Control & Actuated Valve

CONTENT (PART 1)

1) What valve means?
2) How it’s work?
3) Classification of valves?

Introduction to Valves

- Mechanical devices specifically designed to direct, start, stop, mix or regulate the flow, pressure or temperature of a process fluid.
- Manufactured from various materials, mostly made from steel, iron, plastic, brass, bronze and special alloys.

Valves Classification According To;

1) Function
2) Application
3) Motion

Valves Classification According To Function

- Categorized into **three** areas:

i) On-Off Valves

ii) Non return Valves

iii) Throttling Valves

- Specific valve-body designs may fit into one, two, or all three category.

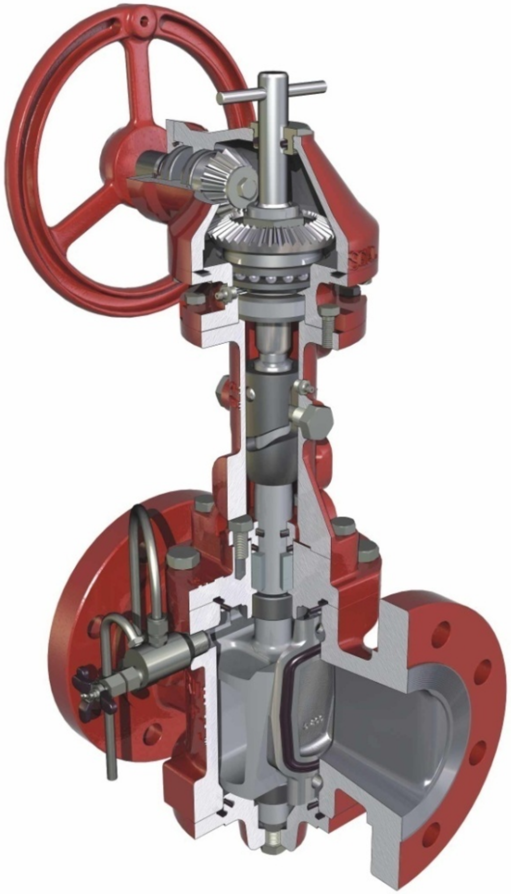
Valves Classification According To Function

1) On-Off Valves

- **Start or stop** the flow of the medium through the process.
- Example: gate, plug, ball and pressure-relief valves.
- Can be **hand-operated** or automated with the addition of an **actuator**.

Valves Classification According To Function

(On-Off Valves)



Valves Classification According To Function

(On-Off Valves)

- Used in **mixing applications** where a number of fluids are combined for a predetermined amount of time (exact measurements are not required).
- Used for **immediate shut down** of a system when an emergency situation occurs.

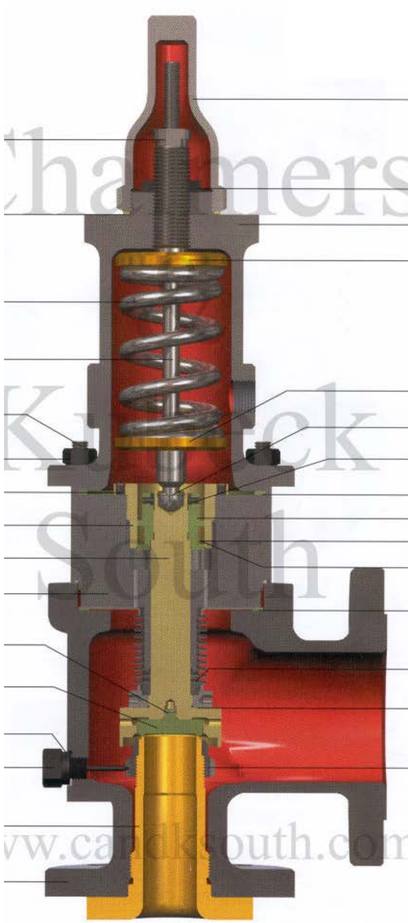
Valves Classification According To Function

(On-Off Valves)

- Pressure-relief valves are **self-actuated** on-off valves that open only when a preset pressure is surpassed.
- Used for guarding against **overpressurization** of a liquid service.
- Applied in gas applications where overpressurization of the system shows a **safety or process hazard** and must be vented.

Valves Classification According To Function

(On-Off Valves)



Valves Classification According To Function

2) Non return Valves

- Allow the fluid to flow **only** in the desired direction.
- Any flow or pressure in the opposite direction is **mechanically restricted** from occurring.
- All **check valves** are non return valves.

Valves Classification According To Function

(Non-return Valves)

Valves Classification According To Function

(Non-return valves)

- Backflow of fluid is prevented to ensure the **safety of equipment** and the **desired dynamic** of the process.
- Applied in process systems that have varying pressures, which must be kept separated.

Valves Classification According To Function

3) Throttling Valves

- Used for **regulating** the flow, temperature or pressure of the service.
- Can be **moved to any position** within the stroke of the valve and hold that position, including the fully-open or fully-closed positions.

Valves Classification According To Function

(Throttling valves)

- Also **provided with actuation system** for greater thrust and positioning capability (automatic control).
- Example: pressure regulator varies the valve’s position to maintain constant pressure downstream (close to decrease and open to increase the pressure).
- **Control valves** are valves that are capable of varying flow conditions to match the process requirements (always equipped with actuators).

Valves Classification According To Function

(Throttling Valves)

Valves Classification According To Application

Categorized into **three**:

1) General Service Valves
2) Special Service Valves
3) Severe Service Valves

Valves Classification According To Application

1) General Service Valves

- Designed for the majority of the **commonplace applications** that have lower-pressure ratings, moderate-temperature ratings, noncorrosive fluids and common pressure drops that do not result in cavitation or flashing.
- Had some degree of **interchangeability and flexibility** for wider range of applications.

Valves Classification According To Application

2) Special Service Valves

- Designed for a **single application** that is outside normal process applications (custom-engineered valves).
- Handled a demanding temperature, high pressure or a corrosive medium.

Valves Classification According To Application

3) Severe Service Valves

- Equipped with **special features** to handle volatile applications and high pressure drops (highly engineered trims).
- **Special actuation** may be required to overcome the forces of the process.

Valves Classification According To Motion

Categorized into **two**:

1) Linear-motion Valves
2) Rotary-motion Valves

Valves Classification According To Motion

1) Linear-motion Valves

- Had a **sliding-stem design** that pushes a closure element into an open or closed position.
- Simple design, easy maintenance, and versatile with various sizes, pressure class and design options.
- Example: gate, globe, diaphragm, three-way.

Valves Classification According To Motion

(linear-motion valves)

Valves Classification According To Motion

2) Rotary-motion Valves

- Used a **closure element that rotates** through a quarter-turn range to open and block the flow.
- Limited to certain pressure drops.
- Prone to **cavitations** and **flashing problems**.

Valves Classification According To Motion

(Rotary-motion valves)

Common Piping Nomenclature

- Heavily influenced by imperial system, ANSI, e.g. psi for pressure, nominal pipe size (NPS) for valve, inches for pipes
- Metric system widely used in Asia, e.g. kpa or bar for nominal pressure (PN), nominal diameter (DN), mm for pipes

Common Piping Nomenclature

NPS versus DN

inches	millimeters
0.25	6
0.5	15
1.0	25
2.0	50
4.0	100
8.0	200
16.0	400

ANSI Pressure versus PN

psi	bar
150	16
300	40
600	100
900	160
1500	250
2500	400
4500	700

Note: PN correlates to DIN (Deustche Industrie Norme) pressure-temperature rating standards, which may vary significantly from ANSI pres.-temp. ratings.

CONTENT (PART 2)

1) Control Valve
2) Globe Valve
3) Gate Valve
4) Ball Valve
5) Needle Valve
6) Diaphragm Valve
7) Solenoid Valve
8) Valve Actuators
9) Valve Positioners

1) Control Valves

- The most common **final control elements.**
- Function- **control system** by adjusting **the flows** that affect the controlled variable.
- Final control elements include control valves, metering pumps, dampers and louvers, variable pitch fan blades, and electrically driven control devices.
- There are many different type of control valve, difficult to classify them

Control Valves

- The **control valve** is the most widely used type of final control element and it must perform satisfactorily with a **minimum amount of maintenance attention**, even in severe conditions of temperature, pressure, corrosion and contamination .

Control Valves

- A control valve functions as **variable resistance** in a pipeline. It provides pressure drop, called **throttling**, which limits the flow through a pipeline.

- There are many different kinds of control valves in common use:
  - globe valves,
  - butterfly valves,
  - ball valves,
  - eccentric disc valves and
  - diaphragm valves

VALVE

- Can operated

1) Manual (Human)
2) Automatic (Actuators)

➢ Hydraulics
➢ Air (pneumatic)
➢ Electrical

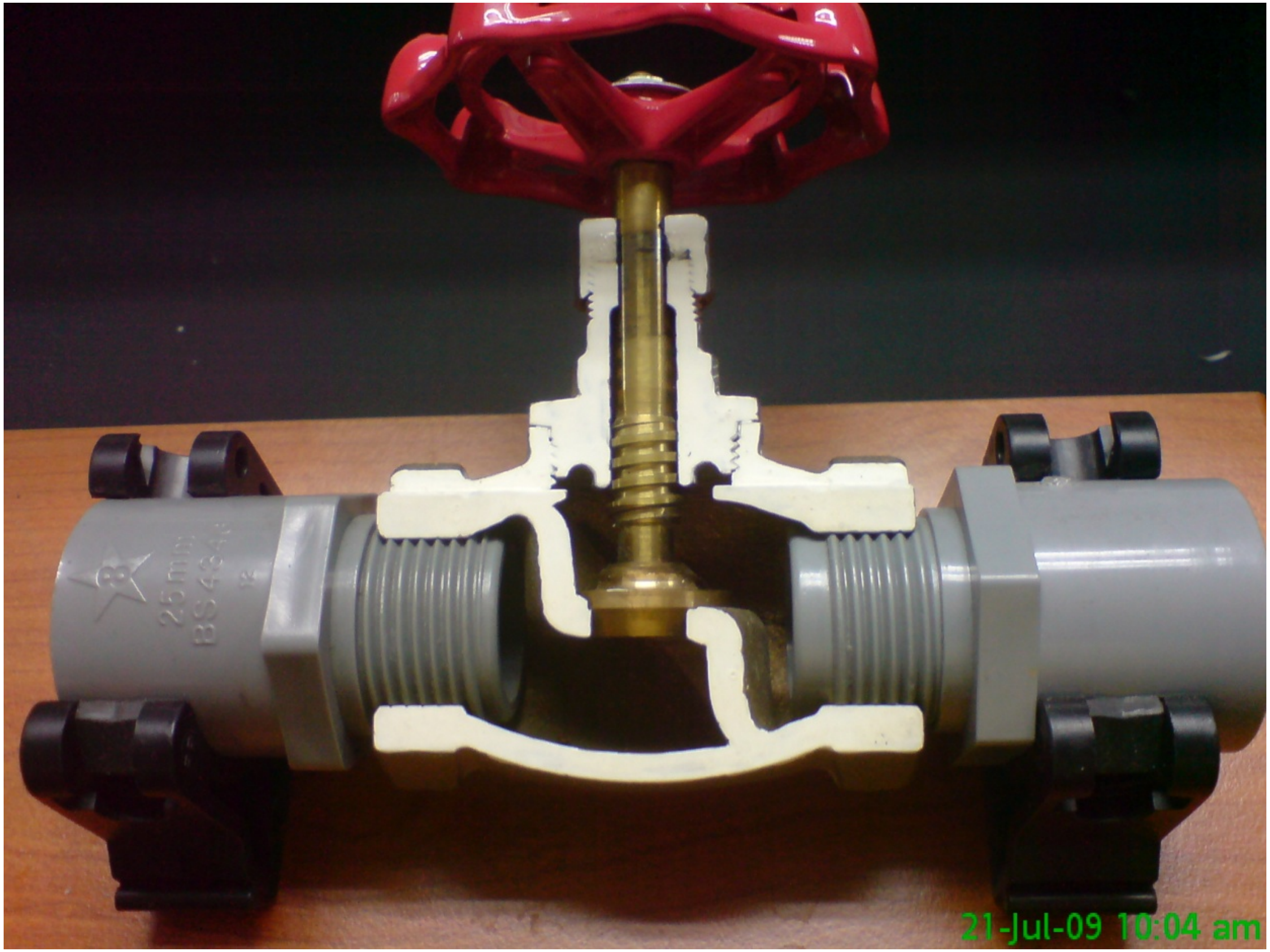
2) Globe Valve

- The valve is devided into 2 general areas

i) Actuators- is the part of the valve that converts the electrical/ pressure energy input to the valve into mechanical motion (stem) to increase or decrease the flow restriction

ii) Body- contains and regulates the fluid flow

Globe Valve



Globe Valve

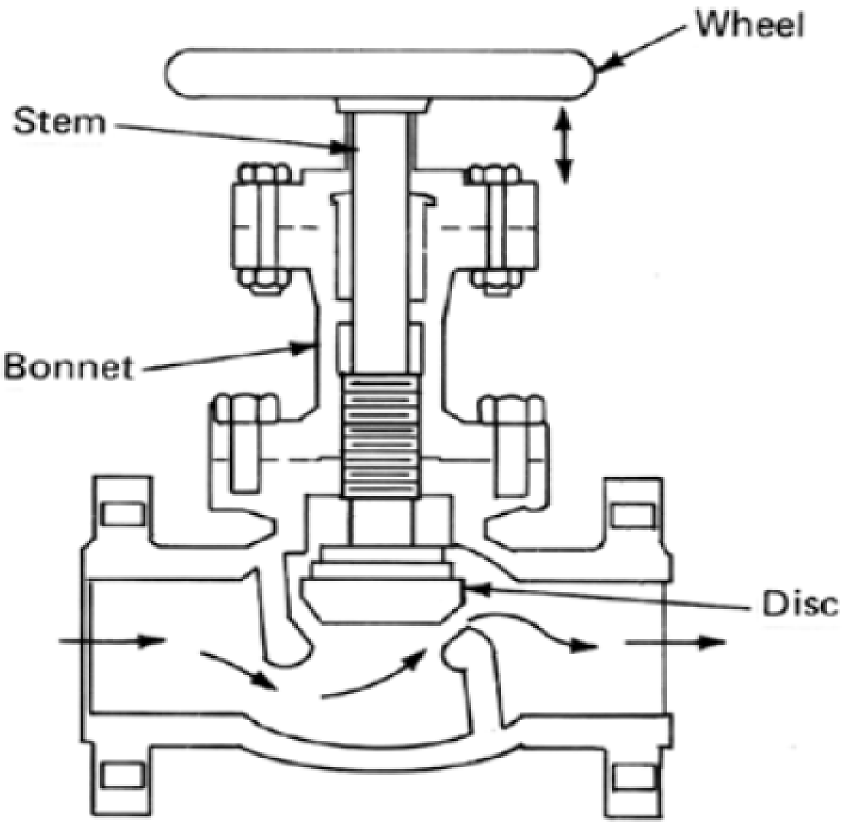
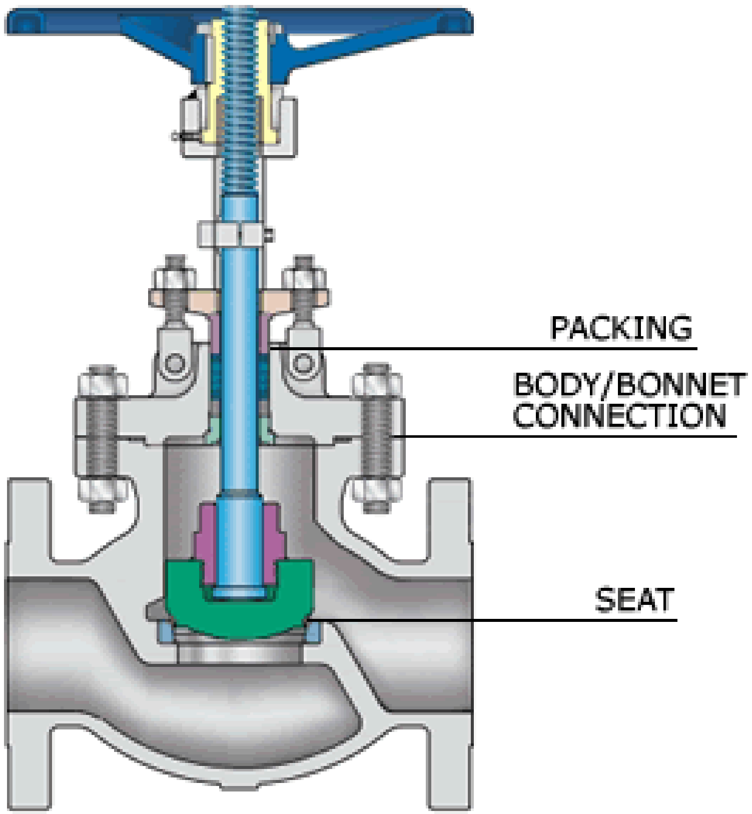


Figure 2: Globe Valve



Globe Valve

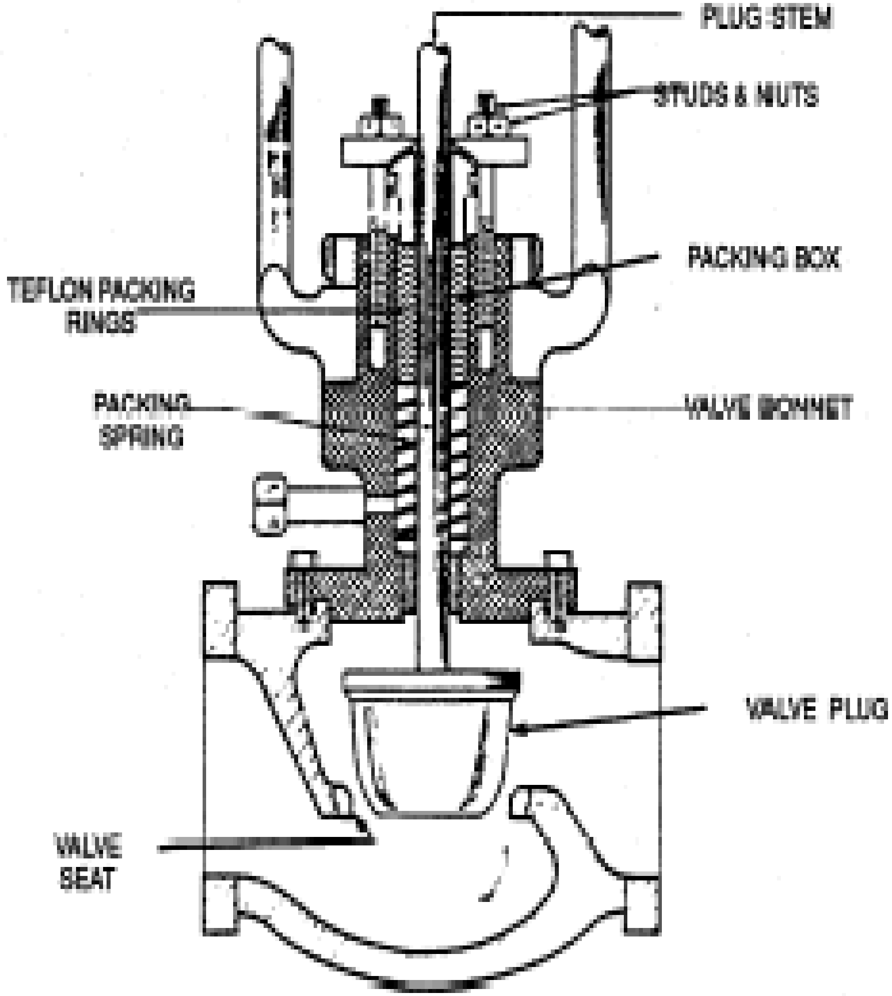
- A type of valve for regulating flow in a pipeline, consisting of a **movable disk-type element** and a **stationary ring seat** in a generally spherical body.
- Named for their spherical body shape with the two halves of the body being separated by an internal baffle. This has an opening that forms a seat onto which a **movable plug (also called a disc)** can be screwed in to close the valve.
- The disc is connected to a stem which is operated by screw action in manual valves. Typically, **automated valves use sliding stems**.

Globe Valve

- Automated globe valves have a **smooth stem** rather than threaded and are opened and closed by an **actuator assembly**.

Globe Valve

- The **bonnet assembly** is the part of the valve body through which the valve plug stem moves.



Globe Valve

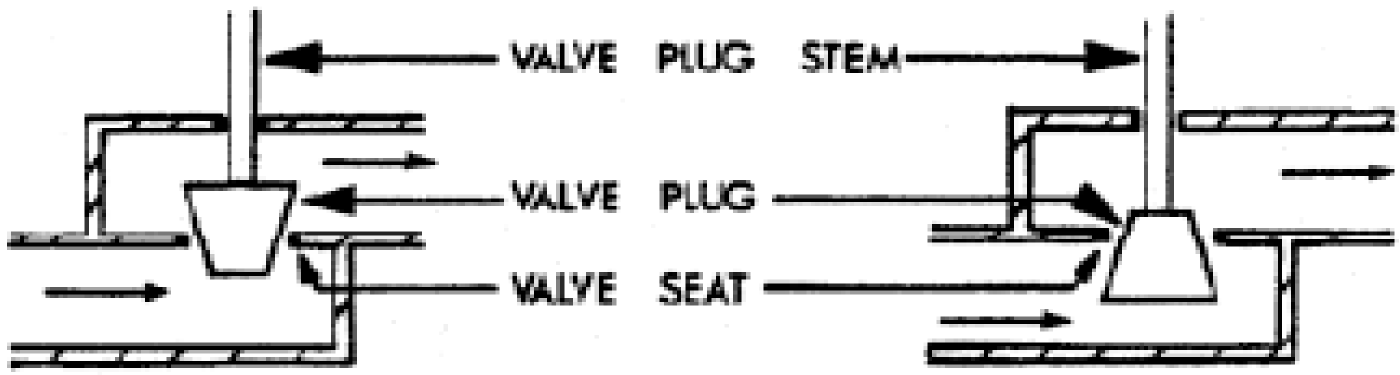
- The bonnet provides a means of **sealing against leakage** along the stem by using packing in the packing box. Force is exerted by the stud and nuts in the packing material to squeeze it against the walls of the packing box and the valve stem providing an effective seal.
- The valve stem extends through the bonnet to **permit positioning of the valve plug**, and therefore provide a variable restriction to the fluid flow.

Globe Valve

- Globe valve bodies can be classified as :

➢ **direct acting** valve body - a downward movement of the valve plug stem results in the **valve closing.**

➢ **reverse acting** valve body - a downward movement of the valve plug stem results in the **valve opening**.



a) Direct Acting

(b) Reverse Acting

Globe Valve

- A globe valve can contain either one or two plugs. When there is only **one plug/disc**, the valve is called **single ported globe valve**.
- When there are **two plugs**, it is called a **double-ported globe valve**.

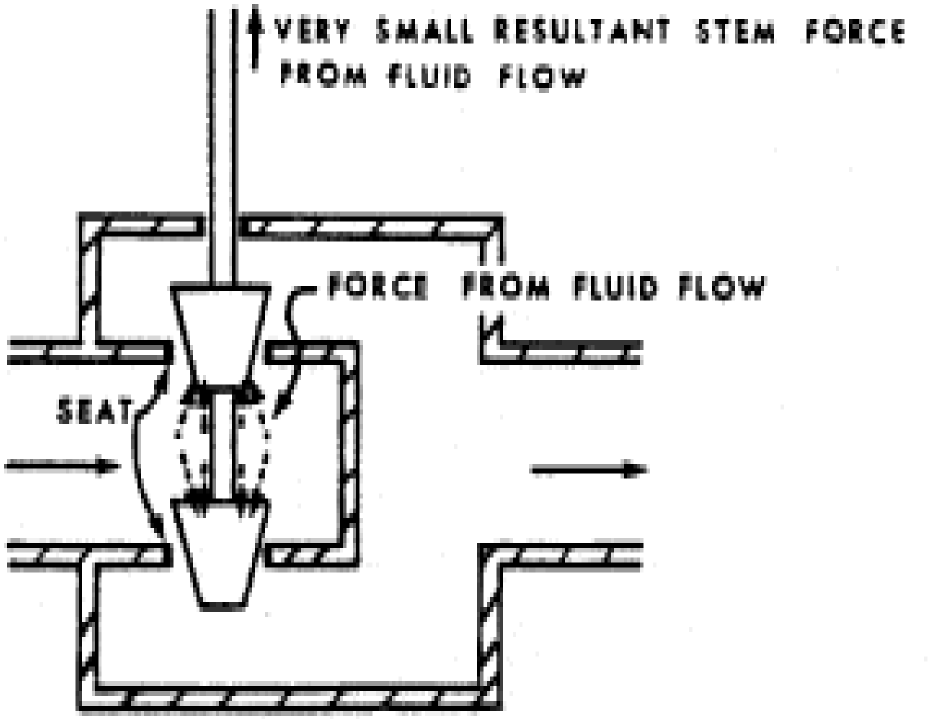


Figure 16: Double Seated Globe Valve.

Globe Valve

- The double-ported valve arrangement produces almost **no unbalanced force** on the valve stem.

- The fluid flows through the valve ports in opposite directions and therefore generates forces that offset each other.

- As a result, only a relatively **small actuator force** is needed for positioning the valve plugs.

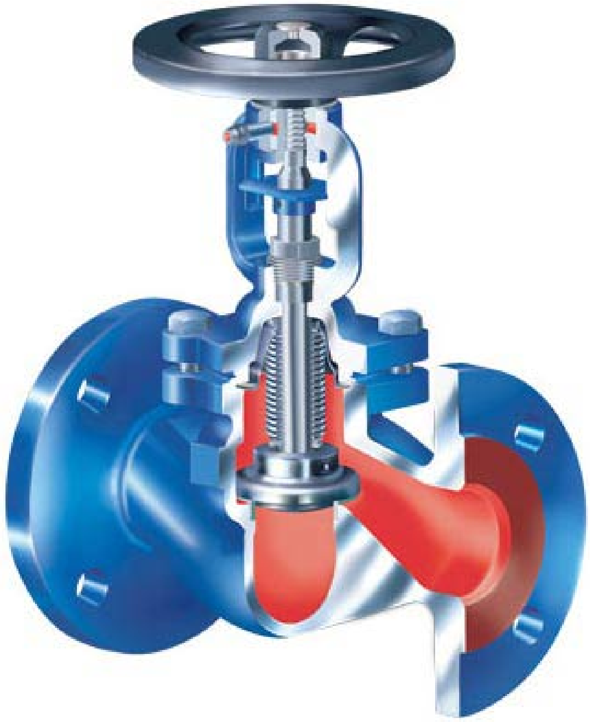
- This makes the double-ported globe valve suitable for **high pressure applications**.

Globe Valve

- Globe valves are used for applications requiring **throttling and frequent operation**.

- Globe valves are the **most frequently encountered** control valves in process plants.

Globe Valve



3) Gate Valve

- Used when a **straight-line flow of fluid** and minimum restriction is desired.
- The gate is usually **wedge shaped**. When the valve is wide open, the gate is fully drawn up into the valve, leaving an opening for flow through the valve the same size as the pipe in which the valve is installed.
- Therefore, there is **little pressure drop** or flow restriction through the valve.
- Gate valves are **not suitable for throttling purposes** since the control of flow would be difficult due to valve design and since the flow of fluid slapping against a partially open gate can cause extensive damage to the valve.

Gate Valve

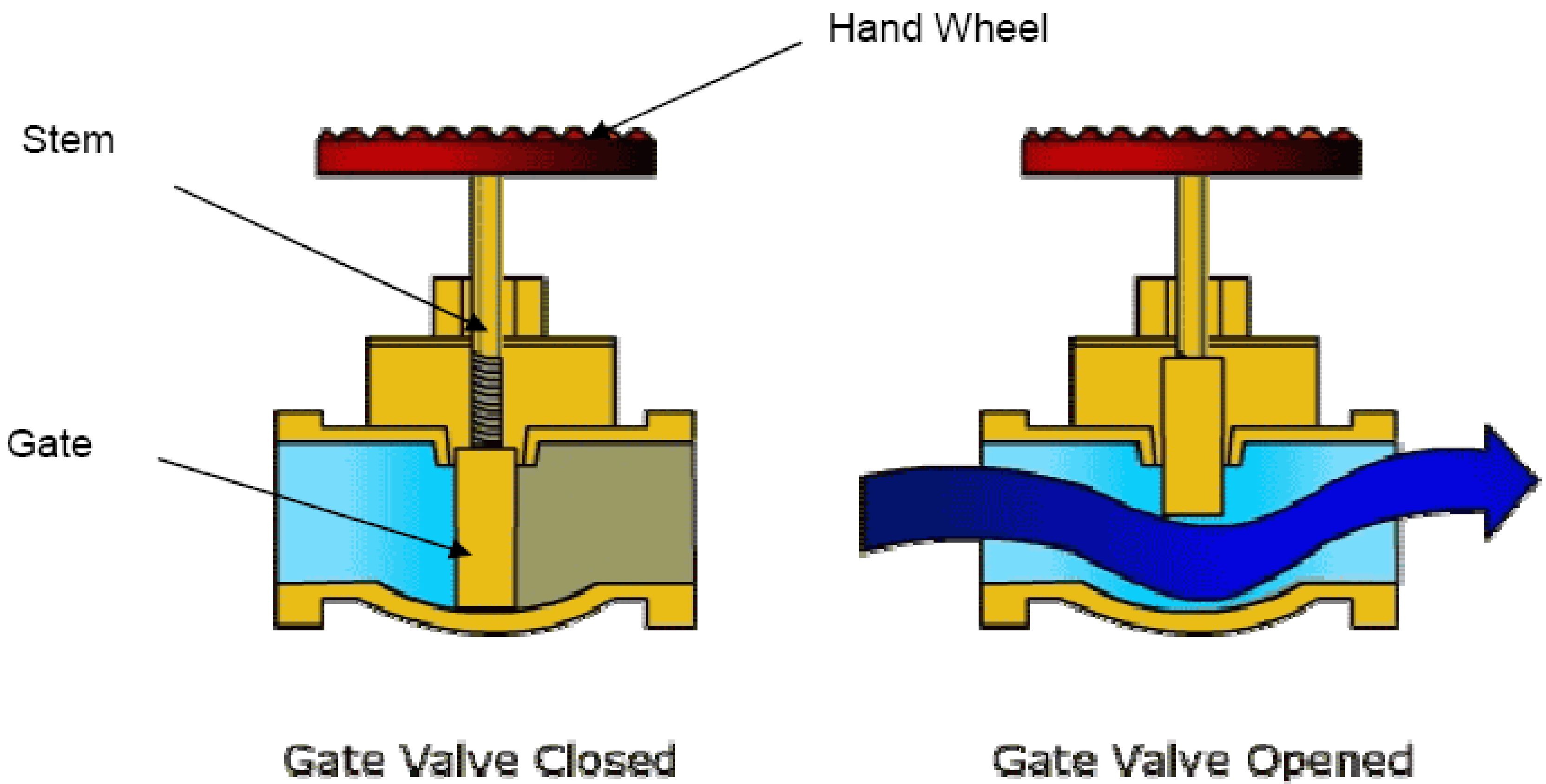
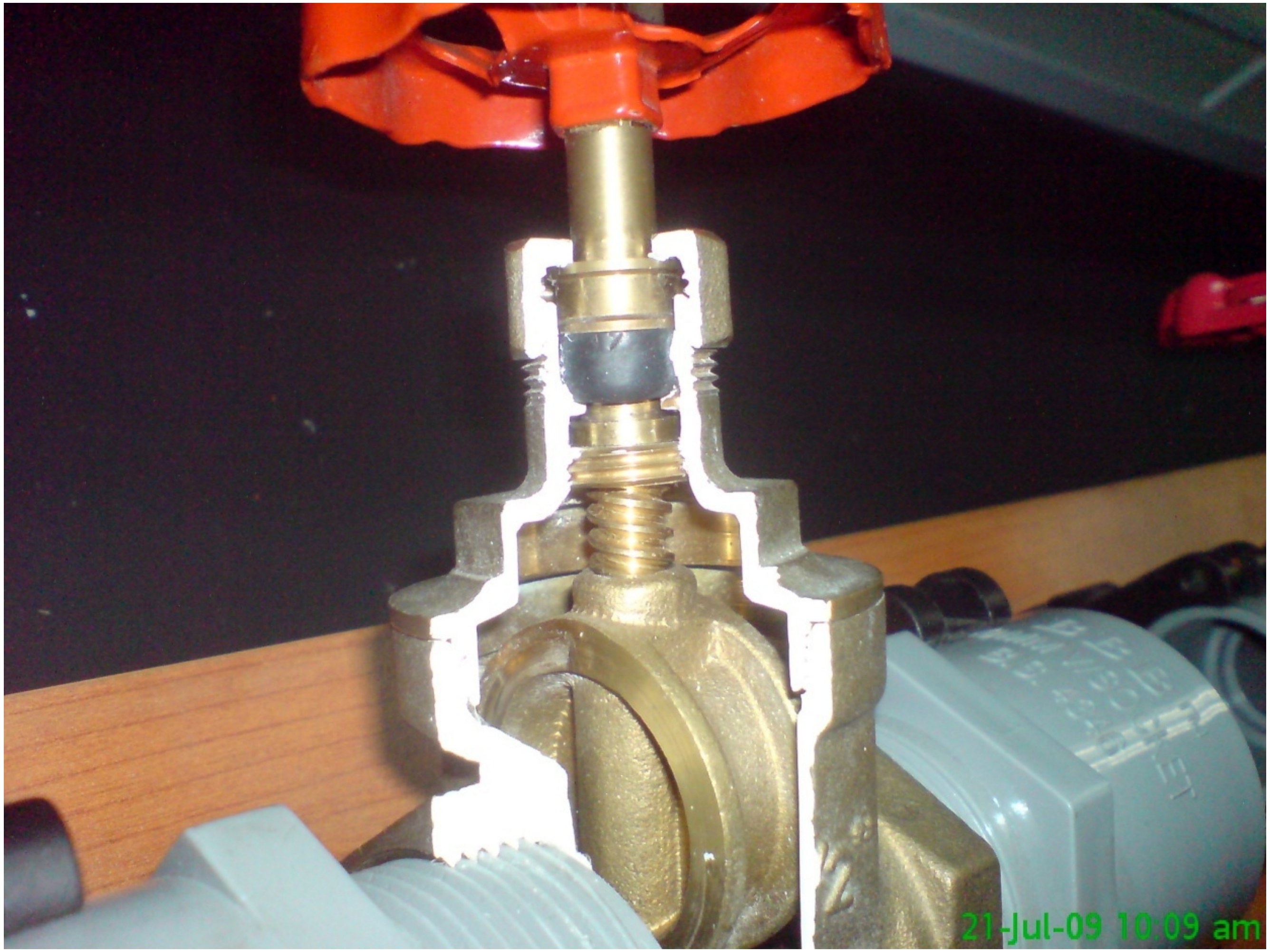


Figure 1: Gate valve opened and closed

Gate Valve



Gate Valve

- Can be classified as:

1) rising stem valves - the stem attached to the gate; the gate and stem rise and lower together as the valve is operated.

Gate Valve

2) non-rising stem valves - the stem is threaded on the lower end into the gate. As the hand wheel on the stem is rotated, the gate travels up or down the stem on the threads, while the stem remains vertically stationary.

4) Ball Valve

- Stop valves that use **a ball** to stop or start the flow of fluid.
- 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, which requires only a 90-degree rotation of the hand wheel for most valves, the ball is **rotated so the hole is perpendicular to the flow openings** of the valve body, and flow is stopped.

Ball Valve

Ball Valve

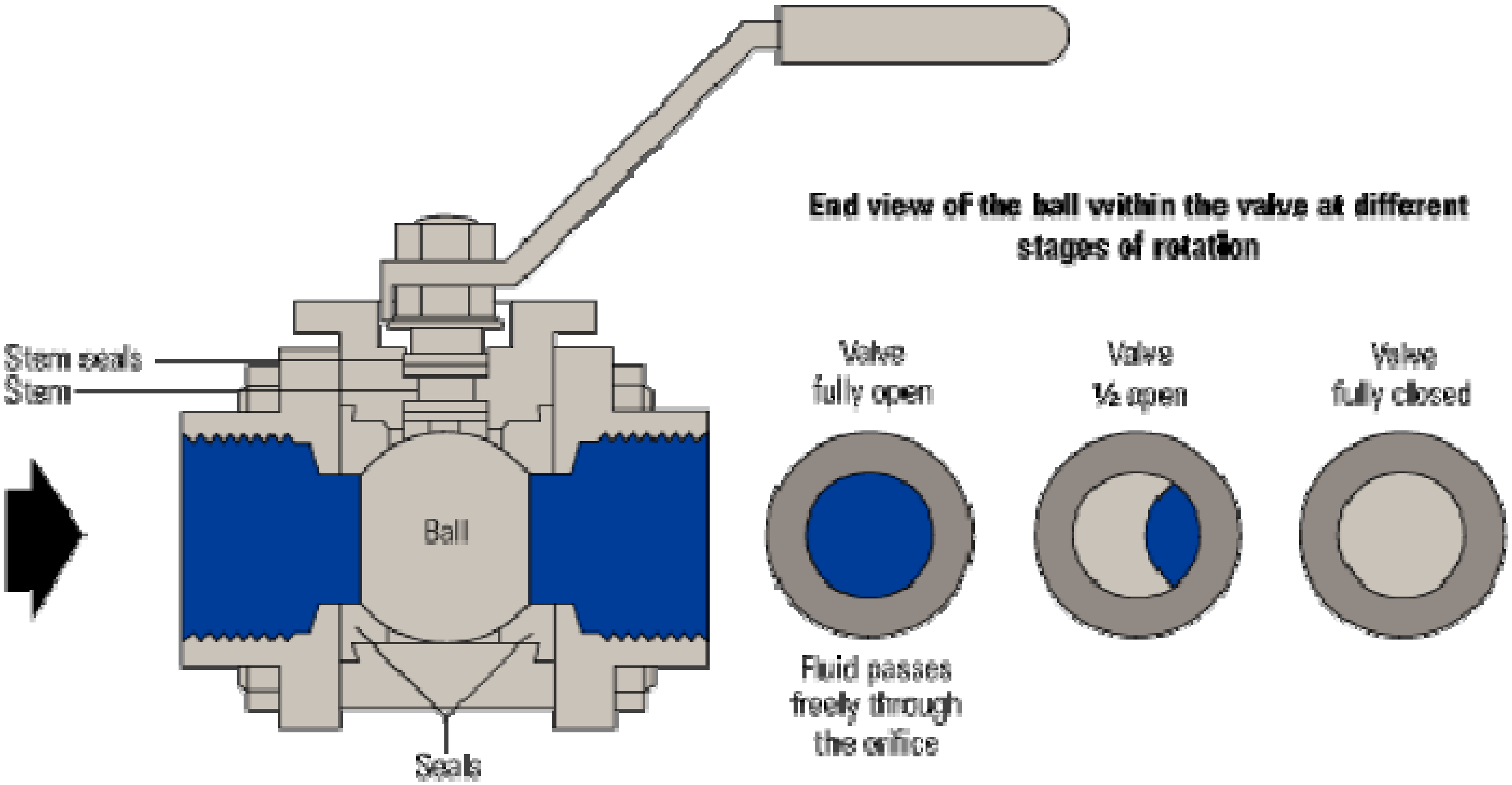


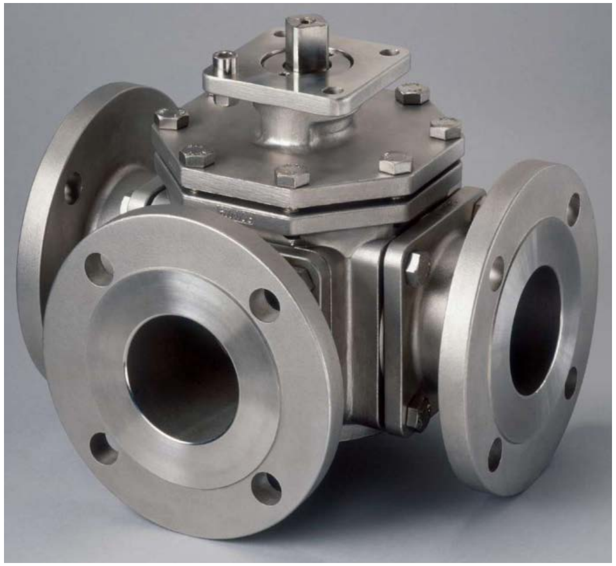
Figure 3: Ball valve

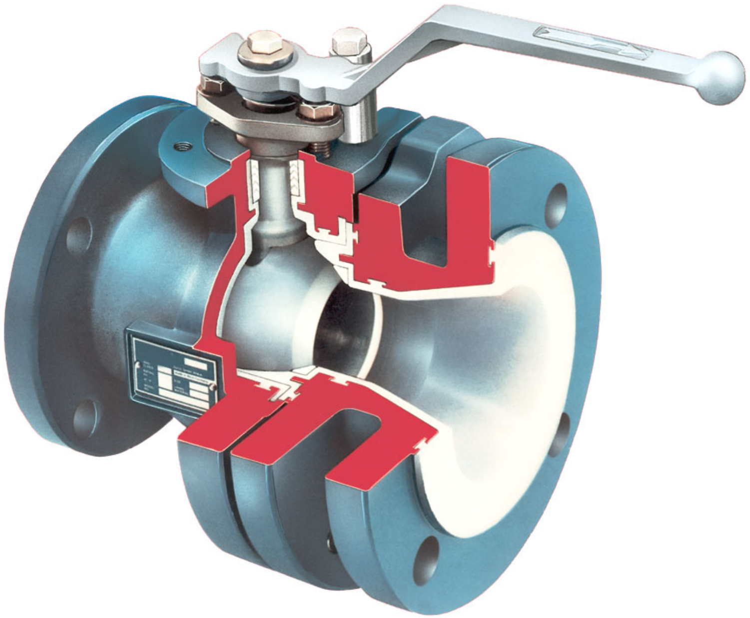
Ball Valve

- Most ball valves are of the **quick-acting type** (requiring only a 90-degree turn to operate the valve either completely open or closed), but many are **planetary gear operated**.
- This type of gearing allows the use of a relatively **small hand wheel** and operating force to operate a fairly **large valve**. The gearing does, however, increase the operating time for the valve.

Ball Valve

- Some ball valves contain a **swing check** located within the ball to give the valve a check valve feature.
- Ball valves are normally found in the following systems aboard ship: seawater, sanitary, trim and drain, air, hydraulic, and oil transfer.





5) Needle Valve

- Has a relatively **small orifice** with a long, tapered, conical seat. A **needle-shaped plunger**, on the end of a screw, exactly fits this seat.
- As the screw is turned and the plunger retracted, flow between the seat and the plunger is possible; however, until the plunger is completely retracted the fluid flow is significantly impeded.
- **Precise regulation** of the flow rate is possible.

Needle Valve

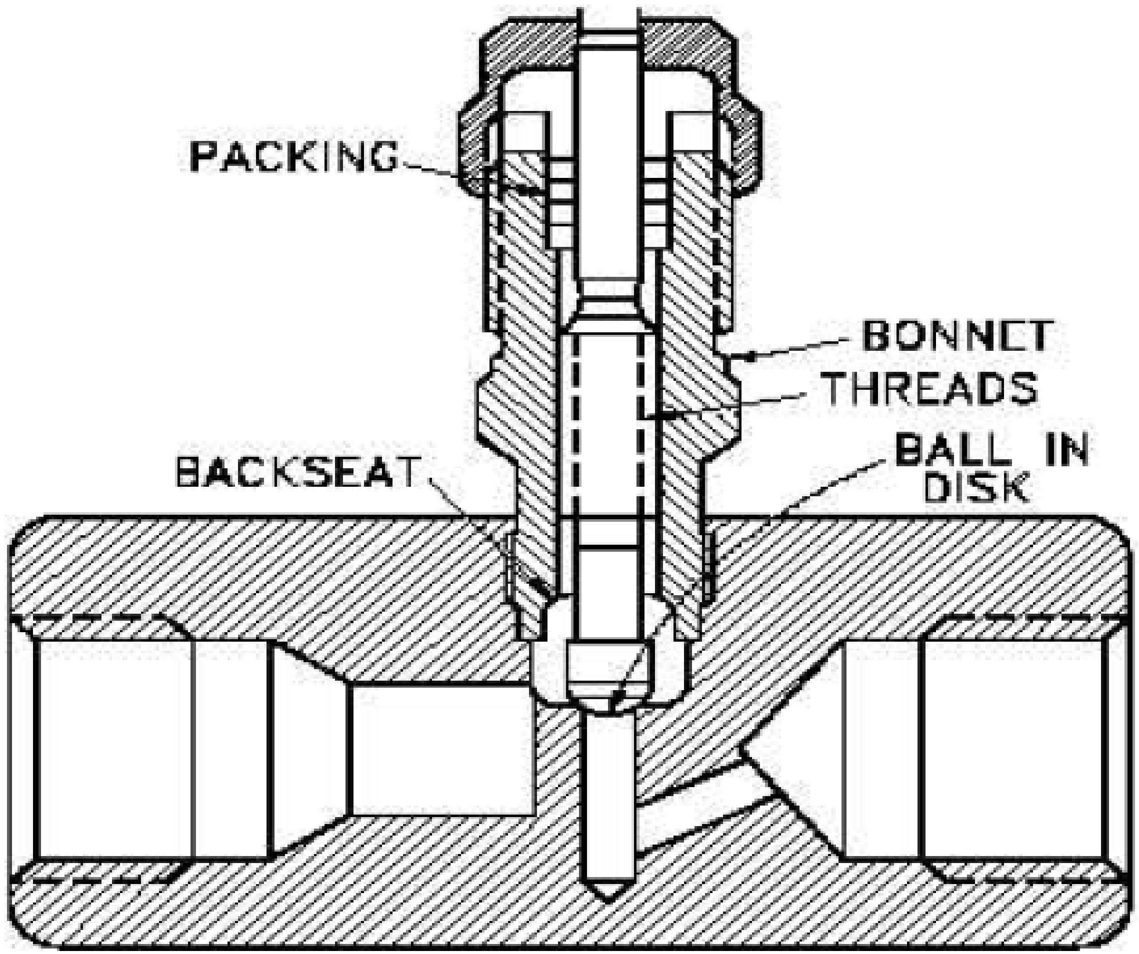
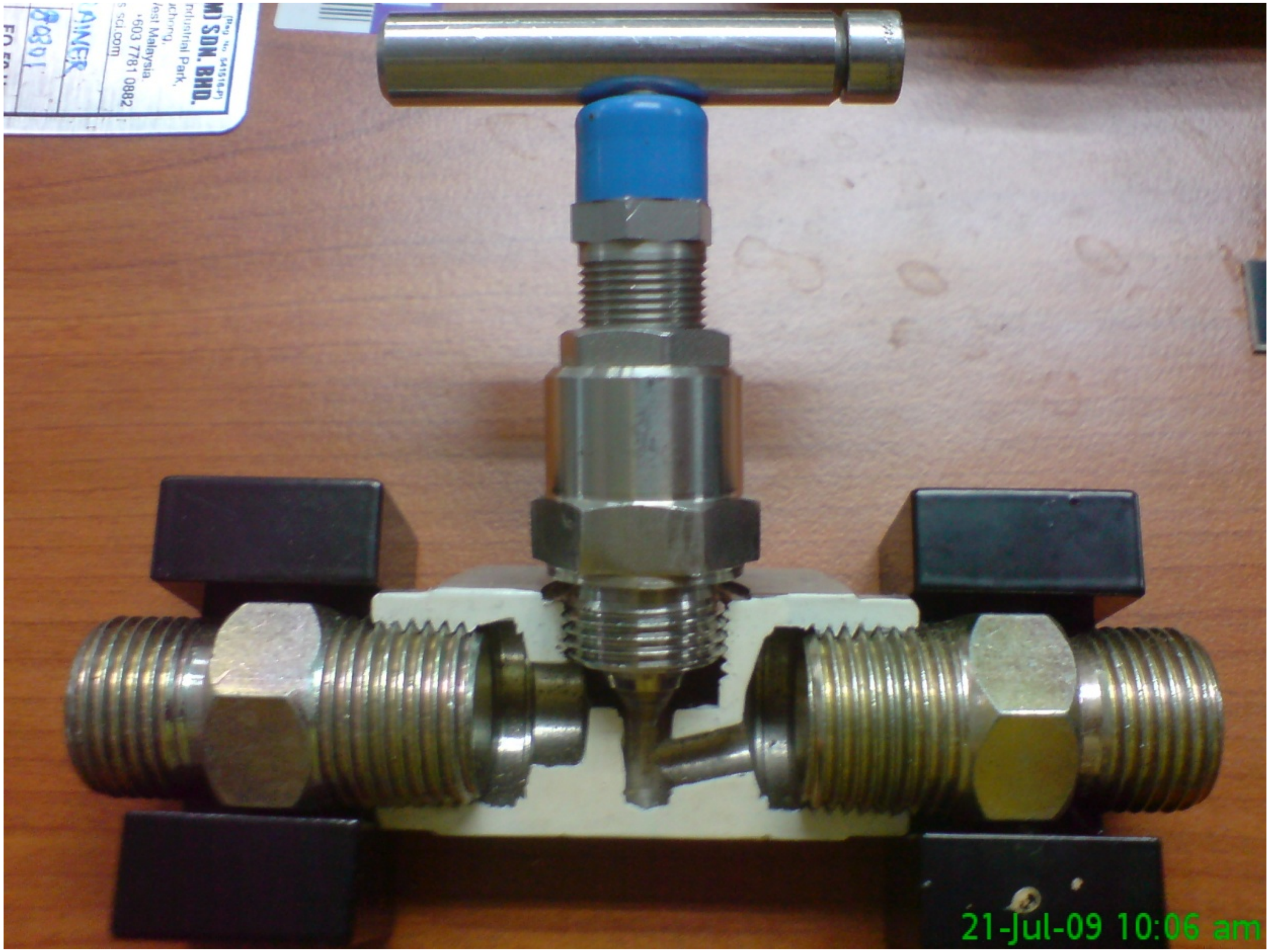
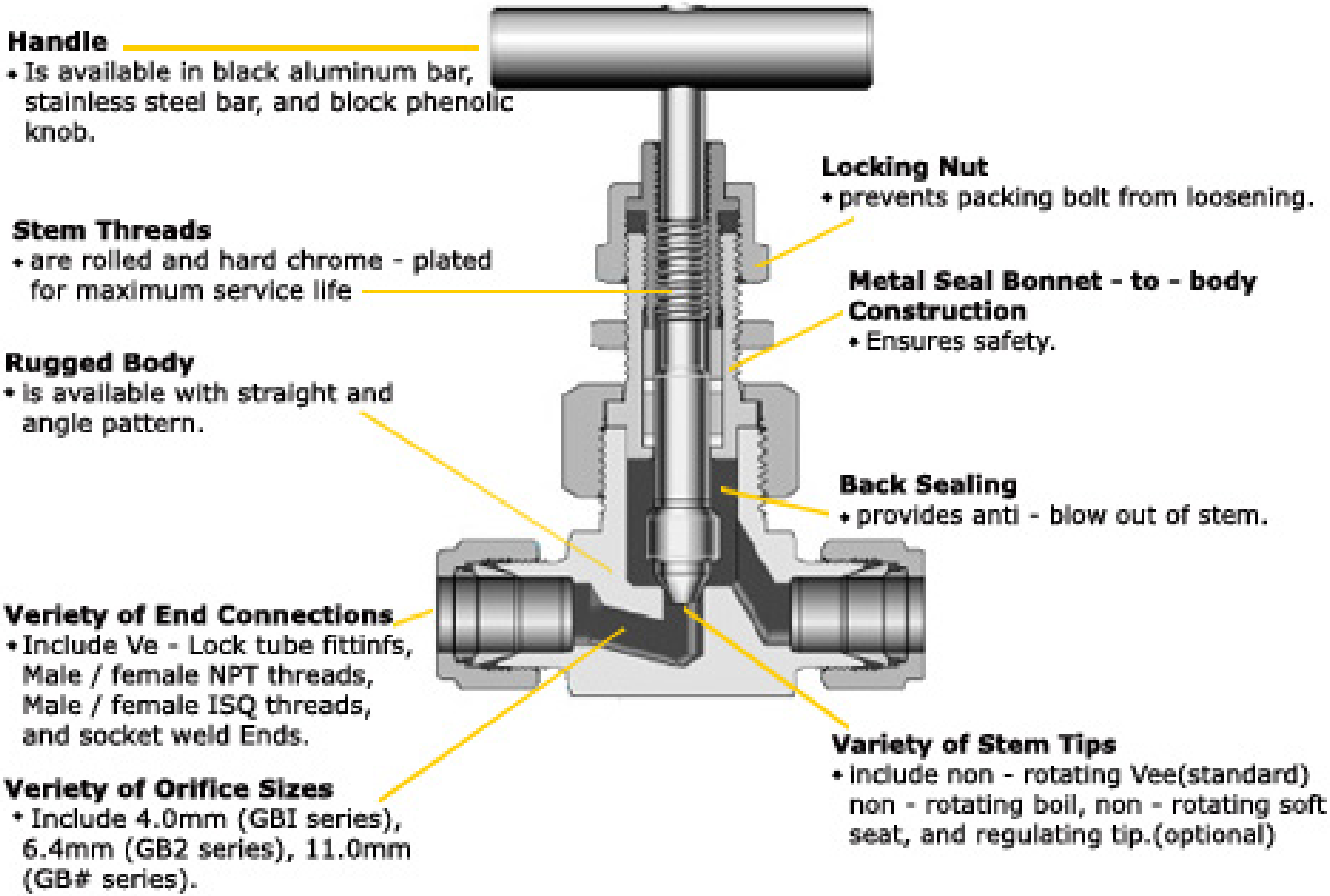


Figure 4: Needle Valve

Needle Valve



Needle Valve

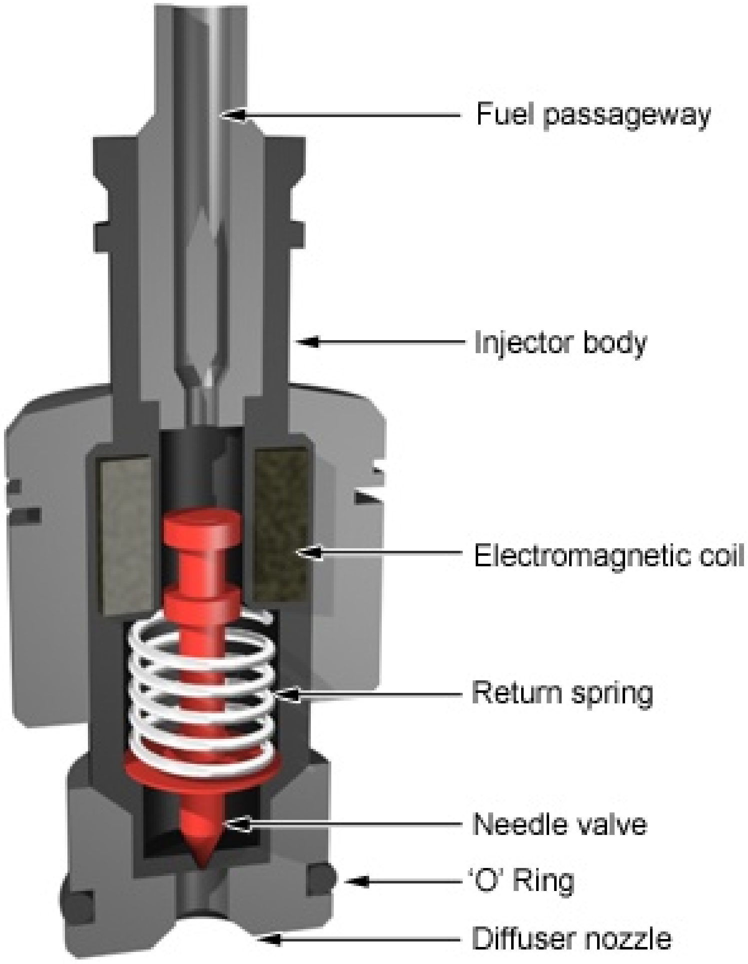


Needle Valve

- Used in **flow metering applications**, especially when a constant, calibrated, low flow rate must be maintained for some time, such as the idle fuel flow in a carburetor.

- Since flow rates are low and many turns of the valve stem are required to completely open or close, needle valves are **not used for simple shutoff applications**.

Needle Valve



Needle Valve

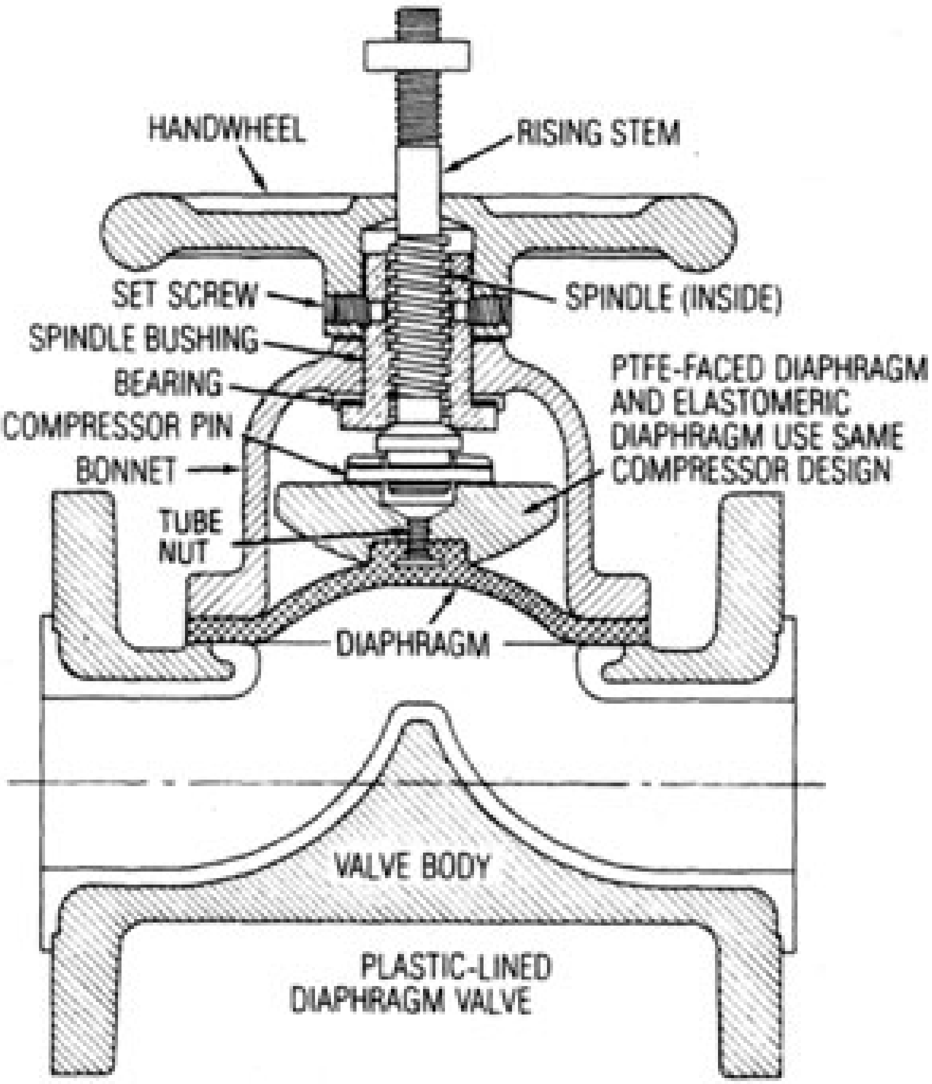
- Since the orifice is small and the force advantage of the fine-threaded stem is high, needle valves are usually easy to shut off completely, with merely **"finger tight" pressure**.

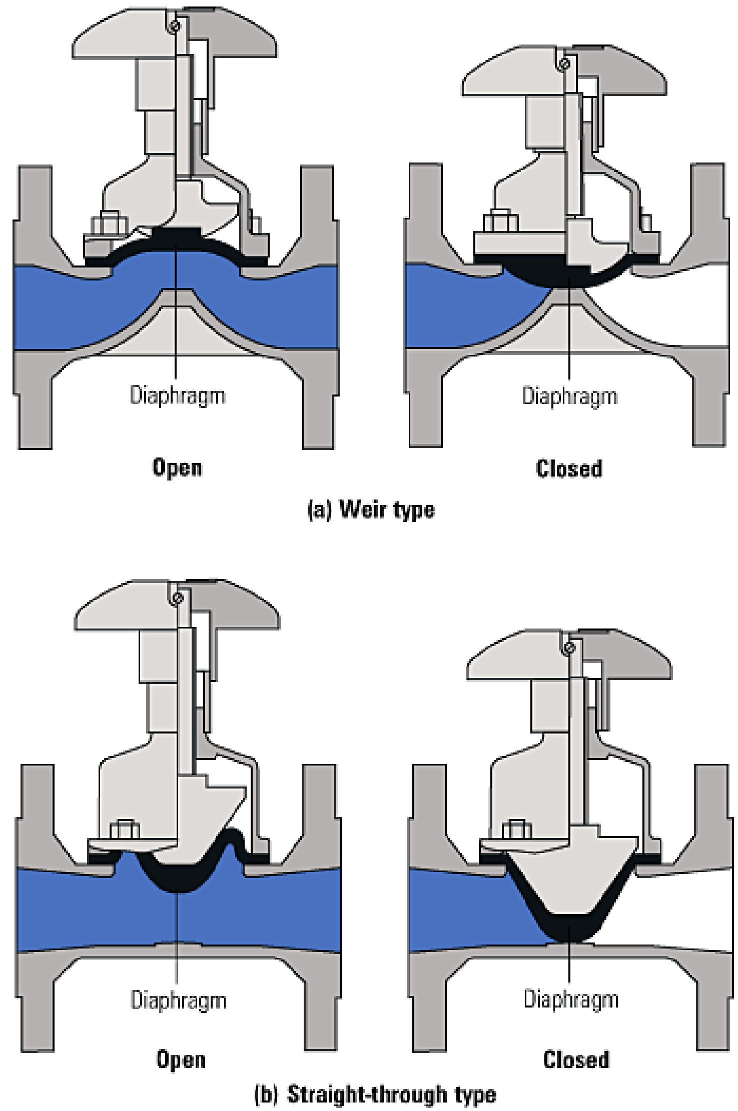
- Small, simple needle valves are often used as **bleed valves** in hot water heating applications.

6) Diaphragm Valve

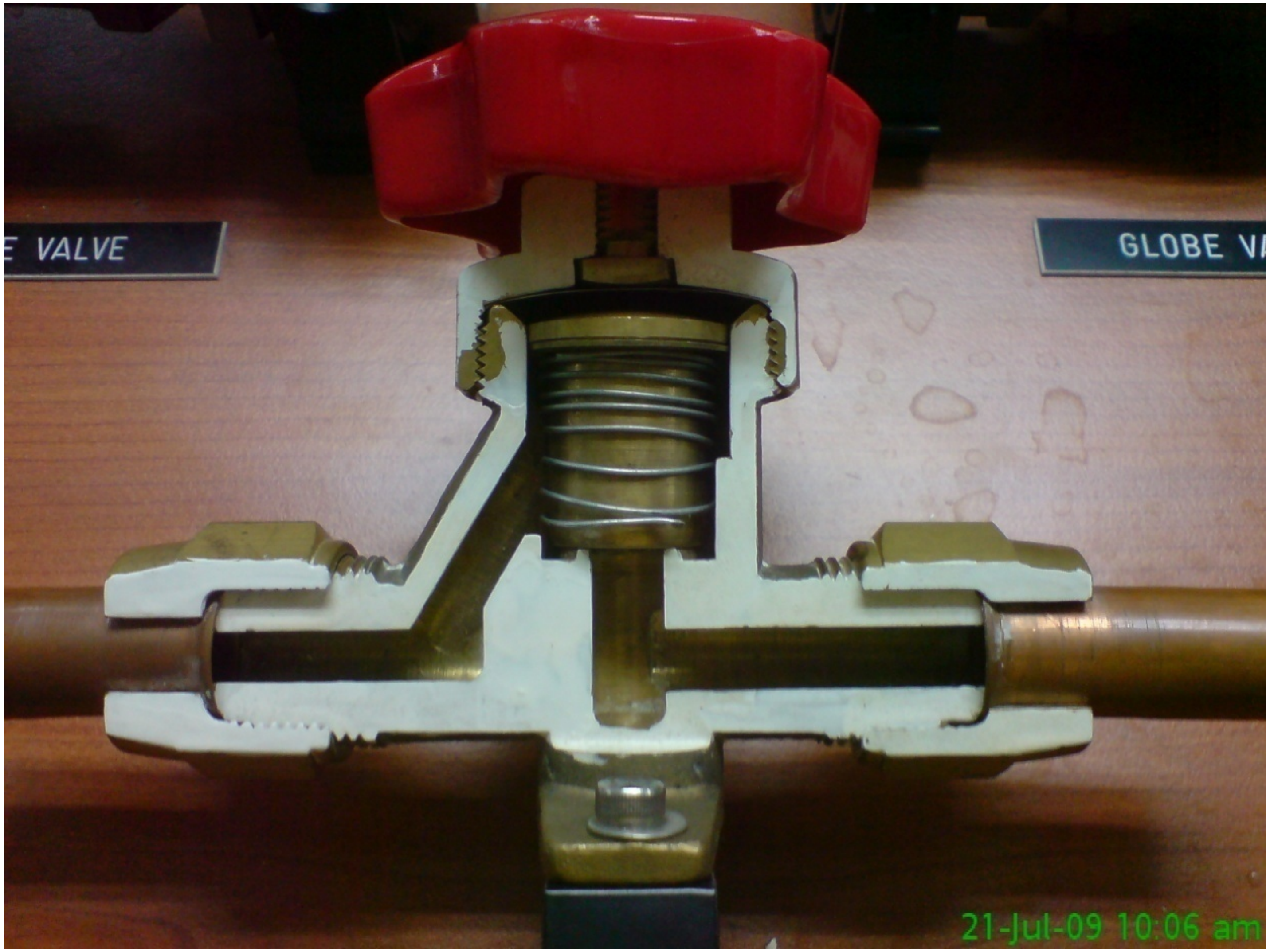
- Nearly all hand-operated valves in **large refrigeration systems** are diaphragm valves.
- The fluid has to rise up and over a seat. There is a **pressure drop** through this type of valve.
- The upper part is sealed off from the lower part by a **diaphragm**.
- An **upward-seating ball check** in the lower valve stem makes it possible for the spring to lift the lower stem regardless of pressure differences developed while the valve was closed. Thus, the valve will operate properly **regardless of direction of flow**.

Diaphragm Valve

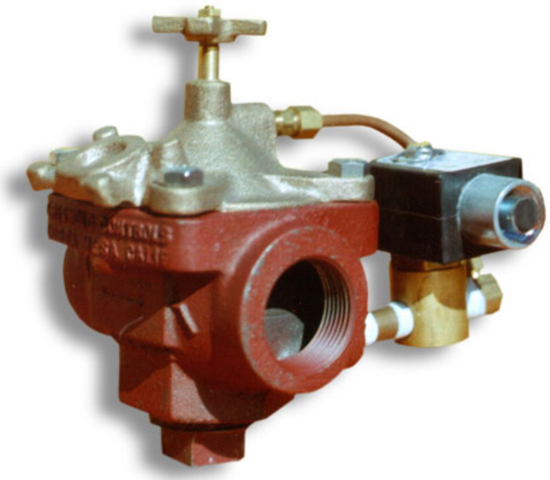


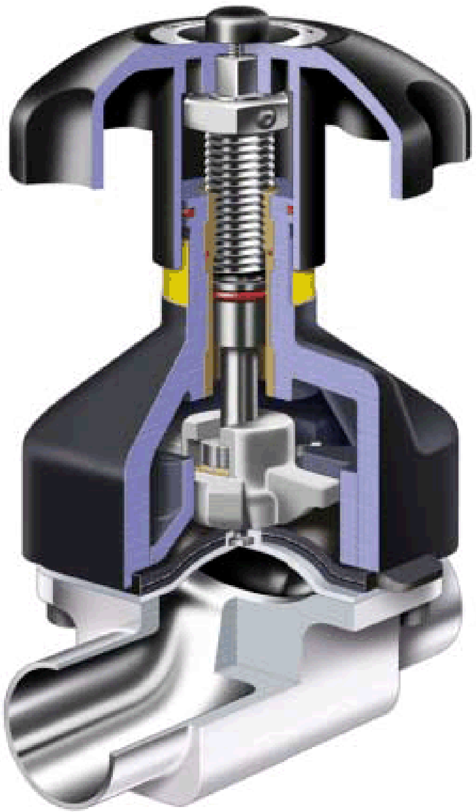


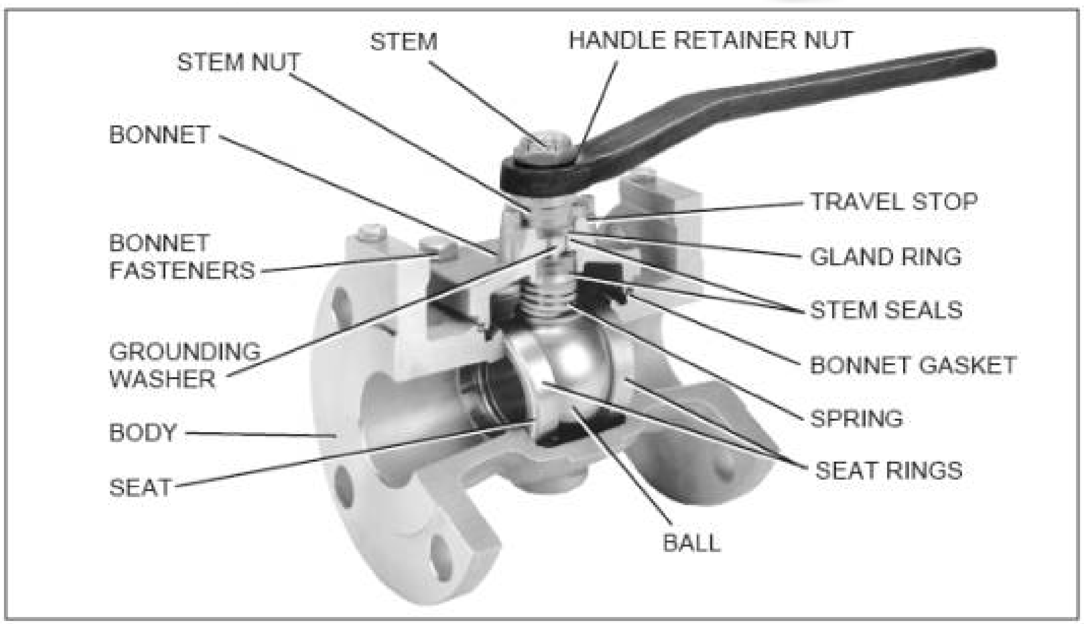
Diaphragm Valve



Diaphragm Valve







Diaphragm Valve

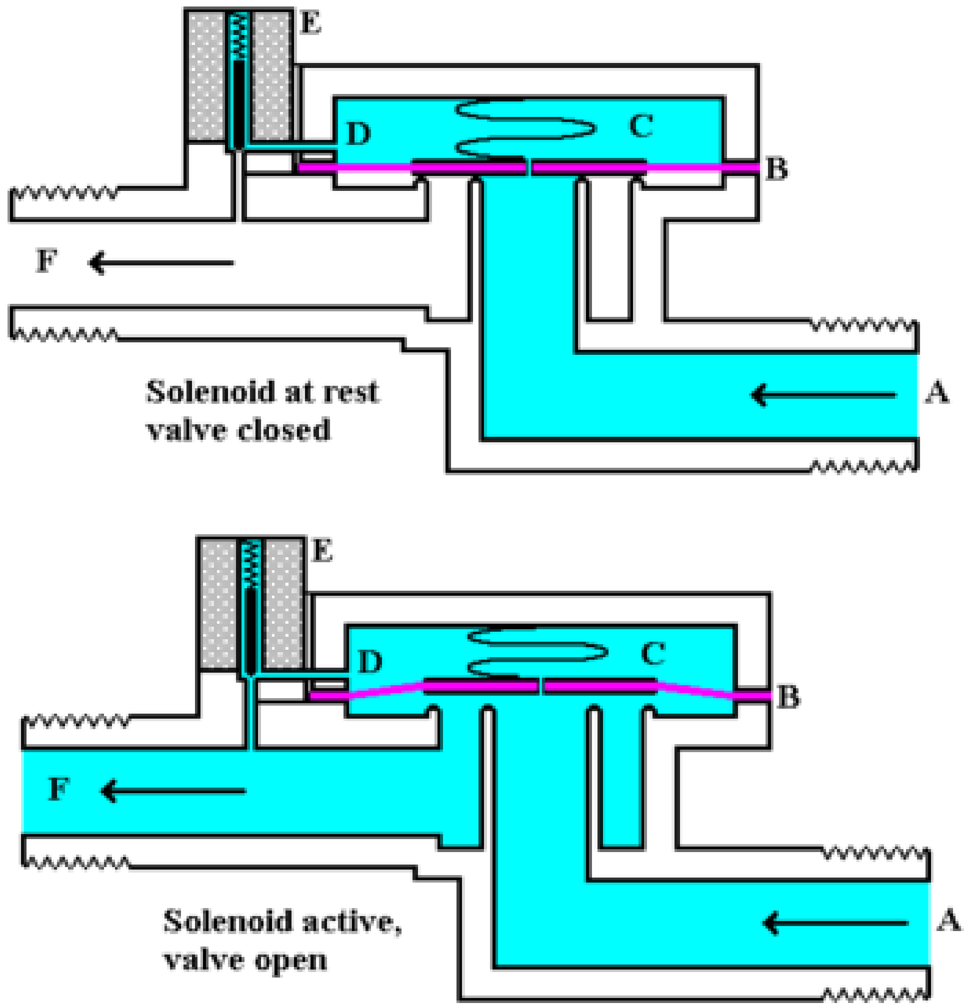
- Can be **tightened by hand** enough to hold back high pressures.
- Can be installed into the system with either a flare or soldered connection.
- When it is soldered, care should be taken that it is not overheated. Most of these valves have **seats** made of materials that would not melt when the valves was being soldered into a line.

7) Solenoid Valve

- **An electrically operated valve** where an electromagnet is used as an actuator to change the valve state.
- Used only in an **ON/OFF manner**. In a two-way solenoid valve, the valve is open when the solenoid coil is energized.

Solenoid Valve

- The energized solenoid coil acts as an electromagnet which pulls the plunger and the valve disc upwards.
- The valve is closed when the coil is de-energized.



Solenoid Valve

Solenoid Valve

- The closing action of the valve is achieved by the **weight of the plunger, valve stem and disc**.
- Once the disc comes close to its seat, flow (from left hand side) will **snap** the valve tightly shut

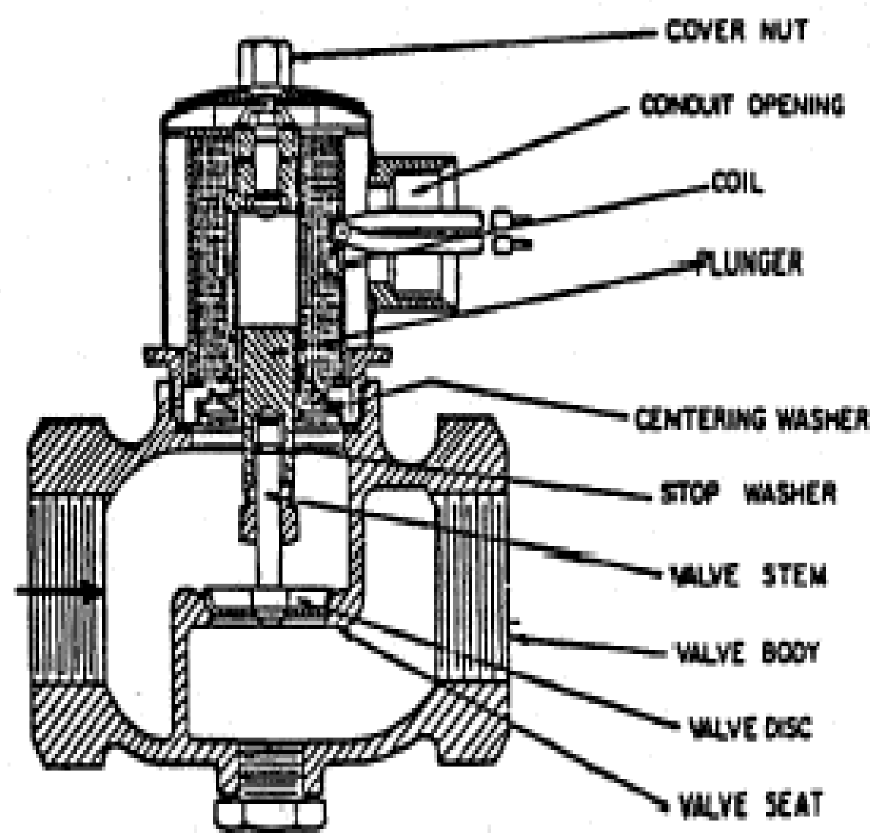


Figure 23. A Two-Way Solenoid Valve.

Solenoid Valve

- In a three-way solenoid valve, energizing the solenoid coil causes the valve to open from **Port 1 to Port 2** while deenergizing the coil causes the valve to open from **Port 2 to 3.**

- A solenoid valve is often used in conjunction with a **pneumatically actuated diaphragm** control valve to obtain ON/OFF valve operation by an electrically applied signal.

Solenoid Valve

- This arrangement, depending on the valve size, may be much more reliable, more powerful, less expensive and faster responding than using an all electric control valve.

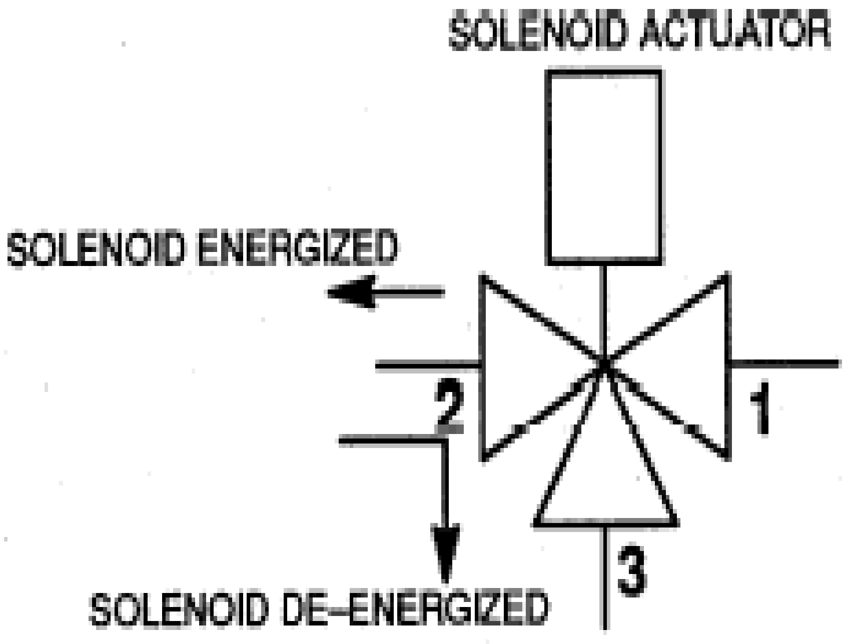
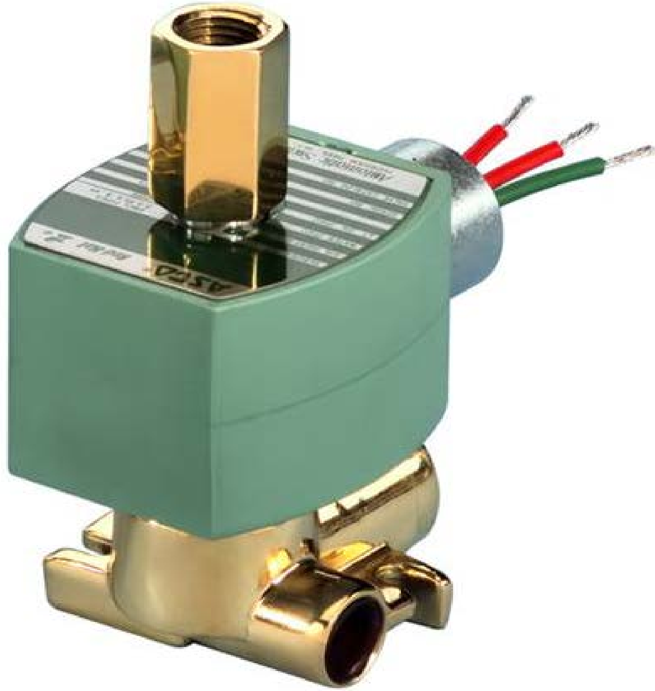


Figure 24: A Three-Way Solenoid Valve.

Solenoid Valve

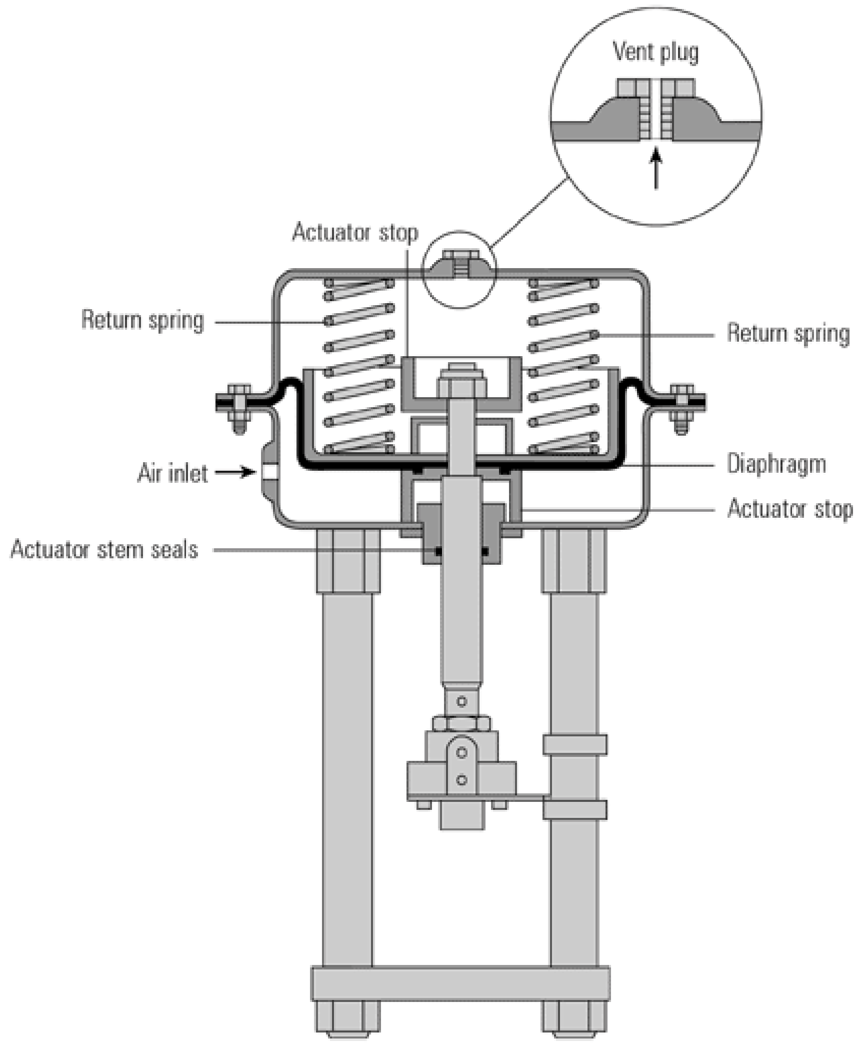


8) Valve Actuators

- A **control valve actuator** is a device which is used to **drive the valve plug stem** and therefore sets the position of the plug with respect to the valve seat.

- The most common valve actuator is the **pneumatic diaphragm actuator**. It is simple in construction and very reliable. It operates by the injection of a single, low pressure air signal into the diaphragm housing.

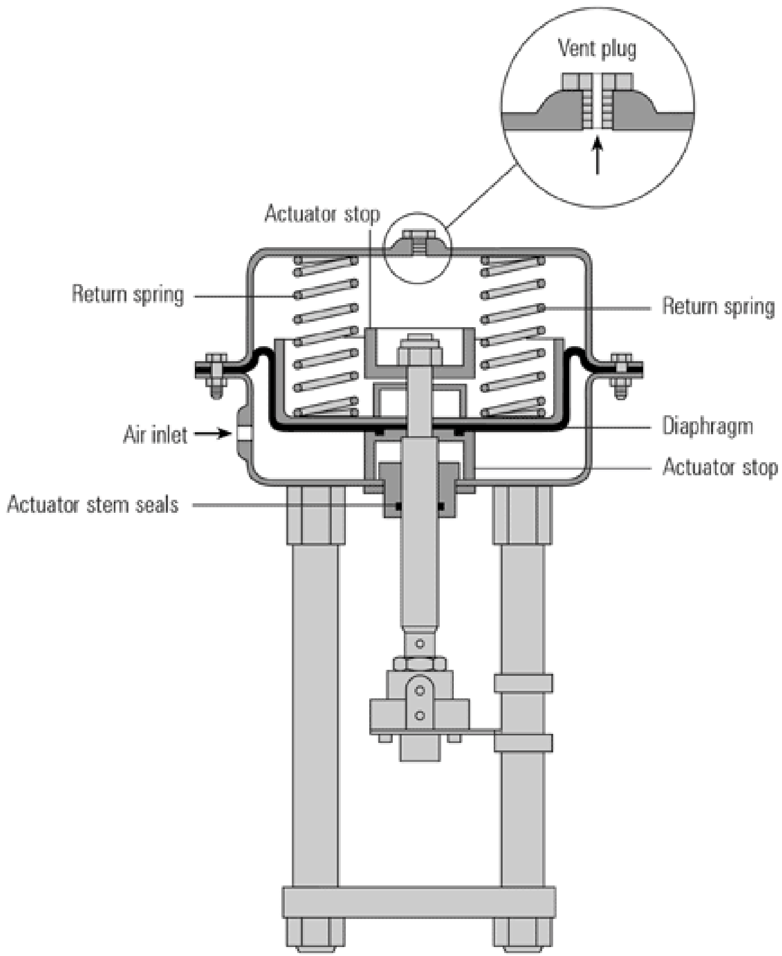
Valve Actuators

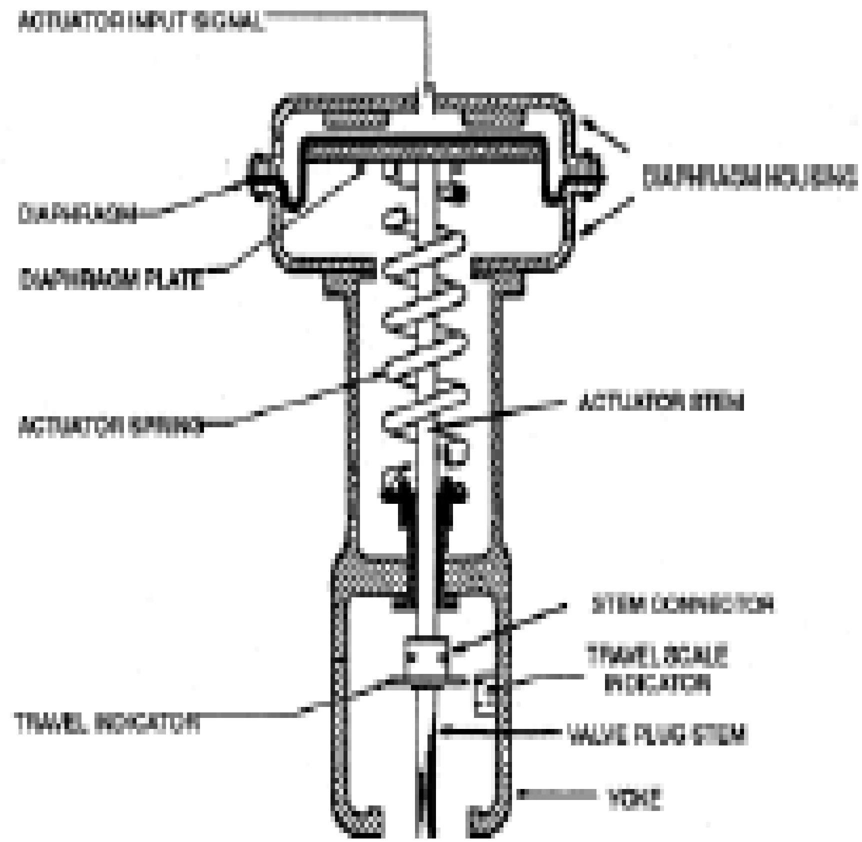


Valve Actuators

- The diaphragm housing is made up of two sections separated by a **flexible diaphragm.**
- The **air pressure** applied on the diaphragm develops a **working force**. This force is transmitted to the actuator stem via the **diaphragm plate**, which is a supportive metal disk attached to the diaphragm.
- The actuator spring provides a **restoring force** which positions and returns the actuator stem.

Valve Actuators





Valve Actuators

- The **travel indicator** (a pointer attached near the stem connector) indicates the valve travel on the indicator scale.
- The actuator is supported rigidly on the valve bonnet assembly by the **yoke.**
- The actuator stem is connected by the **stem connector** to the valve plug stem.

Valve Actuators

- The **diameter of the diaphragm plate** determines the force that will be applied to the actuator stem.
- For example, if the maximum input signal pressure is 100 kPa and the plate diameter is 30 cm, then:

Force applied to stem = **P**ressure x Plate **A**rea

= 100 kPa x 3.14 x $(0.\ 15)^2$ m^2

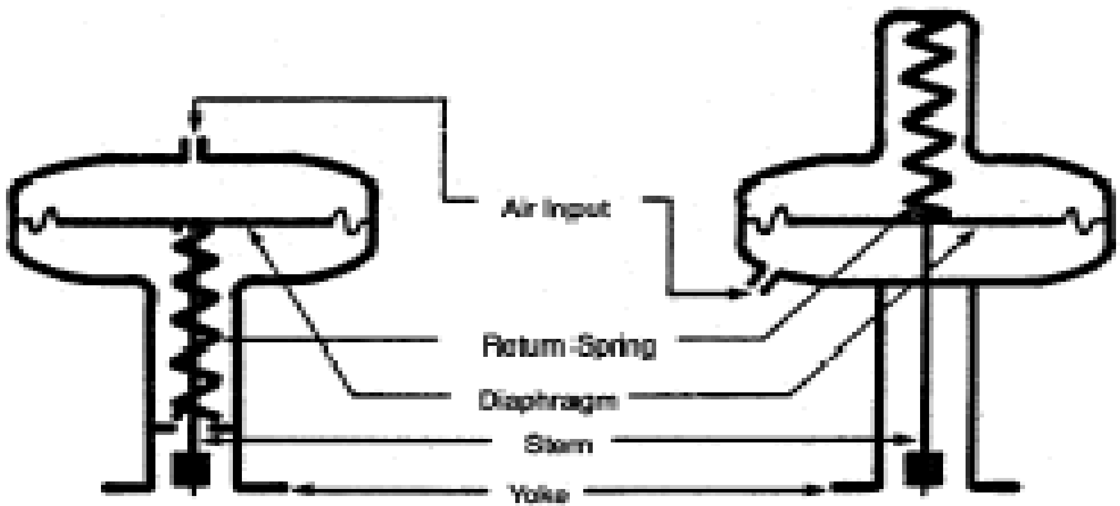
= 7.07 KN (1590 lb)

Valve Actuators

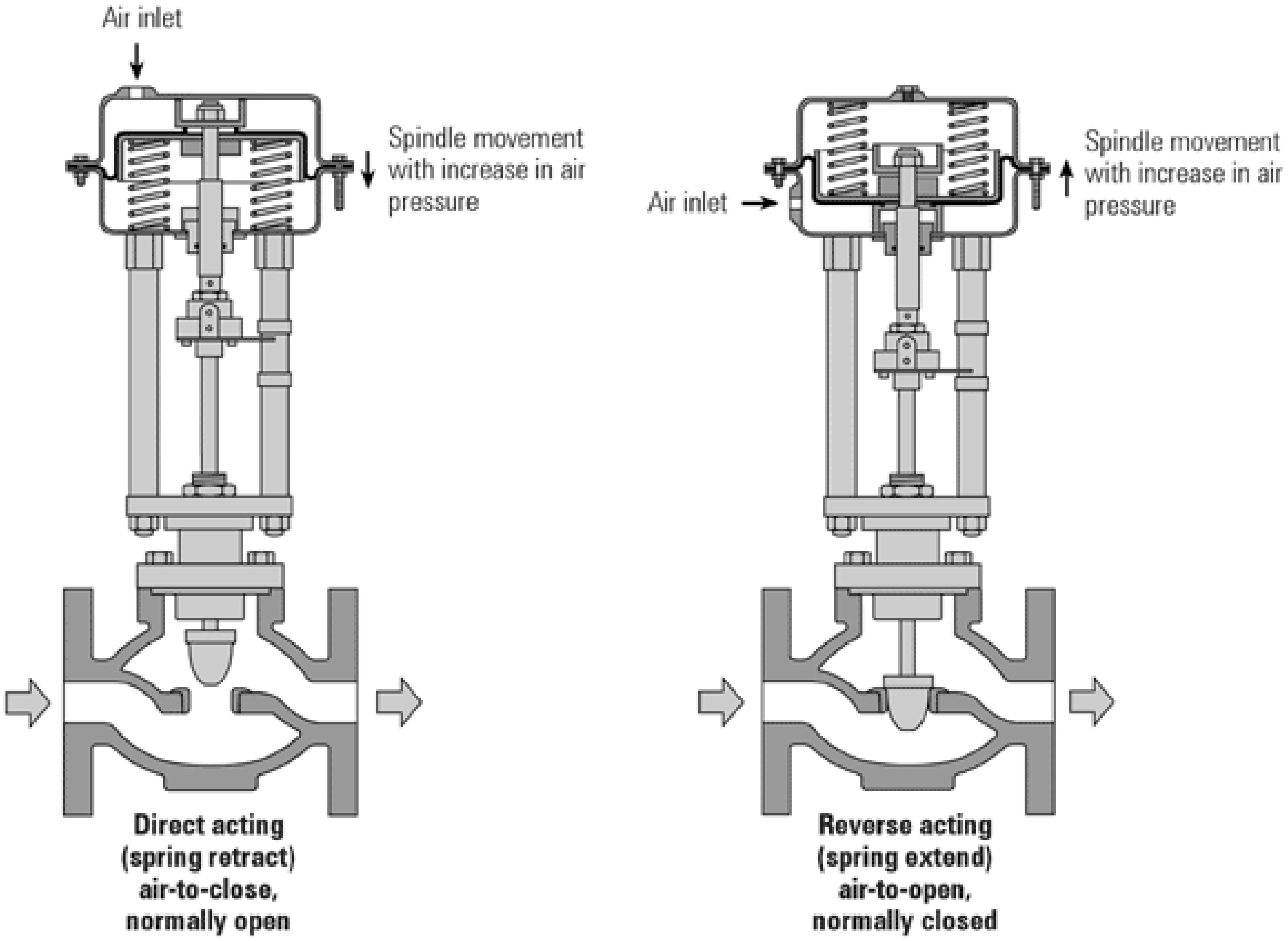
- Although the signal pressure of 100 kPa seems to be fairly low, a substantial force can still be generated if the diaphragm diameter is large.
- A larger valve and/or a higher differential pressure to work against, needed more force to obtain full valve movement.
- To create more force, a larger diaphragm area or higher spring range is needed.

Valve Actuators

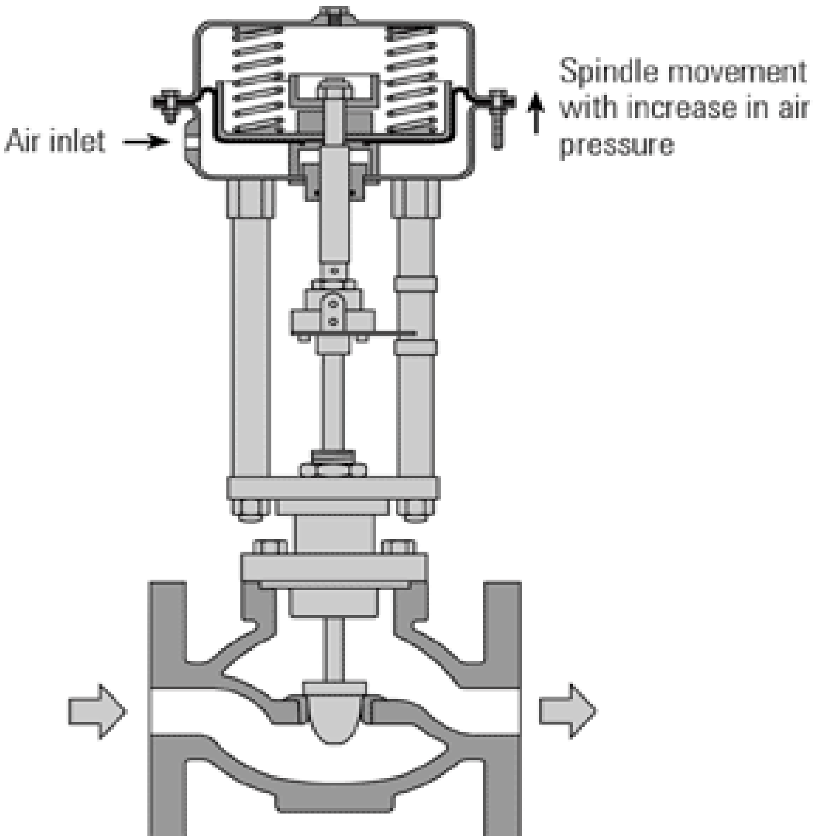
- Diaphragm actuators can be classified as :
- **direct acting actuator** - cause the actuator stem to be pushed **downwards** as a result of applying signal air to the top of the diaphragm.
- **reverse acting actuator** - push the actuator stem **upwards** as signal air is applied to the bottom of the diaphragm.



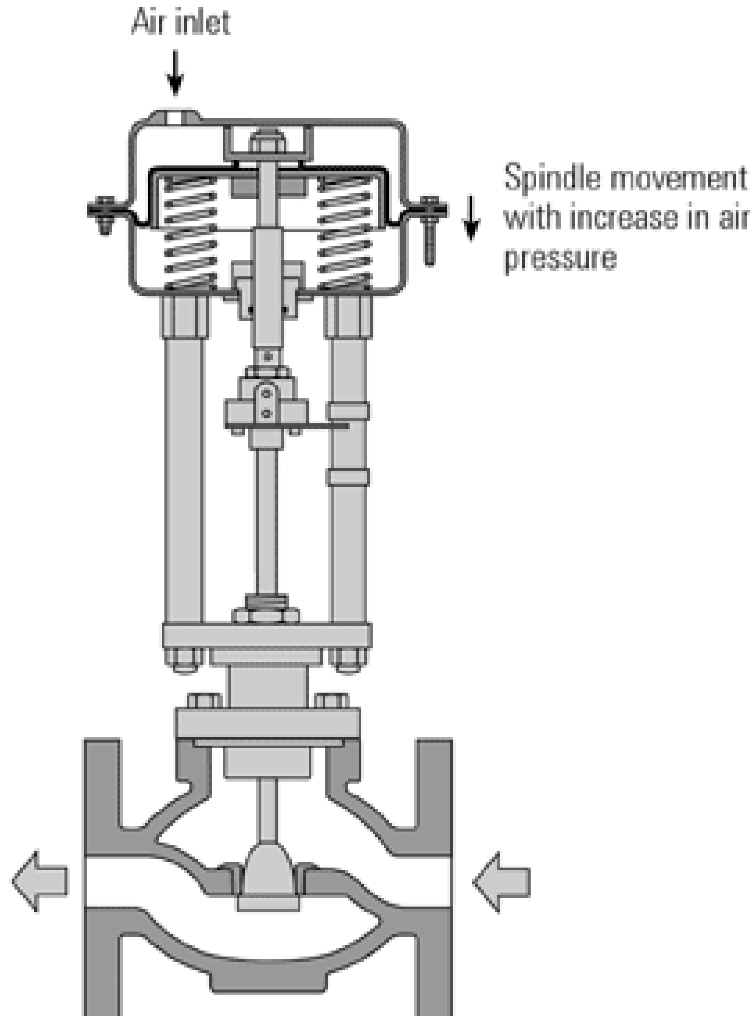
Valve Actuators



Valve Actuators



Reverse acting (spring extend) air-to-open, normally closed



Air-to-open, normally closed

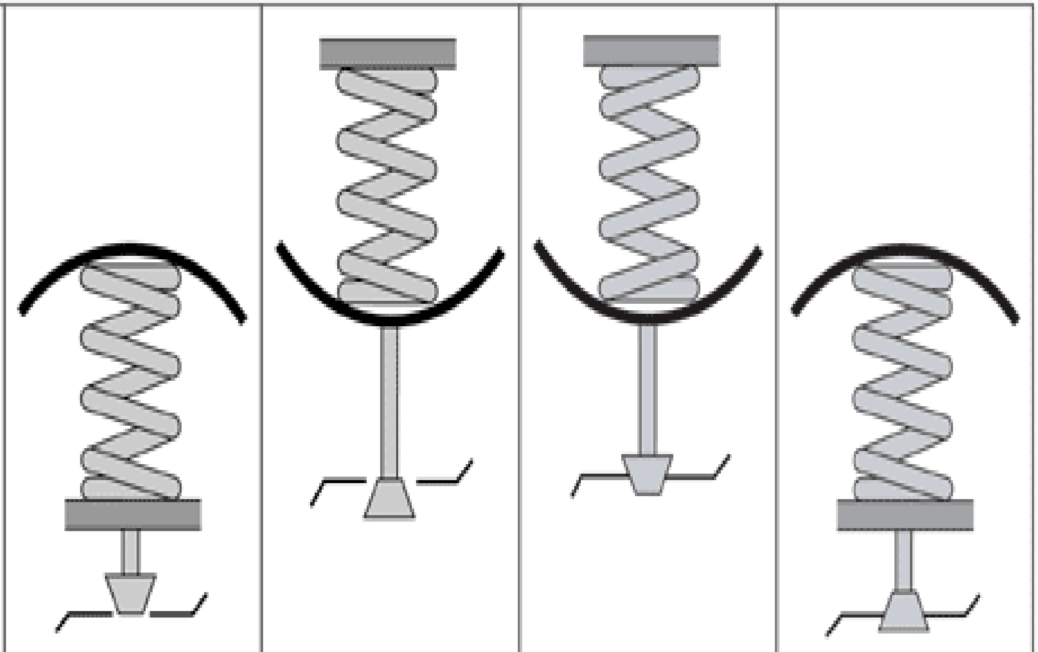
Valve Actuators

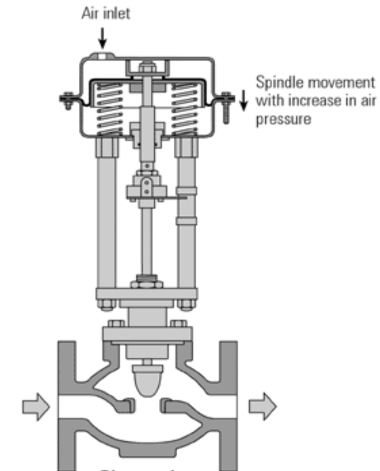
- The choice between direct acting and reverse acting pneumatic controls depends on what position the valve should revert to in the event of failure of the compressed air supply.

  i.e. it depends upon the nature of the application and safety requirements.

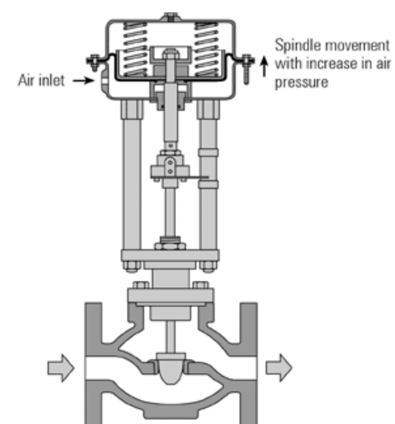
- It makes sense for steam valves to close on air failure, and cooling valves to open on air failure.

Valve Actuators

Two port valves				
Actuator action	Direct	Reverse	Reverse	Direct
Valve action	Direct	Reverse	Direct	Reverse
On air failure	Valve opens		Valve closes	

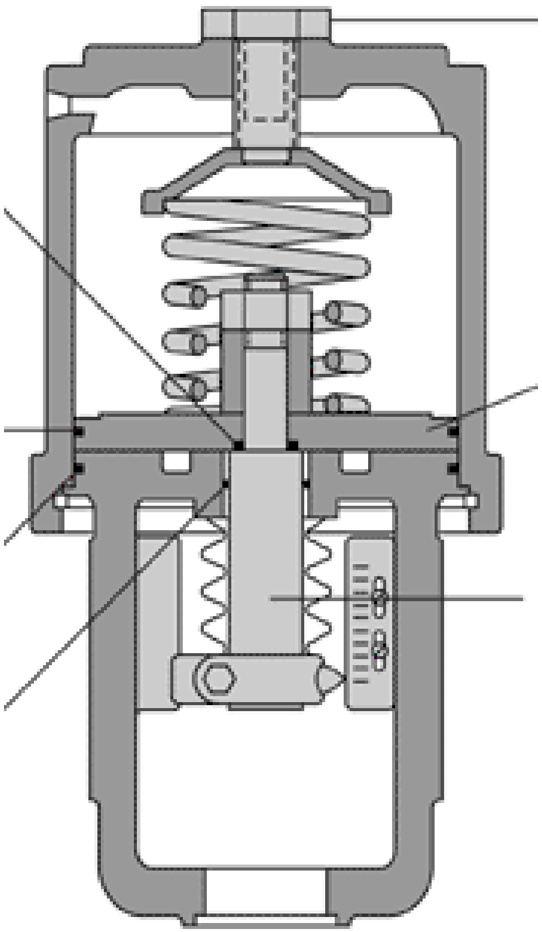


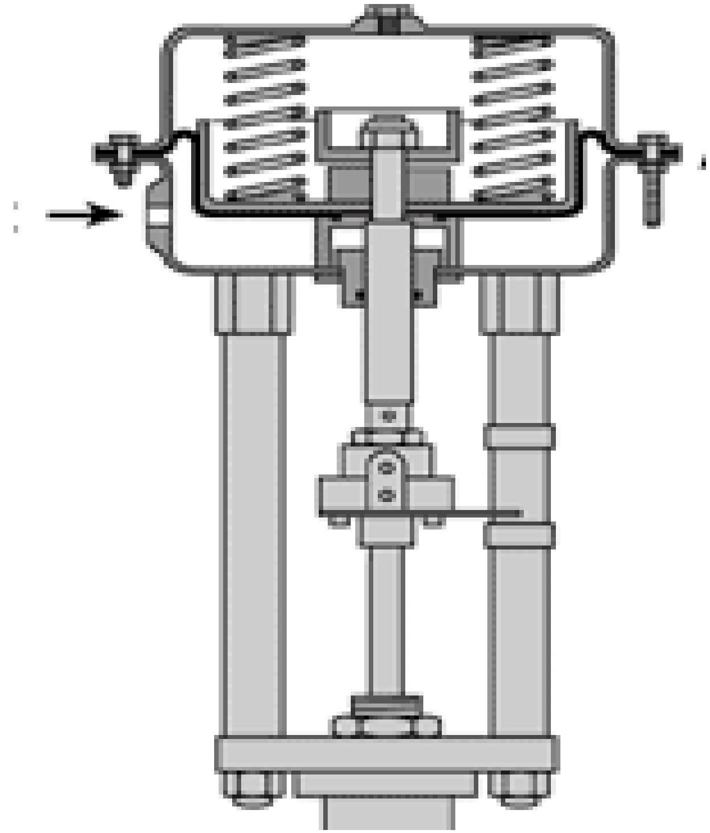
Direct acting (spring retract) air-to-close, normally open



Reverse acting (spring extend) air-to-open, normally closed

Valve Actuators

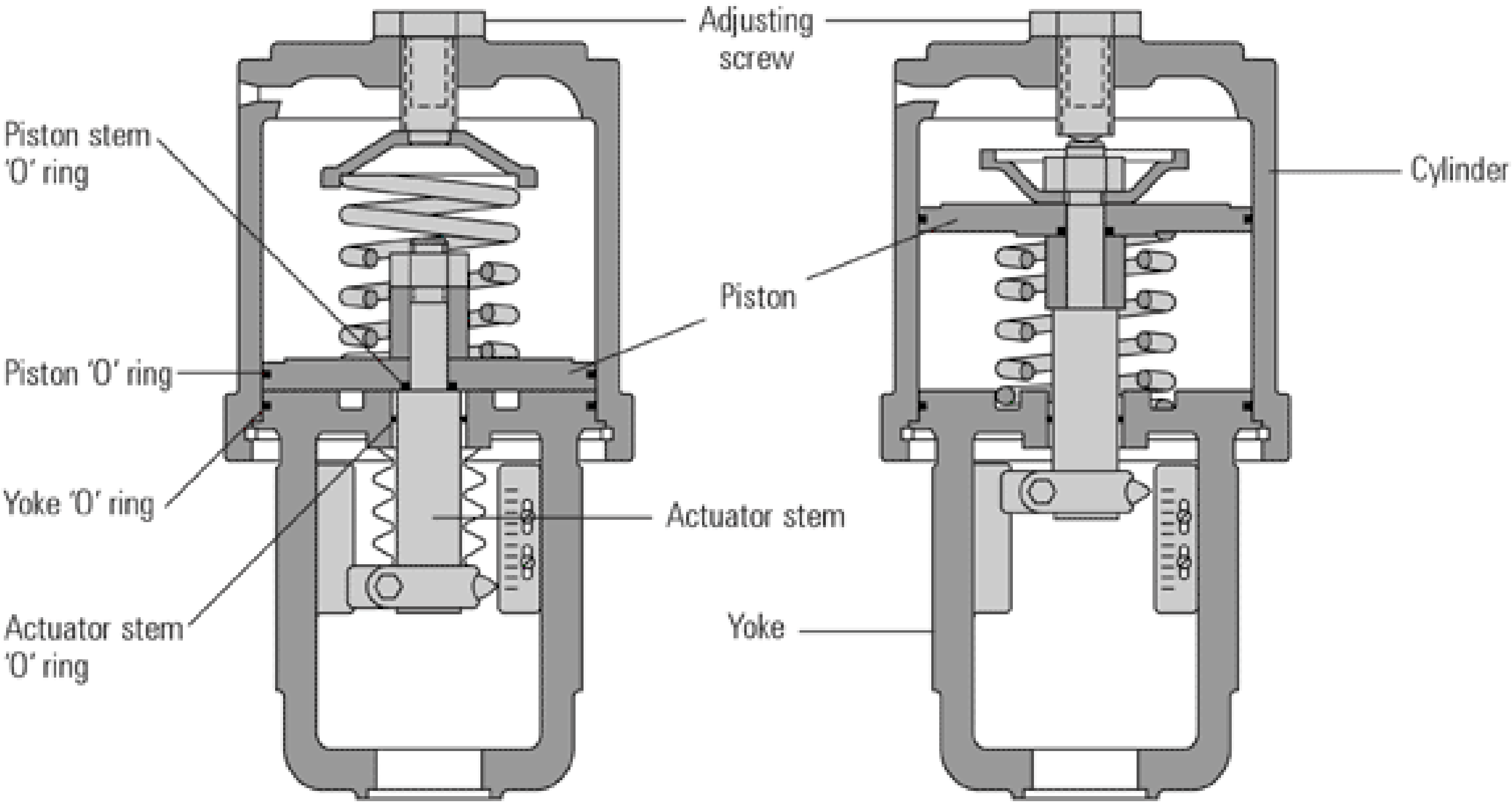




Valve Actuators

- Piston actuators are generally used where the stroke of a diaphragm actuator would be too short or the thrust is too small.
- The compressed air is applied to a solid piston contained within a solid cylinder.
- Piston actuators can be single acting or double acting, can withstand higher input pressures and can offer smaller cylinder volumes, which can act at high speed.

Valve Actuators



Air-to-retract (Air-to-open)

Air-to-extend (Air-to-close)

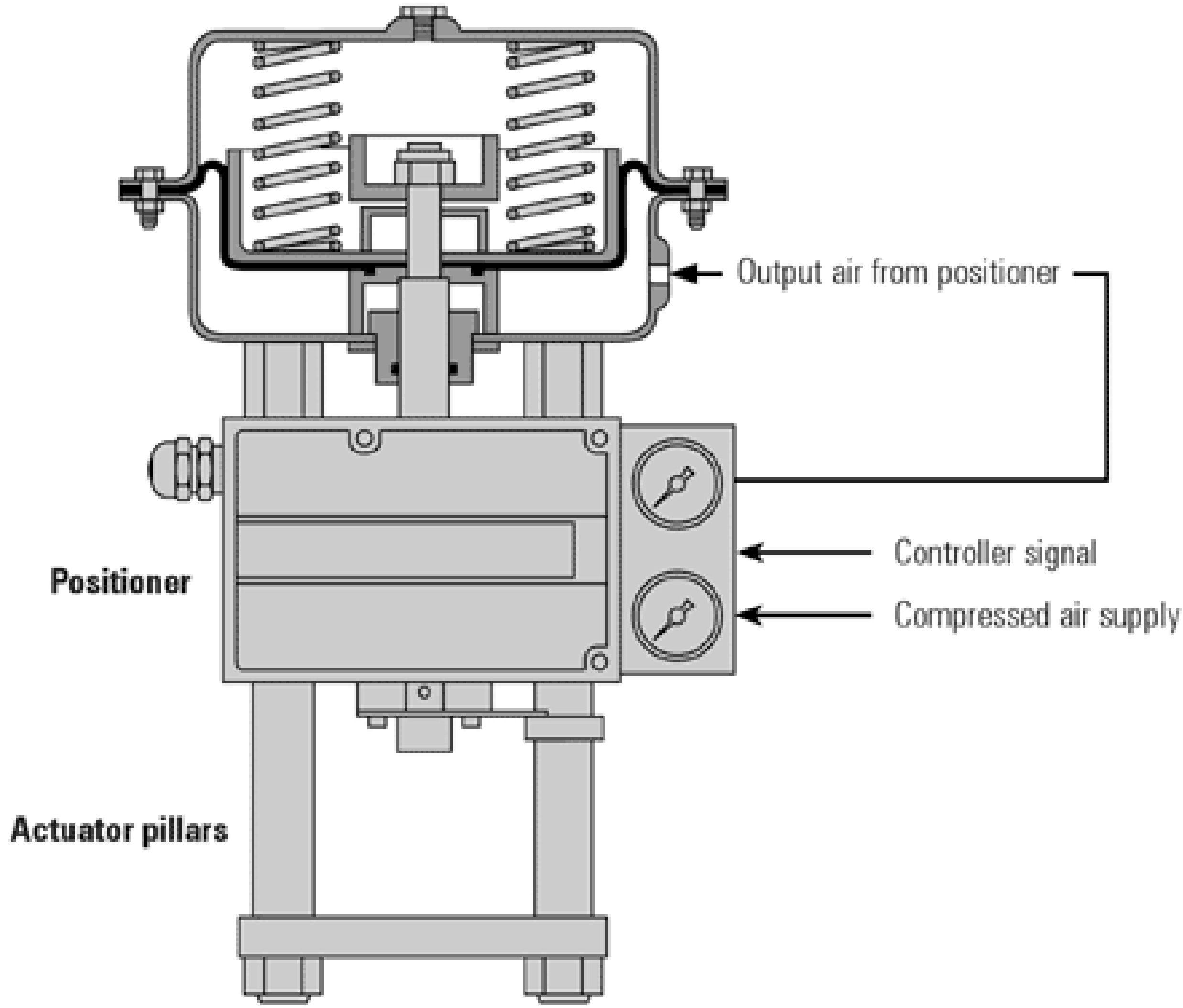
9) Valve Positioners

- **Pneumatic** valve positioners are the most commonly used valve accessories.

- A valve positioner is a device which will **accurately position a control valve** in accordance with the pneumatic control signal.

- The control signal is routed to the positioner where comparison of the **valve position (actual)** to the **control signal (desired)** is used to develop an output pneumatic signal which operates the valve actuator.

Valve Positioners



Valve Positioners

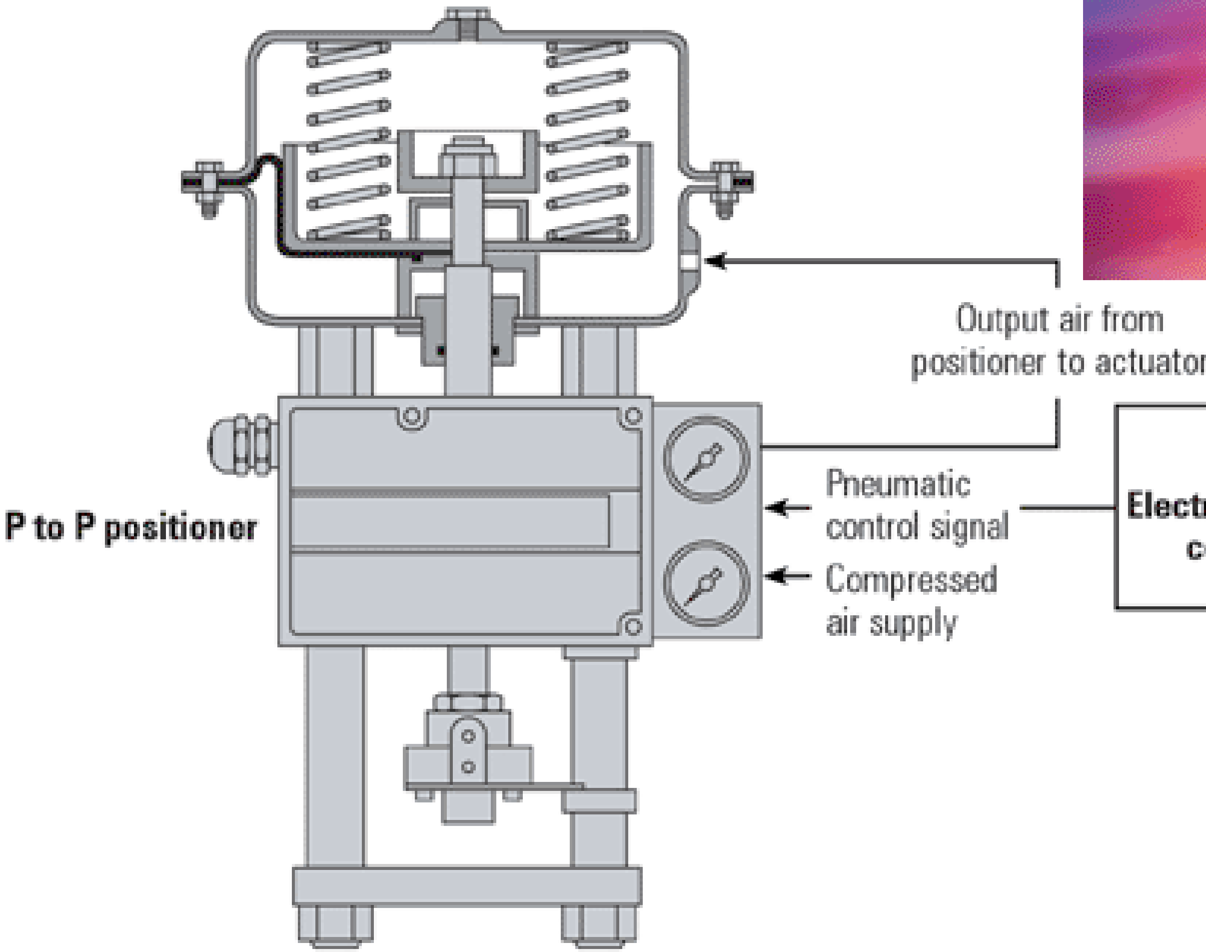
- The positioner compares the control signal **(the requested valve position)** with the actual valve position through the **mechanical feedback linkage**.

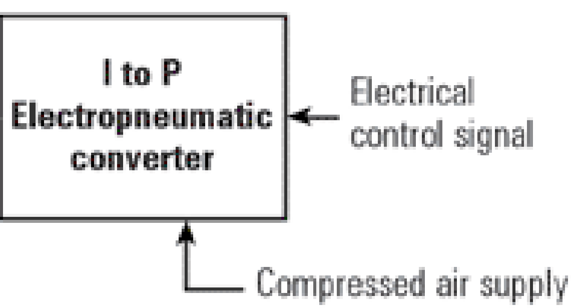
- If the valve position is incorrect, the positioner will either load or exhaust air from the valve actuator **until the correct valve position is obtained.**

- A positioner requires both a **control signal** and an **instrument supply air** for normal operation.

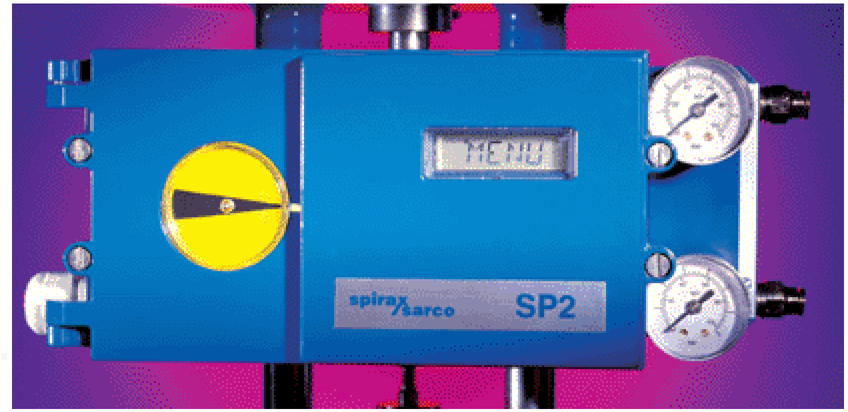
- Most positioners come equipped with **three gauges** to indicate **supply** air pressure, **control signal** pressure and **actuator diaphragm signal** (output) air pressure.

Valve Positioners





Valve Positioners



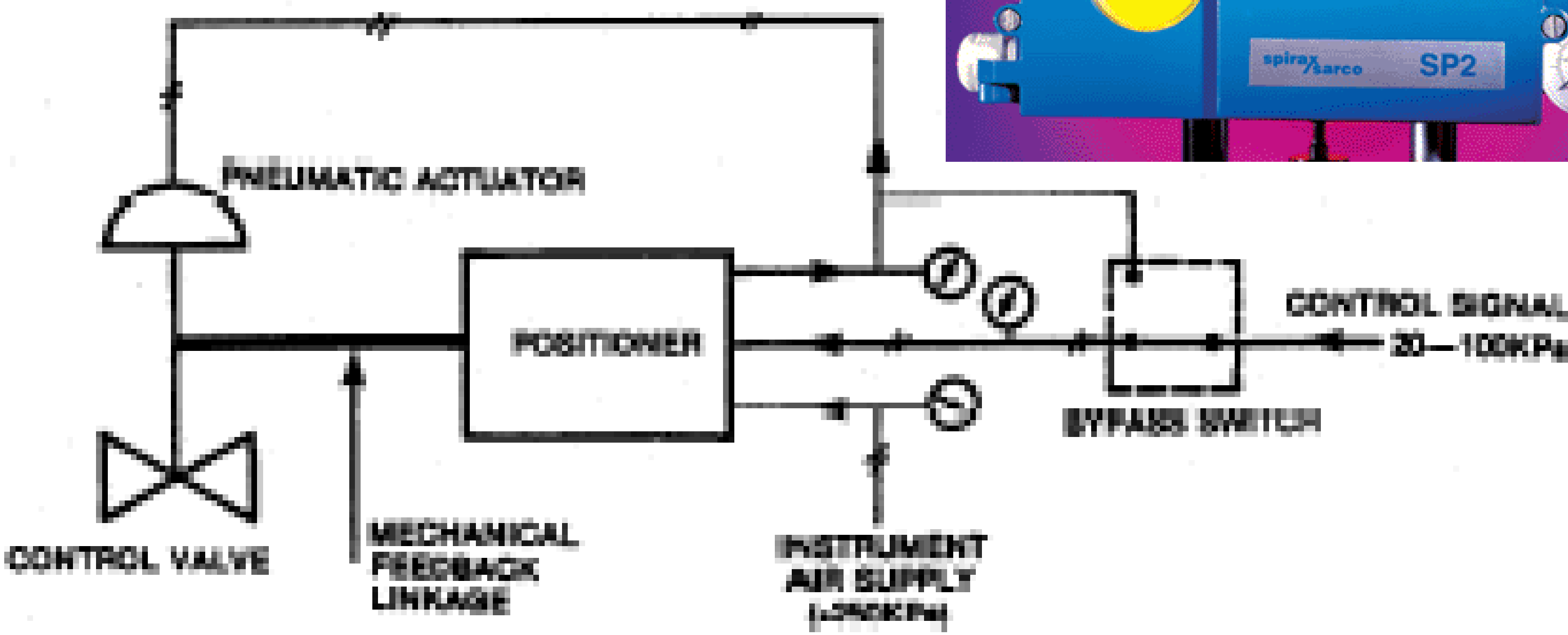


Figure 17: A Simplified Valve Positioner Installation.

Valve Positioners

- Advantages of the valve positioner include:

1) **Minimizing the effect of friction, hysteresis and deadband** on the valve stem. With a high pressure system, tighter valve stem packing is needed to prevent leakage and a high frictional force is generated. With a positioner valve stem **movements of as little as 25 µm** are possible.

2) **Enables signal range change**. A positioner can **amplify** the incoming control signal when a greater actuating force is needed. A 20-100 kPa control signal can be amplified to 40-200 kPa before being applied to the actuator.

Valve Positioners

3) **Allows signal reversal**. A positioner can operate in either direct or reverse acting mode. For example, in reverse acting mode, an increase in control signal pressure causes a decrease in positioner output air pressure. For example, in reverse mode, a 100 - 20 kPa actuator signal would correspond to a 20 - 100 kPa control signal from the I/P transducer.

4) **Increases the speed of response of the actuator**. The speed of response of the valve actuator depends on:

(a) the actuator volume, and

(b) the flow rate of the control signal air.

Valve Positioners

- **Allows valve flow characteristic to be changed**. Most valve positioners employ a **rotating cam in the feedback** system. This cam can be changed to simulate different valve flow characteristics. A linear globe valve can be used to respond in an equal percentage manner.
- **Allows split range operation**. In a split range control loop, one controller is used to drive two control valves.

Valve Positioners

- 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.

Valve Positioners

- 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.

Valve Positioners

- 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.

CONTENT (PART 3)

1) Valve sizing selection criteria
2) Valve sizing nomenclature
3) Body sizing of liquid service control valves

Valve Sizing Selection Criteria

For correct sizing, the following conditions are needed:

1. **Upstream pressure**
2. **Maximum and minimum temperatures**
3. **Type of process fluid**
4. **Flow rate that is based upon the maximum flow rate, the average flow rate, and the minimum flow rate**
5. **Vapor pressure**
6. **Pipeline size, schedule, and material**
7. **Maximum, average, and minimum pressure drop**
8. **Specific gravity of the fluid**
9. **The critical pressure.**

Valve Sizing Selection Criteria

1. **Upstream and Downstream Pressures:**

- ✓ In order for the process to flow in a particular direction through a valve, the **upstream (P1) and downstream pressures (P2)** must be different.
- ✓ If **P1**=**P2**→ no flow will occur.
- ✓ **Upstream pressure (P1)** is the pressure reading taken before the valve.
- ✓ **Downstream pressure (P2)** is the pressure reading taken after the valve.

Valve Sizing Selection Criteria

2. Pressure Drop/Pressure Differential:

- ✓The difference between the upstream and downstream pressures, $\Delta P = P_1 - P_2$.
- ✓The pressure drop allows for the flow of fluid through the process system from the upstream side of the valve to the downstream side.
- ✓**ΔP** , **Flow** through the valve.

Valve Sizing Selection Criteria

3. **Flow Capacity:**

- ✓ **Valve coefficient (Cv)** numerically equal to the number of U.S. Gallons of water at 60°F that will flow through the valve in one minute with 1.0 psi pressure drop.

$$C_v = Q\sqrt{\frac{S_g}{\Delta P}}$$

where C_v = required flow coefficient for the valve
Q = flow rate (in gal/min)
S_g = specific gravity of the fluid
ΔP = pressure drop (psi)

- ✓ When calculated properly, **Cv** determines the correct trim size (or area of the valve's restriction) that will allow the valve to pass the required flow while allowing stable control of the process throughout the stroke of the valve.

Valve Sizing Selection Criteria

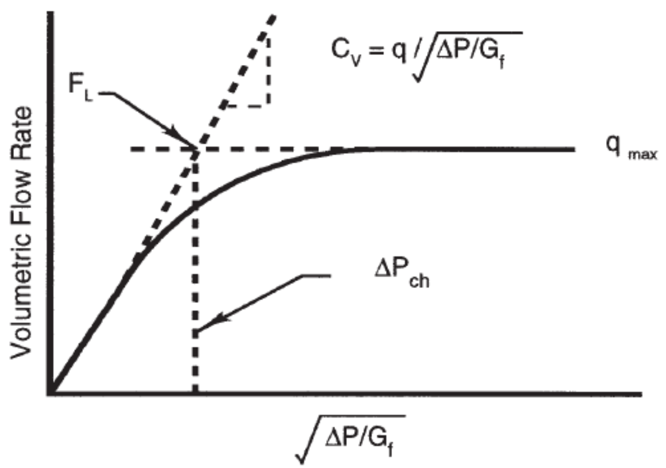
4. <u>Actual Pressure Drop</u>

- ✓ is defined as the difference between the upstream (inlet) and downstream (outlet) pressures.
- ✓ When the choked and actual pressure drops are compared and the actual pressure drop is smaller, it is used in the **Cv** sizing equation.

Valve Sizing Selection Criteria

5. **Choked Pressure Drop**

- ✓ where further increases in the pressure drop will not change the valve's flow rate. This is what is commonly called **choked flow**.
- ✓ Because of the choked condition, the flow rate will reach a maximum condition due to the existence of cavitation in liquids or sonic velocity with gases.
- ✓ the term **choked pressure drop, ΔPchoked** is used to show the theoretical point where choked flow occurs, intersecting the linear lines of the constant C_v and the maximum flow rate Q_{max}.
- ✓ This point is known as the liquid pressure-recovery factor F_L.
- ✓ For gas applications, the terminal pressure-drop ratio x_T is used to describe the choked pressure drop for a particular valve.



Valve Sizing Selection Criteria

6. <u>Allowable Pressure Drop</u>

- ✓The allowable pressure drop, ΔP_a is chosen from the smaller of the actual pressure drop or the choked pressure drop and is used in the determination of the correct C_v
- ✓Should be used in the determination of the C_v in liquid application when:
  - ➢ first, if the inlet pressure P_1 is fairly close to the vapor pressure.
  - ➢ second, if the outlet pressure P_2 is fairly close to the vapor pressure;.
  - ➢ third, if the actual pressure drop is fairly large when compared to the inlet pressure P_1.

Valve Sizing Selection Criteria

7. <u>Cavitation</u>

- ✓ when the fluid passes through the narrowest point of the valve (vena contracta), the pressure decreases inversely as the velocity increases.
- ✓ If the pressure drops below the vapor pressure for that particular fluid, vapor bubbles begin to form.
- ✓ As the fluid moves into a larger area of the vessel or downstream piping, the pressure recovers to a certain extent. This increases the pressure above the vapor pressure, causing the vapor bubbles to collapse or implode.
- ✓ creation of the vapor bubbles and their subsequent implosion—is called *cavitation* and is a leading cause of valve damage in the form of erosion of metal surfaces.

Valve Sizing Selection Criteria

8. <u>Flashing Issues</u>

- ✓ When the downstream pressure does not recover above the vapor pressure, the vapor bubbles remain in the fluid and travel downstream from the valve, creating a mixture of liquid and gas. This is called *flashing.*
- ✓ Problems typically associated with flashing are higher velocities and erosion of valve components.

Valve Sizing Selection Criteria

9. **Liquid Pressure-Recovery Factor (F_L)**

- ✓ Is a critical element in liquid sizing.
- ✓ predicts the effect the geometry of a valve's body on the maximum capacity of that valve.
- ✓ is used to **predict the amount of pressure recovery** occurring between the vena contracta and the outlet of the body.
- ✓ The liquid pressure-recovery factor is determined by the manufacturer through flow testing that particular valve style.
- ✓ *FL* factors can vary significantly depending on the internal design of the valve.
- ✓ Generally, rotary valves, especially ball and butterfly valves, allow for a high recovery of the fluid following the vena contracta. Therefore, they tend to cavitate and choke at smaller pressure drops than globe valves.
- ✓ For the most part, globe valves have better *FL* factors and are able to handle severe services when compared to rotary valves.

Valve Sizing Selection Criteria

10. <u>Liquid Critical-Pressure Ratio Factor</u>

- ✓ The *liquid critical-pressure ratio factor* F_F is important to liquid sizing because it **predicts the theoretical pressure at the vena contracta**, when the maximum effective pressure drop (or in other words, the choked pressure drop) occurs across the valve.

Valve Sizing Selection Criteria

11. <u>Choked Flow</u>

- ✓ the presence of cavitation or flashing expands the specific volume of the fluid.
- ✓ The volume increases at a faster rate than if the flow increased due to the pressure differential.
- ✓ At this point, the **valve cannot pass any additional flow, even if the downstream pressure is lowered.**
- ✓ With gas and vapor services, choked flow occurs when the velocity of the fluid achieves sonic levels (Mach 1 or greater).
- ✓ as the pressure decreases in the valve to pass through restrictions, velocity increases inversely. As the pressure lowers, the specific volume of the fluid increases to the point where a sonic velocity is achieved.
- ✓ Because of the **velocity limitation** [**Mach 1** for gases and **50 ft/s** (12.7 m/s) for liquids], the flow rate is limited to that which is permitted by the sonic velocity through the vena contracta or the downstream piping.

Valve Sizing Selection Criteria

12. Velocity

- ✓ As a general rule, smaller valve sizes are better equipped to handle higher velocities than larger-sized valves.
- ✓ For **liquid services**, the general guideline for maximum velocity at the valve outlet is **50 ft/s** (12.7 m/s), while **gas** services are generally restricted to **Mach 1.0.**
- ✓ When cavitation or flashing is present, creating a higher velocity associated with the liquid–gas mixture, the maximum velocity is usually restricted to 500 ft/s (127 m/s).
- ✓ In services where temperatures are close to saturation point, the velocity must be less—approximately 30 ft/s (7.6 m/s). This lower velocity prevents the fluid from dropping below the vapor pressure, which will lead to the formation of vapor bubbles.

Valve Sizing Selection Criteria

13. <u>Reynolds-Number Factor</u>

- ✓ Some processes are characterized by nonturbulent flow conditions in which laminar flow exists (such as oils).
- ✓ **Laminar fluids have high viscosity**, operate in lower velocities, or require a flow capacity requirement that is extremely small.
- ✓ The ***Reynolds-number factor FR*** is used to correct the *Cv* equation for these flow factors.
- ✓ In most cases, if the viscosity is fairly low (for example, less than SAE 10 motor oil), the Reynolds-number factor is **insignificant**.

Valve Sizing Selection Criteria

14. <u>Piping-Geometry Factor</u>

- ✓ The **flow capacity of a valve** may be affected by **nonstandard piping configurations**, such as the use of increasers or reducers, which must be **corrected in the *Cv* equation** using the *piping-geometry factor FP.*
- ✓ Standardized *Cv* testing is conducted by the valve manufacturer with straight piping that is the same line as the valve.
- ✓ The use of piping that is larger or smaller than the valve, or the close proximity of piping elbows, can decrease these values and must be considered during sizing.

Valve Sizing Selection Criteria

15. <u>Expansion Factor</u>

- ✓ With gas services, **the specific weight** of the fluid varies as the gas moves from the upstream piping and through the valve to the vena contracta.
- ✓ **The *expansion factor Y*** is used to compensate for the effects of this change in the specific weight of the gas.
- ✓ The expansion factor is important in that it takes into account the changes in the cross-sectional area of the vena contracta as the pressure drop changes in that region.

Valve Sizing Selection Criteria

16. <u>Ratio of Specific Heats Factor</u>

- ✓ Because the ***Cv* equation for gases is based upon air**, some adjustment must be **made for other gases**.
- ✓ The *ratio of specific heats factor FK* is used to adjust the *Cv* equation to the individual characteristics of these gases.

17. <u>Terminal Pressure-Drop Ratio</u>

- ✓ With gases, the point where the valve is choked (which means that increasing the pressure drop though lowering the downstream pressure cannot increase the flow of the valve) is predicted by the *terminal pressure-drop ratio xT.*
- ✓ is affected by the geometry of the valve’s body and varies according to valve style and individual size.

Valve Sizing Selection Criteria

18. <u>Compressibility Factor</u>

- ✓Because the **density of gases varies** according to the temperature and pressure of the fluid, the **fluid's compressibility must be included** in the *Cv* equation.
- ✓Therefore the ***compressibility factor Z*** is included in the equation and is a function of the temperature and pressure.

Liquid Sizing Example

- Consider the following service conditions:

Liquid	Water
Critical pressure P_c	3206.2 psia
Temperature	250°F
Upstream pressure P_1	314.7 psia
Downstream pressure P_2	104.7 psia
Flow rate Q	500 gal/min
Vapor pressure P_v	30 psia
Specific gravity S_g	0.94
Kinematic viscosity v	0.014 cS
Pipeline size	4 in (ANSI Class 600)
Valve	Globe, flow-to-open
Flow characteristic	Equal percentage

Determine the appropriate valve size.

Liquid Sizing Example

1. Find the actual pressure drop.

$$\Delta P = P_1 - P_2 = 314.7 \text{ psia} - 104.7 \text{ psia} = 210 \text{ psi}$$

2. Find ΔP_{choked}:

   I. Find F_L from Table 7.4

Table 7.4 Valve Recovery Coefficient and Incipient Cavitation Factors*

Valve Type	Flow Direction	Trim Size	F_L	F_i	x_T	F_d
Globe	Over Seat	Full Area	0.85	0.75	.70	1.0
	Over Seat	Reduced Area	0.80	0.72	.70	1.0
	Under Seat	Full Area	0.90	0.81	.75	1.0
	Under Seat	Reduced Area	0.90	0.81	.75	1.0
Valdisk	60° Open	Full	0.76	0.65	.36	.71
Rotary Disc	90° Open	Full	0.56	0.49	.26	.71
ShearStream	60° Open	Full	0.78	0.65	.51	1.0
Rotary Ball	90° Open	Full	0.66	0.44	.30	1.0
CavControl	Over Seat	All	0.92	0.90	N/A	$.2/\sqrt{d}$
MegaStream	Under Seat	All	~1.0	N/A	~1.0	$(n_s/25d)^{2/3}$**
ChannelStream	Over Seat	All	~1.0	0.87 to 0.999	N/A	.040"
Tiger-Tooth	Under Seat	All	~1.0	0.84 to 0.999	~1.0	.035"

Globe, flow-to-open

   II. Calculate F_F

$$F_F = 0.96 - 0.28\sqrt{\frac{P_V}{P_C}} = 0.96 - 0.28\sqrt{\frac{30}{3206.2}} = 0.93$$

Liquid Sizing Example

2. Find ΔP_{choked}:

   III. Calculate ΔP_{choked}

$$\Delta P_{choked} = F_L^2 (P_1 - F_F P_V) = (0.90)^2[314.7 - (0.93)(30)] = 232 \text{ psi}$$

Since P< ΔP_{choked}, no choked flow occurs.

3. Find $\Delta P_{cavitation}$:

$$\Delta P_{cavitation} = F_i^2(P_1 - P_V) = (0.81)^2(314.7-30) = 187 \text{ psi}$$

This determine at what pressure drop the cavitation begins.

Liquid Sizing Example

4. Calculate $C_{v,}$ at given SG & assuming F_p =1.0

$$C_v = \frac{Q}{F_p}\sqrt{\frac{S_g}{\Delta P_a}} = \frac{500}{1}\sqrt{\frac{0.94}{210}} = 33.4$$

5. Check the body valve using Table 7.2 (at the calculated C_v):

SIZE	TRIM NO	STROKE	F_L	PERCENT OPEN										SEAT AREA
				100	90	80	70	60	50	40	30	20	10	
1.00	.81	.75	.87	9.0	8.9	8.9	8.7	8.6	8.5	7.5	5.7	3.5	1.9	.52
1.50	1.25	1.00	.85	24	24	24	24	24	21	18	13	8.7	4.9	1.23
2.00	1.62	1.50	.87	41	41	40	40	39	39	34	26	15	8.1	2.06
3.00	2.00	2.00	.86	106	106	105	104	104	94	81	62	39	21	5.41
4.00	3.50	2.50	.87	185	185	183	181	178	162	139	105	68	37	9.62
6.00	5.00	3.00	.85	382	382	381	380	355	317	270	210	140	75	19.63

2-in valve body would be the smallest size to pass the required C_v (which is 33.4)

Liquid Sizing Example

6. Calculate Re Number:

$$\mathrm{Re}_V = \frac{N_4 F_d Q}{v\sqrt{F_L C_v}}\left(\frac{F_L^{\,2} C_v^{\,2}}{N_2 d^4} + 1\right)^{0.25}$$

$$= \frac{(17{,}300)(1)(500)}{(0.014)\sqrt{(0.90)(33.4)}}\left(\frac{(0.\,90)^2(33.4)^2}{(890)(2)^2} + 1\right)^{0.25}$$

$$= 114 \times 10^6$$

Re> 40000, indicates the turbulent flow.

Liquid Sizing Example

If the valve Reynolds number (Re_V) is equal to or greater than 40,000 ($Re_V \geq 40{,}000$), 1.0 should be used for the Reynolds-number factor F_R. The following equation is used to find F_R, if the valve Reynolds number is less than 40,000 ($Re_V \leq 40{,}000$):

$$F_R = 1.044 - 0.358\left(\frac{C_{vS}}{C_{vT}}\right)^{0.655}$$

through use of these equations:

$$C_{vS} = \frac{1}{F_S}\left(\frac{Q\mu}{N_S \Delta P}\right)^{0.667}$$

$$F_S = \frac{F_d^{\,0.667}}{F_L^{\,0.333}}\left(\frac{F_L^{\,2} C_v^{\,2}}{N_2 d^4} + 1\right)^{0.167}$$

Flow is considered to be laminar when the Reynolds-number factor F_R is less than 0.48 ($F_R < 0.48$). That means that the C_v is the same as the C_{vS}, which is determined from the equation in Sec. 7.3.7.

If F_R is larger than 0.98 ($F_R > 0.98$), the flow is determined to be turbulent and assumed to be equal to 1.0 ($F_R = 1.0$). At this point, the C_v is determined from the standard C_v liquid sizing equation found in Sec. 7.3.1. The piping-geometry factor F_p is not required in this situation and should not be figured into the C_v equation.

If F_R falls between 0.48 and 0.98, the flow is determined to be in a transitional stage, which is calculated using the following equation:

$$C_v = \frac{Q}{F_n}\sqrt{\frac{S_g}{\Delta P}}$$

Liquid Sizing Example

7. Find F_p from Table 7.5:
   I. Calculate d/D
   II. Calculate C_v/d^2

$$\frac{d}{D} = \frac{2}{4} = 0.5$$

$$\frac{C_v}{d^2} = \frac{33.4}{2^2} = 8.35$$

C_v / d^2	d / D				
	0.50	0.60	0.70	0.80	0.90
4	0.99	0.99	1.00	1.00	1.00
6	0.98	0.99	0.99	1.00	1.00
8	0.97	0.98	0.99	0.99	1.00
10	0.96	0.97	0.98	0.99	1.00
12	0.94	0.95	0.97	0.98	1.00
14	0.92	0.94	0.96	0.98	0.99
16	0.90	0.92	0.95	0.97	0.99
18	0.87	0.90	0.94	0.97	0.99
20	0.85	0.89	0.92	0.96	0.99
25	0.79	0.84	0.89	0.94	0.98
30	0.73	0.79	0.85	0.91	0.97
35	0.68	0.74	0.81	0.89	0.96
40	0.63	0.69	0.77	0.86	0.95

$F_p = 0.97$

Liquid Sizing Example

8. Find new C_v:

$$C_v = \frac{Q}{F_P}\sqrt{\frac{S_g}{\Delta P_a}} = \frac{500}{0.97}\sqrt{\frac{0.94}{210}} = 34.5$$

9. Calculate the velocity through the valve:

   I. Find A_v using Table 7.9

Valve Size (inches)	Valve Outlet Area, A_v (Square Inches)						
	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500	Class 4500
1/2	0.20	0.20	0.20	0.20	0.20	0.15	0.11
3/4	0.44	0.44	0.44	0.37	0.37	0.25	0.20
1	0.79	0.79	0.79	0.61	0.61	0.44	0.37
1 1/2	1.77	1.77	1.77	1.50	1.50	0.99	0.79
2	3.14	3.14	3.14	2.78	2.78	1.77	1.23
3	7.07	7.07	7.07	6.51	5.94	3.98	2.78
4	12.57	12.57	12.57	11.82	10.29	6.51	3.98
6	28.27	28.27	28.27	25.97	22.73	15.07	10.29
8	50.27	50.27	48.77	44.18	38.48	25.97	19.63
10	78.54	78.54	74.66	69.10	60.13	41.28	28.27
12	113.10	113.10	108.43	97.12	84.62	58.36	41.28
14	137.89	137.89	130.29	117.86	101.71	70.88	50.27
16	182.65	182.65	170.87	153.94	132.73	92.80	63.62
18	233.70	226.98	213.82	194.83	167.87	117.86	84.46
20	291.04	283.53	261.59	240.53	210.73	143.14	101.53
24	424.56	415.48	380.13	346.36	302.33	207.39	143.14
30	671.96	660.52	588.35	541.19	476.06	325.89	
36	962.11	907.92	855.30				
42	1320.25	1194.59					

$$V = \frac{0.321Q}{A_v} = \frac{0.321(500)}{3.14} = 51\ \text{ft/s}\ (130\ \text{m/s})$$

Velocity of 51ft/s exceed the limit Of 50 ft/s for liquids.

→Since the service is cavitating, Damage will most likely occur to Valve body.

→Option: Lower the velocity by Choosing the next larger valve size, a 3-in body, with A_v = 7.07

QUESTIONS

Any Questions???