# Introduction to Control Valves

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# Chapter 1: Introduction to Control Valves

# Introduction

There are many different types of final control element that are used to manipulate or control the flow of fluids. These elements can take the form of metering pumps, dampers or louvers, variable pitch fan blades or even speed regulators for engines, but, the most often used final control element is the control valve. It should be noted now that the subject of control valves and flowing fluid behavior has become a science within itself.

There've been many books compiled by valve manufacturers and independent publishers alike, that cover all aspects of valve construction, valve characteristics, fluid behavior, valve sizing, valve noise in far greater detail, thus this course is purely an introduction to the subject.

# Throttling and Shut Off  Action of a Valve

A control valve acts as a variable resistance in a pipeline and provides a pressure drop, often referred to as *throttling*.

Throughout their functional life, most control valves will be a certain percentage open for the purpose of throttling. However, there are occasions when flow has to stop, therefore a control valve must also be able to achieve a tight shut off condition.

# Wear and Tear

Despite its wide use, there is probably no other element in a system which receives more abuse and less attention than a control valve.

In most control systems, a control valve is subjected to more severe conditions of temperature, pressure, corrosion and contamination than other components, yet it still must perform satisfactorily with a minimum amount of maintenance, as it manipulates the flow of process fluids.

# Typical Control Valve

This image shows a typical pattern of a pneumatically-operated valve.

*Note that the control valve consists of two major components:*

- valve body assembly
- actuator

This style of valve falls into the category of sliding-stem valves; the other group of valve being the rotary shaft type.

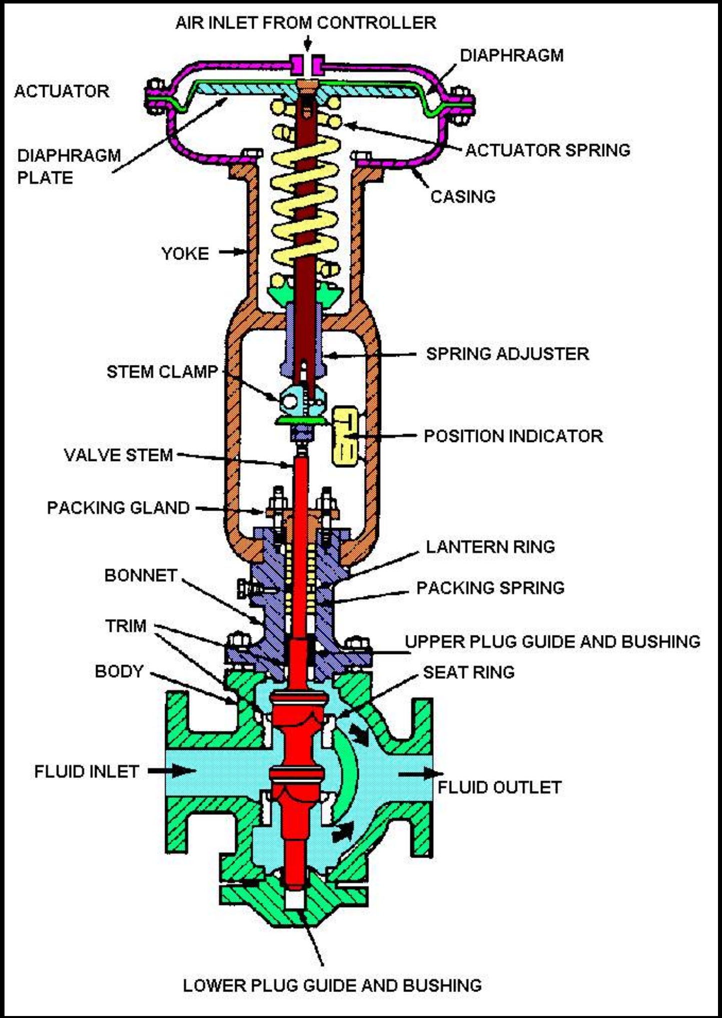



Figure 1- Typical control valve

# Operation

Its operation is relatively simple. Air pressure is applied to the top of the flexible diaphragm which exerts a downward force. The force moves the valve stem downwards against the restraining action of the spring.

This downward movement will continue until either, the plug is fully mated with the seat, or, until the upward force of the spring (and flowing fluid pressure if valve is in service) equals the downward force of the actuator. At this point the valve stem stops moving.

# Chapter 2 – Control Valve Terminology

# Control Valve Terminology

Control valve terminology is quite extensive and can best be learned from manufacturers' handbooks and catalogues.

However, the following paragraphs should be sufficient to give the reader some of the basic terms.

# Valve Body

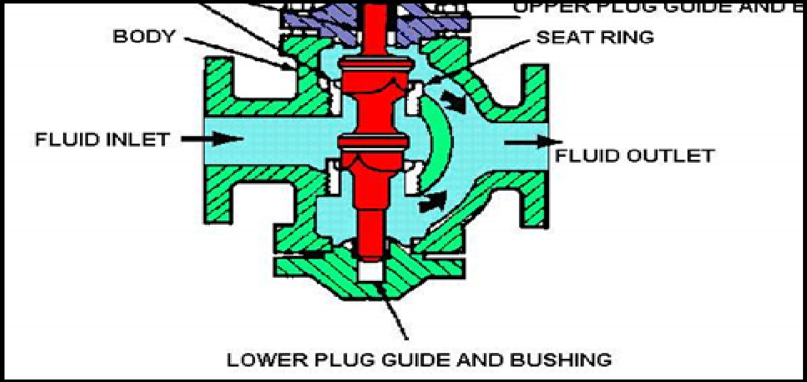



Figure 2 - Typical packing box

The part of the valve that connects to the process piping and through which passes the flowing fluid, is called the valve body (the component in green, in the image). The valve body must be able to withstand the same pressures and temperatures as the process piping.

Small valves are connected to the piping by means of screwed threads, whereas larger valves are connected to the piping by means of flanges and welded end connections.  Whatever the method of connection, these joints should be leak-free and the valve positioned so that it is easily accessible for maintenance purposes.

# Bonnet

The bonnet assembly (component in purple) is a metal casing that is threaded or bolted to the top of the valve body.

It serves as a guide for the plug stem, houses the stem-seal and supports the actuator assembly.

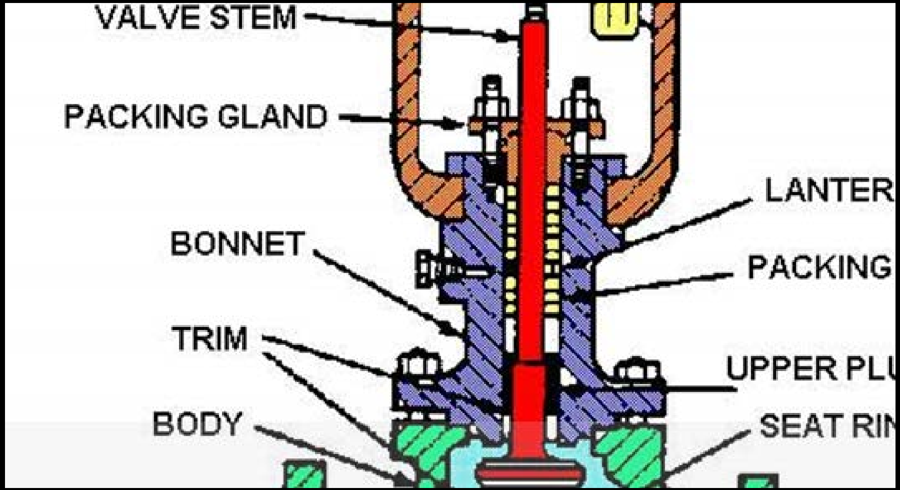



Figure 3 – Bonnet Assembly

For extreme temperature service, extension or longer bonnets are used to prevent extremes of temperature damaging the sealing materials. Valves in very hot service have cooling fins attached to the bonnet.

# Packing Box Assembly

This is part of the bonnet assembly and is used to help prevent leakage around the valve plug stem. It allows the valve stem to move up and down with minimal leakage of the process fluid.

All other valve connections, valve body to process pipework, valve body to bonnet for a little bit unclear example, are fixed or non-moving and are easily sealed using gaskets.

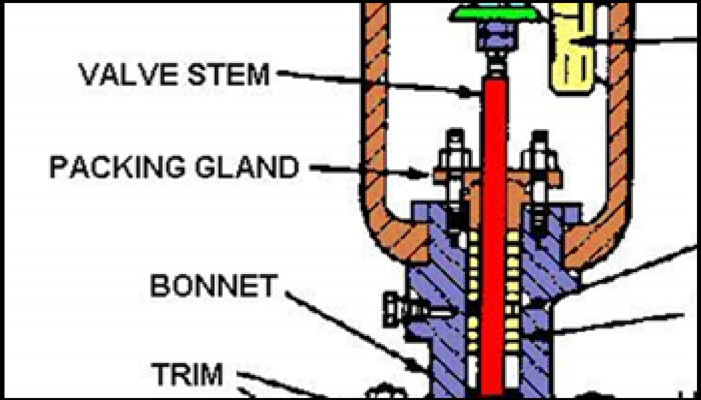



Figure 4 - Typical packing box assembly

# Packing Box

The valve stem however must move up and down. Packing rings within the packing box, seal in the process fluid while allowing the valve stem to move with the minimum of friction.

The packing rings themselves are usually made from a relatively soft and compressible material such as asbestos, teflon, etc.

# Packing Box

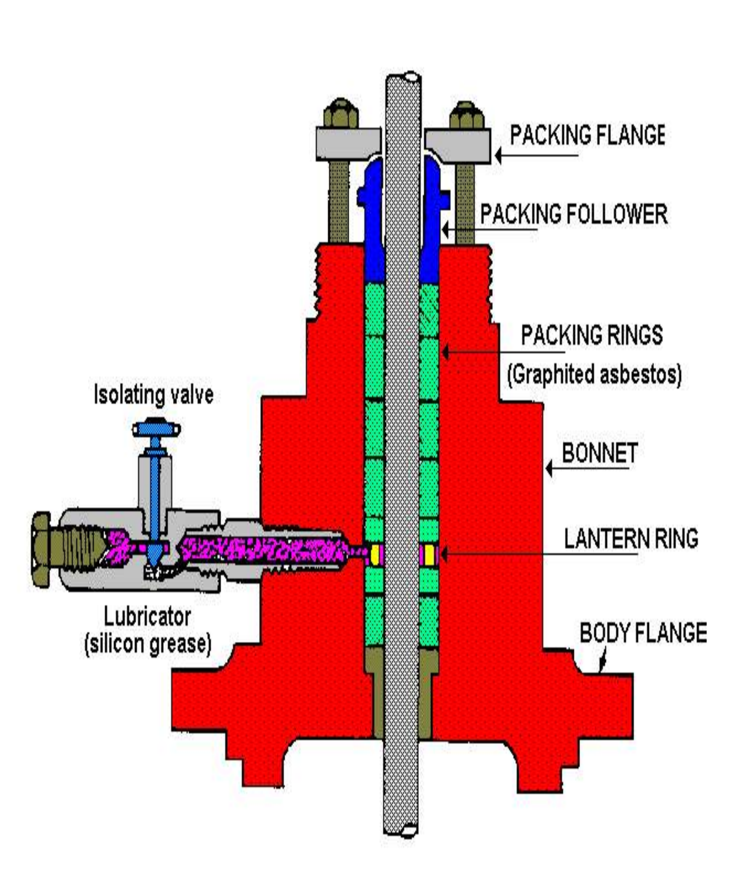



Figure 5 - Typical packing box

# Non-Lubricated Packing Box

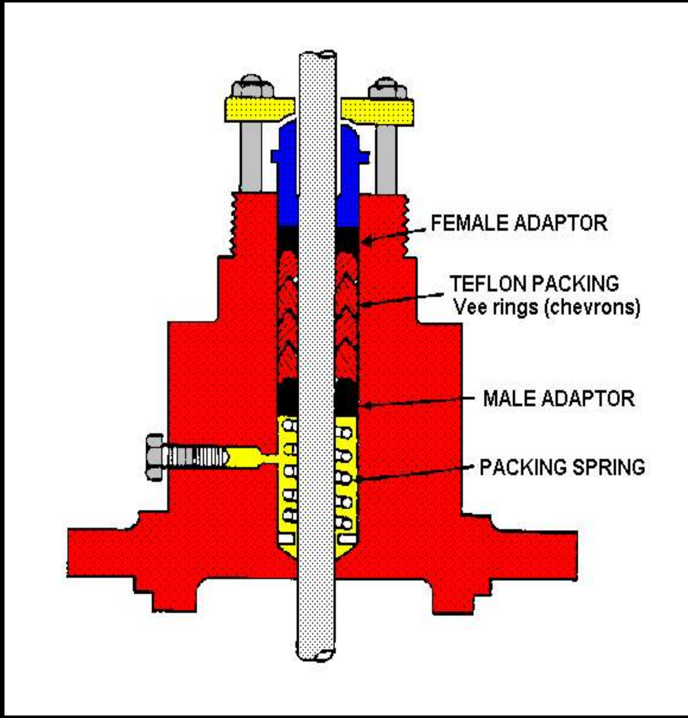



Figure 6 - Typical non lubricated packing box

# Packing (or Pressure) Flange

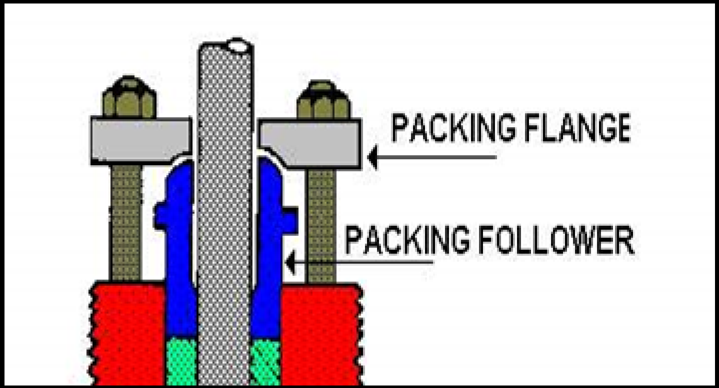



Figure 7 - Typical packing flange

The function of the packing or pressure gland or flange is to compress the packing rings tightly around the valve stem forming a leak proof seal.

However, in normal operation of the control valve, it is not unusual to see some fluid leakage around the valve stem.

With regular maintenance. the packing gland nuts can be adjusted to the correct pressure. Just tight enough to minimize leakage, but not so tight so as to cause stem binding.

# Valve Trim

In general terms, valve trim refers to the plug seat arrangement, but in a broader sense, trim refers to all internal parts of the valve that come into contact with the process fluid.

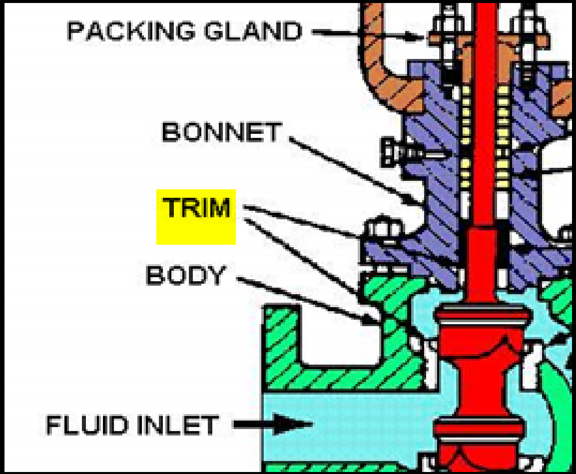


Figure 8 – Valve Trim

This would include the valve stem, valve plug (a device connected to the valve stem that controls fluid flow), seat ring (a ring that forms the valve body port), valve guides and bushings, (metal inserts that fit into the valve body and guide the moving parts), but excluding the valve body or bonnet assembly.

# Different Types of Trim

Valve manufacturers often provide different sets of 'Trim' which can be fitted within a specific valve body.

This enables a valve's characteristics to be changed without replacing the whole valve.

# Yoke

The Yoke is the upper structure of the valve installation which supports the actuator case assembly. It is rigidly fixed to the valve bonnet, usually by means of a large lock-nut. It is open frame provides access to the spring tension adjuster, valve stem and stem connector.

It should also be noted that the Yoke must be strong enough to withstand any forces created by the actuator when it attempts to reposition the valve stem. Salt-water corrosion in offshore locations has been known to weaken the Yoke sufficiently to cause the Yoke to snap or break under normal working stress.

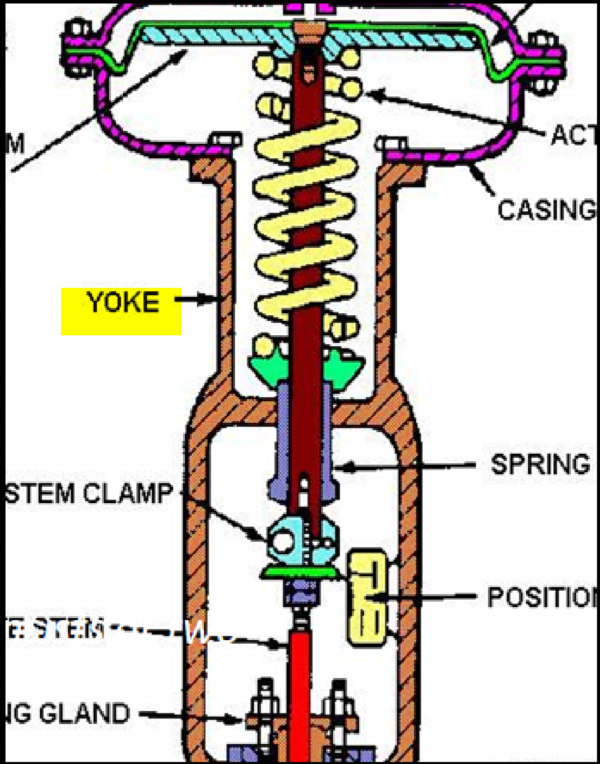



Figure 9 - Yoke

# Actuator

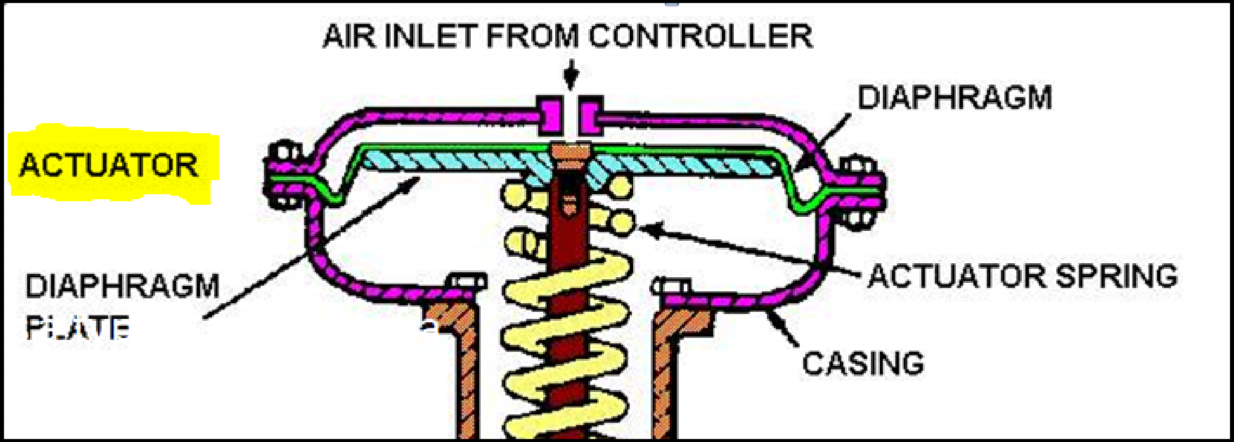



Figure 10 - Actuator

There are many different kinds of actuators (sometimes referred to as motor elements) used in industrial facilities.

The type of actuator used in a specific plant application depends on many factors, including the process to be controlled, the action that is to be performed and the speed with which the, action must occur.

# Types of Actuators

There are electrical and hydraulic actuators, but the spring and diaphragm actuator is by far the most common type of actuator used in automatic process control systems.

Pneumatic actuators use air or gas pressure to produce mechanical motion. The motion produced is then used to position the controlling element anywhere within the actuator's limits of travel.

# Chapter 3 - Fail Safe

# Fail-Safe

Safety at any production facility is of prime importance, so the word FAIL-SAFE should be firmly embedded in the minds of anyone who is involved with the plant or production. Most pneumatic control valves and automatic shut-down valves have spring-loaded actuators.

When the loading pressure is relieved, the spring will move the final control element (valve) to one of its extreme positions, either, fully open or fully closed, the position being determined by the control valve construction.

# Fail Opened or Fail Closed

A 'Normally Open' control valve is one which opens when the diaphragm pressure is reduced to atmospheric. (Figure 11)

A 'Normally Closed' control valve is one which closes when the diaphragm pressure is reduced to atmospheric. (Figure 12)

So, a Normally Closed valve is a Fail Close Valve, or, Air to Open. A Normally Open Valve is a Fail Open Valve, or, Air to Close.

# Fail Open Valve

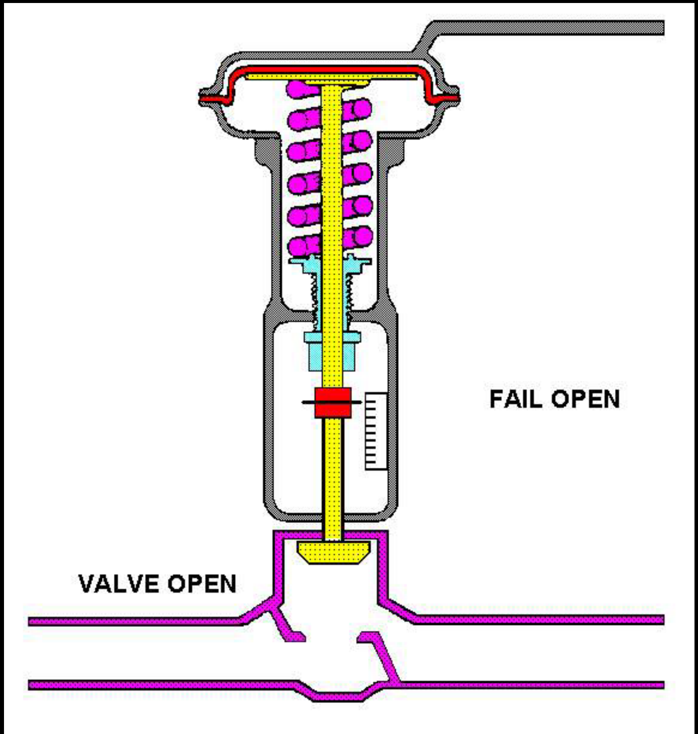



Figure 11 - Fail open valve

# Fail Close Valve

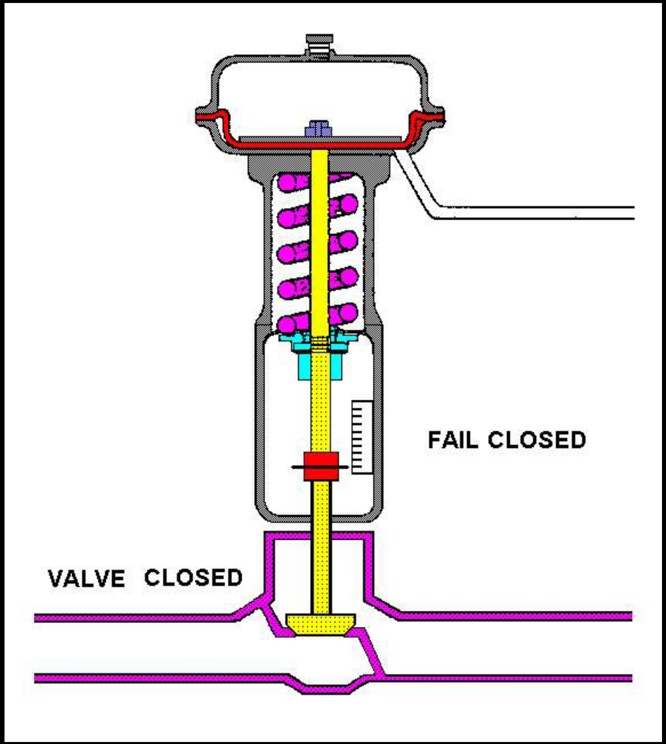



Figure 12 - Fail close valve

# Valve Selection

The criteria for the selection of either one depends on which action will make the process safe should there be a loss of pneumatic supply or damage to the actuator, such as a torn or split diaphragm. If such a condition occurred the valve would return to its 'Normal' or Fail-safe position of either full open or full closed.

A process operator new to a facility that uses pneumatically operated control valves, should try to become familiar with the Fail-safe action of those valves. "Will a particular valve fail open" or "will it fail close?"

If the operator is familiar with these points, then, in the event of an emergency, they will have a much clearer idea of how the plant and process will respond and therefore will be able to react or respond more readily with corrective action if necessary.

# Chapter 4 - Valve Types

# Single Ported Valves

The term 'Single-ported' refers to the fact that a single path exists for passage of fluid through the valve. The diagrams on the following pages show two forms of single ported valves which are quite clearly two similar units, with one obvious difference being that the plugs are reversed with respect to one another.

Notice that with one valve, the downward movement of the plug causes the valve to close (Figure 13), while with the other, a downward movement of the plug causes the valve to open (Figure 14).

The valve that has a downward motion to close, is a direct acting valve and the valve that has a downward motion to open is a reverse acting valve.

# Downward Motion to Close

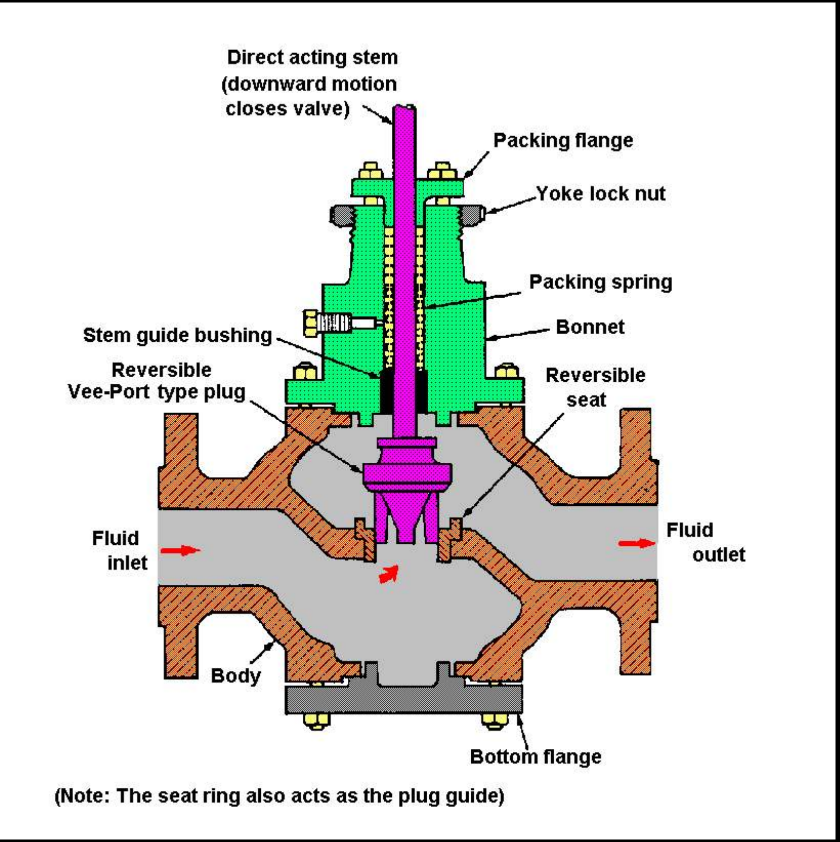



Figure 13 - Single port unbalanced reversible plug valve

# Downward Motion to Open

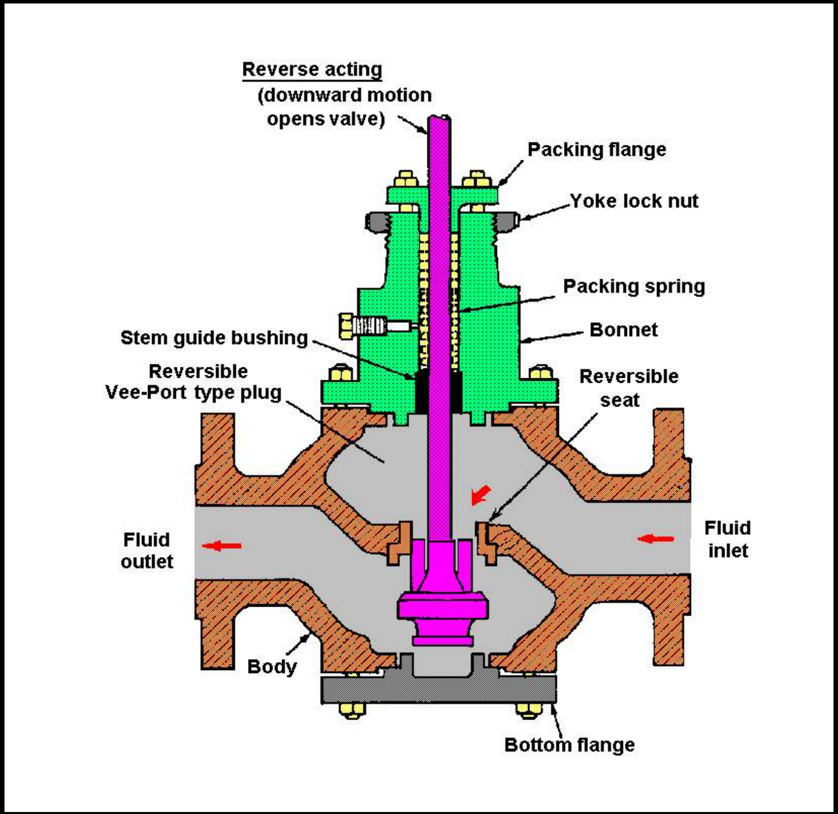



Figure 14 - Single port valve with plug reversed

# Pros and Cons of Single Ported Valves

Compared to Double Ported Valves, Single Ported Valves are generally cheaper to purchase and due to the single plug and seat area, are more resistant to leakage when a tight shut-off is required.

There is a major disadvantage to single ported valves however. and that is when dealing with high fluid pressures that create unbalanced forces across the plug when it is in the closed position. Larger actuators are used to overcome these forces.

Single ported valves are usually installed so that the fluid pressure tends to force the plug away from the seat. This results in smoother operation and reduces the tendency of the plug to slam shut against the seat.

# Double-Ported Valves

The double ported valve was developed to provide a valve that would require less force to position its plug to any position between full open and full closed than was required by the single ported design (Figure 15).

With the double ported design, dynamic forces tend to be more in balance due to the fact that flow tries to open one port and close the other.

# Semi-Balanced Valve

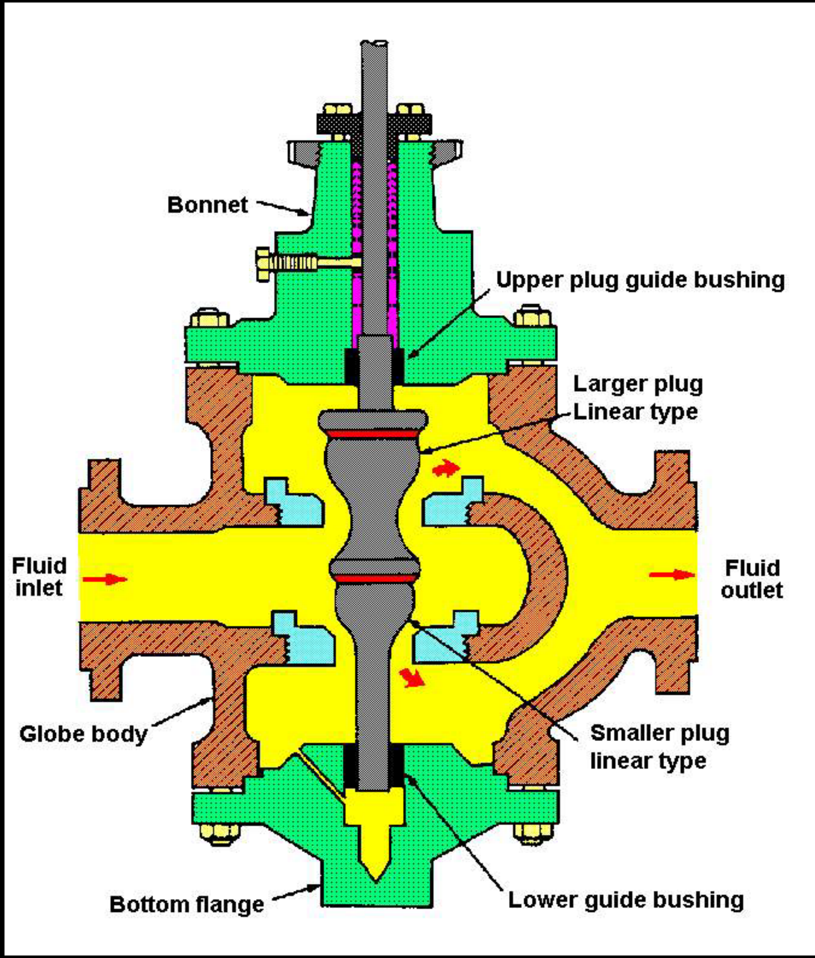



Figure 15 - Double port semi-balanced valve

# Pros and Cons of Double-Ported

These reduced dynamic forces allow better control of the valve and permit choosing a smaller actuator than would be used on a single ported valve of the same capacity.

Many double ported valves are also reversible.  (i.e. a downward movement of the plug to close or a downward movement of the plug to open.)

The major disadvantage of this valve is that it cannot provide sufficient 'shut-off' at the single ported valve. This is due to the problems of uniform alignment and of course wear on 'two' sets of plugs and seats.

# Chapter 5 - Balanced Plug and Cage Style Bodies

# Balanced Plug and Cage Style Bodies

This style of valve is a single ported valve in as much that only one seat ring is used but provides the advantages associated with double ported valves.

Cage style trim is used to give valve plug guiding, seat-ring retention and can provide flow characterization.

Another important development is the addition of a sliding piston ring style seal between the upper section of the valve plug and the wall of the cage cylinder. This minimizes the possibility of leakage.

The plug is balanced by virtue of allowing the downstream pressure to act on both the top and bottom of the plug thereby minimizing the static unbalanced force and allowing the choice of a smaller actuator than would be required for a conventional single ported valve.

The standard direction of flow is through the cage openings and then through the, seat ring.

The cage openings or ports can be shaped to give the valve specific characteristics, e.g. Linear, Quick opening, equal percentage etc.

Some valve bodies can be inverted to permit the valve action to be modified from down to close to down to open.

# Cage Trim Piston Valve

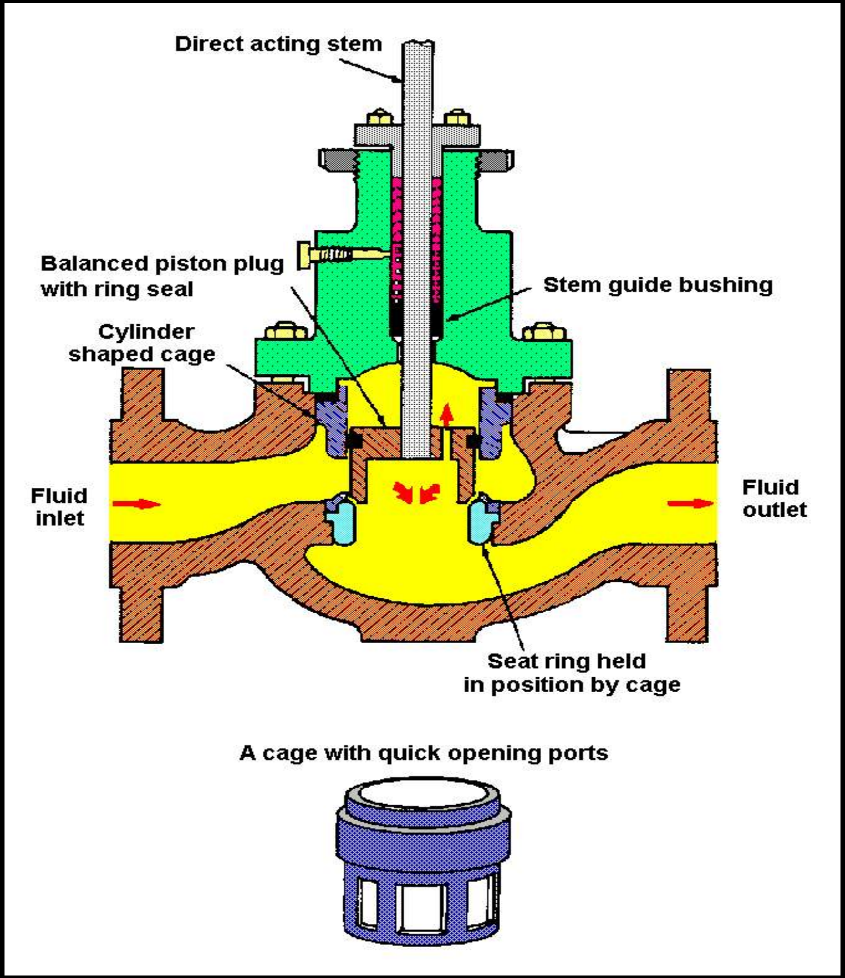



Figure 16 - Single port cage-trim piston valve

# Chapter 6 - Rotary Shaft Valves

# Butterfly Valve

Butterfly valves, ball valves and variations of, fall into this category. The trim element is 'rotated' by the actuator.

The butterfly valve is basically a circular metal disc which is fitted in a short flangeless pipe-spool. The disc is rotated by a shaft which is coupled to an actuator.

The diagram overleaf shows a typical butterfly valve installation showing the valve mounted between two flanges (Figure 17).

# Typical Butterfly Valve Installation

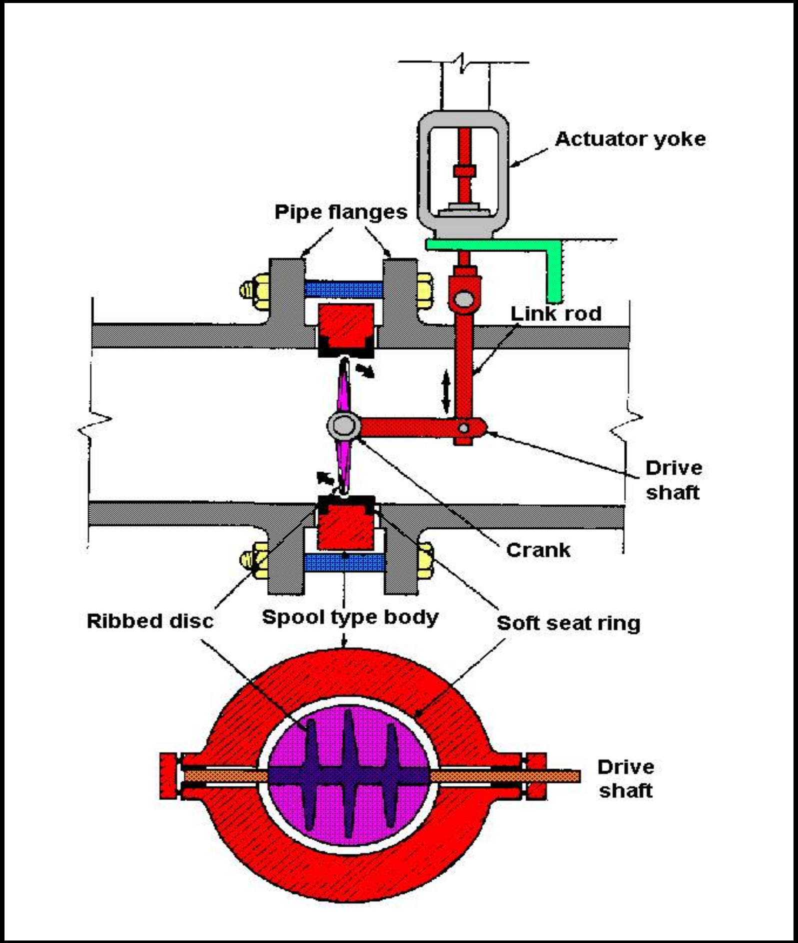



Figure 17 - Butterfly valve in flangeless spool

# Features of Butterfly Valves

Butterfly valves require minimum space for installation and provide high capacity with low pressure loss through the valve. However, they often require high-output piston actuators or larger diaphragm actuators since operating torques can be quite high.

The use of soft seating materials such as T.F.E. or Nitrile provide for good shut off service.

Conventional discs provide throttling control for up to 60° rotation and show equal percentage flow characteristics.

# Ball Valve

A typical ball valve houses a sphere or ball that contains a circular port which is normally equal in size to the bore of the process pipe.

The ball can be rotated through 90° from its "full-open" position to its 'fully closed" position by a drive shaft coupled to an actuator. The ball is in continuous contact with a sealing ring which provides a tight shut off.

# Ball Valve Application

Ball valves are commonly used as "shut down" valves, being held either fully open or fully closed. But, a modified ball valve with a "Vee" shape cut into the circular port will provide equal percentage flow characteristics and is ideal for controlling the flow of viscous fluids that contain entrained solids or fibers.

Flow has a tendency to rotate the ball to the closed position, therefore the actuator must counteract this effect.

# Ball Valve and Diaphragm Actuator Assembly

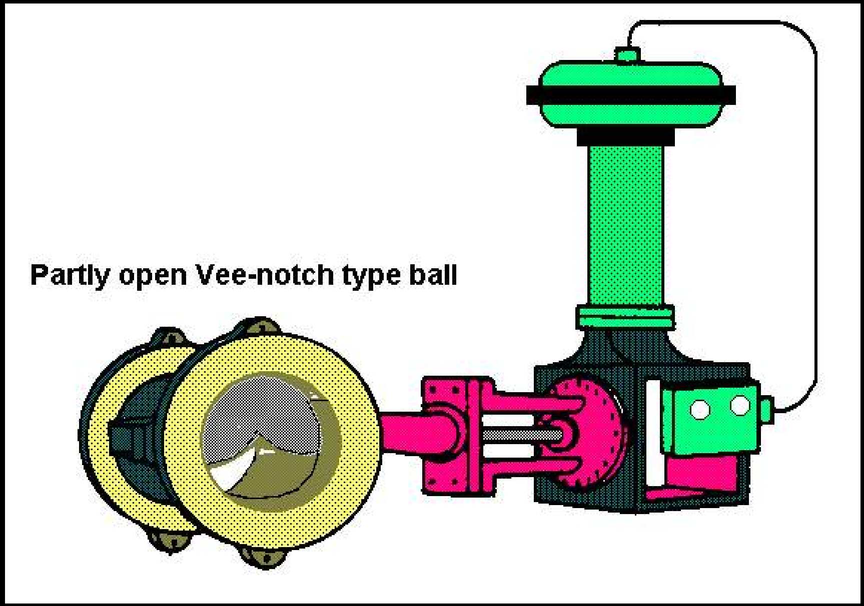



Figure 18 - Ball valve and diaphragm actuator assembly

# Ball Valve (Plan View)

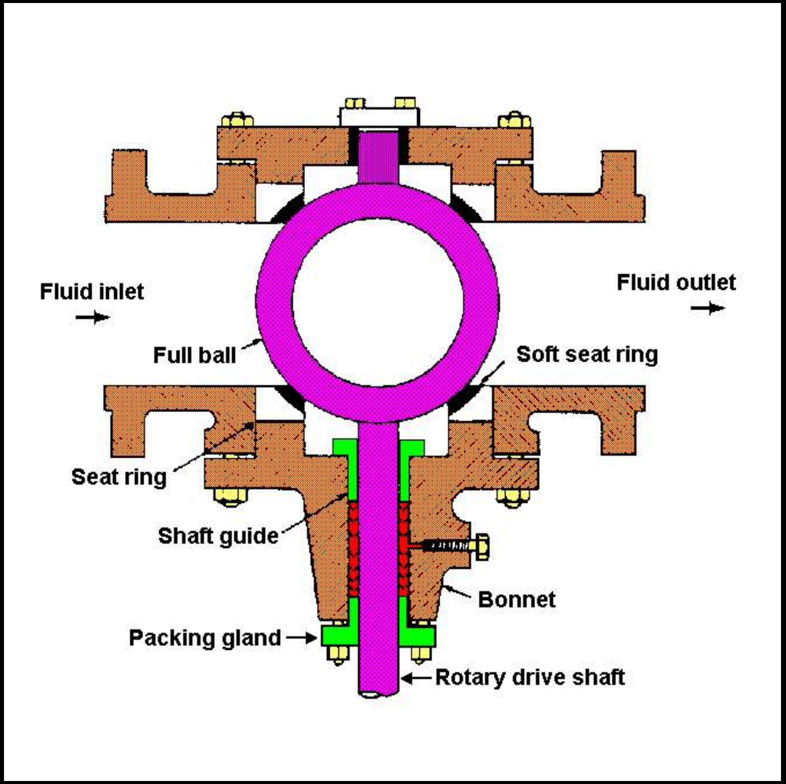



Figure 19 - Ball valve - plan view

# Rotary Eccentric Plug Valves

The operation of this valve is based on an eccentrically rotating spherical plug contained within the valve body.

The plug is attached to a drive shaft which is rotated through 50° by a lever (which is linked to an actuator.)

When moving from open to closed position, the leading edge of the plug passes the seat by a very close margin. As it continues to rotate, the trailing edge comes into contact with the seat.

At this point the leading edge is almost in contact with the seat, but not quite.  Further rotation and application of stem torque by the actuator cause the plug arms to flex and forces the leading edge of the disc into contact with the seat.

Flow through the valve can be in either direction, but, it must be noted that depending on the direction of flow, the dynamic forces will tend to open or close the valve.

Therefore, the flow direction, through the valve is determined by its fail-safe requirements, i.e. if it is desired to fail-open then the fluid flow is in the direction which will tend to open the valve.

# Rotary Eccentric Plug Valve

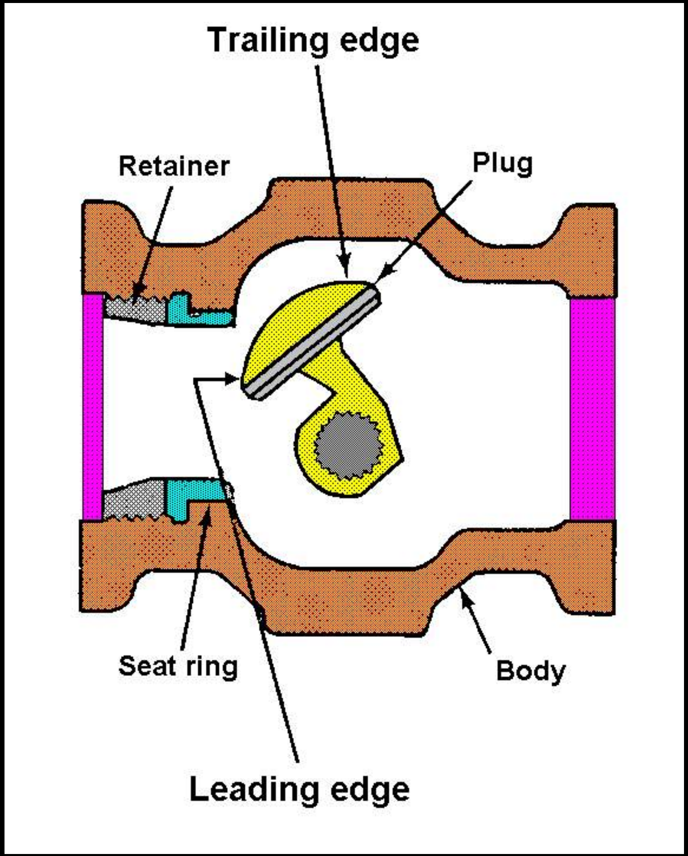



Figure 20 - Rotary eccentric plug valve

# Rotary Eccentric Plug Valve and Actuator

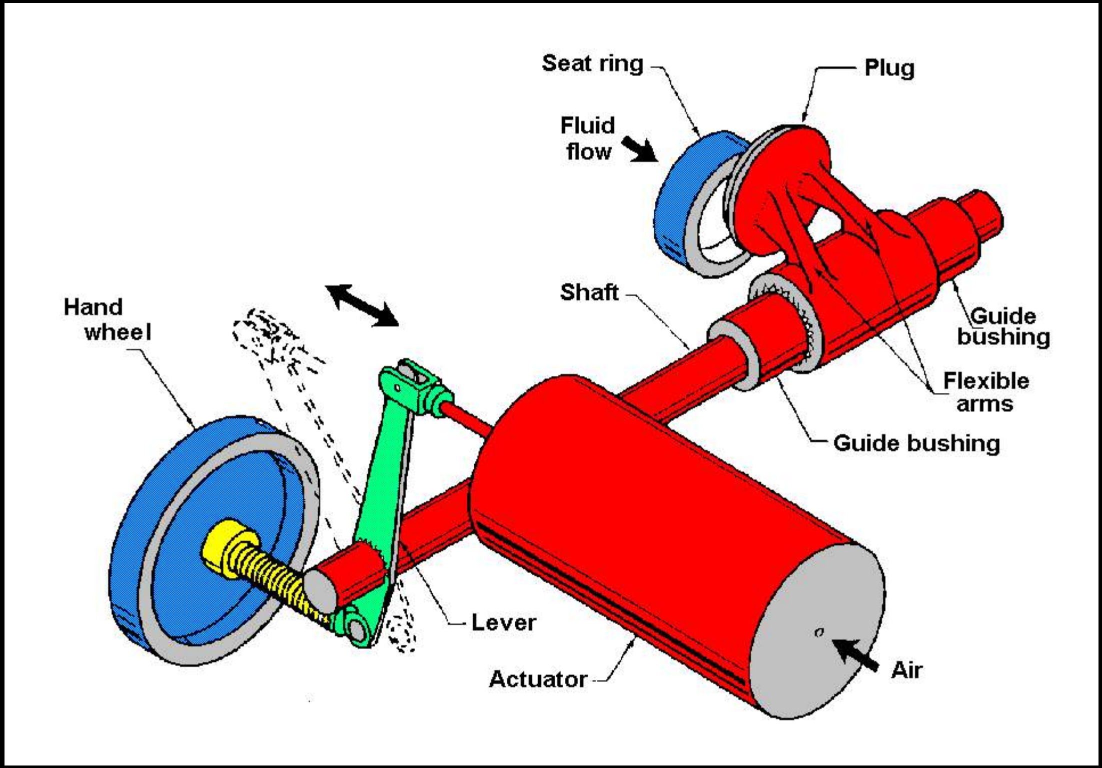



Figure 21 - Rotary eccentric plug valve and actuator

# Chapter 7 – Control Valve Flow Characteristics

# Flow Characteristics of a Valve

The flow characteristic of a valve refers to the relationship between the fluid flow through the valve and the percentage travel or movement of the valve plug stem. (valve lift).

Valve plugs are produced in a variety of shapes and forms, each with a particular flow characteristic in mind.

They can be designed to produce all forms of flow characteristics from "on - off" service to any desired form of throttling action, the choice of which depends upon the process to be controlled.

# Type of Flow Characteristics

There are several main types of flow characteristics; two of which have relevant modifications.

*Note: the following pages will reference back to this curve diagram.*

*Types of Flow Characteristics:*

- Quick opening
- Linear
- Modified linear
- Equal percentage
- Modified parabolic

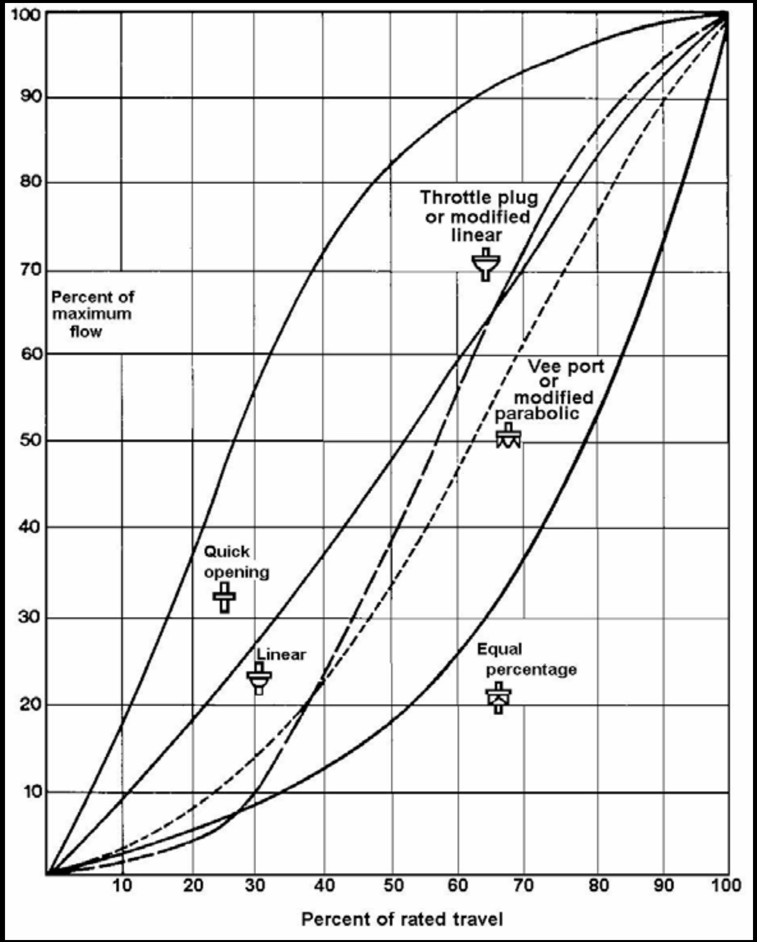



Figure 22 - Flow characteristics for control valves

# Quick Opening

The curve shows that a maximum flow rate change occurs with a relatively small stem travel, up to 35% and thereafter, there is little increase in flow as the stem approaches its wide open position.

This characteristic is required in on-off or two position control valves, self-actuated valves, regulators and relief valves.

Some examples of quick opening plugs are shown in figure 23.

# Examples of Quick Opening Plugs

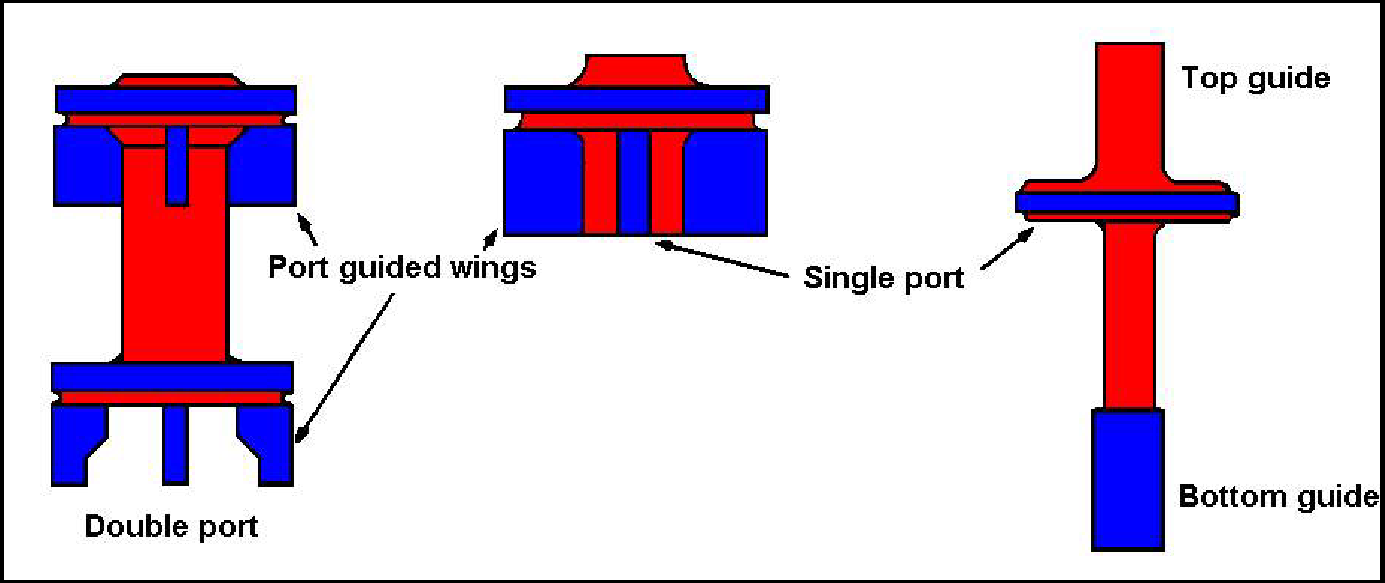



Figure 23 - Quick opening plugs

# Linear

The linear curve shows that the flow rate is directly proportional to the valve travel throughout the travel range, for example. at 70% of travel, the flow is nearly 70%. of maximum.

This characteristic is used in liquid level control valves and in control systems requiring a constant gain, that is, the gain in the proportional increase or decrease in flow for a given controller output.

# Examples of Linear Plugs

Figure 24 below, shows some examples of linear plugs in single or double ported valves.

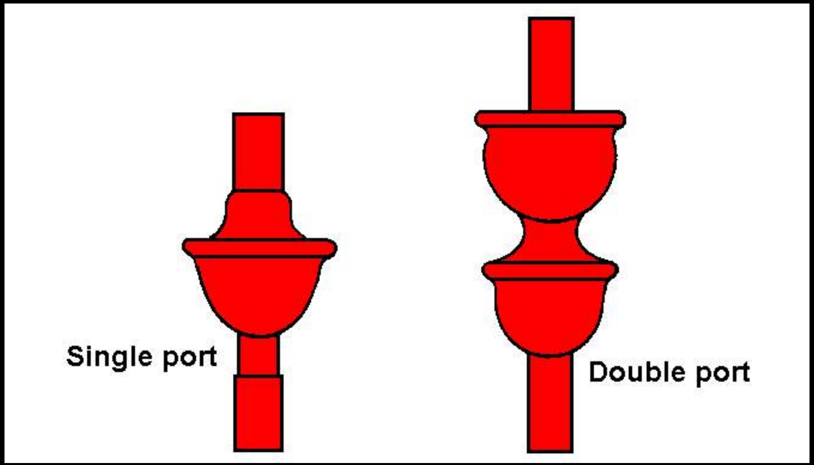



Figure 24 - Linear plugs.

# Modified Linear

The modified linear curve (dashed) is a compromise between the true linear and the quick opening curves. In the high flow region and more particularly in the low flow region, a large valve travel produces only a small change in flow rate.

Two modified linear plugs, also known as throttle plugs, are shown in fig. 25 on the following page.

They are similar to the linear plugs, though their smooth curved surfaces are more suitable than the sharp edges and crevices of other plugs for handling liquids containing entrained solids.

# Modified Linear Plugs

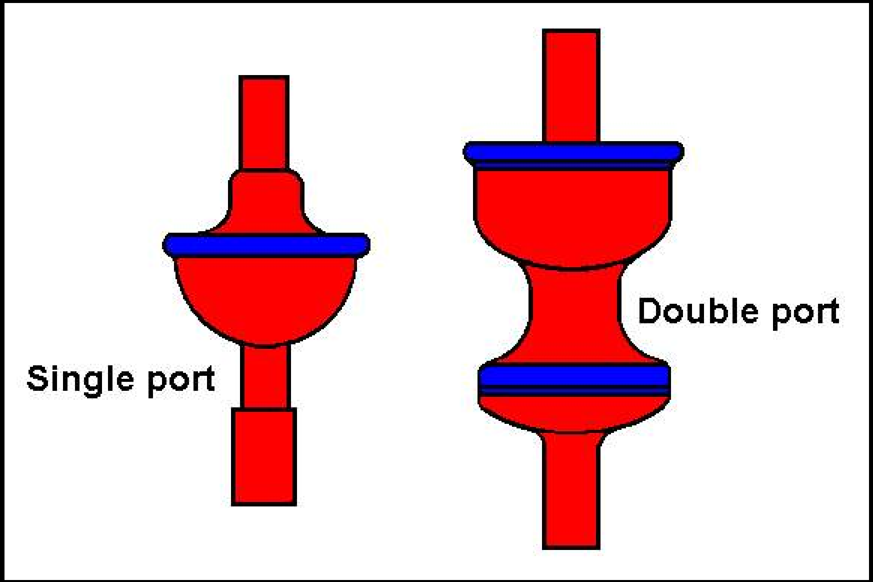



Figure 25 - Modified linear or throttle plugs

# Equal Percentage

An equal percentage characteristic is one in which equal increments of stem travel produce equal percentage changes in flow rate.

The actual curve (shown previously in Figure 22), shows that when the valve is nearly closed, the change in flow rate with respect to travel is small, but is relatively high when the valve is nearly fully open.

In practical terms this means that the valve will give accurate throttling control over its lower travel range and rapidly increasing capacity as it approaches the wide open limit.

# Shape of the Equal % Curve

The shape of a typical equal percentage curve is due to the fact that for every % of valve stem travel, the rate of flow through the valve increases by a given percentage increment.

A typical example is that for every 10% change in valve stem position, the rate of flow through the valve changes by 50%.

(Relating to Fig. 22, shown previously) it can be seen that if the valve stem is at 30% of it's travel there will be approximately 9% of maximum flow through the valve. If the stem travel is increased by a further 10%, the flow rate will increase by approximately 50%. In this example, to 13% of maximum flow.

A further 10% change of valve stem travel will result in another 50% change in the maximum rate of flow. This time the flow rate is approximately 18% of maximum flow. A further 10% change of valve stem position will result in the flow rate changing by a further 50% and so on.

The diagram on the following slide shows three forms of equal percentage plugs which are normally used for pressure control in process systems where only a small proportion of the total pressure drop is available for control purposes.

# Equal Percentage Plugs

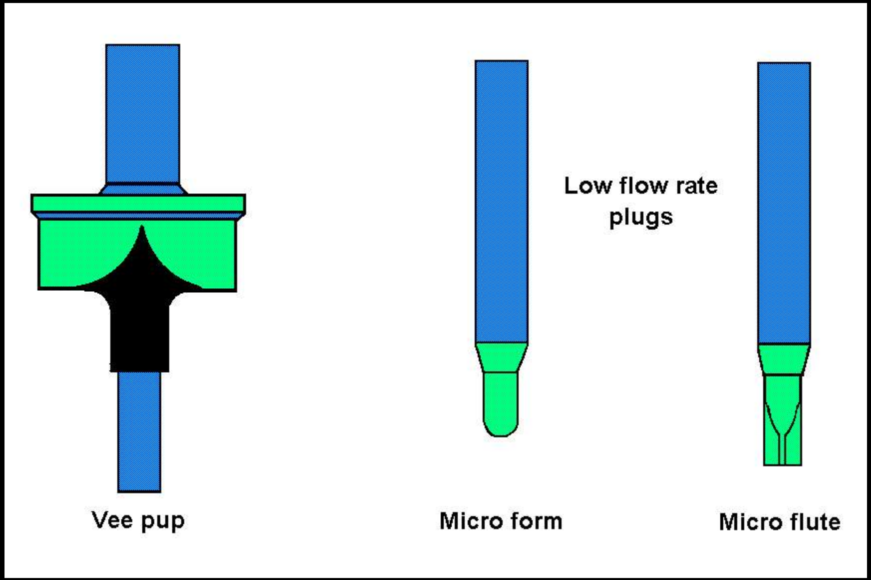



Figure 26 - Equal percentage plugs

# Modified Parabolic

The modified parabolic curve (dotted) falls between the linear and equal percentage characteristic curves and it exhibits a linear characteristic for high values of flow and travel.

Fig. 27 (on the following slide) shows three forms of modified parabolic valve plugs which are commonly called vee-port throttling valves and are port guided.

They are typically used for pressure and flow control service in process systems where the main part of the pressure drop is available for control purposes.

# Modified Parabolic or “Vee" Plugs

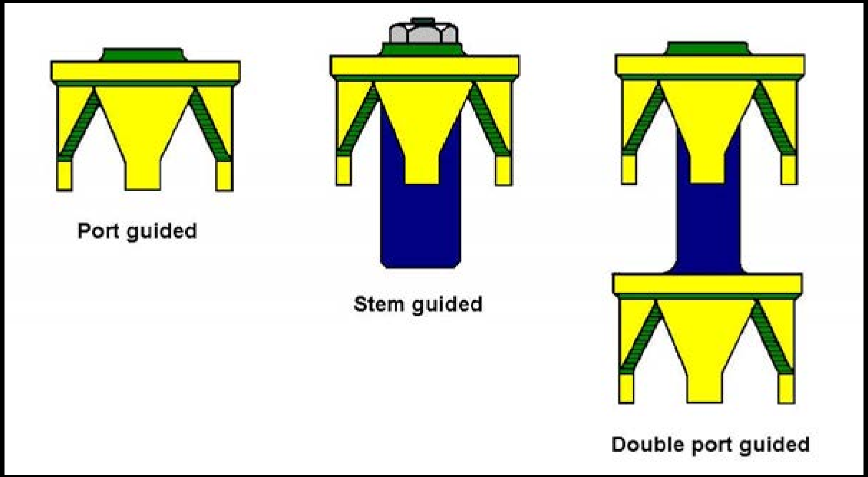



Figure 27 - Modified parabolic or "vee" plugs

# Cage Trim Valves

The flow characteristics so far studied have been determined by shaping the plugs so that the unobstructed flow area changes in size and shape as the plug moves through its travel range.

In cage trim valves the characteristic is determined by shaping the cage ports or 'windows' to produce quick opening, linear or equal percentage curves.

The characteristic for each valve is changed by installing a different cage making it unnecessary to change the plug to alter the flow characteristic.

# Cage Trim Valves

Figure 28 shows the shapes of cage windows used to give quick opening, linear and equal percentage flow characteristics.

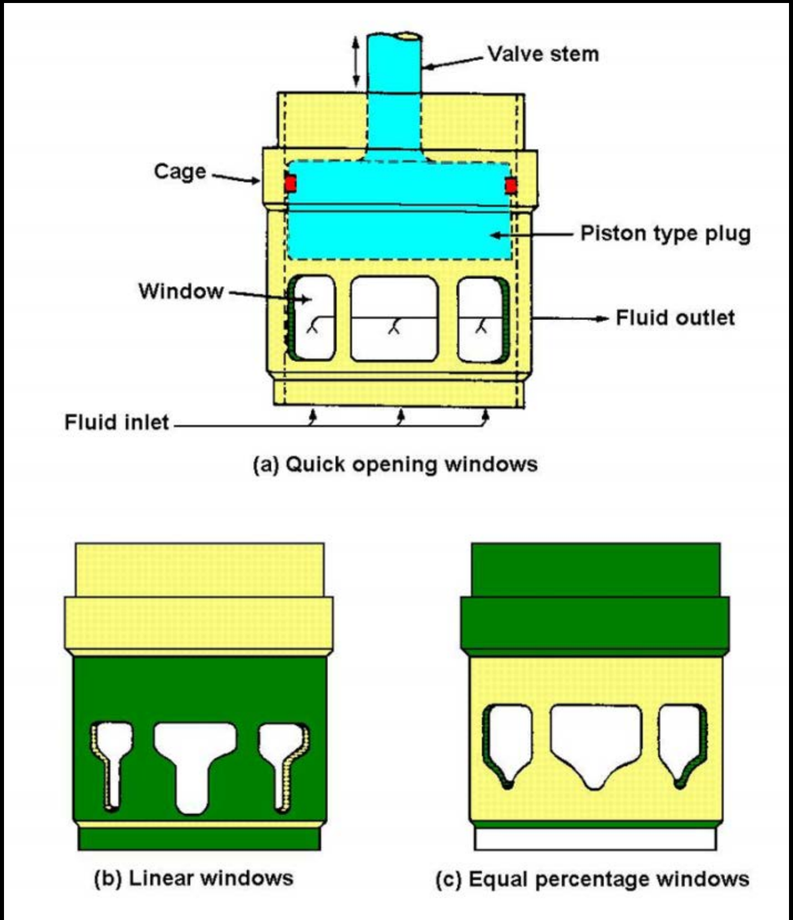



Figure 28 - Cage trim

# Chapter 8 – Actuators

# Types of Actuators

One type is the manual actuator which is simply a handwheel mechanism.

*Additionally, there are 3 types of actuators:*

- Pneumatic
- Hydraulic
- Electric

# Electric Actuators

Electric actuators have an electric motor inside. Though originally designed for on/off applications, they are now able to control the flow as well.

The term of “motor operated valve” (MOV) refers to this type of the valve. This type of actuator is a good choice for the applications where instrument air -which use by pneumatic actuators- are not available.

# Considerations with Electric Actuators

A disadvantage of this type of the actuator is that they can not work in case of power system outage. So, consideration of an electrical battery pack is mandatory in some cases for a reliable operation.

Electric actuators should be explosion proof in the environments with high volume of explosive gases like petroleum refineries and natural gas treatment facilities.

# Hydraulic Actuators

Hydraulic actuators use liquid pressure to operate the stem through a piston rather than diaphragm.

Hydraulic actuators are able to create a high actuating force due to their high pressure nature, even if the area is modest.

Against the air which compressible fluid and the hydraulic oil, does not yield stress. So, these actuators are very stable in valve positioning that makes a perfect choice for applications that actuator must keep the valve in a one position.

# Considerations with Hydraulic Actuators

These type of actuators come in different types and with wide range of accessories and the actuator vendor should be consulted to purchase them.

Hydraulic actuators applications are limited to systems with few number of valves which are located close to each other because of need to vent all gas bubble from the hydraulic fluid tubing and also need to thick wall tubing because of high oil pressure.

Another problem of the hydraulic system compared to pneumatic systems is the lack of intrinsic power storage.

This means that in the case of that compressed air systems due to compressibility nature of the air, store some energy in any pressurized volume which can be considered a level of reserve power in the case of main compressor shut down.

Hydraulic systems naturally are not able to provide this feature.

# Pneumatic Actuators

Spring loaded pneumatically operated actuators are the most commonly used elements for the movement of control valve plugs.

This is basically due to the relatively simple construction. It is totally non electrical so is therefore intrinsically safe. It is proven to be operationally reliable and is easy to maintain.

Different types of pneumatic actuators are described in the following sections.

# Single Acting Diaphragm Actuators

Actuator designs do vary from one manufacturer to another, but the principle of operation is similar in each case. A pneumatic pressure signal is applied to one side of a flexible diaphragm. (Remember that Force = Pressure × Area).

The resultant force created pushes the diaphragm, diaphragm plate, and actuator stem in one direction. As it does so, it is being opposed by an actuator spring. The greater the pressure applied, the greater the stem movement and the more the spring opposes by being compressed.

When the force of the diaphragm in one direction, equals the force of the spring in the opposite direction, the actuator stops moving.

If the pneumatic pressure is relieved, the force of the spring will be greater and therefore push the diaphragm, diaphragm plate and hence the actuator-stem back to its "normal" position.

# Direct and Reverse Acting Actuators

Actuators can also be direct or reverse acting. Loading pressure forcing the diaphragm down, is regarded as direct-acting, whereas loading pressure forcing the actuator up, is regarded as reverse-acting.

*This may now lead to some confusion, as a control valve consists of both valve and actuator. (Direct or reverse acting valve, or direct or reverse acting actuator? )*

Increasing pressure to a control valve causing it to close, is direct acting. Increasing pressure to a control valve causing it to open, is reverse acting.

# Direct Acting Actuator

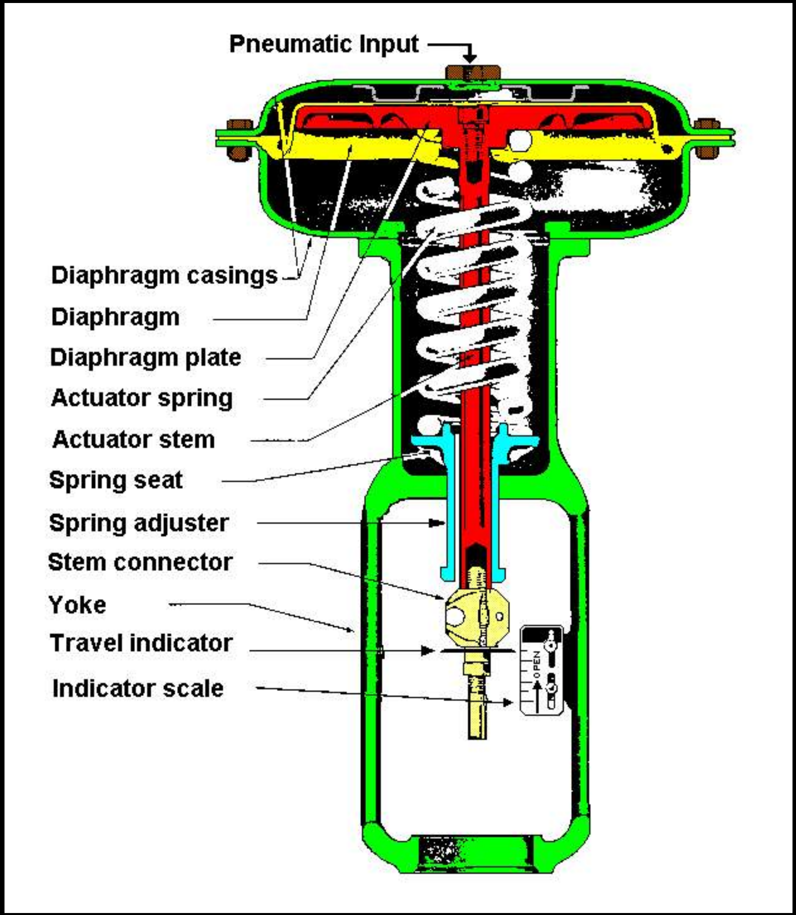



Figure 29 - Direct acting actuator

# Reverse Acting Actuator

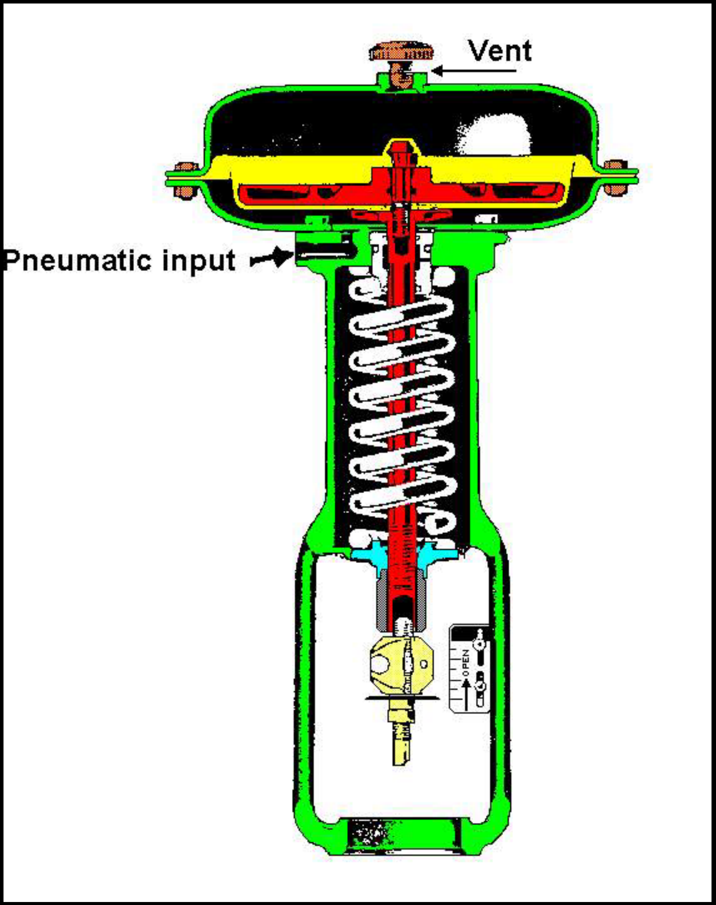



Figure 30 - Reverse acting actuator

Therefore, a direct acting valve with a direct acting actuator is a direct acting control valve. However, a reverse acting valve with a reverse acting actuator will also be "air to close", thus is regarded as a direct acting control valve. Any other combination will produce a reverse acting control valve.

The most important factor to remember is the valve's "Normal" position or it's Fail-Safe action. e.g. When there is a loss of pneumatic signal, will the valve fail to the open or closed position. Operating pressures for diaphragm actuators are normally between 0.2-1 bar, (3-15 psi) or 0.4-2 bar (6-30 psi).

# Piston Actuators

Piston actuators are more ruggedly constructed than diaphragm actuators.

This enables them to be operated at much higher pressures so therefore capable of delivering a much greater force that may be required to overcome large pressure drops across control valves.

Operating pressures of around 7-10 bar (100-150 psi) are quite typical.

Another advantage to piston actuators is that they can be manufactured to produce a substantially longer stroke than could be achieved from a diaphragm actuator.

# Spring Opposed Action

Shutdown valves with piston actuators, are generally spring opposed.

Air pressure moves the piston against spring opposition. When the pressure is relieved, the spring returns the actuator to its "normal" position.

It should be noted that some shutdown systems use a double acting piston, that is, one that is moved in either direction by pneumatic pressure. An accumulator or air reservoir is then used to move the actuator in the event of air supply failure.

Control valves that make use of piston actuators are not normally “spring loaded”. As a rule they will also be double acting and will include a valve positioner.

They make ideal On-Off valves and when a positioner is used, provide accurate positioning.

Beware! Without an opposing spring, there can be no FAIL-SAFE position unless there is some form of pneumatic accumulator incorporated into the air system.

# Pneumatic Piston Actuator

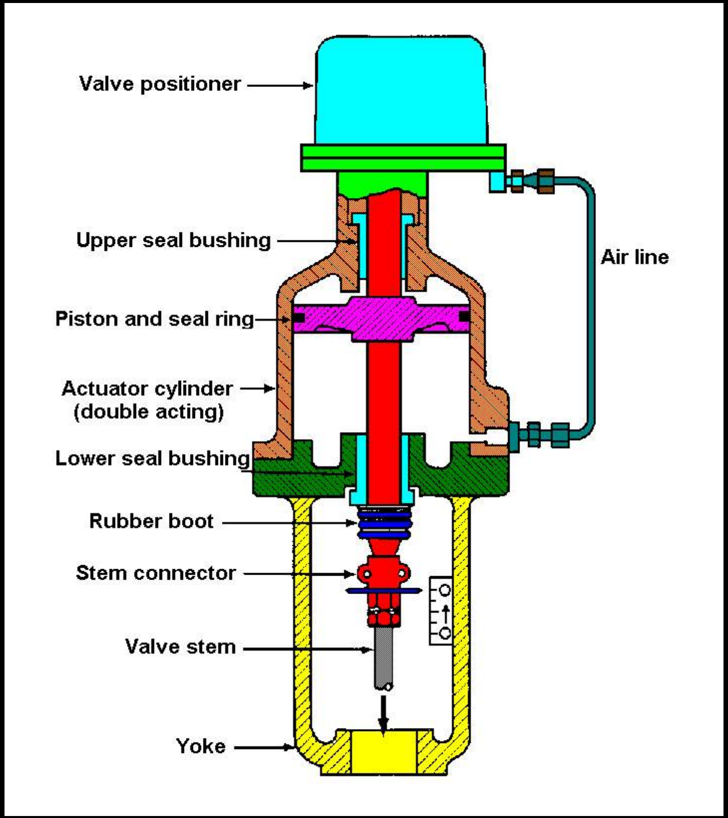



Figure 31 - Pneumatic piston actuator

# Handwheel Actuators (manually-operated)

With some control valve installations hand wheels are fitted onto the actuators for the purpose of manually positioning the final control element.

*There are several circumstances where a handwheel actuator would be used:*

- During plant start-up
- During an emergency
- On failure of pneumatic supply to the actuator
- Where the control valve is not provided with a by-pass valve

# Top or Side Mounted Handwheels

Hand wheels can either be top mounted or side mounted.

Top mounted hand wheels on direct acting diaphragm actuators can be used as adjustable stops to limit the upward direction, or to manually close "push-down" to close valves.

On reverse acting diaphragm actuators the unit can be used as an adjustable travel stop in the downward direction or to manually close "push-down" to open valves.

# Use with Direct/Reverse Acting Actuators

Side mounted actuators can be used with either direct or reverse acting actuators.

This unit can be used to limit the travel of the actuator in either direction or to position the valve manually.

But, it should be noted that for normal service in automatic control, any hand wheel should be positioned at it's "NEUTRAL" position to enable the controller to effectively control the system.

# Top-mounted Handwheels

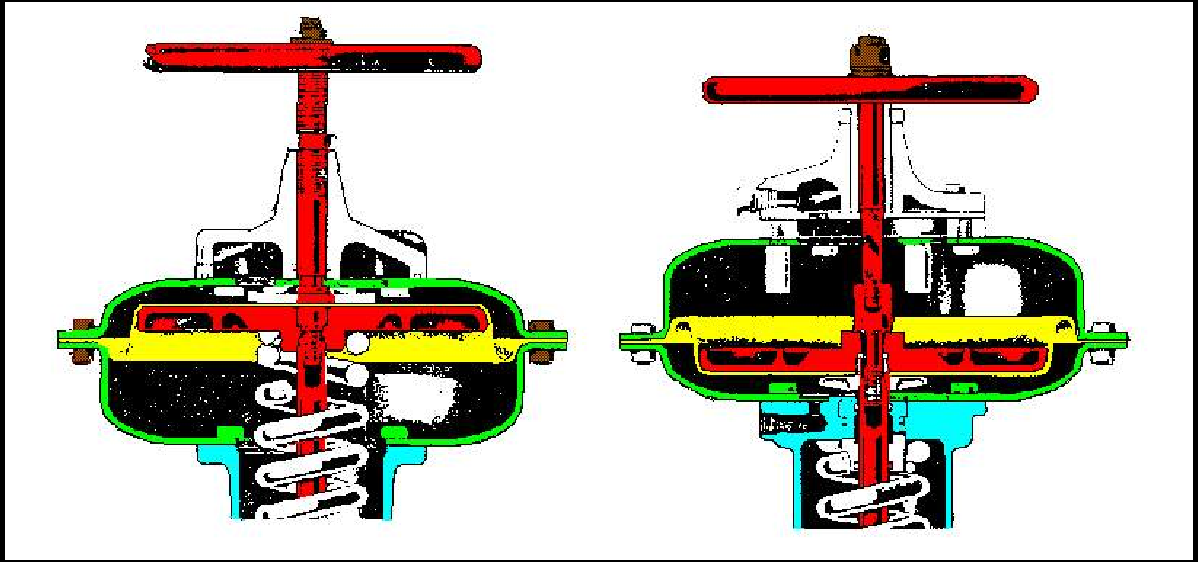


Figure 32 - Top mounted hand-wheels

# Side-Mounted Handwheels

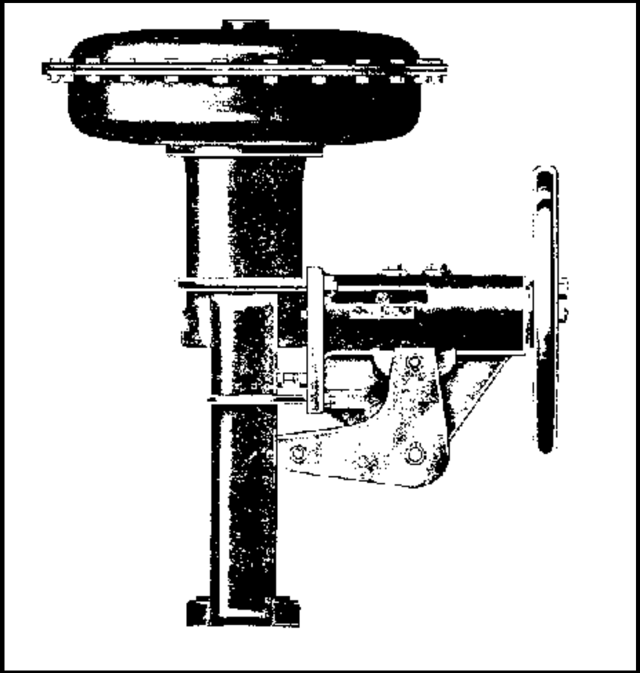


Figure 33 – Side mounted hand-wheel

# Self – Operated Valves

In the self-operated valves, against the other types of valves, the actuator powered by the fluid which is flowing through the valve itself.

The principle can be used for both gas and liquid valves.

The actuating fluid can be taken from the down stream or up stream of the valve, depends to the control philosophy – which could feed forward or feed backward.

Fluid can go directly to the valve actuator or passed true some mechanism named “pilot”.

# Applications for Self-Operating Valves

One of the regular application of this type of the valve is gas pressure regulation for natural gas distribution system. In this application, the valves called “regulator”.

One of its interesting application is to control and set the instrument air system pressure, because it is not required to do instrument air tubing to this valve. (Figure 26, shows a self-operated, spring loaded valve with feedback tube. )

While the spring tries to plug off the seat and let the more gas flows to down stream and increase the pressure, the feedback gas pressure from the downstream, acts against the diaphragm and push it up and move the plug toward the seat and to reduce the flow and regulate the pressure to the set point.

The set point of the valve can be changed by changing the spring stiffness. This can be happened by changing the spring or turning a screw on top of the valve.

This type of the valve is using widely in the industry and has a lot of types for different applications.

# Feedback Self-operated Valve

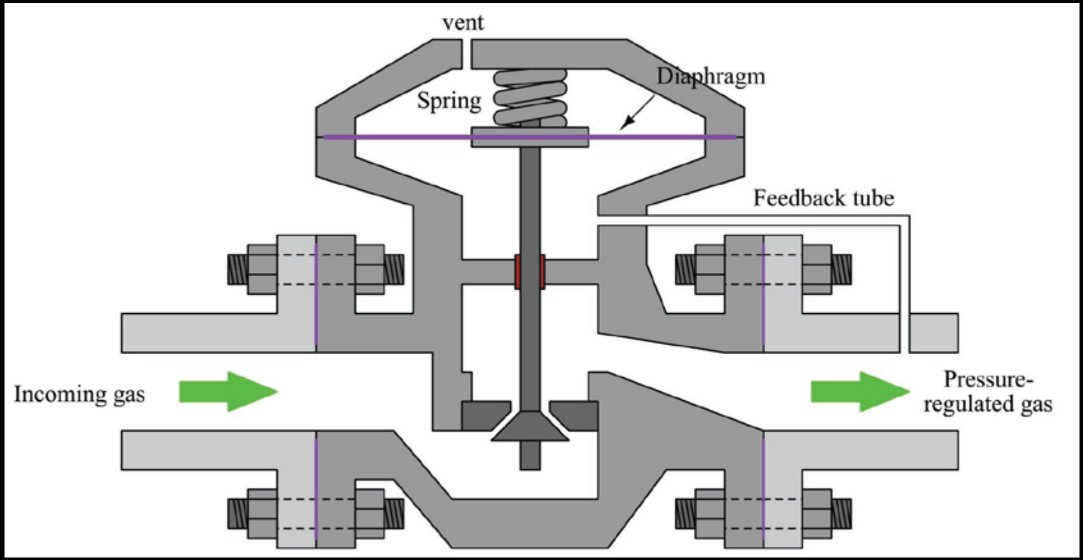



Figure 35 – Feedback self-operated control valve

# Chapter 9 – Valve Positioners

# What is a Valve Positioner?

A positioner for a control valve is used to adjust a valve’s position based on a desired “set point” for a process variable, whether that variable may be pressure, temperature, or flow.

*Properly installing the positioner:*

On linear control valves - the valve positioner is typically installed on the yolk or top casing of a pneumatic actuator

On rotary control valves - the valve positioner is installed in line with the valve and actuator stems on top of the actuator or on the side of the actuator. Installation will depend upon what type of actuator is used.

Affixing the positioner to the actuators allows the positioner to measure the stem travel (linear valves) or degree of rotation (rotary valves). This also changes the position of the valve as required based on the input signal from the instrument controller.

When the process variable differs from the desired set point, the instrument controller sends an electrical or pneumatic signal to the positioner.

This varies its pneumatic output to the actuator to move the valve open or closed accordingly. This occurs until the process variable reaches the desired set point.

# Need for a Valve Positioner

A control valve must be capable of responding quickly and smoothly to control signal changes. In many instances a properly sized valve with a properly sized actuator will do an adequate job without the use of a valve positioner. However there are certain instances where a valve positioner should be considered.

*These are:*

- Where the required diaphragm pressure exceeds the controller signal pressure.
- To "Split-Range" the controller output to more than one valve.
- Where distances between controller output and valve actuator are long, thereby creating a delay between the time of controller output change and subsequent reaction of the actuator.

# Sections of a Valve Positioner

*There are many designs of valve positioner, but regardless of how a positioner is constructed, all positioners can be divided into three sections:*

- The input (or set point)
- The output which is pneumatic signal goes to actuator
- Feedback sections which detect and transfer the valve stem position to the positioner

# Types of Positioners

*Positioners come in three different categories:*

- **Pneumatic positioner** - in which their input signal is a pneumatic signal.
- **Electronic-Pneumatic positioners or I/P positioners** - in which the controller signal is an electric signal and positioners output is a pneumatic signal and they need a I/P transducer modules integrated.
- **Digital positioner or digital valve controller** - in addition to an I/P transducer, these positioner take advantage of a microprocessor to fill in the place of the mechanical position feedback.

*Figure 36 on the following slide, summarizes the three types of positioners.*

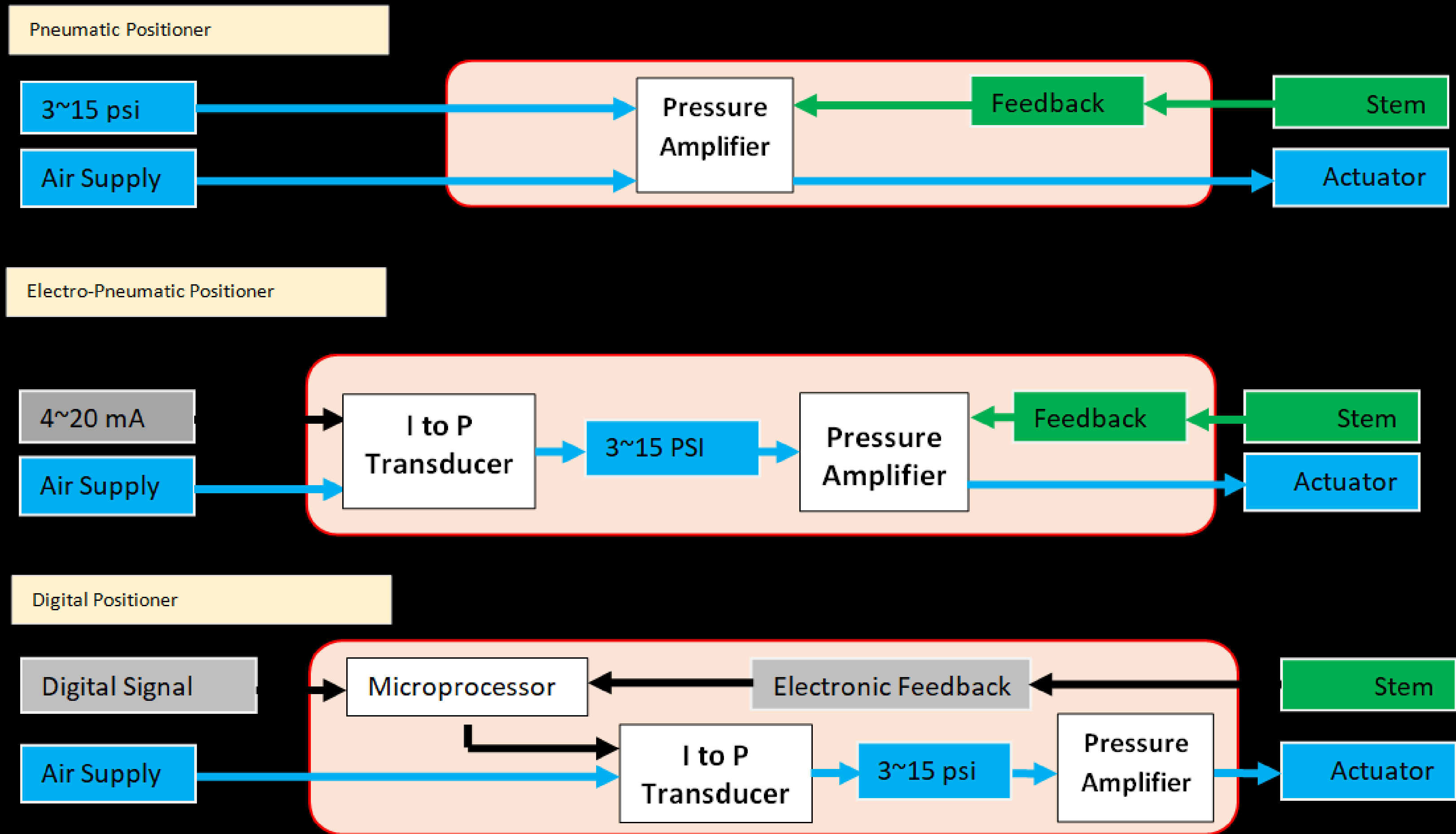



Figure 36: Different types of positioners

# When to use a Positioner

From the foregoing, it can be seen that a valve positioner is capable of converting small signal changes into a very powerful force for positioning the final control element.

But, it should be noted and clearly understood, that in some loops, the use of a valve positioner would most surely lead to control loop instability. Such systems are those which exhibit fast response times such as flow control loops, liquid pressure control loops or some gas pressure control loops.

In these situations a 'booster' may be considered as an alternative. If the system is relatively slow, such as a liquid-level control loop or a temperature control loop, then a valve positioner will perform quite satisfactorily.

# Pneumatic Positioner

When a valve positioner is not used, the controller output is connected directly to the actuator.

Any change in controller output pressure must be effective over the diaphragm surface area.

If the volume of the actuator is large, then it may take some while for the actuator to react. When a positioner is used, the controller output goes to a bellows within the positioner.

*Figure 37 on the following slide, shows a pneumatic positioner*

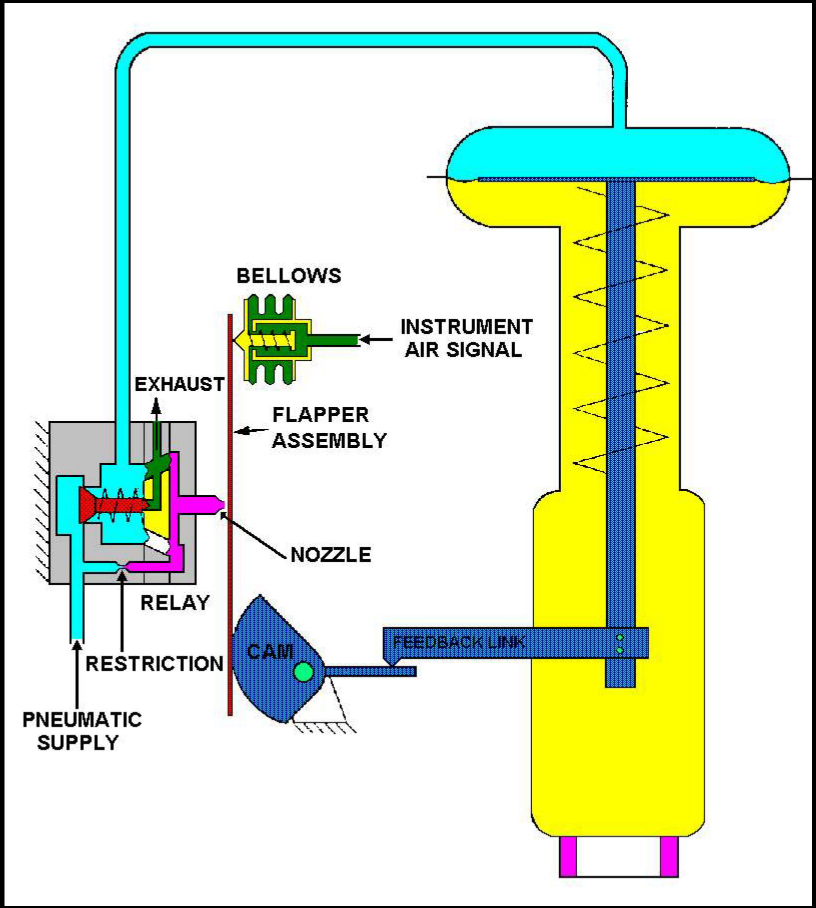



Figure 37 - Pneumatic valve positioner (simplified)

# Pneumatic positioner (cont.)

The volume of the bellows is small compared to the actuator. Hence, a small change in controller output is more readily detected by the bellows.

The motion produced by the bellows is used to move a pilot valve or flapper (if using a flapper-nozzle system,) which in turn causes a large volume of air to rapidly enter the actuator thereby ensuring that it responds rapidly to control signal changes.

The input section usually consists of a bellows into which the controller output signal is fed. (Normally 0.2 ~ 1 bar or 3 ~ 15 psi). As the signal varies, the bellows will either expand or contract thus producing mechanical motion. This motion is then transferred to the output section by means of mechanical linkage.

# Pneumatic Positioner Description

The output section may consist of a pilot valve assembly or flapper/nozzle, relay assembly.  In either case, both will have an independent pneumatic supply.

The motion provided by the input section, causes pressure from the output section to change. Therefore, the actuator will start to move.

Attached to the actuator is a "feedback" link which forms part of the feedback section. The feedback section determines when the correct amount of pressure is received by the actuator.

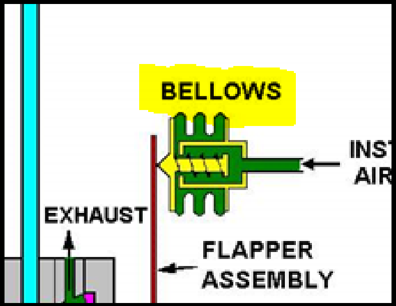
For every value of control signal pressure there is a corresponding position of the feedback link that will cause the output signal to the actuator to cease changing.

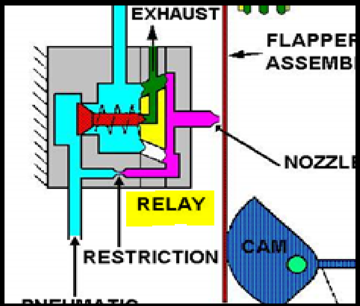
In other words, if the positioner is correctly adjusted, the feedback link makes sure that pneumatic pressure to the actuator is directly proportional to the control signal from the controller.

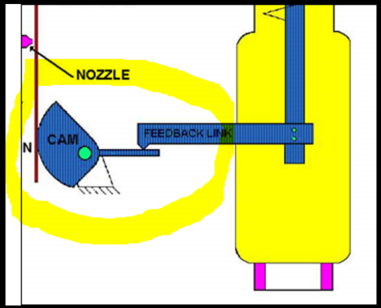
# Pneumatic Positioner Sections

*From the Figure 37 diagram (shown previously), identifying the input, output and feedback sections:*

- Input – the bellows
- Output - the relay assembly
- Feedback - cam and feedback link



# Pneumatic Positioner Action

Assume now that the pneumatic signal from the controller to the bellows increases. The bellows will expand and move the flapper towards the nozzle.

This will cause the nozzle back-pressure to increase which will in turn cause the relay diaphragm assembly to open the supply valve.

Output pressure to the actuator will then increase causing the actuator stem to move downward.

# Pneumatic Positioner Action (cont.)

As it does so it moves the feedback link that rotates the cam in such a direction that enables the flapper to move away from the nozzle.

Nozzle back-pressure now decreases and therefore the relay supply valve closes and therefore the actuator stops moving. So, a change of input signal has produced a change of actuator position.  The positioner is again in balance with a higher signal pressure, a new actuator position and a slightly different flapper position.

# Pneumatic Positioner Action (cont.)

When the controller signal decreases, the bellows contracts (aided by a range spring) and the flapper starts to move away from the nozzle. Nozzle back-pressure decreases and so actuator pressures within the relay overcome the forces of nozzle pressure and move the relay diaphragm so that the exhaust port is opened.

As the actuator pressure exhausts to atmosphere the actuator spring moves the actuator upwards. As it does so, the feedback link rotates the cam such that it moves the flapper back towards the nozzle, thus raising nozzle back-pressure and causing the exhaust valve to close.

# Pneumatic Positioner Action (cont.)

The result, a new input signal, a new valve position and a slightly different flapper nozzle gap.  Valve positioners can be either direct or reverse acting.

Direct acting infers than an increase of input signal causes an increase of output signal, whereas a reverse acting positioner is one where an increase of input signal causes a decrease in output signal.

# Cam Characteristics

Most valve positioners change valve-stem position linearly to controller signal output. However, some manufacturers provide a means (generally a cam) to alter this relationship.

The cam, which forms part of the feed-back assembly, can be made in slightly different shapes or forms and can simulate quick opening, (cam 2) linear (cam 1) or various forms of throttling characteristics (cam 3).

# Typical Cam Characteristics

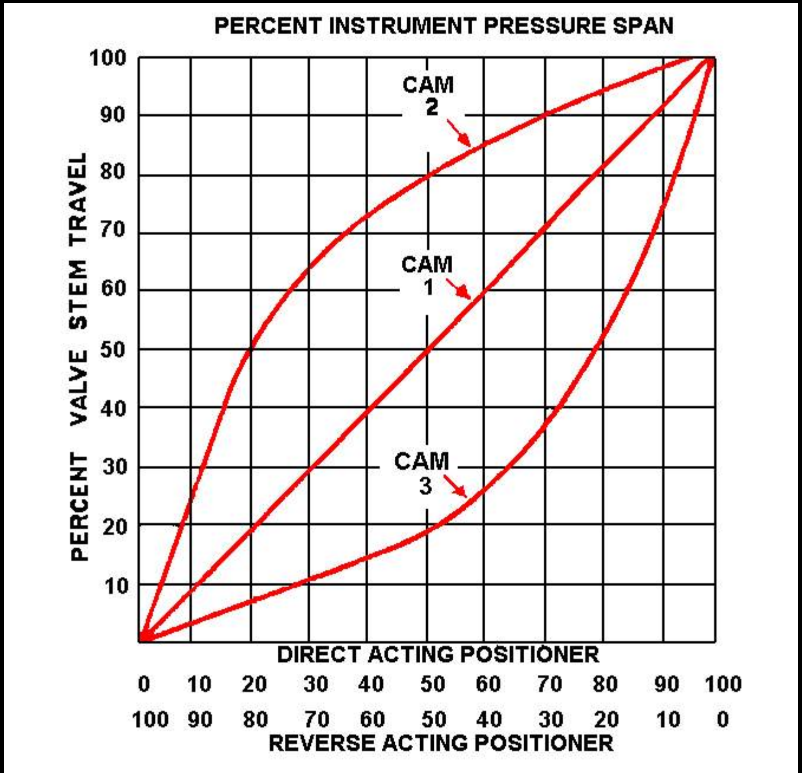



Figure 38 – Typical cam characteristics

# Digital Positioner

The input signal from the controller will directly send to the microprocessor. The valve position feedback which is measured electronically, will also enter the microprocessor. Comparing these two electro-signals, the microprocessor is able to adjust the valve position.

This type of the positioner is quite accurate in comparison to the other two types of positioner. By using this type of the positioner, we are able to communicate with the valve by using different communication protocols such as HART or Fieldbus.

# Bypass for Positioner

Some valve positioners are fitted with by-pass switches or levers. Caution should be exercised before attempting to change to positioner bypass mode. Remember, when the positioner is in use, the controller output signal is directed into the positioner bellows and hence the positioner output moves the actuator.

When in by-pass, the positioner is by-passed. That means the controller output signal goes directly to the actuator.

# Bypass for Positioner (cont.)

Therefore, do not expect the control valve to perform in the same manner as it does when using the positioner. When in the by-pass mode, keep a constant watch on the process being (or trying to be) controlled.

It therefore stands to reason, if a valve positioner is reverse acting or being used as a pressure amplifier or both, the bypass facility should be made inoperative.

# Conclusion

This now concludes our course on control valves. We hope you have enjoyed this slideshow presentation from Online-PDH!