EQUIPMENT

COCK VALVES AND CHECK VALVES

TRAINING MANUAL
Course EXP-PR-EQ050
Revision 0.1

EQUIPMENT

COCK VALVES AND CHECK VALVES

CONTENTS

1. OBJECTIVES

2. FUNCTIONS OF COCK VALVES

Cock valves are all the devices installed on pipelines and which modify or stop the flow of fluids.

These devices have a **CLOSURE ELEMENT** which is operated either manually or by an on/off **ACTUATOR.**

3. THE DIFFERENT TYPES OF COCKS

3.1. INTRODUCTION

There are several different types of valves and cocks:

- Stop valves
- Check or non-return valves
- Safety and relief valves
- Bleed valves (also called purge or drain valves)

Relief and bleed valves are not covered in this training course.

The type of valve used will depend on:

- The flow control required
- The type of fluid conveyed
- The operating conditions
- Isolation and availability

3.2. STOP VALVES (also called stopcocks and gate valves)

Of the various types of stop valves, we make the distinction between:

- Gate valves
- Globe valves
- Butterfly valves
- Plug valves
- Piston valves
- Diaphragm valves

3.2.1. Gate valves

There are several types of gate valves:

- Straight-through gate valves
- Taper-wedge gate valves
- Parallel seat gate valves
- Flexible wedge gate valves

3.2.1.1. Straight-through gate valves

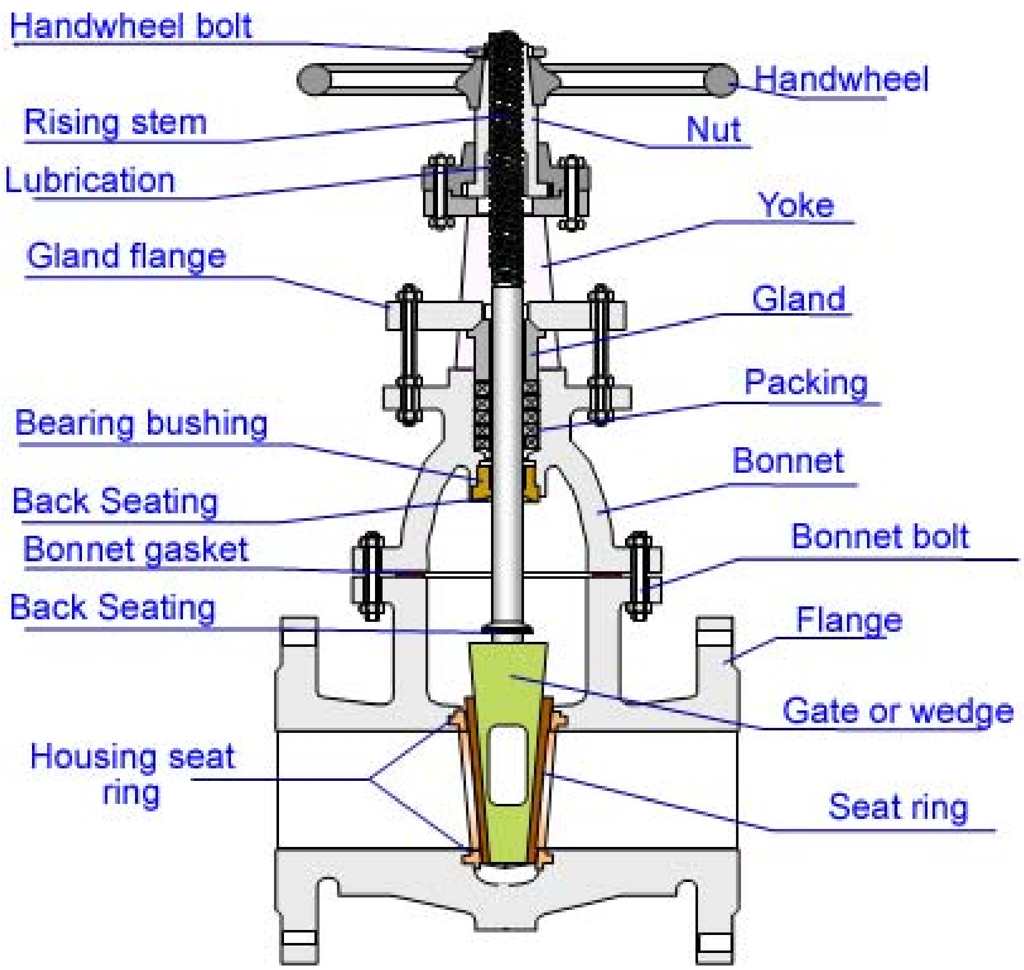


Figure 1: Component parts of a gate valve

Straight-through gate valves have the following features:

- The closure element moves parallel to the seat.
- The valve stem moves vertically – it does not rotate
- There is a relationship between the stem length and the closure element diameter
- Good sealing
- Low pressure drop

3.2.1.2. Taper-wedge gate valves

- Made of the same material as straight-through gate valves
- Tapered contact faces with an incline > 33%.
- Zero leakage when tightly closed by wedging or by differential pressure.
- Avoids too high a force being required on the handwheel when opening the valve.
- Closure element extremely rigid.

Disadvantages:

Not suitable if the fluid pressure and / temperature or the external forces can cause mechanical distortion.

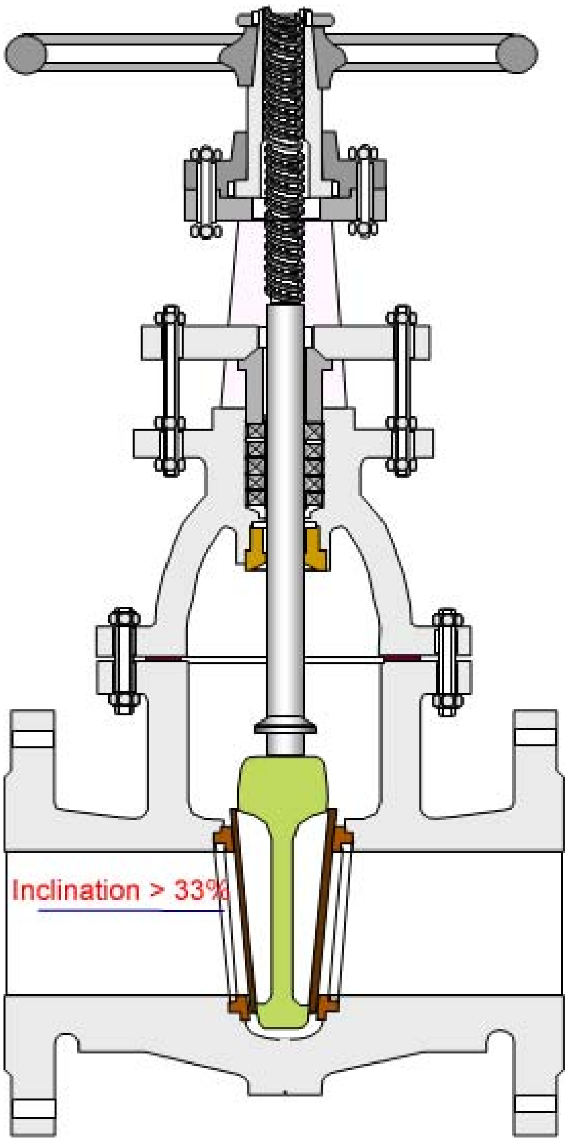


Figure 2: Taper-wedge gate valve

3.2.1.3. Expanding parallel seat gate valves

- Used in High Pressure Water and Steam systems.
- Closure element consists of 2 flat discs held apart by a spring, which maintains them pushed against the two parallel seats.
- The sealing is achieved by the spring force and the fluid pressure.

A stop ring helps obtain precise positioning relative to the seat.

Disadvantages:

The closure elements remain in contact with the seats during opening and closing, therefore the contact surfaces wear rapidly.

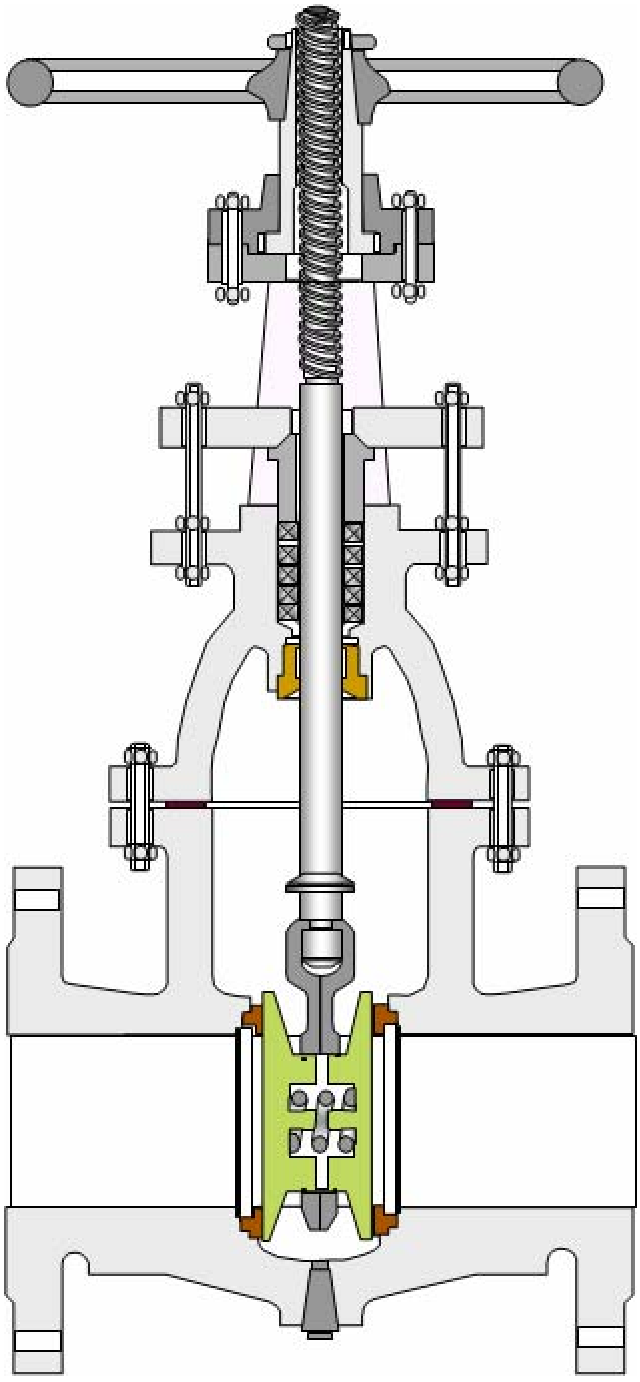
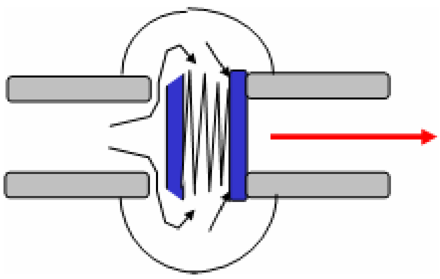


Figure 3: Parallel seat gate valve



Fluid action during pressure build-up

3.2.1.4. Self-tightening Gate Valves

- The closure element consists of two independent discs which, in closed position, are held tightly against the seat by one or more wedges.
- The specially-shaped wedge forces the discs apart when it comes into contact with the bottom of the valve body.
- Easy to open.
- Used for low-pressure saturated steam.

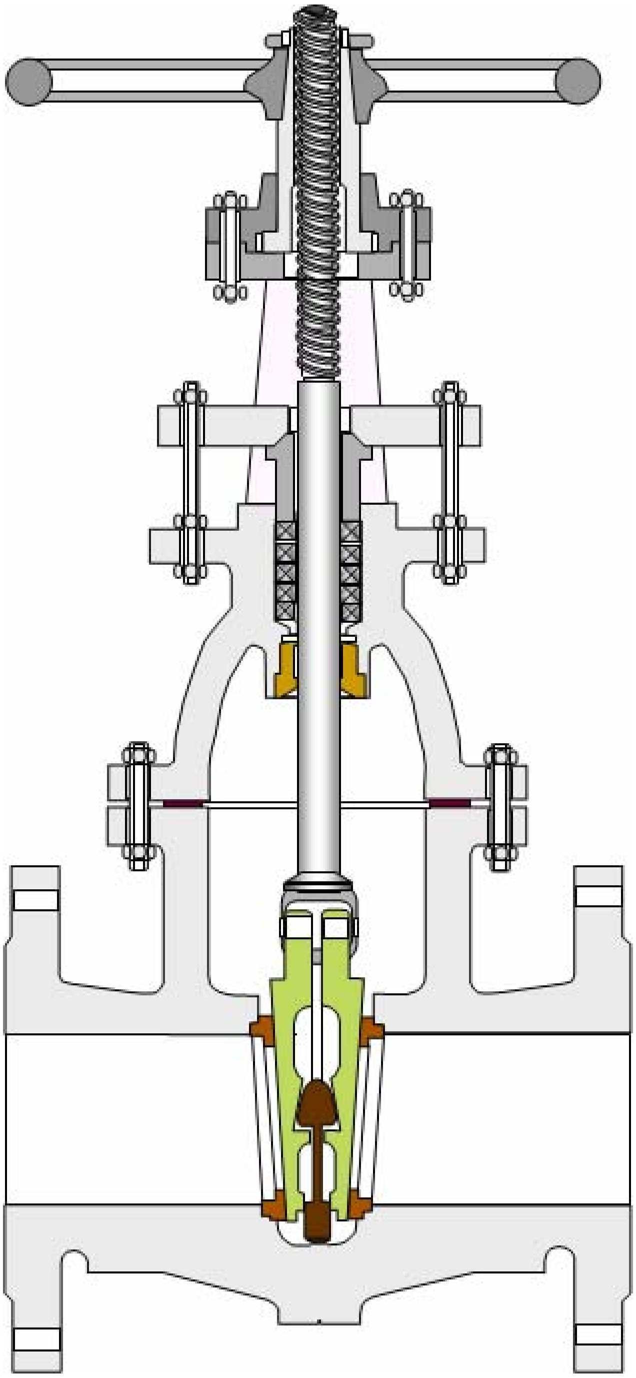


Figure 4: Self-tightening gate valve

Comment: Cock valves do not have to be installed in any particular direction with respect to the fluid flow.

3.2.2. Globe valves or (disc and plug valves)

Globe valves are used mainly for flow control. Some can be used for fluid shutoff.

The disc moves:

- Parallel to the fluid
- Perpendicular to the seat

There are several types of globe valves:

- Flat disc
- Taper plug
- Needle plug
- Parabolic plug
- Flat and taper plug
- Seat generally inclined by 45°

3.2.2.1. Flat disc globe valve

Flat disc globe valves are used for steam when good sealing is required.

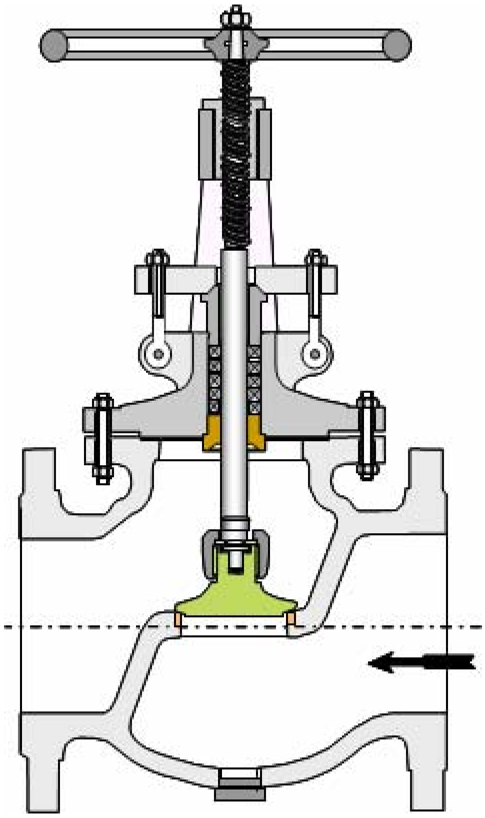


Figure 5: Flat disc globe valve

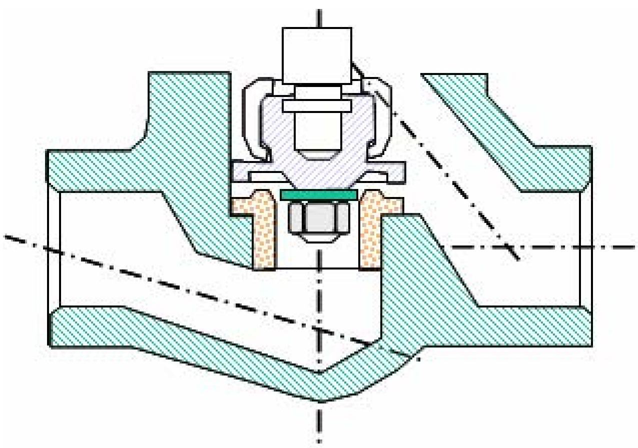


Figure 6: Flat disc

3.2.2.2. Taper plug globe valve

- The closure element called a **disc** or **plug** moves perpendicularly to the seat.
- It can be used in any position between Fully Open and Fully Closed, thus allowing the flow rate to be controlled.
- **Suitable for flow control** but **unsuitable for fluid shutoff,** after prolonged used as they do not provide total sealing.
- Their opening is generally assisted by the movement of the fluid; closing is in the opposite direction to the flow, therefore the **direction of assembly must be correct.**
- Fixed stem nut on the bonnet.
- The stem and handwheel move up or down when the valve is opened or closed.
- For small valves, the plug is very tapered, the valves are then called **needle valves.**

The taper plug globe valve can be used both for fluid shutoff and control.

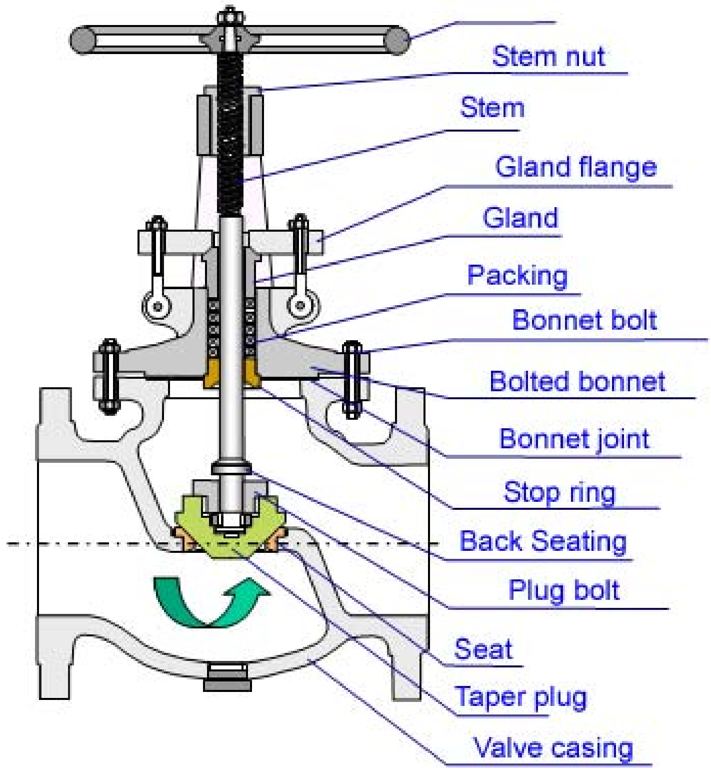


Figure 7: Taper plug globe valve

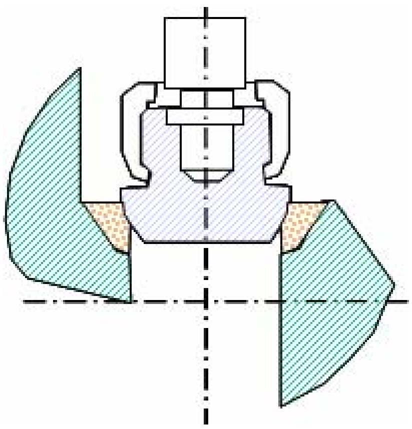


Figure 8: Taper plug

3.2.2.3. Needle and parabolic plug globe valves

The needle plug globe valves (also called needle valves).
These valves are used to control flow rate.

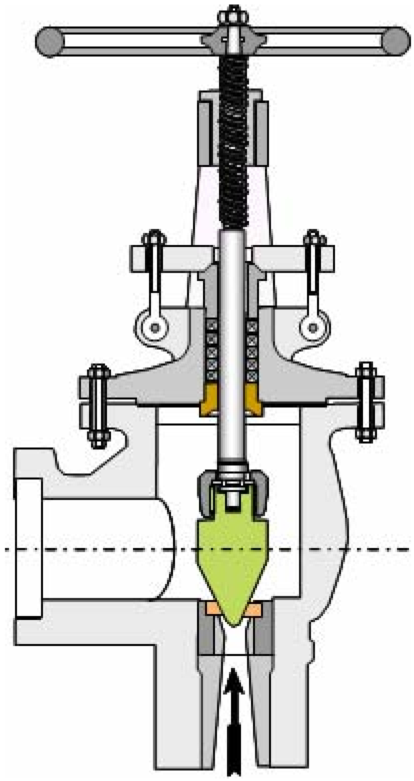


Figure 9: Needle plug globe valve

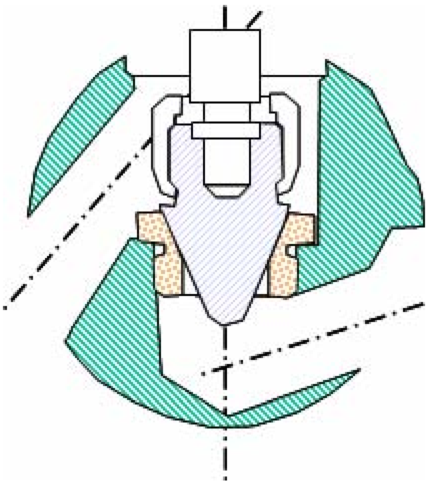


Figure 10: Needle plug

3.2.2.4. Flat and taper plug globe valve

Flat and taper plug globe valves are used for steam.

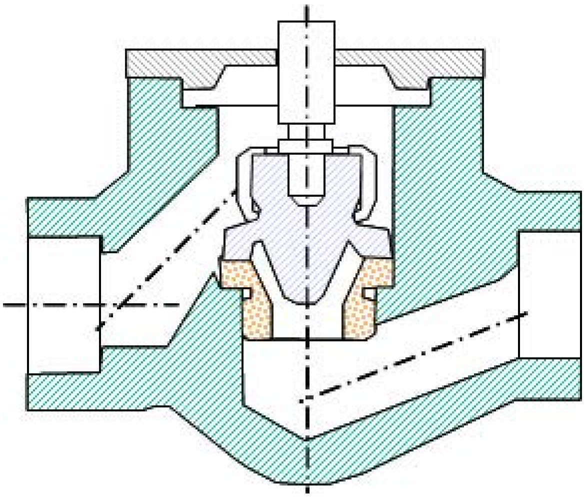


Figure 11: Flat and taper plug globe valve

3.2.2.5. Slanted seat globe valve

The pressure drop in the valve is lower since the fluid flows over baffles in the valve body, if it is used for isolation instead of a straight through valve.

It is used to control flowrate with heavily charged fluids as it is less sensitive to deposits.

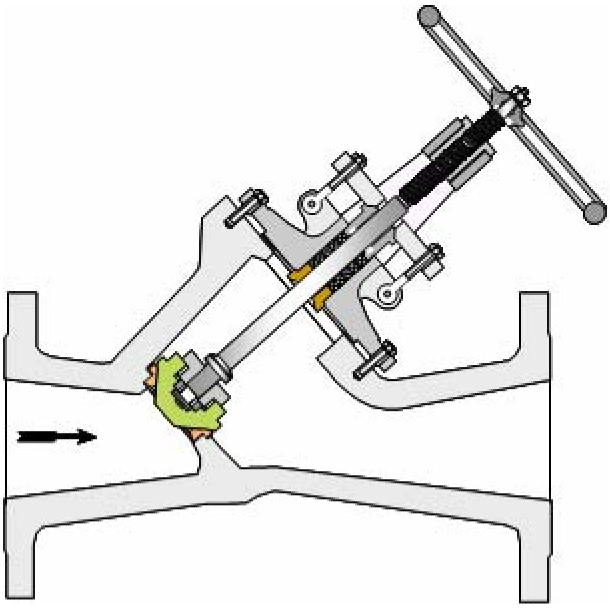


Figure 12: Slanted seat globe valve

3.2.3. Butterfly valves

The closure element is an oval disc which rotates perpendicularly to the fluid flow direction.

Small diameter valves are directly operated by a square-end shaft, the operation of the large diameters is facilitated by a reduction gear. These valves can also be motorised.

They are installed between two flanges and themselves have flanges.

Advantages of butterfly valves:

- Low pressure drop: The fluid does not change direction.
- Safe and easy to operate - Small size and weight.
- Easy to install - Can be adjusted and locked.
- Can be used for isolation and flow control
- Satisfactory sealing, for Pressures < 10 b and Temperatures < 120°C.

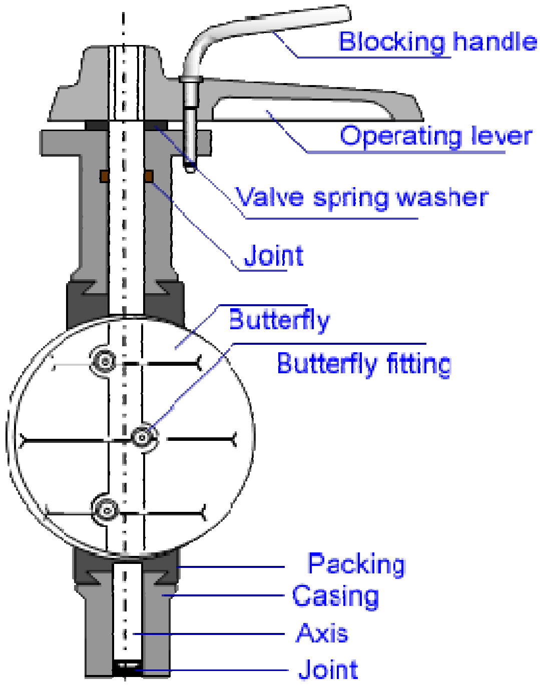
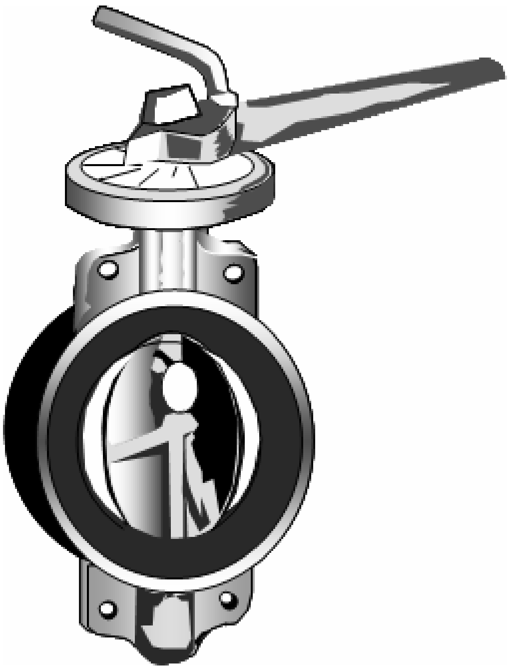


Figure 13: Component parts of a butterfly valve



There are two types of butterfly valves:

- Non-leakproof butterfly valves
- Leakproof butterfly valves

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Figure 14: Butterfly valve

3.2.3.1. Non-leakproof butterfly valves

There is a metal-metal contact between the closure element and the seat.

They are only used for flow control and are unsuitable for fluid shutoff.

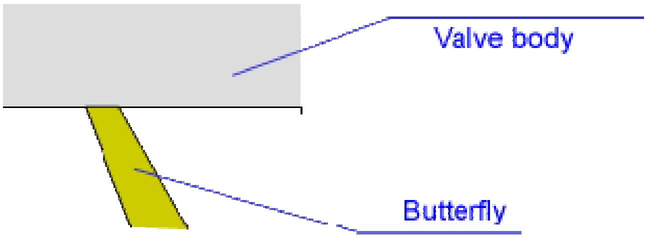
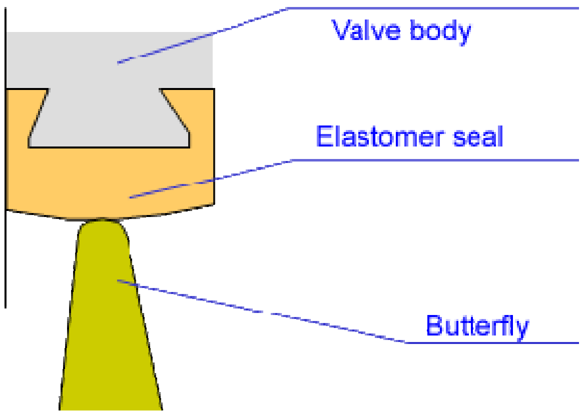


Figure 15: Non-leakproof butterfly valve sealing

3.2.3.2. Leakproof butterfly valves



The sealing is obtained by elastomer-metal contact. The elastomer seal is fixed either to the butterfly or to the valve body.

They are unsuitable for flow control (destroy the packing).

If the seal is fixed to the valve body, it also protects the body against corrosion.

Figure 16: Leakproof butterfly valve (1)

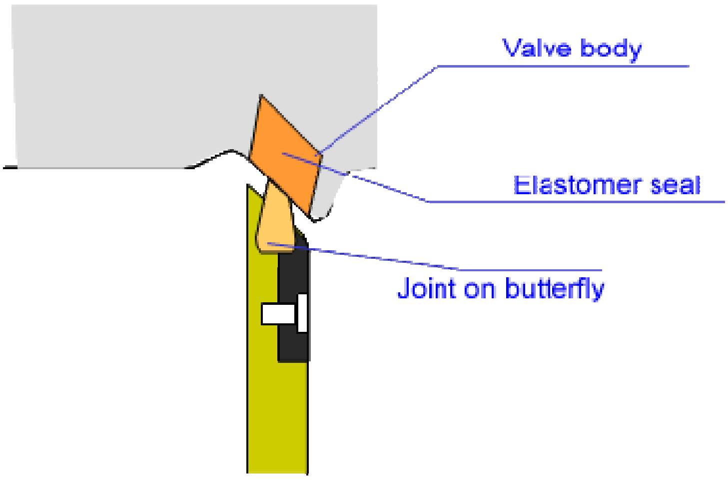


Figure 17: Leakproof butterfly valve (2)

3.2.4. Plug valves

Plug valves (also called **rotary or plug-cock valves**) consist of a valve body and a closure element.

The closure element **rotates** perpendicularly to the fluid flow direction, and is called a **plug.**

The valve body and the plug have ports which:

- line up when the valve is open
- do not line up when the valve is closed.

The name of the plug depends on its shape. The various types are:

- **Spherical plug** valves (ball valves)
- **Cylindrical plug** valves with rectangular plug port
- **Standard taper plug** valves with trapezoidal plug ports and the small end of the truncated cone at the bottom
- **Reverse taper plug** valves with trapezoidal plug ports and the small end of the truncated cone at the top

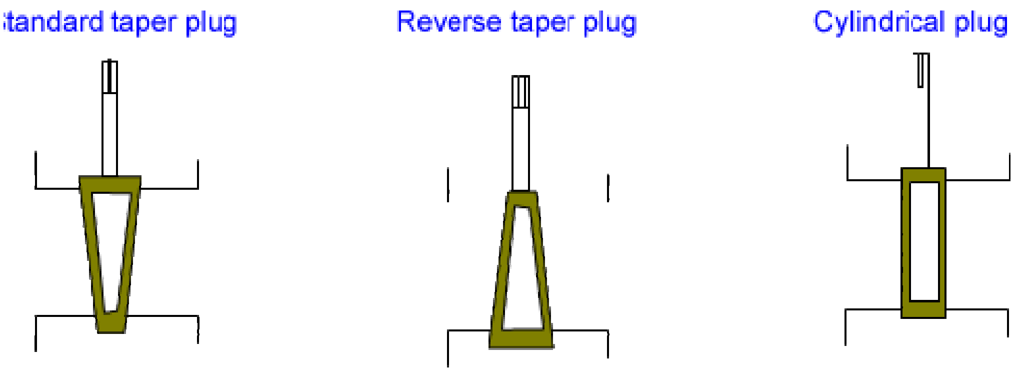


Figure 18: Plugs and ports

They are used for:

- **light hydrocarbons**
- **viscous hydrocarbons**
- **gases**
- **many corrosive products.**

Cylindrical and taper plug valves are **exclusively used as stop valves**.

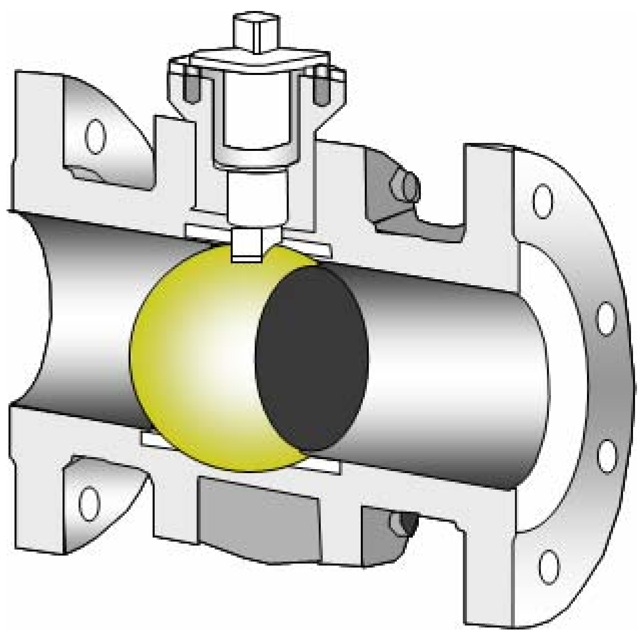
Spherical plug valves can also be used exceptionally for flow control, according to the process.

The pressure drops for plug valves are generally low and disappear when the valve is fully open.

Disadvantages:

- Lack of visual indication of opening and closing.
- Requires lubricated plugs for perfect sealing, except for spherical rotating plugs.

3.2.4.1. Spherical plug valves (ball valves)



The plug is spherical and the plug port is circular.

This type of valve increasingly tends to replace cylindrical and taper plug valves.

Figure 19: Spherical plug valve

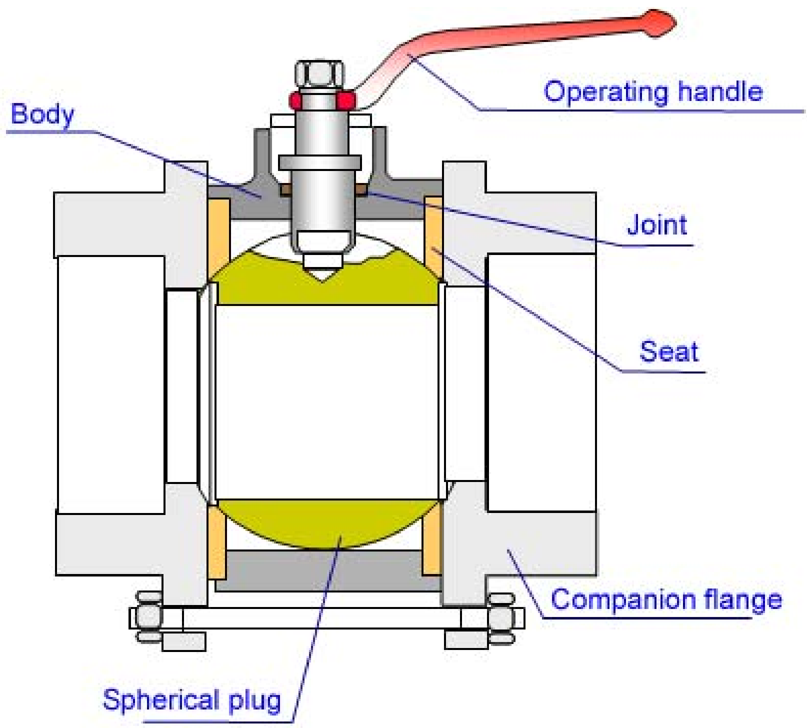
The valve is operated by a quarter-turn lever up to a 4" diameter, and by a reduction gear for larger valves.

Diam. > 2": Connected to pipes by flanges (Sometimes fitted between flanges.)

Diam. < 2": Screw-on unions required.

They are suitable for use as stop valves and exceptionally for flow control and they are greatly used for fuel gas systems feeding furnace burners.

Figure 20: Component parts of a spherical plug valve



3.2.4.2. Standard taper plug valve

The **Diaphragm** prevents the packing from being damaged by the rotation of the plug. It is clamped between the valve body and the bonnet and is an efficient seal against leaks to the exterior.

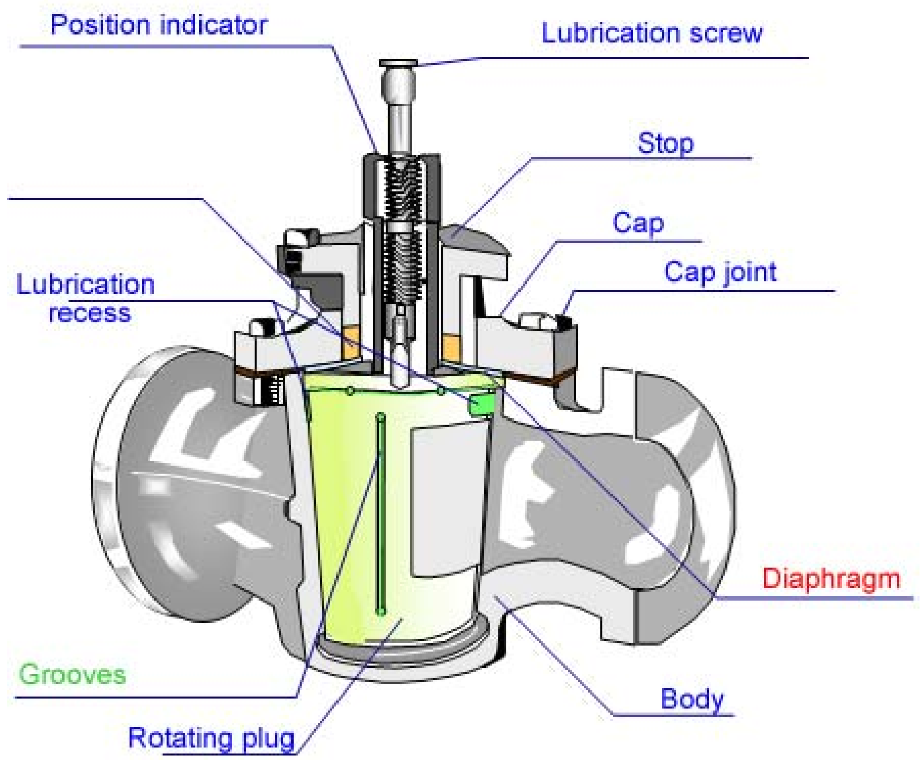


Figure 21: Standard taper plug valve

The **Slots** on the plug and **recesses** in the valve body are for lubrication, so that when a groove passes the port during rotation it is isolated from the pressure lubrication system, thus resulting in low grease loss when the valve is operated.

3.2.4.3. Reverse taper plug valve

Reverse taper plug valves are used for:

- Compressed air
- Inert gases
- Clean liquids.

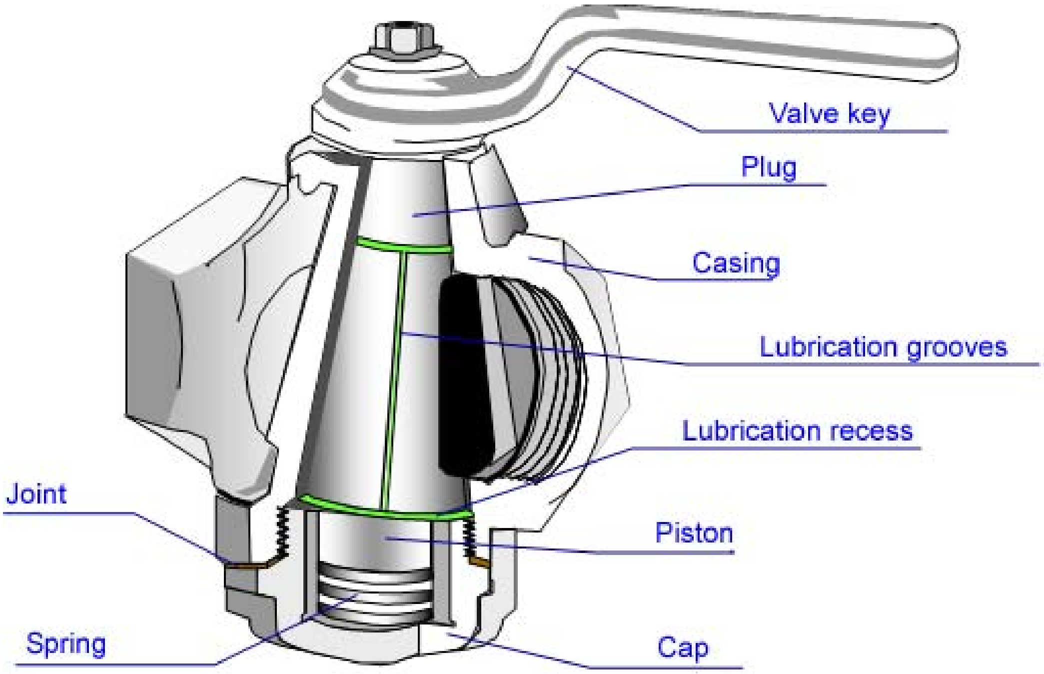


Figure 22: Reverse taper plug valve

They have a reservoir of grease which is pressurised by a piston and a spring and is sufficient for several thousand operations.

They are used for diameters ND 15 to ND 50 and pressures < 7 bars.

3.2.4.4. Piston valves

Feature: Seatless, they are similar in design to globe valves.

The closure element is a **cylindrical piston** which moves perpendicularly to the fluid flow direction.

The valve body is made of cast steel, the **piston** is made of stainless steel and the **stem** is made of carbon steel.

The **piston** moves in a metal ring drilled with windows, called the **cage,**

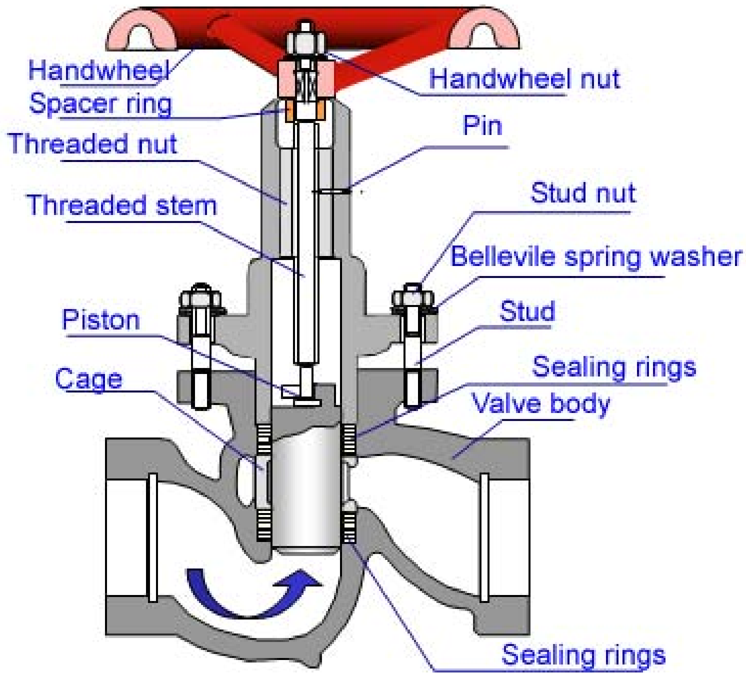


Figure 23: Piston valve in closed position

By masking these windows to a greater or lesser extent, the piston controls the flow rate.

The **sealing** is provided by interchangeable sealing rings on either side of the cage.

***"Belleville"* spring washers** are placed under the stud nuts to **compensate for the stud expansion** due to the fluid temperature.

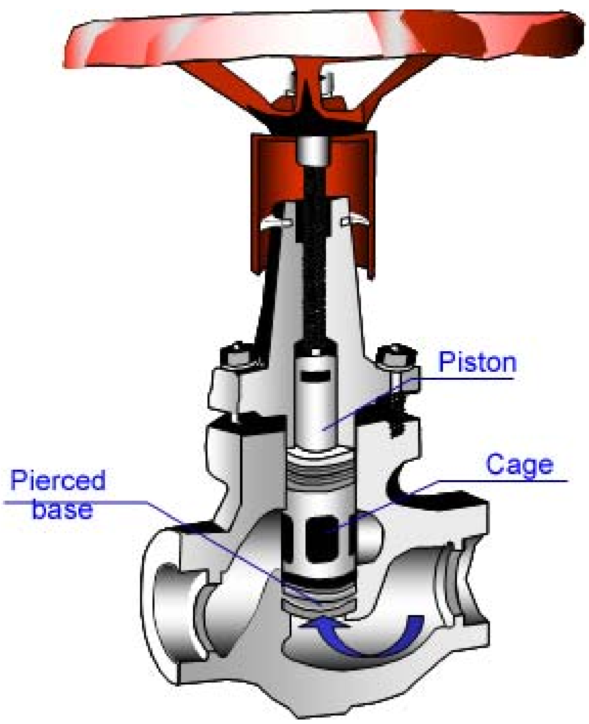


Figure 24: Piston valve in open position

Tightening the stud nuts compresses the sealing rings against the wall of their housing, and against the piston, which provides good sealing;

They provide good sealing and are suitable for use as stop valves.

3.2.4.5. Diaphragm valves

The closure element is a flexible diaphragm inserted between the body and the bonnet of the valve.

The valve is closed by this diaphragm bearing on the seat.

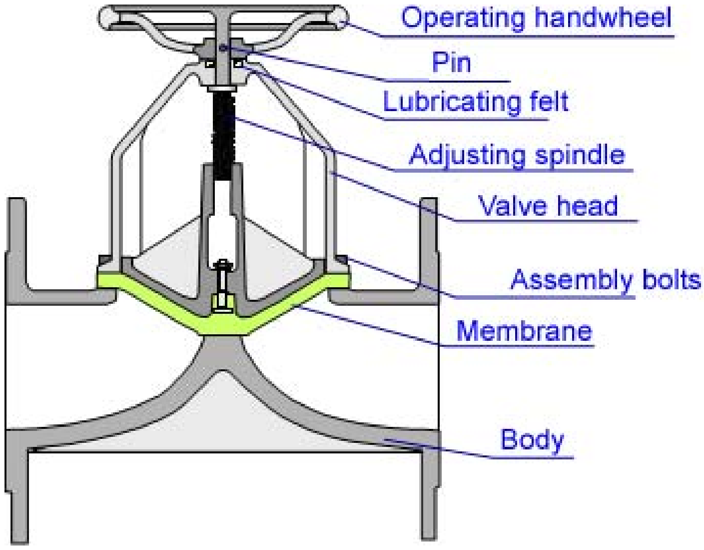
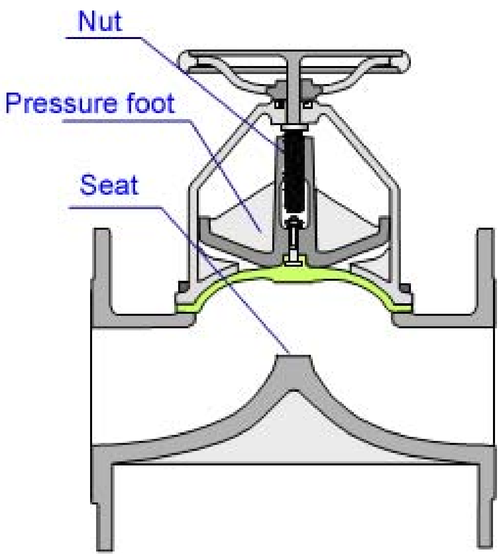


Figure 25: Diaphragm valve in closed position

The bearing pressure is due to the distortion of the diaphragm pushed by a pressure foot, under the action of the control stem. These valves can also be equipped with a pneumatic actuator.

Advantages:



- The mechanism is isolated from the product and there is no stuffing box.
- Seizing impossible.
- Low pressure drop.
- Good sealing, therefore suitable for fluid shutoff.
- Are used with corrosive products, muds, at low pressures and temperatures.

Figure 26: Diaphragm valve in open position

3.2.4.6. Gauge cock valves

These are globe valves, but are designed with a housing for a ball which acts as a plug by bearing on the seat.

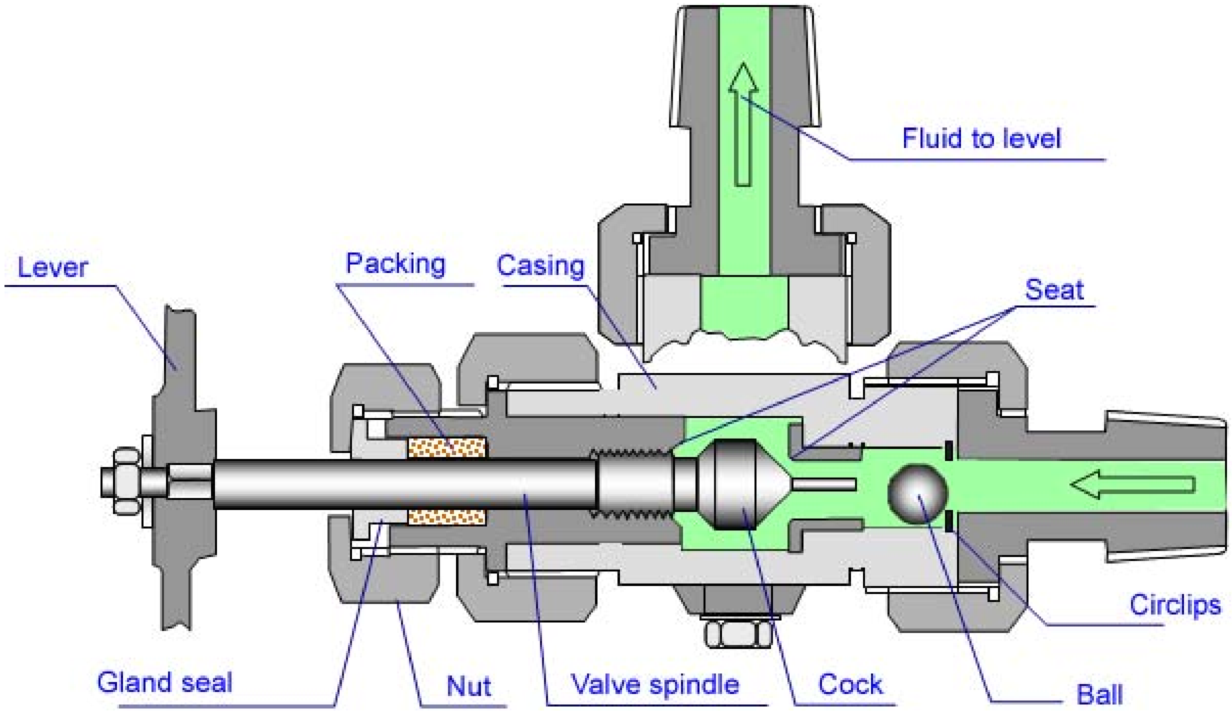
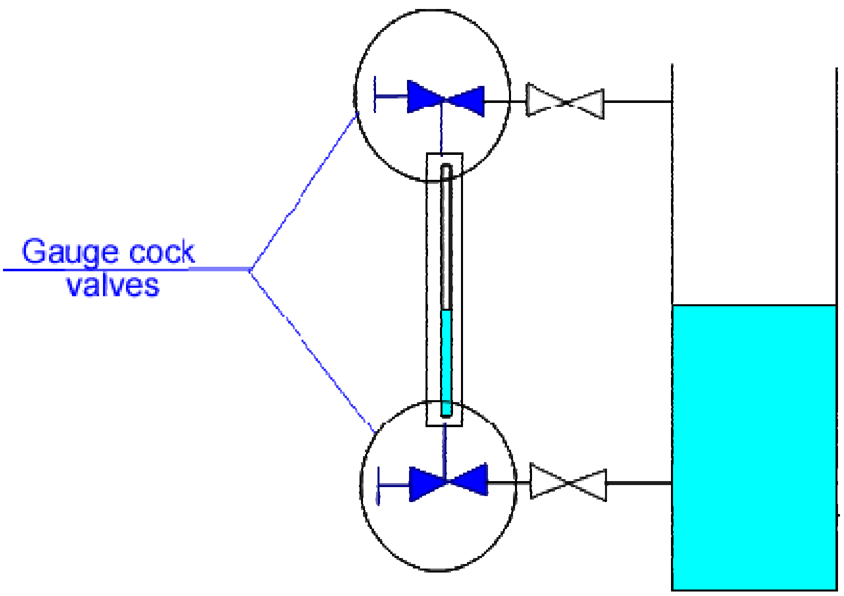


Figure 27: Lower gauge cock valve



These valves are installed in pairs on each gauge, perpendicularly to the tank and as perfectly level as possible.

Figure 28: Gauge cock valve assembly principle

Gauge cock valve in closed position:

- The front of the plug is bearing on the seat and isolates the gauge from the tank.
- The gauge can be drained.
- The ball is pushed on its seat by the stem.
- P1 = 0 (atmospheric pressure)

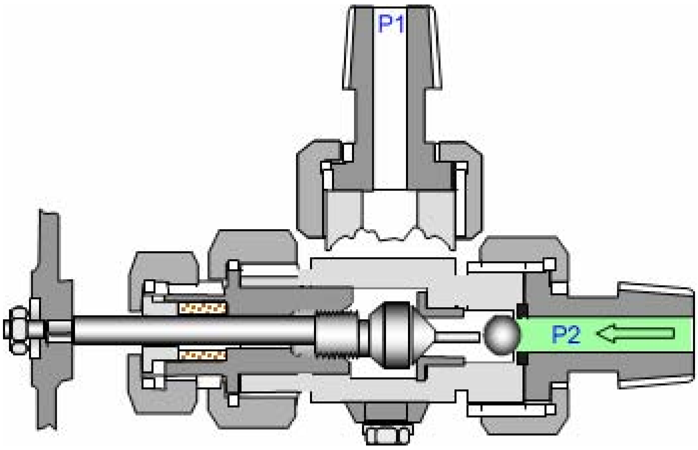


Figure 29: Gauge in closed position

Putting the gauge into service:

- The valve is closed.
- Open the valve a quarter turn.
- The plug moves away from its seat, the stem maintains the ball away from its seat.
- Top valve: the gas enters the gauge.
- P1 = P2, fully open the valve.
- Bottom valve: the liquid enters the gauge.
- When the level is stabilised, fully open the valve.

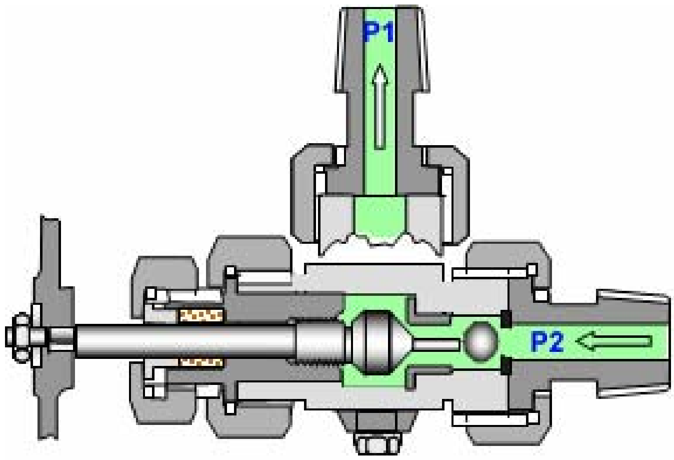


Figure 30: Putting the gauge into service

Normal operation of the gauge:

- The valve is fully open and the rear of the plug is pressed against a seat.
- Pressures P1 and P2 are balanced, therefore the ball lies at the bottom of its housing.
- The liquid in the tank communicates with the liquid in the gauge and each variation will be visible on the gauge.

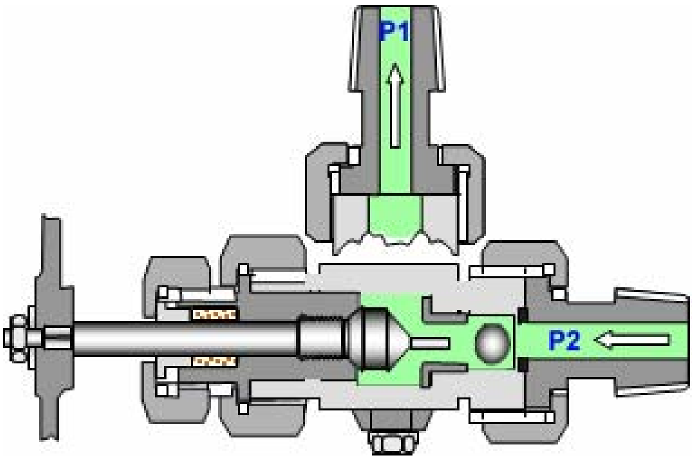


Figure 31: Gauge normal operation

Fail-safe position in case the gauge glass breaks

- The valve is fully open.
- The rear of the plug is bearing on the seat.
- The liquid empties out of the gauge.
- The tank is full of liquid which exerts a pressure P2 > P1 and thus forces the ball onto the seat and creates the seal.

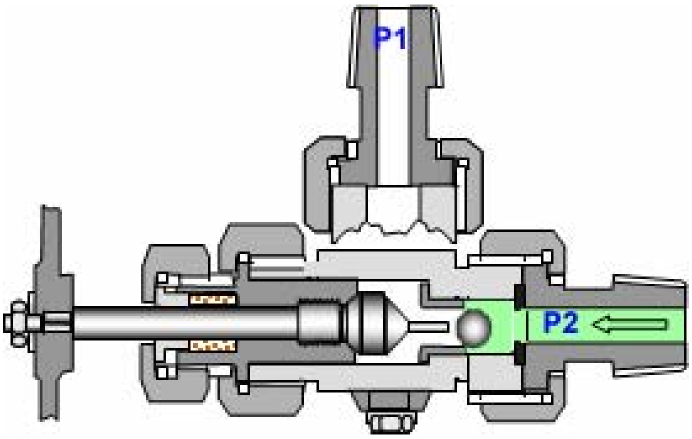


Figure 32: Fail-safe position in case the gauge glass breaks

	Closure element movement	Stem movement	Suitable for	Equipment	Connections	Pressure drop	Remarks
Gate valve	Perpendicular to the fluid	Fixed rotation Free translation	Stop valves	Back-seating	<2" screwed or welded >2" Flanges	Very low	General service, unsuitable for control
Globe valve	Parallel to the fluid	Integral stem and handwheel	Control, unsuitable for fluid shutoff	Back-seating	<2" screwed or welded >2" Flanges	Fairly high	Respect the direction of assembly
Butterfly valve	Perpendicular rotation	Quarter turn	Control and stop valves		Flanged or between flanges	Low	Sealing limits 10 b and 120°C
Plug valve	Perpendicular rotation	Quarter turn	Stop and control valves	Lubrication system	Flanged or between flanges	Very low	
Piston valve	Perpendicular to the fluid	Integral stem and handwheel	Stop and control valves		Flanges	Low	Assembly direction
Diaphragm valve	Pressure by diaphragm	Integral stem and handwheel	Stop valves		Flanges	Low	Limited in pressure and temperature
Orbit valve	Spherical closure element moves apart then rotates	Guided translation and rotation	Stop valves		Flanges	Very low	Assembly direction
Goodwin valve	Taper closure element moves apart then rotates	Guided translation and rotation	Stop valves	Fuel oil flushing	Flanges	Very low	Assembly direction

Table 1: Summary of the different valves

3.3. CHECK VALVES

Check valves (also called non-return valves) allow a fluid to flow in one direction only.

The fluid no longer flows in the opposite direction.

The different types of check valves are:

- Swing check valve,
- Vertical lift check valve,
- Ball check valve,
- Double-flap swing check valve.

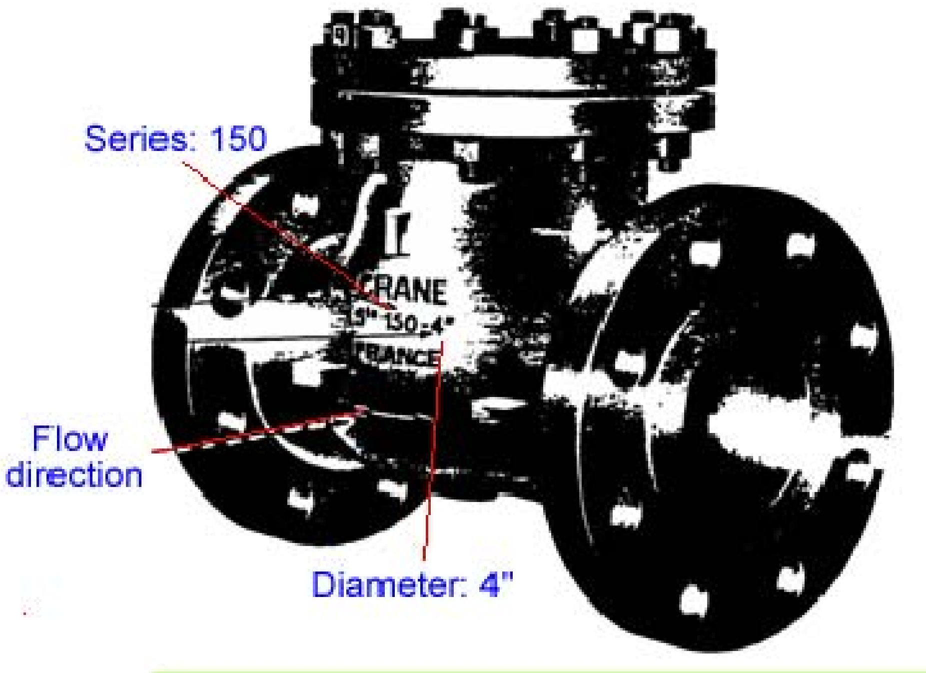


Figure 33: Check valve

3.3.1. Swing check valves

Swing check valves are widely used for liquids.

- They operate by a hinged disc.
- They allow direct flow through the body of the valve.
- They induce low flow resistance to fluid flow.
- They can be installed horizontally or vertically.

1 Body
2 Cap
3 Seat
4 Disc
5 Disc hinge
6 Hinge pin
7 Seal
8 Disc attachment nut
9 Cap bolts

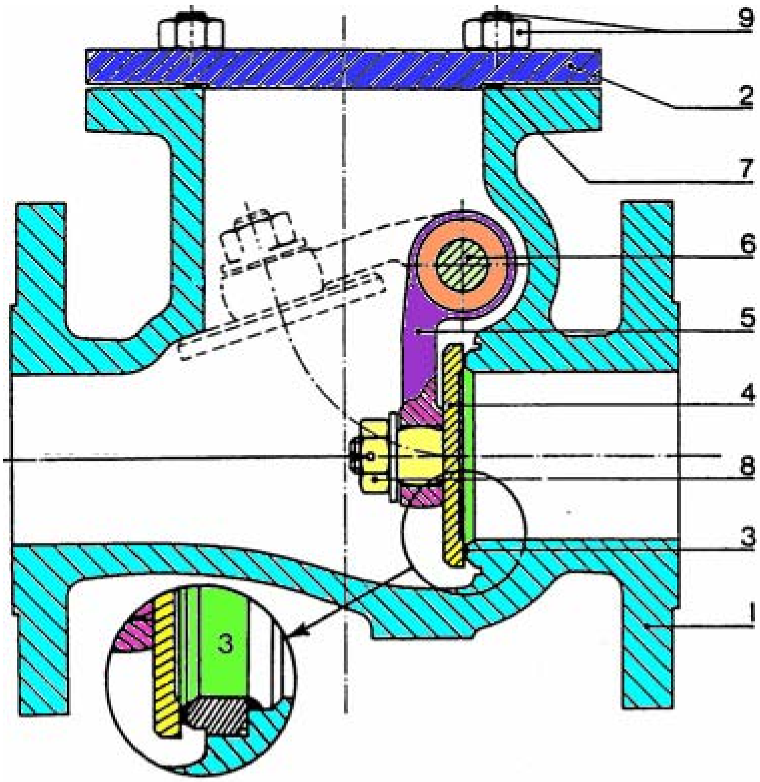


Figure 34: Swing check valve

3.3.2. Piston check valve

Piston check valves comprise a piston or swing which sits on its seat. The piston is guided in the body of the valve.

When fluid passes through the valve body the piston lifts off the seat.

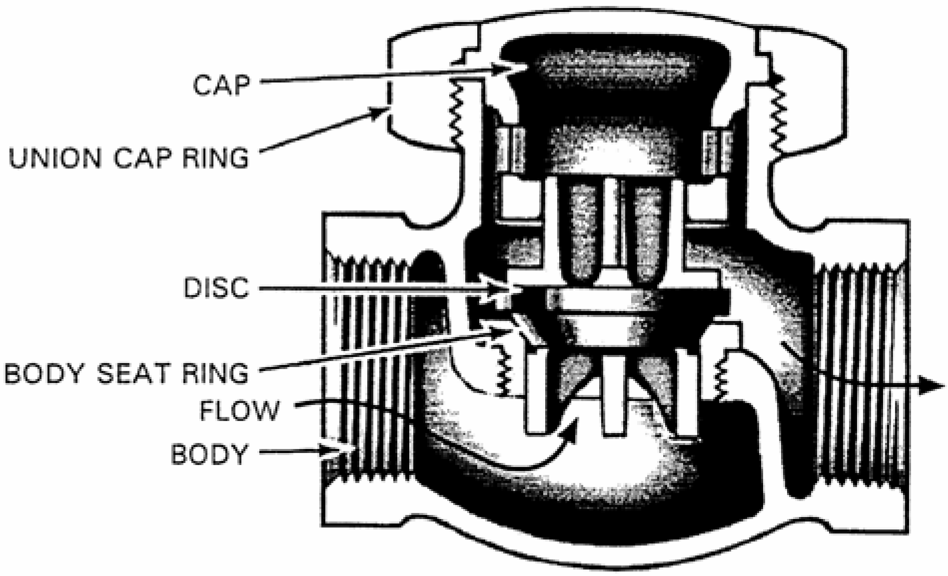


Figure 35: Piston check valve

The reverse flow on the opposite side of the piston forces the piston onto the seat and closes the valve:

The springless system must be installed horizontally; however, a spring-bearing system can be installed vertically.

3.3.3. Ball check valve

The ball check valves work in the same way as piston check valves but use a ball instead of a piston.

They can be used for heavy fluids.

They can be installed horizontally or vertically.

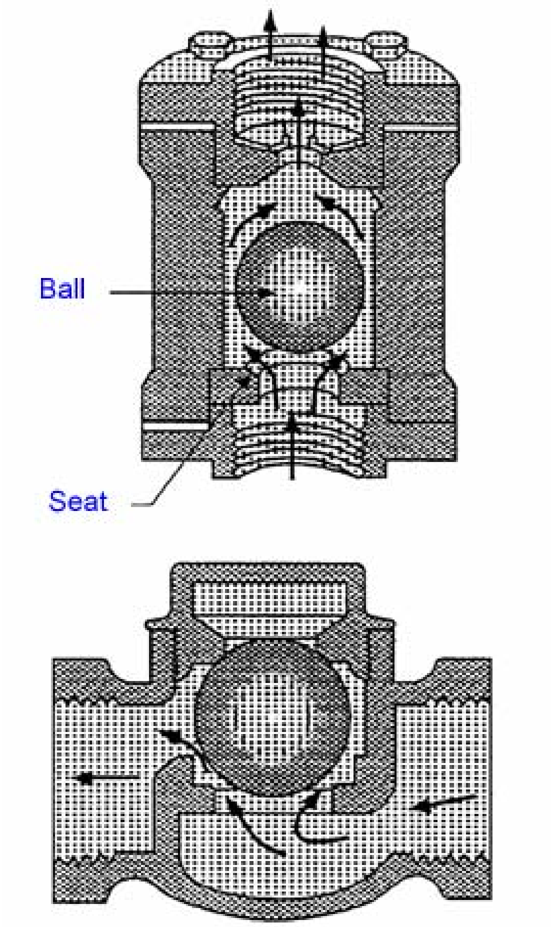


Figure 36: Ball check valve

4. VALVE SELECTION AND OPERATION

4.1. VALVE SELECTION

There are no precise rules for selecting a valve. The type of valve chosen depends on the job to be done.

To shut off or isolate a fluid we use either:

- Gate valves
- Globe valves
- Plug valves
- Leakproof butterfly valves

To control the flow of a fluid, we use either:

- Globe or needle valves.
- Butterfly valves.

Once the type of valve has been selected, we must then consider the operating conditions, which allow us to precisely determine the valve to be used:

- Pressure
- Temperature
- Fluid type and flow rate
- Pressure drop.

The pressure and temperature will dictate:

- the shape of the valve
- the alloys to be used.

The type of fluid (viscosity - chemical characteristics) affects:

- the cross sectional area of the valve bore,
- the sealing,
- the stuffing box
- the construction alloys

4.2. VALVE OPERATION

When opening the valve: Fully open the valve until it is on its stop.

Where the valve is operated by a threaded stem and handwheel, close the valve by a quarter turn to release the thread so that it does not remain blocked open.

When closing the valve: Close the valve using moderate pressure, then open it slightly to allow the fluid flowing between the seat and the plug to clean the contact surfaces. Close the valve.

Shutting off hot products: Close the valve as previously, after rolling the fluid channel between the seat and the plug, to make sure the doors are clean. .
Fully close the valve without forcing and check that the product is cooling down.

A hot valve which is closed too tightly is highly likely to remain permanently seized when cold.

Piston valves: They have no seat. It is **unnecessary to try to lock it shut**. After closing the valve, back off a half turn.

Gate valves and ball valves are fitted with an air safety sealing device called back-seating. This device is used only when the valve is fully open by locking the wheel as far as possible. The device must not be used on a line in service, or to add or replace braids.

4.3. CONCEPT OF VALVE SIZING

To size a valve, we must determine the flow coefficient Cv.

The Cv is a coefficient determined experimentally by the manufacturer for each valve type and size.

It characterises the fluid flow through the valve.

Definition of the flow coefficient Cv

It is the flow of water at 60°F (15.6°C) expressed in US gallons which flows through a fully open valve in 1 minute, creating a pressure drop of 1 psi (70 hPa / 69 mbar) in the valve.

$$Cv = Q\sqrt{\frac{d}{\Delta P}}$$

Q : flow rate in US gallons per minute
d : density
ΔP: pressure drop in psi

$$Cv = 1{,}16.Q\sqrt{\frac{d}{\Delta P}}$$

Q : flow rate in m^3/h
d : density
ΔP: pressure drop in bars

5. VALVE OPERATING SYSTEMS

Various devices are used to facilitate valve operation. Among these, we can mention:

- Chainwheels
- Extension rods
- Angle drives
- Reduction gears
- Pneumatic actuators
- Electric actuators
- Hydraulic actuators

5.1. MANUAL SYSTEMS

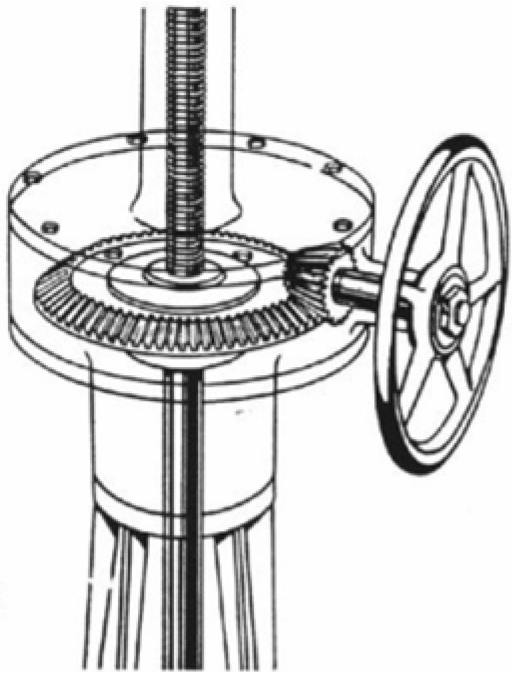
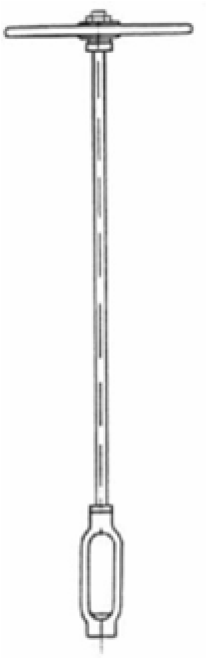


Figure 37: Control by angle drive

Figure 38: Single extension rod



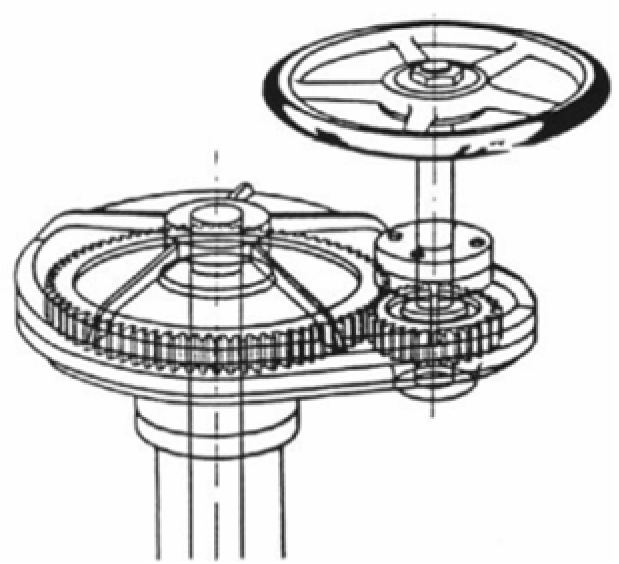
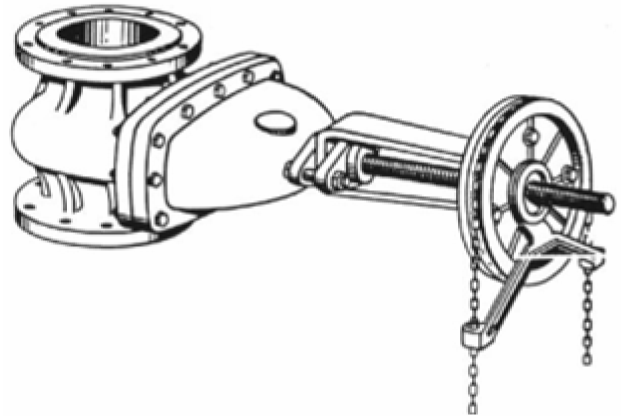


Figure 39: Control by reduction gears

Figure 40: Chain wheel



5.2. AUTOMATIC SYSTEMS

As we saw previously, valves can be operated manually or automatically.

An automatic valve consists of two different parts:

- The actuator
- The valve body

This drawing shows the different parts of the ACTUATOR and the valve body.

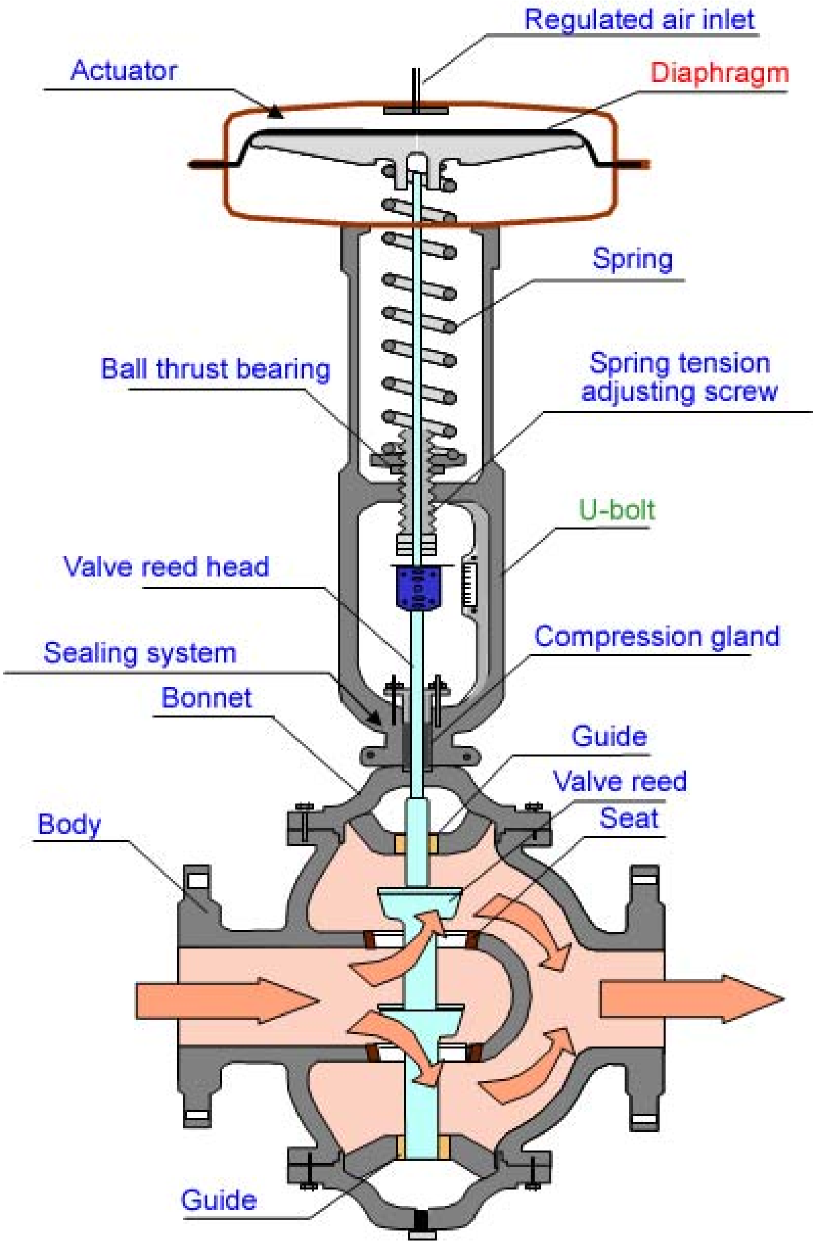


Figure 41: Different parts of an automatic valve

5.2.1. Operation of an automatic valve

On one side we have the **force due to the pressure** in the actuator (modulated pressure from the controller). It is proportional to the air pressure and the cross sectional area of the diaphragm.

On the other side we have the **force due the spring compression,** which is greater when the spring is compressed.

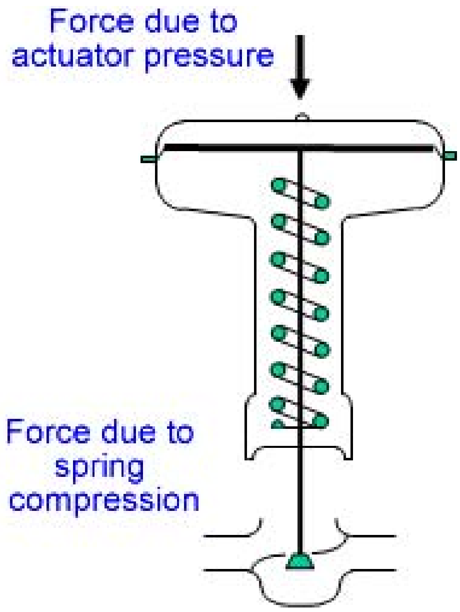


Figure 42: Forces in an automatic valve

For a given air pressure in the actuator, the spring contracts by a length such that the **resultant force** (proportional to the shortening of the spring) is equal to the corresponding driving force.

For each pressure value, the displacement of the diaphragm is transmitted by the stem to the valve whose travel is thus proportional to the air pressure on the diaphragm.

The flow variation in the valve depends on the opening (or travel), expressed in percent, and can be represented by a curve which is the valve's "Flow Characteristic".

<u>There are 3 main types of Flow Characteristics</u>:

- **Linear,** if the flow rate varies proportionally to the valve travel
- **Equal percentage,** if a same variation in travel gives a same percentage increase in flow rate.
- **Quick opening**, the use of a disc allows the valve to be fully opened very fast. Discs are generally used in safety valves.

5.2.2. Piston actuators

Piston actuators operate at much higher pressures than diaphragm actuators.

These pneumatic or hydraulic pressures can be several tens of bars.

They can develop much higher forces and longer travels and can compensate for very high pressure drops through the valve body.

Safety valves use:

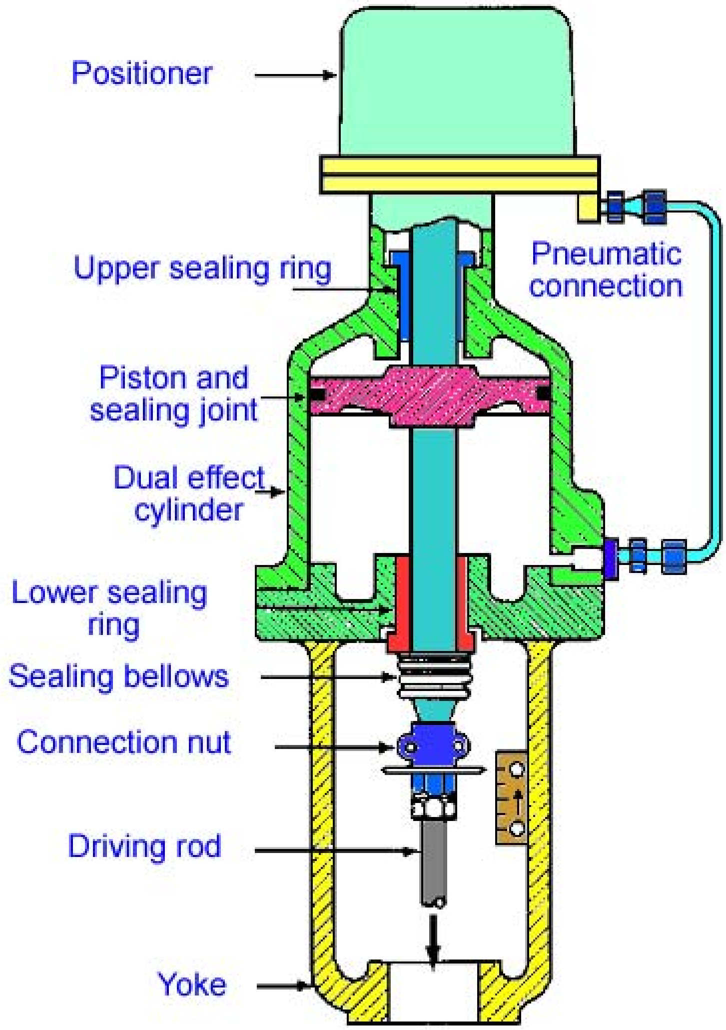
- single-acting pistons with a return spring allowing the desired fail-safe position to be obtained.

- double-acting pistons with hydraulic accumulator or pneumatic reservoir, which are used during a pressure failure to return the valve to its fail-safe position.

Control valves generally use double-acting pistons with a positioner.

Without the return spring, no fail-safe position is possible.

Figure 43: Piston actuator



5.2.3. Pneumatic actuator

Pneumatic actuators can be used on control valves since they can control all the valve's positions between fully open and fully closed.

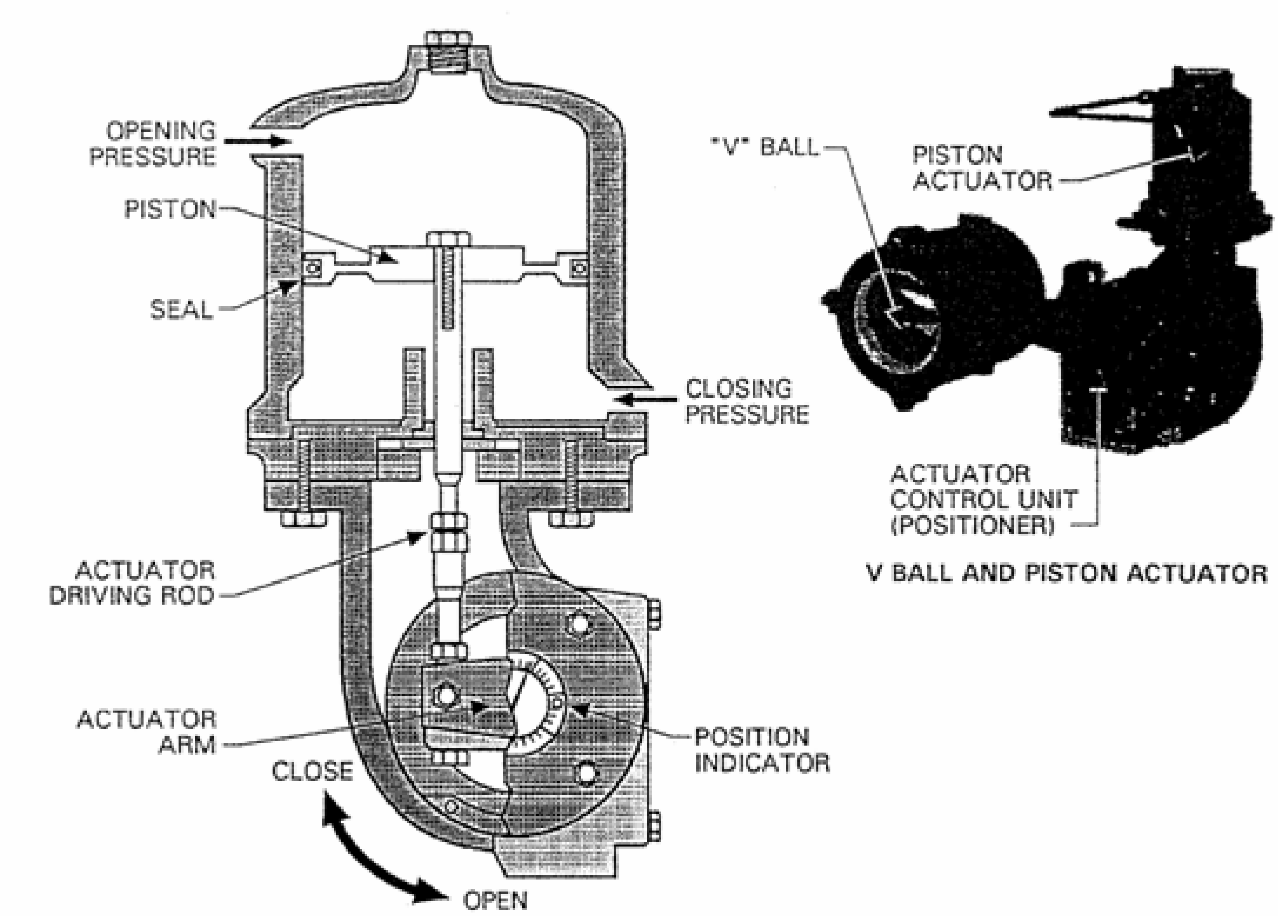


Figure 44: Pneumatic actuator

5.2.4. Electric actuator

Electric actuators are mainly used to fully open or fully close valves.

The can only place a valve in 2 positions:

- Fully open
- Fully closed

Valves which can only be fully open or fully closed are not true control valves.

However, we have included electric actuators here because the operators will use them in the course of their work.

There are two main types:

- Solenoid-operated
- Motorised

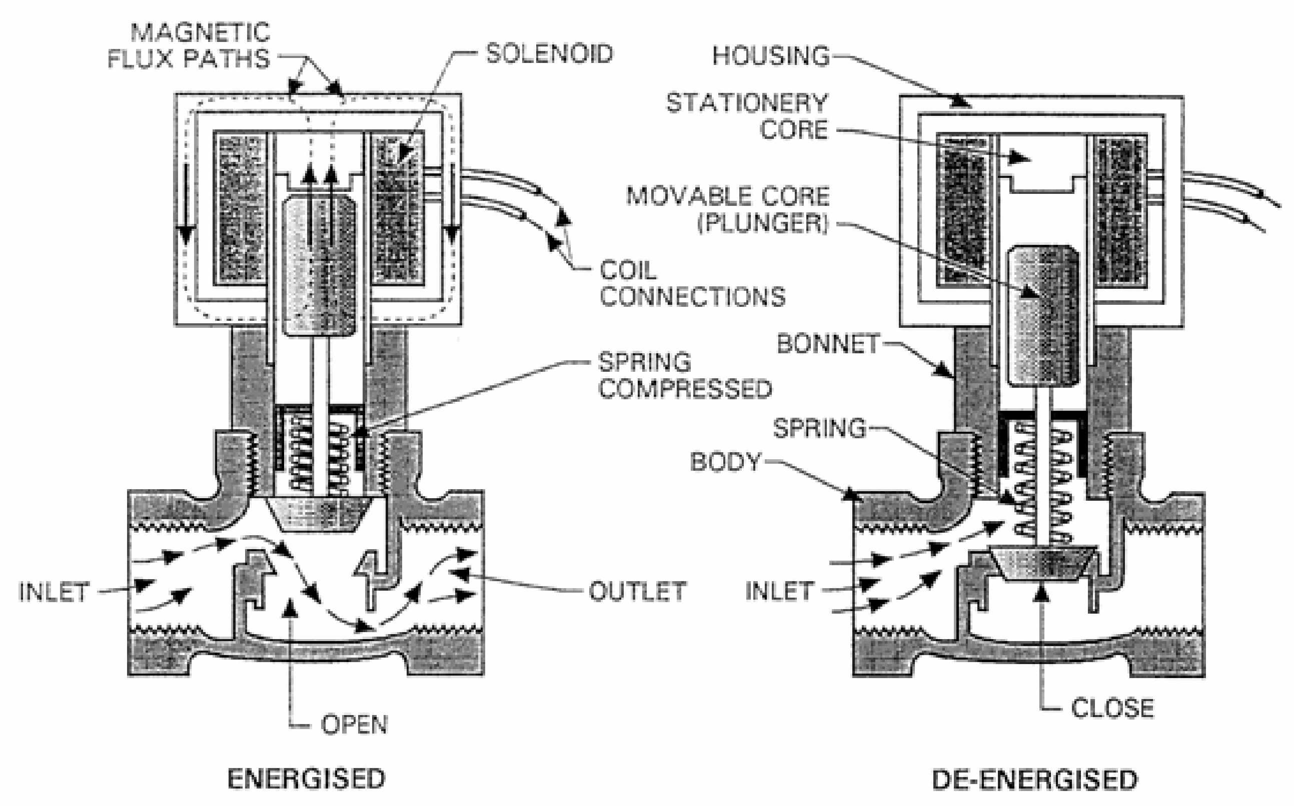


Figure 45: Electric actuator

5.2.5. Fail-safe position

It may be the case that the automatic valve's actuator is no longer supplied, for various reasons:

- Instrument Air system failure
- Blocked pressure regulator filter
- Positioner malfunction
- Defective positioner – actuator link, etc.

The diaphragm is then under spring pressure only and, in this case the valve is in its fail-safe position:

- Either fully open (Fail Open (FO).
- Or fully closed (Fail Closed FC)).

The figure shows the **valve's fail-safe position** according to the operating direction of each of these 2 components.

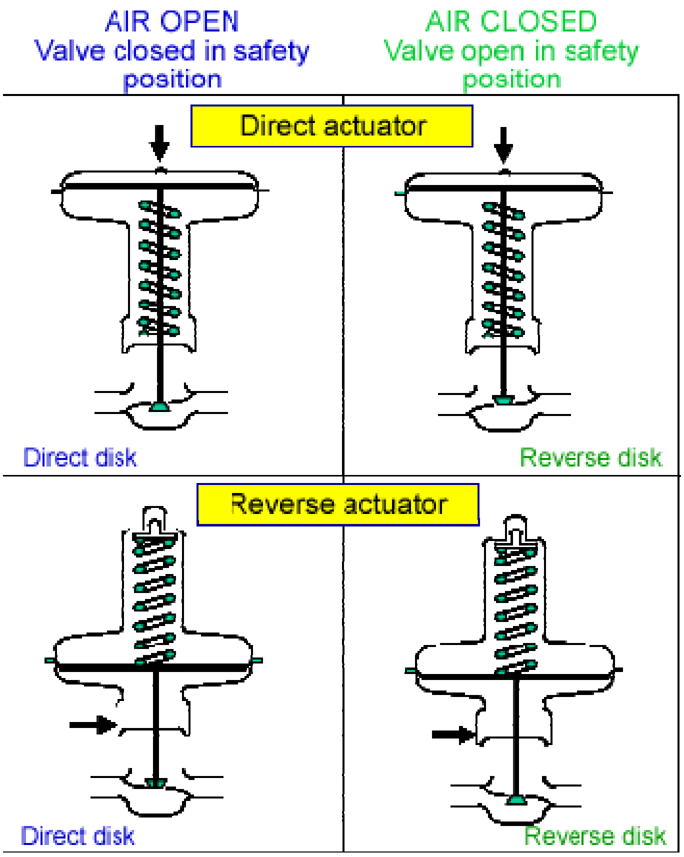


Figure 46: Fail-safe positions

The choice of the valve fail-safe position depends on its location in the process, it is dictated by safety reasons.

5.2.6. Automatic valve accessories

Some auxiliaries may be equipped with an automatic valve. We may find, for example:

- **Solenoid-trip valve**
  It quickly places the valve in fail-safe position by venting the actuator air to atmosphere.

- **Travel limiters**
  They are used to prevent valves closing completely, mostly for safety reasons. Therefore they equip exchanger train feed valves.

- **Lubricators**
  To lubricate the valve operating stem and the stuffing box

- **Valve positioners**
  They operate the valve stem to control the flow rate and pressure, and feed back information to the control room

- **Actuators**
  Actuators are the components which automatically open, close or control the valves.

6. VALVE CONTROL

For the control to operate correctly it is essential that the valve travel (plug travel) is exactly proportional to the controller output signal value*.*

However, ***disruptive forces*** can hamper the valve movement:

- **Force exerted by the fluid** (particularly in the case of single-seat valves)
- **Friction on the transmission stem** in the stuffing box
- **Spring exerting a force** which is not exactly proportional to its displacement (hysteresis)
- **Surface variation** due to distortion of the diaphragm, etc. These forces depend on the service conditions

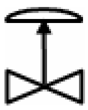
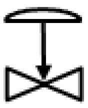
Symbol	Abbreviation	Meaning	Fail-safe position
 FO	FO	FAIL OPEN	Open
	AFO	NO AIR OPEN	
 FC	FC	FAIL CLOSED	Closed
	AFC	NO AIR CLOSED	

Table 2: Automatic valve symbols

6.1. CONTROL WITHOUT POSITIONER

The valve Actuator directly receives the pneumatic signal (0.2 – 1 bar) of the controller signal **I / P** conversion.

6.2. CONTROL WITH POSITIONER

The positioner, supplied with Instrument Air (1.4 bars) receives the control signal.

A feedback link allows the positioner to compare the position of the valve with the theoretical position corresponding to the controller signal and to modulate the air pressure to the Actuator diaphragm as required.

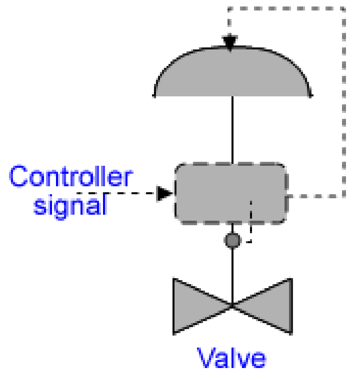
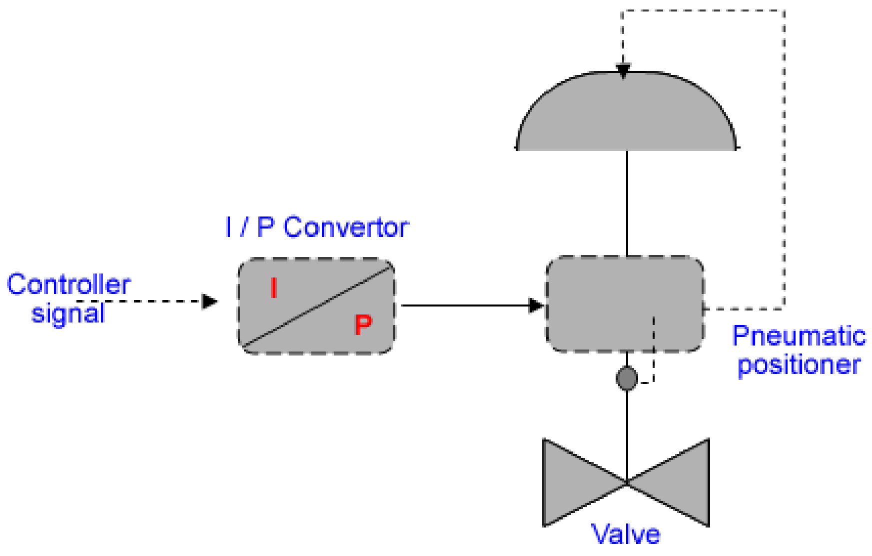


Figure 47: Pneumatic positioner



This outlet pressure can, depending on the case, be greater or less (in %) than that of the controller signal.

If an electropneumatic positioner is used, there is an electrical signal from the controller.

Figure 48: Electropneumatic positioner

This electrical signal is converted into a pneumatic signal by the I/P converter and sent to the pneumatic positioner.

The following diagram shows the location of the positioner with respect to the other components in a pneumatic control loop.

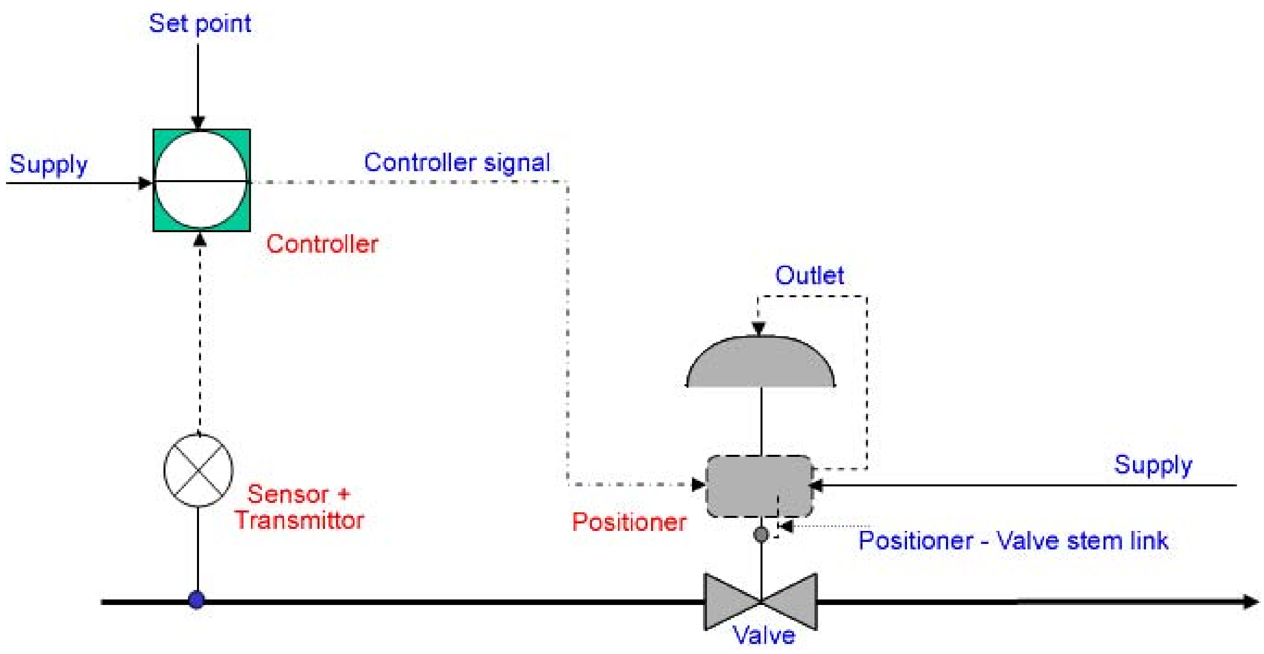


Figure 49: Pneumatic control loop

7. GLOSSARY

8. LIST OF FIGURES

9. LIST OF TABLES