CONTROL COMPONENTS
(Code: 3331704)

Unit – I Control Valve

1.1. Control valve parameters:

Rangeability:
The ratio of the largest flow coefficient (Cv) to the smallest flow coefficient (Cv) within which the deviation from the specified inherent flow characteristic does not exceed the stated limits.

Hysteresis:
The maximum difference in output value for any single input value during a calibration cycle, excluding errors due to dead band.

Capacity:
The rate of flow through a valve under stated conditions.

Linearity:
The flow rate of valve varies linearly with valve plug lift.

1.2. Control valves in industries

Globe Valve
A globe valve is a linear motion valve used to stop, start, and regulate fluid flow. A Z-body globe valve is illustrated in Figure 1. As shown in Figure 1, the globe valve disk can be totally removed from the flow path or it can completely close the flow path.

The essential principle of globe valve operation is the perpendicular movement of the disk away from the seat. This causes the annular space between the disk and seat ring to gradually close as the valve is closed. This characteristic gives the globe valve good throttling ability, which permits its use in regulating flow.

Therefore, the globe valve may be used for both stopping and starting fluid flow and for regulating flow. When compared to a gate valve, a globe valve generally yields much less seat leakage. This is because the disk-to-seat ring contact is more at right angles, which permits the force of closing to tightly seat the disk.

Drawbacks:
- The high head loss.
- In a large high pressure line, the fluid dynamic effects from pulsations, impacts, and pressure drops can damage trim, stem packing, and actuators.
- Large valve sizes require considerable power to operate.
- Noisy in high-pressure applications.
- Large openings necessary for disk assembly
- Heavier weight than other valves of the same flow rating
- The cantilevered mounting of the disk to the stem.

**Ball Valve**

A ball valve is a rotational motion valve that uses a ball-shaped disk to stop or start fluid flow. The ball, shown in Figure 2. When the valve handle is turned to open the valve, the ball rotates to a point where the hole through the ball is in line with the valve body inlet and outlet. When the valve is shut, the ball is rotated so that the hole is perpendicular to the flow openings of the valve body and the flow is stopped.

![Ball Valve Diagram](image)

Most ball valve actuators are of the quick-acting type, which require a 90° turn of the valve handle to operate the valve. Other ball valve actuators are planetary gear-operated. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve.

Some ball valves have been developed with a spherical surface coated plug that is off to one side in the open position and rotates into the flow passage until it blocks the flowpath completely. Seating is accomplished by the eccentric movement of the plug. The valve requires no lubrication and can be used for throttling service.

**Butterfly Valve:**

A butterfly valve, illustrated in Figure 5, is a rotary motion valve that is used to stop, regulate, and start fluid flow. Butterfly valves are easily and quickly operated because a 90 degree rotation of the handle moves the disk from a fully closed to fully opened position. Larger butterfly valves are actuated by handwheels connected to the stem through gears that provide mechanical advantage at the expense of speed.
Butterfly valves possess many advantages over gate, globe, plug, and ball valves, especially for large valve applications. Savings in weight, space, and cost are the most obvious advantages. The maintenance costs are usually low because there are a minimal number of moving parts and there are no pockets to trap fluids.

Butterfly valves are especially well-suited for the handling of large flows of liquids or gases at relatively low pressures and for the handling of slurries or liquids with large amounts of suspended solids.

Butterfly valves are built on the principle of a pipe damper. The flow control element is a disk of approximately the same diameter as the inside diameter of the adjoining pipe, which rotates on either a vertical or horizontal axis. When the disk lies parallel to the piping run, the valve is fully opened. When the disk approaches the perpendicular position, the valve is shut. Intermediate positions, for throttling purposes, can be secured in place by handle-locking devices.

**Needle Valve:**

A needle valve, as shown in Figure, is used to make relatively fine adjustments in the amount of fluid flow. The distinguishing characteristic of a needle valve is the long, tapered, needle like point on the end of the valve stem. This "needle" acts as a disk. The longer part of the needle is smaller than the orifice in the valve seat and passes through the orifice before the needle seats. This arrangement permits a very gradual increase or decrease in the size of the opening. Needle valves are often used as component parts of other, more complicated valves. For example, they are used in some types of reducing valves.

**Needle Valve Applications**

Most constant pressure pump governors have needle valves to minimize the effects of fluctuations in pump discharge pressure. Needle valves are also used in some components of automatic combustion control systems where very precise flow regulation is necessary.

**Pinch Valve:**

The relatively inexpensive pinch valve, illustrated in Figure, is the simplest in any valve design. It is simply an industrial version of the pinch cock used in the laboratory to control the flow of fluids through rubber tubing. Pinch valves are suitable for on-off and throttling services. However, the effective throttling range is usually between 10% and 95% of the rated flow capacity.

Pinch valves are ideally suited for the handling of slurries, liquids with large amounts of suspended solids, and systems that convey solids pneumatically. Because the operating mechanism is completely isolated
from the fluid, these valves also find application where corrosion or metal contamination of the fluid might be a problem.

The pinch control valve consists of a sleeve molded of rubber or other synthetic material and a pinching mechanism. All of the operating portions are completely external to the valve. The molded sleeve is referred to as the valve body.

Pinch valve bodies are manufactured of natural and synthetic rubbers and plastics which have good abrasion resistance properties. These properties permit little damage to the valve sleeve, thereby providing virtually unimpeded flow. Sleeves are available with either extended hubs and clamps designed to slip over a pipe end, or with a flanged end having standard dimensions.

**Diaphragm Valve**

A diaphragm valve is a linear motion valve that is used to start, regulate, and stop fluid flow. The name is derived from its flexible disk, which mates with a seat located in the open area at the top of the valve body to form a seal. A diaphragm valve is illustrated in Figure 3.
Diaphragm valves are, in effect, simple "pinch clamp" valves. A resilient, flexible diaphragm is connected to a compressor by a stud molded into the diaphragm. The compressor is moved up and down by the valve stem. Hence, the diaphragm lifts when the compressor is raised. As the compressor is lowered, the diaphragm is pressed against the contoured bottom in the straight through valve illustrated in Figure 3 or the body weir in the weir-type valve illustrated in Figure 4.

![Diaphragm Valve Diagram]

**Figure 4: Weir Diaphragm Valve**

Diaphragm valves can also be used for throttling service. The weir-type is the better throttling valve but has a limited range. Its throttling characteristics are essentially those of a quick opening valve because of the large shutoff area along the seat.

Diaphragm valves are particularly suited for the handling of corrosive fluids, fibrous slurries, radioactive fluids, or other fluids that must remain free from contamination.

**Solenoid Valve:**

A solenoid valve is an electromechanical device used for controlling liquid or gas flow.

**Parts of the Solenoid Valve**

Here are the various parts of the solenoid valve and their working (please refer the figure above).

1) **Valve body:** This is the body of the valve to which the solenoid valve is connected. The valve is usually connected in the process flow pipeline to control the flow of certain fluid like liquid or air.

2) **Inlet port of the valve:** This is the port through which the fluid enters inside the automatic valve and from here it can enter into the final process.

3) **Outlet port:** The fluid that is allowed to pass through the automatic valve leaves the valve through the outlet port.

4) **Coil/ Solenoid:** This is body of the solenoid coil. The body of the solenoid coil is cylindrical in shape, and it is hollow from inside. The body is covered with steel covering and it has metallic finish. Inside the solenoid valve there is solenoid coil.
5) **Coil windings:** The solenoid consists of several turns of the wire wound around the ferromagnetic material like steel or iron. The coil forms the shape of the hollow cylinder.

6) **Lead wires:** These are external connections of the solenoid valve that are connected to the electrical supply. The current is supplied to the solenoid valve from these wires.

7) **Plunger or piston:** This is the solid round metallic part cylindrical in shape and placed in the hollow portion the solenoid valve.

8) **Spring:** The plunger moves inside the hollow space due to the action of the magnetic field against the action of the spring.

9) **Orifice:** The orifice is an important part of the valve though which the fluid is flowing. It is the connection between the inlet and the outlet port.

The solenoid valve is controlled by electrical current, which is run through a coil. When the coil is energized, a magnetic field is created, causing a plunger inside the coil to move. Depending on the design of the valve, the plunger will either open or close the valve. When electrical current is removed from the coil, the valve will return to its de-energized state.

In direct-acting solenoid valves, the plunger directly opens and closes an orifice inside the valve. In pilot-operated valves (also called the servo-type), the plunger opens and closes a pilot orifice. The inletline pressure, which is led through the pilot orifice, opens and closes the valve seal.
The most common solenoid valve has two ports: an inlet port and an outlet port. Advanced designs may have three or more ports. Some designs utilize a manifold-type design.

**Piston type valve (single acting/double acting)**

Piston valve is a seatless (soft seated), glandless piston type globe valve.

![Diagram of a piston valve](image)

**PRINCIPLE OF OPERATION**

Sealing between ports is achieved by piston (outer surface) coming in contact with the inner surface of soft ring (the lower ring).

Sealing towards atmosphere is achieved by the piston traveling upwards and by forming the sealing (outer surface of piston and inner surface of upper ring). Hence no gland is required.

Piston valve was innovated by replacing the disk and seat of a conventional globe valve with a cylindrical piston and two resilient, replaceable sealing rings. Constant research and development have resulted in sealing rings that provide the piston valve with an extraordinary ability to seal line pressure and prevent leakage to the atmosphere.

**ADVANTAGES OF PISTON VALVE OVER GLOBE VALVE:**

1. **SOFT SEATED VALVES FALL UNDER CLASS VI**
2. **DOES NOT GET AFFECTED BY FOREIGN MATTER.**
3. **LARGE SEALING AREA BETWEEN OUTER SURFACE OF PISTON AND INNER SURFACE OF THE RING 950 MM2 FOR 25NB.**
4. **UNIQUE DESIGN OF PISTON & LANTERN BUSH CAN PROVIDE GOOD REGULATION WITH LINEAR CHARACTERISTICS.**
5. **BELLEVILLE (INVERTED CUP) WASHERS COMPENSATE FOR THERMAL EXPANSION NO THERMAL CHATTERING DUE TO SOFT SEATING**

**Single acting and Double acting Piston Valve:**

**Single-acting**

A single-acting valve in a reciprocating engine is a cylinder in which the working fluid acts on one side of the piston only. A single-acting cylinder relies on the load, springs, other cylinders, or the momentum of a flywheel, to push the piston back in the other direction. Single-acting cylinders are found in most kinds of reciprocating engine. They are almost universal in internal combustion engines (e.g. petrol and diesel engines) and are also used in many external combustion engines such as Stirling engines and some steam engines. They are also found in pumps and hydraulic rams.
Double-acting

A double-acting valve is a cylinder in which the working fluid acts alternately on both sides of the piston. In order to connect the piston in a double-acting cylinder to an external mechanism, such as a crank shaft, a hole must be provided in one end of the cylinder for the piston rod, and this is fitted with a gland or "stuffing box" to prevent escape of the working fluid. Double-acting cylinders are common in steam engines but unusual in other engine types. Many hydraulic and pneumatic cylinders use them where it is needed to produce a force in both directions. A double-acting hydraulic cylinder has a port at each end, supplied with hydraulic fluid for both the retraction and extension of the piston. A double-acting cylinder is used where an external force is not available to retract the piston or where high force is required in both directions of travel.

1.3. Basic Parts of Control Valve:

Valve body:

It is a housing for internal valve parts having inlet and outlet flow connection.

It serves as the principal element of a valve assembly because it is the framework that holds everything together.

The body, the first pressure boundary of a valve, resists fluid pressure loads from connecting piping. It receives inlet and outlet piping through threaded, bolted, or welded joints.

Trim:

The parts (except the body) of control valve that comes into contact with the flowing fluid is known as Trim.
The internal elements of a valve are collectively referred as a valve trim. The trim typically includes a disk, seat, stem, and sleeves needed to guide the stem. The performance of valve is determined by the disk and seat interface.

**Stem:**

*It is a rod extending through the bonnet assembly to permit the positioning the valve plug.*

Stems are typically forged and connected to the disk by threaded or welded joints. For valve designs requiring stem packing or sealing to prevent leakage, a fine surface finish of the stem in the area of the seal is necessary. Typically, a stem is not considered a pressure boundary part.

**Plug:**

*It is the movable part, which provides variable restriction in a port.*

**Cage:**

*A part of a valve trim that surrounds the closure member and may provide flow characterization and/or a seating surface.*

It may also provide stability, guiding, balance, and alignment, and facilitate assembly of other parts of the valve trim.

**Seat:**

*It is the portion of the valve, which a valve plug contact for closure.*

The seat or seal rings provide the seating surface for the disk. In some designs, the body is machined to serve as the seating surface and seal rings are not used. In other designs, forged seal rings are threaded or welded to the body to provide the seating surface.

**Bonnet:**

*The cover for the opening in the valve body is the bonnet.*

In some designs, the body itself is split into two sections that bolt together. Like valve bodies, bonnets vary in design. Some bonnets function simply as valve covers, while others support valve internals and accessories such as the stem, disk, and actuator.

**Actuator.**

*An actuator is a pneumatic hydraulic, or electrically powered device which supplies force and motion to open or close a valve.*

### 1.4. Flow characteristics of control valve

Each valve has a flow characteristic, which describes the relationship between the flow rate and valve travel.
As a valve opens, the flow characteristic, which is inherent to the design of the selected valve, allows a certain amount of flow through the valve at a particular percentage of the stroke. This enables flow regulation through the valve in a predictable manner.

The three most common types of flow characteristics are:

1. Linear
2. Equal percentage
3. Quick opening

**Linear valve characteristics**

This characteristic provides a linear relationship between the valve position and the flow rate.

The flow through a linear valve varies directly with the position of the valve stem.

This flow travel relationship, if plotted on rectilinear coordinates, approximates a straight line, thereby giving equal volume changes for equal lift changes regardless of percent of valve opening.

These valves are often used for liquid level control and certain flow control operations requiring constant gain.

**Equal percentage valve characteristics**

The equal percentage valve plug produces the same percentage change in flow per fixed increment of valve stroke at any location on its characteristic curve.

For example, if 30% stem lift produces 5 gpm and a lift increase of 10% to 40% produces 8 gpm or a 60% increase over the previous 5 gpm, then a further stroke of 10% now produces a 60% increase over the previous 8 gpm for a total flow of 12.8 gpm.
These types of valves are commonly used for pressure control applications and are most suitable for applications where a high variation in pressure drop is expected.

**Quick opening valve characteristics**

A quick opening valve plug produces a large increase in flow for a small initial change in stem travel. Near maximum flow is reached at a relatively low percentage of maximum stem lift.

Quick opening plugs are normally utilized in two position - applications but may be used in some linear valve applications.

This is possible because of its initial linear characteristic at a low percentage of stem travel.

The slope of this linear region is very steep which produces a higher initial gain than the linear plug but also increases the potential instability of the control valve.

**Inherent valve characteristics**

An inherent flow characteristic is the relation between valve opening and flow under constant pressure conditions.

The inherent characteristic of a valve is obtained when there is a constant pressure drop across the valve for all valve positions; the process fluid is not flashing, cavitating or approaching sonic velocity (choked flow); and the actuator is linear (valve stem travel is proportional to the controller output).

Some valves have inherent characteristics that cannot be changed, such as full port ball valves and butterfly valves. For other valve types, such as the globe type, the inherent characteristics can be changed to suit the application.

**Installed Flow Characteristics**

The inherent flow characteristics do not reflect the actual performance of the valve as installed.

The ideal condition of constant valve pressure drop is unlikely to be true and the “operating” characteristics will have deviation from the inherent characteristics and is termed as the “Installed Flow Characteristics”

**Difference between installed and inherent characteristics**

The variations in pressure drop across the valve can be attributed to two basic causes:

1. The pump characteristic which results in an increase in pump head as the flow is reduced;
2. The reduction in line losses as the flow is reduced, causing more and more of the pump head to appear across the valve.

**1.5. Calibration procedure (Control Valve).**

Calibration of control valve is to be done as per following steps.

**Required Material:**

1) Data sheet
2) Portable pneumatic calibrator

Step wise Procedure:

- Ask panel man to put the controller in manual mode for control loop
- Isolate the Control valve from the process.

(WARNING – The Isolation of control valve from the process shall be done by field operator. Careful step shall be done to ensure no upset to the operation.)

- Ask panel man to put the controller in manual mode for control loop
- Isolate the Control valve from the process.
- To calibrate a valve first check the input signal range if it is 0.2 to 1.0 Kg/cm² or different.
- Calculate the span (Difference between higher limit to lower limit=1.0-0.2=.8)
- Now divide it in four equal parts that is **0.2 Kg/cm²** this is 25% of the span.
- Now check the valve travel like 2 inches, 3 inches or any other value.
- Divide it in four equal parts 25% of the travel. That is **0.5 inch** for 2 inch valve travel.
- Apply 25% of the span value+ 0.2= 0.4 Kg/cm² and check is it 25% of travel (0.5 inch) and apply full span value (1 Kg/cm²) and see you get the complete travel (2 inches).
- Follow the table below for this case.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Output Pressure</th>
<th>Stem Travel (2 Inch Full Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 %</td>
<td>0.2 Kg/cm²</td>
<td>0 inch</td>
</tr>
<tr>
<td>25%</td>
<td>0.4 Kg/cm²</td>
<td>0.5 inch</td>
</tr>
<tr>
<td>50%</td>
<td>0.6 Kg/cm²</td>
<td>1 inch</td>
</tr>
<tr>
<td>75%</td>
<td>0.8 Kg/cm²</td>
<td>1.5 inch</td>
</tr>
<tr>
<td>100%</td>
<td>1 Kg/cm²</td>
<td>2 inch</td>
</tr>
</tbody>
</table>

- If you find difference, adjust the spring accordingly.
- After completion of the job ask panel operator to put loops back in normal mode
- Fill the calibration form and file it for future reference.

1.6. Classification of control valve

**ATO/ATC (Air to open/close valves)**

Air to open valves are normally held closed by the spring and require air pressure (a control signal) to open them - they open progressively as the air pressure increases.

Air to close valves are valves which are held open by the valve spring and require air pressure to move them towards the closed position.
The reason for the two types of valves is to allow failsafe operation. In the event of a plant instrument air failure it is important that all control valves fail in a safe position (e.g. an exothermic reactor's feed valves (or, perhaps, just one of the valves) should fail closed (air to open) and its coolant system valves fail open (air to close)).

**Linear/Rotary Valve**

Linear valves, also known as multi-turn valves, have a sliding-stem design that pushes a closure element into an open or closed position by moving plug in a straight line to start, stop, or throttle the flow.

Rotary valve use a closure element that rotates a disc or ellipse about an angular or circular shaft extending across the diameter of an orifice usually through a quarter-turn or 90° range, to block the flow.

**Manually operated/Remote operated**

Closure of the valve can be initiated only from a point local to the valve itself is known as manually operated valve.

Closure of the valve can be initiated from a point remote from the valve itself is known as the remotely operated valve.
Based on plug shapes

Following are the types of valve based on the plug shapes.

- Gate Valves
- Globe Valves
- Plug Valves
- Ball Valves
- Butterfly Valves
- Needle Valves
- Check Valves
- Pressure Relief Valves
- Diaphragm Valves

Based on actuators

Following are the types of valves based on the types of actuators.

Manual: A manual actuator employs levers, gears, or wheels to move the valve stem. Manual actuators are powered by hand.

Pneumatic: Air (or other gas) pressure is the power source for pneumatic valve actuators. Air pressure acts on a piston or bellows diaphragm creating linear force on a valve stem.

Hydraulic: Hydraulic actuators convert fluid pressure into motion. Fluid pressure acting on a piston provides linear thrust for gate or globe valves.

Electric: The electric actuator uses an electric motor to provide torque to operate a valve.

1.7. Valve actuators:

Mechanical

A mechanical actuator functions to execute movement by converting one kind of motion, such as rotary motion, into another kind, such as linear motion. An example is a rack and pinion. The operation of mechanical actuators is based on combinations of structural components, such as gears and rails, or pulleys and chains.

A rack and pinion with two racks and one pinion is used in actuators. An example is pneumatic rack and pinion actuators that can be used to control valves in pipeline transport. The actuators in the figure are used to control the valves of large water pipeline.

In the top actuator, a gray control signal line can be seen connecting to a solenoid valve (the small black box attached to the back of the top actuator), which is used as the pilot for the actuator. The solenoid
valve controls the air pressure coming from the input air line (the small green tube). The output air from the solenoid valve is fed to the chamber in the middle of the actuator, increasing the pressure. The pressure in the actuator's chamber pushes the pistons away. While the pistons are moving apart from each other, the attached racks are also moved along the pistons in the opposite directions of the two racks. The two racks are meshed to a pinion at the direct opposite teeth of the pinion. When the two racks move, the pinion is turned, causing the attached main valve of the water pipe to turn.

**Pneumatic (Diaphragm, piston),**

A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion. Pneumatic energy is desirable for main engine controls because it can quickly respond in starting and stopping as the power source does not need to be stored in reserve for operation.

Pneumatic actuators enable considerable forces to be produced from relatively small pressure changes. These forces are often used with valves to move diaphragms to affect the flow of liquid through the valve.

Advantages

- The benefits of pneumatic actuators come from their simplicity. Most pneumatic aluminum actuators have a maximum pressure rating of 150 psi with bore sizes ranging from \( \frac{1}{2} \) to 8 in., which translate into approximately 30 to 7,500 lb. of force. Steel actuators have a maximum pressure rating of 250 psi with bore sizes ranging from \( \frac{1}{2} \) to 14 in., and they generate forces ranging from 50 to 38,465 lbf.

- Pneumatic actuators generate precise linear motion by providing accuracy, for example, within 0.1 inches and repeatability within .001 inches.

- Pneumatic actuators typical applications involve areas of extreme temperatures. A typical temperature range is -40°F to 250°F. In terms of safety and inspection, by using air, pneumatic actuators avoid using hazardous materials. They meet explosion protection and machine safety requirements because they create no magnetic interference due to their lack of motors.
• In recent years, pneumatics has seen many advances in miniaturization, materials, and integration with electronics and condition monitoring. The cost of pneumatic actuators is low compared to other actuators. According to Bimba Manufacturing, for example, the average pneumatic actuator costs $50 to $150. Pneumatic actuators are also lightweight, require minimal maintenance, and have durable components that make pneumatics a cost-effective method of linear motion.

Disadvantages

• Pressure losses and air’s compressibility make pneumatics less efficient than other linear-motion methods. Compressor and air delivery limitations mean that operations at lower pressures will have lower forces and slower speeds. A compressor must run continually operating pressure even if nothing is moving.

• To be truly efficient, pneumatic actuators must be sized for a specific job. Hence, they cannot be used for other applications. Accurate control and efficiency requires proportional regulators and valves, but this raises the costs and complexity.

• Even though the air is easily available, it can be contaminated by oil or lubrication, leading to downtime and maintenance. Companies still have to pay for compressed air, making it a consumable, and the compressor and lines are another maintenance issue.

Hydraulic

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

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

• Hydraulic actuators are rugged and suited for high-force applications. They can produce forces 25 times greater than pneumatic cylinders of equal size. They also operate in pressures of up to 4,000 psi.

• Hydraulic motors have high horsepower-to-weight ratio by 1 to 2 hp/lb greater than a pneumatic motor.

• A hydraulic actuator can hold force and torque constant without the pump supplying more fluid or pressure due to the incompressibility of fluids.

• Hydraulic actuators can have their pumps and motors located a considerable distance away with minimal loss of power.

Disadvantages

• Hydraulics will leak fluid. Like pneumatic actuators, loss of fluid leads to less efficiency. However, hydraulic fluid leaks lead to cleanliness problems and potential damage to surrounding components and areas.

• Hydraulic actuators require many companion parts, including a fluid reservoir, motors, pumps, release valves, and heat exchangers, along with noise-reduction equipment. This makes for linear motions systems that are large and difficult to accommodate.

Electropneumatic Actuator

Differential pressure is sensed by the same type of liquid-filled diaphragm capsule, which transmits force to the force bar.

If the force bar moves out of position due to this applied force, a highly sensitive electromagnetic sensor detects it and causes an electronic amplifier to send a different amount of electric current to a force coil.

The force coil presses against the range bar which pivots to counteract the initial motion of the force bar. When the system returns to equilibrium, the mill ampere current through the force coil will be a direct, linear representation of the process fluid pressure applied to the diaphragm capsule.

Electrical

An electric actuator is powered by a motor that converts electrical energy into mechanical torque. The electrical energy is used to actuate equipment such as multi-turn valves. It is one of the cleanest and most readily available forms of actuator because it does not directly involve oil or other fossil fuels.
Advantages

- Electrical actuators offer the highest precision-control positioning. An example of the range of accuracy is +/- 0.000315 in. and a repeatability of less than 0.0000394 in. Their setups are scalable for any purpose or force requirement, and are quiet, smooth, and repeatable.

- Electric actuators can be networked and reprogrammed quickly. They offer immediate feedback for diagnostics and maintenance.

- They provide complete control of motion profiles and can include encoders to control velocity, position, torque, and applied force.

- In terms of noise, they are quieter than pneumatic and hydraulic actuators.

- Because there are no fluids leaks, environmental hazards are eliminated.

Disadvantages

- The initial unit cost of an electrical actuator is higher than that of pneumatic and hydraulic actuators. According to the example from Bimba Manufacturing, an electrical actuator can range from $150 to greater than $2,000 depending on its design and electronics.

- Electrical actuators are not suited for all environments, unlike pneumatic actuators, which are safe in hazardous and flammable areas.

- A continuously running motor will overheat, increasing wear and tear on the reduction gear. The motor can also be large and create installation problems.

- The motor chosen locks in the actuator’s force, thrust, and speed limits to a fixed setting. If a different set of values for force, thrust, and speed are desired, the motor must be changed.

1.8. Valve Positioners:

For many applications, the 0.2 to 1 bar pressure in the diaphragm chamber may not be enough to cope with friction and high differential pressures. A higher control pressure and stronger springs could be used, but the practical solution is to use a positioner.
This is an additional item (see Figure), which is usually fitted to the yoke or pillars of the actuator, and it is linked to the spindle of the actuator by a feedback arm in order to monitor the valve position. It requires its own higher-pressure air supply, which it uses to position the valve.

![Diagram of a mechanical valve positioner](image)

**Fig. 6.6.11 Basic pneumatic positioner fitted to actuator pillars (valve not shown)**

**Mechanical**

Mechanical Valve Positioner is a force balance device which ensures the position of the plug, which is directly proportional to the controller output pressure.

The Positioner compares the forces generated by the control signal and the control valve stem through the motion connector and the feedback cam, and accordingly it feeds or bleeds the air going to the valve actuator.
The instrument air signal is applied to the signal diaphragm. An increase in signal will drive the diaphragm and flapper-connecting stem to the right.

The flapper-connecting stem will then open the supply flapper admitting supply pressure into the output which is connected to the actuator-diaphragm. The exhaust flapper remains closed when the flapper connecting stem is deflected to right.

The effect of increasing signal is to increase the pressure in the actuator. This increased pressure in the actuator drives the valve stem downward and rotates the positioner lever clockwise.

This clockwise rotation of the lever results in a compression of range spring through cam. When the valve stem reaches the position called for by the controller, the compression in the range spring will give a balance force resulting the closure of both the flapper.

If the control signal is decreased, the force exerted by the signal diaphragm will also decrease and the force from the range spring will push the flapper-connecting stem to the left, opening the exhaust flapper. This causes a decrease actuator diaphragm pressure and allows the valve stem to move upward until a new force balance is established.

**Electrical**

Electric valve positioners receive electric (usually 4-20 mA) signals. They perform the same function as pneumatic positioners do (supplies the valve actuator with the correct air pressure to move the valve to the required position.), but use electricity instead of air pressure as an input signal. There are three electric actuation types: single-phase and three-phase alternating current (AC), and direct current (DC) voltage.

A positioner ensures that there is a linear relationship between the signal input pressure from the control system and the position of the control valve. This means that for a given input signal, the valve will always
attempt to maintain the same position regardless of changes in valve differential pressure, stem friction, diaphragm hysteresis and so on.

A positioner may be used as a signal amplifier or booster. It accepts a low pressure air control signal and, by using its own higher pressure input, multiplies this to provide a higher pressure output air signal to the actuator diaphragm, if required, to ensure that the valve reaches the desired position.

Some positioners incorporate an electropneumatic converter so that an electrical input (typically 4 - 20 mA) can be used to control a pneumatic valve.

Some positioners can also act as basic controllers, accepting input from sensors.

1.9 Calibration Procedure (Positioner):

Calibration of the valve positioner can be performed at the same time as the I/P in a loop calibration. Simply tee in the pressure module at the I/P outlet in the I/P calibration. Record the valve position at each test point.

If calibrating the valve positioner separately, connect an input test pressure regulator or hand pump, and monitor the input pressure applied with a pressure standard. If there is no supply air, connect the required supply air to the positioner. Apply the pressure for the desired test points and record valve position.

For example, assume our valve positioner is 3-15 psig input = 0-100% valve position. In this case, apply 3.0, 6.0, 9.0, 12.0, and 15.0 psig. The expected valve positions should be 0, 25, 50, 75, and 100%, respectively.

The valve position indicator on the stem usually marks off in 5% or 10% increments. Therefore, a best estimate of the valve position may be all you can obtain. In other cases, a valve position detector provides a remote indication to a DCS. In such cases, ensure both indicators are working properly.

Many organizations do not require calibration of valve positioners for these reasons. There's much documentation that control valve positioner performance is responsible for significant loss in system efficiency and, therefore, increased costs.

To provide guidance on methods for testing positioners and control valve performance, ISA has developed a standard, ANSI/ISA-75.25.01-2000, Test Procedure for Control Valve Response Measurement for Step Inputs.

As to control valve calibration, the process is similar to positioner calibration in that one applies a pressure signal to the actuator and then tallies the resulting valve position. This step can take place with the positioner calibration, if applicable, and it can happen in conjunction with I/P calibration.

Remember to ensure the system is in a safe condition if performing the calibration in the field. In addition, know the correct action, direct or reverse, and fail position before starting.