CONTROL VALVES

SECTION 9

FINAL CONTROL DEVICES ‘ VALVES and ACTUATORS’

SECTION	CONTENT
9.1	Need for Valves and Actuation.
9.2	Valve Categorising and Applications – Body styles Hand operations- bypass/ isolation Control valves Two position valves Direct/ reverse action Air fail action
9.3	Parts of a Control valve - Positioners - Motion balance Force balance Actuators- Diaphragm Cylinder/ piston - Numotor Double piston/ rotary – Hytork Connecting elements - Gland Bellows seals Special purpose Valve bodies and correcting elements - Globe – Characteristics and Cv Saunders /Diaphragm Butterfly Ball
9.4	Common faults and valve maintenance- Valve leakage’s Valve passing Valve stroke Air fail checking Corrosion, Cavitation, erosion
9.5	Valve selection and application - Selection criteria Material selection
9.6	Solenoid valves - Application Operation Checking
9.7	Split range valve arrangements

VALVES/ ACTUATORS.

9.1 Need for Valves and Actuation.

In-order to maintain control of the chemical plant operation or manufacturing process, for the process variables to be kept within their predetermined limits the control system needs to employ a method of changing, manipulating or controlling the amount of chemical flowing through the pipelines, or into and out of vessels.

For this to take place effectively a control valve inserted into the pipeline can be used to restrict the amount of flow and thus help in keeping control of the process condition. In the early days of development, successful control was largely due to the skill of the process operator using very basic manually operated *hand valves*, that were merely large versions of what could only be likened to a household tap.

In-order that accurate control be maintained, automatic valves were needed and developed and have been in common use ever since.

As technology has changed, so has the development of valves and actuators, such that there are a large variety of these devices commercially available. The aim of this section is to look at a cross section of commonly used valves and actuators and the purposes to which they are put.

9.2 Valve Categorising and Applications.

A valve or Control valve can be described as a *variable restriction* in a pipeline, the purpose of which is to control or regulate the flow through it to maintain control of the plant or process which it serves.

Valves can be categorised by:-

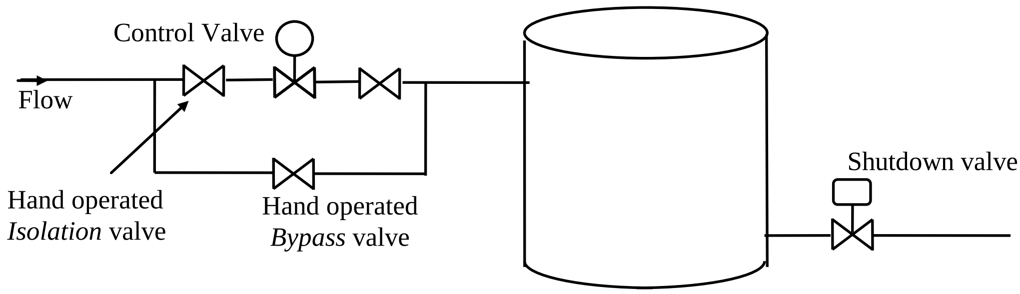
Application
the body style,
the physical size,
its flow capacity,
by the way in which they are operated which can be in 1 of 3 basic ways, either manually, automatically with the ability to have total control of its position, or finally a two position operation known as on /off.
Direct or Reverse acting.
Air fails Action.

9.21 Body styles

The are 4 basic body styles, these are the Ball, Butterfly, diaphragm and the globe valve. Other derivatives exist, but these tend to be very low flowrate, or specialist options, but the basic principle tends to reflect 1 of the previous 4. It is this part of the valve which houses what is referred to as the correcting element. These are going to be dealt with in a later in section 3.

9.22 Hand operated valves for Hand Bypass or Isolation.

From the above not all valves are control valves, manual valves can be used for the purpose of isolating equipment in the pipeline for example control or shutdown valves, in addition they may also be used to create a *bypass* loop which can be used for isolating around either of the other 2 valves that would then facilitate removal or on-line maintenance. The next process flow diagram shows some of the uses of the above mentioned valves:-



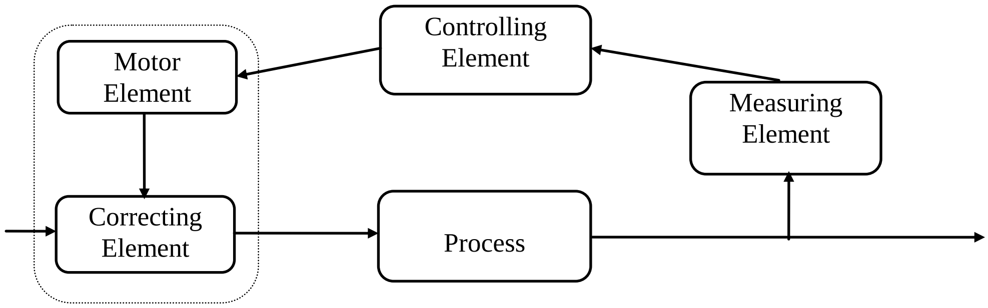
From the above diagram it is important that if the bypass loop is to be used, that the *bypass valve is opened first.* If this does not happen and either of the other valves are closed then it is likely that the section will be shutdown from the resulting loss of flow. When isolating the system it is normal to close the isolation valve on the supply side first, and when de-isolating the system opening the downstream and control valves will prevent a pressure hammer when the supply valve is opened.

- Remember *BYPASS FIRST AND LAST*, and you won't shut the plant down.

The valves used for this purpose all tend to be hand operated, using either a hand wheel or handle. The are required to produce very good shut off, and for this either the Ball or Butterfly are ideal, however the diaphragm type can give perfect shut off but is limited in its pressure application range.

9.23 Control valves.

The Control valve is normally part of automatic control system, which is often referred to a measurement or control loop. The next diagram shows the part were the control valve fits into this system, it is also the device which as part of the control system comes into direct contact with the process fluid, and hence is why control valves etc, are often referred to as *Final control devices*.



As can be seen in the above diagram the combination of the Motor and correcting elements are normally referred to as the control valve. In terms of parts of the control valve the motor element combines the *positioner* and *actuator*, whilst the correcting element is the device used to manipulate or start/ stop or control the flow.

There are different types of control valve. These are generally identified by the correcting element used

Fully automatic operation of this type of valve is only available when the valve is connected into a control loop with all of its component parts operational. Manual control may be employed during times of maintenance on the system by moving the controller into manual operation, in this mode there is no feedback from the process.

9.24 Two position valves.

The two most common applications of the two position valve is with a shutdown system, or alternatively as part of a batch operation control system. As the name suggests these valves only have two positions of operation, being either fully open or fully closed. Another example of the two position valve is the solenoid valve, these are small bore electrically activated valves, and it is these that are normally used to switch the air on or off to the shutdown or on/ off control valve.

9.25 Direct and Reverse action.

Direct and reverse action is the term applied to the movement of the control valve in relation to an increasing valve signal. The most common valve signal is 3 - 15psi or its equivalent of 0.2 to 1 bar. The following table shows the standard signal position relationship:-

Type	Position at 3psi	Position at 15psi	Air Fail Action
Direct	Closed	Open	Closed
Reverse	Open	Closed	Open

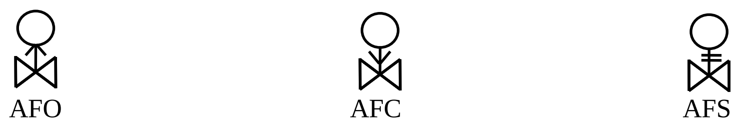
Non standard versions of the actions above are available, in these cases it the air fail action which is normally reversed.

9.26 Air Fail action.

The term air fail action is used to describe what would happen in the event of the air supply being removed from the control valve. The is useful because if an emergency situation occurred it is possible to predetermine and therefore create some control in the plant shutdown, ie: vent systems could be opened or flows stopped.

There are 3 basic options for Air fail action these are Air Fail Open (*AFO*), Air Fail Close (*AFC*) or Air Fail Stayput were the valve is made to hold its current position.

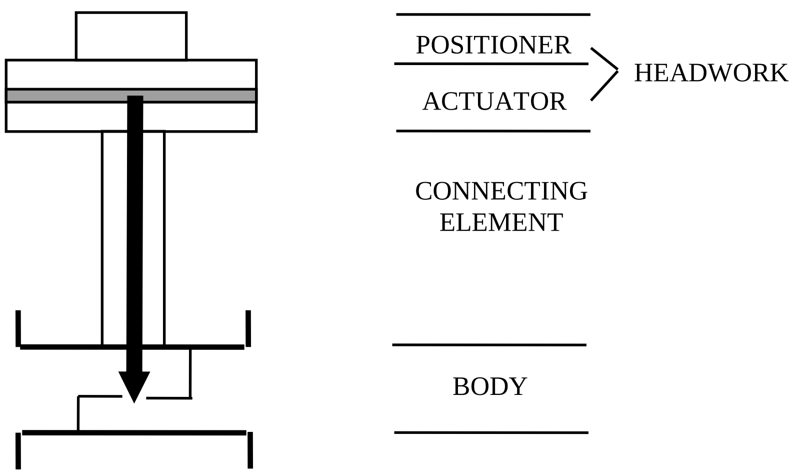
The following symbols are used to denote the above on instrument or process line diagrams:-



An AFO valve may be used on a pressure relief system for example on a reactor, whereas the AFC valve may be used to stop flow into the reactor if a dangerous occurrence was imminent.

9.3 Parts of a Control valve.

The following diagram shows the main parts of a control valve, although most valves are similar way only the headwork or actuation being different:-



The Positioner- this is an optional unit used to accurately position the correcting element. This usually incorporates a feedback mechanism which senses the input in relation to the actual position of the correcting element.

- *The Actuator*- this is the part of the valve which provides the force required to move the correcting element to the desired position.

- *The Headwork-* is a term commonly applied to the Positioner and Actuator combination.

- *The Connecting Element*- this is the part of the valve which connects the headwork to the body.

- *The Body*- is the part of the valve which comes into direct contact with the process fluid, and houses the correcting element.

Moving down the valve, we will now look at each part in more detail.

9.31 The Positioner.

The positioner can be described as a high-gain plain proportional controller that measures the valve stem position and compares this to its setpoint which in this case is the controller output signal. The positioner makes a comparison between the two and if a difference exists will correct the error by changing its own output signal to the valve. The purpose of the positioner therefore is to ensure that the valve moves to the position where the controller wants it to be in order to maintain control of the process.

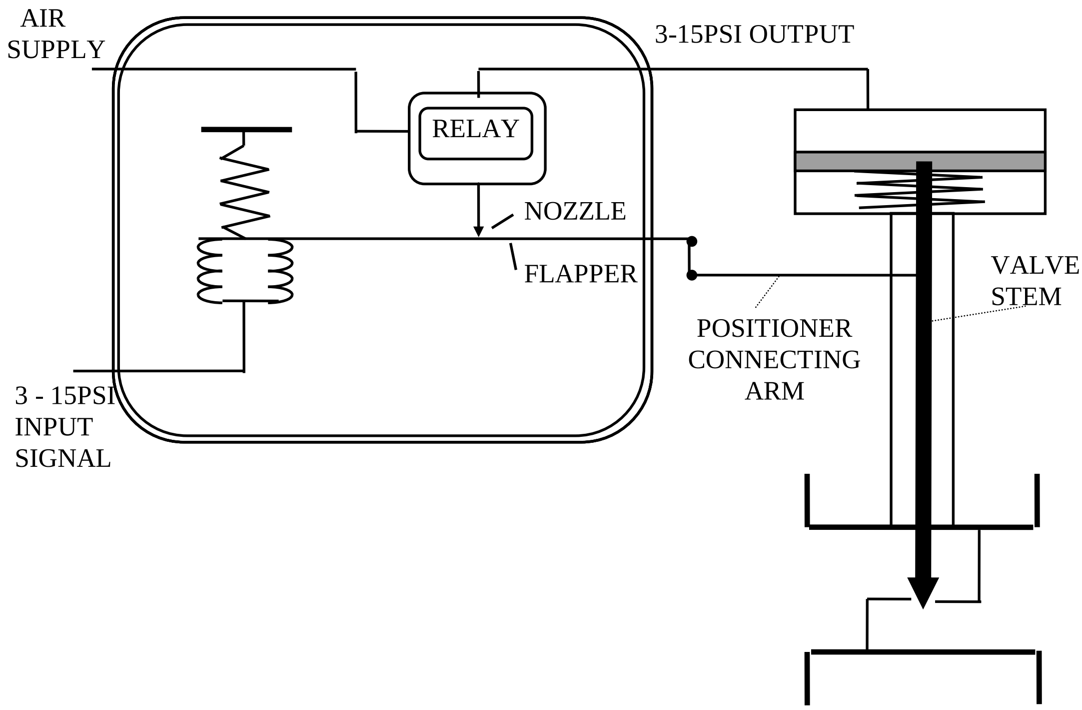
The addition of the positioner can correct some inaccuracies due to the operating conditions, caused by packing friction, dirt, corrosion, sloppy linkages in the actuator. The positioner can also be used for split ranging, increasing actuator speed, and reducing hysteresis errors in manual operation. In automatic operation the positioner will be helpful when system response is slow such as in analytical control systems, temperature, blending, large volumes and liquid level applications.

The Positioner is normally an add on unit to the valve that is responsible for setting the position of the actuator and therefore the correcting element. There are two main types of positioner, these are:-

- Motion Balance. *As used on the Maisoneilan and Fisher valve ranges.*
- Force Balance. *As used on the Glocon valve range.*

Motion Balance Positioners.

These compare the position of the input bellows or diaphragm to the position of the attached valve stem, via a connecting linkage. The next diagram shows the setup of the motion balance positioner:-



From the diagram, it can be seen that when the input signal is increased the flapper is moved towards the nozzle thus increasing the output from the relay to the valve. The increase in signal therefore causes this valve to close. The arm attached to the valve spindle therefore is moved away from the nozzle and thus the reverse tries to take effect, and the valve would try and start to open assisted by the spring located under the piston or diaphragm in the actuator. With the valve trying to start to open and the valve stem rising, the flapper would move away from the nozzle, in turn the position and forces achieve equilibrium the valve would hold position until the next change in input pressure. The control valve action can be altered by switching the 3 -15 valve signal from above to below the piston and likewise moving the spring. The valve gain can be altered also by changing the pivoting positions thus changing the proportional response.

Force Balance Positioner.

Probably the most common positioner is the force balance unit used on the Glocon range of control valves, this positioner uses a double diaphragm unit to sense and compare the feedback from the valve stem position and the 3- 15psi input from the controller. The diagram next shows a section through the positioner:-

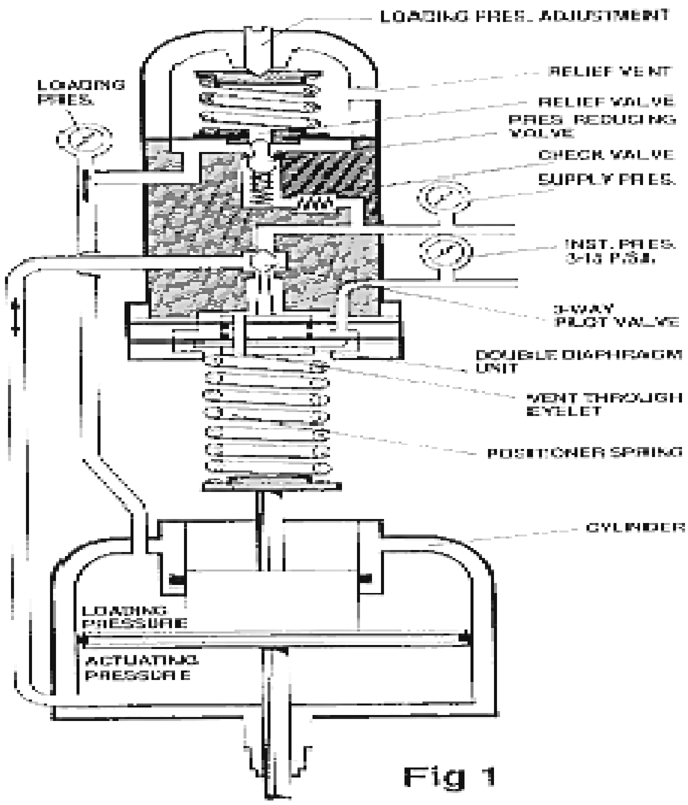


Fig 1

The supply air normally 50psi is fed initially through the check valve to the underside of the reducing valve, at the same time it is also fed to the 3 way pilot valve. Manually turning the loading pressure adjustment will now increase the tension of the spring acting on the diaphragm pushing the pressure reducing valve down thus opening it to allow air to the underside of the diaphragm and to the top of the valve actuator on the topside of the piston, this is what is commonly referred to as *loading pressure*, this is indicated on a small gauge and is normally set to *half of the supply*. This pressure on its own will now force the piston downward thus moving the valve stem likewise. The air supply also travels to the 3 way pilot valve, were altering the 3 - 15psi input signal will cause movement in the double diaphragm unit assisted by force of the spring on its underside causing a change in the position of the valve thus regulating air to the underside of the piston in the actuator, this is known as the *actuating pressure*. When actuating pressure is greater than the loading pressure the valve stem will be moved upward. When both the pressure above and below the piston are the same, the valve will hold its position, reducing the pressure under the piston will cause the valve to move down. A small spring on top of the double diaphragm unit and a reversal of the size of the diaphragm (P or Movement proportional to F/A), reverse action can be created.

The airfail action of the valve can be determined via the *Check valve*. When the supply air is removed, with the valve in place the air is locked above the piston by pushing the check valve against its seat while the air below is allowed to bleed away, as a result the valve will close (AFC). If the check valve is removed the air is allowed to bleed back into the supply line, and with the addition of the process pushing on the underside of the plug and the assistance of a spring fitted below the piston when the air is removed the valve will be forced upward into the open position (AFO). The installation of the valve is normally such that the process pressure assists the air fail action, ie;- airfail close the process assists the action and therefore the pressure seal, whereas the airfail open setup uses the process to assist the valve in opening on air failure. When installing the control valve or shutdown valve care must therefore be taken to ensure the valve is fitted the right way round, this is also important after carrying out a valve overhaul were the valve may have been completely stripped down it is therefore important to ensure that the valve body is fitted correctly in relation to the flow direction.

9.32 The Actuator.

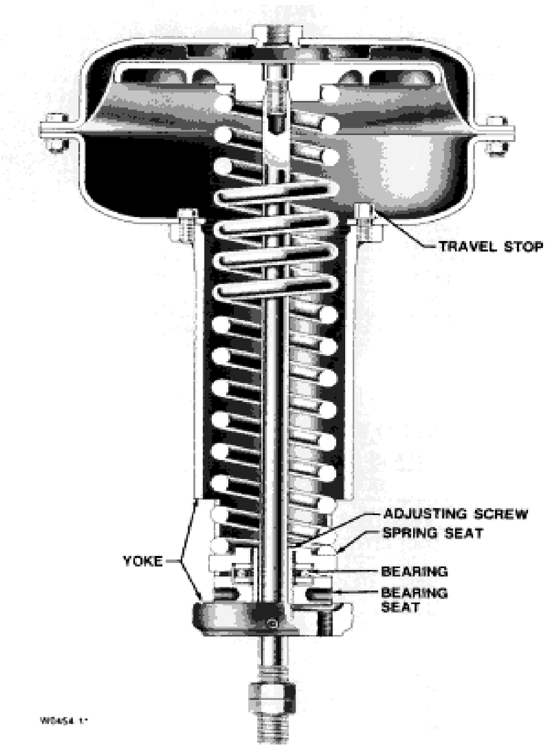
The Actuator is the part of the valve which provides the motive power to move the controlling part of the valve ie; the part of the valve that affects the process directly. In some cases this can be rotary or alternatively an up/ down movement which is typical of plug and seat valves. Types of actuator therefore vary according to the required output, probably the most common actuators are:-

- Diaphragm - *as used by Fisher and Maisoneilan ranges*
- Cylinder / Piston - *as used by the Glocon range*
- Double Piston rotary - *as used by the Hytork and Norbro valve ranges*

Whilst the above listed actuator types are not the only ones available, they are a good reflection of the types commonly used. Other types in existence are the electrical and the Hydraulic actuators.

Whatever the selection, the actuator must be capable of delivering the right amount of force or torque for the application to overcome the amount of friction used for sealing. The matching of positioner to actuator is best kept to the same manufacturer as they tend to be built to suit and are generally not transferable. Actuators are commonly referred to as either on /off or throttling types, the on/ off are typical of the type used for shutdown systems or batch control operations whereas the throttling type are those common for their controllability. Other factors included in selection should be stroking speed, the amount of travel (stroke), vibration and temperature resistance. In some cases a fast stroke speed can have adverse affects on the process such as valve hammer.

Diaphragm Actuators.



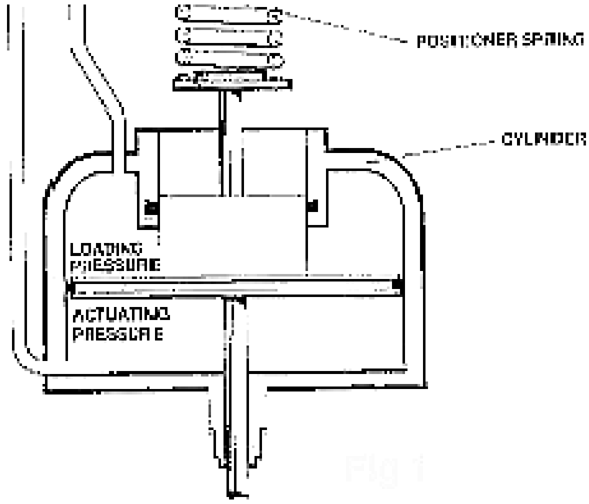
TYPICAL CONSTRUCTION

The diaphragm actuator is a very popular choice for small pipe sized valve applications. The basic design is that of a flexible diaphragm in a sealed casing to which air is applied either above or below the flexible area, increasing the pneumatic signal thus creating movement either upward or downward as required. The addition of a tensioned spring above or below the diaphragm will provide reaction against the signal giving a controllable signal range but also provides the necessary force required to give an air fail action. Due to the simplicity of the design having few moveable parts offering excellent reliability these are an ideal choice for small pipe applications. The diagram opposite shows the basic setup of this valve type:-

The actuator shown opposite is an air fail open type were removing the air will cause the force from the spring to return the valve to its original position. In this valve type the common signal ranges are 3- 15psi or 6- 30psi. For this valve to operate the appropriate signal is applied to the top of the valve above the diaphragm and when the spring tension is overcome the valve will move downward until the maximum signal is reached and the valve is closed. Most of the force created by this operation is taken up by the spring as stored energy therefore these valves are limited to small applications were the forces required to move the valve stem against the sealing friction is comparatively low. To use this valve for large applications would involve large physical sizes, more weight and significant cost increase.

Cylinder/ Piston actuators.

Yet another common actuator type is the piston or cylinder type, these are most common with the Glocon range of valves, with the piston type being the one normally used for throttling service, whereas the cylindrical type tends to be the type used for shutdown or on/ off duty. The piston type actuator is the one which is used were large forces are required to overcome the process conditions, as such they can create large amounts of force and torque, although the supply pressure for these types of actuator is between 50 and 100psi, the forces generated to overcome the stem friction can be upward of 500psi, as such *under no circumstances try to stop a valve stem from moving* by putting fingers under or around the stem, *serious injury may result from this action*.

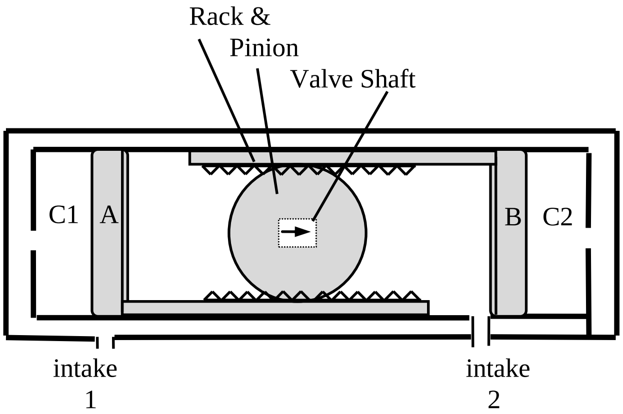


Similar to the diaphragm actuator operation, air is fed above or below the piston, when the pressure above is greatest the piston will move downward and reverse when the air under the piston is greatest the piston will move upward. The pressure above the piston referred to as loading pressure while the pressure below is referred to as the actuating pressure. With equal pressure across the piston it will hold position until one of the previous is altered. For successful operation a double acting valve positioner must be used in conjunction with this type of actuator which will simultaneously adjust the pressures across the piston to control the valve position. Like the diaphragm actuator a spring may be fitted above but more commonly below the piston in order to create air fail operations, to assist when the air is removed. The combination of the positioner and actuator is commonly referred to as *the headwork*.

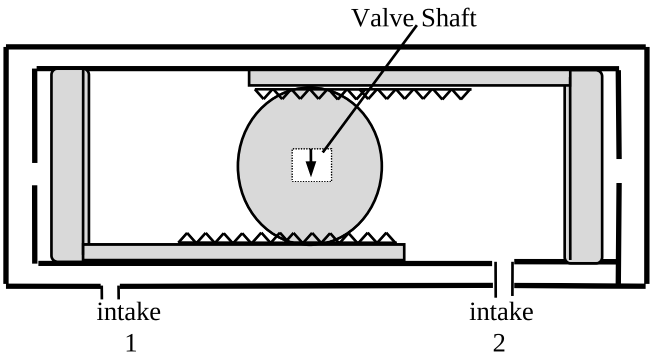
To enable these actuators to be used for purely shutdown or on/ off applications, wit slight modifications it is possible to have a sealed cylinder with pressure access to either above or below the piston but in these cases a heavy duty spring is placed in opposition to supply pressure and the stored energy created by compressing the spring when the supply is applied is then used once the air is removed to create sufficient force to operate the valve to the extreme opposite of its normal operating position. Again care must be taken when overhauling these valves, for safety *always assume that the valve actuator is spring loaded*, and therefore take precautions to remove the spring tension to avoid parts separating under pressure.

Double piston/ Rotary actuators.

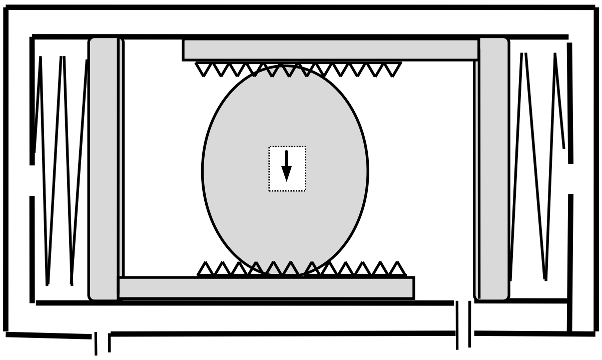
This type of actuator is most common where a rotational movement is required ie; in the case of ball or butterfly valves. The following diagram shows a typical style Rack and Pinion rotary actuator:-



In the above diagram when the air supply is fed through intake 1, it enters chamber C1 and travels around and into C2 thus pushing the 2 pistons into their current position, as indicated by the arrow on the valve shaft this actuator would probably be connected so that the valve is now in its open position. If air is now fed into the actuator via intake 2 with the air into intake 1 being shutoff, the pistons would be forced outward thus turning the valve shaft via the rack and pinion arrangement, this is shown in the next diagram;-

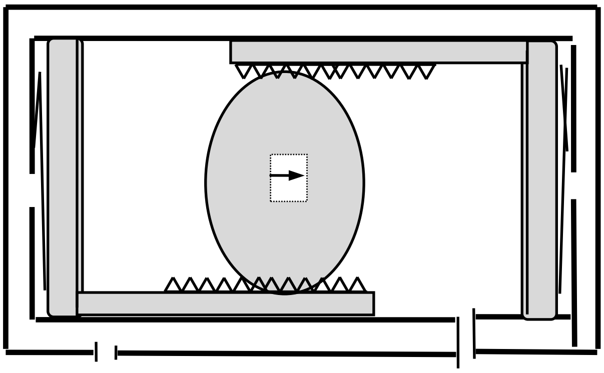


In some cases it may be required that an auto return operation is needed such as for shutdown valves, in this case the supply air will only be fed via intake 2 with intake 1 being used as an exhaust and heavy duty springs would be fitted into chambers 1 and 2, as shown below:-



The diagram left shows the springs fully extended with the valve in the closed position.

The diagram right shows the supply being used to push against the pistons and compress the springs fully, putting the valve into the open position. Removing the air would use the stored energy in the spring to return the valve into the closed position a shown in the previous diagram.



This type of operation is typical of the types of valves manufactured by Norbro and Hytork, their specific applications tend to be shutdown or batch control application. In some instances the top of the valve shaft can be modified to accommodate a proximity position sensor so that a switched signal may be generated that may be used by DCS control systems or panel indications.

Due to the manufacture design the speed of response of these actuators is excellent particularly in on/ off applications, they may also be modified for throttling applications but this would normally require the addition of a valve positioner.

The actuator is normally sat on top of the valve and is connected to the ball or butterfly via a driveshaft which locates into a square slot in the actuator pinion. Over an extended period of time continuous use may create wear in the connection collars and this may need to be taken up using shims, if this is not practical replacement parts may be required to avoid the valve becoming sloppy.

These types of actuator are available for valves with small bores upto ball and butterfly valves of approximately 24 inch.

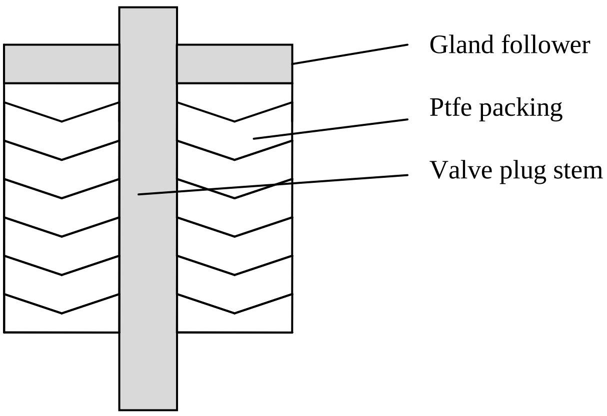
9.33 The Connecting Element.

This is the part of the valve which connects the headwork to the valve body, the term connecting element can be appropriately applied to the valve stem or shaft as this is the connection between the actuator and the body, although the term is more commonly used to describe assembly of the valve that houses the device used for sealing the process, the main 2 devices being the gland seal and the bellows seal although the latter is most commonly used with plug and seat valves. Other more complex methods are available but tend to be used on hazardous applications.

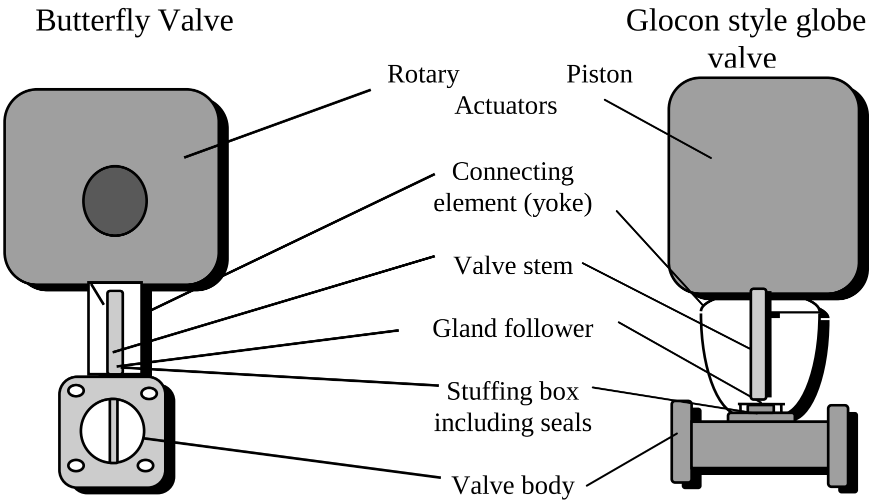
Gland seals.

This is probably the simplest and most commonly used sealing method, the basic operation being the compression of a sealing device against the valve stem, the most commonly used sealing medium is the PTFE or Teflon chevron sealing O-ring although C A F and graphite may be used for example on oxygen where PTFE may not be used, these are often referred to as the *packing*. This type of sealing method provides excellent sealing against the most rigorous conditions and is particularly useful in high temperature and pressure applications.

The construction of the valve body that connects to the connecting element normally provides a deep recess around the valve stem/shaft; this is known as the *stuffing box*. Into the stuffing box the packing o-rings are fitted and the valve stem is inserted through the centre, these are then compressed against the stem to create a seal. Care must be taken not to over tighten these as increased friction against the stem will make opening and closing the valve difficult. The diagram below shows a typical design:-

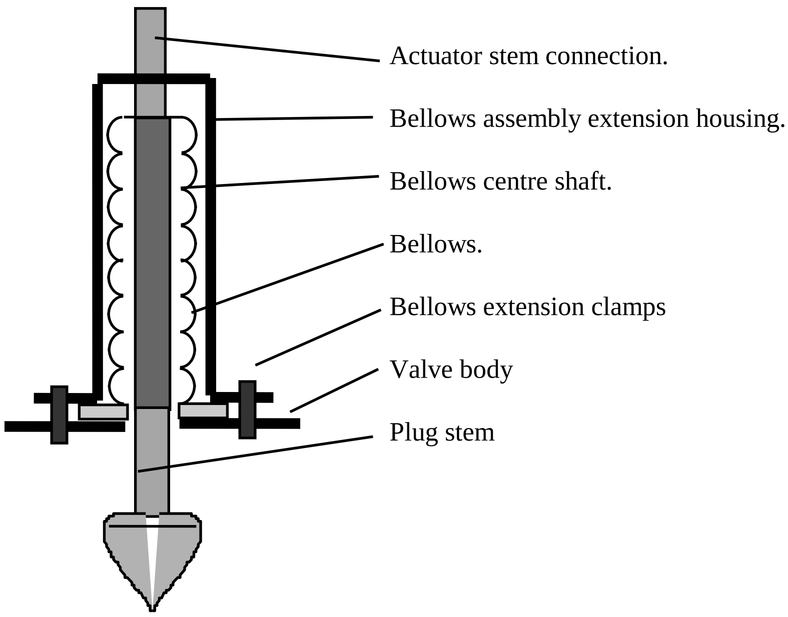


The diagram above shows a typical arrangement as used in the Glocon valve range, although with slight variation this method can be adapted for most valve types including rotary and diaphragm. It is the gland follower that is used to compress the packing into the stuffing box, and as mentioned previously the friction pressure or force creating the compression seal between the packing and the valve stem can be as much as 500psi. The following simple diagrams show where the glanded seal arrangement may be located:-

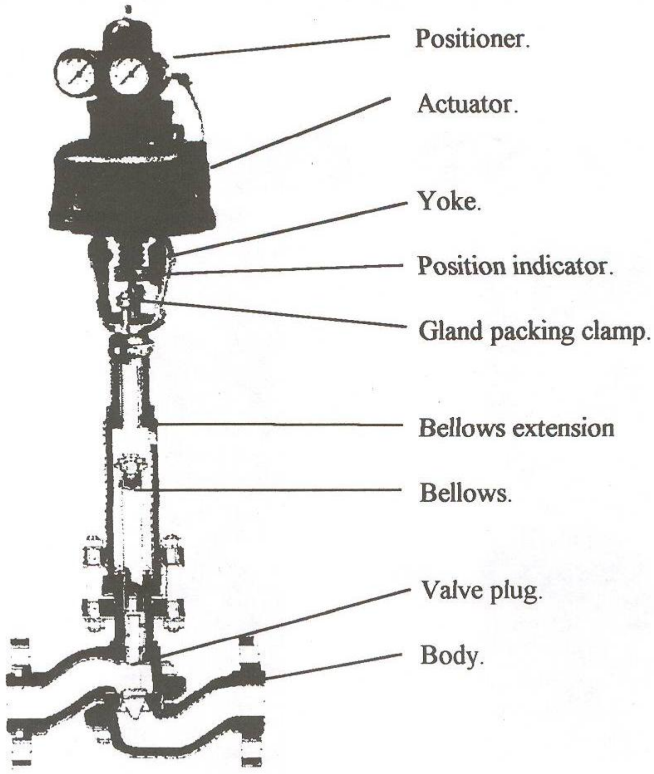


Bellows seal assembly.

This method takes its name from the primary sealing arrangement which is via a bellows. The bellows, normally made from stainless steel or Monel, is inserted into an extension piece between the valve body and the yoke, the design incorporates a flexible bellows that is fixed rigid and sealed inside the extension to the body, whilst the top is free to move up and down, to the top of the bellows the stem from the actuator is connected via a connecting shaft, inside the bellows is another shaft that allows the valve plug to be screwed into it. This can be seen in the next simple diagram:-



As can be seen from the diagram, the process fluid is capable of entering into the bellows around the centre shaft. As the valve position is altered by the actuator the bellows acts like a concertina thus retaining the process, the only method for escape is via damage or corrosion, thus periodic overhaul and inspection are required. It is important that once clamped between the body and the extension, that the bellows shaft must not be twisted as this will cause the bellows to shear. In addition to the bellows seal a secondary seal may be created using the gland packing against the valve stem. The following diagram shows a complete example of this type of valve from the Glocon product range:-



Connecting Elements for Special purpose.

Due to the extensive amount of chemical ranges and nature, it is often not suitable to use primary connecting elements such as glanded seals or bellows on their own, in such cases manufacturers information will provide specific detail on equipment suitability, however one of the simplest and common examples is involving extremes of high and low temperatures for this cooling fins/ or heat exchangers on an extension between the body and the yoke are used to allow ambient air to cool or raise the temperature of the valve stem area, making sealing more effective. The devices are often referred to as *normalising fins*. The use of this assembly can radically improve the operating range of the valve from -80 to +1000°C.

9.34 Valve Bodies and Correcting elements.

Following the valve as we have looked at it so far this is the final part, it is also the only part of the valve that comes totally into contact with the process fluid. The body is the name applied to the part of the valve which houses or contains the process fluid, whilst the correcting element is the device used to affect the fluid flow through the valve body. There are 4 main valve body styles and hence general correcting element design option, these are:-

1. Globe valve - (plug and seat)
2. Saunders diaphragm valve.
3. Butterfly valve.
4. Ball valve.

In each case the body of the valve is designed around the correcting element from where the valve takes its name. There are others available such as the pinch, sliding gate and plug valve (no reference to No1.) and needle (a very small sized derivative of the globe), however these are less common as control valves and will not be covered in this section.

All of the valves mentioned can be modified for use as either throttling control valves or alternatively as two position on/ off valves for shutdown duty, they can also be modified as hand operated valves by using either a handwheel or handle this option is normally used for isolation purpose.

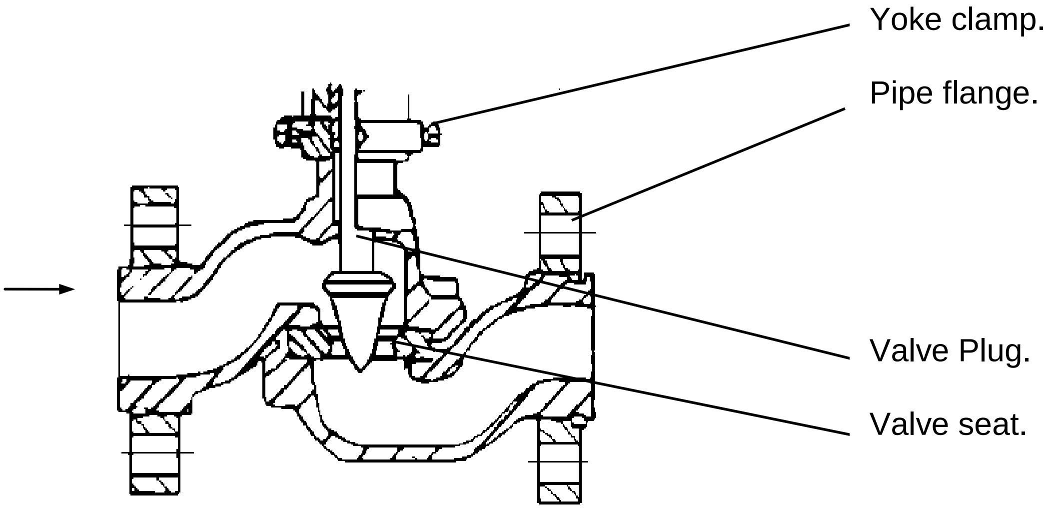
Globe valves.

This type of valve is probably the most common and most versatile control valve in use. There are several types available but these only differ due to manufacturer and actuator designs, the operation of the valve and its characteristics are the same. The term globe valve is normally applied to the range of control valves using the plug and seat method of controlling and characterising the flow, the combination of the plug and seat are often referred to as the *trim set* .

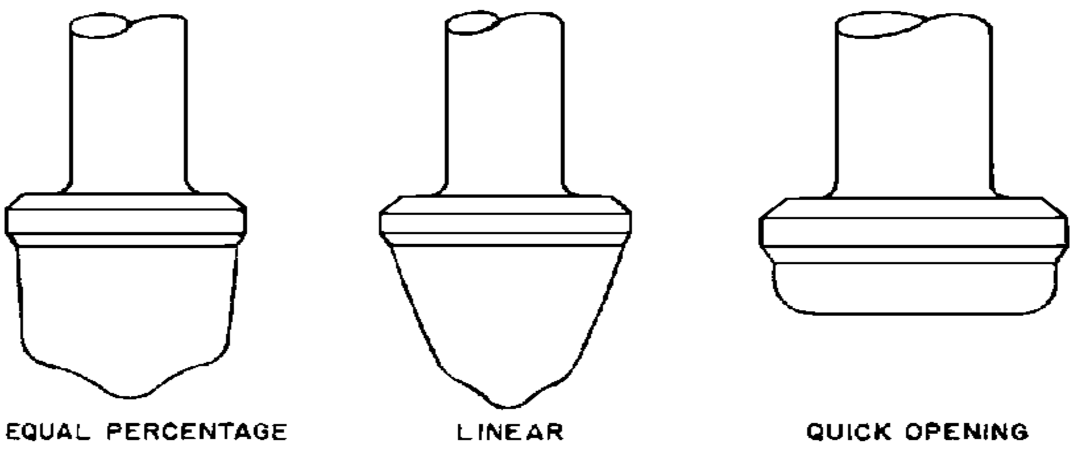
The versatility of this valve means that there is an endless list of options available for its use. In summary some of these options can be categorised and listed by:-

1. Body Design - Split body, angle body, and 3 way body.
2. Physical size - 0.5 to 16 inch (sized from the inside nominal bore)
3. Flow Characteristic - plug shape
4. Valve coefficient - Cv - flow capacity.
5. Seat type - soft seat, or metal to metal.
6. Construction material.

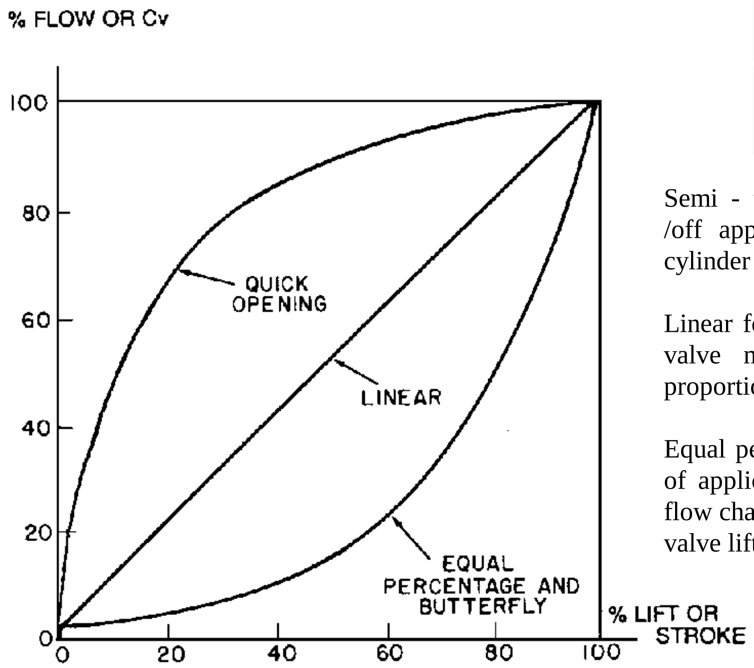
The most common body design is the split body ‘S’ shape, with the most common sizes used being from 3/4 inch to 4 inch this is obviously determined by the pipe diameter. The use of the ‘S’ shape body is ideal as its shape minimises clogging, reduces turbulence, reduces maintenance time, makes valve linings easier to apply. The next diagram shows the basic 'S' shape split body design:-

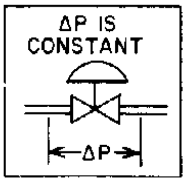


In operation the process fluid enters the valve in the direction of the arrow, with the plug in the closed position (ie; pushed against the seat) the process fluid is prevented from passing through the valve and a leak tight shutoff should be created, the assistance of the line pressure should help this by pushing the plug into the seat. When the control signal to the valve is increased, the actuator will cause the valve plug to be pulled upward off the seat thus opening the valve and allowing the fluid to pass through it. The shape of the plug will determine exactly what the flow characteristic through the valve will be. There are 3 main plug shapes, these are *Linear*, *Equal percentage* and the *semi throttle(quick opening)*, a fourth known as the *mini contour* plug is available but this is based on the linear design and is only for very small applications below 1cv. The next diagram shows these designs:-



Valve plug shapes to produce the three common flow characteristics.





Semi - throttle typically for on /off applications or 2 position cylinder shutdown valves.

Linear for wide range where the valve movement is in direct proportion to the input change.

Equal percentage for wide range of applications were the rate of flow changes in proportion to the valve lift.

Inherent flow characteristics: quick-opening, linear, and equal percentage.

The choice of plug is to reflect the application, such as the equal percentage, this could be required on high pressure systems when opening the valve from closed could cause valve hammer. The following diagram shows the graphical characteristic of each of the 3 plugs:-
The above set of responses are in an ideal situation where the pressure drop across the valve would remain constant, however in practice this is not always the case as the pressure across the valve will naturally reduce as the valve is opened up further. Now that the correct characteristic has been chosen it is important to get the right size plug and also match this against the flow capacity or Cv.

The term Cv is a unit less figure used to denote the flow capacity or valve coefficient. It tends only to be applicable to the globe valve range. The general statement defining Cv is:-

The number of gallons per minute of water, that the valve will pass, with a pressure drop of 1 psi across it.

Example:- From the following information, if a pump can deliver 150gallons/ min, and the substance is ethyl glycol (sg = 0.8) at a maximum pressure of 50psi, what Cv would the valve need to be in order to meet this demand:-

$Cv = Q\sqrt{\frac{SG}{\Delta P}}$ where Q = maximum flowrate (in imperial units),
SG is the fluid specific gravity or relative density,
ΔP is the maximum pressure or maximum differential

therefore $Cv = Q\sqrt{\frac{SG}{\Delta P}} = 150 \times \sqrt{\frac{0.8}{50}}$

Cv = 18.97

The above method is only true *for liquids*, where *gases* are present the formula would be:-

$Cv = Q\sqrt{\frac{SG}{P_1 \Delta P}}$ where P_1 = the downstream absolute pressure,

Where *steam* is present the formula is $Cv = \frac{Q}{3\sqrt{P_1 \Delta P}}$.

Where temperature is an important factor, and is prone to large variations, this also may need to be compensated for by multiplying the Cv by $\frac{\sqrt{\text{absolute temp}}}{22.8}$

This compensation is only required on temperatures above 80°C, as below this the accuracy should be within 5%.

Now that the necessary calculations have been made, selecting the right size valve is the next step. This is done by matching the valve size to the Cv. The following diagram is a sample:-

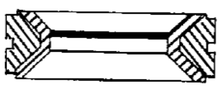
VALVE CAPACITY FACTOR TABLE

BODY SIZE	STANDARD MAXIMUM VALVE Cv
¾"	4·8
1"	7·6
1½"	19
2"	35
3"	76
4"	130
6"	290
8"	492
10"	770

Values shown on the above tables are those guided as being the maximum for the valve size, smaller Cv's may be used.

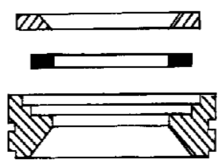
Now that the correct plug has been chosen, the *seat* type is also important, the 2 main types are either the solid metal seat, whose metal to metal sealing or shutoff can be better than 0.5%, or alternatively the soft insert seat, this is a 3 part seat consisting of a body, a PTFE seat insert and a metal over seat. With the soft seat insert perfect shutoff can be guaranteed, although because these are a non metal substance they do have an increased wear rate. The following diagrams show the 2 plug types:-

standard seat ring metal or ceramic



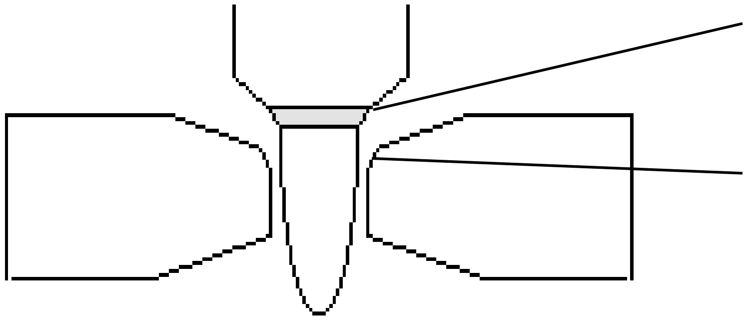
The self-aligning seat is spigot located between the upper and lower body halves. The seat ring is released immediately the body members are separated. Standard material for valve trims is 316 Stainless Steel. These can be hard faced to suit service conditions. We consider seats are as important as plugs and attention is paid to flow passage design and finish to give extra life and economy due to reduced turbulence, cavitation and erosion.

seat ring with soft element



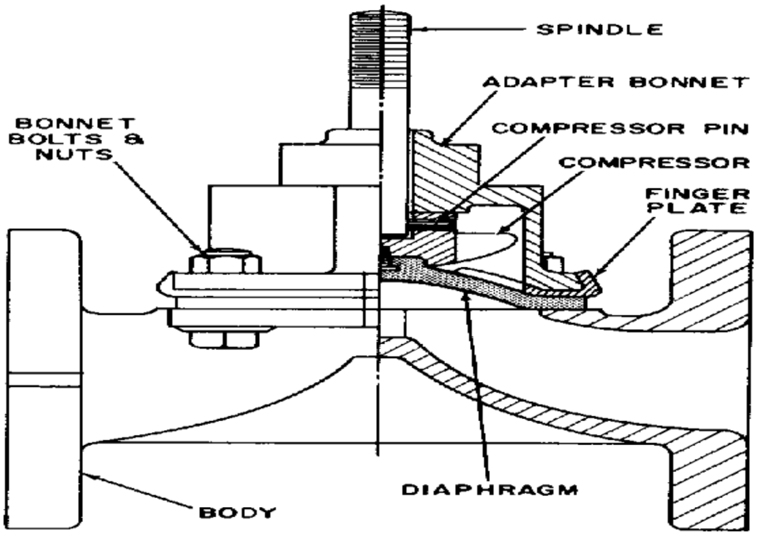
Where an abolsute shut off is required, soft elements may be used. These can be manufactured from Teflon, Hostaflon, copper or other suitable materials, depending on the service.
This simple seat unit produces exceptional service on strong acids, highly corrosive gases and many other fluid applications where tight shut off has heretofore been impossible. Used in 150, 300 and 600 lb. ASA Rated Bodies.

Important to note that the seat generally has 2 chamfered edges, the shallow chamfer is the top and normally the seating edge, whilst the deeper is the bottom or downstream side of the seat. The actual seating edge is only about 1 mm in length as shown below:-



The most common materials used for plug and seats are stainless steel, Stellite, stainless steel with Stellite coating , or Monel. Stellite or Monel material tends to be used on particularly corrosive natured substances, whilst the stainless steel option is probably best suited for general purpose.

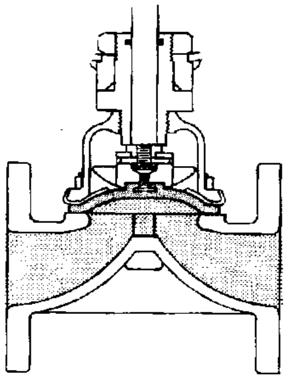
Saunders diaphragm valve.



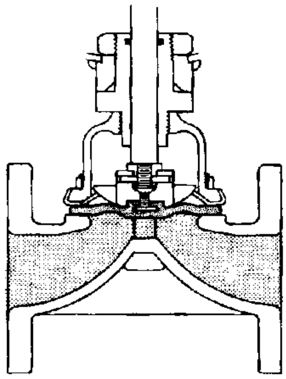
The Saunders valve or diaphragm valve consists of a metal weir body and flexible diaphragm. The next diagram shows the basic parts diagram of this type of valve:-

Because this valve uses a non- metallic diaphragm, perfect seals and shutoff can be achieved, and because of the split body design linings are very easily applied. Therefore this valve can be manufactured to be well suited to hazardous substances and conditions, however because the valve uses a flexible diaphragm they cannot be used on extremes of heat or pressure.

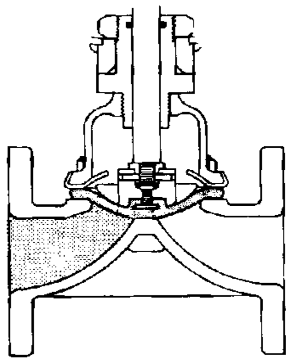
In most cases the diaphragm is made from rubber, although where it is to be used on corrosive substances a thin PTFE lining disc may be placed between the diaphragm and the weir to provide extra protection.



STREAMLINE FLOW
IN OPEN POSITION



FLOW CONTROL IN
THROTTLING POSITION

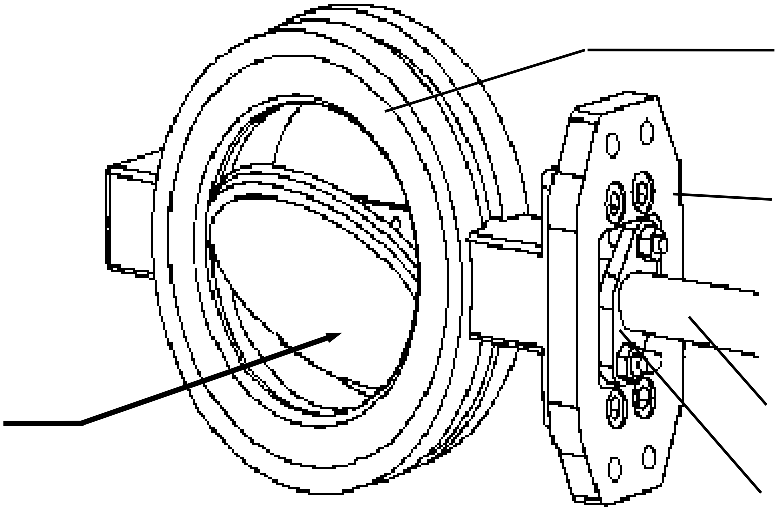


LEAK-TIGHTNESS IN
CLOSED POSITION

It is opened and closed by moving the diaphragm closer to or away from the weir, this is done via spindle which is connected to the valve actuator and the other end to the diaphragm.
The characteristics of this type of valve are similar to that of the quick opening or semi throttle globe valve plug.

Butterfly valve.

The butterfly valve, *baffle* or *damper*, as they are commonly called, consists of a disc inserted into the pipeline and able to turn on a diametral axis (ie ; across the pipe). Earliest dated use of this type of valve is 1920, and since then have become used extensively in the chemical industry etc, also in power stations as dampers for the gas feed intakes for furnaces and boilers, but also more commonly it forms the operation of the air choke in the car carburettor or fuel injection systems. They range in size from as small as 25mm up to 5m, and costing from a £500 to £100,000 including actuators. An industrial butterfly body is shown in the next diagram:-



The operation of this valve requires a rotary actuator, as the butterfly is required to be turned through 90 degrees, although a piston actuator and lever mechanism can be used for large applications.

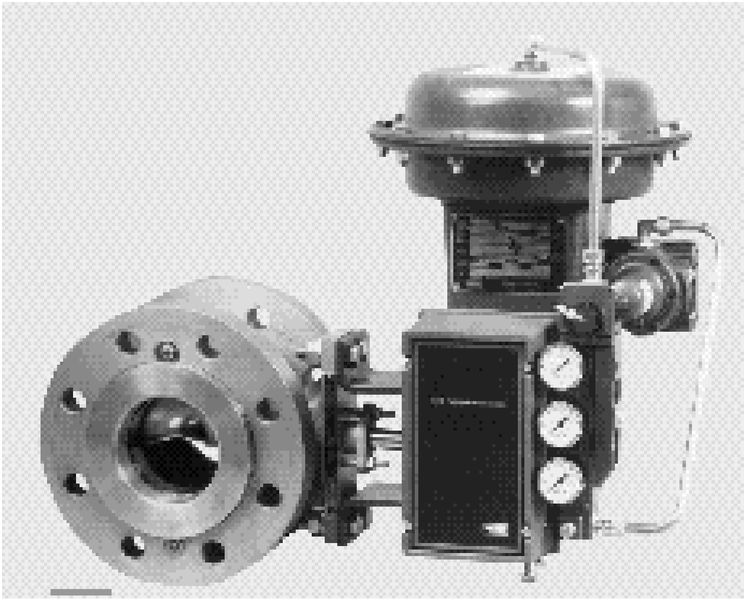
This type of valve can be manufactured to produce excellent seating and shutoff capabilities using soft seat inserts and sealing rings, it is also well capable of being used for throttling or control applications, in this case it is normal only to use the valve through 0 to 60 degrees of travel as beyond this the valve tends to yield near full flow capacity. Due to its design shape the valve can be made to produce comparatively small pressure drop in relation to some of the other valve designs.

The materials of construction used range from stainless steel for the common applications, to high grade Monel and tungsten titanium carbide coated butterflies for corrosive and abrasive applications.

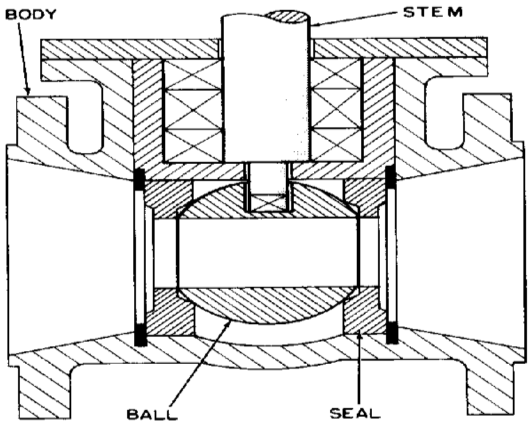
Installation note: If this was an air fail open application, the valve would require an air supply and signal to remove it from the pipeline as the butterfly will lie 90 degrees to the opening and will require closing to remove it.

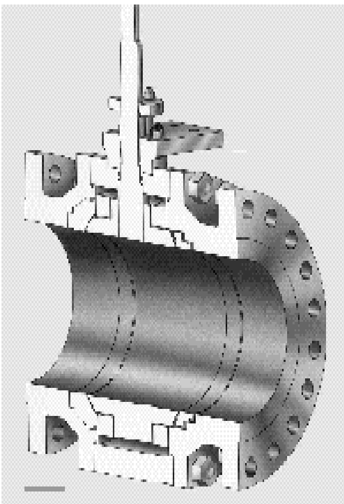
Ball valve.

The conventional ball valve consists of a body into which a spherical ball is cradled between 2 seats that also act as seals. Into the top of the ball a recess allows a stem or spindle to be connected or slotted in order that the ball may be turned to control the flow. A rotary actuator is normally used for this purpose to generate the torque required. The diagram opposite shows a typical ball valve arrangement:-

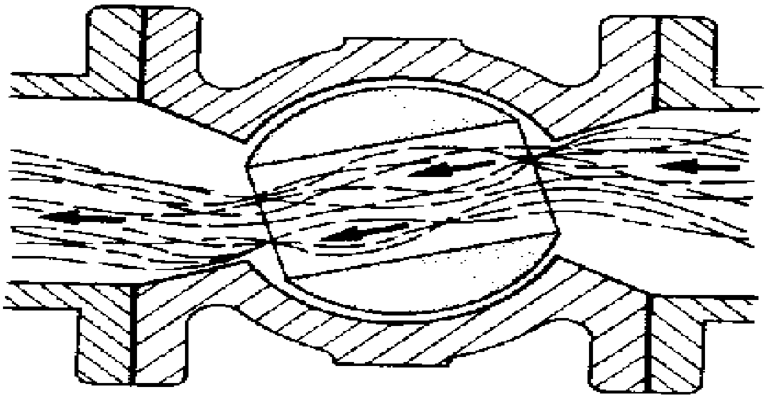


The type of valve shown in the diagram uses a diaphragm actuator and positioner, whilst the diagrams below show cross sections through the valve body:-





The flow control part of this valve is a hole through the centre of the ball, when the valve is closed the flow is prevented from passing through it as the hole is at 90 degrees, as the ball is turned through from 0 to 90 degrees the hole is opened up and the process passes through. The most common applications use a stainless steel ball with ptfe sealing materials, although as with all the other valves discussed alternative materials can be used. The next diagram shows a cross section of fluid passing through the valve:-



The characteristic of this type of valve is similar in shape to the equal percentage, however in the nearly closed sections of its travel the valve will due to its design create an increasing pressure drop across itself. Due to its design shape these valves are excellent against such problems as cavitation, and were slurries are the process they *provide excellent resistance* to build up. The sealing methods are excellent and therefore slight modifications give this valve excellent fire safe application for use on flammable fluids.

Only recently have these valves been used for control purpose due to the noise generated by the fluid travelling at speed through the valve, although as early as 1961 experimental spacecraft used these valves because of their safety characteristics, and the Atlas rocket used them for mixing the liquid ammonia and liquid oxygen propellants.

Due to the physical weight and therefore cast, ball valves tend only to be used for below 12″ pipe diameters, for example a 12″ bore pipe would require a stainless steel ball of 14″.

Beyond the basic shape *other ball designs* are available including a half moon design shape used for generating specific flow characteristics.

9.4 Common faults and Valve Maintenance

One of the primary functions of a control technician would be to maintain control valves on the plant. This next section is aimed at being able to recognise some of the more common faults, and importantly identify methods to test and correct faults if they are found. With some companies technicians are merely required to remove valves and replace them, or carry out on-line checks, where more serious faults are encountered the valve would be removed from the plant and then be sent away for a complete overhaul. Some larger companies have their own valve maintenance departments.

Where a complete overhaul is required manufacturer information will provide detailed and specific information on the individual requirements.

In general, problems associated with valves can be categorised such that whether the valve is a globe, ball, diaphragm or butterfly, inspections and testing procedures are common and similar.

9.41 Valve leakages.

Some problems on the valve are visual and occasionally audible, such as leaking. On any valve there are a number of different seals and gaskets and are all prone at some time to leakage, particularly those where movement is involved and this is common along plug/ valve stems and actuator stems. More so on the plug stem this leakage can be brought about by scouring lines on the stem itself, visible signs of this can be clearly seen as process fluid can be seen externally around the stem areas, and if the leakage is air or from a high pressure source a high pitched noise may sometimes be heard.

- *Actuator seals* often perish as they are normally rubber, curing of these problems normally require a complete actuator overhaul. Other leakage in this area normally arises from the *Positioner*; again complete overhaul of the positioner would be required in order to cure these faults. Improper valve movement would be a reasonable indicator to this area.

- *Valve stem leakage* can often be cured by tightening the stem packing; if this fails a complete overhaul may be required, as this may be due to plug damage.

- *Valve body leaks* can also occur around the seals and can sometimes be cured by re-tightening the body bolts, although leaks of this nature tend to be caused by something more serious, such as corrosion damage.

- *Overtightening* can also be a major contributor to gasket and seal leaks, it is important to pressure/ leak test all joints before installation. It is suggested that before use the valve should be set up with a blank flange to seal the exit and have a flange fitted with an adapter to connect a 50 - 100psi air supply to the valve. Open the valve fully with the supply on to pressure test it. Any leaks can be found using leak detection spray or soapy water around seal or gasket areas.

Other common faults include:-

- The valve does not respond correctly when the supply air is removed.
- The valve not stroking (travelling) fully in relation to the input.
- The valve is said to be *passing.*
- Cavitation

9.42 Valve passing.

The term is used to refer to the fact that the valve is allowing fluid through it even though the control signal is telling the valve to take up the fully closed position.

Causes of this generally are that the plug is not meeting the seat, corrosion or pitting of the seating and mating edges, or that the ball or butterfly are not travelling or rotating far enough. The latter is normally caused by wear and would require packing shims or even replacement parts.

With the *globe valve* this can be adjusted by giving the valve the signal for the closed position, then opening it to gain access to the stem and then turning the plug stem downwards from the actuator stem, this may be done without removing the valve or stripping it down, although depressuring it would be advisable were possible. *Important, if this is applied to a bellows seal valve the actuator must be turned whilst holding the plug stem rigid, as failure to do this will result in shearing the bellows and cause irreparable costly damage and will require a new bellows unit*. If this is done in the workshop the valve can be checked by removing the bottom body adapter and closing the valve whilst holding the seat into the body housing. If the plug meets and pushes the seat away this proves they are meeting together. If after doing this and the body is replaced and it still passes, the plug and seat will need regrinding to mate the surfaces although this of often worthwhile doing as a precaution. If possible test it by putting air (approx 50 - 100 psi) through the valve (using a flange with a small air line fitting adapter connected through the centre). Close the valve and the air should not escape through the valve.

9.43 Valve stroke.

This term is used to define the valve stem movement or travel from fully open to fully closed. Depending on the size of actuator the stroke length will vary, small series actuators may only have a stroke length of around 1 inch, whereas larger actuators may have stroke length of around 3 inches in some cases much more. In some actuators the stroke will be rotational from 0 - 90 degrees.

One of the common faults with the valve is when it does not stroke fully, this is normally due to the valve not being set-up properly or it can be caused by wear and tear. Wear and tear generally causes sloppiness in the movement and thus either the defective part needs replacing or the excess movement needs to be absorbed using shims. Where the problem is due to improper set-up, a set-up procedure needs to be followed, in some valves this can be via a small adjustment wheel under the actuator; this is similar to a zero adjustment.

In some cases, valves can be *split range*. For example the valve may not start moving until 9 psi and then complete its stroke at 15 psi. Alternatively it could be a 3 - 9 psi split range. Problems arise because this is normally determined via a range spring, and occasionally the wrong one is fitted.

Another inspection when carrying out a stroke check is to look for valve stiction, or smoothness of travel. If the packing is too tight against the stem, this can cause the valve to stick at certain points of its travel, thus affecting the accurate control of the process. A simple solution for this is to smear a small amount of silicone grease on the stem during refit, or this can be done by raising and lowering the stem. However the long term cause could be over tightened chevron packing, therefore a complete overhaul may be required to eliminate the problem completely.

9.44 Air Fail Action.

The air fail action of the valve may be tested by connecting the valve with its normal supply and where applicable a mid range signal, the valve should now take up an open or semi open position. The supply should now be quickly shutoff or removed, and note made of the action.

In-correct air fail action is normally caused by failing to install the actuator spring or putting them in incorrectly (ie:- wrong side of the piston). Another cause can be in the positioner, with some being incorrectly fitted (or not) with *check valves,* so that the air is either locked in or alternatively is allowed to escape.

Occasionally air fail action can be affected by air leakage from around the actuator seals.

9.45 Corrosion, Erosion and Cavitation.

Another problem associated to valves is one of corrosion, erosion and cavitation. The result of these circumstances over a long term causes mechanical damage would eventually require the replacement of affected parts. The parts most affected are the valve body and the valve plug/ seat.

Early signs of cavitation occurring tend to be small pit marks in the metal. In the plug and seat this can be ground out although excessive pitting will cause the valve to pass, and again would require replacement parts.

Where corrosion is a major problem, careful selection of construction material should help to minimise re-occurrence, although this should have been dealt with the design stage.

9.5 Valve selection and applications

The following tables show information for a range of valve types.

Feature and Application	Valve Type			
	Ball	Butterfly	Globe	Diaphragm
Max pressure rating (psi)	2500	300	2500	150
Maximum Cv per unit size	45	40	12	20
Ability to change Characteristics	F	P	E	P,F
Corrosive service	E	G	E	P,F
Cost relative to globe valve	0.7	0.6	1.0	0.6
Suitability above 300°C	Y	E	Y	NA
Cavitation resistance	L	L	H	NA
Dirty Service	G	F	F,G	G,E
Viscous Service	G	G	G	G,E
High pressure application	Y	Y	Y	N

NA = Not Available
F = Fair
E = Excellent
L = Low
N = No

P = Poor
G = Good
H = High
Y = Yes

In addition to the applications shown above, in the globe valve the selection of control valve plug shape needs to be selected based on the required characteristic to accurately maintain control of the process condition. As a simple guide, most flow applications use Equal percentage plug design, whereas majority of level and pressure systems use linear particularly where large volumes are present. In addition to affecting the flow characteristics the plug shape can also affect the gain of the system, therefore affecting the controllability. The following table provides a useful quick guide to selection:-

Service	Valve ∆P Under 2:1	Valve ∆P Over 2:1
Orifice type flow installation	Semi – throttle	Linear
Linear flow	Linear	Equal Percentage
Level	Linear	Equal Percentage
Gas Pressure	Linear	Equal Percentage
Liquid Pressure	Equal Percentage	Equal Percentage

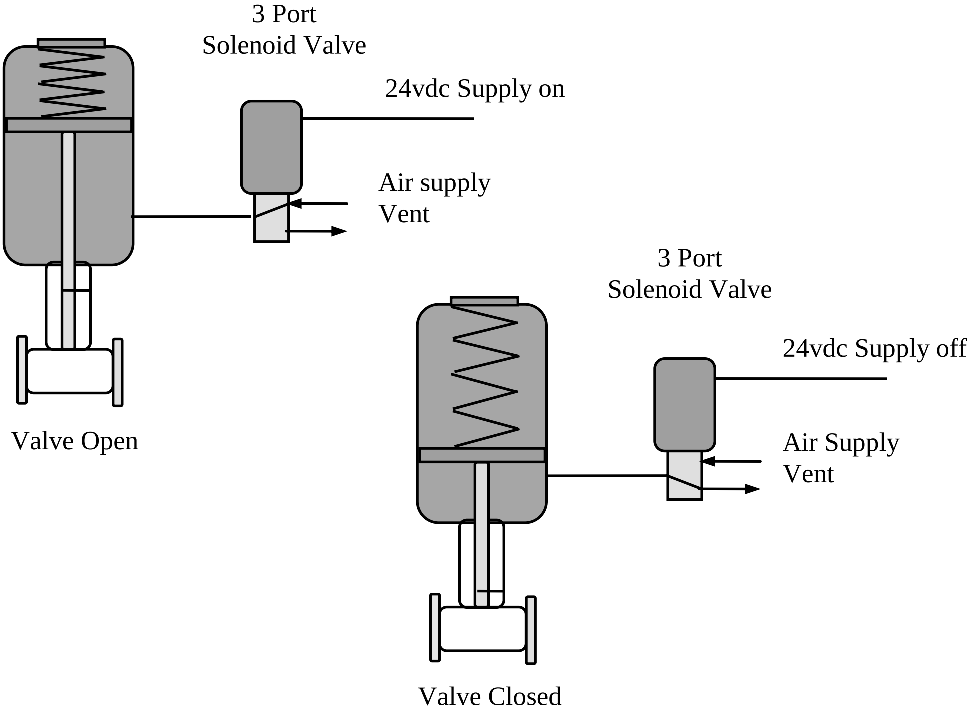
For temperature applications, due to the inherent slow nature of this process the Semi- throttle valve is often used.

9.6 Solenoid valves.

The Solenoid valve can be described simply as an electrically activated pneumatic switch. Its main use is to switch air on and off or vent it, from ‘control’ or more commonly ‘shutdown’ valves. In addition these valves are used in batch processes again providing an air on/ air off operation.

The activation voltage on these devices differs, although the majority use the safest and lowest option of 24vdc. It is possible to have 50 and even 110v solenoids.
The 2 main methods of connecting solenoids is on the output of either a shutdown system, or for batch systems quite often these provide connection for the output from PLC control systems. In some systems they are connected via pressure switches and other similar equipment.

The next diagrams show some of the examples of the use of solenoids:-

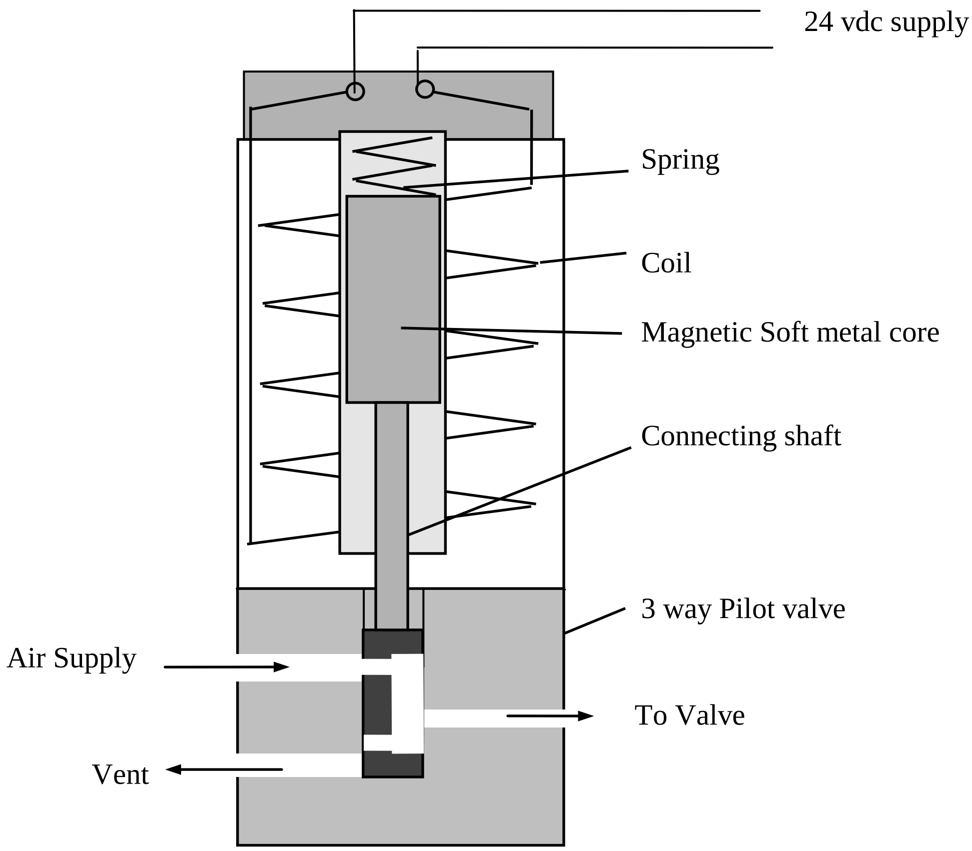


In the above diagrams the set-up shows how the solenoid can be used to switch the air on, or vent it from the shutdown valve. It can be seen that with the solenoid activated the air supply is allowed through to the valve, however when the activation voltage is removed the valve supply air is switched off, thus allowing the excess to be vented back via the solenoid to atmosphere, using the spring in the valve to assist with the air fail action, therefore in normal operating mode the air supply for the valve must be able to overcome the spring tension, and so the solenoid must be capable of handling at least 50 psi.

In terms of response they can move from fully open to fully closed in a split second, therefore giving some shutdown valves the ability to close in under 0.2 of a second*.*

9.61 Solenoid valves operation.

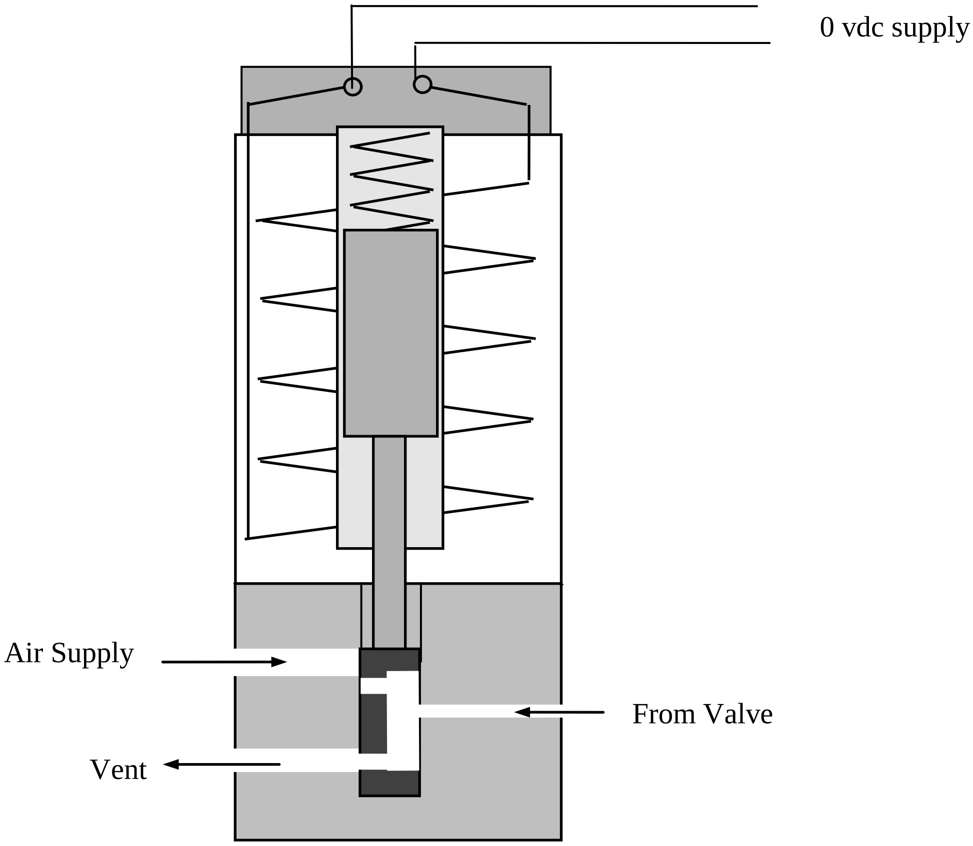
As mentioned previously, the solenoid can be described as an *electrically operated pneumatic switch,* in terms of response they can move from fully open to fully closed in under 0.2 of 1 second*.* They can be either *3 Port* or *5 Port* operation, the term port is used to describe the inlet and outlet connections. The next diagram shows the basic components of a simple 3 port solenoid valve:-



From the above diagram, the basic solenoid consists of a coil, soft metal core connected to a 3 way pilot valve.

In the above energised state, 24vdc is applied to the coil, the electromagnetic field created is sufficient to move the soft metal core against the resistance of the spring, thus via the connecting shaft open the 3 way pilot valve so that the air supply can now pass through the solenoid and on to the valve, and at the same time blocking the vent exit so that there is no excess air escaping.

The operation of the solenoid can often be detected by a clunk noise as the valve switches position when the supply is switched on or turned off. Solenoids can exhibit a small degree of deadband when resetting or returning the supply signal slowly back to zero volts, this can be found on the test bench by connecting the solenoid up for test and reducing the supply voltage slowly, generally this should have no effect on the operation of the device, but is worth being mindful of when testing.



The previous diagram shows the solenoid in its de-energised state. The small spring is used to force the metal core to its original position, with this movement happening in micro-seconds. The supply is now blocked off, whilst the air to the valve is allowed to backtrack through the solenoid and via the vent to atmosphere.

It is important therefore for the solenoid to function correctly it must be wired correctly, and also the pneumatic connections must also be the correct way round. A common fault is when they are piped incorrectly that the air is not allowed to vent thus preventing air fail action to take place.

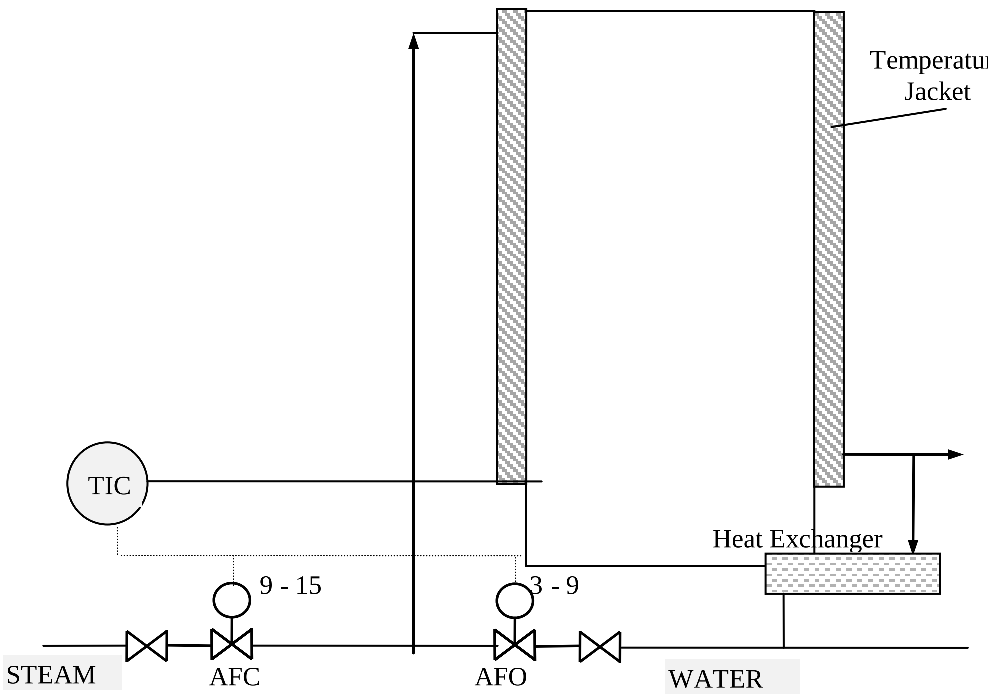
9.62 Solenoid valve maintenance.

Probably the most common fault with solenoid valves is when they stick or jam in position, with the second major fault being that the coil fails. When these faults occur is possible to clean the 3 way pilot valve assembly, this can involve replacement of o-rings, alternatively the area around the coil can become clogged and may require cleaning. Should a failed coil be detected this normally will require replacement. Connecting the solenoid up both electrically and pneumatically, then switching the supply voltage on and off should be sufficient to highlight faults if they are present, a clunk should be heard or the air venting to denote successful operation.

9.7 Split range control valve arrangements.

The term Split ranging is applied when the output of a single controller is split between 2 control valves, where the first operates from 3 - 9psi (fully open to fully closed) and the second operates 9 -15psi (fully closed to fully open).

A typical application of this is in temperature control systems which blend steam and water to create the desired temperature in the process vessel, this technique can be particularly useful in reactions where heat is produced and lost, and needs to be accurately controlled.



In the above diagram, the water valve would be open at 3 psi and closed at 9 psi, while the steam valve would start to open at 9 (from closed), and be fully open at 15psi. The effect would be maximum cooling at minimum signal and maximum heating at full. The temperature control system would measure the reactor contents temperature, and use the steam/water blend in the jacket to control the contents temperature by adding heat or cooling. In the event of an emergency, or air failure, the steam valve would be closed fully and the water valve would be opened fully. Allowing the heating process to continue would have the addition problem of creating pressure build up.