valve characteristic with a valve positioner?

Lesson 3.2 Electro Pneumatic Positioner:

<u>Principles of Operation:</u>

The I/P transducer converts a 4-20 ma input signal to a 3-15 psi pneumatic output. The 3-15 psi output pressure is transmitted to the diaphragm on the balance arm. The unit operates on a force balance principle. The opposing force is achieved through the feedback spring and is proportional to the position of the lower arm. The lower arm position is determined by the position of the cam that is secured to the spindle and connected to the actuator shaft, thus providing the feedback from the actuator/valve. When these two forces are equal, the balance arm and the spool in the pilot valve are in the neutral position, the complete unit is in a balanced position. Air is supplied to the pilot valve through Port S and controls the air flow through Ports C1 and C2. Assume an equilibrium position. An increased control signal will defect the diaphragm (1) down, compressing the feedback spring (3). The balance arm (2) moves the spool (7) in the pilot valve (8) supplying air to the actuator. At the same time, air is exhausted from the actuator and is vented to atmosphere through the pilot valve. When the pressure imbalance exists, the actuator rotates moving the positioner shaft (6). The shaft and cam (5) rotate, forcing the lower arm (4) upwards compressing the feedback spring (3). The motion will continue until the two forces are equal and the unit is in an equilibrium position.

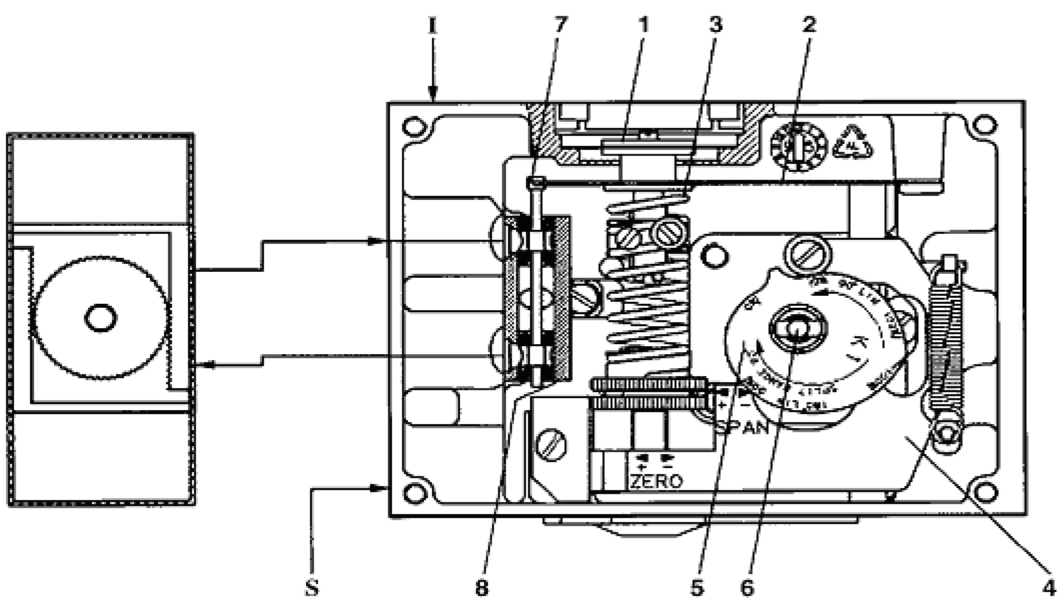


Figure 3.2-1: Schematic view of Electro-Pneumatic Positioner

Exercise 11: Calibration of Control Valve with Electro-Pneumatic Positioner

Objective:

- To study the principle of electro-pneumatic positioner.

- To be able to know how to calibrate the control valve with electro-pneumatic positioner.

Introduction:

Electro-pneumatic positioners are used in electronic control loops to operate pneumatic diaphragm control valve actuators. The positioner receives a 4 to 20 ma DC input signal, and uses an I/P converter, nozzle-flapper, and pneumatic relay to convert the input signal to a pneumatic output signal. The output signal is applied directly to the actuator diaphragm, producing valve plug position that is proportional to the input signal. Valve plug position is mechanically fed back to the torque comparison of plug position and input signal. Split-range operation capability can provide full travel of the actuator with only a portion of the input signal range.

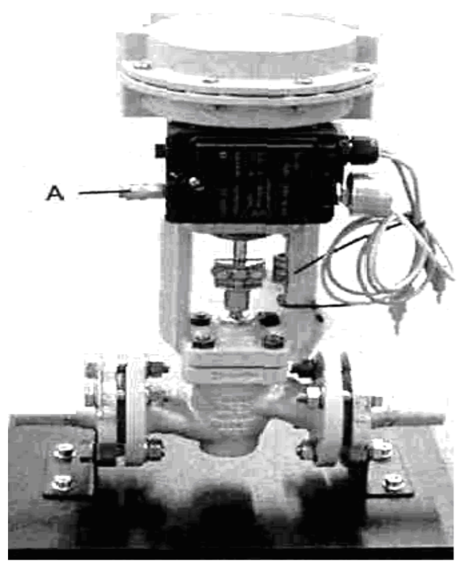


Figure 11-1: Electro-Pneumatic valve Positioner

Equipment List:

- Control Valve with electro-pneumatic positioner
- 4-20ma current simulator
- ¼ O.D. tubing
- Hand Tools

Procedure:

1- Connect tubing and apply desired air supply for the valve positioner. (see control valve spec. sheet for details)

2- Connect 4-20ma current simulator to the valve positioner input terminal.

3- Apply 4ma signal, the valve position should be fully close.

4- Apply 20ma signal, the valve position must be fully open.

5- Apply the following inputs and check the control valve linear calibration from 0%, 25%, 50%, 75% & 100%. Record your observation in the table below.

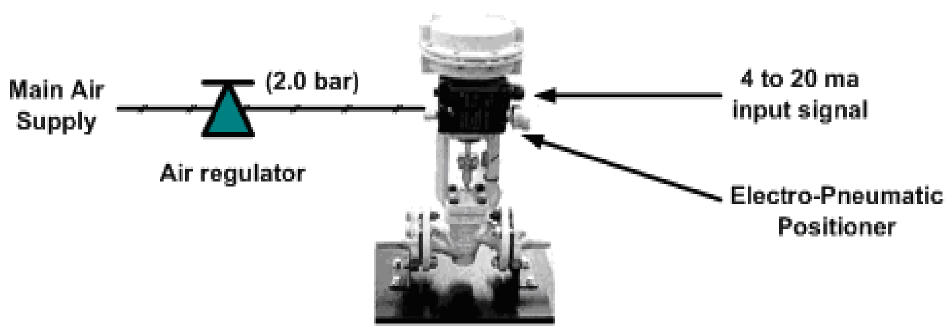


Figure 11-2: Calibration Hook-up of Electro-Pneumatic Positioner

Sample Calibration Sheet:

Input signal (ma)	Valve position (%) As found:	Valve Position (%) As left:
4 ma		
8 ma		
12 ma		
16 ma		
20 ma		

Questions:

1. What is the input signal required for electro-pneumatic positioner?

2. What is the advantage of electro-pneumatic positioner compared with the pneumatic positioner?

3. How do you identify a control valve with electro-pneumatic positioner?

Lesson 3.3 Digital Positioner:

Sometimes referred to as a SMART positioner, the digital positioner monitors valve position, and converts this information into a digital form. With this information, an integrated microprocessor offers advanced user features such as:

- High valve position accuracy.
- Adaptability to changes in control valve condition.
- Many digital positioners use much less air than analogue types.
- An auto stroking routine for easy setting-up and calibration.
- On-line digital diagnostics*
- Centralized monitoring*

*Using digital communications protocols such as HART®; Fieldbus, or Profibus.

The current industrial trend is to provide equipment with the capability to communicate digitally with networked systems in a Fieldbus environment. It is widely thought that digital communications of this type offer great advantages over traditional analogue systems.

Figure 3.3-1: DVC 6200 Fisher Smart Positioner

Exercise 12: Calibration of Control Valve with Digital Positioner

Objectives:

- To be able to know the principle of operation of a digital valve positioner.
- To be able to know how to calibrate the digital valve positioner.

THEORY OF OPERATION

Traditional positioners use a mechanical force/balance concept, whereby a pneumatic input signal forces a diaphragm down, actuating a valve which ports air into one side of a piston and vents the other side. A feedback spring provides a counterbalancing force as the actuator approaches set point.

Mechanical positioners have worked well for many years, but are subject to sticking as mechanical components become soiled, resulting in a situation where the actuator “hunts” for the proper position. The process variable is always above or below set point, providing poor control that costs significant money and causes excessive wear on the actuator/linkage/dampers system.

The FIELDVUE DVC6000/6200 Digital Valve Controller directly receives a 4-20 mA or fieldbus input signal. An independent feedback transducer provides an actuator position input, ensuring that the PowerVUE drive always moves to the set point demanded by the control system. Fieldbus versions of the DVC5000/6000 also offer PID loop control capability.

DIGITAL COMMUNICATIONS

4-20mA HART versions:

All operator information for setup and diagnostics is transmitted digitally via HART communications. A Rosemount 375 Hand-held or similar communicator may be used or a laptop computer with ValveLink Software. Emerson’s AMS offers the ValveLink software as an optional “snap-on” application. Instruments may be accessed individually or multiplexed through an “interchange” unit, providing continuous access to any number of Emerson’s instruments.

Figure 12-1: Model 375 Hart Communicator

Figure 12-2: Eccentric-Disk Rotary-Shaft Control Valve with Digital Positioner

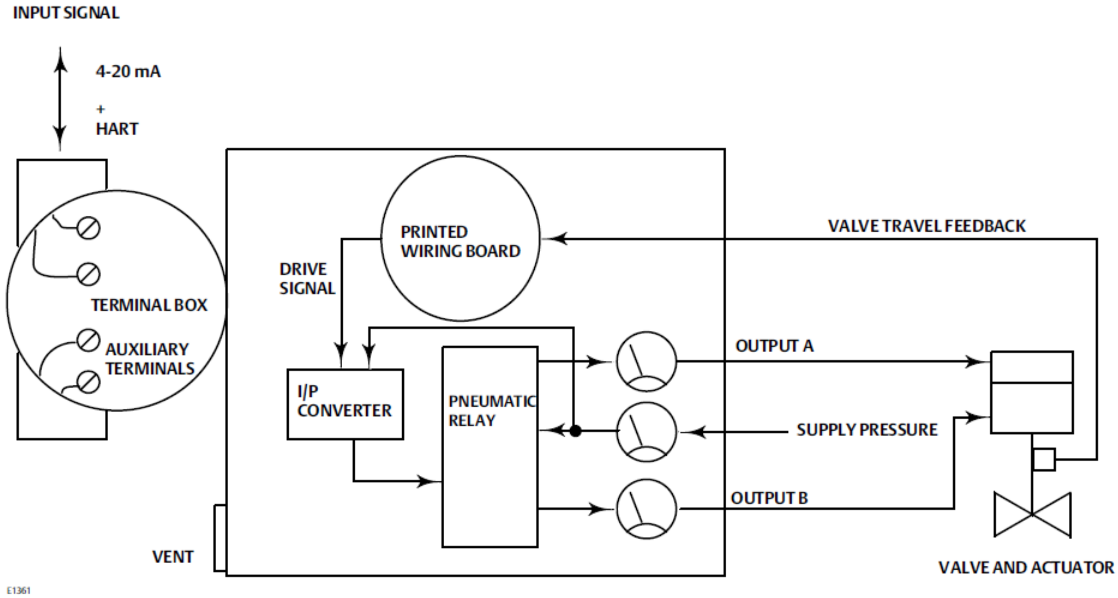


Figure 12-3: DVC 6000 Schematic Drawing

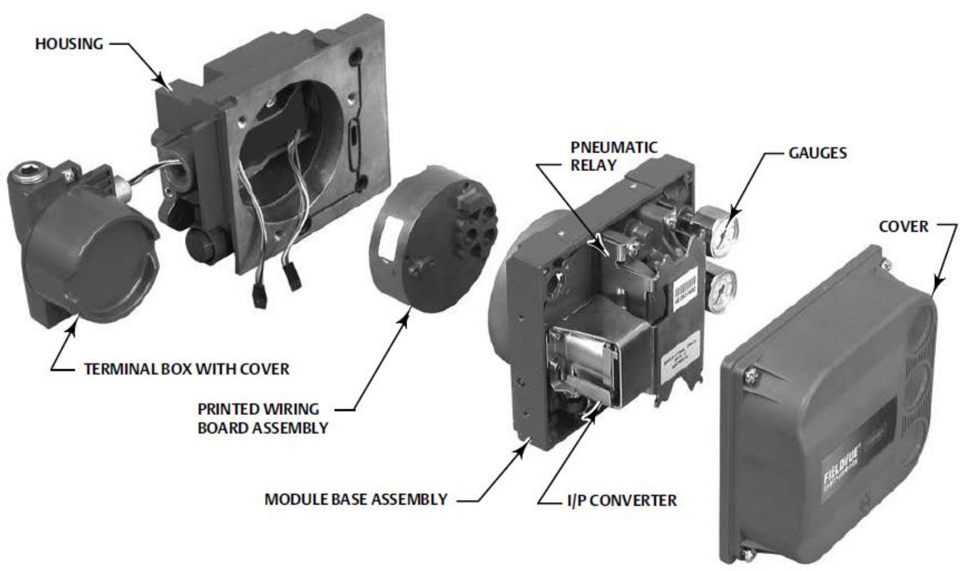


Figure 12-4: Cutaway View of FIELDVUE Type DVC6200 Digital Valve Controller Showing Master Module Assembly

Equipment List:

- DVC 6000 or DVC 6200 Valve assembly
- Air supply
- 4-20 ma source
- Hand Held Communicator Hart 375 or Hart 475

Procedure:

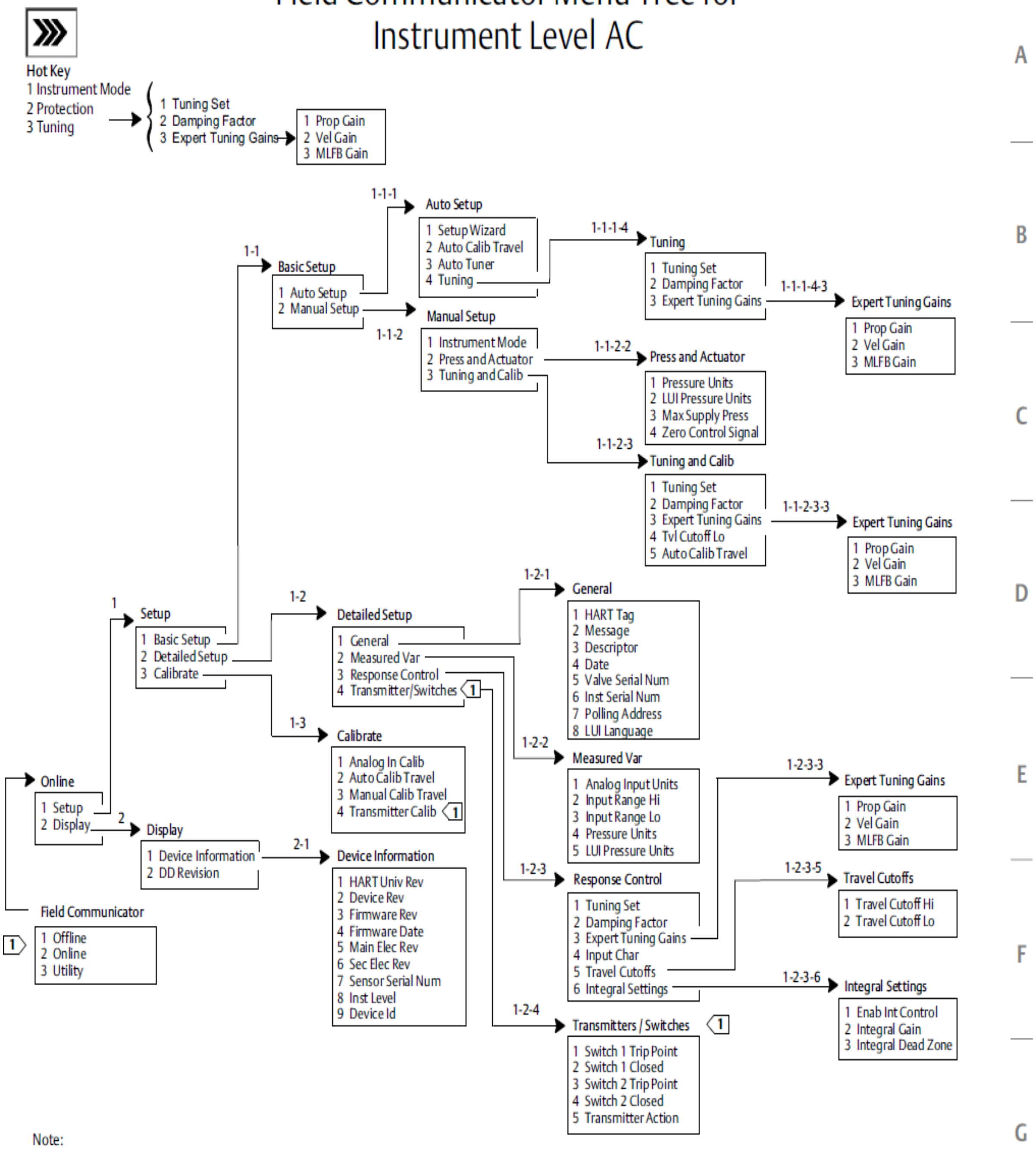
1. Connect the desired air supply to the valve positioner.

2. Connect the 4-20 milliamp source to the valve positioner input terminal as shown on schematic drawing.

3. Connect the hand held communicator parallel to the milliamp source.

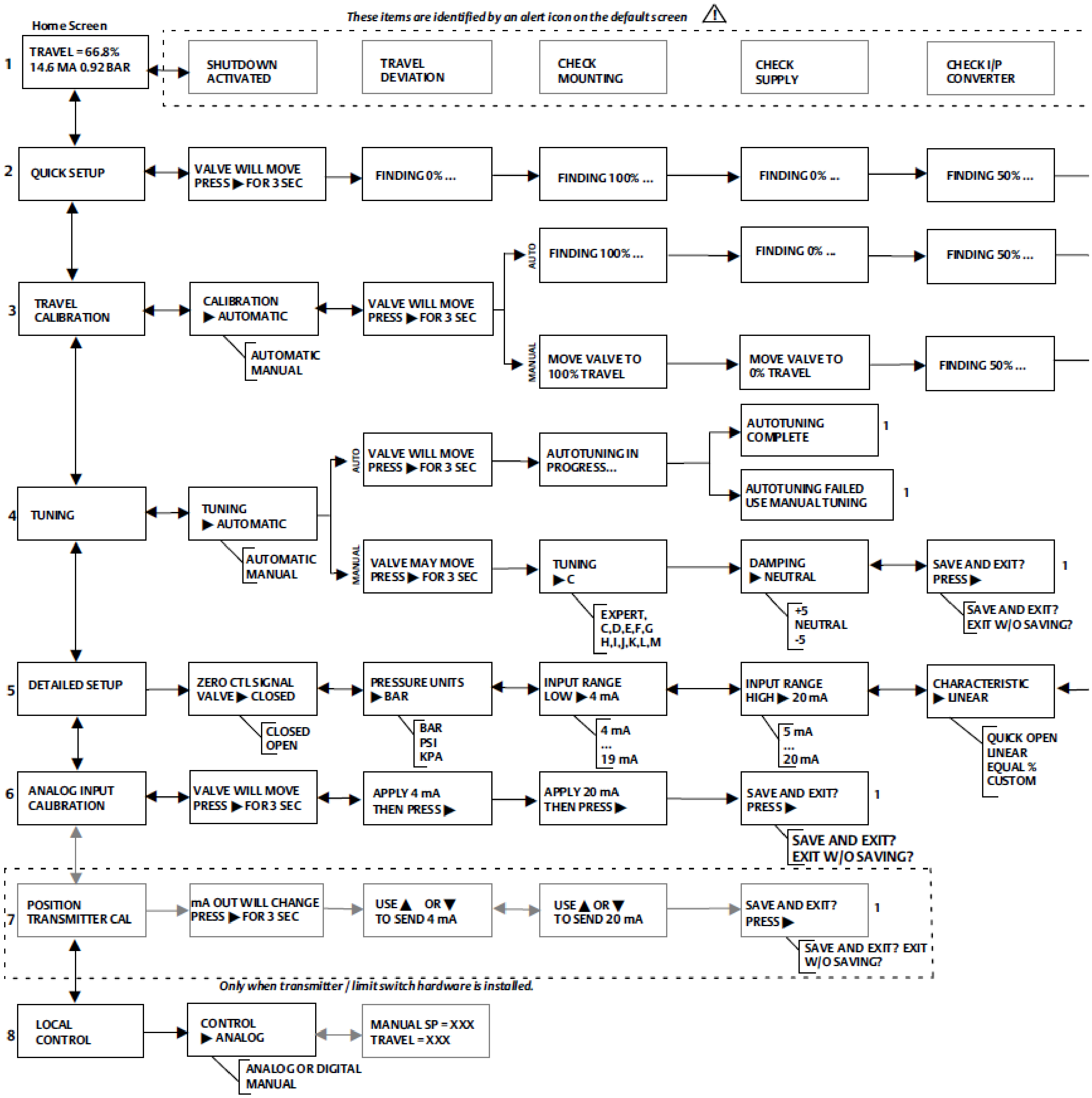
4. Follow the calibration steps using the menu tree provided on the manual. (Below is the sample calibration menu tree of Fieldvue DVC 5000 series digital positioner).

Field Communicator Menu Tree for Instrument Level AC



Note:
1 Available only if the instrument has a transmitter and limit switches installed.

Local Interface Flow Chart



Questions:

1. What are the advantages of the digital positioner compared to the mechanical or conventional type positioner?

2. What is the standard input signal for a digital valve positioner?

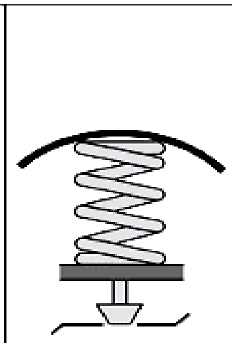
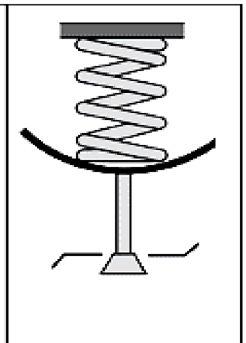
3. What is the principle of operation of the digital positioner?

4. How do you calibrate a digital valve positioner?

Unit 4: Action of Control Valve

In the previous example, the operation of the valve Air Pressure is referred to as air-to-close; when force is applied to the valve stem by the actuator in an air-to-close valve, the plug moves toward the seat, closing the valve. When the force applied by the actuator decreases, the plug moves away from the seat, opening the valve.

Some valves operate in the opposite manner. In an air-to-open valve, the force applied to the valve stem by the actuator causes the plug to move away from the seat. This movement opens the valve. When the force applied by the actuator is decreased, the plug moves toward the seat and the valve closes.

Two port valves		
Actuator action	Direct	Reverse
Valve action	Direct	Reverse
On air failure	Valve opens	

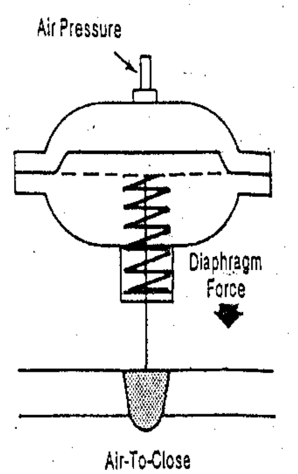
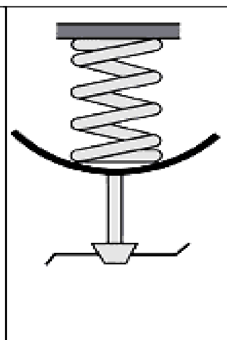
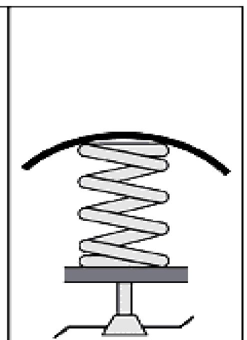


Figure 4-1a: Air Failure Valve opens

Two port valves		
Actuator action	Reverse	Direct
Valve action	Direct	Reverse
On air failure	Valve closes	

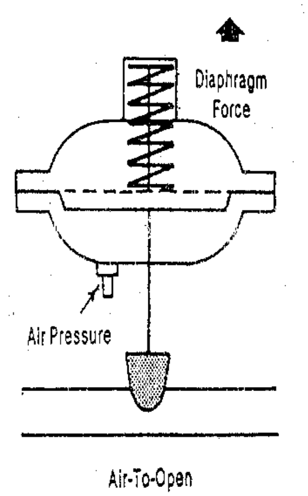


Figure 4-1b: Air Failure Valve Closes

Exercise 13: Servicing a Control Valve

Objectives:

- To study the principle of operation of FOXBORO type V1400U pneumatic control valve.
- To see the applications of a control valve.
- To learn how to disassemble and assemble of this control valve.
- To practice the adjustment procedure of this control valve.

Equipment List:

- FOXBORO type V1400U control valve.
- Pneumatic calibrator.
- Air pressure supply.
- Plastic tubing and connectors.

Discussion:

The figure below shows two control valves (FOXBORO type V1400UE) which we will work with in this experiment. The valves are shown with their diaphragm actuators. The one on the left is fail open (FO) type and the one on the right is fail close (FC) type. In this experiment we will take the valve parts and do maintenance and repair if needed.

This valve is globe type which is ideal for throttling. This type of actuator can be installed to make the valve either Fail open or Fail closed.

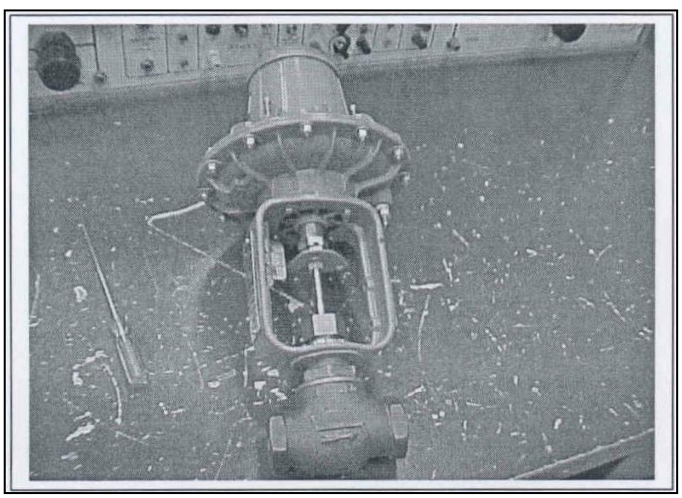


Figure 13-1: FOXBORO V1400U Control Valve

PROCEDURE:

Disconnecting The Valve From the Process:

1. Shut off block valves or turn off pump to relieve pressure within valve.
2. Remove air pressure to actuator and disconnect air line.
3. Remove the valve with the actuator from the process line if it can not be repaired in line.

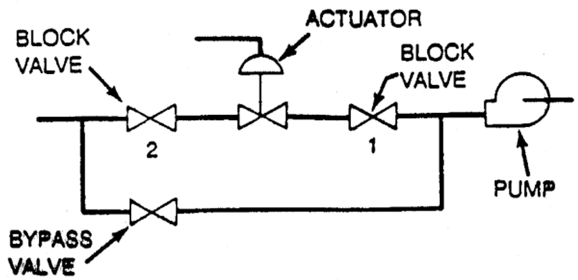


Figure 13-2: Valve P&ID diagram

Valve Disassembly:

1. Fail open only: Remove air pressure to actuator and disconnect air line.
2. Fail close only: Depending upon force exerted by the actuator spring, apply 15 to 20 psi (or 30 to 35 psi) to actuator to provide stem clearance.
3. Loosen valve stem locknut and slide loose parts down on stem.
4. Turn lower (smaller) hex portion of actuator connection assembly to unscrew valve stem. Valve stem must not turn during this step.
5. Fail close only: Remove air pressure to actuator and disconnect air line.
6. Remove bushing, and yoke lock ring. Separate yoke from valve. (**Important: do not remove the packing**)

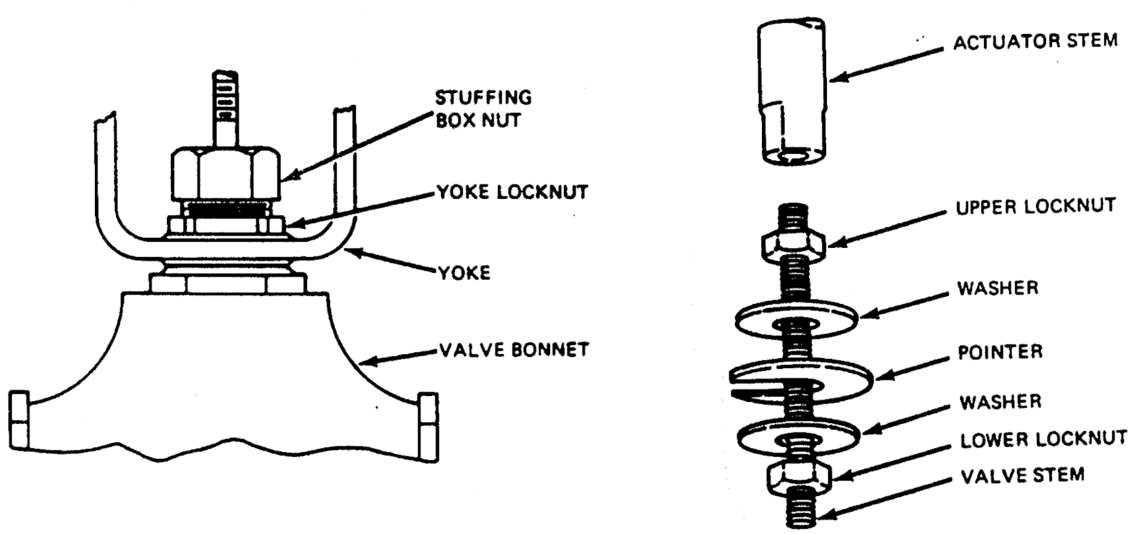


Figure 13-3: Valve external assembly

TO REMOVE ACTUATOR FROM VALVE

Removing Actuator from Other Than V1 Series Valves.

1. Shut off pump or close block valve 1 and open bypass valve. Next open control valve and block valve 2 to relieve pressure and/or drain system. Then close block valve 2 to prevent backup. Remove Actuator and valve if required.

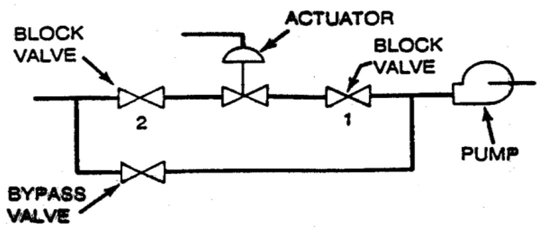


Figure13-5. Relieving Pressure within valve

2. For air-to-close action, remove air pressure to actuator and disconnect air line.

   For air-to-open action, depending on actuator spring, applies 15 to 20 or 30 to 35 psi (100 to 140 or 200 t0 240 kpa) to actuator to provide stem clearance.

3. Loosen valve stem locknut and slide loose parts down on stem (Figure 4).

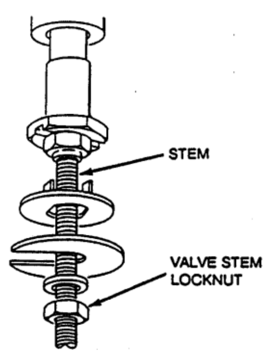


Fig 13-7. Valve Stem Locknut

4. Turn lower (smaller) hex portion of connection assembly clockwise until assembly is unscrewed from valve stem. See Figure 5.

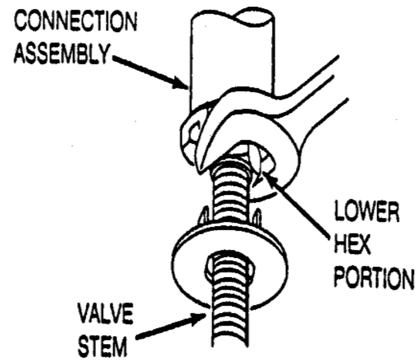


Figure 13-4. Hex Portion of Connection Assembly

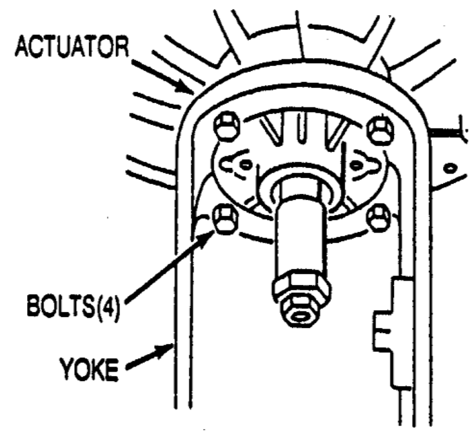


Figure 13-6. Yoke Mounting Bolts

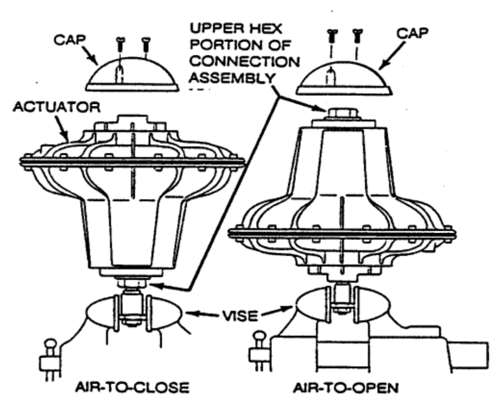


Figure 13-8. Mounting Actuator in Vise

5. Remove air pressure to actuator and disconnect air line (air-to-open action only) and remove four bolts (Figure 6) holding actuator to yoke. Lift off actuator

6. Remove actuator cap and mount actuator in vise, tightening jaws on upper (larger) hex portion of connection assembly (Figure 7).

7. Insert hex-key wrench (see table below) into recess and rotate counterclockwise. In unison, both wrench and actuator, to remove connection assembly from actuator. See Figure 8.

Actuator Model	Hex Key Size
P25A	7/16 in
P50A	9/16 in
P110A	3/4 in

CAUTION

Both hex-key wrench and housing must rotate together to avoid damaging diaphragm.

NOTE

With hex-key shipped before November 1972, actuator shafts were slotted to take a 1/8 in (3 mm) bar (instead of hex-key wrench).

Removing Actuator from V1 Series Valves

Refer to MI 012-150 to remove or reinstall actuator when using V1 Series Valves.

TO CHANGE ACTUATOR DIAPHRAGM

1. Remove actuator from valve as outlined in to Remove Actuator from Valve" section. Release spring tension by turning spring preloading adjustment nut clockwise until it turns freely (see Figure 9).

2. Disassemble actuator as shown in Figure 10.

NOTE

Figure 10 shows actuator with air-to-open action. When changing diaphragm of actuator with air-to-close action, illustration in Figure 10 should be inverted.

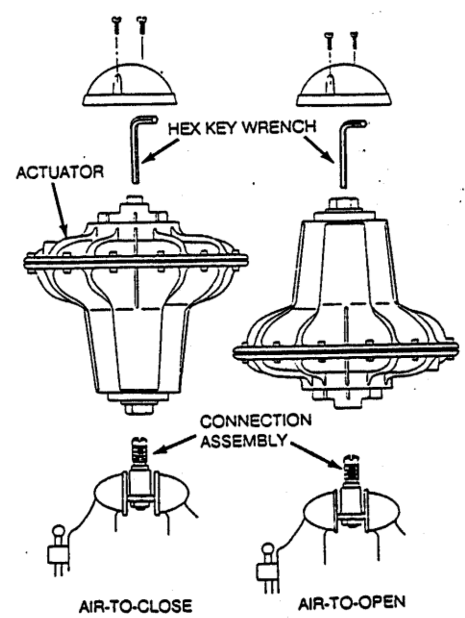


Figure 13-9. Removing Connection Assembly from Actuator

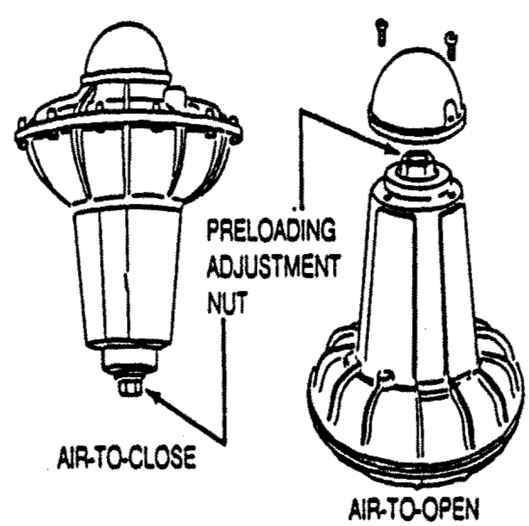


Figure 13-10. Preloading Adjustment Nut

3. Replace diaphragm and reassemble actuator but do not bolt upper and lower housings together.

4. Rotate upper housing back and forth until peripheral beading on outer edge of diaphragm falls into V-notched grooves in actuator housing. A tight seal between upper and lower housings will indicate that diaphragm is properly seated.
5. Rotate upper housing, taking care not to unseat diaphragm, until bolt holes of upper and lower housing are aligned (see Figure 11. Bolt housings together.

6. Reinstall actuator to valve as outlined in "To Install Actuator on Valve" section.

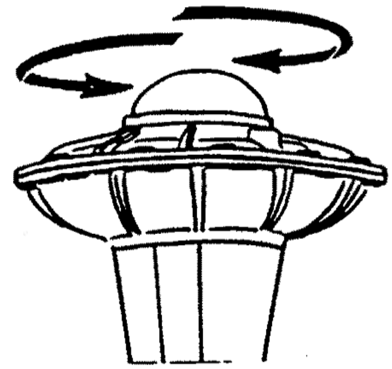


Figure 13-11.
Rotating Upper Housing

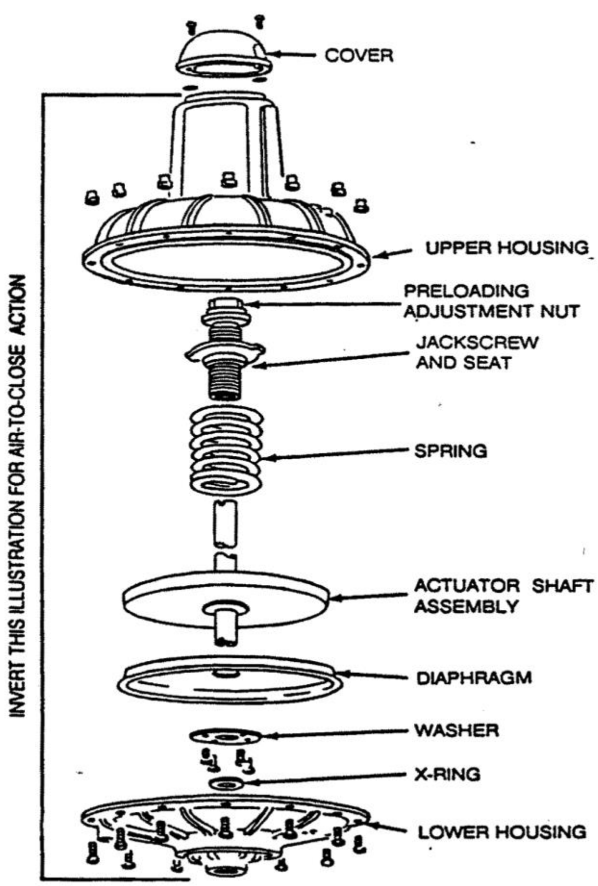


Figure 13-12 Disassembling Actuator (Air-to-Open Action Shown)

TO REVERSE ACTUATOR ACTION

The P25A, and P110A Actuators are constructed in such a manner that they can be changed from air-to-open to air-to-close operation, or vice versa, by disconnecting the actuator from the valve stem, removing the actuator from the yoke, and reinstalling in an inverted position.

Reversing Actuator Action for Other than V1 Series Valves

1. Remove actuator from valve as outlined in the preceding “To Remove Actuator from Valve” section.
2. Insert actuator and reinstall to valve as outlined in the “To Install Actuator on Other Than V1 Series Valves” section. Be sure to screw connection assembly into opposite end of actuator shaft.

NOTE

When actuator action is reversed, pressures listed on yoke data plate no longer apply. For updated data, contact Foxboro giving serial number, valve type and size, desired actuator action (air-to-open

Reversing Actuator Action for V1 Series Valves

The P25A, PSOA, and P110A Actuators are inter- changeable between air-to-open and air-to-close action by removing the actuator and reinstalling it in an inverted position.

1. Shut off pump or close block valve 1 and open bypass valve (Figure 12). Next open control valve and block valve 2 to relieve pressure and/or drain system. Then close block valve 2 to prevent backup. Remove actuator and valve if required.

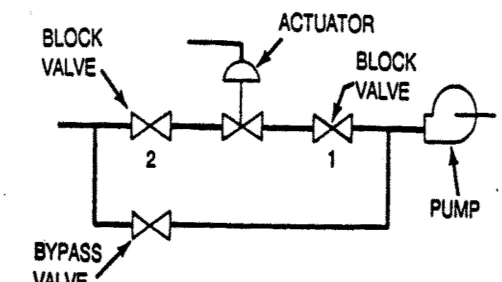


Figure 13-13. Relieving Pressure within Valve

2. Disconnect air line at actuator. If valve is equipped with a positioner, disconnect positioner lever arm from valve stem.

3. Remove the four bolts connecting actuator and yoke. See Figure 13.

4. Loosen the two connector bolts uniformly so that connector halves can be separated, and actuator shaft removed from connector.

5. Lift out actuator.

6. Unscrew actuator shaft adapter from actuator shaft.

7. Remove cover from opposite end of actuator, and screw adapter into internally threaded opening of actuator shaft. See Figure 14.

NOTE

With 1/2 through 2 in valves using Model P110A Actuator, if action is being changed to air-to-close, a spacer may be required with connector. If spacer is not already on connector, order from Foxboro Part No. B6302LX. Position spacer on adapter shaft, and then screw in adapter; if action is being changed to air-to-open, remove spacer and store in a convenient location.

8. Attach cover to other end of actuator.
9. Reinstall actuator as outlined in instruction MI 012-150.

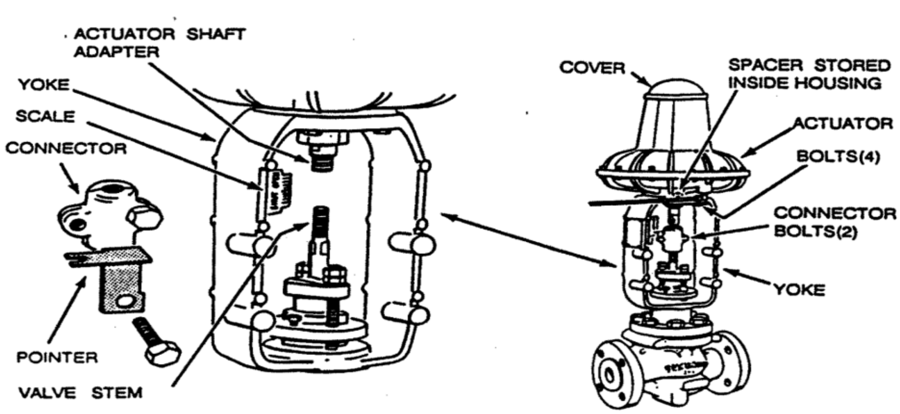


Figure 13-14 Removing Actuators from Yoke

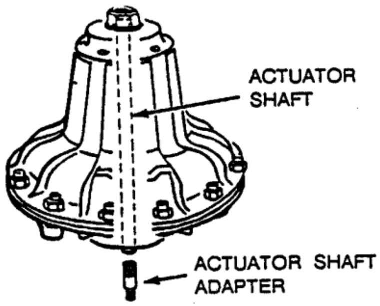


Figure 13-15.
Removing and Reinstalling Actuator

TO INSTALL ACTUATOR ON OTHER THAN V1 SERIES VALVES

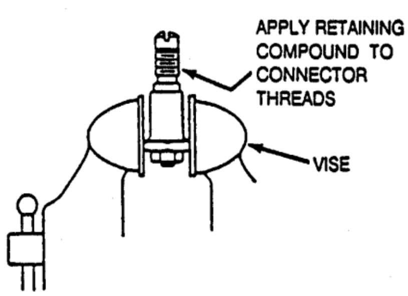
Installing Actuator with Air-to-Close (A TC) Action

1. Accomplish this step if connection assembly has been removed from actuator. Otherwise, proceed to Step 2.

   a. Apply retaining compound (Foxboro Part No. XO118CR) to threads of connector and mount connector In vise with jaws tightening on large, hex portion of connection assembly. See Figure 15.

NOTE

With Model P11 OA Actuators, using 3/8 or 1/2 in diameter valve stems, a spacer may be required with connector. If spacer is not already on connector, order from Foxboro Part Number B6302LX.



Insert hex-key wrench (see table in "To Remove Actuator from Valve" section) into recess and rotate clockwise, in unison, both wrench and actuator, until actuator and connector assembly are securely tightened together (Figure 16).

CAUTION

Both hex-key wrench and housing must be rotated together to avoid damaging diaphragm.

2. Mount actuator valve on valve yoke with four bolts provided. right in line with SHUT position on scale. Any further increase in pressure should not cause any movement of connector.

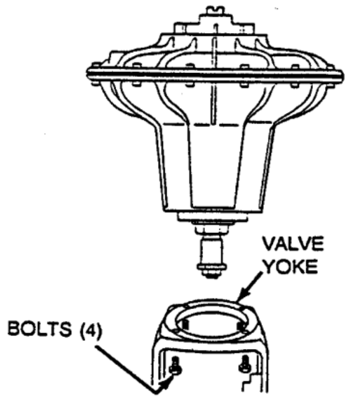


Figure 13-16. Valve Yoke Bolts

3. Check pointer position on scale by holding pointer up against bottom of connecter. Loosen screws holding scale and reposition it so that that the OPEN position is in line with the pointer. See below figure.
4. Check pointer position on scale by holding pointer up against bottom of connector. Loosen screws holding scale and reposition it so that the OPEN position is in line with the pointer. See Figure 18.

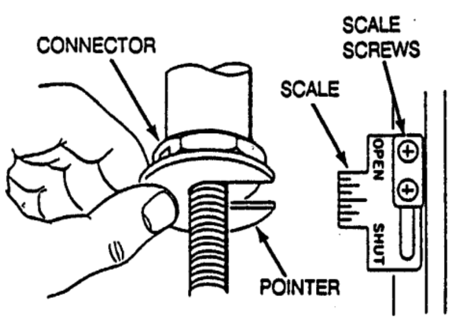


Figure 13-17. Aligning Pointer and Scale

5. Reconnect air supply to actuator and slowly increase pressure. When connector reaches valve stem, turn lower hex portion of connector counterclockwise to screw connector and stem.

5. Turn of air supply to actuator.

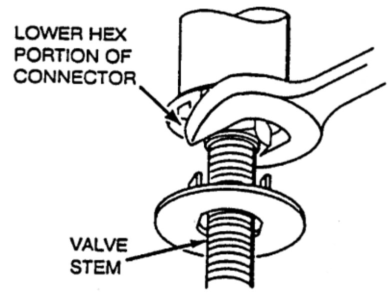


Figure 13-18. Connector & Valve Stem

6. Slide loose parts on valve stem up to connector assembly. Fit tabs of large washer into slots in connector and tighten valve stem locknut. See Figure 20.

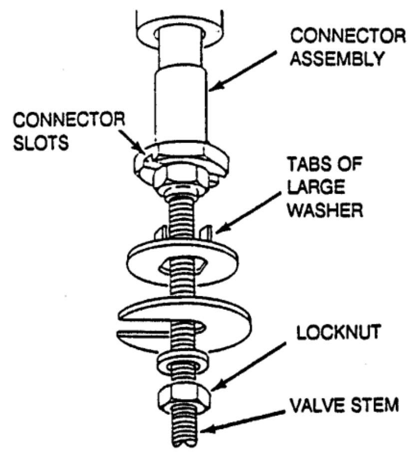


Figure 13-19.Assembling Valve Stem Parts

7. Check that actuator motion correctly positions indicator at scale. If necessary, readjust scale as outlined in Step 3.

8. Adjust spring for proper preloading as outlined in "To Adjust Spring Preloading" section.

Installing Actuator with Air-to-Close (A TC) Action

1. Accomplish this step if connection assembly has been removed from actuator. Otherwise, proceed to Step 2.

   a. Apply retaining compound (Foxboro Part No. XO118CR) to threads of connector and mount connector In vise with jaws tightening on large, hex portion of connection assembly. See Figure 15.

   NOTE

   With Model P110A Actuators, using 3/8 or 1/2 in diameter valve stems, a spacer may be required with connector. If spacer is not already on connector, order from Foxboro Part Number B6302LX.

   b. Insert hex-key wrench (see table in "To Remove Actuator from Valve" section) into recess and rotate clockwise, in unison, both wrench and actuator, until actuator and connector assembly are securely tightened together (Figure 16).

CAUTION

Both hex-key wrench and housing must be rotated together to avoid damaging diaphragm

1. Using a blunt rod and mallet, loosen the yoke locknut (Figure 22). Raise locknut approximately 3mm (1/8 in).

2. Mount actuator on valve yoke with four bolts provided (Figure 23).

3. Check pointer position on scale by holding pointer up against bottom of connector. Loosen screws holding scale and reposition it so that the SHUT position is in line with the pointer. See Figure 24.

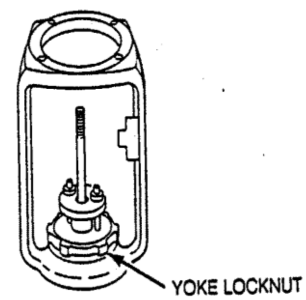


Figure 13-20. Loosening Yoke Locknut

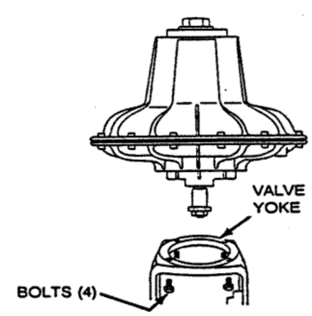


Figure 13-21. Valve Yoke Bolts

4. Reconnect air supply to actuator. Depending on actuator spring, apply 15 to 20 or 30 to 35 psi (100 to 140 or 200 to 240 kPa) to actuator to provide stem clearance.

5. Retighten yoke locknut.

6. Decrease air pressure to actuator gradually. When connector reaches valve stem, turn lower hex potion of connector counterclockwise to screw connector and stem together. Continue turning hex nut until pointer (held against bottom of connector as in Step 4) is again in line with SHUT position on scale (Figure 25). Any further decrease in air pressure should not cause any movement of connector. Turn off air supply.

7. Slide loose parts on valve stem up to connector assembly. Fit tabs of large washer into slots in connector and tighten valve stem locknut. See Figure 26.

8. Check that actuator motion correctly positions indicator at scale. If necessary, readjust scale as outlined In Step 4.

9. Adjust spring for proper preloading as outlined in the next section.

TO INSTALL ACTUATOR ON V1 SERIES VALVES

Refer to MI 012-150 to remove or reinstall Actuator on V1 Series Valves.

TO ADJUST SPRING PRELOADING

The spring preloading can be changed while an air signal is applied to the diaphragm. Changing the preloading shifts both the initial-motion and full-stroke pressures by the same amount.

This adjustment does not affect the length of stroke.

1. Turn off process flow so that there is not pressure drop across valve, or take actuator and vale out of line as required.

2. Adjust actuator pressure to bench Initial-motion value (on data plate) or to desire value.

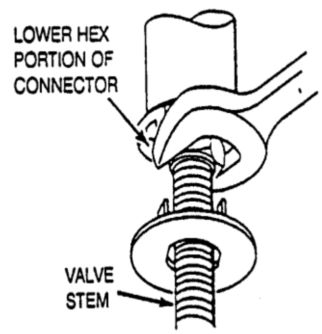


Figure 13-22 Connector and Valve Stem

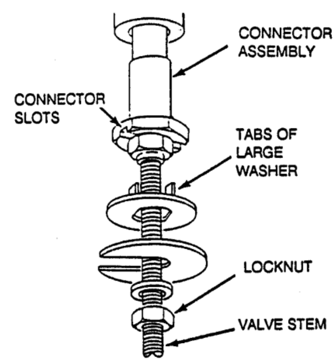


Figure 13-23. assembling Valve Stem Parts

When actuator action is reversed, pressures listed on data plate no longer apply. For updated data, contact Foxboro giving serial number, valve type and size desired actuator action (air-to-open or air-to-close valve) and maximum upstream line pressure.

3. Gradually turn preloading adjustment nut (clockwise to decrease preloading tension) until valve stem just starts to move. See Figure 27.

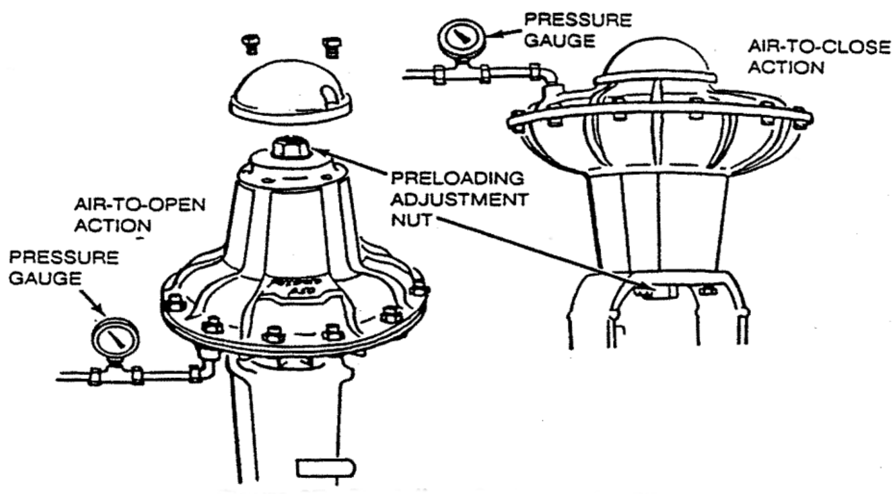


Figure 13-24. To Adjust Spring Preloading

TO ADJUST OPTIONAL STROKE STOPS

As an option, the actuator may include stops to limits its stroke. These stops are most commonly used with air-to-close action when it is imperative that flow is not completely shut off. They are adjusted as outlined below.

1. Turn actuator air supply to zero.
2. Determine portion of full actuator stroke required. (Full actuator stroke is listed on data label on valve yoke.)
3. Apply air to actuator and increase pressure until pointer position on scale indicates that the valve has been stroked desired amount.
4. Turn the four stop screws until bottomed (see Figure 28).

NOTE

The optional top-mounted hand wheel jackscrew can also be used to limit travel, in one direction.

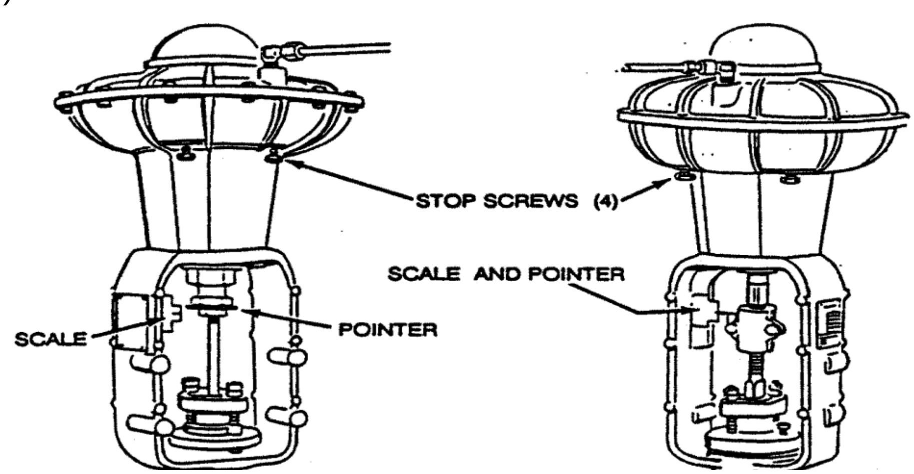


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Figure 13-25.To Adjust Optional Stroke Stops
(Left – with other than V1 series; Right – with V1 Series Valve)

Unit 5: Control Valve Functions and Characteristics Terminology

Bench Set: The calibration of the actuator spring range of a control valve to account for the in-service process forces.

Capacity: Rate of flow through a valve under stated conditions.

Clearance Flow: That flow below the minimum controllable flow with the closure member not seated.

Diaphragm Pressure Span: Difference between the high and low values of the diaphragm pressure range. This can be stated as an inherent or installed characteristic.

Double-Acting Actuator: An actuator in which power is supplied in either direction.

Dynamic Unbalance: The net force produced on the valve plug in any stated open position by the fluid pressure acting upon it.

Effective Area: In a diaphragm actuator, the effective area is that part of the diaphragm area that is effective in producing a stem force. The effective area of a diaphragm might change as it is stroked, usually being a maximum at the start and a minimum at the end of the travel range. Molded diaphragms have less change in effective area than flat sheet diaphragms; thus, molded diaphragms are recommended.

Equal Percentage Flow Characteristic:
(See Process Control Terminology: Equal Percentage Flow Characteristic.)

Fail-Closed: A condition wherein the valve closure member moves to a closed position when the actuating energy source fails.

Fail-Open: A condition wherein the valve closure member moves to an open position when the actuating energy source fails.

Fail-Safe: A characteristic of a valve and its actuator, which upon loss of actuating energy supply, will cause a valve closure member to be fully closed, fully open, or remain in the last position, whichever position is defined as necessary to protect the process. Fail-safe action can involve the use of auxiliary controls connected to the actuator.

Flow Characteristic: Relationship between flow through the valve and percent rated travel as the latter is varied from 0 to 100 percent. This term should always be designated as either inherent flow characteristic or installed flow characteristic.

Flow Coefficient (Cv): A constant (Cv) related to the geometry of a valve, for a given travel, that can be used to establish flow capacity. It is the number of U.S.

gallons per minute of 60_F water that will flow through a valve with a one pound per square inch pressure drop.

High-Recovery Valve: A valve design that dissipates relatively little flow-stream energy due to streamlined internal contours and minimal flow turbulence.
Therefore, pressure downstream of the valve vena contracta recovers to a high percentage of its inlet value. Straight-through flow valves, such as rotary-shaft ball valves, are typically high-recovery valves.

Inherent Diaphragm Pressure Range: The high and low values of pressure applied to the diaphragm to produce rated valve plug travel with atmospheric pressure in the valve body. This range is often referred to as a bench set range because it will be the range over which the valve will stroke when it is set on the work bench.
Inherent Flow Characteristic: The relationship between the flow rate and the closure member travel as it is moved from the closed position to rated travel with constant pressure drop across the valve.

Installed Diaphragm Pressure Range: The high and low values of pressure applied to the diaphragm to produce rated travel with stated conditions in the valve body. It is because of the forces acting on the closure member that the inherent diaphragm pressure range can differ from the installed diaphragm pressure range.

Installed Flow Characteristic: The relationship between the flow rate and the closure member travel as it is moved from the closed position to rated travel as the pressure drop across the valve is influenced by the varying process conditions.

Leakage: (See Seat Leakage.)
Linear Flow Characteristic: (See Process Control Terminology: Linear Characteristic.)

Low-Recovery Valve: A valve design that dissipates a considerable amount of flowstream energy due to turbulence created by the contours of the flowpath. Consequently, pressure downstream of the valve vena contracta recovers to a lesser percentage of its inlet value than is the case with a valve having a more streamlined flowpath. Although individual designs vary, conventional globe-style valves generally have low pressure recovery capability.

Modified Parabolic Flow Characteristic:
An inherent flow characteristic that provides equal percent characteristic at low closure member travel and approximately a linear characteristic for upper portions of closure member travel.

Normally Closed Valve: (See Fail-Closed.)

Normally Open Valve: (See Fail-Open.)

Push-Down-to-Close Construction: A globe-style valve construction in which the closure member is located between the actuator and the seat ring, such that extension of the actuator stem moves the closure member toward the seat ring, finally closing the valve (figure 1-3). The term can also be applied to rotary-shaft valve constructions where linear extension of the actuator stem moves the ball or disk toward the closed position. (Also called direct acting.)

Push-Down-to-Open Construction:
A globe-style valve construction in which the seat ring is located between the actuator and the closure member, so that extension of the actuator stem moves the closure member from the seat ring, opening the valve. The term can also be applied to rotary-shaft valve constructions where linear extension of the actuator stem moves the ball or disk toward the open position. (Also called reverse acting.)

Quick Opening Flow Characteristic:
(See Process Control Terminology: Quick Opening Characteristic.)

Rangeability: The ratio of the largest flow coefficient (Cv) to the smallest flow coefficient (Cv) within which the deviation from the specified flow characteristic does not exceed the stated limits. A control valve that still does a good job of controlling when increases to 100 times the minimum controllable flow flow has a rangeability of 100 to 1. Rangeability can also be expressed as the ratio of the maximum to minimum controllable flow rates.

Rated Flow Coefficient (Cv): The flow coefficient (Cv) of the valve at rated travel.

Rated Travel: The distance of movement of the closure member from the closed position to the rated full-open position. The rated full-open position is the maximum opening recommended by the manufacturers.

Relative Flow Coefficient: The ratio of the flow coefficient (Cv) at a stated travel to the flow coefficient (Cv) at rated travel.

Seat Leakage: The quantity of fluid passing through a valve when the valve is in the fully closed position with pressure differential and temperature as specified. (ANSI leakage classifications are outlined in Chapter 5.)

Spring Rate: The force change per unit change in length of a spring. In diaphragm control valves, the spring rate is usually stated in pounds force per inch compression.

Stem Unbalance: The net force produced on the valve stem in any position by the fluid pressure acting upon it.

Vena Contracta: The portion of a flow stream where fluid velocity is at its maximum and fluid static pressure and the cross-sectional area are at their minimum. In a control valve, the vena contracta normally occurs just downstream of the actual physical restriction.

Other Process Control Terminology

The following terms and definitions not previously defined are frequently encountered by people associated with control valves, instrumentation, and accessories. Some of the terms (indicated with an asterisk) are quoted from the ISA standard, Process Instrumentation Terminology, ISA 51.1. Others included are also popularly used throughout the control valve industry.

ANSI: Abbreviation for American National Standards Institute.

API: Abbreviation for American Petroleum Institute.

ASME: Abbreviation for American Society of Mechanical Engineers.

ASTM: Abbreviation for American Society for Testing and Materials.

Automatic Control System*: A control system that operates without human intervention.

Bode Diagram*: A plot of log amplitude ratio and phase angle values on a log frequency base for a transfer function (figure 1-15). It is the most common form of graphically presenting frequency response data.

Calibration Curve*: A graphical representation of the calibration report (figure 1-15). Steady state output of a device plotted as a function of its steady state input. The curve is usually shown as percent output span versus percent input span.

Calibration Cycle*: The application of known values of the measured variable and the recording of corresponding values of output readings, over the range of the instrument, in ascending and descending directions (figure 1-15). A calibration curve obtained by
varying the input of a device in both increasing and decreasing directions. It is usually shown as percent output span versus percent input span and provides a measurement of hysteresis.

Clearance Flow: That flow below the minimum controllable flow with the closure general member not seated.

Controller*: A device that operates automatically to regulate a controlled variable.

Enthalpy: A thermodynamic quantity that is the sum of the internal energy of a body and the product of its volume multiplied by the pressure: $H = U + pV$. (Also called the heat content.)

Entropy: The theoretical measure of energy that cannot be transformed into mechanical work in a thermodynamic system.

Feedback Signal*: The return signal that results from a measurement of the directly controlled variable. For a control valve with a positioner, the return signal is usually a mechanical indication of closure member stem position that is fed back into the positioner.

FCI: Abbreviation for Fluid Controls Institute.

Frequency Response Characteristic*:
The frequency-dependent relation, in both amplitude and phase, between steady-state sinusoidal inputs and the resulting fundamental sinusoidal outputs. Output amplitude and phase shift are observed as functions of the input test frequency and used to describe the dynamic behavior of the control device.

Hardness: Resistance of metal to plastic deformation, usually by indentation. Resistance of plastics and rubber to penetration of an indentor point into its surface.

Hunting*: An undesirable oscillation of appreciable magnitude, prolonged after external stimuli disappear. Sometimes called cycling or limit cycle, hunting is evidence of operation at or near the stability limit. In control valve applications, hunting would appear as an oscillation in the loading pressure to the actuator caused by instability in the control system or the valve positioner.

Hysteresis: A retardation of an effect when the forces acting upon a body are changed (as if from viscosity or internal friction).

ISA: Abbreviation for the Instrument Society of America. Now recognized as the International Society for Measurement and Control.

Instrument Pressure: The output pressure from an automatic controller that is used to operate a control valve.

Loading Pressure: The pressure employed to position a pneumatic actuator. This is the pressure that actually works on the actuator diaphragm or piston and it can be the instrument pressure if a valve positioner is not used.

NACE: Used to stand for National Association of Corrosion Engineers. As the scope of the organization became international, the name was changed to NACE International. NACE is no longer an abbreviation.

OSHA: Abbreviation for Occupational Safety and Health Act. (U.S.A.)

Operating Medium: This is the fluid, generally air or gas, used to supply the power for operation of valve positioner or automatic controller.

Operative Limits*: The range of operating conditions to which a device can be subjected without permanent impairment of operating characteristics.

Range: The region between the limits within which a quantity is measured, received, or transmitted, expressed by stating the lower and upper range values (for example: 3 to 15 psi; -40 to +212_F; -40 to +100_C).

Repeatability*: The closeness of agreement among a number of consecutive measurements of the output for the same value of the input under the same operating conditions, approaching from the same direction, for full range traverses. It is usually measured as a non-repeatability and expressed as repeatability in percent of span. It does not include hyesteresis (figure 1-15).

Sensitivity*: The ratio of the change in output magnitude to the change of the input that causes it after the steady-state has been reached.

Signal*: A physical variable, one or more parameters of which carry information about another variable the signal represents.

Signal Amplitude Sequencing (Split Ranging)*: Action in which two or more signals are generated or two or more final controlling elements are actuated by and input signal, each one responding consecutively, with or without overlap, to the magnitude of that input signal (figure 1-15).

Span*: The algebraic difference between the upper and lower range values (for example: Range = 0 to 150_F; Span = 150_F; Range = 3 to 15 psig, Span = 12 psig).

Stiction: the force required to cause one body in contact with another to begin to move.

Supply Pressure*: The pressure at the supply port of a device. Common values of control valve supply pressure are 20 psig for a 3 to 15 psig range and 35 psig for a 6 to 30 psig range.

Zero Error*: Error of a device operating under specified conditions of use when the input is at the lower range value. It is usually expressed as percent of ideal span.