CHAPTER 1: INSTRUMENTATION EQUIPMENT
MODULE 8: Control Valves and Accessories

MODULE OBJECTIVES: At the end of this module, you will be able to:

1. State the combinations of pneumatic actuator and globe valve body required to provide:
   a) air to open action; b) air to close action.
2. State the three flow characteristics usually available for a globe valve. Sketch the flow characteristic curve for each kind.
3. State a typical application for each of the three flow characteristics and explain why it is used in that application.
4. State the effect of the unbalanced force on valve position and explain how, by giving an example, bench setting would correct this problem.
5. Briefly explain at least five advantages a positioner gives when it is used in conjunction with a control valve.
6. Explain the situations where the by-pass switch of the positioner should not be operated.
7. Describe the failure mode of a control valve, when the valve configuration and positioner action are given.
8. State the advantages of the following control valves: a) Y-ball valve; b) a rotating plug valve;
   c) a diaphragm valve.
9. Explain, with a diagram, how a three-way solenoid valve can be used for ON/OFF control of a pneumatic valve.
10. Explain the type and function of typical electric motor operated valves and state a typical application for a Rotork, Limitorque and Hopkinson valve.
11. State why it is often advisable to use different sized valves in parallel when the process variable has a very large range.

Control Valves and Accessories

The final control element in a system is used to vary the flow of a manipulated variable in an attempt to maintain a process parameter at a desired setpoint. Final control elements include control valves, metering pumps, dampers and louvers, variable pitch fan blades, and electrically driven control devices.

The control valve is the most widely used type of final control element and it must perform satisfactorily with a minimum amount of attention, even in severe conditions of temperature, pressure, corrosion and contamination.

A control valve functions as variable resistance in a pipeline. It provides a pressure drop, called throttling, which limits the flow through a pipeline.

There are many different kinds of control valves in common use: globe valves, butterfly valves, ball valves, eccentric disc valves and diaphragm valves are some of the more popular types encountered.

Globe Valve

Globe valves are the most frequently encountered control valves in process plants. Figure 1 shows the side view of a typical globe valve, which is named after its globular shaped valve body.

The globe valve consists of two main components:

1. the valve body; which contains and regulates the fluid flow, and
2. the valve actuator, which converts electrical or pressure energy into stem movement which changes the regulating effect of the valve body.

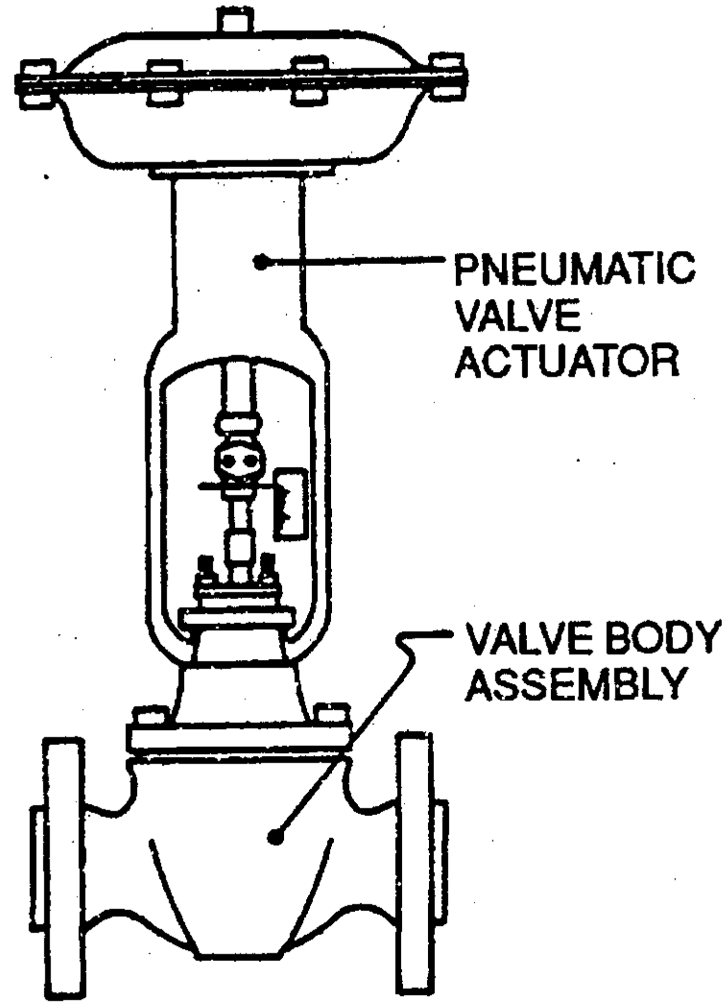


Figure 1: A Typical Globe Valve.

Globe Valve Body

The globe valve body itself is made up of the components shown in Figure 2.

- **The bonnet assembly is the part of the valve body through which the valve plug stem moves.**
- **The bonnet provides a means of sealing against leakage along the stem by using packing in the packing box. Force is exerted by the stud and nuts on the packing material to squeeze it against the walls of the packing box and the valve stem. This acts as a effective seal.**
- **The valve stem extends through the bonnet to permit positioning of the valve plug, and therefore provide a variable restriction to the fluid flow.**

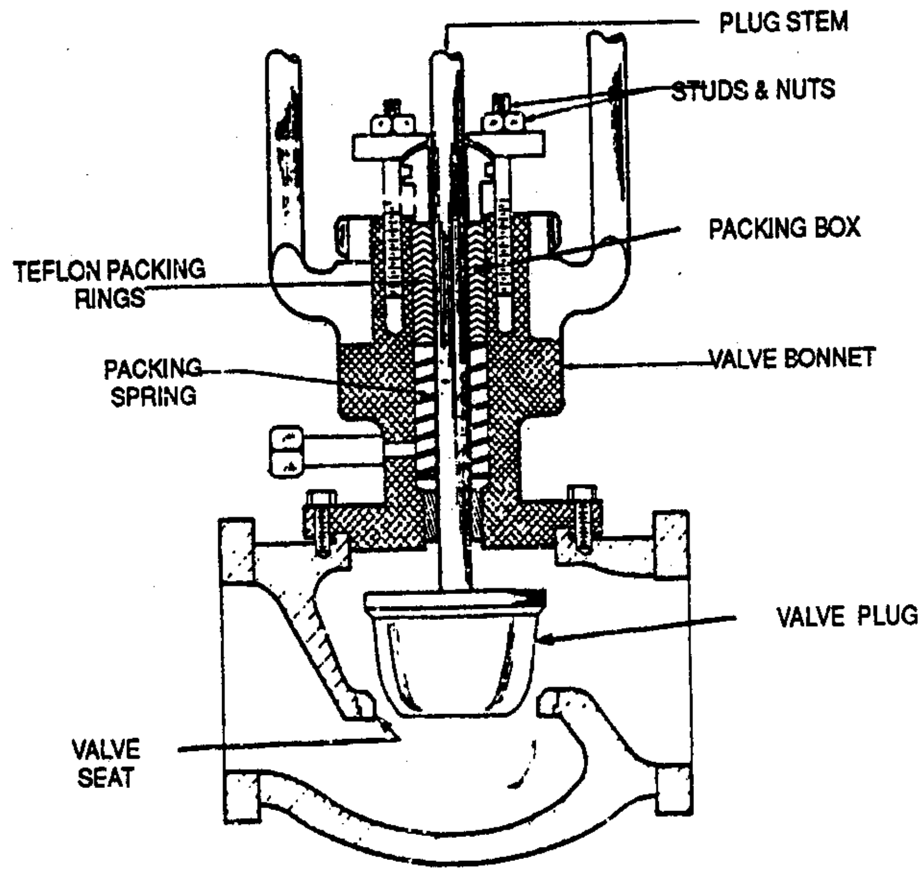
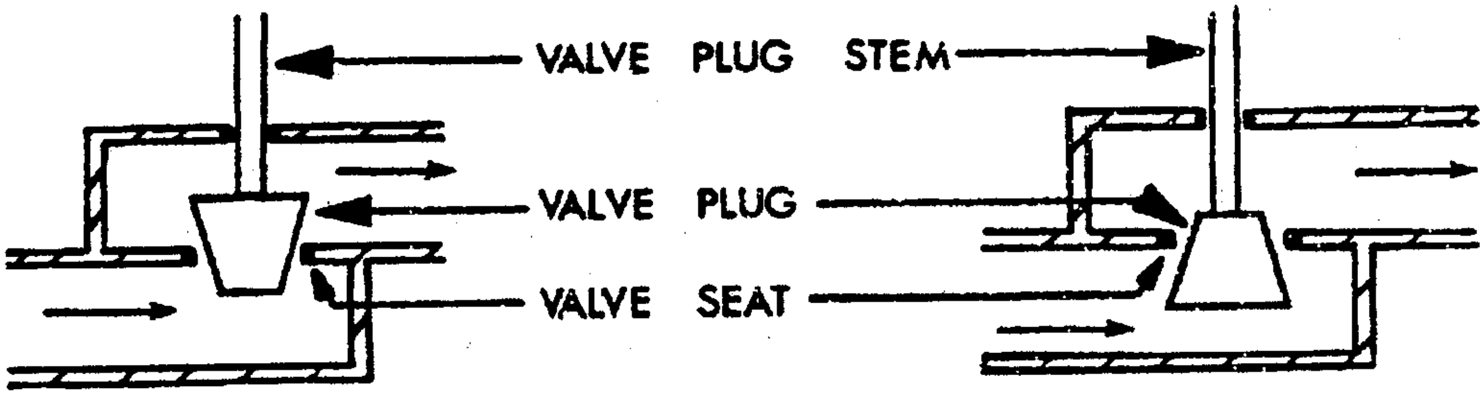


Figure 2: Cross--Sectional View of a Globe Valve Body.

Globe valve bodies can be classified as either direct or reverse acting, as shown in Figure 3



a) Direct Acting (b) Reverse Acting

Figure 3: A Simplified Diagram Showing Control Valve Body Action.

- In a direct acting valve body, a downward movement of the valve plug stem results in the valve closing
- In a reverse acting valve body, a downward movement of the valve plug stem results in the valve opening

Valve Actuators

A control valve actuator is a device which is used to drive the valve plug stem and therefore sets the position of the plug with respect to the valve seat.

The most common valve actuator is the pneumatic diaphragm actuator. It is simple in construction and very reliable. It operates by the injection of a single, low pressure air signal into the diaphragm housing.

- The diaphragm housing is made up of two sections. Between the two sections a flexible diaphragm is installed.
- The air pressure applied on the diaphragm develops a working force. This force is transmitted to the actuator stem via the diaphragm plate, which is a supportive metal disk attached to the diaphragm.
- The actuator spring provides a restoring force which positions and returns the actuator stem.
- The travel indicator (a pointer attached near the stem connector) indicates the valve travel on the indicator scale.
- The actuator is supported rigidly on the valve bonnet assembly by the yoke.
- The actuator stem is connected by the stem connector to the valve plug stem.

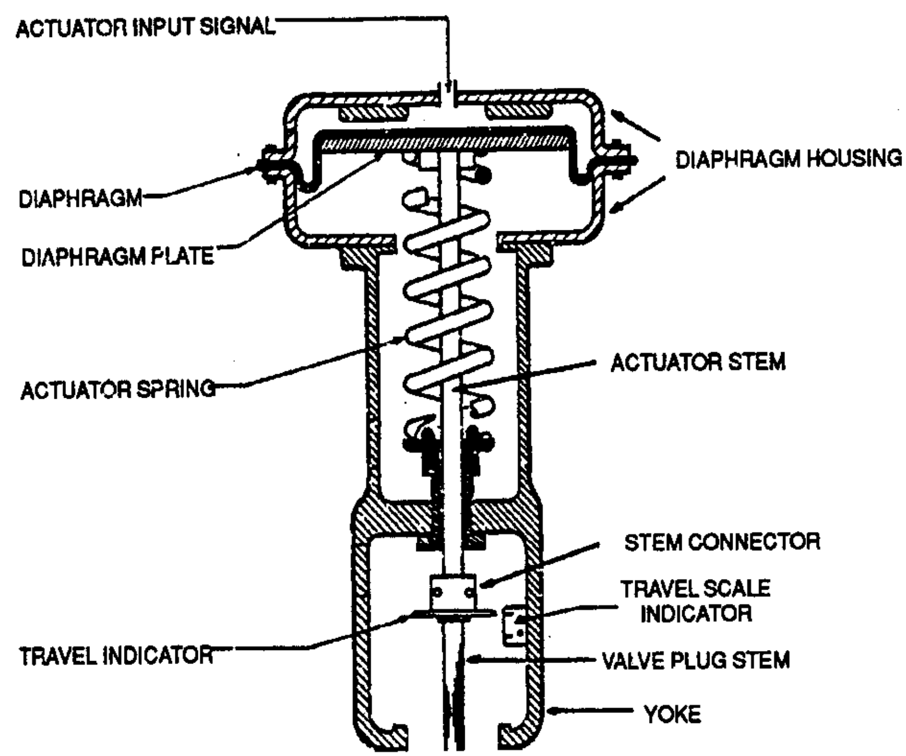


Figure 4: A Typical Pneumatic Diaphragm Actuator.

The diameter of the diaphragm plate determines the force that will be applied to the actuator stem. For example, if the maximum input signal pressure is 100 kPa and the plate diameter is 30 cm, then:

Force applied to stem = Pressure x Plate Area

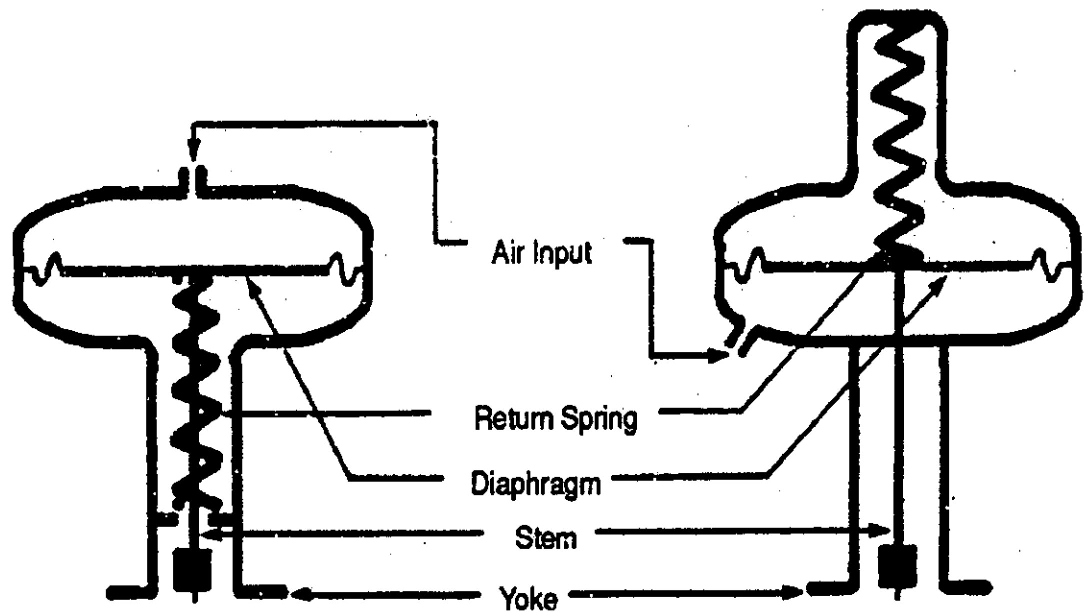
= 100 kPa x 3.14 x $(0.15)^2$ m^2

= 7.07 KN (1590 lb)

Although the signal pressure of 100 kPa seems to be fairly low, a substantial force can still be generated if the diaphragm diameter is large.

Diaphragm actuators, as in the case of valve bodies, can be classified as either direct or reverse acting.

- A direct acting actuator will cause the actuator stem to be pushed downwards as a result of applying signal air to the top of the diaphragm (Figure 5(a)).
- The reverse acting actuator will push the actuator stem upwards as signal air is applied to the bottom of the diaphragm (Figure 5(b)).



(a) Direct Acting (b) Reverse Acting

Figure 5: Direct and Reverse Acting Actuators.

Valve Action

Control valves can be built from various combinations of valve actuator and valve body. The combination of actuator and valve body is usually chosen to provide a particular failure mode should the compressed instrument air supply fail for any reason.

Any failure mode can be obtained with a combination of direct or reverse acting actuator and direct or reverse acting valve body.

- An air to close (A/C), and therefore fail open valve, can be obtained with the combination of a reverse acting actuator and a reverse acting valve body or a direct acting actuator and a direct acting valve body. (Figure 6(a)).
- Similarly, an air to open (A/O), and therefore fail close valve, can be obtained with a combination of direct actuator and reverse body or reverse actuator and direct body (Figure 6(b)).

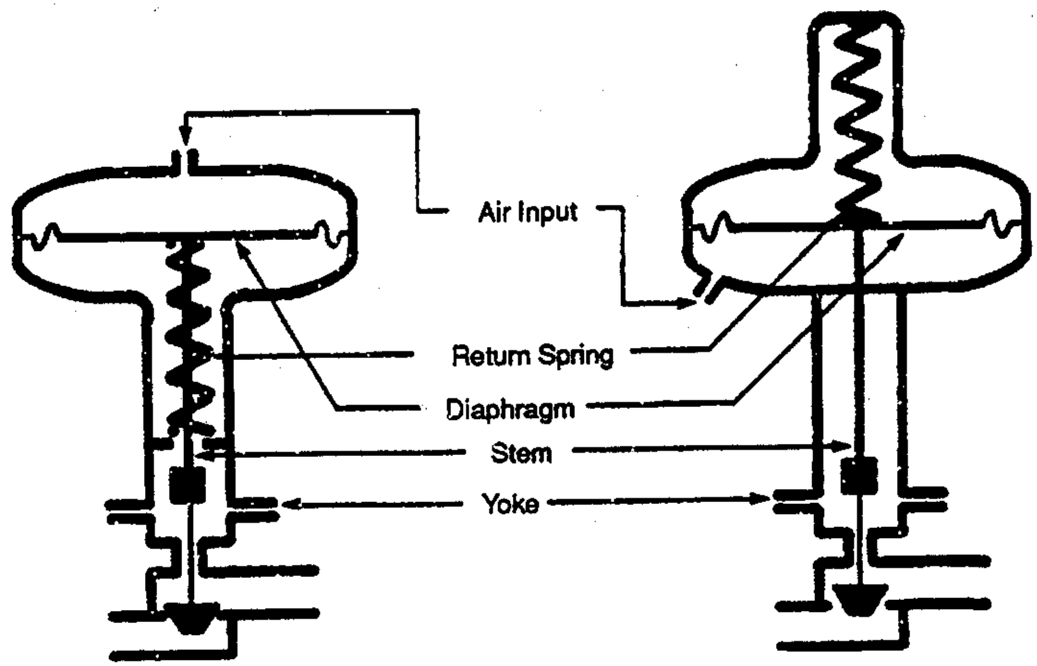


Figure 6(a)
Air to Close (A/C) Valve

Figure 6(b)
Air to Open (A/O)

Valve

Below are all possible combinations of valve body and actuator and their failure modes.

Actuator	Valve Body	Valve Action	Failure Mode
Direct	Direct	Air to Close	Fail Open
Reverse	Reverse	Air to Close	Fail Open
Direct	Reverse	Air to Open	Fail Closed
Reverse	Direct	Air to Open	Fail Closed

Table 1: Summary of Valve Action and Failure Mode.

Note that often it is not possible to determine the over all action of a valve by observation alone. Whilst the action of actuators can be easily determined (usually by whether the air is supplied to the upper or lower half of the housing), direct or reverse acting valve bodies are not always readily identifiable. Reference to the nameplate or flowsheet is usually necessary for positive identification.

Globe Valve Flow Characteristics

The flow characteristic of a valve is the relationship between the flow capacity of the valve and the valve plug position.

- **Flow capacity of a valve is the flowrate of the fluid through the valve under specified condition.**
- **A standard method of defining a valve's flow capacity is to use the valve flow coefficient (CV).**
- **The valve flow coefficient is a function of flowrate of a specified fluid through the valve at a specified pressure drop across the valve (ΔP). (Usually expressed in U.S. gallons per minute at a ΔP of 1 psi.)**

Mathematically, flowrate is related to valve coefficient (CV) and pressure drop across the valve (ΔP) by the equation:

$$Q = CV\sqrt{\Delta P / S}$$

where

Q = flowrate of the fluid
S = fluid specific gravity

Therefore $CV = Q\sqrt{S / \Delta P}$

The CV's of valves are determined experimentally by measuring the flowrate of the water (Q) when the pressure drop across the valve (ΔP) is 1 psi. CV's are often used to compare valves with each other. The valve with the higher CV will have a higher flow capacity.

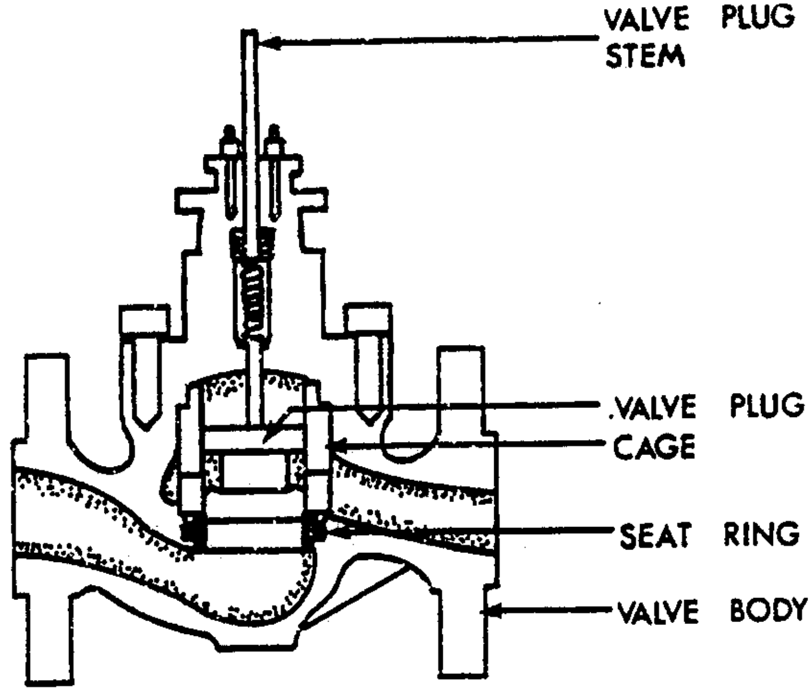


Figure 7: Valve Trim Components for a Globe Valve.

Quick Opening Globe Valves

- A typical quick opening valve plug is shown in Figure 8(a). The plug is designed to provide full capacity with a very short stem travel.
- Figure 8(b) illustrates the relationship between valve travel and CV of the quick opening valve. As can be seen, quick opening valve plugs achieve 80% of maximum CV with only 50% valve travel.

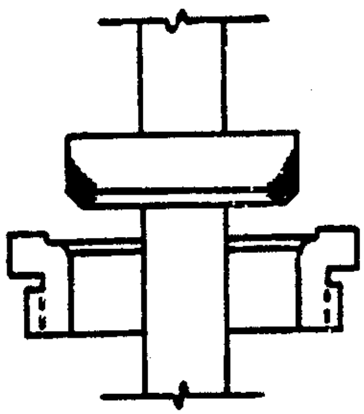


Figure 8(a)
Quick Opening Valve Plug

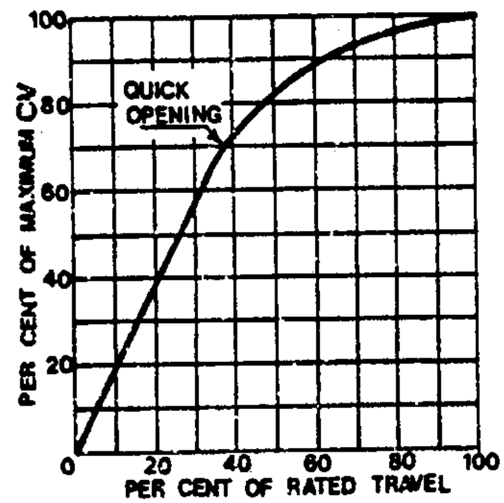


Figure 8(b)
Flow Characteristic of Quick Opening Valves

Quick opening valves are used primarily in an ON/OFF manner in situations where rapid responses are required.

Shown in Figure 9 is the simplified poison injection system of a CANDU reactor shutdown system.

The triplicated poison injection valve arrangement increases the reliability of the system.

When a trip signal is received by the valves, they open to admit high pressure helium to the poison tank and therefore inject poison into the reactor.

Total response time for the poison injection system is typically under 1.5 seconds.

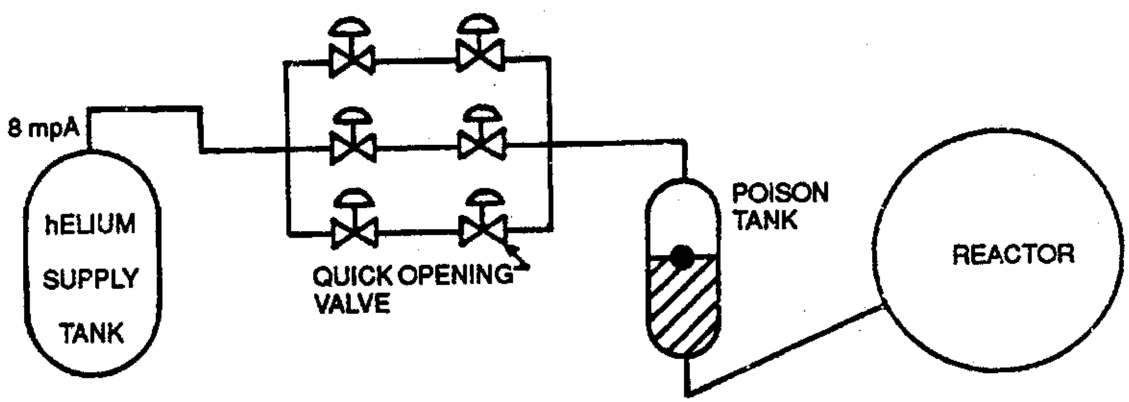


Figure 9: Simplified Poison Injection System for a CANDU nuclear reactor.

Linear Globe Valves

A linear valve plug is designed to produce a linear relationship between valve travel and CV.

A typical linear valve plug is shown in Figure 10(a).

Figure 10(b) shows the flow characteristic of a linear valve plug.

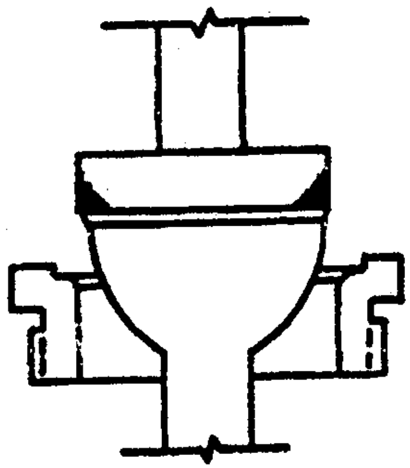


Figure 10(a)
A Typical Linear Valve Plug

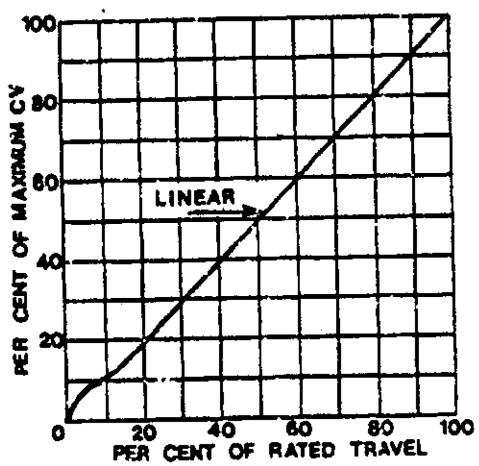


Figure 10(b)
Flow Characteristic of Linear Valve Plug

To facilitate automatic control, a linear relationship between <u>flowrate</u> (<u>not CV</u>) and <u>valve travel</u> is desirable. From Figure 10(b) it can be seen that for a linear valve plug, CV and valve travel exhibit a linear relationship. Since flow rate (Q) is given as: $Q = CV\sqrt{\Delta P / S}$

If ΔP, which is the pressure drop across the valve, can be kept constant, the flowrate will be linearly proportional to the valve travel.

One application of a linear globe valve is in the primary heat transport (PHT) feed and bleed system for PHT pressure control.

- Linear globe valves are used as feed valves to throttle the discharge of the pressurizing pumps.
- The pressures at the discharge of the pressurizing pumps and the PHT system are fairly stable.
- Therefore the pressure drop across each valve is essentially constant.
- In this manner. the flow rate is linearly proportional to the valve travel.

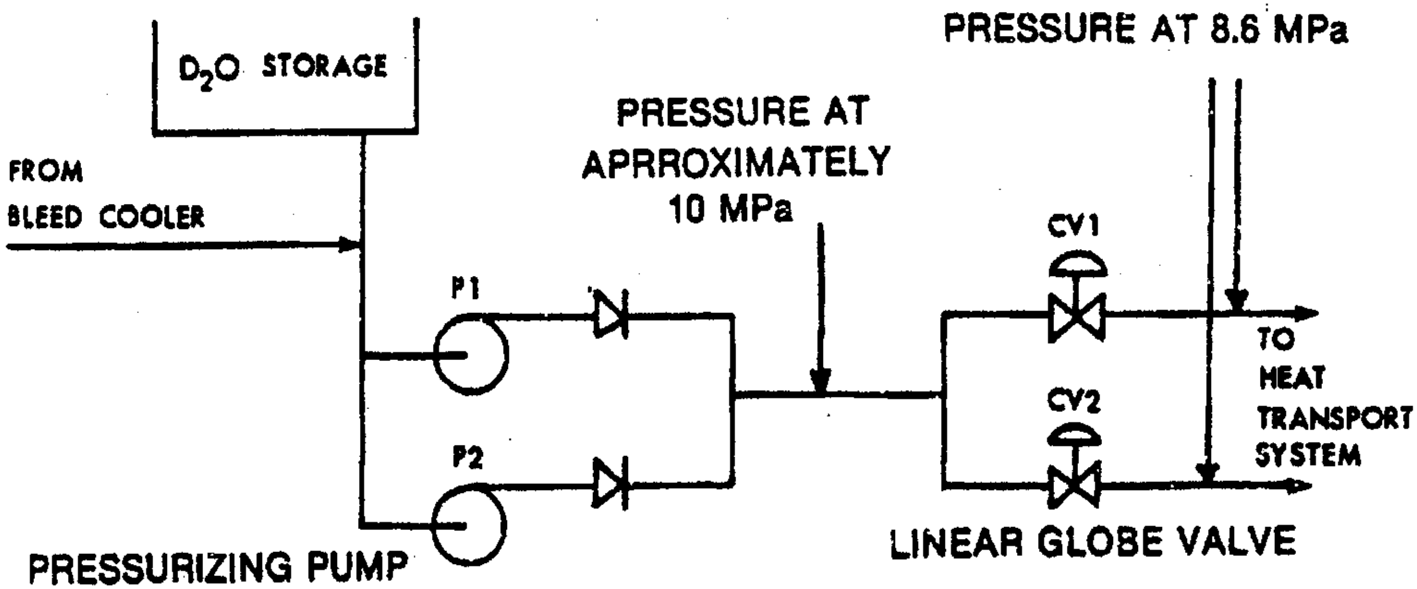


Figure 11: Simplified PHT Feed and Bleed System.

Equal Percentage Globe Valves

Figure 12(a) shows, a typical equal percentage valve plug. The valve flow characteristic is shown in Figure 12(b).

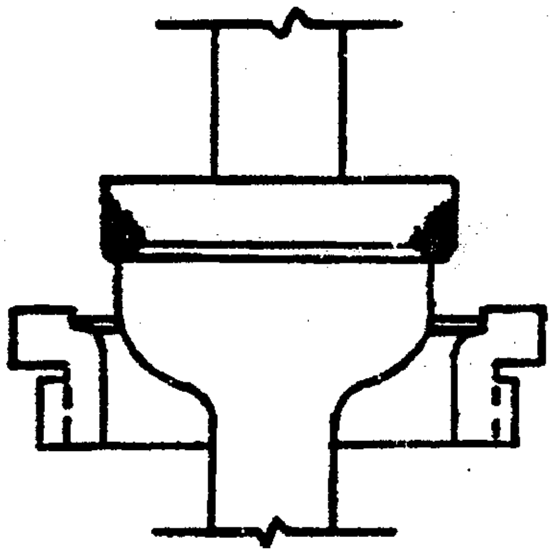


Figure 12(a): A Typical Equal Percentage Valve Plug

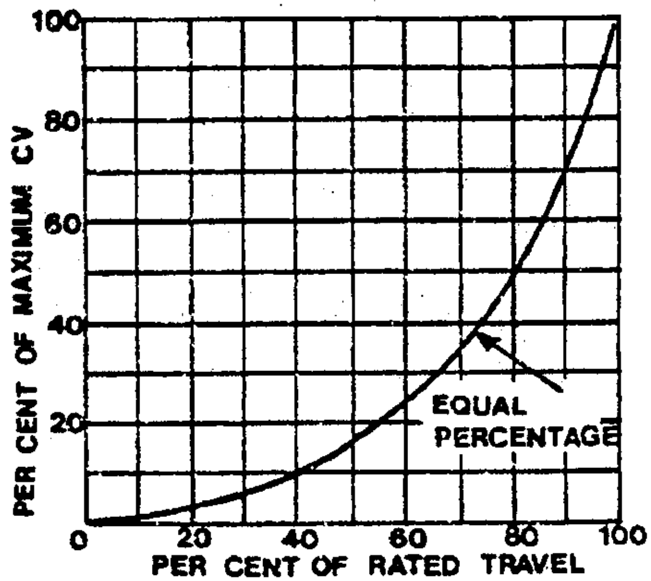


Figure 12(b): Flow Characteristic of an Equal Percentage Valve.

An equal percentage valve gets its name because for equal increments in valve plug travel, the valve coefficient will change by the same predetermined percentage over its original value.

For example, (refer to Figure 12(b)) if the valve plug position increases from 50% to 60% (an increase of 10%) the CV increases from 17.5% to 25%. For the same percentage (10%) increase in valve travel, say from

60% to 70%, the CV increases from 25% to 36%, again a 43% increase when compared with initial CV of 25%.

As with linear globe valves, equal percentage valves are also used to throttle the discharge of centrifugal pumps.

- Equal percentage valves are used in situations where there is a highly varying pressure drop (ΔP) across the valve. Figure 13 shows a typical centrifugal pump discharge pressure head curve with associated pressure loss.
- Recall that for a typical centrifugal pump, pump head diminishes as flowrate increases. Also, as flowrate increases, system pressure, loss (static plus dynamic) increases.
- From Figure 13, it can be seen that the difference between the pump head curve (line 1) and system pressure loss (line 2) curve is the pressure (ΔP) that is allocated to the valve, (line 3). In this case, ΔP decreases rapidly as flowrate increases.
- Recall that flowrate across a valve is given by:

  $Q = CV\sqrt{\Delta P / S}$

- As ΔP decreases, the valve coefficient CV has to increase drastically to compensate for the change in ΔP if a linear relationship between <u>flowrate</u> and <u>valve travel</u> is to be maintained. An equal percentage valve with flow characteristic as shown in line 4 is used for this purpose. The result is a linear relationship between flowrate and

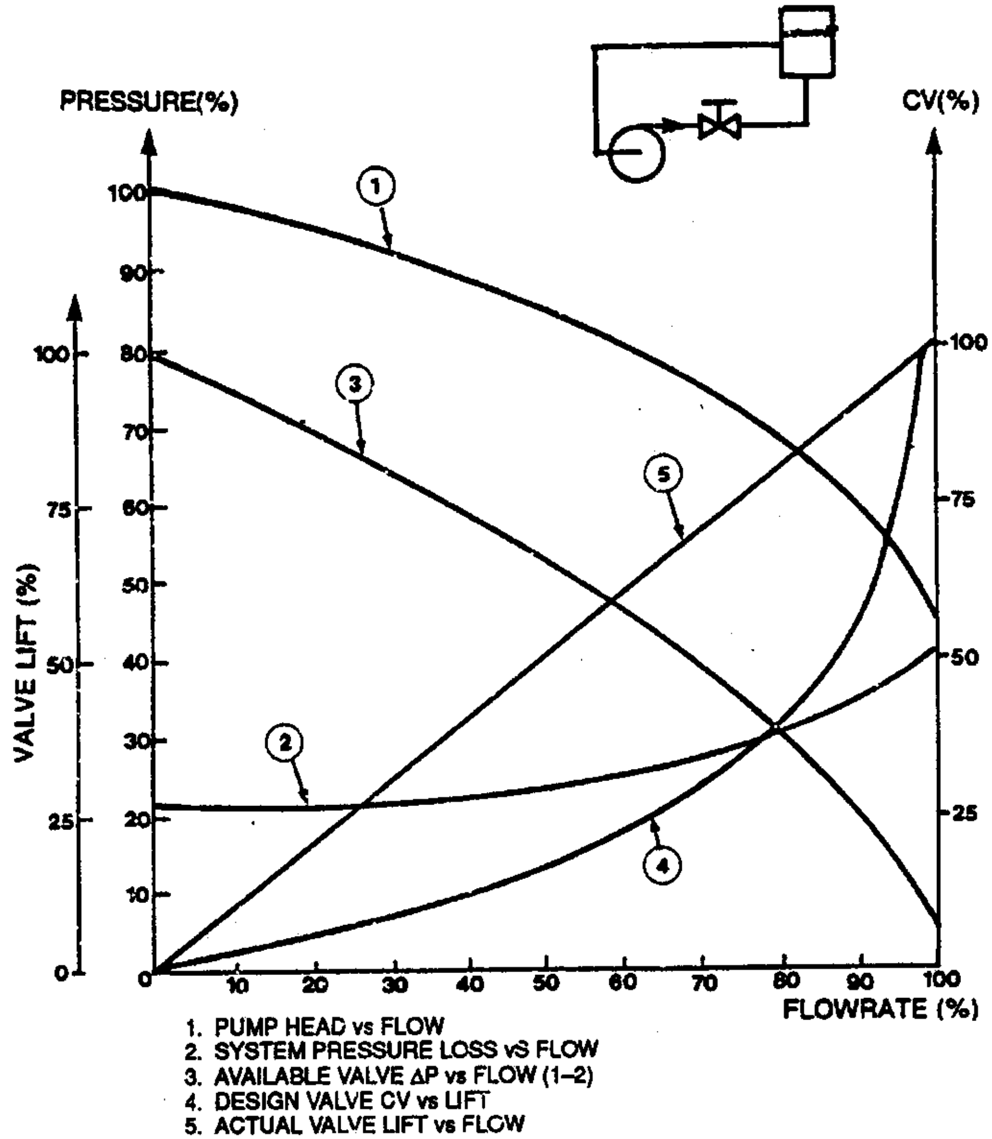


Figure 13: A Typical Pump Head Curve With Losses.

valve lift as represented by line 5.

As application of equal percentage valves in CANDU nuclear plants is for the control of light water flow into the Liquid Zone Control System.

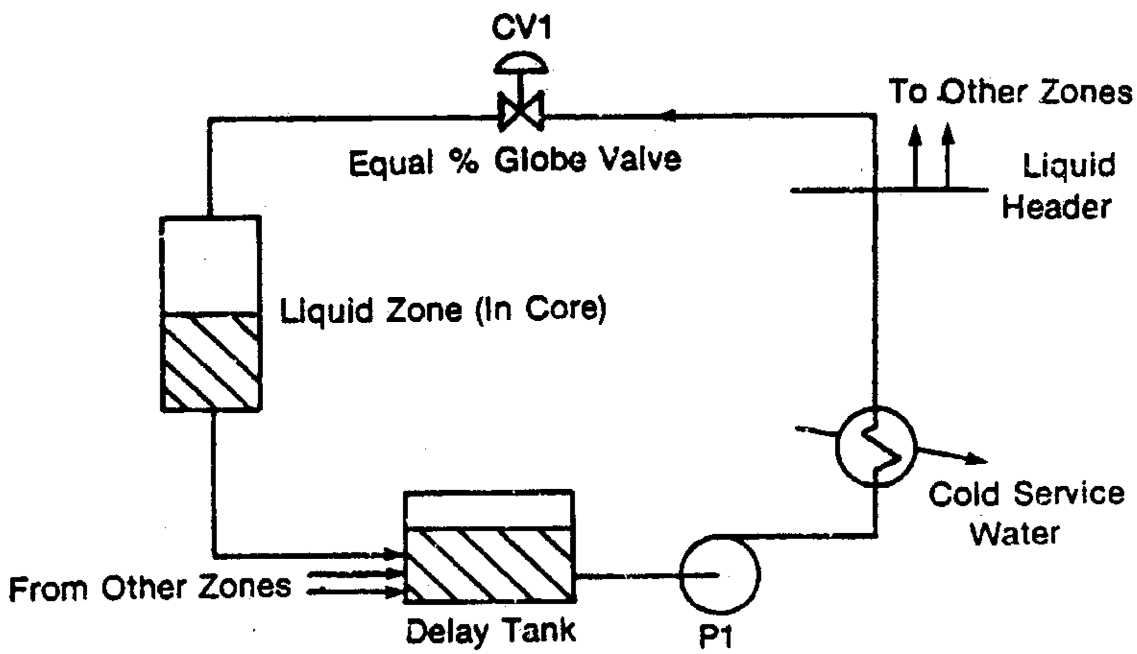


Figure 14: A Simplified Zone Level Control Circuit.

- **In this system, the light water flow to the liquid zone is varied by valve CV1.**
- **The outflow from the liquid zone <u>is kept constant</u>.**
- **In order to vary the water level in the zone, the inflow has to be increased or decreased.**
- **Valve CV1 has to control the inflow over the range 0.2 - 0.9 liters /sec.**
- **Because of this relatively large flow change, the system (piping) losses will vary over a fairly wide range.**
- **In an attempt to linearize the flow characteristic, and equal percentage valve is used as CV1.**

Bench Setting

Assume that we have an air to open globe valve which consists of a direct acting actuator and a reverse acting valve body.

- The valve is usually calibrated such that a 20 kPa signal applied to the actuator will cause the valve to be fully closed, and a 100 kPa signal will cause it to be fully open.
- However, these settings do not take into account the pressure that is exerted by the process fluid on the valve plug when it is installed in a flow system.

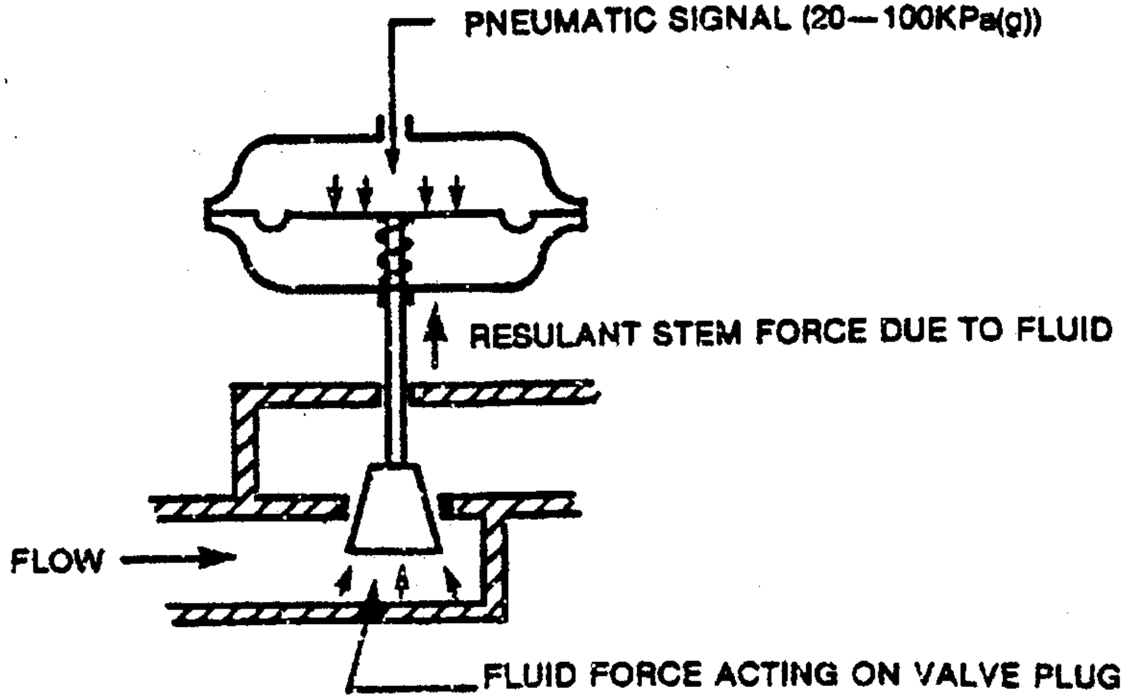


Figure 15: Air to Open Valve.

- If the fluid pressure is high, the resultant force acting on the valve plug will be able to offset part of the upward force exerted by the actuator.
- Assume the upward force exerted on the valve plug by the fluid is equivalent to the downward force generated by 10 kPa of the actuator pressure. When the signal pressure is 100 kPa, the net pressure on the diaphragm is only (100 - 10 kPa) 90 kPa. This will cause the valve to be open only to 90% rather than the theoretical 100%.
- Bench setting is the calibrating technique used to take into account the anticipated force exerted by the process fluid. For the air to open valve described above, bench setting would result in the valve spring being calibrated such that the valve is fully closed at 10 kPa and fully open at 90 kPa actuator pressure.

Double-Ported Globe Valve

A globe valve can contain either one or two plugs. When there is only one plug, the valve is called single ported (refer to Figure 2 at the beginning of this module). When there are two plugs as shown in Figure 16, it is called a double-ported globe valve.

- The double-ported valve arrangement produces almost no unbalanced force on the valve stem.
- The fluid flows through the valve ports in opposite directions and therefore generates forces that offset each other.
- As a result, only a relatively small actuator force is needed for positioning the valve plugs.
- This makes the double-ported globe valve suitable for high pressure applications.

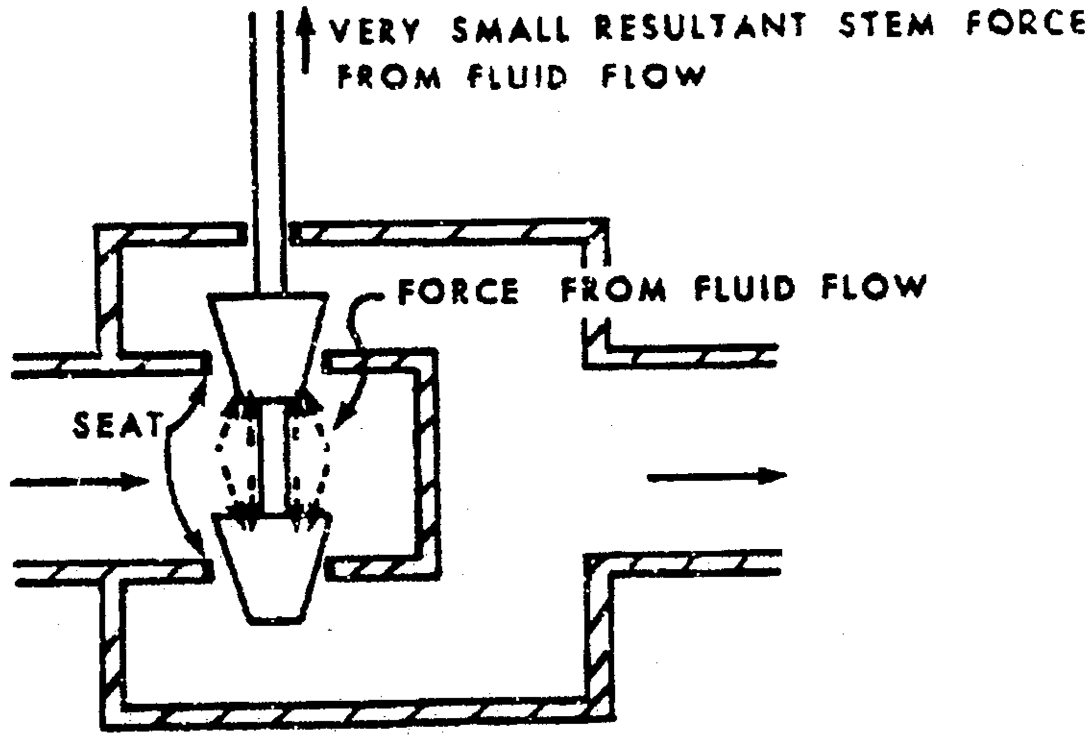


Figure 16: Double Seated Globe Valve.

A double-ported globe valve does not offer such complete shut off as a single ported unit, mainly because of the difficulty of maintaining correct alignment and uniform wear and also differential expansion problems if the process is hot.

Valve Positioners

Pneumatic valve positioners are the most commonly used valve accessories. A valve positioner is a device which will accurately position a control valve in accordance with the pneumatic control signal. With a positioner, the control signal goes to the positioner instead of directly to the valve actuator. The positioner outputs another pneumatic signal which operates the valve actuator.

- **The positioner compares the control signal (the requested valve position) with the actual valve position through the mechanical feedback linkage.**
- **If the valve position is incorrect, the positioner will either load or exhaust air from the valve actuator until the correct valve position is obtained.**
- **A positioner requires both a control signal and an instrument supply air for normal operation. Most positioners come equipped with three gauges to indicate supply air pressure, control signal pressure and actuator diaphragm (output) air pressure,.**

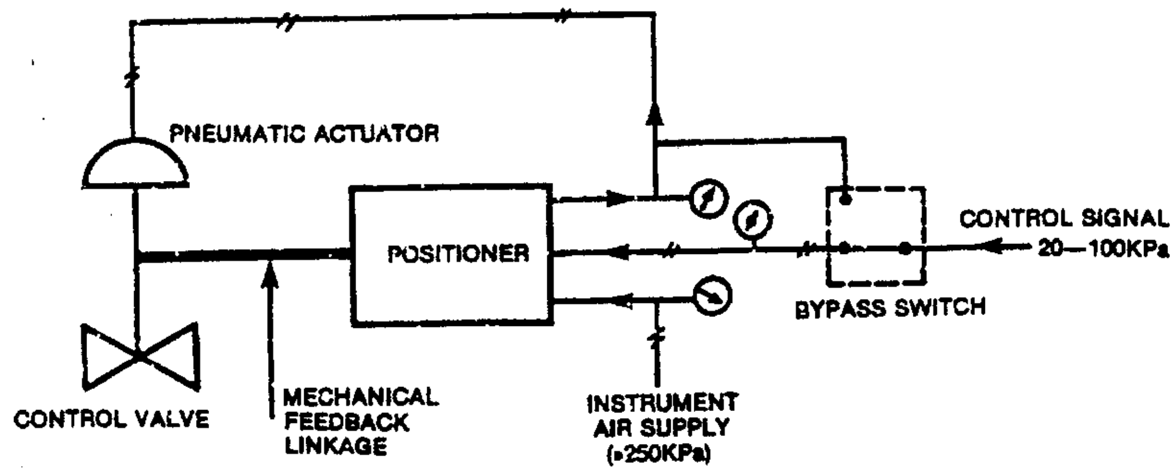


Figure 17: A Simplified Valve Positioner Installation.

Other advantages of the valve positioner include:

1. Minimizing the effect of friction, hysteresis and deadband on the valve stem. With a high pressure system, tighter valve stem packing is needed to prevent leakage and a high frictional force is generated. With a positioner valve stem movements of as little as 25 μm are possible.

2. Enables signal range change. A positioner can amplify the incoming control signal when a greater actuating force is needed. A 20-100 kPa control signal can be amplified to 40-200 kPa before being applied to the actuator.

3. Allows signal reversal. A positioner can operate in either direct or reverse acting mode. In direct acting mode, an increase in control signal pressure causes and increase in positioner output air pressure. In reverse acting mode, an increase in control signal pressure causes a decrease in positioner output air pressure. For example, in reverse mode, a 100 - 20 kPa actuator signal would correspond to a 20 - 100 kPa control signal.

4. Increases the speed of response of the actuator. The speed of response of the valve actuator depends on:

   (a) the actuator volume, and

   (b) the flowrate of the control signal air.

   The positioner has a larger output capacity than other pneumatic devices, say an I/P transducer (typically 40 - 50 cfm vs 4 - 5 cfm). With a positioner, quicker fill up of the actuator and therefore faster speed of response can be achieved.

5. Allows valve flow characteristic to be changed. Most valve positioners employ a rotating cam in the feedback system. This cam can be changed to simulate different valve flow characteristics.

   A linear globe valve can be used to respond in an equal percentage manner.

6. Allows split range operation. In a split range control loop, one controller is used to drive two control valves.

An example of a split-range control loop is the wide range heat transport (PHT) pressure control loop as shown in Figure 18.

- In this system, both valves use the same 4 - 20 mA signal from the controller.
- However, the feed valve is A/C and the bleed valve is A/O. (Note the different range of signal the feed and bleed valve responds to.)
- Under normal conditions, i.e., PHT pressure constant, both valves are closed, i.e., signal at 63% for both valves.
- If the pressure in the PHT system starts to increase, the PT will send an increasing signal to the controller.
- This results in an increasing control signal applied to both the bleed and the feed valve. The bleed valve will open more, removing more D_2O from the PHT system, while the feed valve stays closed. The net result is the pressure in PHT system remains constant. The opposite occurs if the pressure decreases, i.e., decreasing signal to both valves - feed increases bleed decreases.

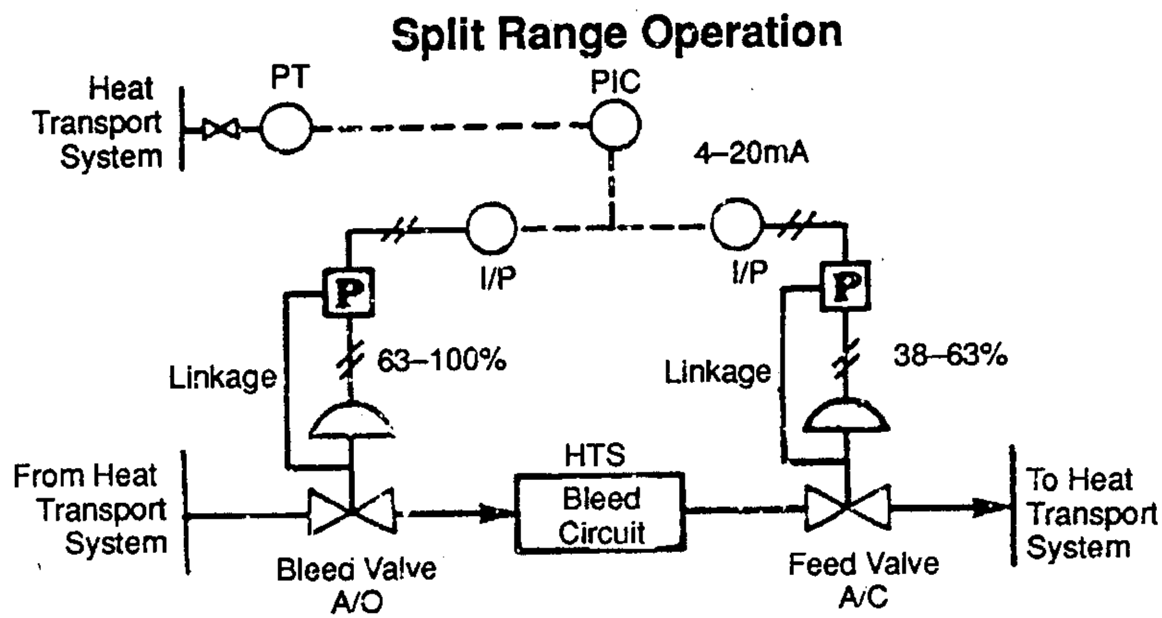


Figure 18: Split Range Control Loop for PHT Pressure Control by Feed and Bleed.

Bypassing the Positioner

On most positioners, a bypass switch is available (see Figure 17). In the bypass mode, the positioner itself is bypassed and the control signal is applied directly to the control valve actuator.

The bypass switch must be used with caution. If the positioner is amplifying the control signal, operating the bypass switch win result in a lower pressure signal to be applied to the valve actuator. This will cause an erroneous valve opening. Likewise, when the positioner is operating in reverse mode, switching to bypass may result in the valve moving instantaneously from one extreme to the other. In practice, the bypass switch is often removed after the positioner has been commissioned to avoid possible confusion and misuse.

Failure Mode With Valve Positioner

- With the addition of a valve positioner, the operating mode of a control valve could be changed.
- A globe valve which consists of a direct acting actuator and a direct acting valve body is shown in Figure 19.
- With the positioner in direct mode, a 100 kPa control signal will drive the valve to the fully closed position.
- The valve is therefore (signal) air to close and will fail open.

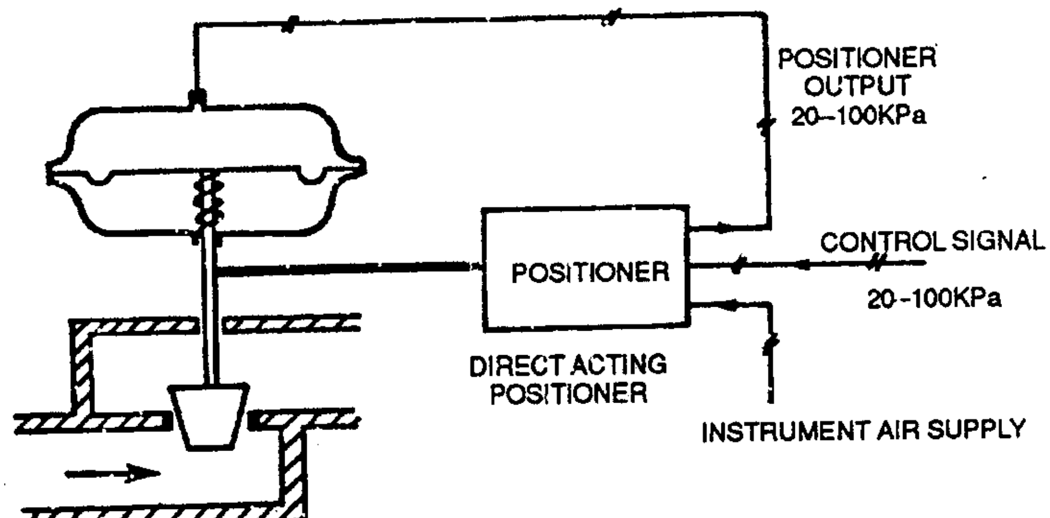


Figure 19: Air To Close Valve With Direct Acting Positioner.

However, when the positioner is in reverse mode as shown in Figure 20, a 20 - 100 kPa control signal will cause the positioner to output a 100 - 20 kPa signal to the actuator.

- **In this case, a 20 kPa control signal will cause the valve to be fully closed (positioner output at 100 kPa)**
- **whereas a 100 kPa control signal will cause the valve to be fully open (positioner output at 20 kPa).**
- **The valve will be (signal) <u>air to open</u> and <u>fail open</u>.**
- **With a positioner different operating and failure modes can be obtained.**

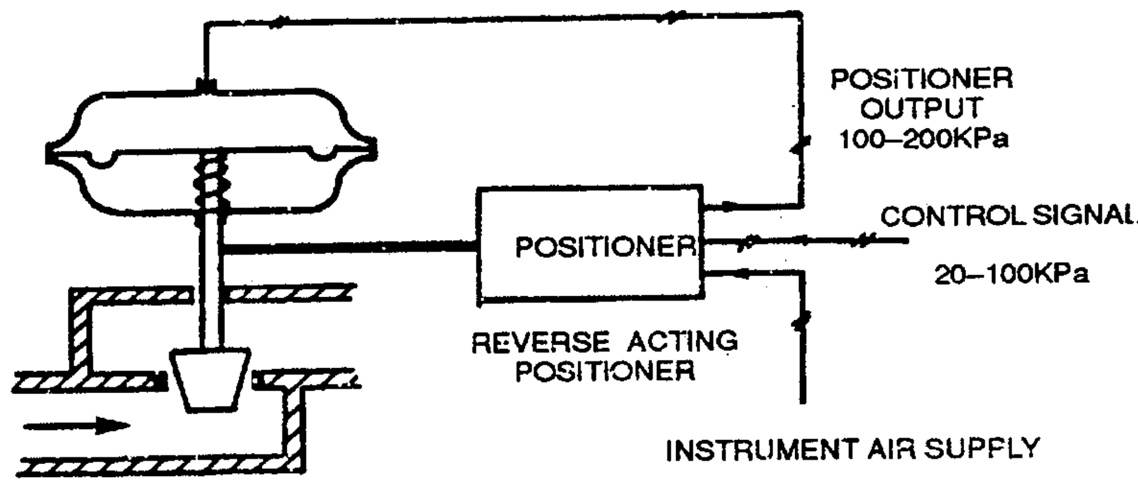


Figure 20: Air To Close Valve With Reverse Acting Positioner.

Butterfly Valves

Butterfly valves are one of the most popular types of rotary valve. A typical butterfly valve is shown in Figure 21.

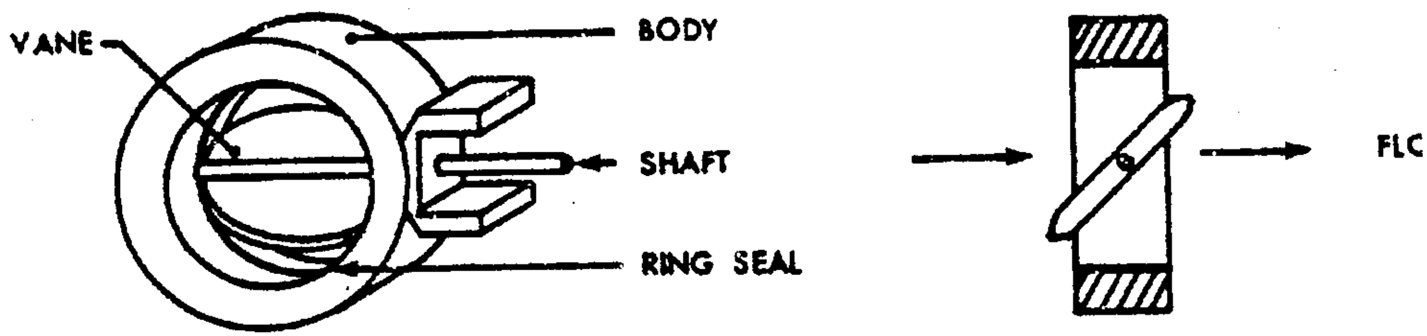


Figure 21: Typical Butterfly Valve.

The butterfly valve consists of a body, a vane or disc, a shaft supporting the disc and various seal and bearings to accommodate shaft operation and leak-fight shutoff. In a butterfly valve, rotation of the disc within the body controls fluid flow.

Advantages of Butterfly Valves

Of all the valve types, a butterfly valve contains the least amount of body material. This is important when the valve has to be manufactured from expensive material such as stainless steel. Another advantage of butterfly valves is that the valve body occupies a minimal amount of flow line space. For applications where large isolation valves are required, butterfly valves are the least expensive.

Application of Butterfly Valves

In industrial applications butterfly valves are primarily used for ON/OFF control associated with low static pressure, high flowrate situations.

An example of such an application is in the condenser cooling water system of a 500 MW generating stations, shown in Figure 22.

- **In this system circulating pumps P1 and P2 provide a flow of approximately 25,000 kg/s through the three condensers.**
- **The individual condensers can be isolated independently using motorized valves MV101-106 and manual valves V3-8. All of these valves are 72 inch butterfly valves.**
- **As well, the whole bank of condensers can be isolated from the pump discharge by motorized valves MV1 and MV2, also butterfly type, but 96 inches in size. In this application, the butterfly valves allow isolation at a relatively low cost considering the large sizes involved.**

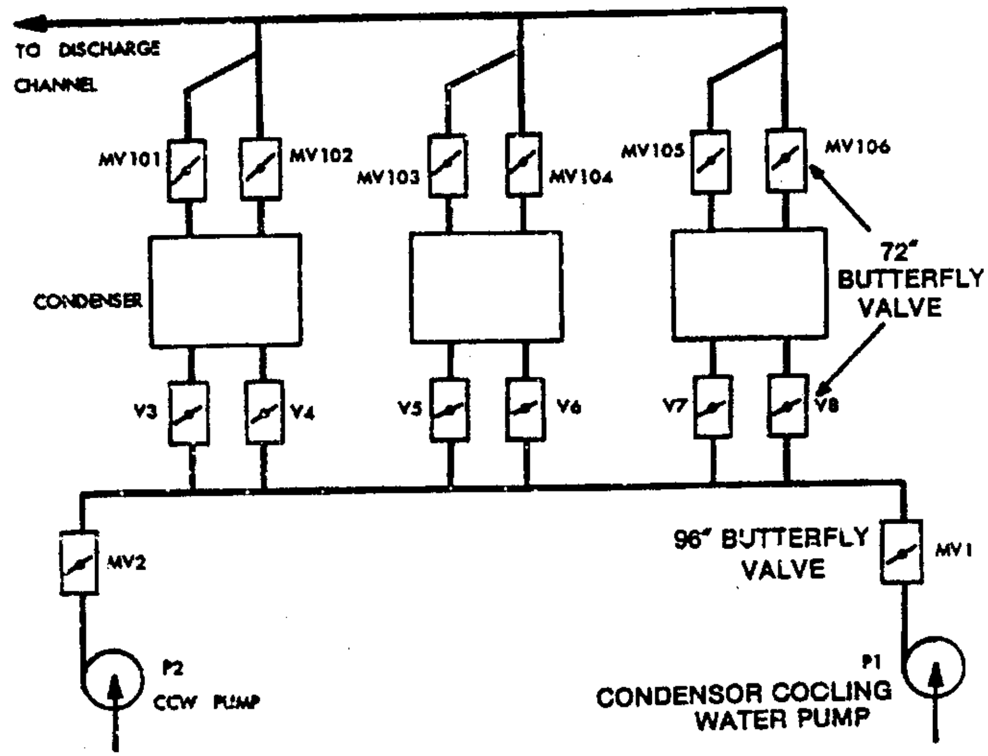


Figure 22: Condenser Cooling Water System of a 500 MW generating station.

Ball Valves

The ball valve gets its name from the spherical shape of its rotating plug.

As with the butterfly valve, the ball valve also rotates about a central shaft. Usually, a quarter turn is sufficient to position the valve from fully closed to fully open. Figure 23 shows a typical full ball valve.

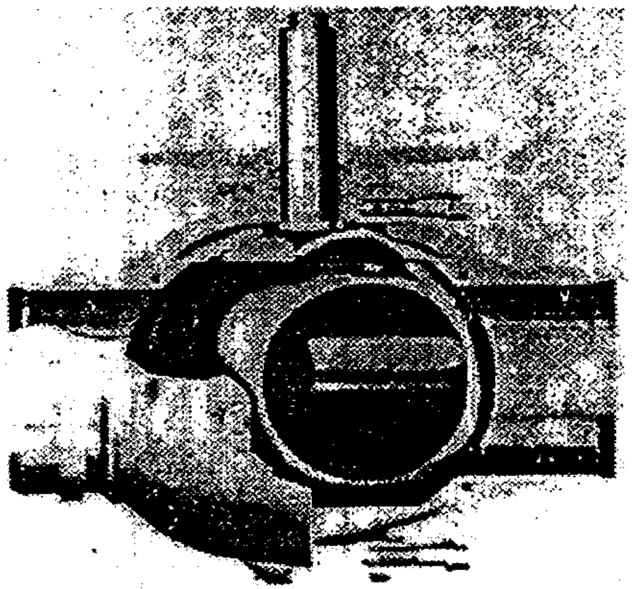


Figure 23: A Typical Full-Ball Valve.

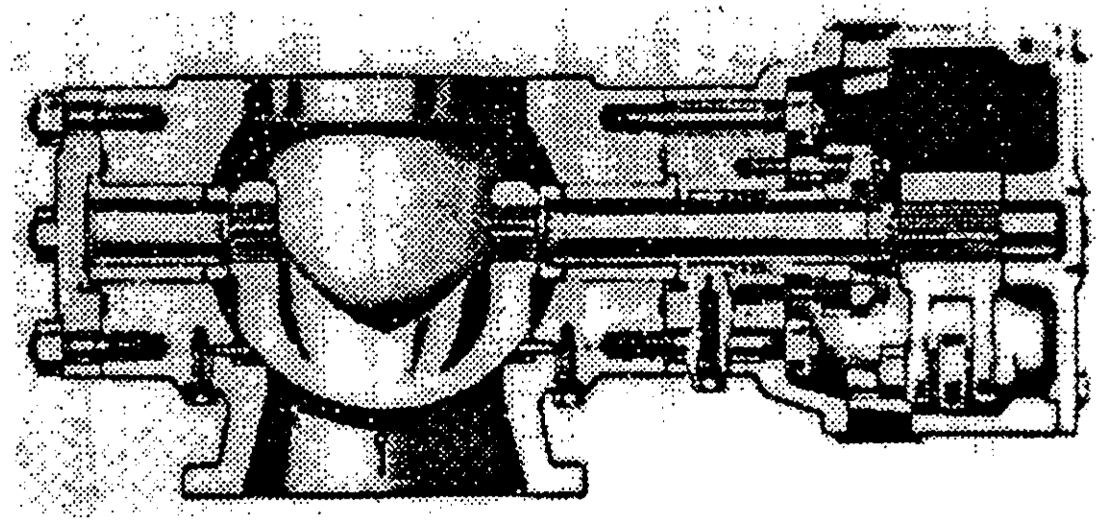


Figure 24: A Typical V-Ball Valve.

To obtain a specific flow characteristic during throttling, the opening of the ball valve plug can be shaped or contoured, as in the case of the V-ball shown in Figure 24.

One advantage of the V-ball valve is its high flow capacity when fully open. Little restriction is imposed by the valve when it is open. In partially open (throttling) position, it has minimal interference with the flow stream and therefore provides good control characteristics and wear resistance. In industrial applications, V-ball valves are used in locations where good corrosion and erosion resistance are required.

Eccentric - Rotating Plug Valves

The eccentric-rotating plug valve has the advantages of the butterfly and ball valve with the added advantage of positive seating and therefore tight shut-off. Figure 25 shows the cross-sectional view of an eccentric rotating plug valve.

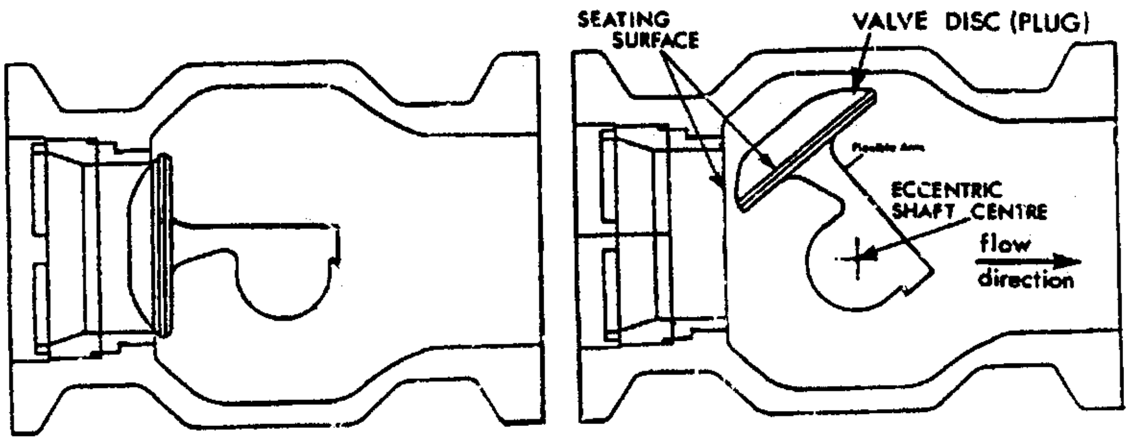


Figure 25: An Eccentric Rotating Plug Valve.

The arm which directly supports the valve plug is slightly flexible so that when it is rotated against the seat, it will bend or flex to compensate for minor misalignment. The eccentric rotating valve covers a large percentage of process control requirements and is fairly widely used in large process systems.

Diaphragm (Saunders) Valve

The diaphragm valve, shown in Figure 26 has a straight through construction with a leak-tight closure. No packing or seal assembly is required in the valve stem to prevent leakage. Flow control is achieved by pressing a flexible diaphragm against a weir formed in the body wall.

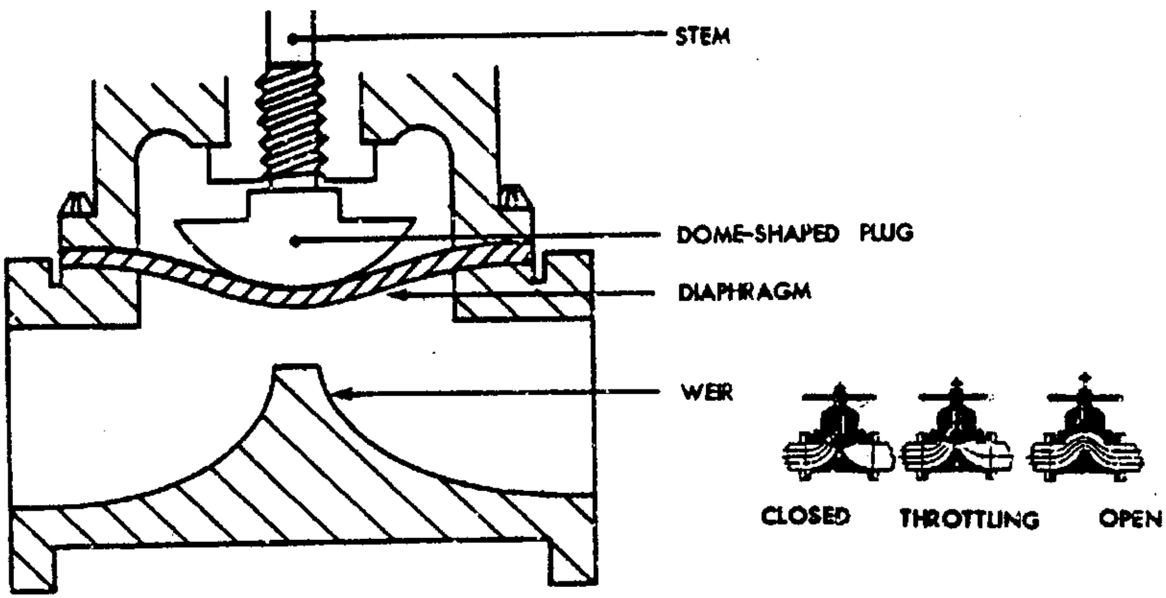


Figure 26: A Typical Diaphragm Valve.

The flow characteristic of a diaphragm valve approximates a quick open valve. Materials used for the diaphragm vary with conditions of flow, temperature, pressure and type of fluid. Plastic, tin, synthetic and natural rubbers can be used. The diaphragm is chosen such that erosion caused by crud formation is minimized and at the same time provides a leak-tight shut-off.

Solenoid Valves

- A solenoid valve is an electrically operated valve where an electromagnet is used as an actuator to change the valve state.
- Solenoid valves are used only in an ON/OFF manner.
- In a two-way solenoid valve (shown in Figure 27), the valve is open when the solenoid coil is energized.
- The energized solenoid coil acts as an electromagnet which pulls the plunger and the valve disc upwards.
- The valve is closed when the coil is de-energized. The closing action of the valve is achieved by the weight of the plunger, valve stem and disc.
- Once the disc comes close to its seat, flow (from left hand side) will snap the valve tightly shut.

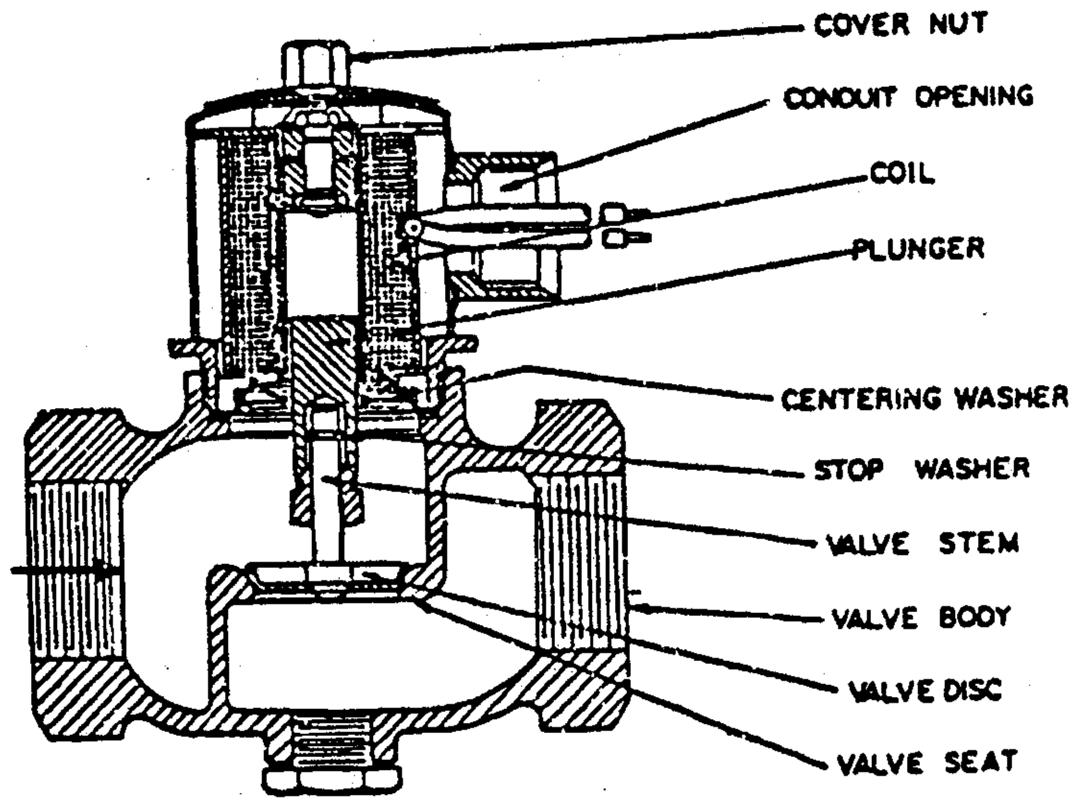


Figure 27: A Two-Way Solenoid Valve.

In a three-way solenoid valve, as illustrated in Figure 28, energizing the solenoid coil causes the valve to open from Port 1 to Port 2 while de-energizing the coil causes the valve to open from Port 2 to 3.

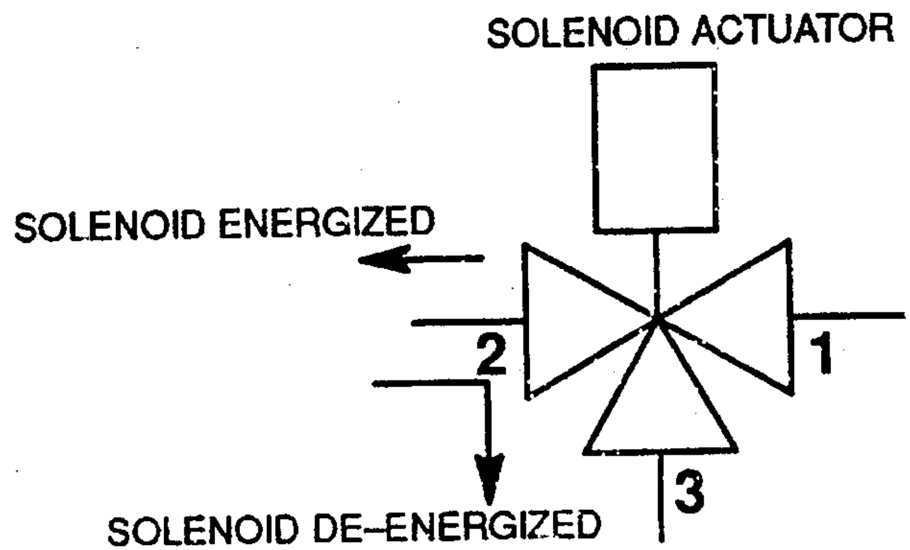


Figure 28: A Three-Way Solenoid Valve.

- A solenoid valve is often used in conjunction with a diaphragm control valve to obtain ON/OFF valve operation with an electrically applied signal.
- The arrangement, depending on the valve size, may be much less expensive and faster responding than using an all electric control valve.

Figure 29 shows an ON/OFF application of a three-way solenoid valve used to operate an A/0 pneumatically actuated valve.

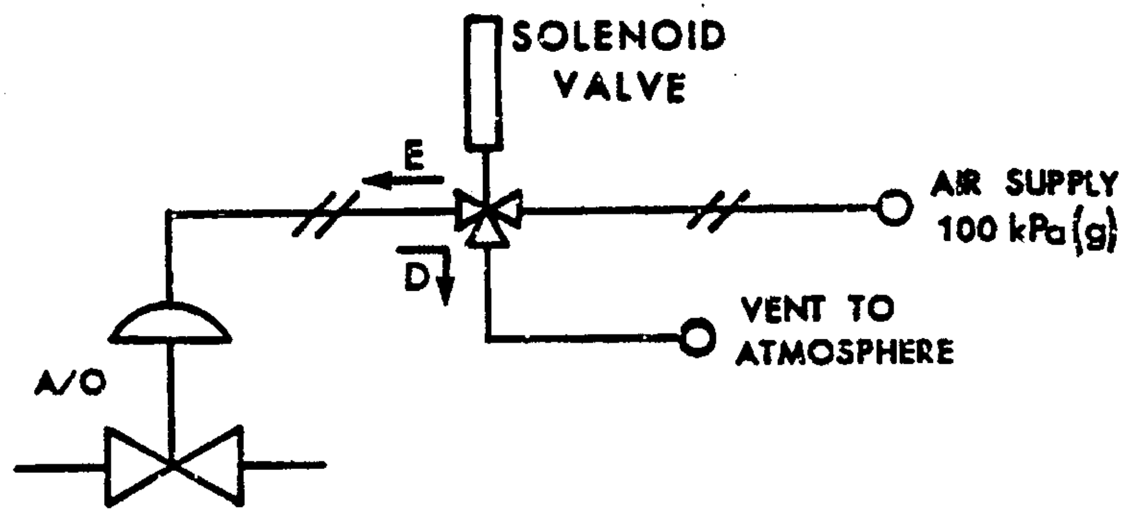


Figure 29: ON/OFF Application of a Solenoid Valve.

- When the solenoid valve is energized, 100 kPa(g) is applied to the A/O valve, keeping it fully open.
- When the solenoid valve is de-energized, the air supply (100 kPa(g)) is cut off, and simultaneously the pressure trapped between the two valves is vented to atmosphere. This allows the A/O valve to go fully closed.

Motorized Valves

Motor driven valves are often used to isolate pneumatic actuator control valves and other equipment. A typical motor driven actuator has a reversible, 3 phase electric motor which drives the valve between two predetermined position limiters.

- The majority of motorized valves are parallel slide gate valve, as shown in Figure 30.
- For this kind of valve, the sliding gate lowers as the valve stem is rotated.
- A spring between the two parallel gates exerts a force against the fluid flows and therefore maintains a leak tight seal during isolation.

Many different designs of motor driven gate valve are used in process industries, all of them work on essentially the same principle discussed above. The most frequently encountered types are referred to by their brand names, such as Limitorque, Rotork, and Hopldnson.

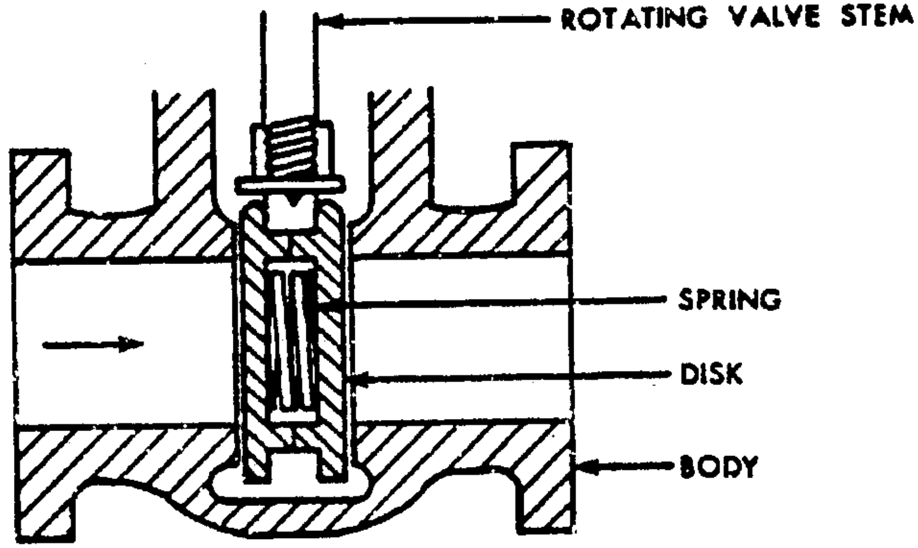


Figure 30: A Parallel Slide Gate Valve Body Assembly.

Figure 31 illustrates a typical motor driven valve installations on the steam generator system of a CANDU nuclear station.

- Limitorque valves MV1 and MV2 are used to isolate the boiler from the heat transport system for maintenance or in case of boiler tube failure.
- The boiler level for any steam condition is controlled by manipulating the feedwater inflow using pneumatic actuator control valves CV1, CV2 and CV3.
- All three boilers in the bank are controlled simultaneously by the same set of valves.
- At normal power levels, one of CV2 or CV3 (A/O, 10" doubled-ported globe valves) provides feedwater control, the other valve is held closed and kept as a backup.
- At low power levels, finer control of feedwater flow is required. The system is adjusted such that below 10% full power CV1 (A/C, 2" globe valve) provides feedwater flow control.
- Above 10% full power, CV1 is fully open and either CV2 or CV3 takes over, giving a higher flow capacity.
- During normal operation, Rotork valves MV6 and MV7 are held open, but can be used to isolate the feedwater control valves in case of a failure.

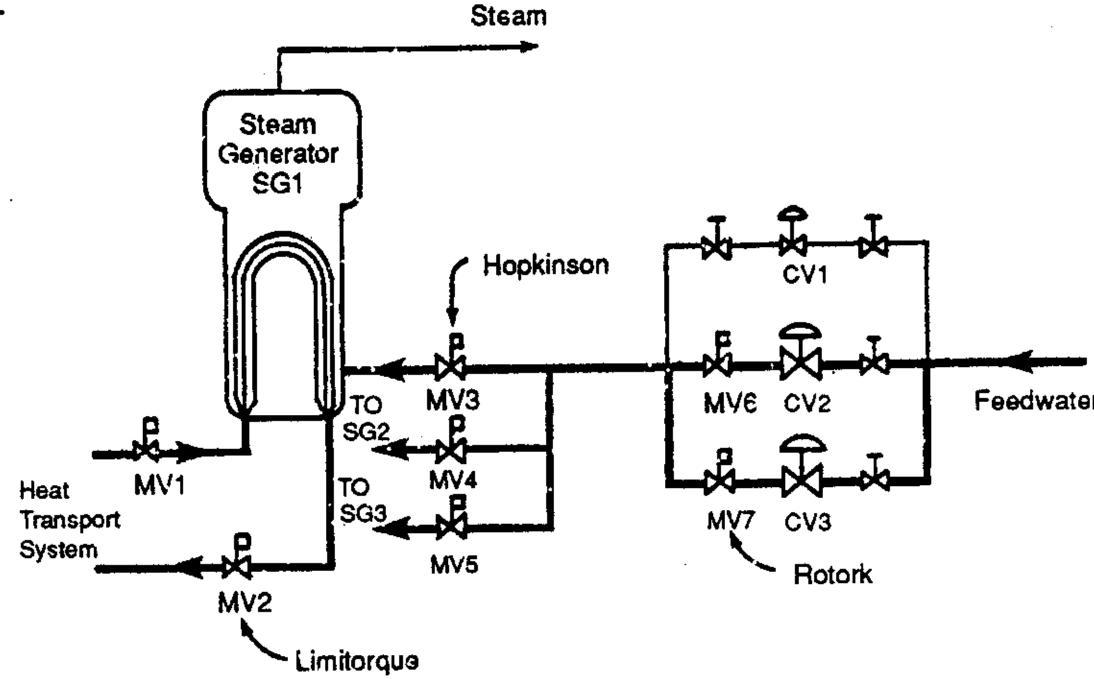


Figure 31: Motorized Valve Installations in a CANDU Steam Generator System

Although the same set of feedwater valves are used to control the feedwater inflow to three boilers, the boilers might produce steam at different rates (due to blocked U-tubes or sludge and scale formation) and cause feedwater level between boilers to vary. To make sure that all three boilers are at the same level, Hopkinson valves MV3, MV4, and MV5 are used, one for each boiler. These valves are operated until the feedwater levels on the three boilers are identical. In this case, Hopkinson valves are used for trimming the flow to each boiler independently, as well as providing the means of isolating the boiler from the feedwater circuit.

Use of Different Sized Valves in Parallel

- Many industrial processes have a large range of controlled flow requirements between 0% and 100% of the controllable range, boiler level control is a typical example. The feed flow to the boiler must be adjusted to maintain boiler level at the setpoint over the entire range of possible steam flows i.e., feedwater and steam flows must always be in mass balance.

- The volume of feedwater required at full power conditions is large typically hundreds of kilograms per second of feedwater per boiler - and necessitates the use of a large CV valve to meet the CV flow requirements (10" or 25 cm is typical).

- If just one valve, capable of meeting the 100% requirement, was used control at low power (low flow) levels would be imprecise. To obviate this disadvantage, two valves are provided, one with 100% capability and another with 10-25% capability, in parallel.

- In operation of this type of system requires the smaller valve to open to its maximum whilst the larger valve remains closed. As the small valve reaches its maximum opening (or perhaps just before fully open) the large valve commences to take up the flow.

Boiler Level Control

There are two options for the small valves when the large valves are fully open:

- remains fully open,
- reclose (in order to avoid excessive erosive wear)

When the large valves close the reverse actions follow (see Figure 32).

The method of achieving this operation differs between various installations, but in general the operation can be achieved basically as follows.

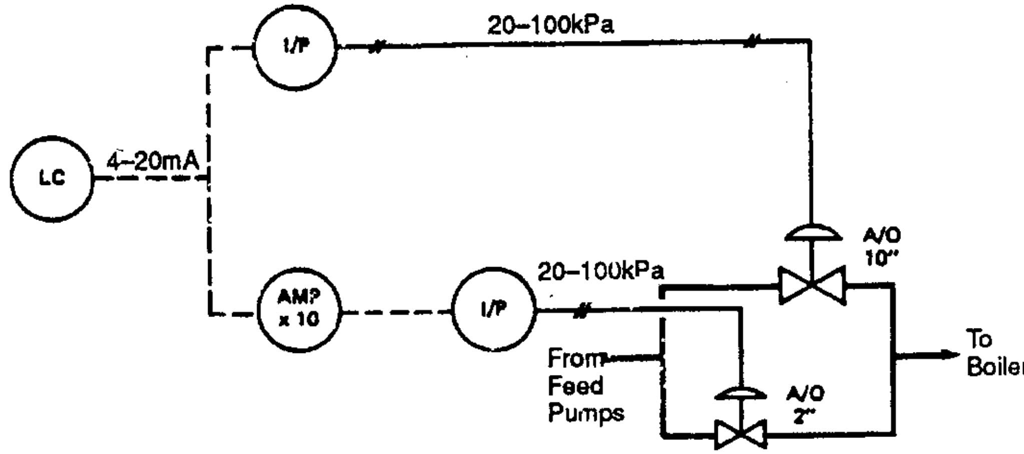


Figure 32: Representative Boiler Level Control Scheme.

The boiler level controller (LC) has a 100% output range of 4 - 20 mA (16 mA span). The small valve requirement is to go to the fully open position at 10% range i.e., after LC output has increased by 1.6 mA to 5.6 mA. By amplifying the LC output signal by a factor of 10 the signal applied to the small valve I/P is now 4 - 20 mA or an LC output of 4 - 5.6 mA i.e., the valve will stroke fully open.

Until this time the large valve should remain closed i.e., we require no valve movement until the large valve I/P's input exceeds 5.6 mA. This can be achieved by a calibration adjustment to the positioner, a necessary item of equipment, fitted to the large valve. In actual practice the large valve would probably be adjusted to commence opening slightly below 5.6 mA to avoid a "step" in the flow pattern. (See Figure 33).

Fine and Course System Control of Boiler Feed Water

An absence of this parallel valving arrangement can lead to serious control problems such as those contributing in part to the accident at Chernobyl. At Chernobyl, the operator was attempting to control water level in the steam drum at low power levels with a single, 100% capacity valve. This caused wide fluctuations in boiler level which, since it was a boiling water reactor, caused severe problems with reactivity control.

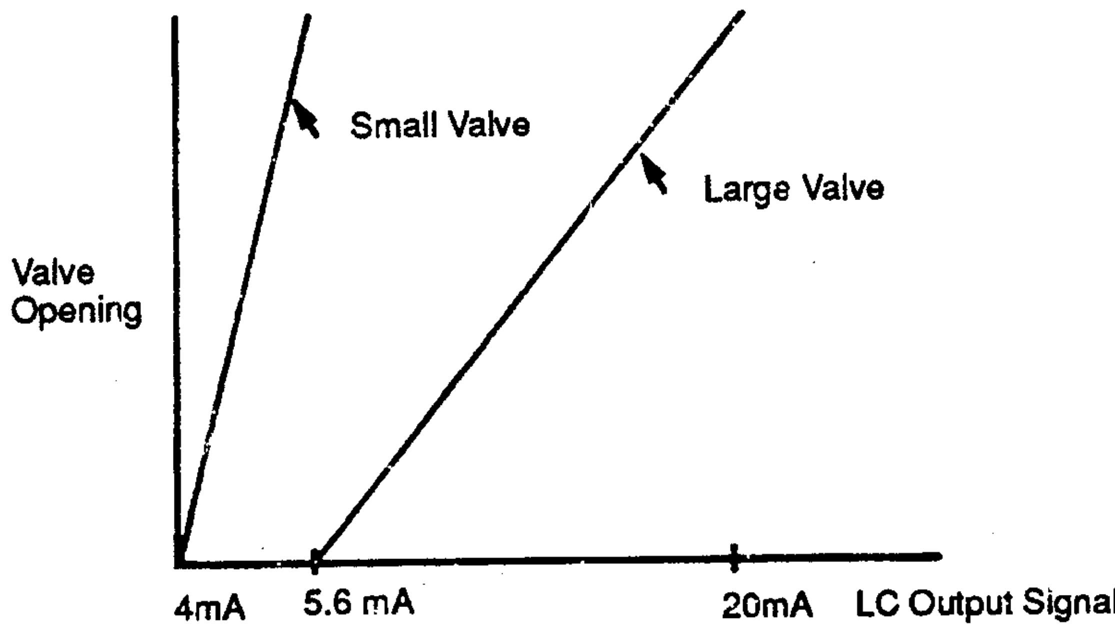


Figure 33: Boiler Feedwater Valve Control Logic.