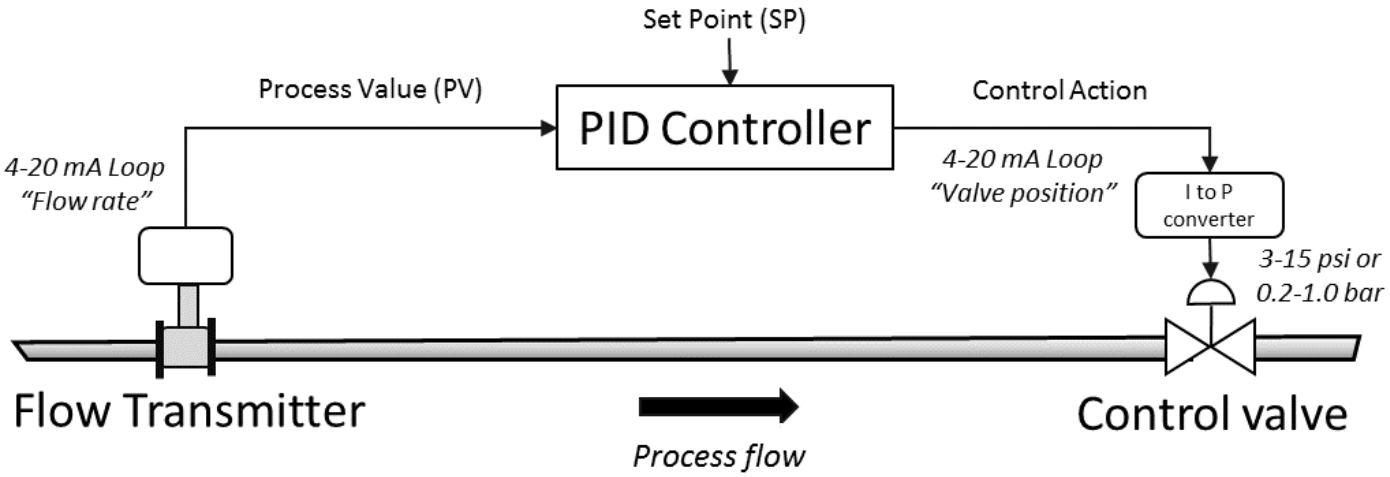
Industrial Automation Module 3 : Actuators

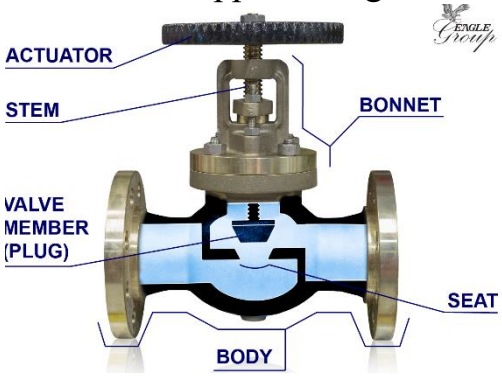
Process control loop



Flow Control Valves

A valve is device that regulates, directs or controls flow of fluid by opening, closing, or partially obstructing various passageways.

A valve is defined as any device by which flow of fluid may be started, stopped or regulated by movable part that opens or obstructs passage.



Major Parts of valve

Valve Functions

1. Stopping & starting fluid flow.
2. Varying (throttling) amount of fluid flow.
3. Controlling direction of fluid flow.
4. Regulating downstream system or process pressure.
5. Relieving component or piping over pressure.

Valve Selection Consideration

A. Pressure

B. Temperature

C. Type of Fluid

1. Liquid 2. gas(steam/air) 3. dirty or abrasive(erosive) 4. corrosive

D. Flow Considerations

1. On-Off /Throttling
2. is valve needed to prevent backflow
3. concern for pressure
4. velocity

E. Operating Conditions

1. Frequency of operation
2. Accessibility
3. Overall space/size available
4. Manual / automated control
5. Need for bubble-tigh shut off
6. Concerns about body joint leaks
7. Fire safe designs
8. Speed of closure

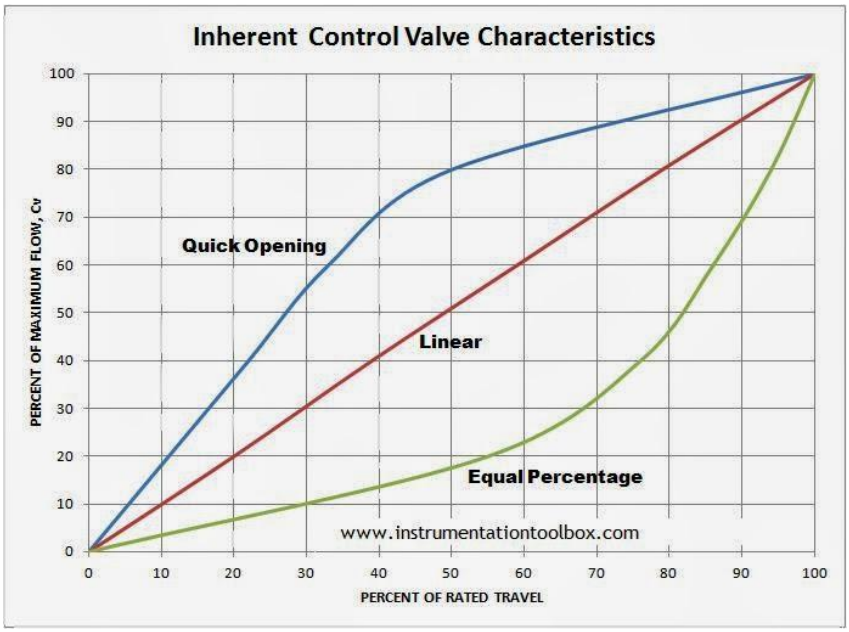
Flow Characteristics

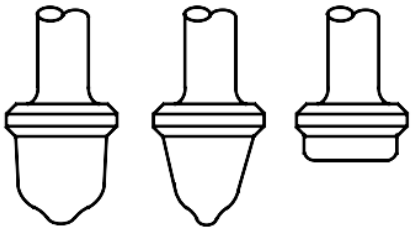
It describes how flow rate changes with movement or lift of stem. shape of plug primarily decides flow characteristics.

1. Inherent or ideal characteristics
2. Effective or installed characteristics

An inherent characteristic is ideal flow characteristics of control valve & is decided by shape & size of plug. On other hand, when valve is connected to pipeline, its overall performance is decided by its effective characteristic.

Control valve characteristics





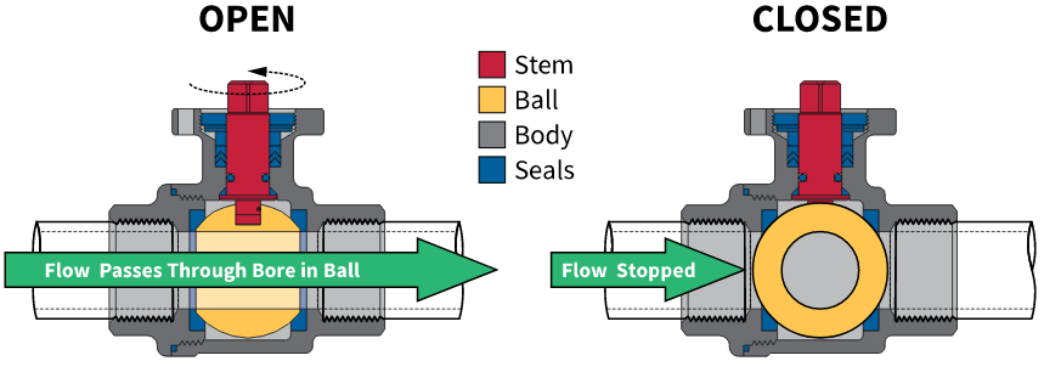
Valve plug shapes for the three common flow characteristics.

Types of Control Valves based on Application

- Flow control- Ball , Gate , Globe, Needle, Pinch/Diaphragm, Butterfly
- Pressure control- Relief, Safety
- Directional control-Check

Ball valve

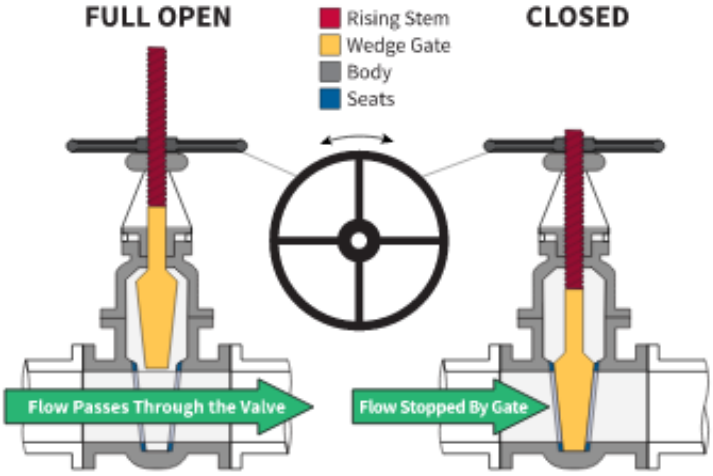
It is quarter-turn rotary motion valve that uses ball-shaped disk to stop or start flow.
Most ball valves are of quick-acting type, which requires 90° turn of handle to operate valve.
It is Smaller & lighter than gate valve of same size & rating.



Stem & Ball Rotate 90° from OPEN to CLOSED

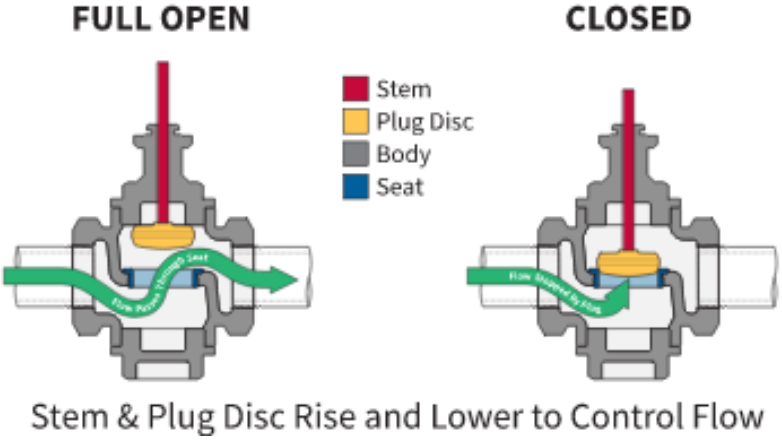
Gate valve

It is most common type of valve in any process plant.
It is linear motion valve used to start or stop fluid flow.
In service, these valves are either in fully open or fully closed position.
They are used in almost all fluid services such as air, fuel gas, feed water, steam, lube oil, hydrocarbon, & all most any services.
They provides good shutoff.



Globe valve

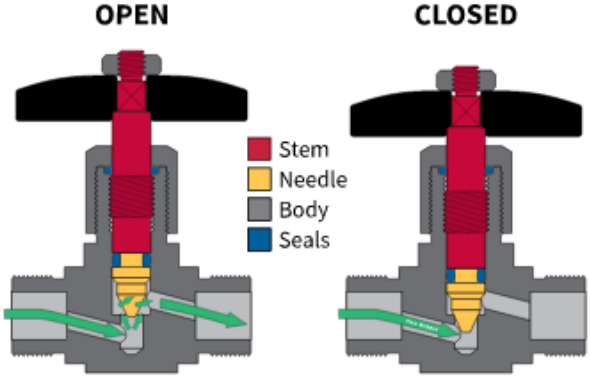
It is used to stop, start, & regulate fluid flow.
They are used in systems where flow control is required & leak tightness is also necessary.
They provides better shut off as compared to gate valve & it is costlier than gate valve.

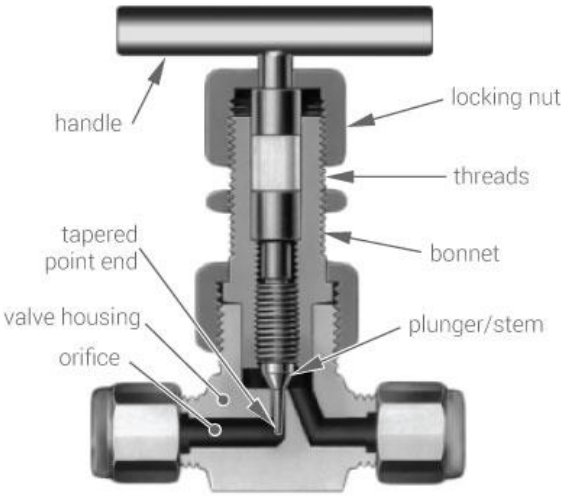


Stem & Plug Disc Rise and Lower to Control Flow

Needle valve

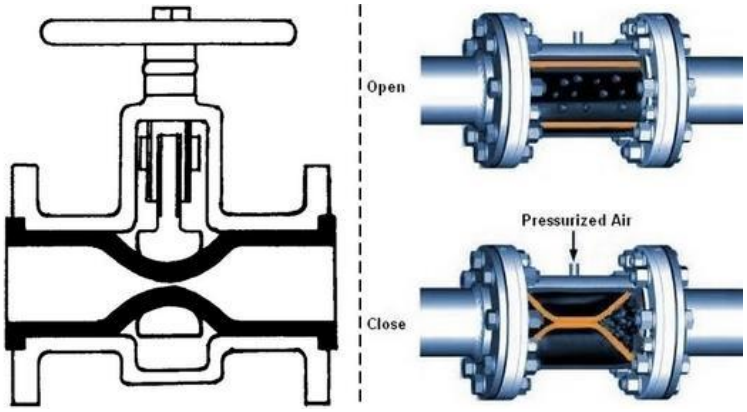
They are similar to globe valve in design with biggest difference is sharp needle like disk.
They are designed to give very accurate control of flow in small diameter piping systems.
They get their name from their sharp-pointed conical disc & matching seat.

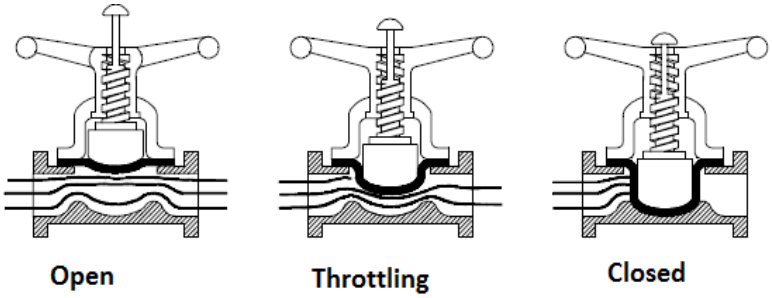




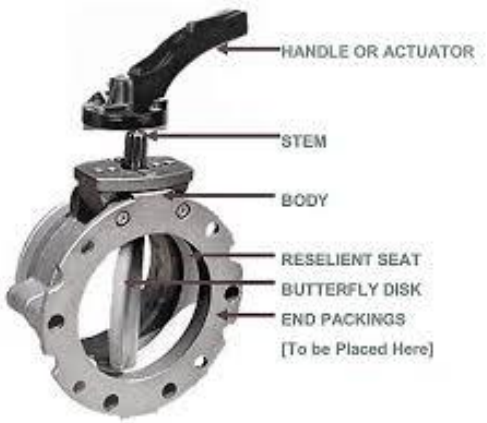
Pinch / Diaphragm / Clamp Valve

It is linear motion valve.
It is used to start, regulate, & stop fluid flow.
It uses rubber tube, also known as pinch tube & pinch mechanism to control fluid.
It is ideally suited for handling of slurries, liquids with large amounts of suspended solids, & systems that convey solid material pneumatically.



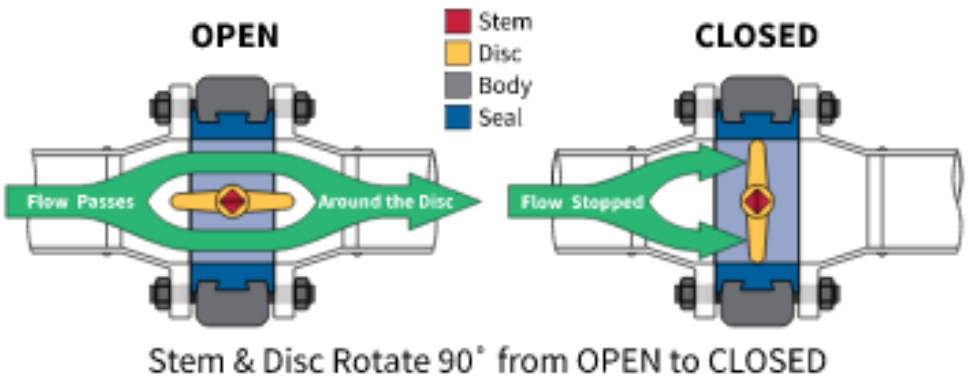


Diaphragm Valve Basics

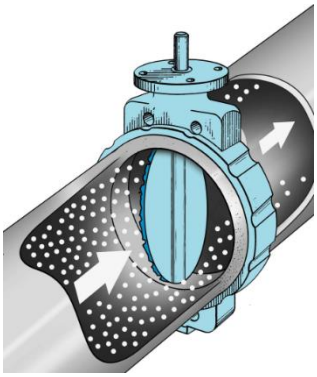


Butterfly valve

It is quarter-turn rotary motion valve, that is used to stop, regulate, & start flow.
It has short circular body.
It is suitable for large valve applications due to Compact, lightweight design that requires considerably less space, as compared to other valves.

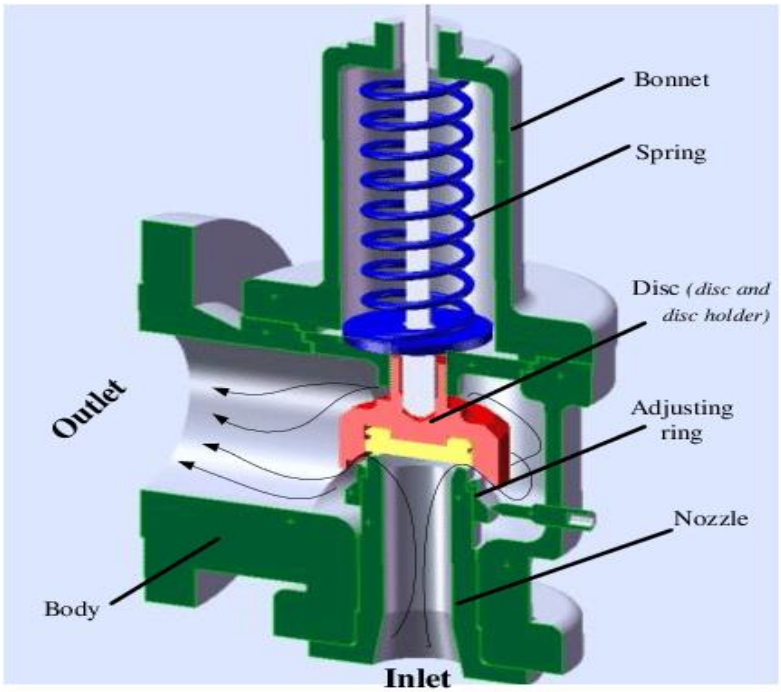


Stem & Disc Rotate 90° from OPEN to CLOSED



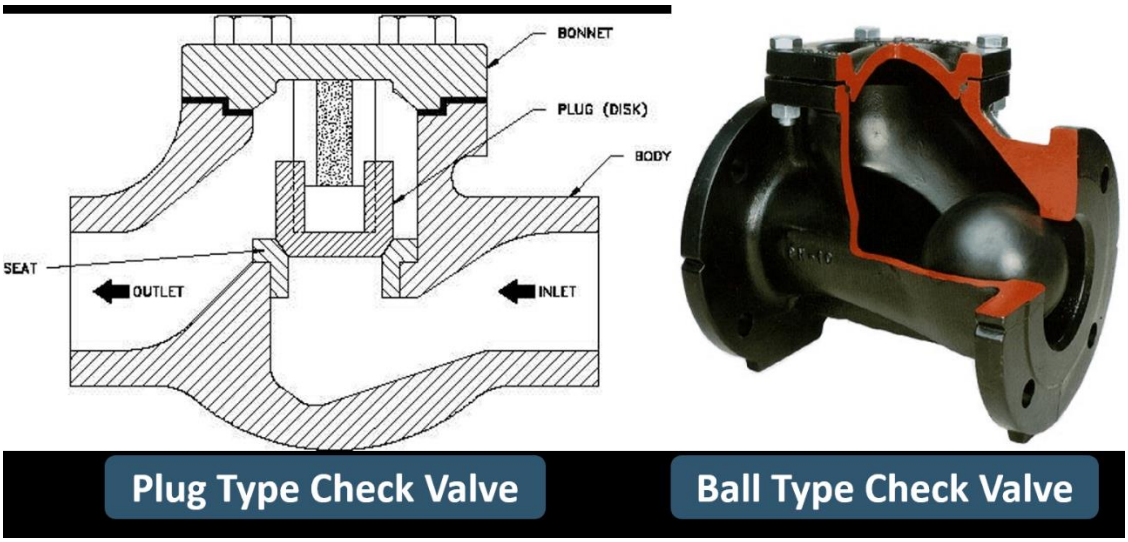
Pressure Relief / Safety valve

They are used to protect equipment or piping system during overpressure event or in event of vacuum. It releases pressure or vacuum at pre-defined set pressure.



Check valve

It valve prevents backflow in piping system. Pressure of fluid passing through pipeline opens valve, while any reversal of flow will close valve.



Classification of control valves

(a) application
(b) action
(c) number of plugs, and
(d) flow characteristics.

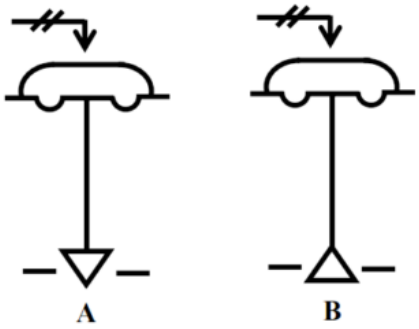
Types of Control Valves based on Action

Control valves operated through pneumatic actuators can be either

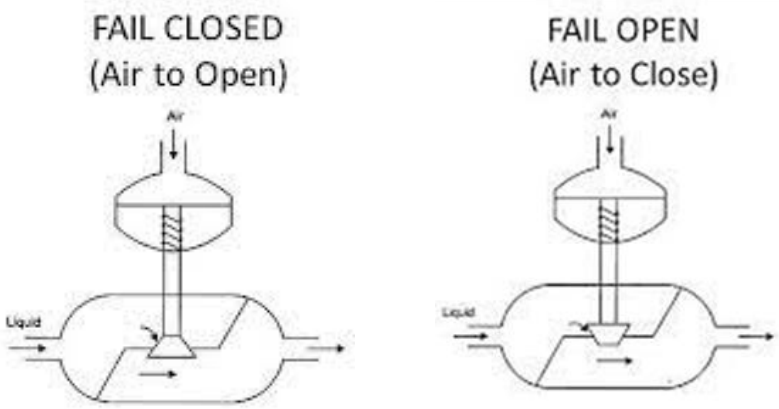
(i) Air To Open

They are designed such that if air supply fails, control valve will be either fully open, or fully closed, depending upon safety requirement of process.

For example, if valve is used to control level of liquid in tank, valve should be shut off completely in case of air failure(A).



- **Fail open or Air to close : A**
- **Fail closed or Air to open : B**



(ii) Air To Close

If valve is handling cooling water to reactor, flow should be max in case of emergency (B)

Types of Control Valves based on Number of plugs

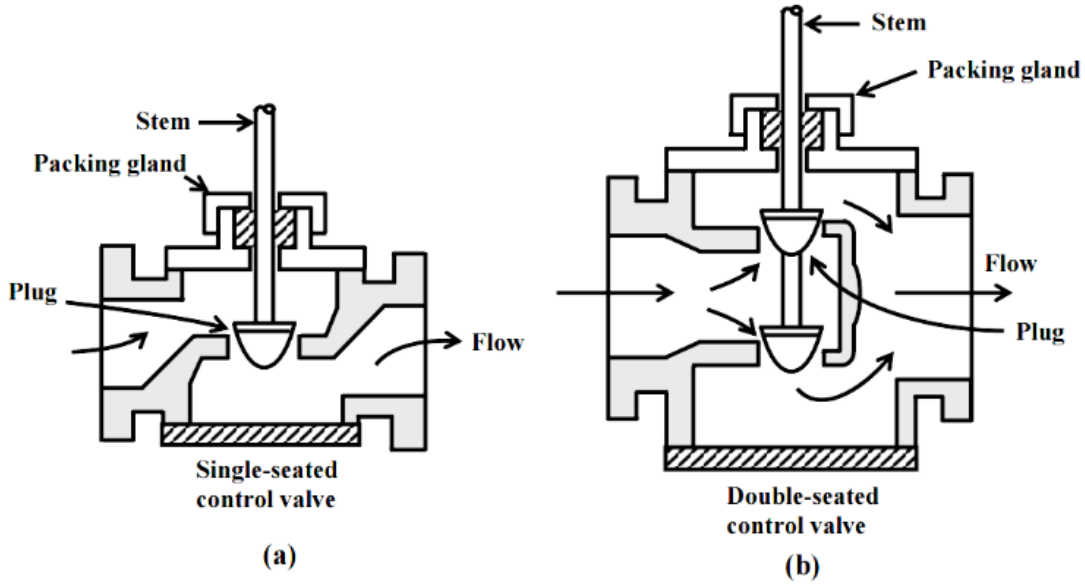
(i) single-seated valve

(ii) double-seated valve

Advantage of single-seated valve is that, it can be fully closed & flow variation from 0 to 100% can be achieved. But looking at its construction, due to pressure drop across orifice large upward force is present in orifice area, & as result, force required to move valve against this upward thrust is also large.

Thus this type of valves is more suitable for small flow rates. There are two plugs in double-seated valve; flow moves upward in one orifice area, & downward in other orifice.

Resultant upward or downward thrust is almost zero. As result, force required to move double-seated valve is comparatively much less.

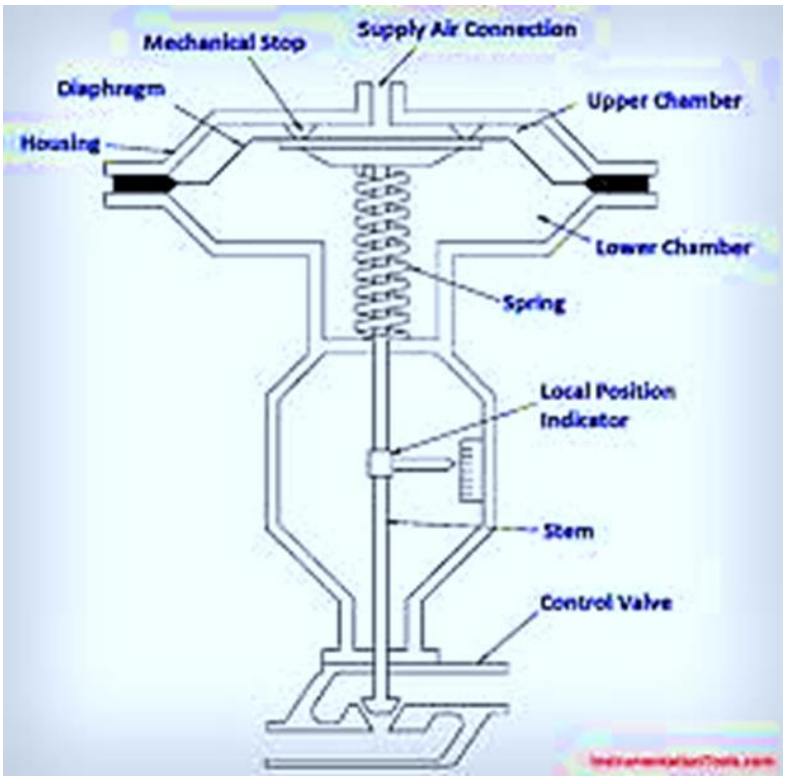


Actuator

It is component of machine that is responsible for moving & controlling mechanism or system, for example by opening valve. In simple terms, it is "mover".
It requires control signal & source of energy. Control signal is relatively low energy & may be electric voltage or current, pneumatic or hydraulic pressure, or even human power. Its main energy source may be electric current, hydraulic fluid, or pneumatic pressure. When it receives control signal, actuator responds by converting signal's energy into mechanical motion.

Pneumatic Actuators

Pneumatic actuators enable considerable forces to be produced from relatively small pressure changes. pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion.
Moreover, pneumatic actuators are safer, cheaper, & often more reliable & powerful than other actuators. These forces are often used with valves to move diaphragms to affect flow of air through valve.



Advantages of Pneumatic actuators

1. Biggest advantage is their failsafe action. By design of compressed spring, engineer can determine if valve will fail closed or open, depending on safety of process.
2. Provide high force & speed, which are easily adjustable & are independent of each other
3. Have delayed response which makes them ideal for being resilient against small upsets in pressure changes of source.
4. Most economical when scale of deployment matches capacity of compressor.
5. Provide inherent safety & are ideal for hazardous & explosive environment.
6. Low component cost & smaller footprint.

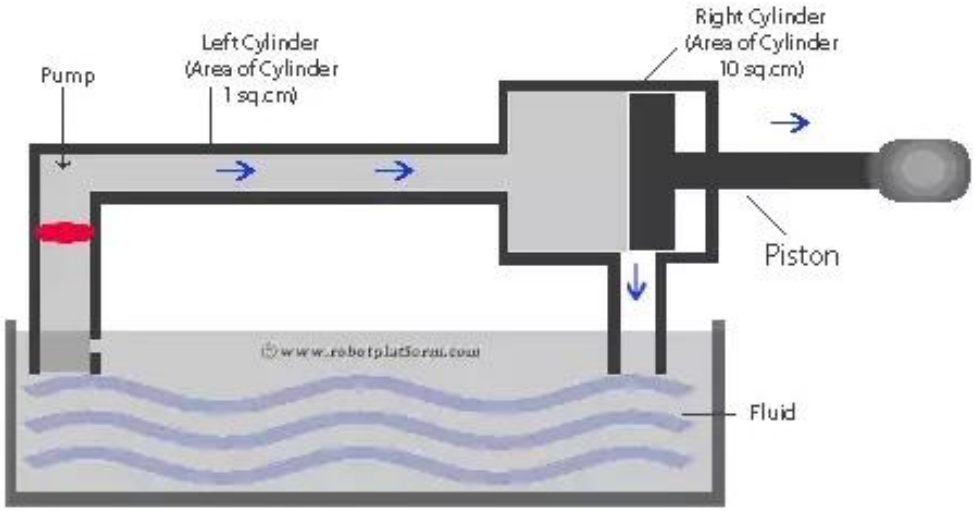
Limitations of Pneumatic Actuators

Maintenance & operating costs can be high, especially if serious effort has not been made to quantify & minimize costs. Maintenance costs include replacement cylinder costs & plugging air-line leakages whereas operating costs include cost of compressed air, i.e. electricity for compressor.

Hydraulic actuators

It consists of cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. Mechanical motion gives output in terms of linear or rotatory motion. As liquids are nearly impossible to compress, hydraulic actuator can exert large force. drawback of this approach is its limited acceleration.

Hydraulic cylinder consists of hollow cylindrical tube along which piston can slide. Term *single acting* is used when fluid pressure is applied to just one side of piston. Piston can move in only one direction, spring being frequently used to give piston return stroke. Term *double acting* is used when pressure is applied on each side of piston; any difference in pressure between two sides of piston moves piston to one side or other.



Hydraulic Actuator

Advantages of hydraulic actuation system

Variable speed & direction
Power-to-weight ratio
Stall condition & overload protection(pressure relief valves)
Hydraulic fluid must essentially be non-compressible to be able to transmit power instantly from one part of system to another.
Most common liquid used in hydraulic systems is petroleum oil.

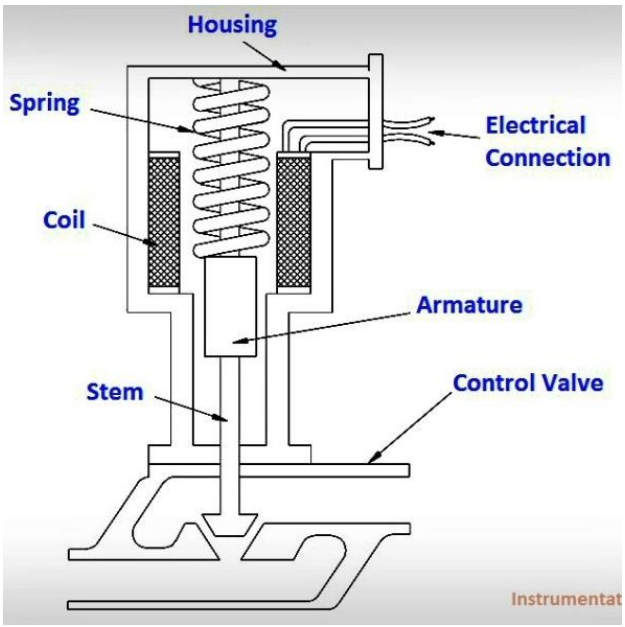
Electrical type actuators Solenoids Servomotor

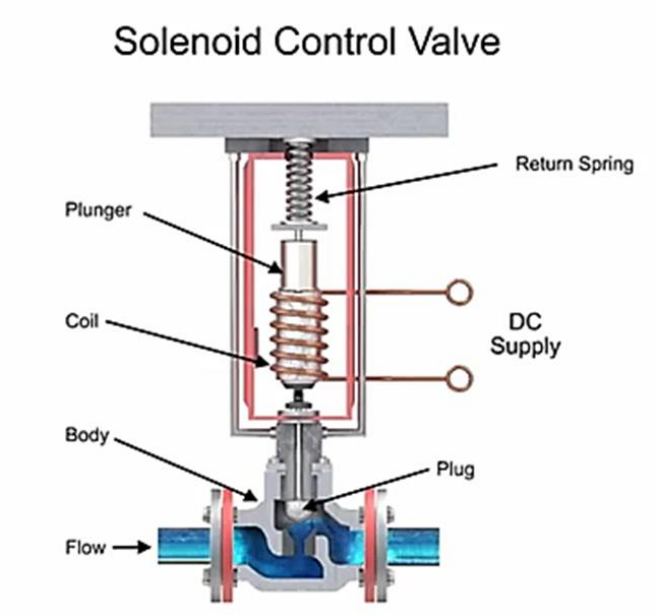
Solenoid Actuators

When current flows through coil, magnetic field forms around coil. magnetic field attracts armature toward center of coil. As armature moves upward, spring collapses & valve opens. When circuit is opened & current stops flowing to coil, magnetic field collapses. This allows spring to expand & shut valve.

A major advantage of is their quick operation. Also, they are much easier to install than pneumatic or hydraulic actuators.

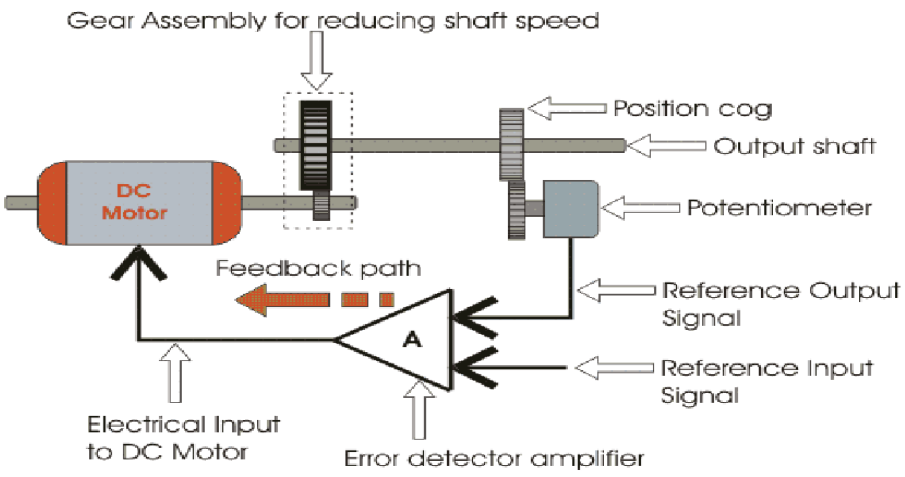
However, solenoid actuators have two disadvantages. First, they have only two positions: fully open & fully closed. Second, they don't produce much force, so they usually only operate relatively small valves.

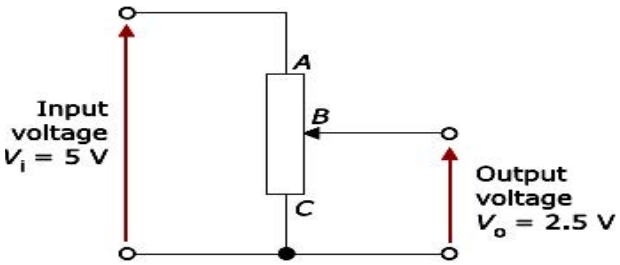




Servo Motor actuator

It is rotary actuator that allows for precise control of angular position, velocity & acceleration. It consists of suitable motor coupled to sensor for position feedback. It also requires relatively sophisticated controller, often dedicated module designed specifically for use with servomotors. They are used in applications such as robotics, CNC machinery or automated manufacturing.





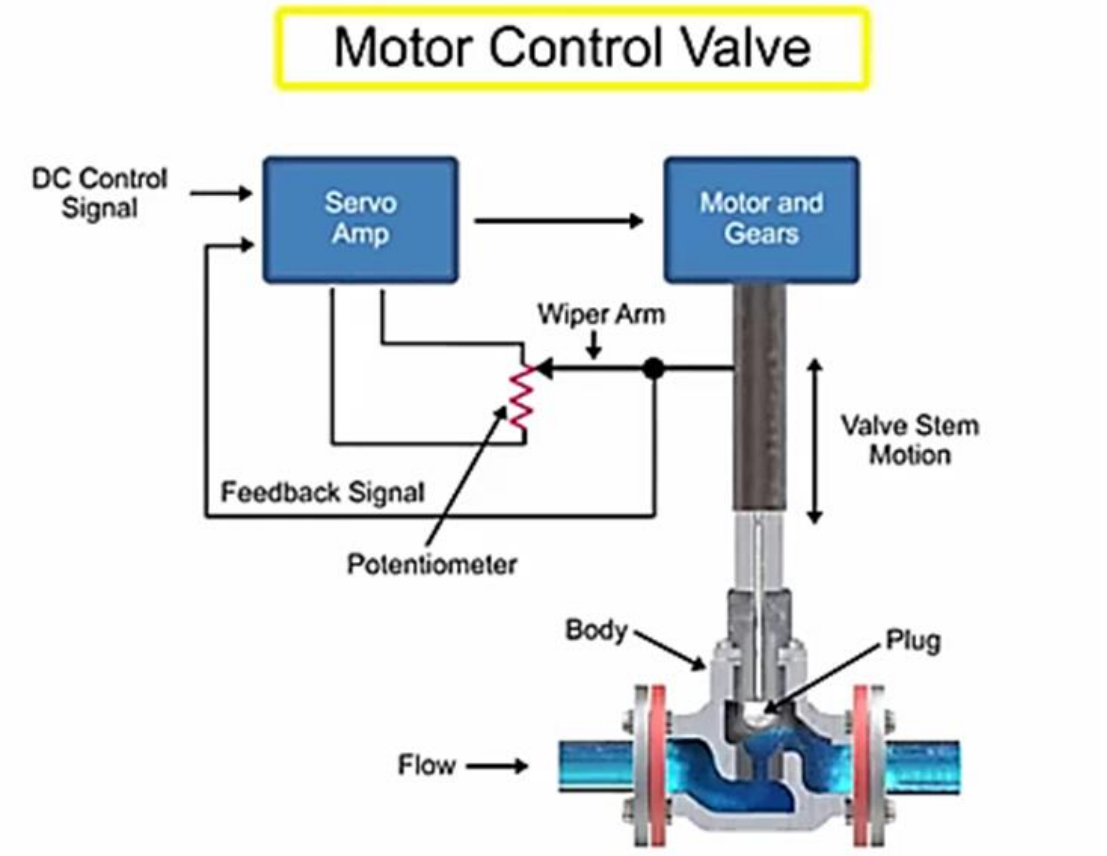
Suppose, we have given signal to rotate servomotor by angle of 45° & then stop & wait for further instruction.

Shaft of DC motor is coupled with another shaft called output shaft, with help of gear assembly. This gear assembly is used to step down high rpm of motor's shaft to low rpm at output shaft of servo system.

Voltage adjusting knob of potentiometer is so arranged with output shaft by means of another gear assembly, that during rotation of shaft, knob also rotates & creates varying electrical potential. This signal i.e. electrical potential is increased with angular movement of potentiometer knob along with system shaft from 0° to 45°. This electrical potential or voltage is taken to error detector feedback amplifier along with input reference commends i.e. input signal voltage.

As angle of rotation of shaft increases from 0° to 45° voltage from potentiometer increases. At 45° this voltage reaches to value which is equal to given input command voltage to system. As at this position of shaft, there is no difference between signal voltage coming from potentiometer & reference input voltage(command signal) to system, output voltage of amplifier becomes zero.

From Figure, it can be observed that output electrical voltage signal of amplifier, acts as input voltage of DC motor. Hence motor will stop rotating after shaft rotates by 45°. motor will be at this rest position until another command is given to system for further movement of shaft in desired direction.



Advantages of Electric actuators

1. Provide precise control & positioning in comparison to pneumatic actuators.
2. Response time is essentially instantaneous.
3. High degree of stability.
4. Help adapt machines to flexible processes.
5. Low operating cost. Controllers & drivers low voltage circuitry consume power to far lesser degree.

Disadvantages of Electric actuators

1. The primary disadvantage of electric actuator is that, should power failure occur, valve remains in last position & fail-safe position cannot be obtained easily unless there is convenient source of stored electrical energy.
2. Higher cost than pneumatic actuators. High component costs often deter use of electric actuators because savings in operating costs compared to pneumatics are often not adequately considered or are outright ignored.
3. The actuator needs to be in environment that is rendered safe. Generally, not recommended for flammable atmospheres.