

3

Manual Valves

3.1 Introduction to Manual Valves

3.1.1 Definition of Manual Valves

By definition, *manual valves* are those valves that operate through a manual operator (such as a handwheel or handlever), which are primarily used to stop and start flow (block or on-off valves), although some designs can be used for basic throttling.

The best manual valves for on-off service are those that allow flow to move straight through the body, with a full-area closure element that presents little or no pressure drop. Usually if a manual valve is used to start and stop flow, as an on-off valve, and the manual operator is placed in a midstroke position, partial flow is possible as a throttling valve. However, some on-off designs in a midstroke position are not conducive to smooth flow conditions and may even cause turbulence and cavitation. Even though a manual on-off valve is being used in a throttling situation, it is not considered a control valve because it is not part of a process loop, which requires some type of self-actuation as well as input from a controlling device to a valve and position feedback. Throttling manual valves used to control flow are those that offer a definite flow characteristic—inherent or otherwise—between the area of the seat opening and the stroke of the closure element.

Besides on-off and throttling functions, manual valves are also used to divert or combine flow through a three- or four-way design configuration.

3.1.2 Classifications of Manual Valves

Manual valves are usually classified into four types, depending on their design and use. The first classification type of manual valves is

rotating valves, which includes those manual-valve designs that use a quarter-turn rotation of the closure element. Rotating manual valves have a flow path directly through the body and closure element without any right-angle turns. The most common designs in the rotating-manual-valve family are plug, ball, and butterfly valves. They are most commonly used for on-off, full-flow services. In some applications they can be used for throttling control, as well as diversion and combination service. Overall, because rotating valves are inexpensive and versatile, they are the most common type of manual valve used in the process industry today. As a general rule, rotating valves—except butterfly valves—perform well in less-than-clean services, because the rotation of the closure element has a tendency to sever particulates when closing.

The second classification is *stopper valves*, which are defined as those manual-valve designs that use a linear-motion, circular closure element perpendicular to the centerline of the piping. These manual valves use a globe body to direct the flow through a right-angle turn under or above the closure element. If the valve uses an angle body, the flow continues from that right angle. If the valve has a straight-through body design, another right-angle turn is necessary after the closure element for the flow to be redirected in the same direction as the inlet. The two most common designs in the classification are the globe and piston manual valves. Because of the right-angle turns in these valves, stopper valves take more of a pressure drop than other designs. Therefore, among manual valves, they are the most frequently used throttling control and diversion applications, although they are often used for simple on-off service. Because of the stopper design, particulates can trap solids between the closure element and the seat, causing leakage; therefore, stopper valves are preferred for cleaner services.

The third classification is *sliding valves*, which are described as those manual valves that use a flat perpendicular closure element that intersects the flow. Like rotating valves and unlike stopper valves, sliding valves have a body with straight-through flow. Like stopper valves, the closure element—which is a flat element reaching from wall to wall—slides down from its full-open position (which is out of the fluid stream) into the flow stream, acting as a barrier wall. Both gate and piston valves are considered to be sliding valves. The sliding-seal design is best used for on-off service, although it can roughly control flow services where exact positioning is not required. Because the sliding valve seats at the bottom of the valve body, particulates can prevent full seating; therefore, sliding valves are usually used in nonslurry services.

The fourth classification is *flexible valves*, which are defined as valves with an elastomeric closure element and a body that allows straight-through flow. Overall, the design is similar to a sliding-valve design, although the closure element pushes against a highly flexible elastomeric or rubber insert until it meets against the bottom of the body or the other side of an elastomeric inset, literally pinching the flow closed. Both pinch and diaphragm valves are considered to be flexible manual valves. They are typically used in on–off services where tight shutoff (ANSI Class IV) is important or with slurries or other particulate-laden services.

3.2 Manual Plug Valves

3.2.1 Introduction to Manual Plug Valves

By definition, a *plug valve* is a quarter-turn manual valve that uses a cylindrical or tapered plug to permit or prevent straight-through flow through the body (Fig. 3.1). The plug has a straight-through opening. With a full-port design, this opening is the same as the area of the inlet and outlet ports of the valve.

Plug valves can be applied to both on–off and throttling services. Plug valves were initially designed to replace gate valves, since plug valves by virtue of their quarter-turn action can open and close more easily against flow than a comparable gate valve. For this reason, some plug-valve designs are built to face-to-face specifications used for gate valves.

Plug valves are commonly applied to low-pressure–low-temperature services, although some higher-pressure–higher-temperature designs exist. The design also permits for easy lining of the body with such materials as polytetrafluoroethylene (PTFE) for use with corrosive chemical services. They are also ideal for on–off, moderate throttling, and diverting applications. They are applied in liquid and gas, nonabrasive slurry, vacuum, food-processing, and pharmaceutical services. Abrasive and sticky fluids can be handled with special designs.

Depending upon the required end connection, plug valves are commonly found in sizes up to 18 in (DN 450) and in the lower-pressure classes [ANSI Classes 150 and 300 (PN 16 and 40)].

3.2.2 Manual-Plug-Valve Design

The most common plug-valve design allows for straight-through, two-way service (inlet and outlet), with the closure element in the middle



Figure 3.1 Nonlubricated, PTFE-sleeved quarter-turn plug valve. (Courtesy of The Duriron Company, Valve Division)

of the body. The closure element, which is a plug and a sleeve, is accessible through top-entry access in the body and is sealed by a *bonnet cap* (sometimes called a *top cap*). Most plug-valve bodies are equipped with integral flanges, but screwed ends are also common. Three-way bodies are also commonplace, with a third port typically at a right angle from the inlet. With the three-way design, the closure element is used to divert or combine the flow, depending on the installation of the valve as well as the position of the plug. Figure 3.2 shows six such three-way flow arrangements.

The face-to-face standard for plug valves is normally associated with ANSI Standard B16.10, with designations for both long and short patterns. However, many manufacturers have elected to use the face-to-face dimensions provided for gate valves. Not only does this standard better fit the design criteria of the plug valve, but it also allows quarter-turn plug valves to replace gate valves in existing process services.

The plug may be cylindrical in shape, which does present some problems in providing a solid seal between the body wall and the plug. The seal is important so that excessive leakage around the out-

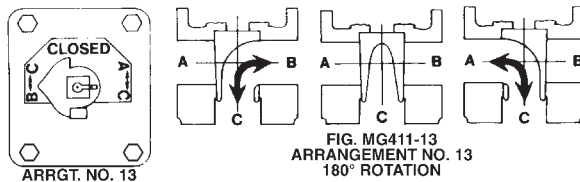
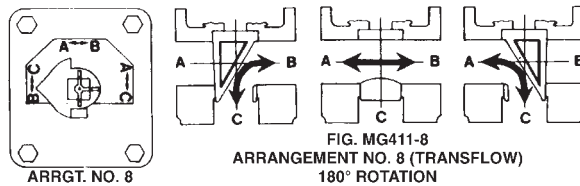
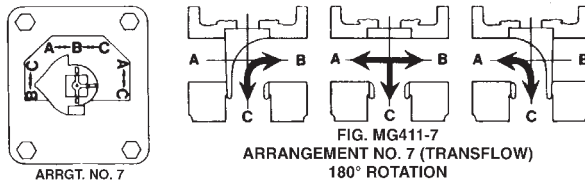
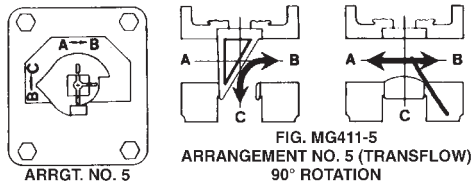
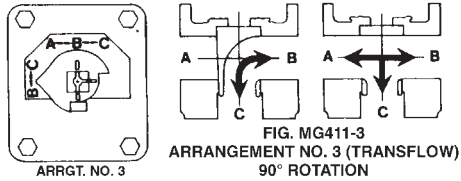
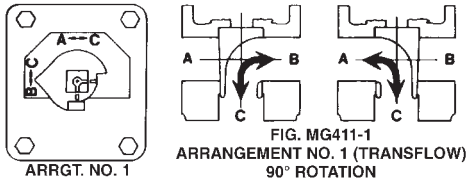
Flow Arrangements

Figure 3.2 Three-way flow arrangements for quarter-turn plug valves. (Courtesy of The Duriron Company, Valve Division)

side diameter of the closure element does not occur. It also provides a seal for the top-works of the valve. To provide an adequate seal, three methods are commonly used: a cylindrical sleeve between the plug and the body, a series of O-rings between the plug and the body, and the injection of a malleable sealant. With the cylindrical sleeve, tightening the top-works applies compression to the sleeve against the plug. The force-fit with the O-rings provides an adequate seal also. However, the sealant design poses an inherent maintenance problem with the gradual erosion of the sealant after the valve has been stroked several times. In some high-temperature applications, the sealant may need to be reinjected after each stroke of the valve.

One of the best methods of sealing the plug and the body is to use a tapered plug, which is wedged into the plastic or other nonmetallic sleeve (again refer to Fig. 3.1). As the bonnet cap is tightened, the axial force provided by the tightening of the bonnet cap pushes the tapered plug into the softer sleeve, which provides a tight seal. The sleeve's inside diameter has a smooth surface to help seal the flow against the outside surface of the plug, while the outside surface has a series of ribs to help the sleeve hold its position in the body. The sleeve is typically manufactured from a semirigid elastomer, such as PTFE or other plastic. Because a metal surface slides with minimal friction on a plastic surface, the tapered plug is manufactured from stainless steel or carbon steel with a hard chrome surface.

Plugs can be designed with the flow port in a variety of flow areas, shapes, and functions. A common port design allows for maximum flow area, providing minimal pressure drop. The plug shape can also be characterizable (see Sec. 2.2) for throttling applications. Some cylindrical plugs have full-area ports with the same shape as the flow passages, which allow the passage of a cleaning pig. Self-cleaning ports that prevent particulate clogging or buildup are also available from certain plug-valve manufacturers. Other plugs have multihole designs to prevent or minimize the damage of cavitation (see Sec. 9.2). With cylindrical plugs the shape of the flow port is typically rectangular or round-bored, while tapered plugs are typically triangular. With throttling services, a V-shaped port is used to allow an equal-percentage flow characteristic. The ports of plugs used for three-way services are typically round with vanes contained on the inside diameter of the plug to channel flow, depending on the orientation of the plug in the body.

As previously indicated, a number of sealing designs are used to prevent the fluid from leaking through the closure element: lubricants, O-rings, and sleeves. Overall, the most common method used today is the sleeve and tapered-plug arrangement, which provides not only a

good seal through the closure element but also works in conjunction with the top-work's sealing mechanism to prevent atmospheric leakage through the top-works. With most plug valves used in lower-pressure and lower-temperature service, the primary seal to the top-works is the sleeve itself, which seals between the body and the sleeve as well as between the sleeve and the plug. The top-works are further sealed with a metal thrust collar and an elastomeric diaphragm arrangement, which seals around the plug stem. The diaphragm has a spring action that helps provide constant thrust to the plug, keeping it fully seated. The outside portion of the diaphragm also acts as a gasket, sealing the gap between the body and the bonnet cap. Some plug valves—especially those used in higher temperatures and higher pressures—use packing boxes, which effectively seal the stem, but require a gland-flange arrangement to apply compression to the packing. When packing is used, a diaphragm is often not necessary, but a gasket between the body and bonnet cap is required instead.

For some corrosive chemical services (such as hydrochloric acid, sulfuric acid, waste acids, or acid brine), plug-valve bodies are completely lined with PTFE, as well as a similar coating on the plug (Fig. 3.3).

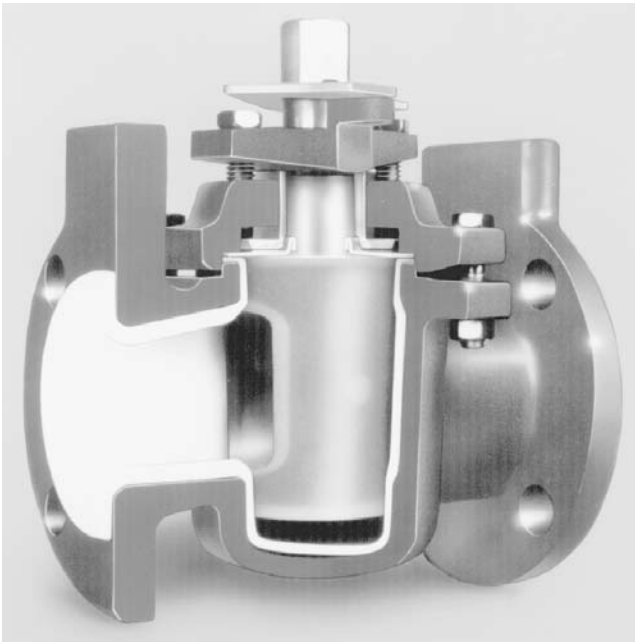


Figure 3.3 Lined quarter-turn plug valve. (Courtesy of The Duriron Company, Valve Division)

Other similar linings include PVDF (polyvinylidene fluoride), PVDC (polyvinylidene chloride), polyethylene, and polypropylene. Lined plug valves may have a double seal at the stem to prevent leakage to the atmosphere as well as a corrosion-resistant coating on the exterior surface of the body itself to protect the valve against process drippings. Although lined valves may be more expensive than normal plug valves, they are considerably less expensive than requesting corrosion-resistant metals. As with most corrosion-resistant materials, the lining is completely inert and impermeable. The one disadvantage of a lined valve is that the plastic-on-plastic seal provides a higher break-out torque than a metal-on-plastic seal.

To allow for the correct quarter-turn motion without over- or under-stroking of a plug valve, a stop-collar arrangement is used. The stop collar is designed so that it fits over the flats at the top of the plug and thus turns with the plug stem. A portion of the stop collar is designed with a quarter-turn path, which intersects a fixed key on the bonnet cap, gland flange, etc. As the plug stem is moved, the fixed key keeps the stop collar and the plug from moving outside the quarter-turn range.

3.2.3 Manual-Plug-Valve Operation

When the opening in the plug is in line with the inlet and outlet ports, flow continues uninhibited through the valve, taking a pressure drop through the reduced area of the plug port—although with a full-area cylindrical plug the pressure drop is minimal.

When the hand operator is turned to the full quarter-turn position (90°), the plug's opening is turned perpendicular to the flow stream, with the edges of the plug rotating through the sealing device (sleeve, lubricant, etc.). When the full quarter-turn rotation is reached, the port is completely perpendicular to the flow stream, creating complete shutoff. In throttling situations, where the plug is placed in a midturn position, the plug takes a double pressure drop. The inlet port's flow area is reduced by the turning of the plug away from the full-port position, taking a pressure drop at that point. The flow then moves into the full-port area inside the plug, where a pressure recovery takes place, followed by another restriction at the outlet port. Leakage is prevented through the seat by the compression of the plug against the sleeve or other sealing mechanism, while the packing or the collar-diaphragm assembly prevents leakage through the stem.

With three-way valve arrangements requiring diverting flow, flow enters at the inlet and moves through the plug, which channels the

flow to one of the other two outlets. When the plug is moved 90° , the flow is channeled to the other outlet. At a midway position, flow may be equally diverted to both outlets. With combining flow, flow is directed from two inlets to a single outlet. In order for some of these arrangements to occur, the plug must be turned by half-turn (180°) instead of the typical quarter-turn action.

With larger plug-valve sizes [3 in (DN 80) or larger], the torque required for seal breakout may become somewhat excessive. This is caused by the larger contact surface between the plug and sealing device as well as any adverse operating conditions, such as a high process pressure, temperature extreme, corrosion deposits, etc. In this case, handlevers are typically replaced with geared handwheels, which reduce the torque requirement significantly. Table 3.1 shows the turning torque requirements for a typical plug valve for both handlevers and gear-operated handwheels. (The user should note that these numbers are torque values for turning the plug and do not indicate the higher breakout torque.)

3.3 Manual Ball Valves

3.3.1 Introduction to Manual Ball Valves

Related in design to the plug valve, the *manual ball valve* is a quarter-turn, straight-through flow valve that uses a round closure element with matching rounded elastomeric seats that permit uniform seating stress. The ball has a flow-through port and is seated on both sides. A common manual-ball-valve design is shown in Fig. 3.4. Because the design of manual ball valves are somewhat different than its automated cousin, the ball control valve, the designs associated with the ball control valve are covered in Chap. 4.

Manual ball valves are best used for on-off service, as well as moderate throttling situations that require minimal accuracy. In static high-pressure-drop throttling situations, where the ball's inlet port would be offset from the seal for a long period of time without moving, the velocity may cause the seal to cold flow into the port, creating some interference between the port edge of the ball and the deformed elastomer. This situation can be rectified when the manual ball valve is automated, so that the ball moves more frequently in response to a changing position signal. Ball valves are used in both liquid and gas services, although the service must be nonabrasive in nature. They can also be used in vacuum and cryogenic services.

Table 3.1 Average Run Torques for Manual Plug Valves*

Valve Size	Turning Torque at Plug Stem	Turning Torque with Gear-operator
0.5-inch DN 15	3.0 ft-lbs 4.0 joules	
0.75-inch DN 20	3.0 ft-lbs 4.0 joules	
1.0-inch DN 25	7.0 ft-lbs 9.4 joules	
1.5-inch DN 40	8.0 ft-lbs 10.8 joules	
2.0-inch DN 50	13.0 ft-lbs 17.5 joules	
3.0-inch DN 80	19.0 ft-lbs 25.6 joules	
4.0-inch DN 100	54.0 ft-lbs 72.9 joules	5.0 ft-lbs 6.7 joules
6.0-inch DN 150	140.0 ft-lbs 189.0 joules	8.0 ft-lbs 10.8 joules
8.0-inch DN 200	306.0 ft-lbs 413.0 joules	16.0 ft-lbs 21.6 joules
10-inch DN 250	580.0 ft-lbs 783.0 joules	35.0 ft-lbs 47.3 joules
12-inch DN 300	610.0 ft-lbs 827.0 joules	16.0 ft-lbs 21.6 joules
14-inch DN 350	610.0 ft-lbs 827.0 joules	16.0 ft-lbs 21.6 joules
16-inch DN 400	1170.0 ft-lbs 1587.0 joules	18.0 ft-lbs 24.4 joules
18-inch DN 450	1170.0 ft-lbs 1587.0 joules	18.0 ft-lbs 24.4 joules

*Data courtesy of Durco Valve.

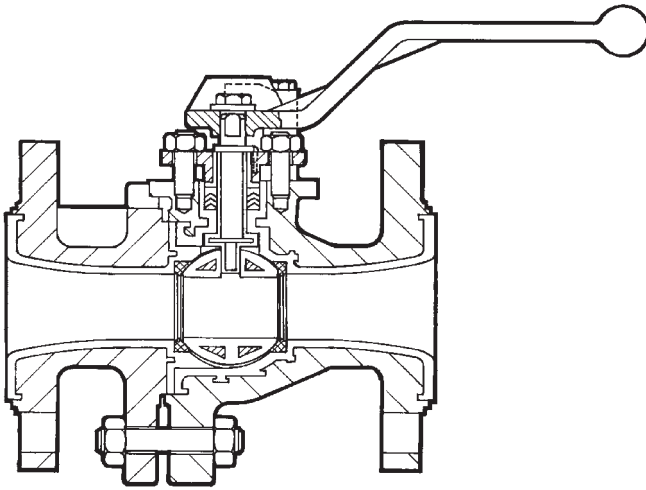


Figure 3.4 Split-body, full-port quarter-turn ball valve.
(Courtesy of Atomac/The Duriron Company)

Because of the wiping rotary motion of ball valves, they are ideal for slurries or processes with particulates, since the ball port has a tendency to separate or shear the particulates upon closing. Occasionally, lengthy thin particulates can foul or wrap around a ball, causing a high-maintenance situation.

When ball valves are applied in highly corrosive chemical services—such as hydrochloric acid, sulfuric acid, waste acid, or acid brine—the wetted surfaces of the body and ball are completely lined with polytetrafluoroethylene, which is inert and impermeable.

Manual ball valves are typically found in sizes up to 12 in (DN 300) and in lower-pressure classes of ANSI Classes 150 through 600.

3.3.2 Manual-Ball-Valve Design

The ball-valve body features a straight-through style, allowing uninhibited flow with minimal pressure drop. A number of body configurations are available, although the most common are the split body (again refer to Fig. 3.4), solid body with side entry (Fig. 3.5), or solid body with top entry (Fig. 3.6). The defining factor for determining the body design is the complexity of installing the ball inside the body. While the split body offers the easiest disassembly and reassembly, it may present problems with an additional joint that can be affected by piping stresses as well as

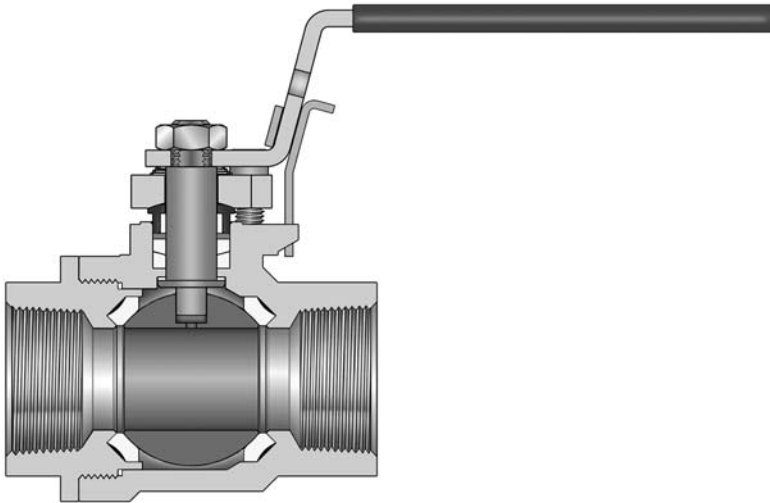


Figure 3.5 Side-entry, full-port quarter-turn ball valve. (Courtesy of Velan Valve Corporation)

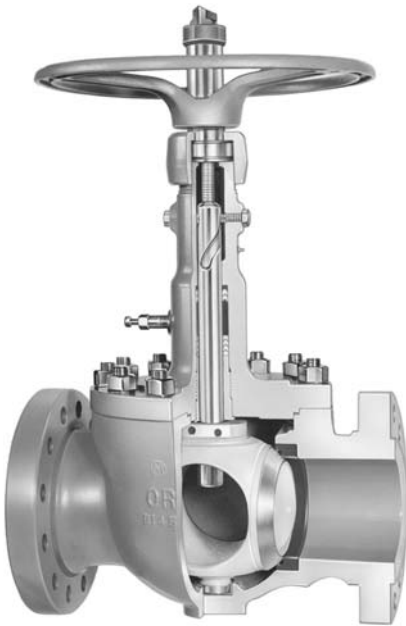


Figure 3.6 Top-entry, full-port, single-seat with tilt-action quarter-turn ball valve. (Courtesy of Orbit Valve Company)

another potential leak path. Face-to-face dimensions for ball valves are established by ANSI Standard B16.10, although with some pressure classifications or special designs manufacturers may use the gate valve face-to-face standard. Face-to-face dimensions are usually specified according to a short pattern (ANSI Class 150) or long pattern for higher-pressure classifications. The most common end connection used with manual ball valves is the integral-flange design.

The ball itself can be either round or tapered, depending on the internal seat design. The flow-through port is a reduced area from the body port, approximately 75 percent of the valve's full area. Full-area ports are also available when minimal pressure drop is needed, such as with on-off service, or when a pig is used to scrape the inside diameter of the pipe and a narrow flow restriction in the line would prevent this. Unlike the one-piece plug of plug valves where the stem is an integral part of the plug, the ball is separate from the stem in manual ball valves. A key slot is machined or cast into the top of the ball, into which a key machined into the bottom portion of the stem fits.

Although a ball's port is normally produced in a round flow passage, with either full or reduced area, characterizable balls are also available (Fig. 3.7) with the inlet port of the ball shaped to provide the correct flow-to-position relationship for that flow characteristic. C-shaped balls are also available for eliminating dead spots (Fig. 3.8).

When two round seats are fixed on the upstream and downstream side of the ball, this is commonly called *double seating*. The two seats are designed to conform with the ball's sealing surface. With moderate pressure drops and elastomeric seating materials, bubble-tight shutoff is possible with double-seated ball valves. Several other seating arrangements are utilized with ball valves. One of the most common arrangements is the *floating ball*, in which the ball is not fixed to the stem and is allowed some freedom of movement through the key slot. With the floating ball, the upstream fluid pressure assists the seal by pushing the ball back against the rear or downstream seat. Another seating arrangement involves a *floating seat*, in which the ball is fixed (called a *trunnion-mounted ball*) at two pivot points, and the process pressure pushes the upstream seat against the ball's sealing surface. The seat can also be prestressed during assembly, using seats that have a spring action. This design applies continuous pressure against a trunnion-mounted ball after the ball is installed, while the top-works apply a load to the entire closure element.

Most seats are made from PTFE, which provides excellent bubble-tight sealing and a temperature range that covers most general services. Buna-N and nylon materials are also specified, but may be limited



Figure 3.7 Characterized ball for throttling applications. (Courtesy of Atomac/The Duriron Company)

in pressure ranges and process compatibility. For higher temperatures, metal seats and carbon-based materials are specified, although higher leakage rates are common.

With ball-valve design, the stem is usually sealed by packing rings, with a packing follower and gland flange applying compression. With split bodies and solid bodies with side entry, the stem is installed through the body and the packing installed above the body. Because of the keyed slot, the ball can be turned so that the key and the slot are parallel with the flow passage, allowing the ball to enter from the side and the stem to intersect with the stem key.

With top-entry ball valves that use trunnion-mounted balls and spring-loaded seats, the ball has either an integral or separate lower post that is seated in the bottom of the body. The seats are placed on both sides of the ball and the entire assembly is placed in the body. The top-works—consisting of a bonnet cap, packing box, gland flange, and separate stem—are installed above the ball. When the bonnet-cap bolting is tightened, the resulting compression energizes the seats. The joint between the bonnet cap and the body is sealed using a gasket.



Figure 3.8 C-ball for eliminating dead spots.
(Courtesy of Atomac/The Durriron Company)

In addition to PTFE, linings can be produced from PVDF, PVDC, polyethylene, and polypropylene. Because of the corrosive nature of the service, lined ball valves are painted with a corrosion-resistant coating on the exterior surface of the body. Although lined valves may be more expensive than normal plug valves, they are considerably less expensive than requesting corrosion-resistant metals. The one disadvantage of lined valves is that the plastic-on-plastic seal provides a higher breakout torque than the metal-on-elastomer seal.

To ensure quarter-turn motion without over- or understroking the valve, a stop-collar arrangement is used. The stop collar is designed to allow only a 90° travel of the wrench or handlever.

3.3.3 Manual-Ball-Valve Operation

With normal service, when the port opening of the ball is in line with the inlet and outlet ports, flow continues uninterrupted through the valve, undergoing a minimal pressure drop if a full-port ball is used.

Obviously, the pressure drop increases with the use of a reduced-port ball. When the hand operator is placed parallel to the pipeline, the flow passages of the ball are in-line with the flow passages of the body, allowing for full flow through the closure element. As the hand operator is turned to the closed position, the ball's opening begins to move perpendicular to the flow stream with the edges of the port rotating through the seat. When the full quarter-turn is reached, the port is completely perpendicular to the flow stream, blocking the flow.

In throttling applications, where the ball is placed in a midturn position, the flow experiences a double pressure drop through the valve, similar to a plug valve. The inlet port's flow area is reduced by the turning of the plug away from the full-port position, taking a pressure drop at that point. The flow then moves into the full-port area inside the plug, where a pressure recovery takes place, followed by another restriction at the outlet port.

When a characterizable ball is used to provide specific flow to position, as the ball is rotated from closed to open through the seat, a specific amount of port opening is exposed to the flow at a certain position, until 100 percent flow is reached at the full-open position.

3.4 Manual Butterfly Valves

3.4.1 Introduction to Manual Butterfly Valves

The manual butterfly valve is a quarter-turn (0° to 90°) rotary-motion valve that uses a round disk as the closure element. When in the full-open position, the disk is parallel to the piping and extends into the pipe itself.

Manual butterfly valves are classified into two groups. *Concentric butterfly valves* are used in on-off block applications, with a simple disk in line with the center of the valve body. Generally, concentric valves are made from cast iron or another inexpensive metal and are lined with rubber or a polymer. For throttling services, *eccentric butterfly valves* are designed with a disk that is offset from the center of the valve body. When butterfly valves are automated, eccentric butterfly valves are preferred since the disk does not make contact with the seat until closing, which prevents premature wear of the seat with the continual positioning associated with automated throttling. In most designs, simple concentric butterfly valves are used for strict on-off service and even when used in throttling applications do not lend themselves as well to automatic control as those butterfly designs

designed specifically for throttling control. Because the initial development was for blocking service, concentric butterfly valves have poor rangeability and inadequate control close to the seat, while throttling butterfly valves have design modifications to allow for better flow control through the entire stroke.

Butterfly valves have a naturally high pressure-recovery factor, which is used to predict the pressure recovery occurring between the vena contracta and the outlet of the valve. The butterfly valve's ability to recover from the pressure drop is influenced by the geometry of the wafer-style body, the maximum flow capacity of the valve, and the service's ability to cavitate or choke. Overall, because of the high-pressure recovery, butterfly valves work exceptionally well with low-pressure-drop applications.

The largest drawback to using a butterfly valve is that its service is limited to low pressure drops because of its high-pressure recovery. Although flashing is not associated with butterfly valves, cavitation and choked flow easily occur with high pressure drops. While some special anticavitation devices have been engineered to deal with cavitation, users normally prefer to deal with cavitation with other valve styles that allow the introduction of internal anticavitation devices.

Butterfly valves are used for on-off and flow-control applications. Common service applications include both common liquids and gases, as well as vacuum, granular and powder, slurry, food-processing, and pharmaceutical services.

The sizes of butterfly valves are limited to 2 in (DN 50) and larger because of the limitations of the rotary design. Because of the side loads applied to the disk, the maximum size that a high-performance butterfly can reach is 36 in (DN 900). Manual designs are limited to ANSI Class 150 (PN 16), although some manufacturers offer ANSI Classes 300 and 600.

3.4.2 Manual-Butterfly-Valve Design

When compared to plug and ball valves, butterfly-valve bodies have a very narrow face-to-face. The faces of the butterfly valve body are serrated to allow the use of flange gaskets for installation in the pipeline. In many cases, this allows the body to be installed between two pipe flanges using a *through-bolt connection*. Through-bolting is only permissible with certain bolt lengths, since thermal expansion of the process itself or an external fire may cause leakage. The butterfly body can be offered in one of two styles. The *wafer body* (Fig. 3.9), sometimes called the *flangeless body*, is a flat body that has a minimal face-to-face, which is equal to



Figure 3.9 Butterfly wafer-style body.
(Courtesy of The Duriron Company, Valve Division)

twice the required wall thickness plus the width of the packing box. Within this dimension, the disk in the closed position and the seat must fit within the flow portion of the body. Wafer-style bodies are more commonly applied in the smaller sizes, 12 in (DN 300) and less.

The *flanged body* (Fig. 3.10) is used with larger butterfly valves [14 in (DN 350) and larger] that have larger face-to-face dimensions, which are more apt to leak from thermal expansion. Generally, flanged bodies are used with high-temperature or fire-sensitive applications where potential thermal expansion is expected. The flanged style has integral flanges on the body that match the standard piping flanges with internal room between the flanges for studs and nuts.

As shown in Fig. 3.11, the *lug-body style* has one integral flange with an identical hole pattern to the piping flanges. Each hole is tapped from opposite direction, meeting in the center of the hole. This arrangement allows the body to be placed between two flanges. A stud is then inserted through the piping flange and threaded into the valve's integral flange. After the stud is securely threaded into the integral flange, a nut is used to secure the entire flanged connection.



Figure 3.10 Flanged butterfly body. (Courtesy of Vanessa/Keystone Valves and Controls, Inc.)

Lug bodies are used for applications in which the risks of straight-through bolting cannot be taken, such as with thermal expansion, when smaller valve size designs cannot permit two integral flanges.

The inside diameter of the butterfly valve is close to the inside diameter of the pipe, which permits higher flow rates, as well as straight-through flow. The closure element of the butterfly valve is called the *disk*, of which the outside diameter fits the inside diameter of the seat. The disk is described as a round, flattened element that is attached to the rotating shaft with tapered pins or a similar connection. As the shaft rotates, the disk is closed at the 0° position and is wide open at the 90° position. When the shaft is attached to the disk at the exact centerline of the disk, it is known as a *concentric disk* (Fig. 3.12). With a concentric disk, where the middle of the disk and the shaft are exactly centered in the valve, a portion of the disk always remains in contact with the seat regardless of the position. At 0° open, the seating surfaces are in full contact with each other. In any other position, the seating surfaces touch at two points where the edges of the disk touch the seat. Because of this constant contact, the concentric disk-seat design has a greater tendency

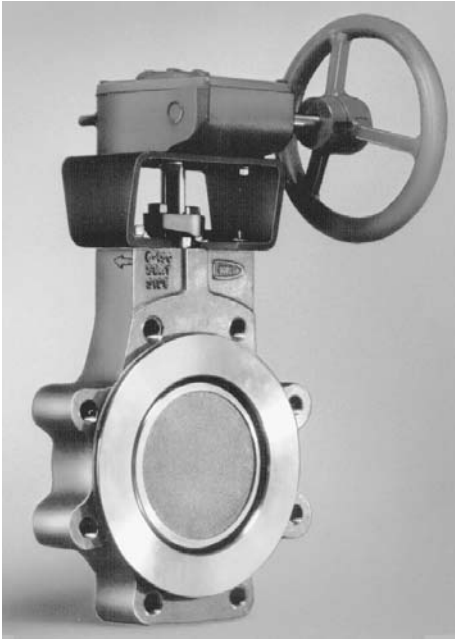


Figure 3.11 Butterfly lug-style body. (Courtesy of The Durriron Company, Valve Division)

for wear, especially with any type of throttling application. During throttling, a butterfly valve may be required to handle a small range of motion in midstroke, causing wear at the points of contact. Although the wear will not be evident during throttling, it will allow leakage at those two points when the valve is closed.

To overcome this problem of constant contact between the seating surfaces, butterfly-valve manufacturers developed the *eccentric cammed disk* design (Fig. 3.13). This design allows for the disk and seat to be in full contact upon closure, but when the valve opens the disk lifts off the seat, avoiding any unnecessary contact. Such designs allow for the center of the shaft and disk to be slightly offset down and away from the center of the valve, as shown in Fig. 3.14. When the valve opens, the disk lifts out of the seat and away from the seating surfaces, enough to avoid constant contact. If a manual butterfly valve is operated often, the eccentric cammed disk-seat closure element is preferred because of the minimal wear to the seat.

The seat fits around the entire inside diameter of the body's flow area and is installed at one end of the body. If a polymer is used for the



Figure 3.12 Slit-body, lined butterfly body.
(Courtesy of The Duriron Company, Valve Division)

seat, it is called a *soft seat*. If a flexible metal is used, it is called a *metal seat*. The seat is installed in the end of the body and is held in place by a *seat retainer*, using screws or a snap-fit to keep the seat and retainer in place. After the seat and seat retainer are in place, the face of the retainer lines up with the face of the body—although some seat-retainer designs protrude slightly from the body face, allowing some final gasket compression when the body is installed in the line.

The shaft is supported by close-fitting guides, sometimes called *bearings*, on both sides of the disk, which are installed in the shaft bore, preventing movement of the shaft and disk. Also, thrust washers are often placed on both sides of the disk, between the disk and the body, to keep the disk firmly centered with the seat.

Some concentric valve bodies are lined with rubber or elastomer. This lining has two purposes: First, it protects the metal body from the process, especially if the service is corrosive or has particulates (like



Figure 3.13 Eccentric and cammed butterfly-valve design. (Courtesy of The Duriron Company, Valve Division)

sand) that would erode metal surfaces. Second, the lining also acts as the soft seat when the disk is in the closed position.

The rubber or elastomer lining is held in place in one of three ways: First, it can be retained in place by the flanged piping connections. Second, it can also be held in place with a tongue and groove configuration, where the rubber lining is U shaped and the body has a T machined into the inside diameter, allowing the two pieces to interlock. The third arrangement is a split-body design with a liner sandwiched between two body halves and bolted together. All three designs allow for easy removal of the lining after it becomes worn. Rubber- or elastomer-lined valves are designed with metal disks that can also be coated with a similar material. When closed, the rubber-on-rubber seat makes for a very tight shutoff in low-pressure-drop applications and mild temperatures.

With eccentric butterfly valves, a number of different resilient seat designs are used to handle higher pressures and temperatures. Some

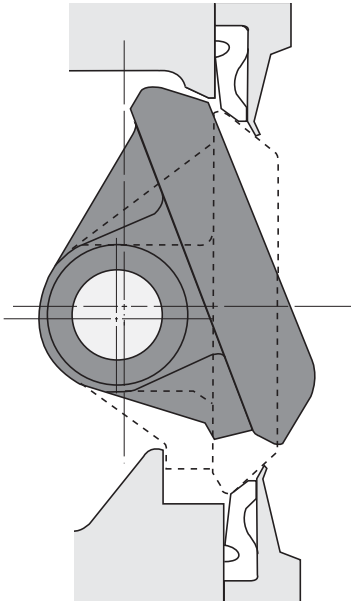


Figure 3.14 Eccentric and cammed disk rotation. (Courtesy of Valtek International)

seat designs use the *Poisson effect*, which refers to a concept that if a soft metal, O-ring, or elastomer is placed in a sealing situation with a greater pressure on one side, the softer seat material will deform with the pressure. When deformation takes place, the pressure pushes the material against the surface to be sealed (Fig. 3.15). With the Poisson effect, the greater the pressure, the greater the seal.

Another common resilient seat design utilizes the *mechanical preload effect*, which allows the disk's seating surface to slightly interfere with the inside diameter of the seat. As the disk moves into the seat, the seat physically deforms because of the pressure applied by the disk, causing the polymer to seal against the metal surface (Fig. 3.16). When soft seats are used, a gasket is not required to prevent leakage between the body and the retainer because the seat also acts as a gasket.

Metal seats are applied to high temperatures (above 400°F or 205°C). Metal seats can be integral to the seat retainer with a gasket placed in the space where a soft seat is normally inserted. In some designs, both a soft and metal seat can be used in tandem, allowing the metal seat to be a back-up in case of the failure of the soft seat (Fig. 3.17). When butterfly valves are specified for fire-safe applications, the tandem seat is preferred.

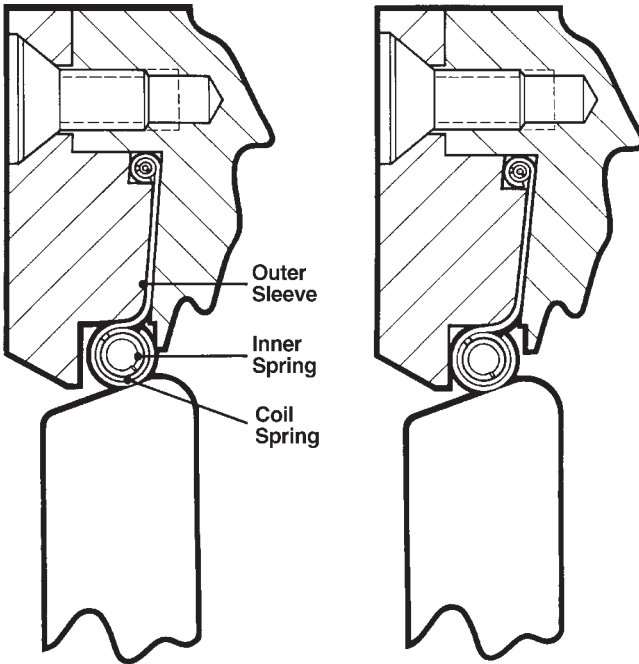


Figure 3.15 Butterfly metal seat assisted by process pressure (Poisson effect). (Courtesy of The Duriron Company, Valve Division)

The body contains the packing box, which is similar to other packing boxes used in plug and ball valves. The packing box features a polished bore and is deep enough to accommodate several packing rings. Normally all that is required is the packing and a packing follower. A gland flange and bolting are used to compress the packing. The shaft bore through the body is usually machined from both ends. A plug or flange cover can be used to cover the bore opening opposite the packing box. On the packing box side of the body, mounting holes are provided allowing the handle lever or gear operator to be mounted.

The designs of common rotary handle levers, gear operators, and actuation systems are detailed in Chap. 5.

3.4.3 Manual-Butterfly-Valve Operation

In butterfly valves, the fluid moves from the inlet to the outlet, with the only obstruction to the flow being the disk itself. Unlike gate- or globe-valve designs, where the closure element moves out of the flow stream, the

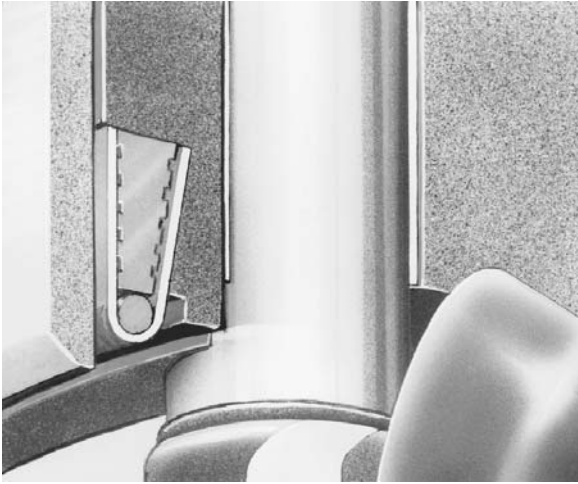


Figure 3.16 Butterfly soft seat assisted by mechanical preloading. (Courtesy of The Duriron Company, Valve Division)

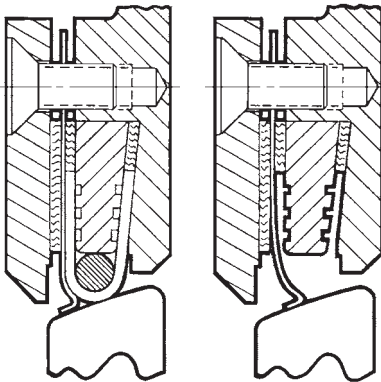


Figure 3.17 Combined metal and soft seat used for fire-safe applications. (Courtesy of The Duriron Company, Valve Division)

butterfly disk is located in the middle of the flow stream, creating some turbulence to the flow, even in the open position. This turbulence occurs when the flow reaches the disk and is temporarily divided into two flow streams. As the flow rejoins after the disk, turbulent eddies are created. To offset a potential problem, the disk is designed with gradual angles, as well as smooth and rounded surfaces. These design modifications allow the flow to move past the disk without creating substantial turbulence.

In closing the valve, as the manual operator is turned in a rotary motion, the shaft can turn anywhere between 0° (full-closed) and 90° (full-open). In throttling situations, as the disk closes by approaching the seat, the full fluid pressure and velocity act upon the full area of the face or back side of the disk, depending on the flow direction. Generally, the major drawback of butterfly valves is that control stability is difficult when the disk is nearing the seat. Because the rangeability of butterfly valves is quite low (20:1), the final 5 percent of the stroke (to closure) is not available because of this instability.

As the disk makes contact with the seat, some deformation is intended to take place. Such deformation allows the resilience of the elastomer or the flexible metal strip with metal seats to mold against the seating surface of the disk and create a seal.

As the valve opens, the rotary motion of the shaft causes the disk to move away from the seating surfaces. Because of the mechanical and pressure forces acting on the disk in the closed position, a certain amount of breakout torque must be generated by the manual operator to force the disk to open. The butterfly valves with the greatest requirement for breakout torque are those designs that require a great deal of operator thrust to close and seal the valve. This is why some manufacturers utilize fluid pressure to assist with the seal—in effect, less breakout torque is required.

As the valve continues to open, the disk is in a near-balanced state. As one side resists the fluid forces, the other side is assisted by the fluid forces. If both sides of the disk were identical, the disk could achieve a balanced state. However, both sides of the disk are not identical—usually the shaft is located on one side, while the other side is more flat. This creates a slight off-balance situation. Therefore, the flow direction has a tendency to either push a disk open or pull it closed. When the shaft portion of the disk is facing the outlet side, the process flow tends to open the valve. When the shaft portion is facing the inlet side, the flow tends to close the valve.

Because of the design limitations of the butterfly disk, a particular flow characteristic cannot be easily designed into a butterfly valve, unlike the trim of a globe valve. Therefore, the user must use the inherent flow characteristic of the butterfly valve, which is parabolic in nature.

3.5 Manual Globe Valves

3.5.1 Introduction to Manual Globe Valves

As shown in Fig. 3.18, a *manual globe valve* is a linear-motion valve characterized by a body with a longer face-to-face that accommodates

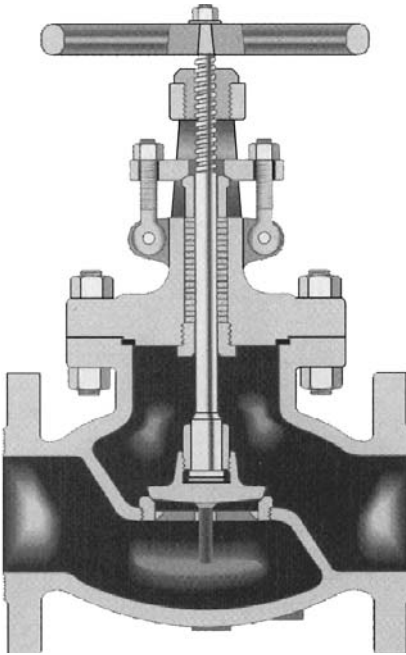


Figure 3.18 Manually operated globe valve.
(Courtesy of Pacific Valves, a unit of the Crane
Valve Group)

flow passages sufficiently long enough to ensure smooth flow through the valve without any sharp turns. It is used for both on-off and throttling applications. The most common closure element is the *single-seat design*, which operates in linear fashion and is found in the middle of the body. The single-seat design uses the plug-seat arrangement: a linear-motion plug moves into a seat to permit low flows or closure, or moves away from the seat to permit higher flows. By virtue of its design, a globe valve is not limited to an inherent flow characteristic like some quarter-turn valves. A particular flow characteristic can be designed into the shape of the plug.

Manually operated globe valves are somewhat more versatile in application than other manual valves, although the overall cost and size factors are higher. Manual globe valves can be applied in both gas and liquid services, although the service should be relatively clean to avoid particulates from being caught in the seat and creating unwanted leakage. Common manual-globe-valve applications include on-off and flow control, frequent stroking, vacuum, and wide temperature extremes. Although the globe body design can handle high-pressure

classes (up to ANSI Class 2500 or PN 400), manual globe valves are usually applied to lower-pressure applications because of the thrust limitations of the hand operator. High-pressure applications will require the use of a gear operator. Using the largest available hand operators, a manual handwheel is limited to 9,000 to 13,000 lb (40 to 60 kN), although some designs—such as a nonrotating plug and a stem nut supported by a roller bearing—may surpass this limit. Globe valves can be designed to handle higher-pressure classes by increasing the wall thickness of the body and using heavier-duty flanges, bolting, and internal parts. Manual globe valves are found in sizes from 0.5 to 48 in (DN 6 to 1200).

The majority of globe-valve designs feature top-entry to the trim (the plug and seat). This design permits easier servicing of the internal parts by disassembling the bonnet flange and bonnet-flange bolting and removing the top-works, bonnet, and plug as one assembly. Unlike rotary-motion manual valves, globe-valve bodies with top-entry access can remain in-line while internal maintenance takes place. Because of top-entry access, globe valves are preferred in the power industry where steam applications require the welding of the valve into the pipeline.

The largest drawbacks to the globe valve are that it can weigh considerably more than a comparable rotary valve and is much more costly. Sizewise, it is not as compact as a rotary valve.

3.5.2 Manual-Globe-Valve Design

The globe-style body is the main pressure-retaining portion of the valve and houses the closure element. The flow passages in a globe valve are designed with smooth, rounded walls with no sharp corners or edges, thus providing a smooth process flow without creating unusual turbulence or noise. The flow passages themselves must be of constant area to avoid creating any additional pressure losses and higher velocities. With two widely spaced end connections, globe-valve bodies are adaptable to nearly every type of end connection, although the face-to-face is too long to accommodate a flangeless design (bolting the body between two pipe flanges, which is commonplace with a rotary valve). With globe valves, mismatched end connections are also acceptable.

The globe valve's trim is more than just a closure element (because a throttling valve does more than just open or close), but rather it is a regulating element that allows the valve to vary the flow rate against the position of the valve according to the flow characteristic, which

may be equal percentage, linear, or quick-open (see Sec. 2.2). Typically, this trim consists two key parts: the *plug*, which is the male portion of the regulating element, and the *seat ring*, which is the female portion. The portion of the plug that seats into the seat ring is called the *plug head*, and the portion that extends up through the top of the globe valve is called the *plug stem*. The plug stem may be threaded at the top of the stem to allow for interaction with the handwheel mechanism. The chief advantage of the single-seated trim design is its tight shutoff possibilities—in some cases better than 0.01 percent of the maximum flow of the valve. This occurs because the force of the manual operator is applied directly to the seating surface.

Two sizes of trim can be used in manual globe valves. *Full trim* is the most common and refers to the area of the seat ring that can pass the maximum amount of flow in that particular size of globe valve. On the other hand, *reduced trim* is used when the valve is expected to throttle a smaller amount of flow than that size is rated for. If full trim is used, the valve must throttle close to the seat, as well as in small increments—which is difficult to achieve with a hand operator. The preferred method, then, is to use a smaller seat diameter with a matching plug, which is called reduced trim.

The *bonnet* is a major element of the valve's top-works and acts as a pressure-retaining part, providing a cap or cover for the body. Once mounted on the body, it is sealed by bonnet or body gaskets. It also seals the plug stem with a packing box—a series of packing rings, followers or guides, packing spacers, and antiextrusion rings that prevent or minimize process leakage to atmosphere. Mounted above the packing box is the gland flange, which is bolted to the top of the bonnet. When the gland-flange bolting is tightened, the packing is compressed and seals the stem as well as the bonnet bore.

Keeping the plug head in alignment with the seat ring is important for tight shutoff. To maintain this alignment, one of two types of guiding mechanisms is used: double-top stem guiding or seat guiding. *Double-top stem guiding* uses two close-fitting guides at both ends of the packing box to keep the plug concentric with the seat ring (Fig. 3.19). These guides can be made entirely from a metal compatible with the plug to avoid galling and can include a hard elastomer or graphite liner. The ideal arrangement is for the two guides to be located as far apart as possible to avoid any lateral movement caused by the process fluid acting on the plug head. The guides, bonnet bore, and actuator stem must all be held to close tolerances to maintain a fit that will allow smooth linear motion without binding or slop.

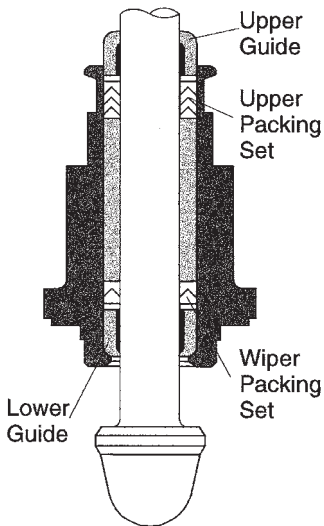
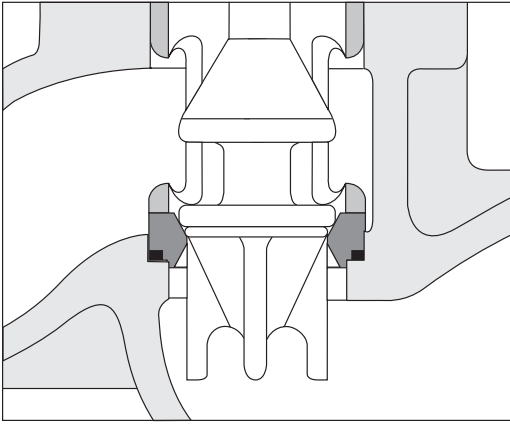


Figure 3.19 Double-top stem guiding.
(Courtesy of Valtek International)

The other common type of guiding in manual globe valves is the *seat-guiding* design, where the plug stem is supported by one upper guide (which also acts as a packing follower). As a second guiding surface, the outer diameter of an extension of the plug head guides inside the seat (Fig. 3.20). This means that the lower guiding surface remains inside the flow stream, so therefore the process must be relatively clean. The lower portion of the plug head has openings that allow the flow to move through the plug head to the seat during opening. By varying the size and shape of these openings, reduced flow and flow characteristics can be introduced. Because the length between the upper guide and the lower guide are at a maximum length, lateral plug movement due to process flow is not an issue and the tolerances required for this type of guiding are not required to be as close as double top-stem guiding. This design minimizes any chance of vibration of the plug in service. When the plug and seat are made from identical materials, galling may occur during long-term or frequent operation. High temperatures may also lead to thermal expansion and binding.

The metal seat surface of the plug is designed to mate with the metal seating surface seat ring, using angles that slightly differ. Normally the plug has a steeper seating angle than the seat ring. This angular mismatch assures a narrow point of contact, allowing the full axial force of



the operator to be transferred to a small portion of the seat only, assuring the tightest shutoff possible for metal-to-metal contact. In most designs, the seat ring for manual globe valves is threaded into the body. This sometimes requires a tool to turn the seat ring into a body with limited space. With threaded seat rings, exact alignment between the seating surfaces of the plug head and seat ring must require *lapping*—a process where an abrasive compound is placed on the seat surface. The plug is then seated and turned until a full contact is achieved. Although simple in concept, threaded seats have some disadvantages. First, in corrosive or severe services the threads can become corroded, making disassembly difficult. Second, alignment between the plug and seat ring require the additional step of lapping to achieve the required shutoff. And third, in situations where vibration is present and the seat ring is not held in place by the plug in the closed position, the seat ring may eventually loosen, allowing leakage through the seat gasket and/or misalignment of the seating surfaces.

Some globe-valve applications require bubble-tight shutoff, which cannot be attained with a metal-to-metal seal. To accomplish this, a soft elastomer can be inserted in the seat ring. In this case, the seat ring is a two-part design with the elastomer sandwiched between the two halves (Fig. 3.21). The metal plug surface pressing against the seat ring's soft seat surface can achieve bubble-tight shutoff if the plug and seat-ring surfaces are concentric. Some manufacturers also insert the elastomer into the plug, which achieves the same effect (Fig. 3.22).

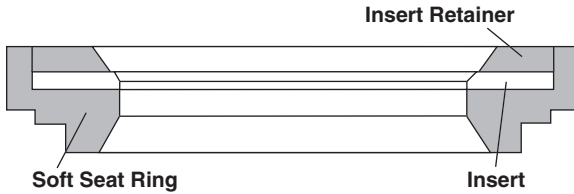


Figure 3.21 Soft-seat design. (Courtesy of Valtek International)

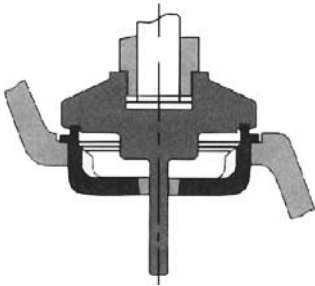


Figure 3.22 Soft-plug design. (Courtesy of Pacific Valve Group, a unit of the Crane Valve Group)

3.5.3 Manual-Globe-Valve Operation

Most manual globe valves use a T-style body, allowing the valve to be installed in a straight pipe. Flow enters through the inlet port to the center of the valve where the trim is located. At this point, the flow makes a 90° turn to flow through the seat, followed by another 90° turn to exit the valve.

The flow direction of globe valves is defined by the manufacturer or the application, although in most manual applications, flow direction is almost always under the plug. Seating the plug against the flow provides constant resistance but not enough to be insurmountable. With under-the-plug flow, the valve is relatively easy to close as long as the fluid pressure and flow rate are low to moderate. In addition, under-the-plug flow provides easy opening by the flow pushing against the bottom of the plug.

Manual-globe-valve trim can be modified to allow for equal-percentage, linear, or quick-open flow characteristics. As explained in detail in Sec. 2.2, flow characteristics determine the flow rate (expressed in flow coefficient or C_v) expected at a certain valve position. Therefore, with a

certain flow characteristic, the user can roughly determine the flow rate by the linear position of the manual handwheel. If the plug head is in a throttling position (between full-open or full-closed), because of the pressure drop the flow moves toward the flow opening in the seat. In a throttling position, the plug head extends somewhat into the seat ring, providing only so much flow in that particular position for a given flow characteristic. As the plug retracts further away from the seat, more flow is provided. If the plug extends further into the seat, less flow is allowed. As the flow moves through the seat, fluid pressure decreases as velocity increases. After the fluid enters the lower portion of the globe body, the flow area expands again, the pressure recovers, and the velocity decreases.

As the flow enters the seat or plug area of the valve, an important design consideration is the gallery area of the body. In ideal situations the flow should freely circulate around the plug and seat, allowing flow to enter the seat from every possible direction. If the gallery is narrow in any one area (for example, in the back side of the plug), velocities can increase, causing noise, erosion, or downstream turbulence. In addition, unequal forces acting on the plug head can cause slight flexing of the plug head if it is not guided by the seat.

When the globe valve closes, the axial force of the manual handwheel is transferred to the plug. The plug's seating surface is forced against the slightly mismatched angle of the seat ring, not allowing any flow to pass through the closure element. In the full-open position, the entire seating area is open to the flow.

Process flow is retained inside the body and bonnet by the static seals of the gaskets in the end connections [if flanges or ring-type joint (RTJ) end connections are used]. Flow seeking to escape through the sliding stem of the plug is prevented by the packing's dynamic seal in the bonnet's packing box. Depending on the shutoff requirements of the user, flow may or may not be leaking through the regulating element itself.

3.6 Manual Gate Valves

3.6.1 Introduction to Manual Gate Valves

A *gate valve* is a linear-motion manual valve that uses a typically flat closure element perpendicular to the process flow, which slides into the flow stream to provide shutoff. Overall, the simplicity of the gate-valve design and its application to a large number of general, low-

pressure-drop services makes it one of the most common valves in use today. It can be applied to both liquid and gas services, although it is mostly used in liquid services. The gate valve was designed primarily for on-off service, where the valve is operated infrequently. For the most part, it can be used in either liquid or gas services. It is especially designed for slurries with entrained solids, granules, and powders and cryogenic and vacuum services. As an on-off block valve, it can be designed for full-area flow to minimize the pressure drop and allow the passage of a pipe-cleaning pig. When compared to other types of manual valves, the gate valve is relatively inexpensive as well as easy to maintain and disassemble. When used with a metal seat, a gate valve is inherently fire-safe and is often specified for fire-safe service.

Gate valves do have some limitations. Gate valves do not handle throttling applications well because they provide inadequate control characteristics. Therefore, they are most commonly applied in simple on-off services as a block valve. They also have difficulty opening or closing against extremely high pressure drops. Tight shutoff is not easily attained in some applications. In addition, they can become fouled with those processes that have entrained solids. Because they are known for lengthy strokes, they take longer to open than other manual valves.

As a general rule, gate valves are divided into one of two designs: parallel and wedge-shaped. The *parallel-gate valve* (Fig. 3.23) uses a flat disk gate as the closure element that fits between two parallel seats—an upstream seat and a downstream seat. To achieve the required shut-off, either the seats or the disk gate are free-floating, allowing the upstream pressure to seal the seat and disk against any unwanted seat leakage. In some designs, the seat is spring-energized by an elastomer that applies constant pressure to the disk gate's seating surface. For the most part, the application of parallel-gate valves is limited to low pressure drops and low pressures, and where tight shutoff is not an important prerequisite.

Some variations of the parallel-gate valve have been designed for specific applications. The *knife-gate valve* (Fig. 3.24) has a sharp edge on the bottom of the gate to shear particulates or other entrained solids as well as to separate slurries. The *through-conduit gate valve* (Fig. 3.25) has a rectangular closure element with a circular opening equal to the full-area flow passageway of the gate valve. By lowering or raising the element, the opening is exposed to the flow or the barrier shuts off the flow, respectively. The through-conduit gate-valve design allows the seating surfaces of the gate to be in contact with the gate at all times. With a full-area opening, it also allows the use of a pig to scour the inside diameter of the line.

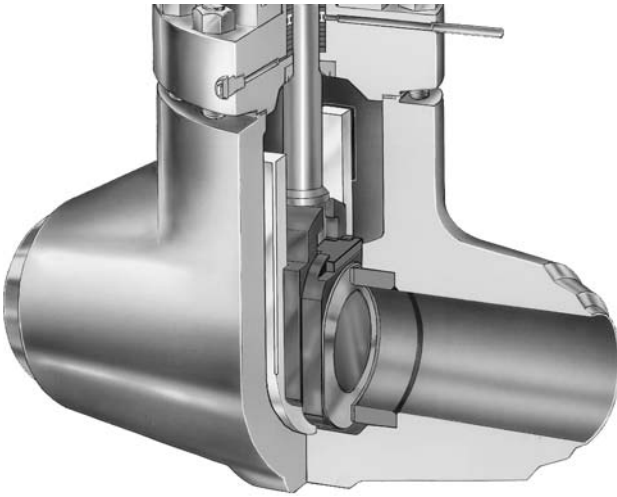


Figure 3.23 Parallel-gate valve. (Courtesy of Velan Valve Corporation)



Figure 3.24 Bidirectional knife-gate valve. (Courtesy of DeZURIK, a unit of General Signal)

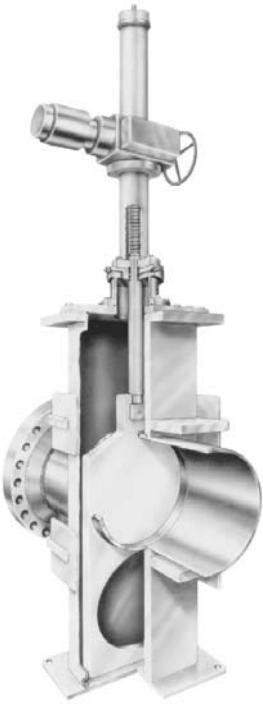


Figure 3.25 Through-conduit valve. (Courtesy of Daniel Valve Company, a division of Daniel Industries, Inc.)

The second classification of gate valves, the *wedge-shaped gate valve* (Fig. 3.26), uses two inclined seats and a slightly mismatched inclined gate that allows for tight shutoff, even against higher pressures. The inclined seats are designed 5° to 10° from the vertical plane, while the inclined gate can be designed with a close, but not exact angle. When the seat and gate angles are slightly mismatched, either the seat or gate is designed with some free movement to allow the seating surfaces to conform with each other as the manual actuator force is applied. This can be accomplished through either a floating seat and a solid gate or by a *flexible* or a *split-wedge gate* that provides flexure (or “give”) of the gate seating surfaces (Fig. 3.27). Also, pressure-energized elastomer inserts can be installed on a solid gate to provide a tight seal (Fig. 3.28).

Gate valves are commonly found in sizes of 2 through 12 in (DN 50 through DN 300) in ANSI Class 150 (PN 16), although larger sizes are sometimes custom designed.

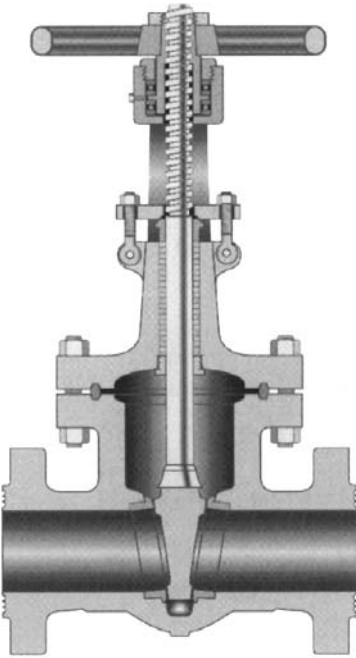


Figure 3.26 Wedge gate valve. (Courtesy of Pacific Valves, a unit of the Crane Valve Group)

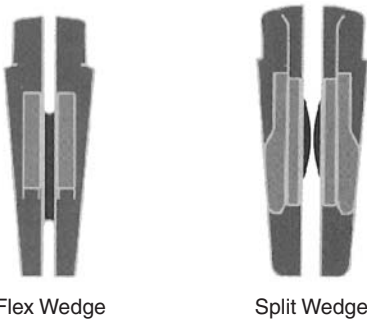


Figure 3.27 Flexible and two-piece split wedges. (Courtesy of Pacific Valves, a unit of the Crane Valve Group)

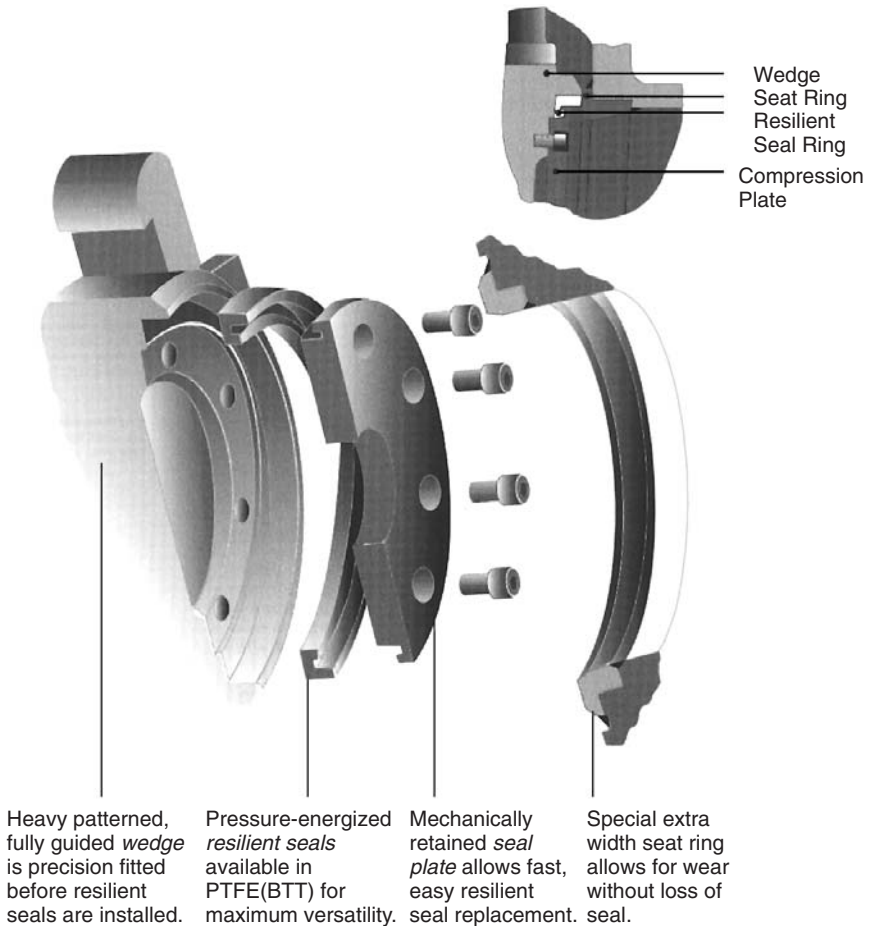


Figure 3.28 Pressure-energized wedge design (with soft seats). (Courtesy of Pacific Valves, a unit of the Crane Valve Group)

3.6.2 Manual-Gate-Valve Design

The gate is attached to the manual operator through the *gate stem*, which may be either fixed (rising stem) to the gate or threaded (nonrising stem) to the gate. The fixed-gate stem does not turn with the manual operator but stays stationary with the gate (Fig. 3.29). As the handwheel is turned, the threads (which are located above the packing box) retract the gate from the flow stream, causing the threaded portion of the stem to rise above the handwheel. With a threaded gate stem, the stem is threaded to the gate itself. Turning the handwheel threads the stem into the gate,

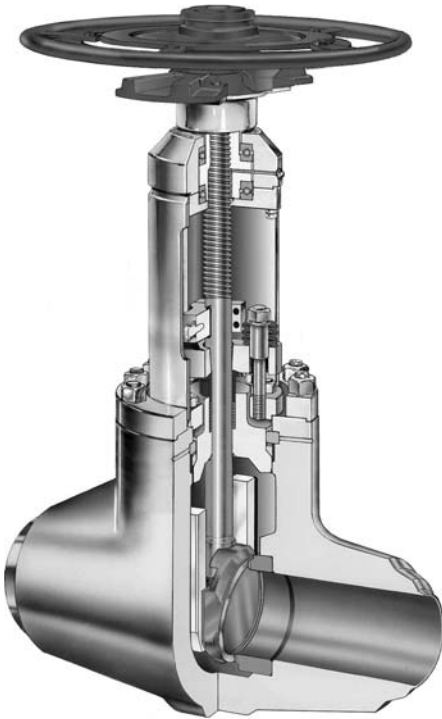


Figure 3.29 Rising-stem gate-valve design.
(Courtesy of Velan Valve Corporation)

causing the gate to lift out of the flow stream (Fig. 3.30). The gate stem is not integral to the gate but rather uses a T-shaped collar that fits into a T-shaped slot in the gate. The T-slot is parallel to the flow stream, but may also be perpendicular to the flow stream in certain designs.

With both parallel- and wedge-shaped gate valves, the screw-driven manual operator lowers or raises the gate either into the flow stream or out of the flow stream. Most designs call for the gate to rise above the flow stream into a cavity created by the bonnet cap, although some designs allow the gate to be extended into a lower body cavity.

The body itself is a straight-through design with a special face-to-face for gate valves (ANSI Standard B16.34). In most cases, the body is designed with flanged end connection, although buttweld, socktweld, and screwed ends are sometimes offered. With simple wedge-gate valves, an integral seating surface may be machined directly into the body. Separable wedge seats are installed through the valve's top-entry opening. The upstream and downstream parallel-gate seats are a



Figure 3.30 Nonrising-stem gate-valve design.
(Courtesy of American Flow Control, a division of
American Cast Iron Pipe)

floating design and are held in place between the body and gate, which also acts as guides for the gate.

With wedge gates, guiding takes place with slot-rib combinations between the body wall and the gate. In some cases, a rib fits a matching slot in the gate, or a slot in the body fits a matching slot in the gate. Although the slots are machined, the ribs are of a cast finish, providing only simple positioning (enough to place the gate and seats into position) after which the force of the operator seals the seating surfaces together and prevents any leakage between the body and gate during guiding.

The bonnet cap not only provides top-entry to the gate, but also encloses the packing box, which seals the gate stem to prevent process leakage. A gland flange is used to apply compression to the packing.

3.6.3 Manual-Gate-Valve Operation

In the open position, as flow moves into the inlet of the valve, it continues through the flow-through globe body with minimal, if any,

pressure drop occurring. This happens because most gate valves have full-area seats and are used for simple on-off blocking applications. Any pressure drop that occurs is due to the geometry of the seats, body guides, or cavities. In the open position, wedge gates and parallel gates are normally located above the seat in the upper body cavity, away from the flow stream. With conduit parallel gates, when the gate is in the open position, the flow opening of the gate is exposed to the full flow.

When the valve begins to close, the rotation of the manual operator turns the threads of the gate stem against either the operator itself (rising stem) or into the gate (nonrising stem). In either case, the gate begins its downward travel into the flow stream. Because gate valves operate in low-pressure or low-pressure-drop applications, the introduction of the gate into the flow stream is met with only moderate resistance.

As the gate valve closes, a parallel gate begins to seal the flow as the upstream pressure builds. In the parallel-gate design, the upstream pressure acts upon the floating seat, pushing the seat against the seating surface of the gate and providing the necessary seal. In the wedge-gate design, when the wedge gate reaches the seat, the thrust applied by the manual operator pushes the gate into the seat. As noted in Sec. 3.6.2, the wedge gate and the seats have some resilience as well as mismatched angles between seating surfaces. As additional thrust is applied, the wedge gate is pushed harder into the seats, providing tighter shutoff.

While the parallel valve requires minimum thrust to close, upon opening it must overcome a greater breakout force because of the upstream pressure pushing against the floating seat, especially if the valve has been in the closed position for some time. Once the flow begins to move through the seat and velocity builds, the upstream pressure is reduced and the gate slides easily to the full-open position without much resistance from the flow.

On the other hand, with a wedge valve, less breakout force is required due to the mismatched seating surfaces and wedge gate, which have a tendency to repel each other upon opening. This action is also enhanced by the natural resilience of the wedge gate. As the operator thrust is reversed and the valve begins to open, the gate and seats separate easily without hindrance or assistance by the flow.

With most applications, unless the flow rate is minimal, keeping the gate in a throttling position (midstroke) results in flutter of the gate as well as vibration and unnecessary wear. Because gate valves create additional flow turbulence in a midstroke position, they are not normally specified for throttling applications.

3.7 Manual Pinch Valves

3.7.1 Introduction to Manual Pinch Valves

A *pinch valve* is any valve with a flexible elastomer body that can be pushed together—or “pinched”—through a mechanism or through fluid pressure (Fig. 3.31). In most cases, the elastomeric body is simply a complete liner that lines the entire inside flow passage as well as the flanges. The liner keeps all moving parts outside of the flow stream; therefore these nonwetted parts can be made from less expensive materials, such as carbon steel. Because the fluid is completely contained inside the liner, the valve has the added benefit of not requiring a packing box or gaskets.

In pinch valves, when the liner seals, the sealing area is large as opposed to a single sealing point with most valves. Because of this characteristic, large objects or particulates can be trapped in the sealed area of the valve, yet the seal can be maintained. For this reason, pinch valves are ideal for particle-entrained fluids or slurries, such as processed food, sand-entrained water systems, sewage treatment, unprocessed water, granular flows, etc. Because of the resilience associated with elastomeric liners, the liner wall effectively resists abrasion

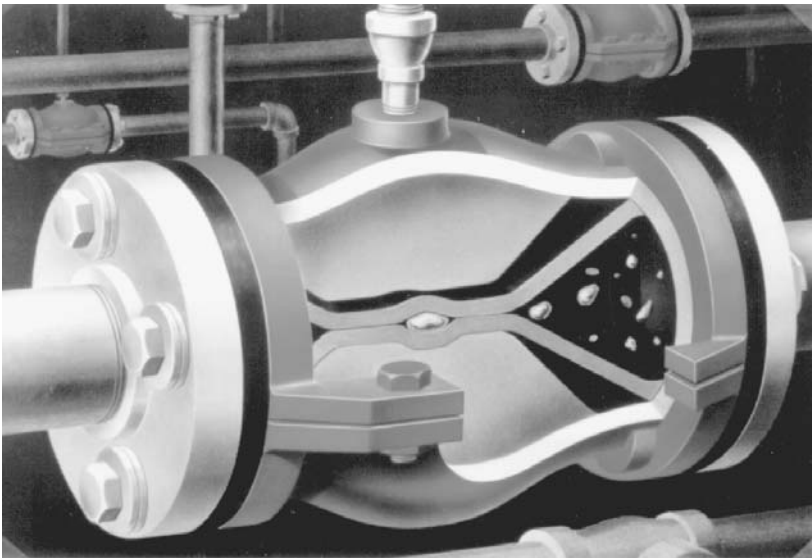


Figure 3.31 Pinch valve closing against entrapped solids. (Courtesy of Red Valve Company, Inc.)

damage that results from the passage of solid matter. Also, depending upon the material selection of the liner, pinch valves do exceptionally well with corrosive fluids that may attack metal surfaces.

The main limitation of pinch valves is that they are used in lower-pressure applications, because of the pressure and temperature limits of the elastomer liner. Since common liner materials (polytetrafluoroethylene, Neoprene, Buna-N, and Viton) are also associated with rubber hoses, rubber-hose pressure ratings are used for pinch valves in lieu of common valve pressure ratings. Although elastomeric pressure ratings are typically low, these limits can be increased by using specialized liners or body designs. For example, the pressure limits can be increased by using a rubber liner that has a metal mesh woven into the rubber or by injecting an outside fluid (under pressure) around the liner to offset the fluid pressure.

Another limitation is that if the pressures inside the process system move toward vacuum or if a high pressure drop is experienced, the liner can collapse with a valve in the open position unless the liner is attached physically to the closure mechanism. Pinch valves also work poorly in pulsating flows, where the liner expands and contracts constantly, causing premature failure. When these valves are used in liquid service, the liquid must have some fluid movement to allow for the displacement of fluid by the large sealing area associated with the liner. Otherwise, the incompressible nature of liquids can place additional strain on the liner and cause it to burst.

With straight-through or uninhibited flow, pinch valves have little or no pressure drop and are ideal for on-off service. Because they are commonly used in lower-pressure services, they can be throttled quite easily and provide good flow control at the last 50 percent of the stroke. This is because the smooth walls and resilience of the liner do not provide a significant pressure drop until at least 50 percent of the stroke has been achieved. Therefore, some pinch valves made for throttling service are designed for maximum opening at 50 percent to avoid using the ineffective half of the full stroke.

With services that are extremely erosive (especially with sharp particulates), the recommended practice is not to throttle the valve close to shutoff since the particulates can etch the liner, causing grooves that can potentially tear. Another positive aspect of the liner is that the smooth walls and gentle turns of the fluid produce minimal turbulence and line vibration. The resilient liner also achieves bubble-tight shutoff easily.

Most pinch valves are operated through the injection of air pressure or another fluid or by manual operators. They can also be automated

and used as a control valve. Pinch valves are commonly found in sizes of 2 to 12 in (DN 50 to DN 300) in ANSI Class 150 (PN 16).

3.7.2 Manual-Pinch-Valve Design

Two designs are prevalent in pinch valves: the open body and enclosed body. The *open-body pinch valve* has no metal body casing and relies upon a skeletal metal structure. This skeletal structure consists of two cross-bars fastened to metal flange supports. The metal flange supports are designed in halves, allowing the rubber liner to be placed between the halves during assembly (Fig. 3.32). Top and bottom supports are used to connect the cross-bars or flange support halves into one structure unit. The top support is also threaded to accept the threaded handwheel stem. This stem has a free-moving connection to a moving closure bar, called the *compressor*, which is located directly above the liner. When the handwheel is turned, the compressor is lowered, squeezing the liner against the bottom support.

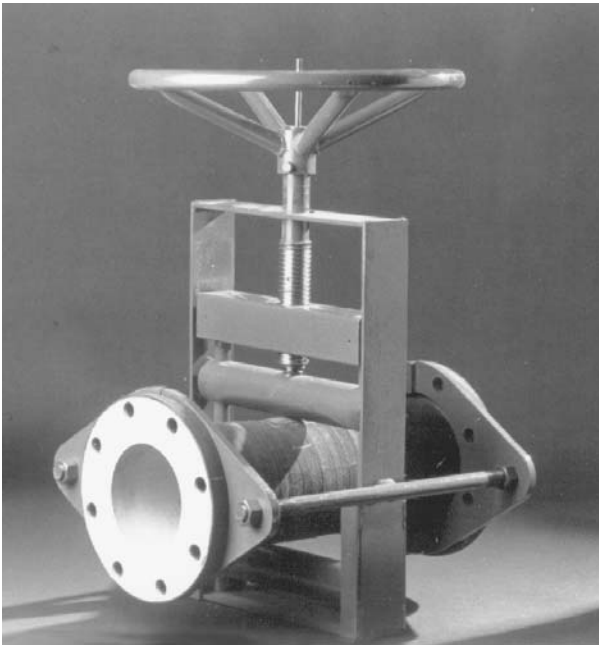


Figure 3.32 Open-body pinch valve. (Courtesy of Red Valve Company, Inc.)

The open-body design is fairly simple, does not require expensive metal castings, and allows for easy inspection of the liner for bulges, leaks, tears, or other failures. A primary disadvantage of this design is that the liner is exposed to the adverse effects of the outside environment, which may shorten the life of the liner.

The *enclosed-body pinch valve* has the appearance of most flow-through globe valves (Figs. 3.33 and 3.34), although the body is not actually a body but rather a protective casing for the liner. The closure mechanism is similar in design to the open-body pinch valve, except that the compressor is totally enclosed inside the body above the liner. The body can be designed with an integral bar cast into the bottom of the casing, perpendicular to the flow stream, which acts as the static closure bar. Other designs do not have this integral cast bar, called a *weir*, using the full compression of the liner against the bottom of the

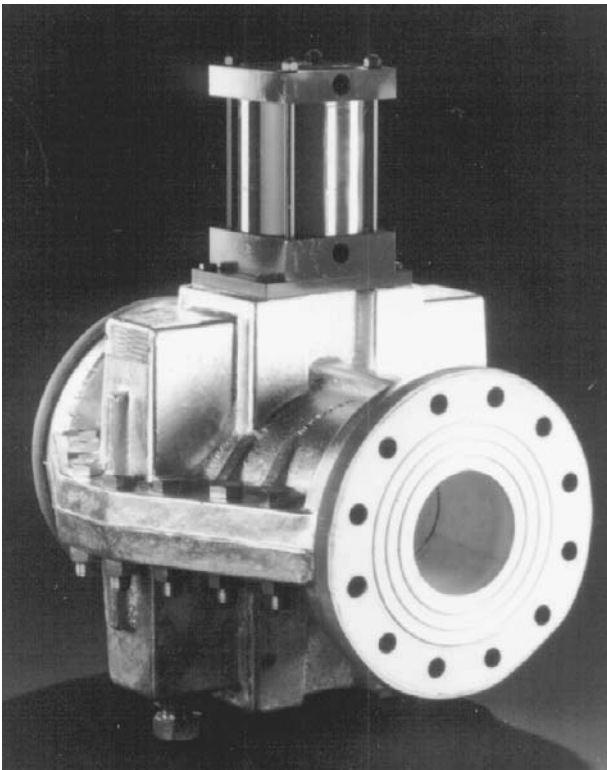


Figure 3.33 Enclosed-body pinch valve. (Courtesy of Red Valve Company, Inc.)

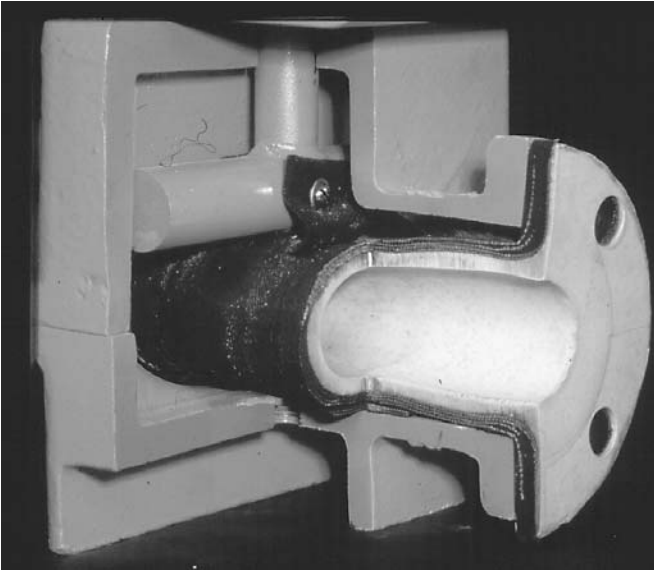


Figure 3.34 Internal view of enclosed-body pinch valve.
(Courtesy of Red Valve Company, Inc.)

casing to shut off the valve. To allow for each assembly of the liner, the casing is split along the axis of the flow passage and bolted together. A drain can be included in the bottom half of the body as a tell-tale indicator that the liner has failed.

The advantage of using the enclosed-body pinch valve is that an outside fluid or pressure can be introduced through a tapped connection into the casing, assisting the liner in staying open or closed. For example, if the process involves a vacuum, the internal casing area outside the liner in the casing can be depressurized to vacuum. This prevents the liner from collapsing when open. In some applications, additional air pressure is introduced into the casing to assist closing.

Manual handwheel operators are simplified in pinch valves because packing boxes are not required. A threaded bonnet and threaded stem (connected to the handwheel) are used to adjust the height of the compressor when operating the valve.

Another common design of pinch valves is the *pressure-assisted pinch valve*, which uses an outside fluid pressure only to close the valve (instead of a manual operator). This design (Fig. 3.35) uses a casing similar to an enclosed-body pinch valve, except the closure mechanism and operator are missing. Fluid is introduced to the inside of the casing (but outside the

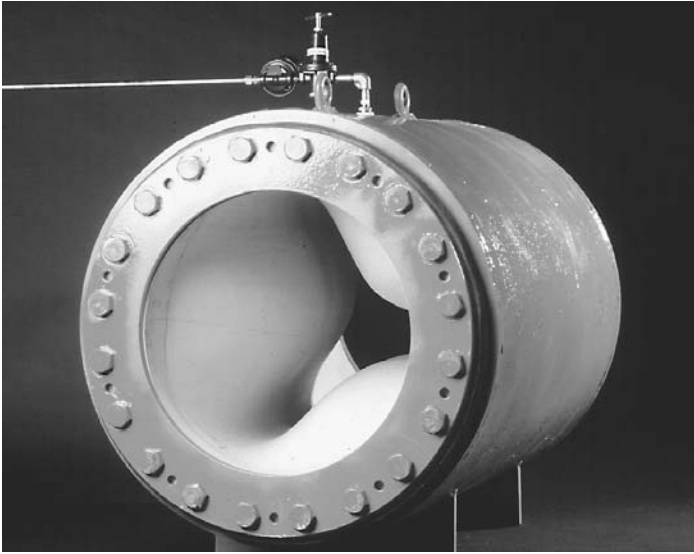


Figure 3.35 Pressure-assisted pinch valve. (Courtesy of Red Valve Company, Inc.)

liner) through tapped connections. When the pressure of the introduced fluid overcomes the process-fluid pressure, the liner closes and remains closed until either the system pressure increases or the introduced fluid pressure decreases. This design is very inexpensive, although it is limited to on-off service only. Throttling service is difficult because changes to the downstream pressure will automatically change the position of the valve, requiring the introduced fluid pressure to be reset.

3.7.3 Manual-Pinch-Valve Operation

Generally, pinch-valve operation is quite simple. Turning the hand-wheel lowers the compressor and moves the upper wall of the liner toward the static lower wall, which is supported by the bottom of the casing or the bottom bracket. In throttling situations, the manual operator is turned until the required flow is achieved and is then left in that position. In on-off situations, the manual operator is turned until the closure mechanism presses the upper wall of the liner against the lower wall, which is supported by either a static lower bar or the bottom of the casing. As more thrust is applied by the manual operator, the two surfaces seal more tightly. When the pinch valve opens, the

turning action of the manual operator is reversed, raising the compressor and allowing the liner to open as it moves toward its natural relaxed position. As the opening increases, the pressure of the process pushes the liner against the closure mechanism, which widens the flow area more as the closure mechanism is raised. Eventually, at the full-open position, the liner will have reached its full area capacity.

With pressure-assisted pinch valves, fluid pressure is introduced above and below the body liner. When the introduced pressure is greater than the pressure of the process fluid, the liner begins to collapse. As the introduced pressure builds, the liner begins to collapse, restricting the flow until the liner totally collapses and forms a seal between the upper and lower walls. When the introduced pressure is relieved or if the process pressure builds, the forces reverse and the liner walls separate, opening the pinch valve.

3.8 Manual Diaphragm Valves

3.8.1 Introduction to Manual Diaphragm Valves

Related to the pinch valve, the *diaphragm valve* uses an elastomeric diaphragm instead of a liner in the body to separate the flow stream from the closure element (Fig. 3.36). When compressed, the diaphragm is pushed against the bottom of the body to provide bubble-tight shutoff.

The advantage of a diaphragm valve is similar to a pinch valve. The closure element is not wetted by the process and therefore can be made from less expensive materials in corrosive processes. The flow stream is straight-through or nearly straight-through, providing a minimal pressure drop, which makes it ideal for on-off service, as well as avoiding the creation of turbulent flow. Diaphragm valves can also be used for throttling service. However, maintaining a throttling position close to the bottom of the valve body can sometimes result in erosion as the particulates can cut grooves into the diaphragm and the bottom of the body. Because the diaphragm is contained in a pressure-retaining body, a diaphragm valve is able to handle somewhat higher pressures than a pinch valve, although the overall pressure and temperature ratings are dependent upon the flexibility of the material or reinforcement of the diaphragm. The design of the body flow passage-way (such as the addition of a weir) has a bearing on the amount of flexibility of the diaphragm. Another advantage of the diaphragm valve is that if the diaphragm fails, the body can contain the fluid leak better than a pinch valve casing.

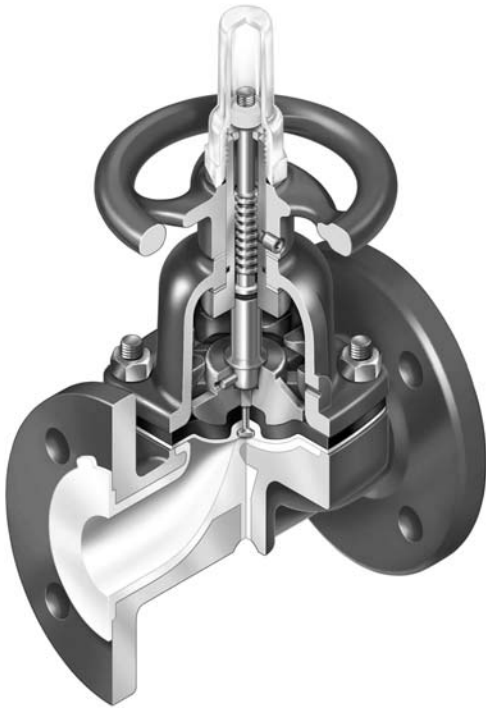


Figure 3.36 Diaphragm valve. (Courtesy of ITT Engineered Valves)

Diaphragm valves have an application similar to pinch valves. The resilience of the diaphragm allows it to seal around particulates in the fluid, making it ideal for service with slurries, processed food, or solid-entrained fluids.

When compared to the pinch valve, the primary disadvantage of the diaphragm valve is that the body can cost more than a pinch-valve casing because the body material must be compatible with the process fluid. Also, while the resilience of the diaphragm has a tendency to resist erosion damage from the process, the body can erode, making shutoff more difficult.

Depending on the design, diaphragm valves are available in larger sizes than pinch valves, typically up to 14 in (DN 350), although some special designs can reach up to 20 in (DN 500). Because of the pressure limitations of the liner, diaphragm valves are nearly always rated at ANSI Class 150 (PN 16).

3.8.2 Manual-Diaphragm-Valve Design

Two designs are typically associated with diaphragm valves: the straight-through design and the weir-type design. The *weir-type diaphragm valve* has the same construction as the straight-through design except for the body and diaphragm. As shown in Fig. 3.37, the body has a raised lip that raises up to meet the diaphragm, allowing the use of a smaller diaphragm. This body design is self-draining, which makes it ideal for food-processing applications. Since the diaphragm can be made from heavier materials, the body can also be used with high-pressure services, which are not as flexible and do not allow for a long stroke. Heavier, reinforced diaphragms also allow the weir-style design to be used for vacuum services. On the other hand, the *straight-through diaphragm valve* has a body in which the bottom wall is nearly parallel with the fluid stream, allowing the flow to move uninhibited through the valve with no major obstructions (Fig. 3.38). The flexibility of the diaphragm allows it to reach the bottom of the valve body. Above the diaphragm is the compressor, a round part shaped much like the body's flow passage, which is connected to the hand-

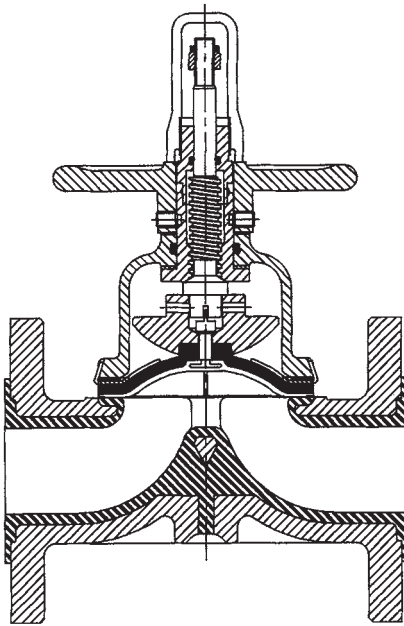


Figure 3.37 Weir-style diaphragm valve.
(Courtesy of ITT Engineered Valves)

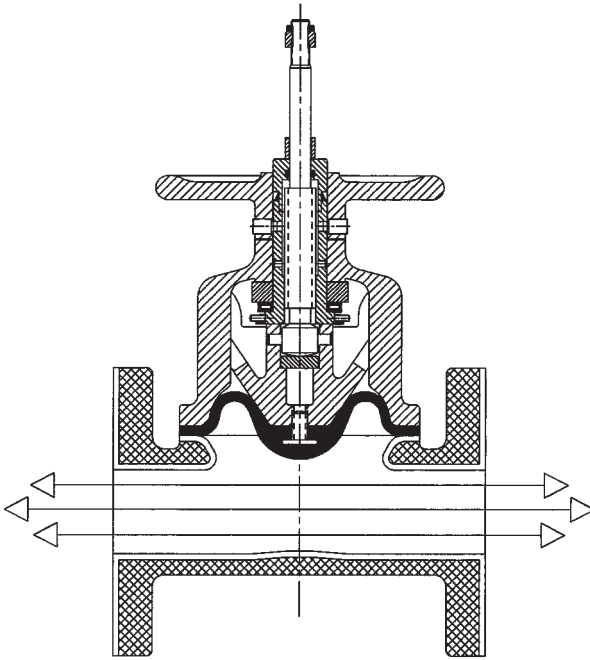


Figure 3.38 Straight-through diaphragm valve.
(Courtesy of ITT Engineered Valves)

wheel stem. The diaphragm is attached to the bottom of the compressor to ensure that the diaphragm is lifted out of the flow stream during full-open. The compressor, the nonwetted portion of the valve, and the handwheel mechanism are contained by the bonnet cap, which is bolted to the body. The diaphragm itself is used as the gasket between the body and bonnet cap and prevents leakage to the atmosphere.

3.8.3 Manual-Diaphragm-Valve Operation

Manual-diaphragm-valve operation is very similar to the operation of a pinch valve. Turning the handwheel lowers the compressor, which begins to move the diaphragm toward the bottom wall of the body. In throttling situations, the manual operator is turned until the required flow is achieved and is then left in that position. In on-off situations, the manual operator is turned until the compressor pushes the diaphragm against the bottom wall of the body. As more thrust is applied by the manual operator, the two surfaces seal tighter until

maximum compression is achieved. When the diaphragm valve opens, the turning action of the manual operator is reversed, raising the compressor and allowing the diaphragm to separate from the bottom body wall. As the opening increases, the pressure of the process keeps the liner pushed against the compressor, widening the flow area as the closure mechanism is raised. Eventually, at the full-open position, the compressor is fully retracted inside the bonnet cap and the diaphragm is out of the flow stream. At this point, the valve is at its full-area capacity.

Generally, diaphragm valves offer an inherent equal-percentage flow characteristic, which tends to move toward linear when installed (Sec. 2.2.5).