

**Department of Energy  
Fundamentals Handbook**

**MECHANICAL SCIENCE  
Module 4  
Valves**

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## REFERENCES

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- Babcock & Wilcox, Steam, Its Generation and Use, Babcock & Wilcox Co., 1978.
- Cheremisinoff, N. P., Fluid Flow, Pumps, Pipes and Channels, Ann Arbor Science.
- Heat Transfer, Thermodynamics and Fluid Flow Fundamentals, Columbia, MD, General Physics Corporation, Library of Congress Card #A 326517, 1982.
- Schweitzer, Philip A., Handbook of Valves, Industrial Press Inc.
- Stewart, Harry L., Pneumatics & Hydraulics, Theodore Audel & Company, 1984.

## VALVE FUNCTIONS AND BASIC PARTS

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*Valves are the most common single piece of equipment found in DOE facilities. Although there are many types, shapes, and sizes of valves, they all have the same basic parts. This chapter will review the common parts and functions of a valve.*

**EO 1.1      DESCRIBE the four basic types of flow control elements employed in valve design.**

**EO 1.2      DESCRIBE how valve stem leakage is controlled.**

**EO 1.3      Given a drawing of a valve, IDENTIFY the following:**

- |                         |                        |
|-------------------------|------------------------|
| <b>a.      Body</b>     | <b>e.      Packing</b> |
| <b>b.      Bonnet</b>   | <b>f.      Seat</b>    |
| <b>c.      Stem</b>     | <b>g.      Disk</b>    |
| <b>d.      Actuator</b> |                        |

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### **Introduction**

A valve is a mechanical device that controls the flow of fluid and pressure within a system or process. A valve controls system or process fluid flow and pressure by performing any of the following functions:

- Stopping and starting fluid flow
- Varying (throttling) the amount of fluid flow
- Controlling the direction of fluid flow
- Regulating downstream system or process pressure
- Relieving component or piping over pressure

There are many valve designs and types that satisfy one or more of the functions identified above. A multitude of valve types and designs safely accommodate a wide variety of industrial applications.

Regardless of type, all valves have the following basic parts: the body, bonnet, trim (internal elements), actuator, and packing. The basic parts of a valve are illustrated in Figure 1.

## Valve Body

The *body*, sometimes called the shell, is the primary pressure boundary of a valve. 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.

Valve bodies are cast or forged into a variety of shapes. Although a sphere or a cylinder would theoretically be the most economical shape to resist fluid pressure when a valve is open, there are many other considerations. For example, many valves require a partition across the valve body to support the seat opening, which is the throttling orifice. With the valve closed, loading on the body is difficult to determine. The valve end connections also distort loads on a simple sphere and more complicated shapes. Ease of manufacture, assembly, and costs are additional important considerations. Hence, the basic form of a valve body typically is not spherical, but ranges from simple block shapes to highly complex shapes in which the bonnet, a removable piece to make assembly possible, forms part of the pressure-resisting body.

Narrowing of the fluid passage (venturi effect) is also a common method for reducing the overall size and cost of a valve. In other instances, large ends are added to the valve for connection into a larger line.

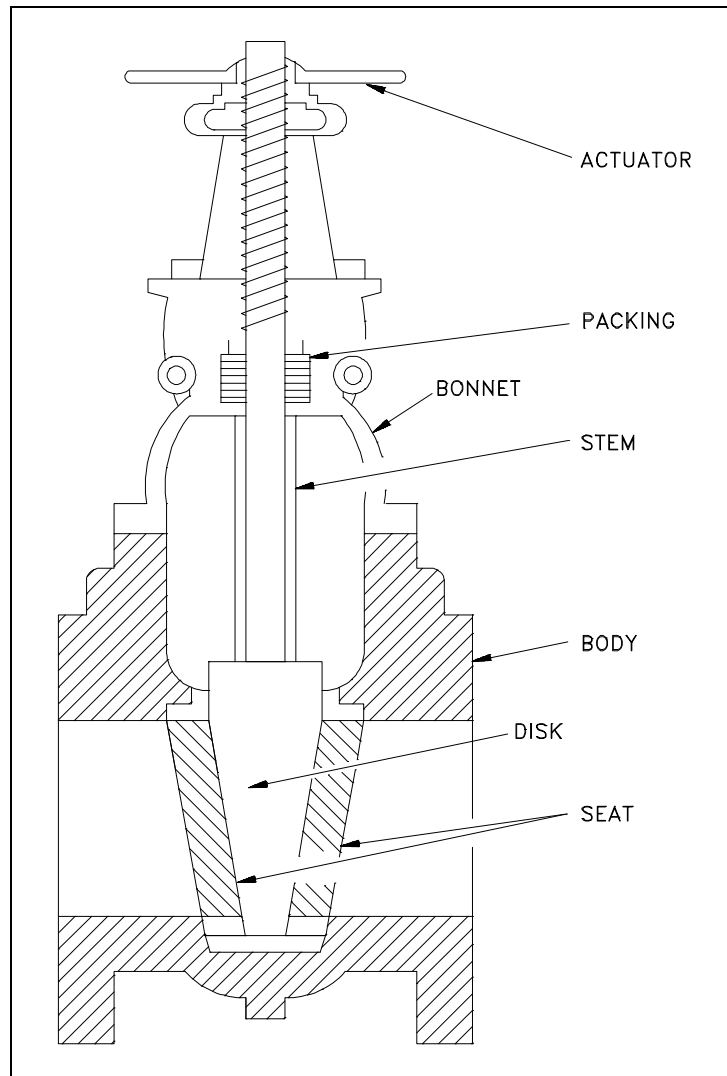


Figure 1 Basic Parts of a Valve

## **Valve 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.

The bonnet is the second principal pressure boundary of a valve. It is cast or forged of the same material as the body and is connected to the body by a threaded, bolted, or welded joint. In all cases, the attachment of the bonnet to the body is considered a pressure boundary. This means that the weld joint or bolts that connect the bonnet to the body are pressure-retaining parts.

Valve bonnets, although a necessity for most valves, represent a cause for concern. Bonnets can complicate the manufacture of valves, increase valve size, represent a significant cost portion of valve cost, and are a source for potential leakage.

## **Valve Trim**

The internal elements of a valve are collectively referred to as a valve's *trim*. The trim typically includes a *disk*, *seat*, *stem*, and *sleeves* needed to guide the stem. A valve's performance is determined by the disk and seat interface and the relation of the disk position to the seat.

Because of the trim, basic motions and flow control are possible. In rotational motion trim designs, the disk slides closely past the seat to produce a change in flow opening. In linear motion trim designs, the disk lifts perpendicularly away from the seat so that an annular orifice appears.

### **Disk and Seat**

For a valve having a bonnet, the disk is the third primary principal pressure boundary. The disk provides the capability for permitting and prohibiting fluid flow. With the disk closed, full system pressure is applied across the disk if the outlet side is depressurized. For this reason, the disk is a pressure-retaining part. Disks are typically forged and, in some designs, hard-surfaced to provide good wear characteristics. A fine surface finish of the seating area of a disk is necessary for good sealing when the valve is closed. Most valves are named, in part, according to the design of their disks.

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. To improve the wear-resistance of the seal rings, the surface is often hard-faced by welding and then machining the contact surface of the seal ring. A fine surface finish of the seating area is necessary for good sealing when the valve is closed. Seal rings are not usually considered pressure boundary parts because the body has sufficient wall thickness to withstand design pressure without relying upon the thickness of the seal rings.

## Stem

The *stem*, which connects the actuator and disk, is responsible for positioning the disk. 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.

Connection of the disk to the stem can allow some rocking or rotation to ease the positioning of the disk on the seat. Alternately, the stem may be flexible enough to let the disk position itself against the seat. However, constant fluttering or rotation of a flexible or loosely connected disk can destroy the disk or its connection to the stem.

Two types of valve stems are rising stems and nonrising stems. Illustrated in Figures 2 and 3, these two types of stems are easily distinguished by observation. For a rising stem valve, the stem will rise above the actuator as the valve is opened. This occurs because the stem is threaded and mated with the bushing threads of a yoke that is an integral part of, or is mounted to, the bonnet.

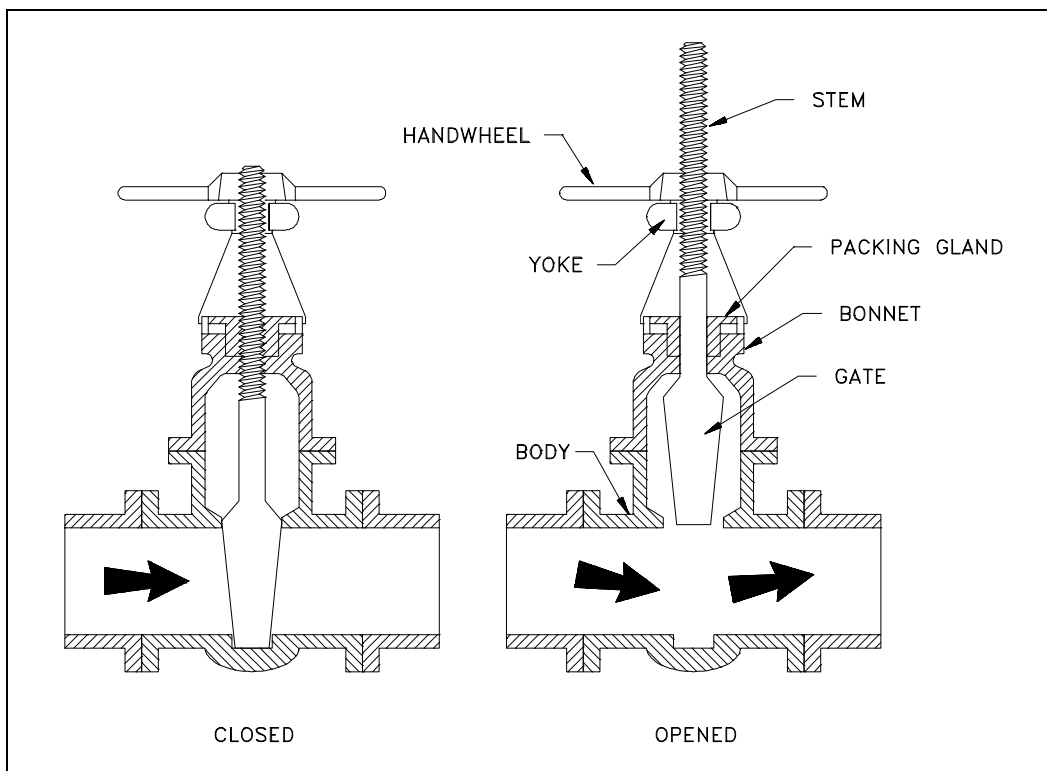


Figure 2 Rising Stems

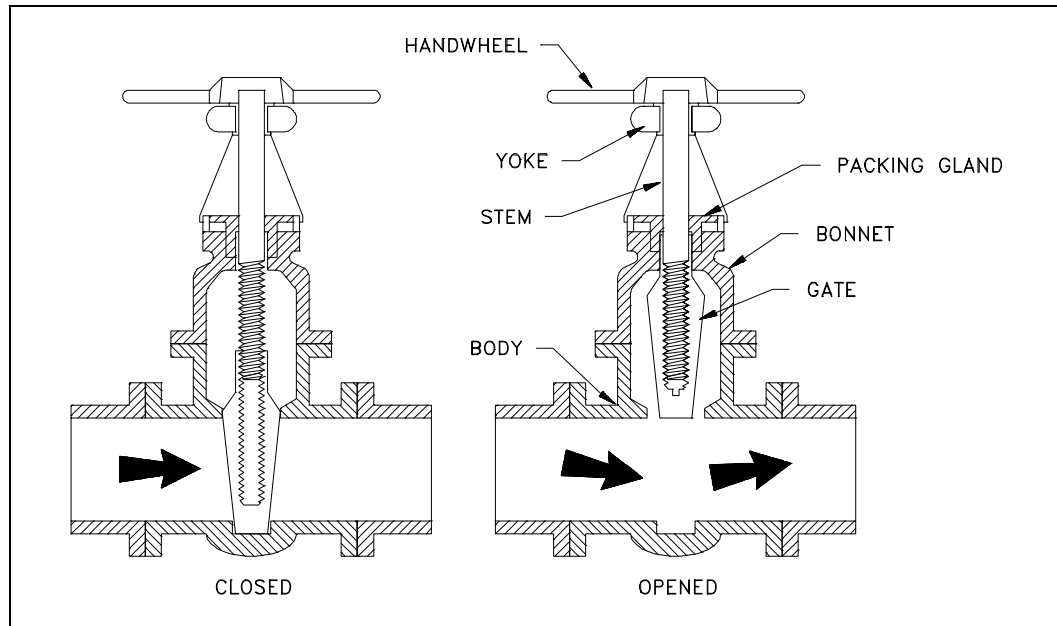


Figure 3 Nonrising Stems

There is no upward stem movement from outside the valve for a nonrising stem design. For the nonrising stem design, the valve disk is threaded internally and mates with the stem threads.

### **Valve Actuator**

The *actuator* operates the stem and disk assembly. An actuator may be a manually operated handwheel, manual lever, motor operator, solenoid operator, pneumatic operator, or hydraulic ram. In some designs, the actuator is supported by the bonnet. In other designs, a yoke mounted to the bonnet supports the actuator.

Except for certain hydraulically controlled valves, actuators are outside of the pressure boundary. Yokes, when used, are always outside of the pressure boundary.

### **Valve Packing**

Most valves use some form of packing to prevent leakage from the space between the stem and the bonnet. *Packing* is commonly a fibrous material (such as flax) or another compound (such as teflon) that forms a seal between the internal parts of a valve and the outside where the stem extends through the body.

Valve packing must be properly compressed to prevent fluid loss and damage to the valve's stem. If a valve's packing is too loose, the valve will leak, which is a safety hazard. If the packing is too tight, it will impair the movement and possibly damage the stem.

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## **Introduction to the Types of Valves**

Because of the diversity of the types of systems, fluids, and environments in which valves must operate, a vast array of valve types have been developed. Examples of the common types are the globe valve, gate valve, ball valve, plug valve, butterfly valve, diaphragm valve, check valve, pinch valve, and safety valve. Each type of valve has been designed to meet specific needs. Some valves are capable of throttling flow, other valve types can only stop flow, others work well in corrosive systems, and others handle high pressure fluids. Each valve type has certain inherent advantages and disadvantages. Understanding these differences and how they effect the valve's application or operation is necessary for the successful operation of a facility.

Although all valves have the same basic components and function to control flow in some fashion, the method of controlling the flow can vary dramatically. In general, there are four methods of controlling flow through a valve.

1. Move a disc, or plug into or against an orifice (for example, globe or needle type valve).
2. Slide a flat, cylindrical, or spherical surface across an orifice (for example, gate and plug valves).
3. Rotate a disc or ellipse about a shaft extending across the diameter of an orifice (for example, a butterfly or ball valve).
4. Move a flexible material into the flow passage (for example, diaphragm and pinch valves).

Each method of controlling flow has characteristics that makes it the best choice for a given application of function.



## **Summary**

The following important information in this chapter is summarized below:

### **Valve Functions and Basic Parts Summary**

- There are four basic types of flow control elements employed in valve design.
  1. Move a disc, or plug into or against an orifice (for example, globe or needle type valve).
  2. Slide a flat, cylindrical, or spherical surface across an orifice (for example, gate and plug valves).
  3. Rotate a disc or ellipse about a shaft extending across the diameter of an orifice (for example, a butterfly or ball valve).
  4. Move a flexible material into the flow passage (for example, diaphragm and pinch valves).
- Valve stem leakage is usually controlled by properly compressing the packing around the valve stem.
- There are seven basic parts common to most valves.

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## TYPES OF VALVES

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*Due to the various environments, system fluids, and system conditions in which flow must be controlled, a large number of valve designs have been developed. A basic understanding of the differences between the various types of valves, and how these differences affect valve function, will help ensure the proper application of each valve type during design and the proper use of each valve type during operation.*

**EO 1.4**      **Given a drawing of a valve, IDENTIFY each of the following types of valves:**

- |    |                  |    |                      |
|----|------------------|----|----------------------|
| a. | <b>Globe</b>     | g. | <b>Diaphragm</b>     |
| b. | <b>Gate</b>      | h. | <b>Pinch</b>         |
| c. | <b>Plug</b>      | i. | <b>Check</b>         |
| d. | <b>Ball</b>      | j. | <b>Safety/relief</b> |
| e. | <b>Needle</b>    | k. | <b>Reducing</b>      |
| f. | <b>Butterfly</b> |    |                      |

**EO 1.5**      **DESCRIBE the application of the following types of valves:**

- |    |                  |    |                      |
|----|------------------|----|----------------------|
| a. | <b>Globe</b>     | g. | <b>Diaphragm</b>     |
| b. | <b>Gate</b>      | h. | <b>Pinch</b>         |
| c. | <b>Plug</b>      | i. | <b>Check</b>         |
| d. | <b>Ball</b>      | j. | <b>Safety/relief</b> |
| e. | <b>Needle</b>    | k. | <b>Reducing</b>      |
| f. | <b>Butterfly</b> |    |                      |

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### Gate Valves

A *gate* valve is a linear motion valve used to start or stop fluid flow; however, it does not regulate or throttle flow. The name gate is derived from the appearance of the disk in the flow stream. Figure 4 illustrates a gate valve.

The disk of a gate valve is completely removed from the flow stream when the valve is fully open. This characteristic offers virtually no resistance to flow when the valve is open. Hence, there is little pressure drop across an open gate valve.

When the valve is fully closed, a disk-to-seal ring contact surface exists for 360°, and good sealing is provided. With the proper mating of a disk to the seal ring, very little or no leakage occurs across the disk when the gate valve is closed.

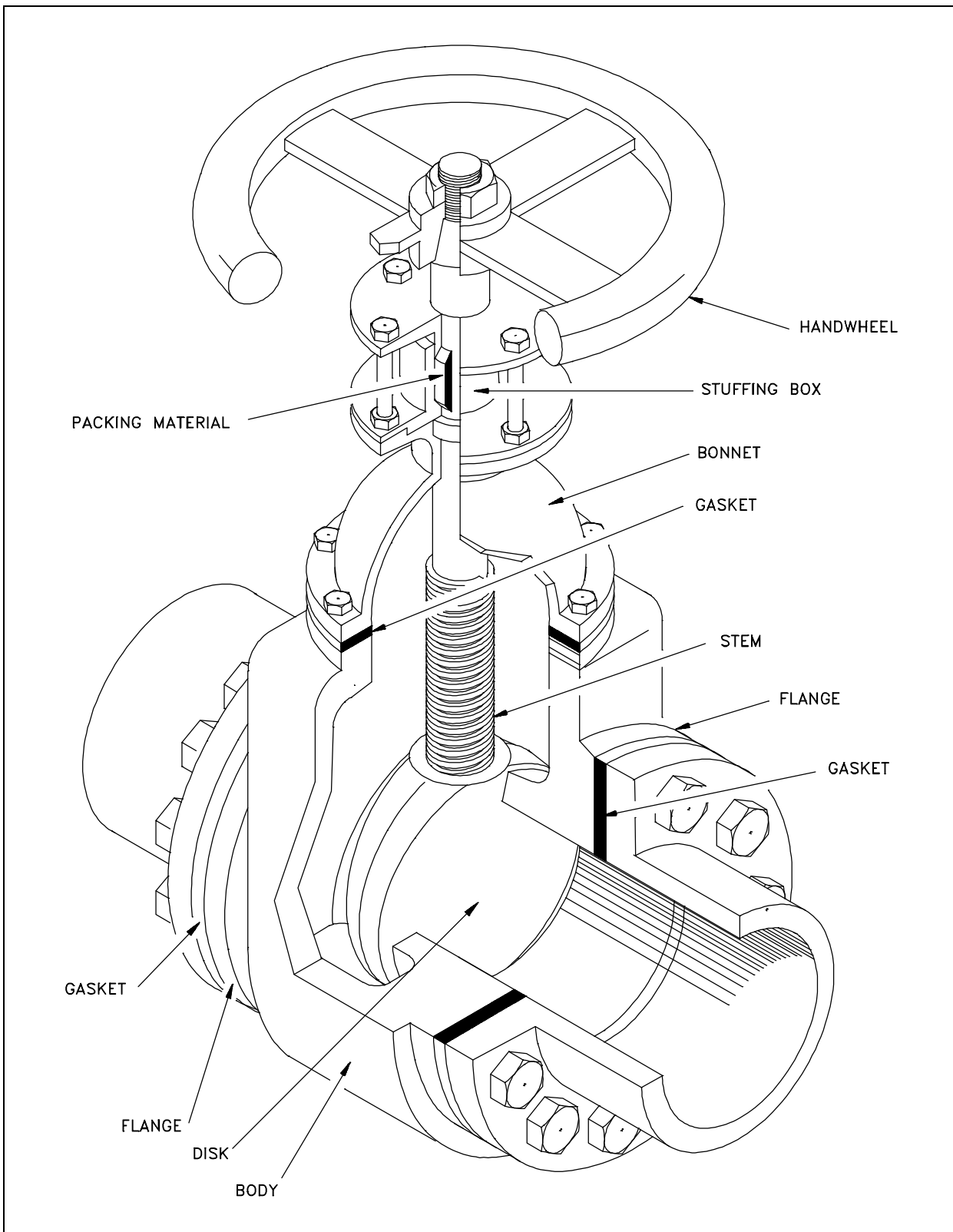


Figure 4 Gate Valve

On opening the gate valve, the flow path is enlarged in a highly nonlinear manner with respect to percent of opening. This means that flow rate does not change evenly with stem travel. Also, a partially open gate disk tends to vibrate from the fluid flow. Most of the flow change occurs near shutoff with a relatively high fluid velocity causing disk and seat wear and eventual leakage if used to regulate flow. For these reasons, gate valves are not used to regulate or throttle flow.

A gate valve can be used for a wide variety of fluids and provides a tight seal when closed. The major disadvantages to the use of a gate valve are:

- It is not suitable for throttling applications.
- It is prone to vibration in the partially open state.
- It is more subject to seat and disk wear than a globe valve.
- Repairs, such as lapping and grinding, are generally more difficult to accomplish.

### **Gate Valve Disk Design**

Gate valves are available with a variety of disks. Classification of gate valves is usually made by the type disk used: solid wedge, flexible wedge, split wedge, or parallel disk.

Solid wedges, flexible wedges, and split wedges are used in valves having inclined seats. Parallel disks are used in valves having parallel seats.

Regardless of the style of wedge or disk used, the disk is usually replaceable. In services where solids or high velocity may cause rapid erosion of the seat or disk, these components should have a high surface hardness and should have replacement seats as well as disks. If the seats are not replaceable, seat damage requires removal of the valve from the line for refacing of the seat, or refacing of the seat in place. Valves being used in corrosion service should normally be specified with replaceable seats.

### **Solid Wedge**

The solid wedge gate valve shown in Figure 5 is the most commonly used disk because of its simplicity and strength. A valve with this type of wedge may be installed in any position and it is suitable for almost all fluids. It is practical for turbulent flow.

### **Flexible Wedge**

The flexible wedge gate valve illustrated in Figure 6 is a one-piece disk with a cut around the perimeter to improve the ability to match error or change in the angle between the seats. The cut varies in size, shape, and depth. A shallow, narrow cut gives little flexibility but retains strength. A deeper and wider cut, or cast-in recess, leaves little material at the center, which allows more flexibility but compromises strength.

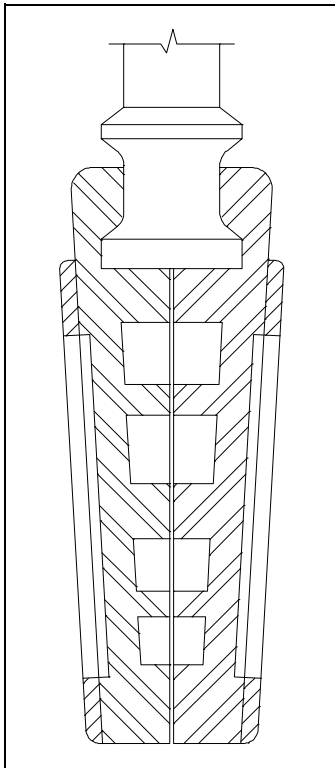


Figure 6  
Flexible Wedge Gate Valve

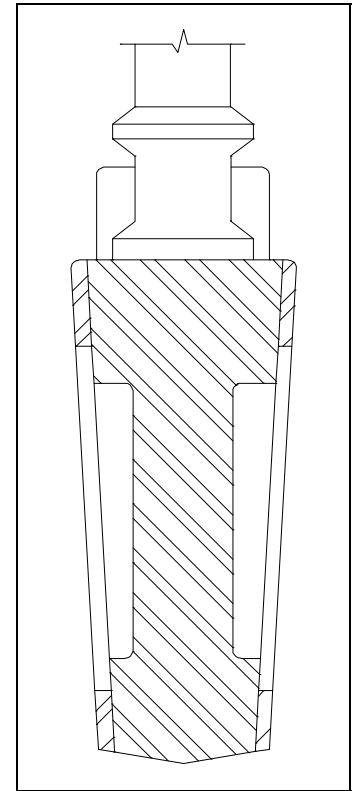


Figure 5  
Solid Wedge Gate Valve

A correct profile of the disk half in the flexible wedge design can give uniform deflection properties at the disk edge, so that the wedging force applied in seating will force the disk seating surface uniformly and tightly against the seat.

Gate valves used in steam systems have flexible wedges. The reason for using a flexible gate is to prevent binding of the gate within the valve when the valve is in the closed position. When steam lines are heated, they expand and cause some distortion of valve bodies. If a solid gate fits snugly between the seat of a valve in a cold steam system, when the system is heated and pipes elongate, the seats will compress against the gate and clamp the valve shut. This problem is overcome by using a flexible gate, whose design allows the gate to flex as the valve seat compresses it.

The major problem associated with flexible gates is that water tends to collect in the body neck. Under certain conditions, the admission of steam may cause the valve body neck to rupture, the bonnet to lift off, or the seat ring to collapse. Following correct warming procedures prevent these problems.

## **Split Wedge**

Split wedge gate valves, as shown in Figure 7, are of the ball and socket design. These are self-adjusting and self-aligning to both seating surfaces. The disk is free to adjust itself to the seating surface if one-half of the disk is slightly out of alignment because of foreign matter lodged between the disk half and the seat ring. This type of wedge is suitable for handling noncondensing gases and liquids at normal temperatures, particularly corrosive liquids. Freedom of movement of the disk in the carrier prevents binding even though the valve may have been closed when hot and later contracted due to cooling. This type of valve should be installed with the stem in the vertical position.

## **Parallel Disk**

The parallel disk gate valve illustrated in Figure 8 is designed to prevent valve binding due to thermal transients. This design is used in both low and high pressure applications.

The wedge surfaces between the parallel face disk halves are caused to press together under stem thrust and spread apart the disks to seal against the seats. The tapered wedges may be part of the disk halves or they may be separate elements. The lower wedge may bottom out on a rib at the valve bottom so that the stem can develop seating force. In one version, the wedge contact surfaces are curved to keep the point of contact close to the optimum.

In other parallel disk gates, the two halves do not move apart under wedge action. Instead, the upstream pressure holds the downstream disk against the seat. A carrier ring lifts the disks, and a spring or springs hold the disks apart and seated when there is no upstream pressure.

Another parallel gate disk design provides for sealing only one port. In these designs, the high pressure side pushes the disk open (relieving the disk) on the high pressure side, but forces the disk closed on the low pressure side. With such designs, the amount of seat leakage tends to decrease as differential pressure across the seat increases. These valves will usually have a flow direction marking which will show which side is the high pressure (relieving) side. Care should be taken to ensure that these valves are not installed backwards in the system.

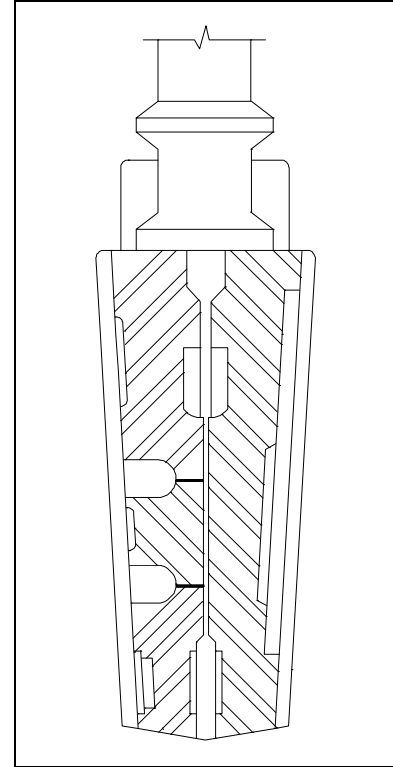


Figure 7 Split Wedge Gate Valve

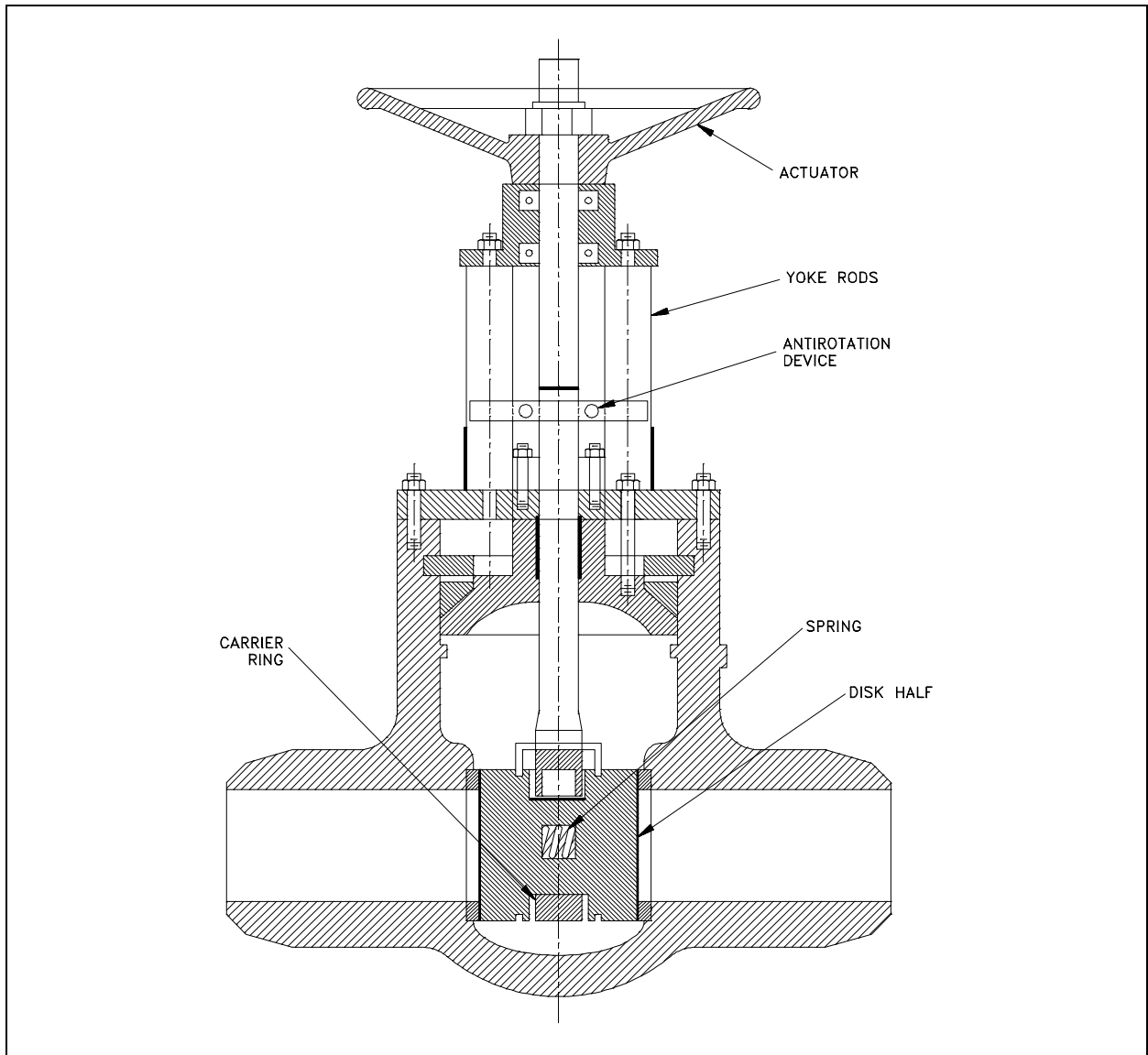


Figure 8 Parallel Disk Gate Valve

Some parallel disk gate valves used in high pressure systems are made with an integral bonnet vent and bypass line. A three-way valve is used to position the line to bypass in order to equalize pressure across the disks prior to opening. When the gate valve is closed, the three-way valve is positioned to vent the bonnet to one side or the other. This prevents moisture from accumulating in the bonnet. The three-way valve is positioned to the high pressure side of the gate valve when closed to ensure that flow does not bypass the isolation valve. The high pressure acts against spring compression and forces one gate off of its seat. The three-way valve vents this flow back to the pressure source.

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## **Gate Valve Stem Design**

Gate valves are classified as either rising stem or nonrising stem valves. For the nonrising stem gate valve, 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. This type valve will almost always have a pointer-type indicator threaded onto the upper end of the stem to indicate valve position. Figures 2 and 3 illustrate rising-stem gate valves and nonrising stem gate valves.

The nonrising stem configuration places the stem threads within the boundary established by the valve packing out of contact with the environment. This configuration assures that the stem merely rotates in the packing without much danger of carrying dirt into the packing from outside to inside.

Rising stem gate valves are designed so that the stem is raised out of the flowpath when the valve is open. Rising stem gate valves come in two basic designs. Some have a stem that rises through the handwheel while others have a stem that is threaded to the bonnet.

## **Gate Valve Seat Design**

Seats for gate valves are either provided integral with the valve body or in a seat ring type of construction. Seat ring construction provides seats which are either threaded into position or are pressed into position and seal welded to the valve body. The latter form of construction is recommended for higher temperature service.

Integral seats provide a seat of the same material of construction as the valve body while the pressed-in or threaded-in seats permit variation. Rings with hard facings may be supplied for the application where they are required.

Small, forged steel, gate valves may have hard faced seats pressed into the body. In some series, this type of valve in sizes from 1/2 to 2 inches is rated for 2500 psig steam service. In large gate valves, disks are often of the solid wedge type with seat rings threaded in, welded in, or pressed in. Screwed in seat rings are considered replaceable since they may be removed and new seat rings installed.



## **Globe Valves**

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 9.

As shown in Figure 9, the globe valve disk can be totally removed from the flowpath or it can completely close the flowpath. 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.

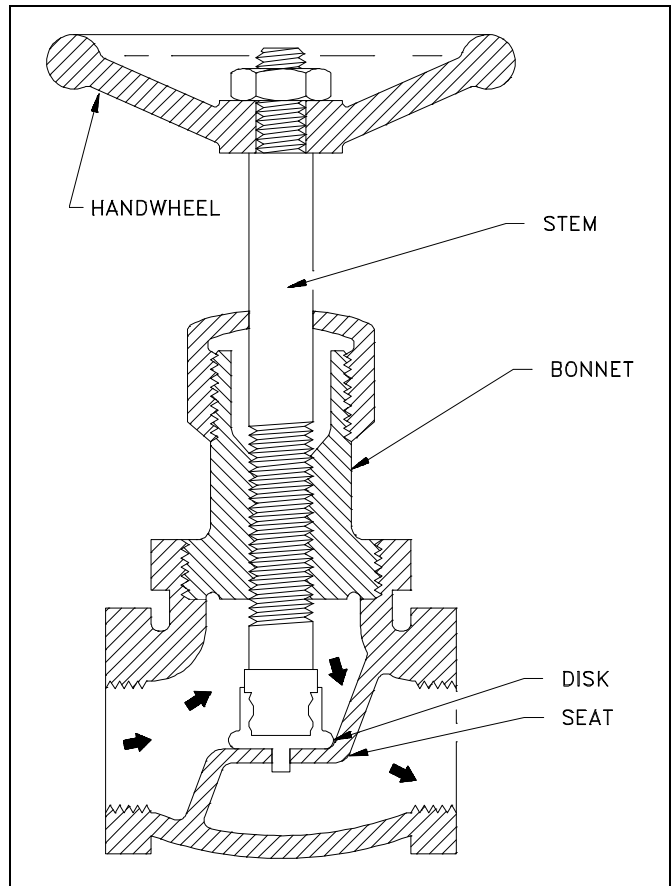


Figure 9 Z-Body Globe Valve

Globe valves can be arranged so that the disk closes against or in the same direction of fluid flow. When the disk closes against the direction of flow, the kinetic energy of the fluid impedes closing but aids opening of the valve. When the disk closes in the same direction of flow, the kinetic energy of the fluid aids closing but impedes opening. This characteristic is preferable to other designs when quick-acting stop valves are necessary.

Globe valves also have drawbacks. The most evident shortcoming of the simple globe valve is the high head loss from two or more right angle turns of flowing fluid. Obstructions and discontinuities in the flowpath lead to 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. In addition, large valve sizes require considerable power to operate and are especially noisy in high pressure applications.

Other drawbacks of globe valves are the large openings necessary for disk assembly, heavier weight than other valves of the same flow rating, and the cantilevered mounting of the disk to the stem.

**Globe Valve Body Designs**

The three primary body designs for globe valves are Z-body, Y-body, and Angle.

**Z-Body Design**

The simplest design and most common for water applications is the Z-body. The Z-body is illustrated in Figure 9. For this body design, the Z-shaped diaphragm or partition across the globular body contains the seat. The horizontal setting of the seat allows the stem and disk to travel at right angles to the pipe axis. The stem passes through the bonnet which is attached to a large opening at the top of the valve body. This provides a symmetrical form that simplifies manufacture, installation, and repair.

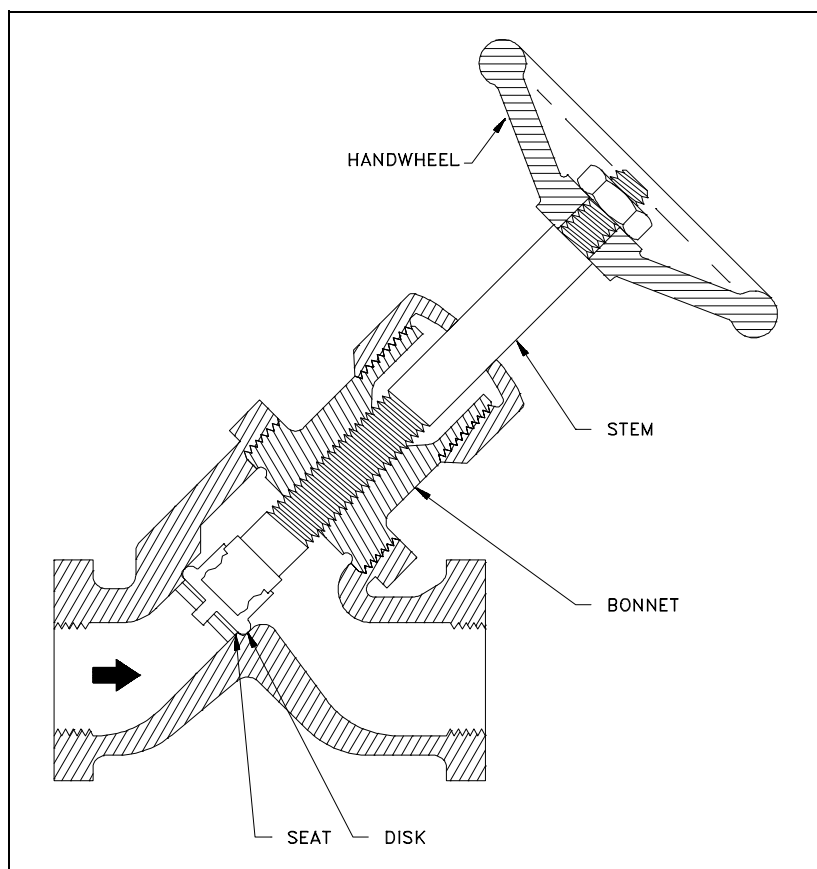


Figure 10 Y-Body Globe Valve

**Y-Body Design**

Figure 10 illustrates a typical Y-body globe valve. This design is a remedy for the high pressure drop inherent in globe valves. The seat and stem are angled at approximately 45°. The angle yields a straighter flowpath (at full opening) and provides the stem, bonnet, and packing a relatively pressure-resistant envelope.

Y-body globe valves are best suited for high pressure and other severe services. In small sizes for intermittent flows, the pressure loss may not be as important as the other considerations favoring the Y-body design. Hence, the flow passage of small Y-body globe valves is not as carefully streamlined as that for larger valves.

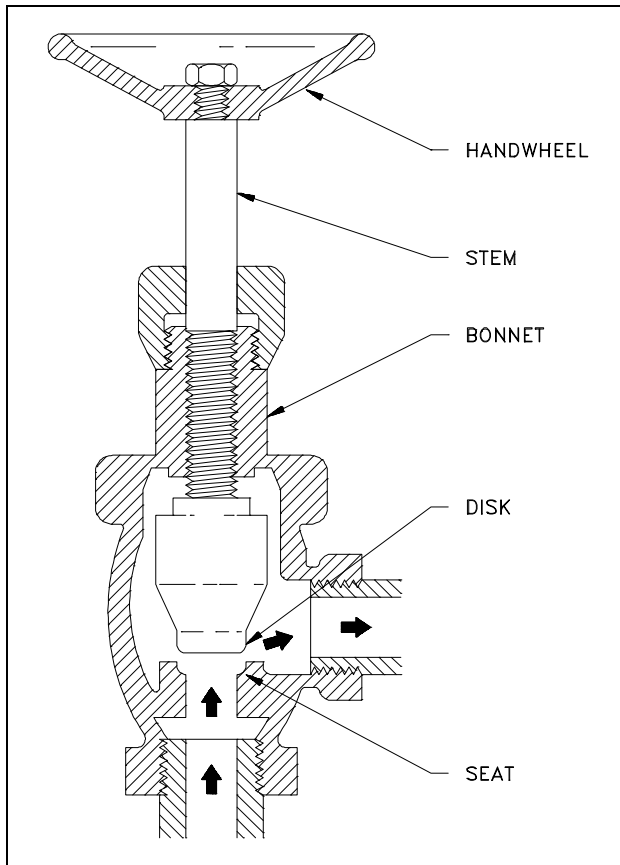


Figure 11 Angle Globe Valve

### **Angle Valve Design**

The angle body globe valve design, illustrated in Figure 11, is a simple modification of the basic globe valve. Having ends at right angles, the diaphragm can be a simple flat plate. Fluid is able to flow through with only a single 90° turn and discharge downward more symmetrically than the discharge from an ordinary globe. A particular advantage of the angle body design is that it can function as both a valve and a piping elbow.

For moderate conditions of pressure, temperature, and flow, the angle valve closely resembles the ordinary globe. The angle valve's discharge conditions are favorable with respect to fluid dynamics and erosion.

### **Globe Valve Disks**

Most globe valves use one of three basic disk designs: the ball disk, the composition disk, and the plug disk.

#### **Ball Disk**

The ball disk fits on a tapered, flat-surfaced seat. The ball disk design is used primarily in relatively low pressure and low temperature systems. It is capable of throttling flow, but is primarily used to stop and start flow.

#### **Composition Disk**

The composition disk design uses a hard, nonmetallic insert ring on the disk. The insert ring creates a tighter closure. Composition disks are primarily used in steam and hot water applications. They resist erosion and are sufficiently resilient to close on solid particles without damaging the valve. Composition disks are replaceable.

#### **Plug Disk**

Because of its configuration, the plug disk provides better throttling than ball or composition designs. Plug disks are available in a variety of specific configurations. In general, they are all long and tapered.

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## **Globe Valve Disk and Stem Connections**

Globe valves employ two methods for connecting disk and stem: T-slot construction and disk nut construction. In the T-slot design, the disk slips over the stem. In the disk nut design, the disk is screwed into the stem.

## **Globe Valve Seats**

Globe valve seats are either integral with or screwed into the valve body. Many globe valves have backseats. A backseat is a seating arrangement that provides a seal between the stem and bonnet. When the valve is fully open, the disk seats against the backseat. The backseat design prevents system pressure from building against the valve packing.

## **Globe Valve Direction of Flow**

For low temperature applications, globe and angle valves are ordinarily installed so that pressure is under the disk. This promotes easy operation, helps protect the packing, and eliminates a certain amount of erosive action to the seat and disk faces. For high temperature steam service, globe valves are installed so that pressure is above the disk. Otherwise, the stem will contract upon cooling and tend to lift the disk off the seat.

## **Ball Valves**

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 12, performs the same function as the disk in the globe valve. 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.

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.

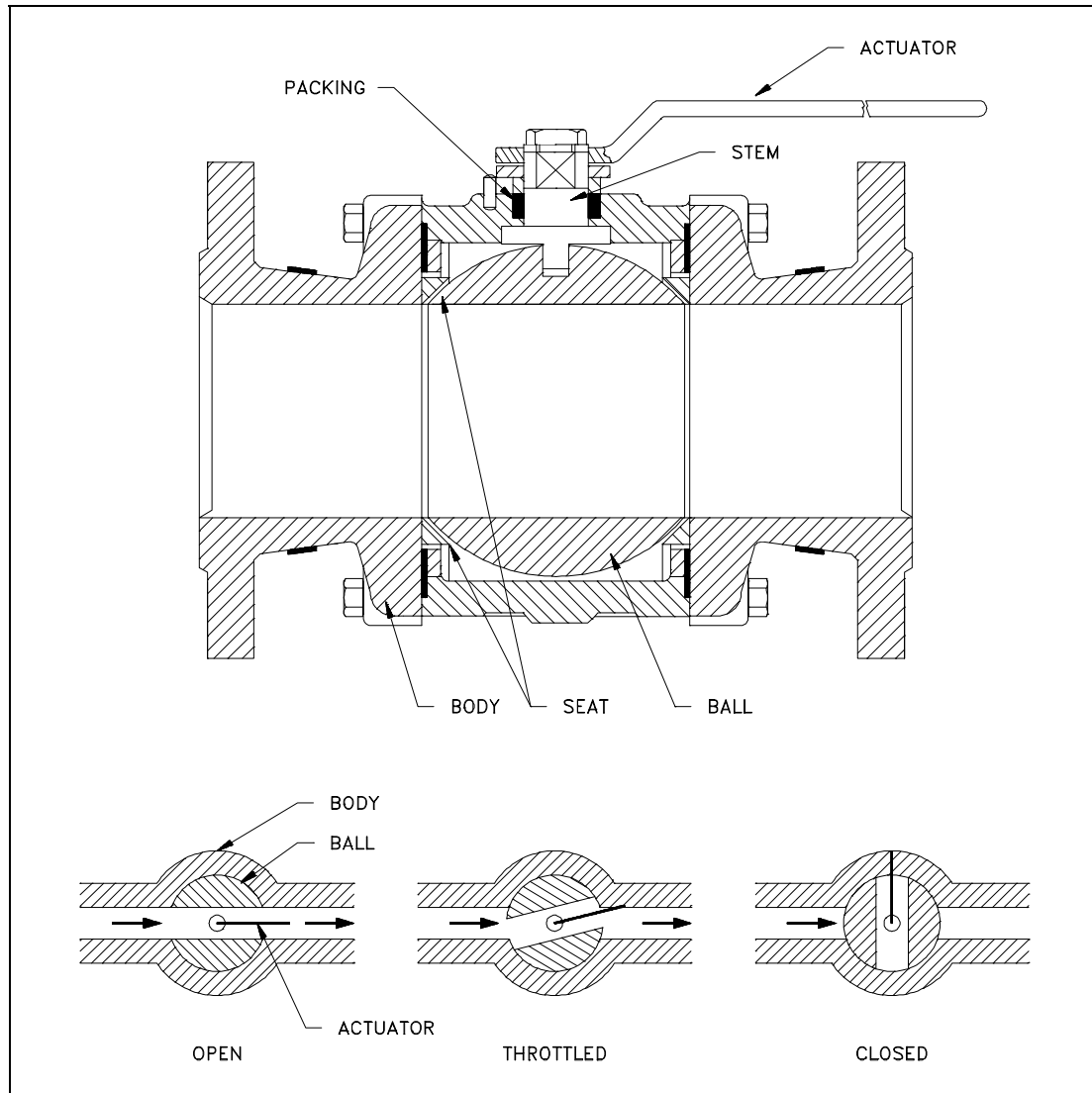


Figure 12 Typical Ball Valve

### **Advantages**

A ball valve is generally the least expensive of any valve configuration and has low maintenance costs. In addition to quick, quarter turn on-off operation, ball valves are compact, require no lubrication, and give tight sealing with low torque.

### **Disadvantages**

Conventional ball valves have relatively poor throttling characteristics. In a throttling position, the partially exposed seat rapidly erodes because of the impingement of high velocity flow.

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## **Port Patterns**

Ball valves are available in the venturi, reduced, and full port pattern. The full port pattern has a ball with a bore equal to the inside diameter of the pipe.

## **Valve Materials**

Balls are usually metallic in metallic bodies with trim (seats) produced from elastomeric (elastic materials resembling rubber) materials. Plastic construction is also available.

The resilient seats for ball valves are made from various elastomeric material. The most common seat materials are teflon (TFE), filled TFE, Nylon, Buna-N, Neoprene, and combinations of these materials. Because of the elastomeric materials, these valves cannot be used at elevated temperatures. Care must be used in the selection of the seat material to ensure that it is compatible with the materials being handled by the valve.

## **Ball Valve Stem Design**

The stem in a ball valve is not fastened to the ball. It normally has a rectangular portion at the ball end which fits into a slot cut into the ball. The enlargement permits rotation of the ball as the stem is turned.

## **Ball Valve Bonnet Design**

A bonnet cap fastens to the body, which holds the stem assembly and ball in place. Adjustment of the bonnet cap permits compression of the packing, which supplies the stem seal. Packing for ball valve stems is usually in the configuration of die-formed packing rings normally of TFE, TFE-filled, or TFE-impregnated material. Some ball valve stems are sealed by means of O-rings rather than packing.

## **Ball Valve Position**

Some ball valves are equipped with stops that permit only 90° rotation. Others do not have stops and may be rotated 360°. With or without stops, a 90° rotation is all that is required for closing or opening a ball valve.

The handle indicates valve ball position. When the handle lies along the axis of the valve, the valve is open. When the handle lies 90° across the axis of the valve, the valve is closed. Some ball valve stems have a groove cut in the top face of the stem that shows the flowpath through the ball. Observation of the groove position indicates the position of the port through the ball. This feature is particularly advantageous on multiport ball valves.

## Plug Valves

A plug valve is a rotational motion valve used to stop or start fluid flow. The name is derived from the shape of the disk, which resembles a plug. A plug valve is shown in Figure 13. The simplest form of a plug valve is the petcock. The body of a plug valve is machined to receive the tapered or cylindrical plug. The disk is a solid plug with a bored passage at a right angle to the longitudinal axis of the plug.

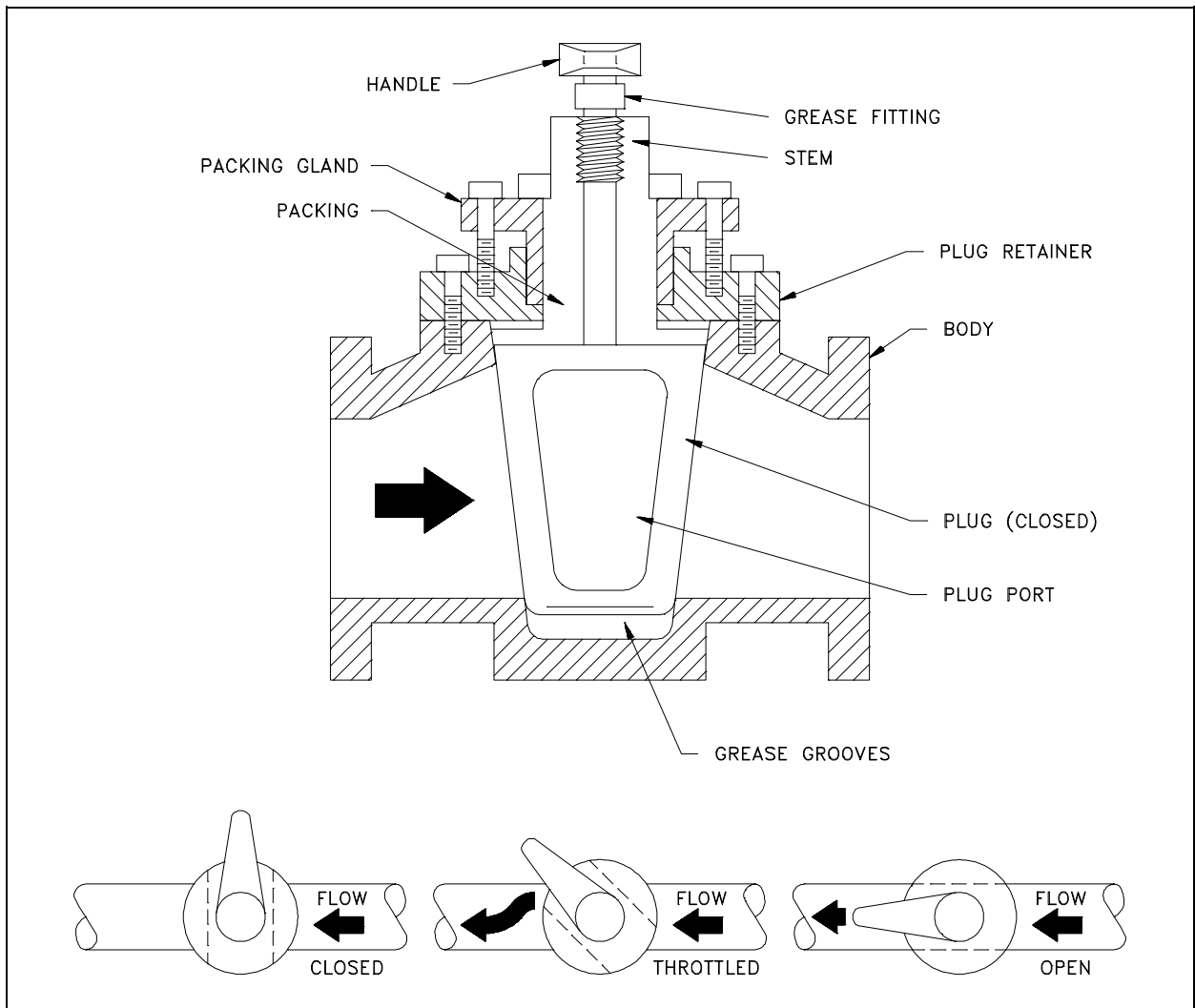


Figure 13 Plug Valve

In the open position, the passage in the plug lines up with the inlet and outlet ports of the valve body. When the plug is turned  $90^\circ$  from the open position, the solid part of the plug blocks the ports and stops fluid flow.

Plug valves are available in either a lubricated or nonlubricated design and with a variety of styles of port openings through the plug as well as a number of plug designs.

### **Plug Ports**

An important characteristic of the plug valve is its easy adaptation to multiport construction. Multiport valves are widely used. Their installation simplifies piping, and they provide a more convenient operation than multiple gate valves. They also eliminate pipe fittings. The use of a multiport valve, depending upon the number of ports in the plug valve, eliminates the need of as many as four conventional shutoff valves.

Plug valves are normally used in non-throttling, on-off operations, particularly where frequent operation of the valve is necessary. These valves are not normally recommended for throttling service because, like the gate valve, a high percentage of flow change occurs near shutoff at high velocity. However, a diamond-shaped port has been developed for throttling service.

### **Multiport Plug Valves**

Multiport valves are particularly advantageous on transfer lines and for diverting services. A single multiport valve may be installed in lieu of three or four gate valves or other types of shutoff valve. A disadvantage is that many multiport valve configurations do not completely shut off flow.

In most cases, one flowpath is always open. These valves are intended to divert the flow of one line while shutting off flow from the other lines. If complete shutoff of flow is a requirement, it is necessary that a style of multiport valve be used that permits this, or a secondary valve should be installed on the main line ahead of the multiport valve to permit complete shutoff of flow.

In some multiport configurations, simultaneous flow to more than one port is also possible. Great care should be taken in specifying the particular port arrangement required to guarantee that proper operation will be possible.

### **Plug Valve Disks**

Plugs are either round or cylindrical with a taper. They may have various types of port openings, each with a varying degree of area relative to the corresponding inside diameter of the pipe.

#### **Rectangular Port Plug**

The most common port shape is the rectangular port. The rectangular port represents at least 70% of the corresponding pipe's cross-sectional area.



### **Round Port Plug**

Round port plug is a term that describes a valve that has a round opening through the plug. If the port is the same size or larger than the pipe's inside diameter, it is referred to as a full port. If the opening is smaller than the pipe's inside diameter, the port is referred to as a standard round port. Valves having standard round ports are used only where restriction of flow is unimportant.

### **Diamond Port Plug**

A diamond port plug has a diamond-shaped port through the plug. This design is for throttling service. All diamond port valves are venturi restricted flow type.

### **Lubricated Plug Valve Design**

Clearances and leakage prevention are the chief considerations in plug valves. Many plug valves are of all metal construction. In these versions, the narrow gap around the plug can allow leakage. If the gap is reduced by sinking the taper plug deeper into the body, actuation torque climbs rapidly and galling can occur. To remedy this condition, a series of grooves around the body and plug port openings is supplied with grease prior to actuation. Applying grease lubricates the plug motion and seals the gap between plug and body. Grease injected into a fitting at the top of the stem travels down through a check valve in the passageway, past the plug top to the grooves on the plug, and down to a well below the plug. The lubricant must be compatible with the temperature and nature of the fluid. All manufacturers of lubricated plug valves have developed a series of lubricants that are compatible with a wide range of media. Their recommendation should be followed as to which lubricant is best suited for the service.

The most common fluids controlled by plug valves are gases and liquid hydrocarbons. Some water lines have these valves, provided that lubricant contamination is not a serious danger. Lubricated plug valves may be as large as 24 inches and have pressure capabilities up to 6000 psig. Steel or iron bodies are available. The plug can be cylindrical or tapered.

### **Nonlubricated Plugs**

There are two basic types of nonlubricated plug valves: lift-type and elastomer sleeve or plug coated. Lift-type valves provide a means of mechanically lifting the tapered plug slightly to disengage it from the seating surface to permit easy rotation. The mechanical lifting can be accomplished with a cam or external lever.

In a common, nonlubricated, plug valve having an elastomer sleeve, a sleeve of TFE completely surrounds the plug. It is retained and locked in place by a metal body. This design results in a primary seal being maintained between the sleeve and the plug at all times regardless of position. The TFE sleeve is durable and inert to all but a few rarely encountered chemicals. It also has a low coefficient of friction and is, therefore, self-lubricating.

**Manually Operated Plug Valve Installation**

When installing plug valves, care should be taken to allow room for the operation of the handle, lever, or wrench. The manual operator is usually longer than the valve, and it rotates to a position parallel to the pipe from a position 90° to the pipe.

**Plug Valve Glands**

The gland of the plug valve is equivalent to the bonnet of a gate or globe valve. The gland secures the stem assembly to the valve body. There are three general types of glands: single gland, screwed gland, and bolted gland.

To ensure a tight valve, the plug must be seated at all times. Gland adjustment should be kept tight enough to prevent the plug from becoming unseated and exposing the seating surfaces to the live fluid. Care should be exercised to not overtighten the gland, which will result in a metal-to-metal contact between the body and the plug. Such a metal-to-metal contact creates an additional force which will require extreme effort to operate the valve.

**Diaphragm Valves**

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 14.

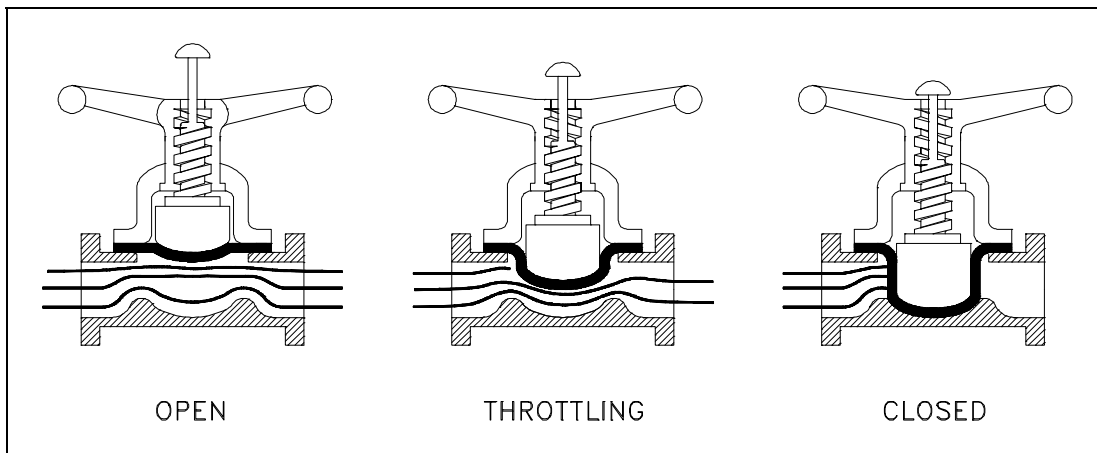


Figure 14 Straight Through Diaphragm Valve

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 14 or the body weir in the weir-type valve illustrated in Figure 15.

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.

A weir-type diaphragm valve is available to control small flows. It uses a two-piece compressor component. Instead of the entire diaphragm lifting off the weir when the valve is opened, the first increments of stem travel raise an inner compressor component that causes only the central part of the diaphragm to lift. This creates a relatively small opening through the center of the valve. After the inner compressor is completely open, the outer compressor component is raised along with the inner compressor and the remainder of the throttling is similar to the throttling that takes place in a conventional valve.

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

### **Diaphragm Construction**

The operating mechanism of a diaphragm valve is not exposed to the media within the pipeline. Sticky or viscous fluids cannot get into the bonnet to interfere with the operating mechanism. Many fluids that would clog, corrode, or gum up the working parts of most other types of valves will pass through a diaphragm valve without causing problems. Conversely, lubricants used for the operating mechanism cannot be allowed to contaminate the fluid being handled. There are no packing glands to maintain and no possibility of stem leakage. There is a wide choice of available diaphragm materials. Diaphragm life depends upon the nature of the material handled, temperature, pressure, and frequency of operation.

Some elastomeric diaphragm materials may be unique in their excellent resistance to certain chemicals at high temperatures. However, the mechanical properties of any elastomeric material will be lowered at the higher temperature with possible destruction of the diaphragm at high pressure. Consequently, the manufacturer should be consulted when they are used in elevated temperature applications.

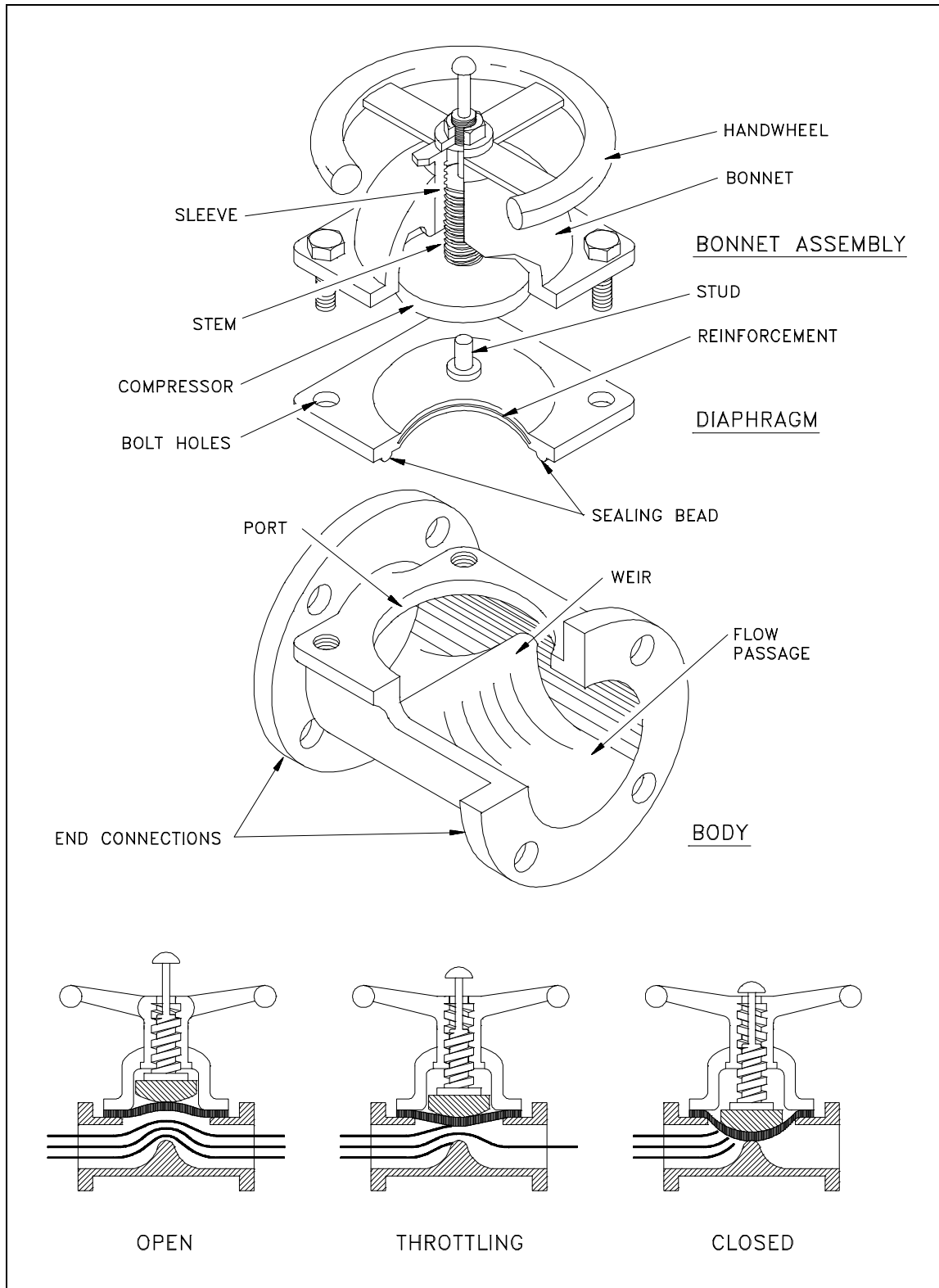


Figure 15 Weir Diaphragm Valve

All elastomeric materials operate best below 150°F. Some will function at higher temperatures. Viton, for example, is noted for its excellent chemical resistance and stability at high temperatures. However, when fabricated into a diaphragm, Viton is subject to lowered tensile strength just as any other elastomeric material would be at elevated temperatures. Fabric bonding strength is also lowered at elevated temperatures, and in the case of Viton, temperatures may be reached where the bond strength could become critical.

Fluid concentrations is also a consideration for diaphragm selection. Many of the diaphragm materials exhibit satisfactory corrosion resistance to certain corrodents up to a specific concentration and/or temperature. The elastomer may also have a maximum temperature limitation based on mechanical properties which could be in excess of the allowable operating temperature depending upon its corrosion resistance. This should be checked from a corrosion table.

### **Diaphragm Valve Stem Assemblies**

Diaphragm valves have stems that do not rotate. The valves are available with indicating and nonindicating stems. The indicating stem valve is identical to the nonindicating stem valve except that a longer stem is provided to extend up through the handwheel. For the nonindicating stem design, the handwheel rotates a stem bushing that engages the stem threads and moves the stem up and down. As the stem moves, so does the compressor that is pinned to the stem. The diaphragm, in turn, is secured to the compressor.

### **Diaphragm Valve Bonnet Assemblies**

Some diaphragm valves use a quick-opening bonnet and lever operator. This bonnet is interchangeable with the standard bonnet on conventional weir-type bodies. A 90° turn of the lever moves the diaphragm from full open to full closed. Diaphragm valves may also be equipped with chain wheel operators, extended stems, bevel gear operators, air operators, and hydraulic operators.

Many diaphragm valves are used in vacuum service. Standard bonnet construction can be employed in vacuum service through 4 inches in size. On valves 4 inches and larger, a sealed, evacuated, bonnet should be employed. This is recommended to guard against premature diaphragm failure.

Sealed bonnets are supplied with a seal bushing on the nonindicating types and a seal bushing plus O-ring on the indicating types. Construction of the bonnet assembly of a diaphragm valve is illustrated in Figure 15. This design is recommended for valves that are handling dangerous liquids and gases. In the event of a diaphragm failure, the hazardous materials will not be released to the atmosphere. If the materials being handled are extremely hazardous, it is recommended that a means be provided to permit a safe disposal of the corrodents from the bonnet.

**Reducing Valves**

Reducing valves automatically reduce supply pressure to a preselected pressure as long as the supply pressure is at least as high as the selected pressure. As illustrated in Figure 16, the principal parts of the reducing valve are the main valve; an upward-seating valve that has a piston on top of its valve stem, an upward-seating auxiliary (or controlling) valve, a controlling diaphragm, and an adjusting spring and screw.

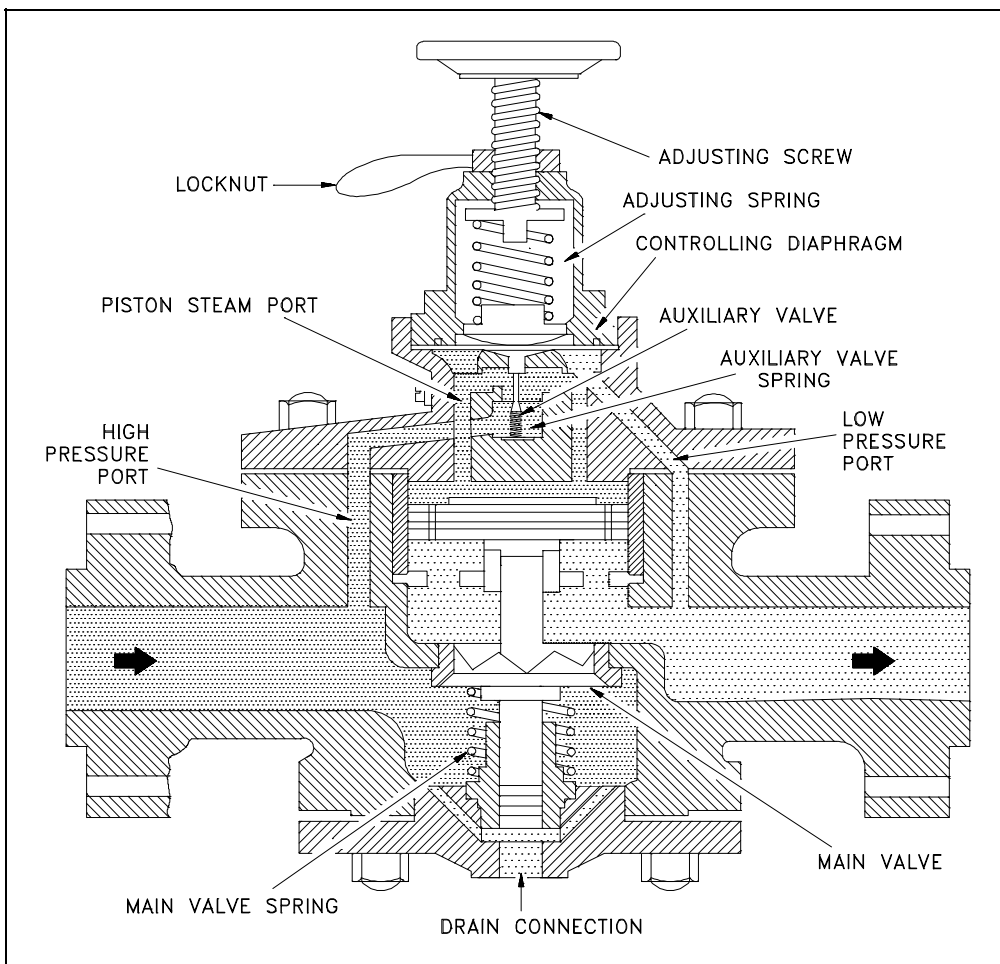


Figure 16 Variable Reducing Valve

Reducing valve operation is controlled by high pressure at the valve inlet and the adjusting screw on top of the valve assembly. The pressure entering the main valve assists the main valve spring in keeping the reducing valve closed by pushing upward on the main valve disk. However, some of the high pressure is bled to an auxiliary valve on top of the main valve. The auxiliary valve controls the admission of high pressure to the piston on top of the main valve. The piston has a larger surface area than the main valve disk, resulting in a net downward force to open the main valve. The auxiliary valve is controlled by a controlling diaphragm located directly over the auxiliary valve.

The controlling diaphragm transmits a downward force that tends to open the auxiliary valve. The downward force is exerted by the adjusting spring, which is controlled by the adjusting screw. Reduced pressure from the main valve outlet is bled back to a chamber beneath the diaphragm to counteract the downward force of the adjusting spring. The position of the auxiliary valve, and ultimately the position of the main valve, is determined by the position of the diaphragm. The position of the diaphragm is determined by the strength of the opposing forces of the downward force of the adjusting spring versus the upward force of the outlet reduced pressure. Other reducing valves work on the same basic principle, but may use gas, pneumatic, or hydraulic controls in place of the adjusting spring and screw.

Non-variable reducing valves, illustrated in Figure 17, replace the adjusting spring and screw with a pre-pressurized dome over the diaphragm. The valve stem is connected either directly or indirectly to the diaphragm. The valve spring below the diaphragm keeps the valve closed. As in the variable valve, reduced pressure is bled through an orifice to beneath the diaphragm to open the valve. Valve position is determined by the strength of the opposing forces of the downward force of the pre-pressurized dome versus the upward force of the outlet-reduced pressure.

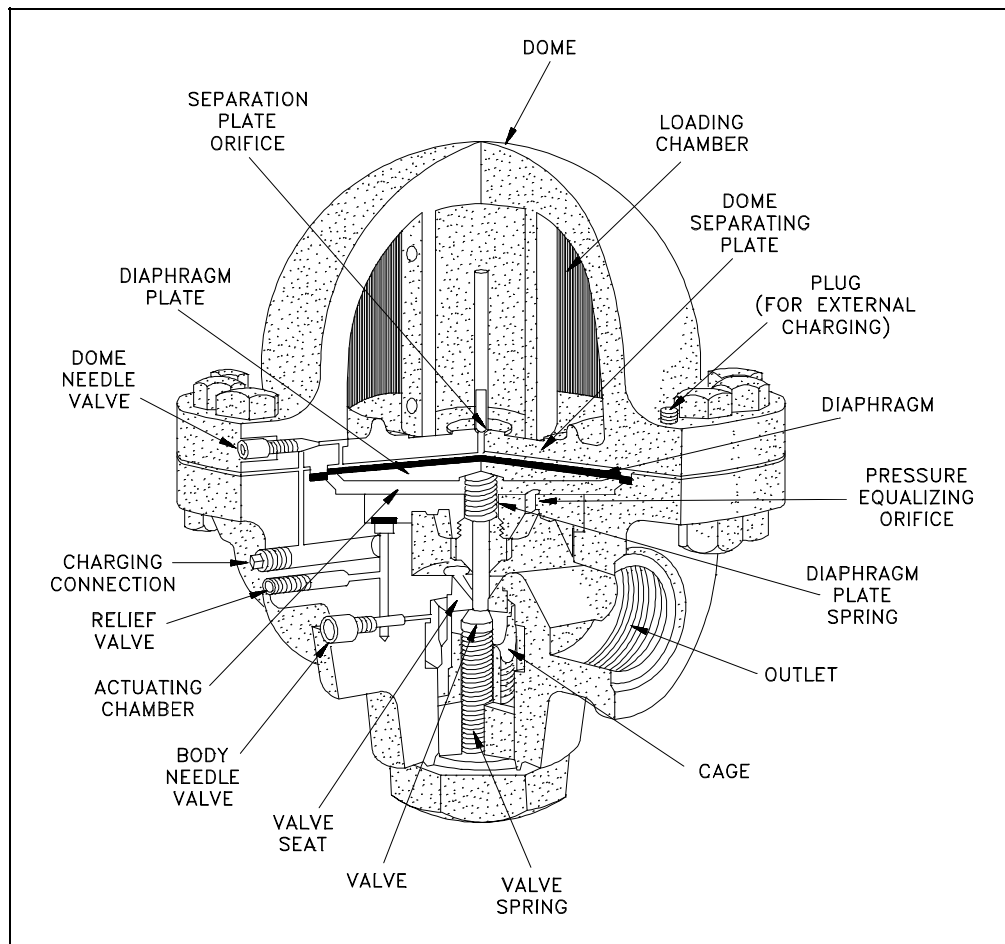


Figure 17 Non-Variable Reducing Valve

Non-variable reducing valves eliminate the need for the intermediate auxiliary valve found in variable reducing valves by having the opposing forces react directly on the diaphragm. Therefore, non-variable reducing valves are more responsive to large pressure variations and are less susceptible to failure than are variable reducing valves.

## **Pinch Valves**

The relatively inexpensive pinch valve, illustrated in Figure 18, 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.

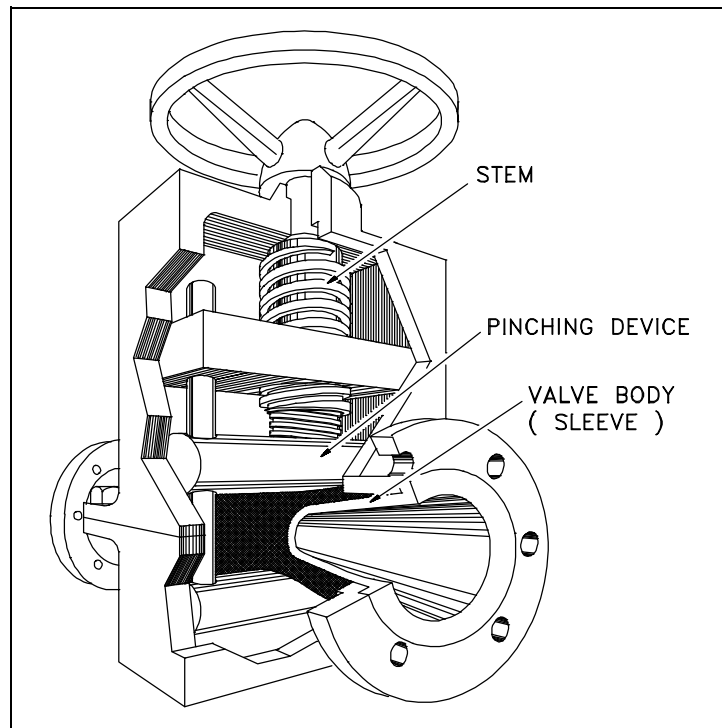


Figure 18 Pinch Valves

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.



## **Pinch Valve Bodies**

Pinch valves have molded bodies reinforced with fabric. Pinch valves generally have a maximum operating temperature of 250°F. At 250°F, maximum operating pressure varies generally from 100 psig for a 1-inch diameter valve and decreases to 15 psig for a 12-inch diameter valve. Special pinch valves are available for temperature ranges of -100°F to 550°F and operating pressures of 300 psig.

Most pinch valves are supplied with the sleeve (valve body) exposed. Another style fully encloses the sleeve within a metallic body. This type controls flow either with the conventional wheel and screw pinching device, hydraulically, or pneumatically with the pressure of the liquid or gas within the metal case forcing the sleeve walls together to shut off flow.

Most exposed sleeve valves have limited vacuum application because of the tendency of the sleeves to collapse when vacuum is applied. Some of the encased valves can be used on vacuum service by applying a vacuum within the metal casing and thus preventing the collapse of the sleeve.

## **Butterfly Valves**

A butterfly valve, illustrated in Figure 19, 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° 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.

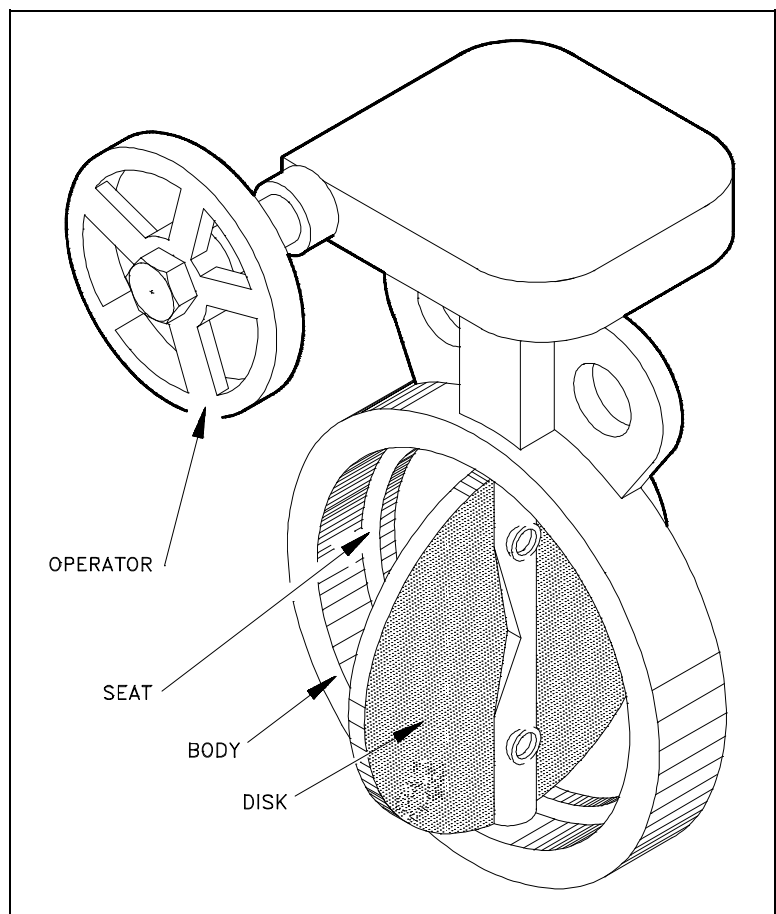


Figure 19 Typical Butterfly Valve

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.

### **Butterfly Valve Seat Construction**

Stoppage of flow is accomplished by the valve disk sealing against a seat that is on the inside diameter periphery of the valve body. Many butterfly valves have an elastomeric seat against which the disk seals. Other butterfly valves have a seal ring arrangement that uses a clamp-ring and backing-ring on a serrated edged rubber ring. This design prevents extrusion of the O-rings. In early designs, a metal disk was used to seal against a metal seat. This arrangement did not provide a leak-tight closure, but did provide sufficient closure in some applications (i.e., water distribution lines).

### **Butterfly Valve Body Construction**

Butterfly valve body construction varies. The most economical is the wafer type that fits between two pipeline flanges. Another type, the lug wafer design, is held in place between two pipe flanges by bolts that join the two flanges and pass through holes in the valve's outer casing. Butterfly valves are available with conventional flanged ends for bolting to pipe flanges, and in a threaded end construction.

### **Butterfly Valve Disk and Stem Assemblies**

The stem and disk for a butterfly valve are separate pieces. The disk is bored to receive the stem. Two methods are used to secure the disk to the stem so that the disk rotates as the stem is turned. In the first method, the disk is bored through and secured to the stem with bolts or pins. The alternate method involves boring the disk as before, then shaping the upper stem bore to fit a squared or hex-shaped stem. This method allows the disk to "float" and seek its center in the seat. Uniform sealing is accomplished and external stem fasteners are eliminated. This method of assembly is advantageous in the case of covered disks and in corrosive applications.

In order for the disk to be held in the proper position, the stem must extend beyond the bottom of the disk and fit into a bushing in the bottom of the valve body. One or two similar bushings are along the upper portion of the stem as well. These bushings must be either resistant to the media being handled or sealed so that the corrosive media cannot come into contact with them.

Stem seals are accomplished either with packing in a conventional stuffing box or by means of O-ring seals. Some valve manufacturers, particularly those specializing in the handling of corrosive materials, place a stem seal on the inside of the valve so that no material being handled by the valve can come into contact with the valve stem. If a stuffing box or external O-ring is employed, the fluid passing through the valve will come into contact with the valve stem.

### Needle Valves

A needle valve, as shown in Figure 20, 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.

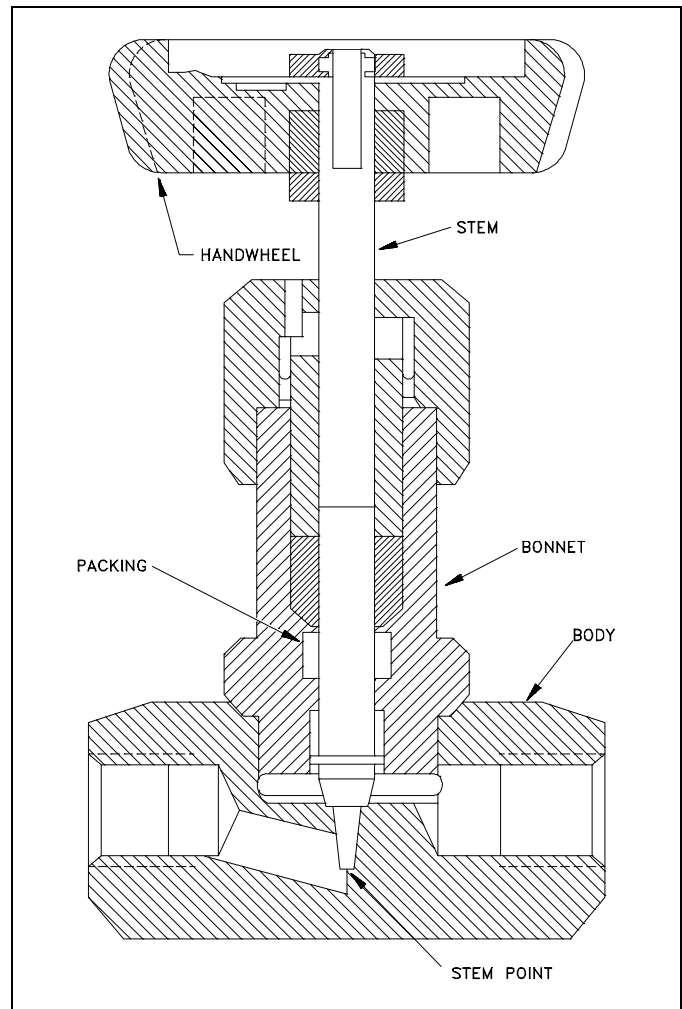


Figure 20 Needle Valve

## Needle Valve Body Designs

One type of body design for a needle valve is the bar stock body. Bar stock bodies are common, and, in globe types, a ball swiveling in the stem provides the necessary rotation for seating without damage. The bar stock body is illustrated in Figure 21.

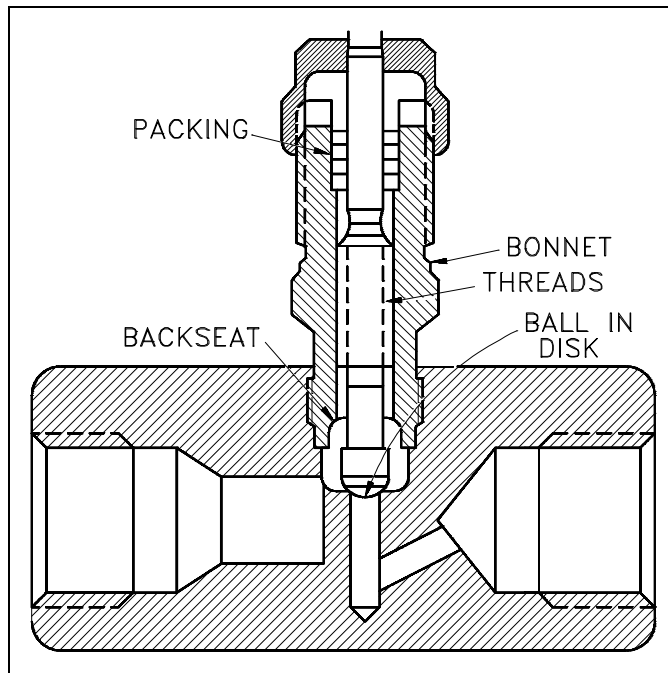


Figure 21 Bar-Stock Instrument Valve

Needle valves are frequently used as metering valves. Metering valves are used for extremely fine flow control. The thin disk or orifice allows for linear flow characteristics. Therefore, the number of handwheel turns can be directly correlated to the amount of flow. A typical metering valve has a stem with 40 threads per inch.

Needle valves generally use one of two styles of stem packing: an O-ring with TFE backing rings or a TFE packing cylinder. Needle valves are often equipped with replaceable seats for ease of maintenance.

## **Check Valves**

Check valves are designed to prevent the reversal of flow in a piping system. These valves are activated by the flowing material in the pipeline. The pressure of the fluid passing through the system opens the valve, while any reversal of flow will close the valve. Closure is accomplished by the weight of the check mechanism, by back pressure, by a spring, or by a combination of these means. The general types of check valves are swing, tilting-disk, piston, butterfly, and stop.

### **Swing Check Valves**

A swing check valve is illustrated in Figure 22. The valve allows full, unobstructed flow and automatically closes as pressure decreases. These valves are fully closed when the flow reaches zero and prevent back flow. Turbulence and pressure drop within the valve are very low.

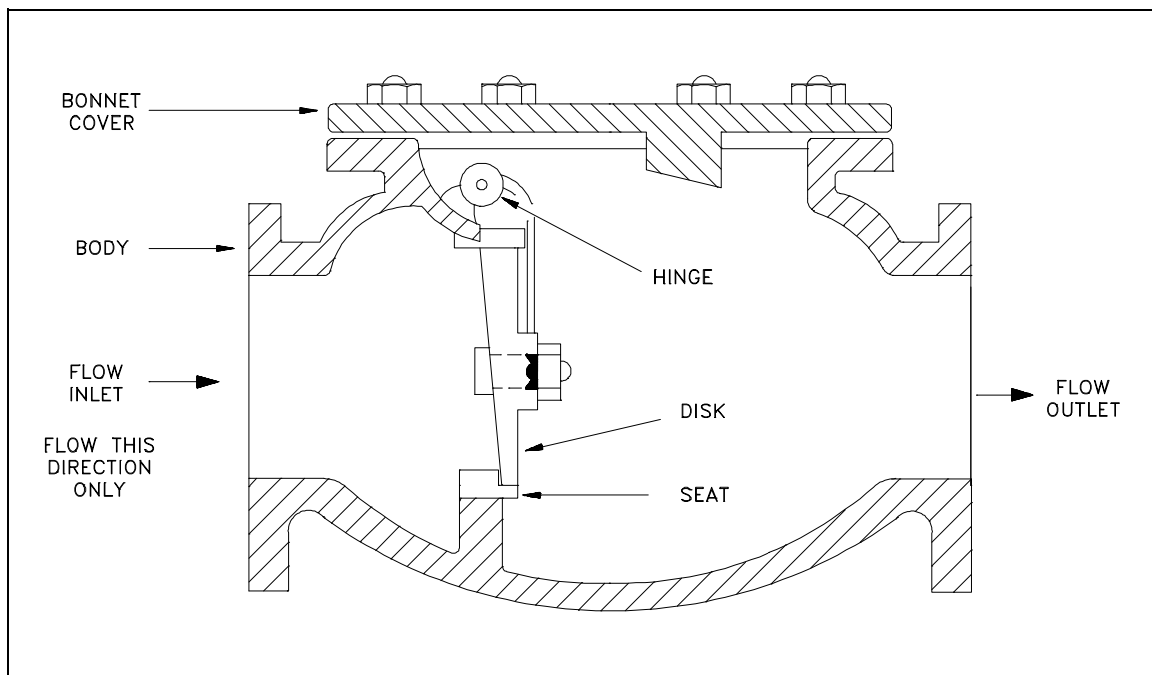


Figure 22 Swing Check Valve

A swing check valve is normally recommended for use in systems employing gate valves because of the low pressure drop across the valve. Swing check valves are available in either Y-pattern or straight body design. A straight check valve is illustrated in Figure 22. In either style, the disk and hinge are suspended from the body by means of a hinge pin. Seating is either metal-to-metal or metal seat to composition disk. Composition disks are usually recommended for services where dirt or other particles may be present in the fluid, where noise is objectionable, or where positive shutoff is required.

Straight body swing check valves contain a disk that is hinged at the top. The disk seals against the seat, which is integral with the body. This type of check valve usually has replaceable seat rings. The seating surface is placed at a slight angle to permit easier opening at lower pressures, more positive sealing, and less shock when closing under higher pressures.

Swing check valves are usually installed in conjunction with gate valves because they provide relatively free flow. They are recommended for lines having low velocity flow and should not be used on lines with pulsating flow when the continual flapping or pounding would be destructive to the seating elements. This condition can be partially corrected by using an external lever and weight.

**Tilting Disk Check Valves**

The tilting disk check valve, illustrated in Figure 23, is similar to the swing check valve. Like the swing check, the tilting disk type keeps fluid resistance and turbulence low because of its straight-through design.

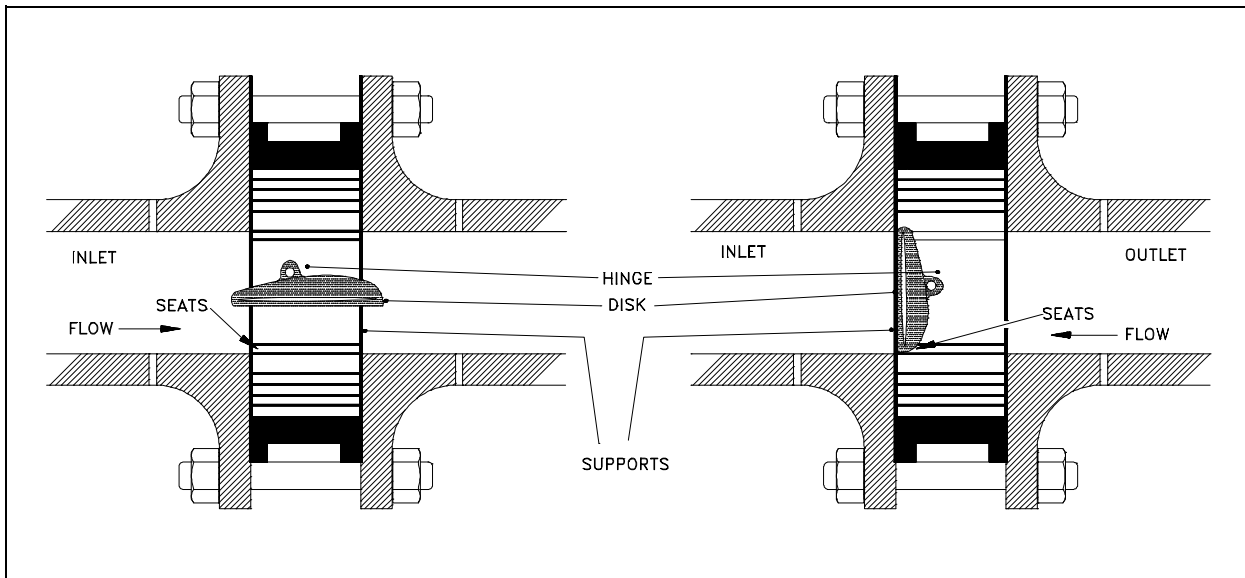


Figure 23 Operation of Tilting Disk Check Valve

Tilting disk check valves can be installed in horizontal lines and vertical lines having upward flow. Some designs simply fit between two flange faces and provide a compact, lightweight installation, particularly in larger diameter valves.

The disk lifts off of the seat to open the valve. The airfoil design of the disk allows it to "float" on the flow. Disk stops built into the body position the disk for optimum flow characteristics. A large body cavity helps minimize flow restriction. As flow decreases, the disk starts closing and seals before reverse flow occurs. Backpressure against the disk moves it across the soft seal into the metal seat for tight shutoff without slamming. If the reverse flow pressure is insufficient to cause a tight seal, the valve may be fitted with an external lever and weight.

These valves are available with a soft seal ring, metal seat seal, or a metal-to-metal seal. The latter is recommended for high temperature operation. The soft seal rings are replaceable, but the valve must be removed from the line to make the replacement.

### **Lift Check Valves**

A lift check valve, illustrated in Figure 24, is commonly used in piping systems in which globe valves are being used as a flow control valve. They have similar seating arrangements as globe valves.

Lift check valves are suitable for installation in horizontal or vertical lines with upward flow. They are recommended for use with steam, air, gas, water, and on vapor lines with high flow velocities. These valves are available in three body patterns: horizontal, angle, and vertical.

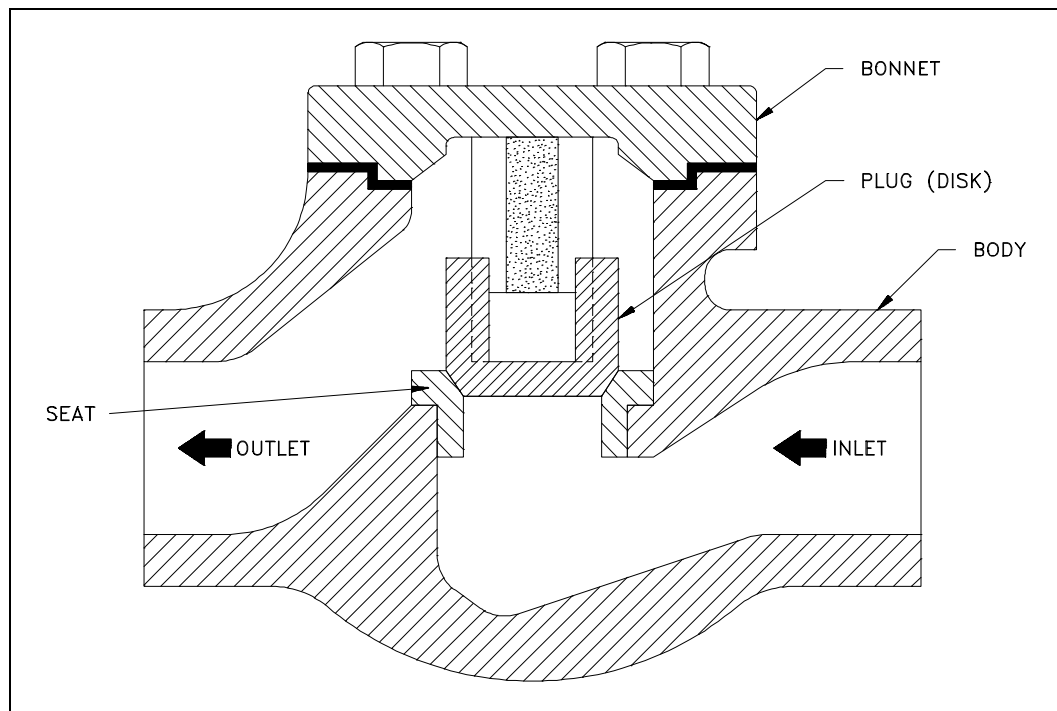


Figure 24 Lift Check Valve

Flow to lift check valves must always enter below the seat. As the flow enters, the disk or ball is raised within guides from the seat by the pressure of the upward flow. When the flow stops or reverses, the disk or ball is forced onto the seat of the valve by both the backflow and gravity.

Some types of lift check valves may be installed horizontally. In this design, the ball is suspended by a system of guide ribs. This type of check valve design is generally employed in plastic check valves.

The seats of metallic body lift check valves are either integral with the body or contain renewable seat rings. Disk construction is similar to the disk construction of globe valves with either metal or composition disks. Metal disk and seat valves can be reground using the same techniques as is used for globe valves.

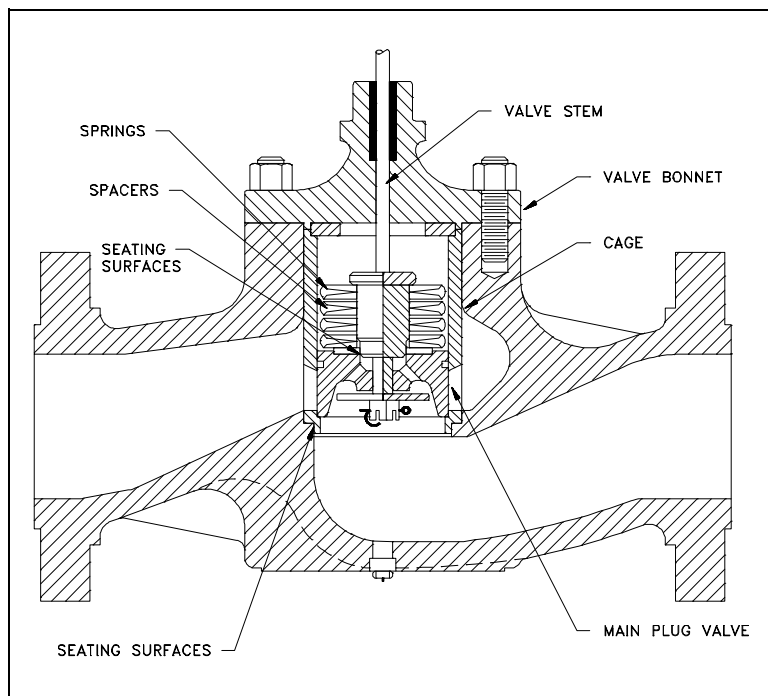


Figure 25 Piston Check Valve

### Piston Check Valves

A piston check valve, illustrated in Figure 25, is essentially a lift check valve. It has a dashpot consisting of a piston and cylinder that provides a cushioning effect during operation. Because of the similarity in design to lift check valves, the flow characteristics through a piston check valve are essentially the same as through a lift check valve.

Installation is the same as for a lift check in that the flow must enter from under the seat. Construction of the seat and disk of a piston check valve is the same as for lift check valves.

Piston check valves are used primarily in conjunction with globe and angle valves in piping systems experiencing very frequent changes in flow direction. Valves of this type are used on water, steam, and air systems.



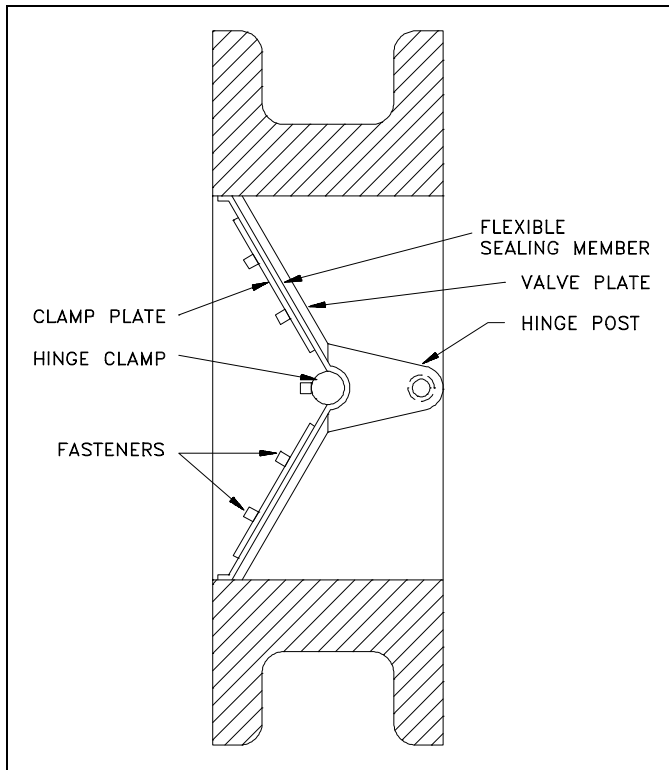


Figure 26 Butterfly Check Valve

## **Butterfly Check Valves**

Butterfly check valves have a seating arrangement similar to the seating arrangement of butterfly valves. Flow characteristics through these check valves are similar to the flow characteristics through butterfly valves. Consequently, butterfly check valves are quite frequently used in systems using butterfly valves. In addition, the construction of the butterfly check valve body is such that ample space is provided for unobstructed movement of the butterfly valve disk within the check valve body without the necessity of installing spacers.

The butterfly check valve design is based on a flexible sealing member against the bore of the valve body at an angle of 45°. The short distance the disk must move from full open to full closed inhibits the "slamming" action found in some other types of check valves. Figure 26

illustrates the internal assembly of the butterfly check valve.

Because the flow characteristics are similar to the flow characteristics of butterfly valves, applications of these valves are much the same. Also, because of their relatively quiet operation they find application in heating, ventilation, and air conditioning systems. Simplicity of design also permits their construction in large diameters - up to 72 inches.

As with butterfly valves, the basic body design lends itself to the installation of seat liners constructed of many materials. This permits the construction of a corrosion-resistant valve at less expense than would be encountered if it were necessary to construct the entire body of the higher alloy or more expensive metal. This is particularly true in constructions such as those of titanium.

Flexible sealing members are available in Buna-N, Neoprene, Nordel, Hypalon, Viton, Tyon, Urethane, Butyl, Silicone, and TFE as standard, with other materials available on special order.

The valve body essentially is a length of pipe that is fitted with flanges or has threaded, grooved, or plain ends. The interior is bored to a fine finish. The flanged end units can have liners of various metals or plastics installed depending upon the service requirements. Internals and fasteners are always of the same material as the liner.

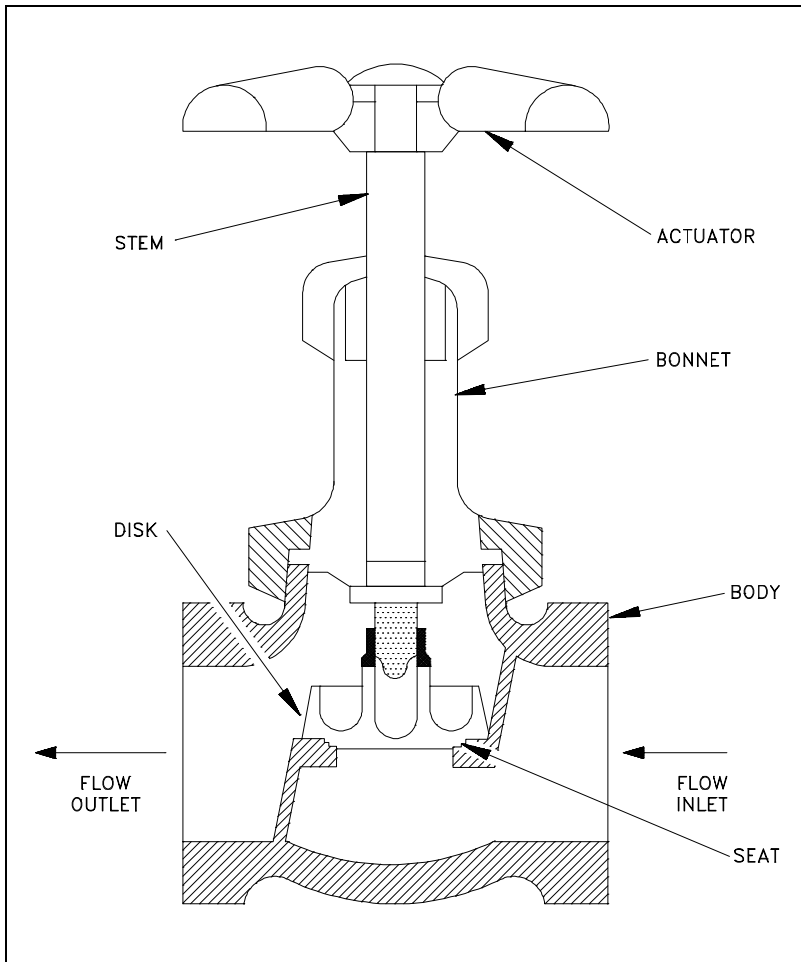


Figure 27 Stop Check Valve

Butterfly check valves may be installed horizontally or vertically with the vertical flow either upward or downward. Care should be taken to ensure that the valve is installed so that the entering flow comes from the hinge post end of the valve; otherwise, all flow will be stopped.

**Stop Check Valves**

A stop check valve, illustrated in Figure 27, is a combination of a lift check valve and a globe valve. It has a stem which, when closed, prevents the disk from coming off the seat and provides a tight seal (similar to a globe valve). When the stem is operated to the open position, the valve operates as a lift check. The stem is not connected to the disk and functions to close the valve tightly or to limit the travel of the valve disk in the open direction.

**Relief and Safety Valves**

Relief and safety valves prevent equipment damage by relieving accidental over-pressurization of fluid systems. The main difference between a relief valve and a safety valve is the extent of opening at the setpoint pressure.

A relief valve, illustrated in Figure 28, gradually opens as the inlet pressure increases above the setpoint. A relief valve opens only as necessary to relieve the over-pressure condition. A safety valve, illustrated in Figure 29, rapidly pops fully open as soon as the pressure setting is reached. A safety valve will stay fully open until the pressure drops below a reset pressure. The reset pressure is lower than the actuating pressure setpoint. The difference between the actuating pressure setpoint and the pressure at which the safety valve resets is called *blowdown*. Blowdown is expressed as a percentage of the actuating pressure setpoint.

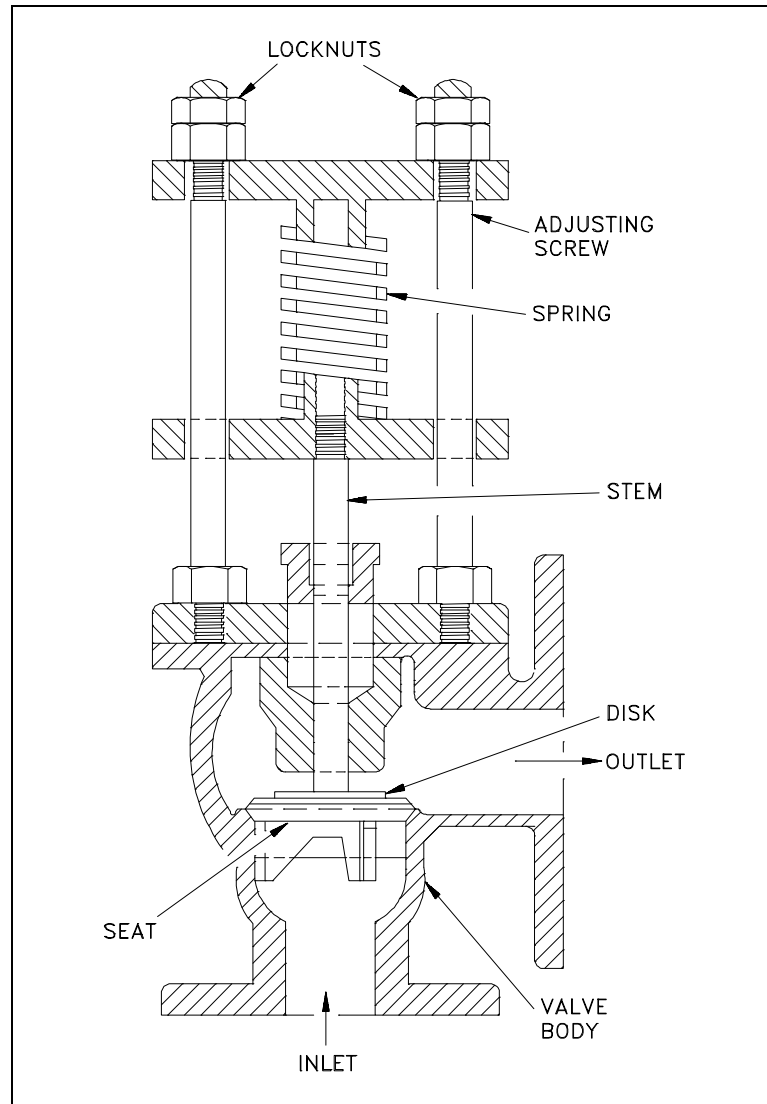


Figure 28 Relief Valve

Relief valves are typically used for incompressible fluids such as water or oil. Safety valves are typically used for compressible fluids such as steam or other gases. Safety valves can often be distinguished by the presence of an external lever at the top of the valve body, which is used as an operational check.

As indicated in Figure 29, system pressure provides a force that is attempting to push the disk of the safety valve off its seat. Spring pressure on the stem is forcing the disk onto the seat. At the pressure determined by spring compression, system pressure overcomes spring pressure and the relief valve opens. As system pressure is relieved, the valve closes when spring pressure again overcomes system pressure. Most relief and safety valves open against the force of a compression spring. The pressure setpoint is adjusted by turning the adjusting nuts on top of the yoke to increase or decrease the spring compression.

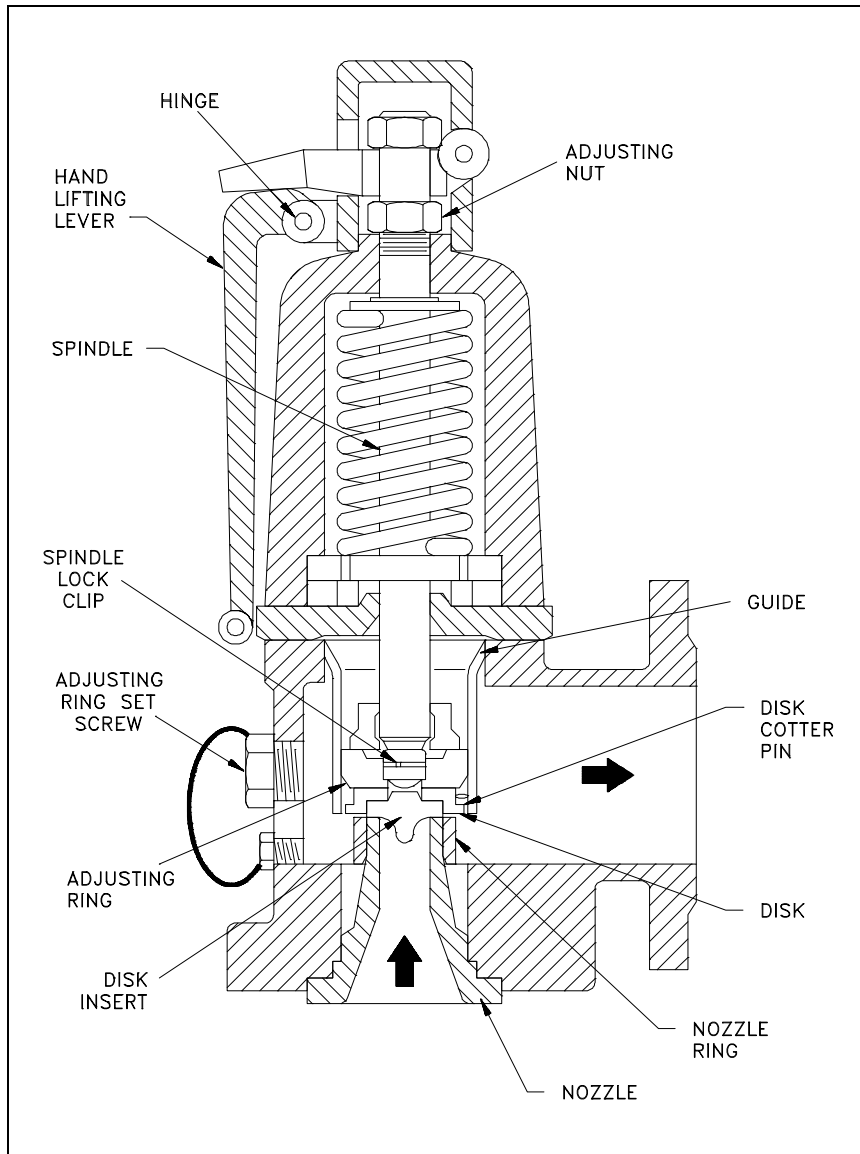


Figure 29 Safety Valve

**Pilot-Operated Relief Valves**

Pilot-operated relief valves are designed to maintain pressure through the use of a small passage to the top of a piston that is connected to the stem such that system pressure closes the main relief valve. When the small pilot valve opens, pressure is relieved from the piston, and system pressure under the disk opens the main relief valve. Such pilot valves are typically solenoid-operated, with the energizing signal originating from pressure measuring systems.

## **Summary**

The following important information in this chapter is summarized below.

### **Types of Valves Summary**

- Gate valves are generally used in systems where low flow resistance for a fully open valve is desired and there is no need to throttle the flow.
- Globe valves are used in systems where good throttling characteristics and low seat leakage are desired and a relatively high head loss in an open valve is acceptable.
- Ball valves allow quick, quarter turn on-off operation and have poor throttling characteristics.
- Plug valves are often used to direct flow between several different ports through use of a single valve.
- Diaphragm valves and pinch valves are used in systems where it is desirable for the entire operating mechanism to be completely isolated from the fluid.
- Butterfly valves provide significant advantages over other valve designs in weight, space, and cost for large valve applications.
- Check valves automatically open to allow flow in one direction and seat to prevent flow in the reverse direction.
- A stop check valve is a combination of a lift check valve and a globe valve and incorporates the characteristics of both.
- Safety/relief valves are used to provide automatic overpressurization protection for a system.

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## VALVE ACTUATORS

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*Some type of actuator is necessary to allow for the positioning of a valve. Actuators vary from simple manual handwheels to relatively complex electrical and hydraulic manipulators.*

**EO 1.6**      **DESCRIBE the construction and principle of operation for the following types of valve actuators:**

- a.      **Manual**
  - b.      **Electric motor**
  - c.      **Pneumatic**
  - d.      **Hydraulic**
  - e.      **Solenoid**
- 

### **Introduction**

Valve actuators are selected based upon a number of factors including torque necessary to operate the valve and the need for automatic actuation. Types of actuators include manual handwheel, manual lever, electrical motor, pneumatic, solenoid, hydraulic piston, and self-actuated. All actuators except manual handwheel and lever are adaptable to automatic actuation.

### **Manual, Fixed, and Hammer Actuators**

Manual actuators are capable of placing the valve in any position but do not permit automatic operation. The most common type mechanical actuator is the handwheel. This type includes handwheels fixed to the stem, hammer handwheels, and handwheels connected to the stem through gears.

#### **Handwheels Fixed to Stem**

As illustrated in Figure 30, handwheels fixed to the stem provide only the mechanical advantage of the wheel. When these valves are exposed to high operating temperatures, valve binding makes operation difficult.

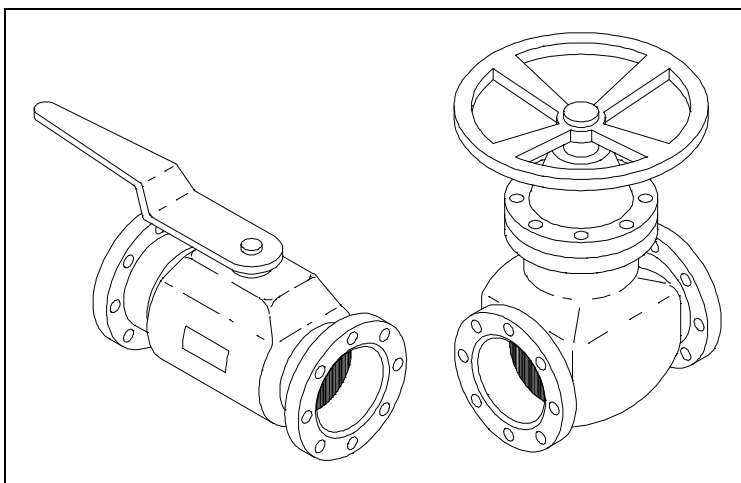


Figure 30 Fixed Handwheel

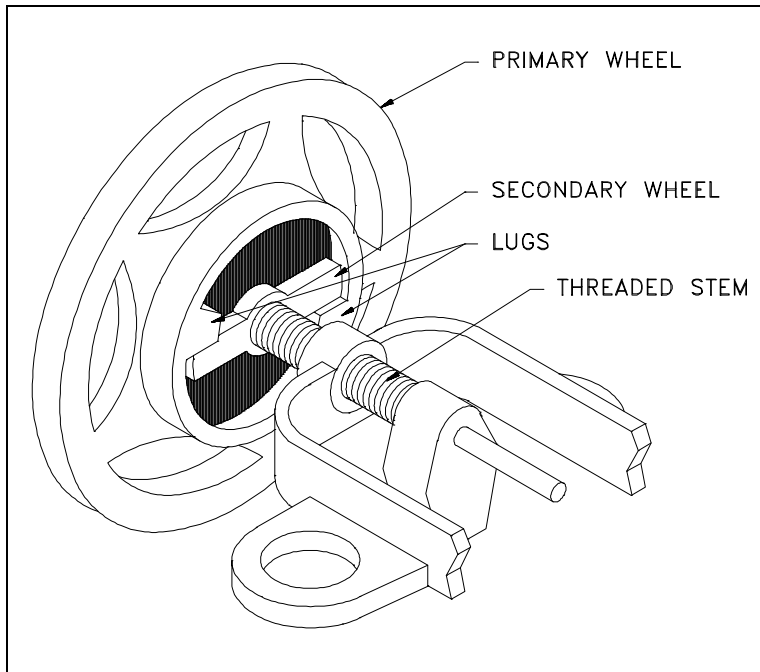


Figure 31 Hammer Handwheel

### **Hammer Handwheel**

As illustrated in Figure 31, the hammer handwheel moves freely through a portion of its turn and then hits against a lug on a secondary wheel. The secondary wheel is attached to the valve stem. With this arrangement, the valve can be pounded shut for tight closure or pounded open if it is stuck shut.

### **Gears**

If additional mechanical advantage is necessary for a manually-operated valve, the valve bonnet is fitted with manually-operated gear heads as illustrated in Figure 32. A special wrench or handwheel attached to the pinion shaft permits one individual to operate the valve when two individuals might be needed without the gear advantage. Because several turns of the pinion are necessary to produce one turn of the valve stem, the operating time of large valves is exceptionally long. The use of portable air motors connected to the pinion shaft decreases the valve operating time.

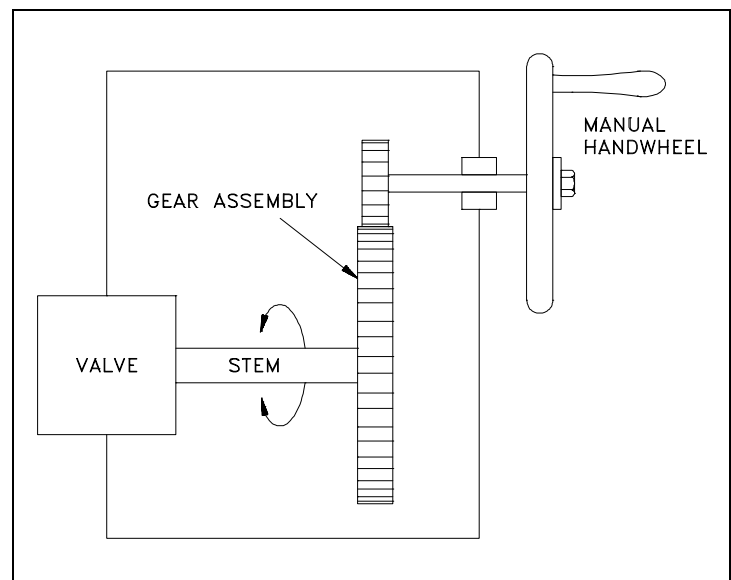


Figure 32 Manual Gear Head

## Electric Motor Actuators

Electric motors permit manual, semi-automatic, and automatic operation of the valve. Motors are used mostly for open-close functions, although they are adaptable to positioning the valve to any point opening as illustrated in Figure 33. The motor is usually a reversible, high speed type connected through a gear train to reduce the motor speed and thereby increase the torque at the stem. Direction of motor rotation determines direction of disk motion. The electrical actuation can be semi-automatic, as when the motor is started by a control system. A handwheel, which can be engaged to the gear train, provides for manual operating of the valve. Limit switches are normally provided to stop the motor automatically at full open and full closed valve positions. Limit switches are operated either physically by position of the valve or torsionally by torque of the motor.

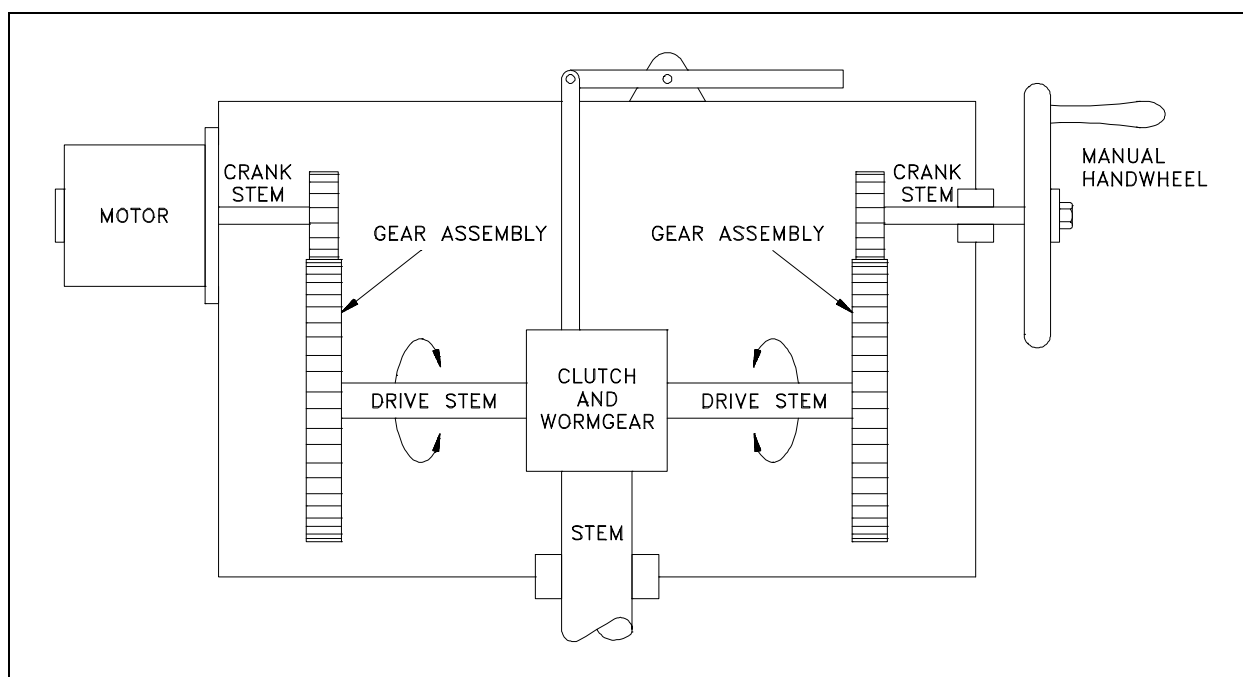


Figure 33 Electric Motor Actuator



## **Pneumatic Actuators**

Pneumatic actuators as illustrated in Figure 34 provide for automatic or semi-automatic valve operation. These actuators translate an air signal into valve stem motion by air pressure acting on a diaphragm or piston connected to the stem. Pneumatic actuators are used in throttle valves for open-close positioning where fast action is required. When air pressure closes the valve and spring action opens the valve, the actuator is termed direct-acting. When air pressure opens the valve and spring action closes the valve, the actuator is termed reverse-acting. Duplex actuators have air supplied to both sides of the diaphragm. The differential pressure across the diaphragm positions the valve stem. Automatic operation is provided when the air signals are automatically controlled by circuitry. Semi-automatic operation is provided by manual switches in the circuitry to the air control valves.

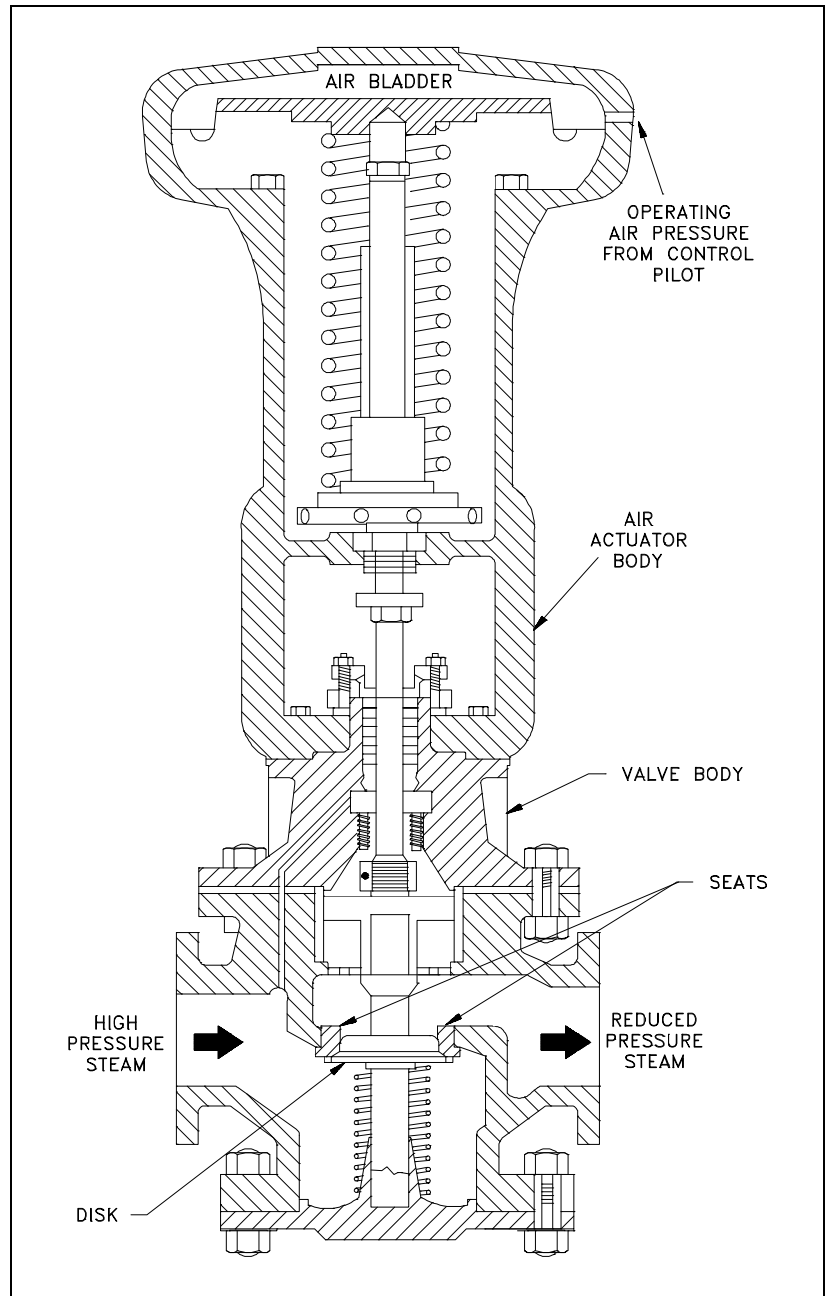


Figure 34 Pneumatic Actuator

## **Hydraulic Actuators**

Hydraulic actuators provide for semi-automatic or automatic positioning of the valve, similar to the pneumatic actuators. These actuators use a piston to convert a signal pressure into valve stem motion. Hydraulic fluid is fed to either side of the piston while the other side is drained or bled. Water or oil is used as the hydraulic fluid. Solenoid valves are typically used for automatic control of the hydraulic fluid to direct either opening or closing of the valve. Manual valves can also be used for controlling the hydraulic fluid; thus providing semi-automatic operation.

## Self-Actuated Valves

Self-actuated valves use the system fluid to position the valve. Relief valves, safety valves, check valves, and steam traps are examples of self-actuated valves. All of these valves use some characteristic of the system fluid to actuate the valve. No source of power outside the system fluid energy is necessary for operation of these valves.

## Solenoid Actuated Valves

Solenoid actuated valves provide for automatic open-close valve positioning as illustrated in Figure 35. Most solenoid actuated valves also have a manual override that permits manual positioning of the valve for as long as the override is manually positioned. Solenoids position the valve by attracting a magnetic slug attached to the valve stem. In single solenoid valves, spring pressure acts against the motion of the slug when power is applied to the solenoid. These valves can be arranged such that power to the solenoid either opens or closes the valve. When power to the solenoid is removed, the spring returns the valve to the opposite position. Two solenoids can be used to provide for both opening and closing by applying power to the appropriate solenoid.

Single solenoid valves are termed fail open or fail closed depending on the position of the valve with the solenoid de-energized. Fail open solenoid valves are opened by spring pressure and closed by energizing the solenoid. Fail closed solenoid valves are closed by spring pressure and opened by energizing the solenoid. Double solenoid valves typically fail "as is." That is, the valve position does not change when both solenoids are de-energized.

One application of solenoid valves is in air systems such as those used to supply air to pneumatic valve actuators. The solenoid valves are used to control the air supply to the pneumatic actuator and thus the position of the pneumatic actuated valve.

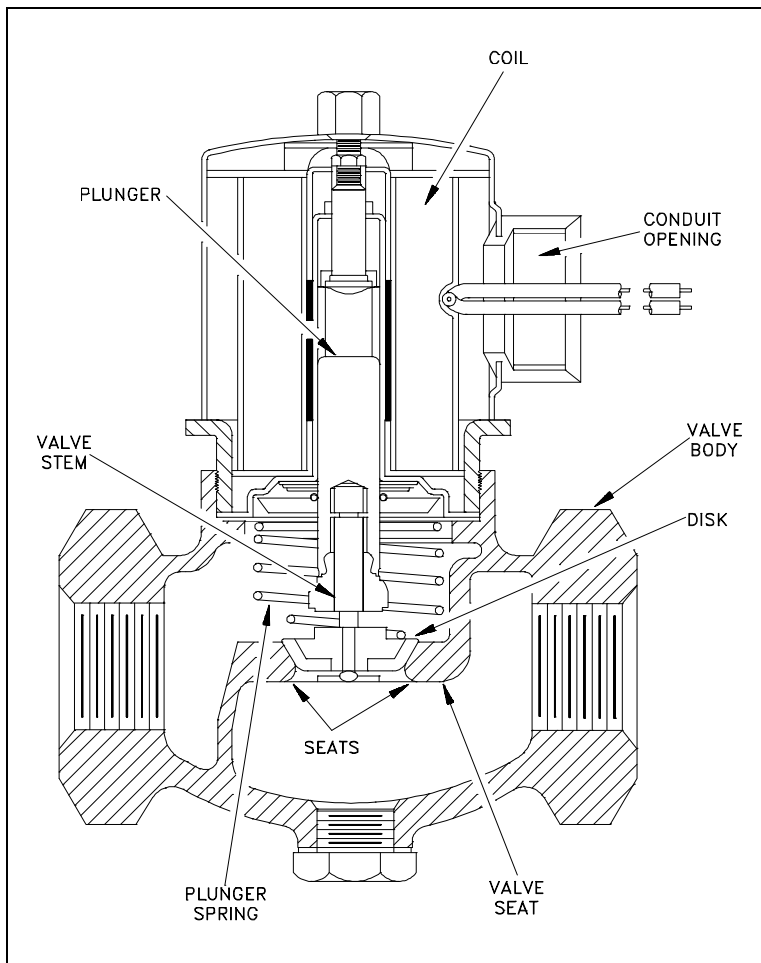


Figure 35 Solenoid Actuated Valve

## **Speed of Power Actuators**

Plant safety considerations dictate valve speeds for certain safety-related valves. Where a system must be very quickly isolated or opened, very fast valve actuation is required. Where the opening of a valve results in injection of relatively cold water to a hot system, slower opening is necessary to minimize thermal shock. Engineering design selects the actuator for safety-related valves based upon speed and power requirements and availability of energy to the actuator.

In general, fastest actuation is provided by hydraulic, pneumatic, and solenoid actuators. However, solenoids are not practical for large valves because their size and power requirements would be excessive. Also, hydraulic and pneumatic actuators require a system for providing hydraulic or pneumatic energy. The speed of actuation in either case can be set by installing appropriately sized orifices in the hydraulic or pneumatic lines. In certain cases, the valve is closed by spring pressure, which is opposed by hydraulic or pneumatic pressure to keep the valve open.

Electrical motors provide relatively fast actuation. Actual valve speed is set by the combination of motor speed and gear ratio. This combination can be selected to provide full valve travel within a range from about two seconds to several seconds.

## **Valve Position Indication**

Operators require indication of the position of certain valves to permit knowledgeable operation of the plant. For such valves, remote valve position indication is provided in the form of position lights that indicate if valves are open or closed. Remote valve position indication circuits use a position detector that senses stem and disk position or actuator position. One type of position detector is the mechanical limit switch, which is physically operated by valve movement.

Another type is magnetic switches or transformers that sense movement of their magnetic cores, which are physically operated by valve movement.

Local valve position indication refers to some visually discernable characteristic of the valve that indicates valve position. Rising stem valve position is indicated by the stem position. Nonrising stem valves sometimes have small mechanical pointers that are operated by the valve actuator simultaneously with valve operation. Power actuated valves typically have a mechanical pointer that provides local valve position indication. On the other hand, some valves do not have any feature for position indication.

## **Summary**

The important information in this chapter is summarized below.

### **Valve Actuators Summary**

- Manual actuators are the most common type of valve actuators. Manual actuators include handwheels attached to the valve stem directly and handwheels attached through gears to provide a mechanical advantage.
- Electric motor actuators consist of reversible electric motors connected to the valve stem through a gear train that reduces rotational speed and increases torque.
- Pneumatic actuators use air pressure on either one or both sides of a diaphragm to provide the force to position the valve.
- Hydraulic actuators use a pressurized liquid on one or both sides of a piston to provide the force required to position the valve.
- Solenoid actuators have a magnetic slug attached to the valve stem. The force to position the valve comes from the magnetic attraction between the slug on the valve stem and the coil of the electromagnet in the valve actuator.