Valves

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Valves perform an important and vital role in almost every industry. They are critical in piping systems because of their basic function: controlling the flow of liquids or gases by on/off service, throttling service, or backflow prevention.

VALVE SELECTION

The selection of the correct type of valve for a specific installation is dictated by the purpose for which it will be used. For example, for starting/stopping service, a gate, butterfly, ball, or plug valve should be used. For backflow prevention, the selection is a check valve.

A valve's primary function is to control the flow of liquids or gases, so selection also depends on the characteristics of the fluid to be controlled. The following factors must be evaluated for satisfactory valve selection:

- Is the fluid a liquid or a gas?
- What is the fluid's viscosity (free-flowing characteristics)?
- Does the fluid contain abrasive, granular, or fibrous particles?
- Is the fluid corrosive?
- What is the fluid's temperature (normal, elevated, or cryogenic)?
- What is the fluid's pressure?
- What degree of leak tightness is required?
- What is the maximum pressure drop that can be tolerated through the valve?

Valve Styles

The three main styles of valves are multi-turn, quarter-turn, and check.

Multi-turn valves are considered linear stroke valves. A handwheel turns, causing the stem to rise, which pulls the wedge or disc off the seat and out of the flow path.

Quarter-turn valves are rotary-type valves. Rotary force applied to a lever turns the closure member 90 degrees for either full open or full closed; however, the closure member stays within the waterway.

Check valves require no manual operation. Operation of the valve depends completely on the flow through the piping system. A check valve is a unidirectional valve that opens by flow in one direction and closes automatically if the flow reverses.

Materials

The following materials are used in the manufacture of valves for commercial and industrial applications:

- Bronze, cast alloy (ASTM B61, ASTM B62, ASTM B584)
- Cast iron (ASTM A126)
- Ductile iron (ASTM A395)
- Forged steel (ASTM A105)
- Cast steel (ASTM A216 WCB)
- Cast stainless steel (ASTM A351 CF8 or CF8M)
- Forged stainless steel (ASTM A182, ASTM F304, ASTM F316)

Material selection is related to the actual application. The material must be compatible with the fluid running through the valve. Valve manufacturers supply chemical resistance charts to help make these determinations.

Many applications are water or water-based, and in these cases bronze and iron are the most cost-effective choices. However, if the fluid is a low-density gas like Freon, a cast material is too porous, so in this case a forged material is the right choice. If the fluid is volatile, like gasoline, then a brittle (low yield and elongation) material such as cast iron is not recommended. Brittle materials also should not be used where thermal or physical shock conditions may occur, such as with severe water hammer or where condensate may flash to steam.

Valves used in potable water systems must conform with the requirements of The Reduction of Lead in Drinking Water Act, which limits the lead content in plumbing products to a weighted average of 0.025 percent.

Dezincification occurs in valve bodies with more than 15 percent zinc. The leeching of the zinc from the brass alloy creates porous copper and subjects the valve body to potential failure. This is no longer a problem with U.S.-made valves, but it may still be a problem with some valves manufactured outside of the United States.

Smooth or electro-polished finishes are typically specified for pharmaceutical, biotech, and food and beverage processes, as standard cast surface finishes promote the growth of bacteria and contaminants, which can lead to unsanitary conditions.

Pressures and Temperatures

Pressure and temperature are critical in selecting the right valve. The valve body is a pressure vessel—the valve's walls must be thick enough to contain the pressure of the fluid passing through it. As temperature increases, materials weaken, and pressure ratings drop. A cast iron gate valve, for example, may be rated at 200 pounds per square inch (psi) for water up to 150°F, but the rating would drop to 125 psi at 353°F. A similar cast steel gate valve would be rated at 125 psi up to 650°F.

Pressure symbols commonly used throughout the industry include the following:

- SP: Steam pressure
- SWP: Steam working pressure
- WOG: Water, oil, gas pressure
- WWP: Working water pressure
- CWP: Cold working pressure

Each material has a temperature limitation, such as:

- Bronze ASTM B62: 450°F
- Cast iron ASTM A126: 450°F
- Cast steel ASTM A216 WCB: 1,000°F

Following are three common examples of ratings:

- 125 lb. WSP, 250 lb. WOG
- 150 lb. WSP, 300 lb. WOG
- 300 lb. WSP, 600 lb. WOG

The number refers to the specific amount of pressure in pounds per square inch gauge (psig) for which the valve is rated. The temperature of saturated steam at 150 psig is 366°F. This is the maximum temperature at which a 150 lb. WSP-rated valve can operate. Above 150 psig, the allowable temperature decreases as the pressure increases.

All valves manufactured to industry standards are classified as to their pressure/temperature limitations. For example, ASME B16.34 covers valves with flanged, threaded, and welding ends and outlines specific pressure/temperature limits for the valves' pressure-containing parts. MSS SP-80, published by the Manufacturers Standardization Society, covers bronze gate, globe, angle, and check valves. Bronze is categorized by material type, pressure by class (i.e., 125, 150, 200, 300, and 350), and temperature.

Cv Factor

A valve's Cv factor is the flow in gallons per minute (gpm) through the valve that will produce a 1-psi pressure drop (2.3 feet of water). Cv factors are listed by valve manufacturers to help determine the actual pressure drop through a valve since pressure varies with flow. (Equivalent lengths do not take this into account.) It can be calculated using the following equations:

Equation 6-1

$$gpm = Cv\sqrt{\frac{\Delta P}{SG}}$$

Equation 6-2

$$\Delta P = \left(\frac{gpm}{Cv}\right)^2 SG$$

where

ΔP = Pressure drop through the valve or fitting, psi

SG = Specific gravity (1.00 for water)

Trim Materials (Wetted Parts)

The term trim as applied to valves encompasses the elements of a valve relative to seating, such as the stem, disc, and seats in gate and globe valves, the stem, ball, and seats in ball valves, and the disc and liner in butterfly valves. The correct trim material is also a critical choice that depends on the actual application and the type of fluid in the body (abrasive, corrosive, etc.).

VALVE COMPONENTS

Bonnets

A bonnet is a cover for the valve and acts as the pressure boundary. Not all valves have bonnets depending on their design.

Screwed Bonnet

This is the simplest, least expensive, and probably most common design for small valves. However, for the internal threaded connection to be leak-tight, the mating threads must be accurate. Screwed-in bonnets are used for low-pressures and where shock and vibration are not present. They should not be used where frequent disassembly of the valve is required.

Union Bonnet

This design utilizes a separate union ring that mates with external threads on the body and pulls the bonnet and body into a close, pressure-tight relationship. The three-piece construction is the preferred choice over the screwed bonnet for rugged service and where frequent dismantling for replacement or maintenance is anticipated. It is stronger and safer than the two-piece screwed configuration. It is used for pressure ratings of 125 psi and higher.

Bolted Bonnet

In this type, the bonnet and body are cast with mating flanges that are machined and drilled. The flanges can be flat faced, male-female, or ring joint. Bolted bonnets are suitable for rugged service and all pressures and temperatures. They are practical for small and large valves, whereas the screwed and union bonnets are generally found on small valves only.

U-Bolt

The U-bolt bonnet is a modified version of the bolted bonnet and is used where moderate pressures are encountered. This type of bonnet is usually found in the oil and chemical industries because of its relative ease of disassembly for cleaning and repair, ruggedness, and economy.

Pressure Sealed

Pressure-sealed bonnets are not removable. They are used in high-pressure and high-temperature applications where seals providing compact and safe body-to-bonnet connections are required.

Seals

Simple Packing Nut

In this design, the packing is placed around the stem and forced down against the body with a packing nut. Maintenance is very easy, but the design is only suitable for use in low-pressure and small-size valves.

Packing Nut and Gland

In this design the stress is taken off the packing nut through the use of a loose gland that rides inside and is pressed against the packing as the nut is tightened. This permits more and tighter adjustments and consequently longer life with less maintenance.

Bolted Gland

Bolted glands are most commonly used in bolted bonnet valves and for valves operating at high pressures and temperatures. The stuffing box is usually much deeper than can be accommodated with a standard packing nut or even with the loose single-piece gland. Good designs prevent scoring of the stem by the gland.

Lantern Ring Design

On larger valves and those exposed to extremely high pressures and temperatures, additional sealing safety is built in through the use of a lantern ring in conjunction with the bolted gland. In effect, this design incorporates a double stuffing box, with the first taking the wear and pressure off of the second. Between the two stuffing box areas, space is provided for the introduction of a lubricant or sealant as further protection against leakage.

End Connections

Threaded End

Threaded ends are tapped with American National Standard female taper pipe threads. Threaded end valves are the least expensive and can be easily installed. Threaded ends are generally used for valves 2 inches and smaller, are suitable for all pressures, and are found in brass, iron, steel, and alloy steel valves.

Flanged End

Flanged ends make a strong, tight joint and are generally used for lines greater than 2½ inches that are frequently disassembled and assembled. Iron valves are typically provided with flanged ends. Flanged-end valves are installed between adjoining pipe flanges and made up with a gasket between the flanges for a tight joint. Cast iron valves come with flat-face flanges, and ductile iron and steel valves come with raised-face flanges.

Weld End

Welded-end steel valves are recommended where high temperatures and pressures will be encountered and absolutely tight, leak-proof connections must be maintained over a long period. Valves are furnished in either butt-weld or socket-weld ends.

Solder End

Solder end valves are used with copper tubing for many low-pressure services. The use of solder joints is limited to a maximum of 250°F because of the low melting point of the solder. Instead of solder, a higher temperature brazing material can be used. Flared ends are also available in small sizes for use with copper tubing.

Operators

Some of the most common valve operators follow:

- Wheel handle: In some cases the wheel on a large valve has a gearbox (6 to 8 inches); where it is 8 feet or more above the floor it may have a chain fall, and it could also be electric motor operated. If a large valve has high pressure on one side, it should have a small bypass valve that can relieve the pressure before opening.
- Horizontal lever: These come in various shapes. The butterfly valve should have a locking lever and should be opened slowly; otherwise, due to pressure on one side, the disc could open very rapidly and cause an injury.
- Vertical lever: These are either hand-operated or operated with an air or hydraulic piston.

GATE VALVES

Valve Stem

The sole function of the stem in a gate valve is to raise and lower the disc. The stem should not be subject to corollary stresses and strains of service conditions on the disc. For this reason, a relatively loose disc-stem connection is required. If the disc-stem connection were rigid, side thrust on the disc by pressure and flow would be transmitted to the stem, with possible straining and bending of the stem.

The most common stem configurations follow (see Figure 6-1):

- Rising stem, outside screw and yoke (OS&Y)
- Rising stem, inside screw
- Non-rising stem, inside screw

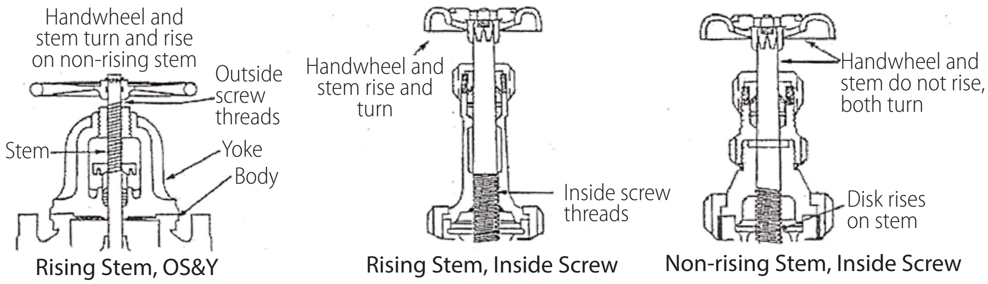

Figure 6-1 Common Valve Stem Configurations

For the OS&Y construction, the stem threads are outside the valve. When the handwheel is rotated to open the valve, the stem's threading mechanism causes the stem to rise while the handwheel remains in the same location. The OS&Y construction is especially recommended for high temperatures, corrosive liquids, and where the liquid contains solids that might damage stem threads located inside the valve. Lubrication is a simple and easy procedure with external threads, but since the threads are exposed, care must be exercised to protect them from damage.

The rising stem, inside screw construction is generally employed with bronze gate valves. The handwheel and stem both rise as the valve is opened, so it is important to provide adequate clearance for valve operation.

The non-rising stem, inside screw construction requires minimum clearance for its operation. The disc moves on the stem as the handwheel is turned. Heat, corrosion, erosion, and solids in the fluid could damage the stem threads due to their constant exposure to the line fluid. In addition, the position of the disc (open or closed) cannot be determined by the position of the handwheel or stem as it can be with the rising stem types.

Disc

The control mechanism in a gate valve is a sliding disc (wedge) that is moved in and out of the flow passage of the body. The disc is restrained by guides in the valve body. In the fully opened position, the disc is completely out of the flow passage and thus allows a straight-through flow of the fluid through the passageway. The diameter of the passageway is nominally equal to the pipe diameter, which results in a pressure loss through the valve that is lower than through a valve that has a restricted flow passage or a design that changes the direction of flow.

Four main types of discs are available in gate valves: solid wedge; double disc, parallel faced; split wedge; and flexible wedge.

The solid wedge disc is the most widely used type in gate valves. It is noted for its simplicity of design and versatility. The solid wedge closes by descending between two tapered seats in the valve body. Solid wedge disc seating is available in brass, iron, and steel gate valves.

The double disc should be selected where the application requires a tight seal to ensure leak-proof shutoff. The double disc closes by descending between two parallel or tapered seats in the valve body. After parallel-faced double discs are lowered into position, they are seated by being spread against the body seats. A disc spreader makes contact with a stop in the bottom of the valve and forces the discs apart. Valves with double discs are widely used in the waterworks and sewage fields and in the oil and gas industries.

The split wedge is a two-piece disc that seats between matching tapered seats in the body. The spreader device that presses the discs against the body seats is simple and integral with the disc halves. As the valve is opened, pressure on the disc is relieved before the disc is raised, thus preventing friction and scoring of the seat. Another type of split wedge is one with a ball and socket joint that forces each disc to align itself against the body seat for tight closure.

Flexible discs were developed especially to overcome sticking in high-temperature service with extreme temperature changes. It is solid through the center but not around the outer portion, where it is flexible. This type finds little application in plumbing work.

Materials

A wide selection of materials is available for gate valves. In the selection procedure, the valve body and bonnet should be considered first, and then the valve trim. Factors to be considered in the selection of materials are pressure, temperature, corrosion resistance, thermal shock, line stresses, and fire hazard.

The most commonly used materials for the majority of gate valves in plumbing applications are bronze and iron. These materials are the most economical, are readily available, and generally satisfy most requirements of pressure, temperature, and corrosion resistance.

Carbon steel and various alloy steels are used when greater strength is required or where high temperatures, cryogenic temperatures, or special corrosive conditions are encountered.

Valve bodies and bonnets are available in cast, forged, or fabricated construction. For greater strength, forged and fabricated steel bodies are preferred over cast steel. The forged steel bodies are available only in a limited size range.

Many material options are available for seat rings, stems, discs, and backseat bushings. For instance, an iron body, bronze mounted (IBBM) gate valve has bronze seat rings, disc rings, stem, backseat bushing, and packing gland. When used within their pressure/temperature ratings, IBBM gate valves offer excellent service for most plumbing systems. Bronze gate valves are available with the body seats machined in the body. However, bronze is a relatively soft metal, and if grit or dirt is present in the fluid, the valve seats on the body or disc can be easily scored or scratched, causing subsequent leakage of the valve. In this case, a bronze gate valve with seats of stainless steel, copper-nickel, or Monel would be preferable. Of course, optional trim material increases the initial cost of a valve, but the extended valve life and lower maintenance costs often justify their selection.

Gate valves are now generally available in nonmetallic materials such as polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), and polypropylene (PP). When these materials are selected, their temperature limitations should be carefully checked.

Packing

Packing is one of the most important and often overlooked features of a valve. Valve manufacturers furnish gate valves with a general-purpose packing, which may not be satisfactory for a particular service.

Most gate valves employ stuffing boxes with packing glands that can be tightened with open-end or adjustable wrenches. Glands that are not sufficiently tightened will allow leakage. Over-tightening can squeeze out the lubricant in the packing.

Other packings for specialized applications include pure graphite, cotton filament, nitrile rubber, and rubber in combination with a cotton jacket.

The proper selection, care, and maintenance of valve stem packing can make a significant difference in the efficiency of a piping system.

Application

Gate valves are used to start or stop flow. The advantage of a gate valve is full flow with minimal pressure drop. The limitation is that a gate valve is not recommended for throttling applications. To throttle, the wedge would be left partially in the waterway, increasing velocity and eroding the wedge. The valve would also be damaged due to the wedge banging against the seats. Wire-drawing (erosion) with subsequent seat leakage is also a danger.

Gate valves should not be used where frequent operation is required. A closed 6-inch gate valve with a 300-psi inlet pressure and atmospheric outlet pressure is subjected to a load of more than 4 tons on the disc. While the valve is tightly seated, no wear or undue stress occurs on the disc or seats, but at each start of the opening or end of the closing cycle is the ever-present danger of erosion of the seating surfaces due to the high velocity of flow. Repeated movement of the disc near the point of closure can cause a drag on the seating surfaces and subsequent galling and scoring on the downstream side.

A major market for gate valves is in commercial, industrial, and institutional construction. They are widely used by water utilities and conform to American Water Works Association (AWWA) requirements for this application. Other major markets are the petroleum, gas, chemical, shipbuilding, pulp, metal, and food and beverage industries. Power generation is another area where gate valves (mainly cast steel and stainless steel) are specified.

Additional types of gate valves for specialized service include:

- Knife gate valves, widely used in the pulp and paper industry where a slab-type valve is desired, as well as in chemical and petroleum plants for fire and explosion protection
- Slide valves, for low-pressure liquids and gases where absolute shutoff is not generally required
- Cryogenic gate valves, for use with liquefied gases requiring a stainless steel extended bonnet and stem to keep the packing out of the freeze area and allow gasification in the bonnet chamber

Operation and Maintenance

Before the piping system is placed in operation, the system should be thoroughly flushed to remove any chips, dirt, and scale that may have entered the lines during construction. No valve should be operated before this is done to prevent damage to the seating surfaces.

Gate valves should be closed slowly as the disc approaches the seat. The increased velocity of flow, caused by the reduced open area, will tend to flush out any solids that may have been trapped between the disc and seat. After opening the valve, the hand-wheel should be turned back one-quarter turn to ensure that the valve does not jam in the open position. The packing nut should be tightened at the first sign of packing leakage. Leaks around the stem could cause corrosion, and a loose stem could vibrate and damage the disc or seat.

Exposed valve stem threads should be kept clean and lubricated for ease of operation and to prevent wear from dirt or rust.

GLOBE VALVES

Globe valves (Figure 6-2) derive their name from the globular shape of the body. Flow through a globe valve follows a changing course; the fluid enters the valve parallel to the valve port and, after two 90-degree turns, leaves the valve again parallel to the valve port. Globe valves are designed for start and stop service and are ideally suited for throttling service.

Globe valves are available in a wide range of materials: bronze, all-iron, cast iron, cast steel, forged steel, and corrosion-resistant alloys. Body end connections are the same as for gate valves: screwed, soldered, flanged and welded.

The following bonnet types are generally available: screwed-in and screwed-on, union, flanged (bolted), pressure sealed, lip sealed, and breech lock.

The following types of stem configurations are available: inside screw, rising stem, OS&Y, and sliding stem.

Globe valves are specified for the following applications:

- Frequent operation
- Throttling (flow regulation)
- Positive shutoff for gases and air
- Where a high pressure drop across the valve can be tolerated

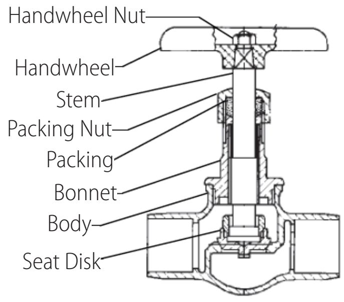

Figure 6-2 Globe Valve

Seating

Unlike the perpendicular seating in gate valves, globe valve seating is parallel to the line of flow. The flow is controlled by a plug (disc) that moves perpendicular to the axis of flow.

The seat of the valve is a machined ring insert fitted in the port opening of the valve. The disc and seat can be quickly and conveniently reseated or replaced, which makes the use of globe valves ideal for applications where frequent maintenance is required.

The disc closes directly into the flow, unlike the gate valve where the disc moves across the flow. In the globe valve, the disc and seat do not come in contact until the actual seating takes place.

The travel distance of the stem is much shorter in a globe valve than in a gate valve. Since the pressure is directly under or over the disc, the globe valve is much easier to operate.

A major disadvantage of a globe valve is that the flow must change directions inside the valve, thus causing significant pressure drop. For better flow control, the globe valve is installed with the flow under the seat. In higher pressure applications, the globe may be installed in the reverse position to prevent the disc from lifting off of the seat.

For general service, such as water, low-temperature fluids, gas, and low-pressure steam, a soft seat is usually recommended. This type of seat is available in bronze and sometimes iron valves.

Where scale, lime, or other buildup is present, a semi-plug is recommended. The disc and seat are usually of a harder alloy, such as copper-nickel. For severe throttling service like steam or particularly dirty fluids, a tapered plug disc is recommended because it provides a wider seating surface. The full plug is provided in a hard alloy, such as 420 stainless steel that is heat treated to 500 Brinell hardness. This design provides maximum resistance to galling, erosion, abrasion, and corrosion.

Globe valves should be installed with the disc closed to prevent seat damage during installation. Most globe valve leakage is due to foreign matter settling on the area between the disc and seat. When this occurs, it can often be corrected by opening the valve slightly and then closing it.

Discs

Globe valves regulate fluid flow by varying the size of the port opening through which the fluid flows. This is achieved by varying the position of the disc. All contact between the seat and the disc ends when flow begins. This is a distinct advantage for throttling flow with a minimum of wire-drawing and seat erosion.

Tapered Plug Disc

This type of flow control element has a wide seating contact with the tapered seat. This configuration results in a directly proportionate relation of size of seat opening to the number of turns of the handwheel and permits close flow regulation. Because of this feature, it is possible to gauge the rate of flow by the number of turns of the handwheel (e.g., if it takes four turns to open fully, then one turn permits 25 percent flow).

Conventional Disc
This disc is constructed of metal and has a line contact between its tapered or spherical seating surface and a conical seat. This particular flow control element is recommended for positive shutoff of liquids but is not recommended for throttling service.

Composition Disc
This disc has a flat face that is pressed against a flat, annular metal seating surface. The disc unit consists of a metal disc holder, composition disc, and retaining nut. Composition discs are available in materials suitable for hot and cold water, steam, oil, air, gas, gasoline, and many other fluids. This disc type is highly regarded for dependable, tight seating for hard-to-hold fluids such as gas and compressed air. It can usually tolerate the embedding of dirt without leaking. A composition disc is not recommended for throttling service.

Sealing
Sealing generally is required in four places in a globe valve. The sealing of three places prevents leakage of the fluid to the outside, and the sealing of the fourth prevents flow of the fluid within the system when the valve is closed. Leakage to the outside is stopped at the valve end connections, the body-to-bonnet joint, and the stem. Valve seats are usually provided as integrally cast or replaceable seat rings that are screwed or pressed into the valve body. Tightness against leakage when the valve is closed depends on the fit-up tolerance, material, fluid characteristics, pressure, and temperature.

Stem and bonnet-to-body seals are the same as for gate valves.

ANGLE VALVES
Angle valves (Figure 6-3) are a form of globe valve and have the same operating characteristics as globe valves. They are used when making a 90-degree turn in the piping to reduce the number of joints and save installation time. An angle valve offers less restriction to flow (less pressure drop) than the globe valve and elbow it replaces.

A valve that has a renewable composition disc should preferably have the pressure below the disc to ensure longer disc life. Where continuous flow is a requirement, it is safer to have the pressure below the disc. It is possible for a disc to become separated from the stem and automatically shut off the flow if pressure is above the disc. If this results in a dangerous condition for a particular service, then the pressure should be below the disc.

Another factor to be considered is the temperature variation. With pressure under the disc, cooling of the stem when the valve is in the closed position may cause sufficient contraction that will unseat the valve and cause leakage. Pressure and temperature above the disc help ensure tight seating.

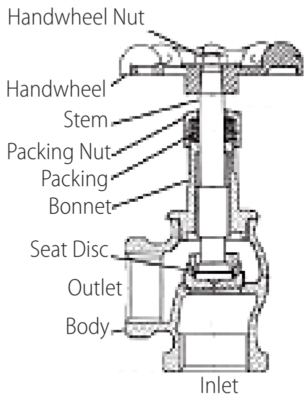

Figure 6-3 Angle Valve

CHECK VALVES
Check valves are the original truly automatic valve; they are actuated by the line fluid. Check valves are designed to perform the single function of preventing the reversal of flow in a piping system. Flow opens these valves (and keeps them open), and reversal of flow plus gravity (or an applied force) causes them to close automatically.

Check valves conform in operating principle to either of the two basic valve types: swing or lift check (Figure 6-4). The flow resistance (head loss) through swing checks is less than through the lift type. The pattern of flow through swing checks is in a straight-through line without restriction at the seat, similar to a gate valve.

Check valves are available in all the materials, end connections, body closures, and seats as for gate and globe valves.

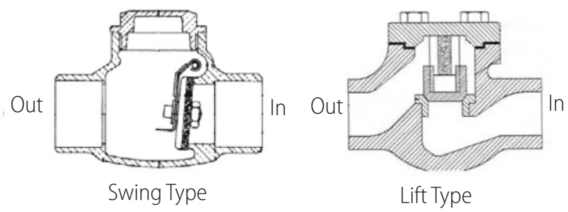

Figure 6-4 Check Valves

Types of Check Valves

Swing Check Valve
Closure of swing checks depends on gravity (the weight of the disc) and reversal of flow. The pivot point of the disc is outside the periphery of the disc, increasing the possibility that the fluid will flow back through the valve (backflow) before the disc can seat itself. The disc must travel through an arc of approximately 90 degrees from the open position to the valve seat to achieve complete shutoff. Since there is no opposing force to the downward movement of the disc, the speed of the disc, impelled by the force of the reverse flow, results in slamming and possible water hammer on shutoff.

To prevent the dangers of water hammer and to eliminate slamming, swing checks are available with an outside lever and weight or spring. By adjusting the lever arm or spring tension, it is possible to cause valve closure at the moment of zero flow velocity (just as flow reversal is about to begin) and thus eliminate slamming and water hammer.

Double-Disc Check Valve

In the double-disc (double-door) swing check, an improved version of the conventional swing check, the disc is split into two separate discs, resulting in a reduction of the mass of the single disc as well as a shortened travel distance from the open to the closed position. A further improvement is achieved by the torsion springs that cause closure of the double discs on minimal flow reversal.

The characteristics of this valve minimize the slam potential as compared to the conventional swing check. They also reduce the potential for water hammer, but do not eliminate it.

The hinge pin in double-disc check valves is stationary, and each disc swings freely when opening or closing. Multiple springs are incorporated in the design of larger-size valves to compensate for the heavier discs and increase the speed of closure.

Slanting-Disc Check Valve

The slanting-disc check valve is a swing check valve that incorporates features for lower head loss and non-slam operation. The main body, constructed of two pieces, provides a 50 percent greater flow area through the disc and seat section. The disc pivots off center, with 30 percent of the disc area above the pivot point to impose resistance against the 70 percent area below the pivot point. Thus, this construction has a built-in non-slam characteristic, but it does not eliminate the possibility of water hammer.

The seat of the valve is placed at a 55-degree angle. The disc swings from this 55-degree closed position (rather than the 90-degree position in a conventional swing check), traveling a short distance to the open position of 15 degrees off the horizontal. The short distance of disc travel allows only minimal flow reversal before closure and provides a non-slam shutoff.

Lift Check Valve

The conventional lift check valve resembles a globe valve in construction and thus has the same characteristics relative to flow and head loss. The disc is equipped with a short guide, usually above and below, which moves vertically in integral guides in the cap and bridge wall. The disc is seated by backflow or by gravity in no-flow conditions. This valve operates in horizontal lines only, so the disc is free to rise and fall depending on the pressure under it.

In addition to the conventional lift check, other available types are the horizontal ball lift, vertical ball lift, and foot valve.

Silent Check Valve

The design principle of the silent check valve is that it is silent when it closes (non-slam). Silent check valves (sometimes called spring-loaded check valves) are available in the globe or wafer style. Both styles operate in an identical manner, but the wafer style has a higher head loss than the globe type.

The center-guided poppet is spring loaded to be normally closed. The short distance between the poppet and the seat during flow conditions results in silent shutoff. This short distance is approximately one-fourth of the valve size (e.g., a 4-inch valve has a 1-inch distance from fully open to fully closed). This short poppet travel distance coupled with the spring force accomplishes the silent shutoff. The range of shutoff time is approximately one-tenth to one-twentieth of a second.

Silent check valves are furnished with helical or conical springs and are available in sizes to suit the specific design pressure conditions of the piping system. Both types of springs perform equally well. Unlike swing checks that require a flow reversal to cause closure, the silent check is designed to close at the instant of zero flow velocity before flow reversal occurs, thus eliminating any possibility of water hammer and slam.

It is important to differentiate between a non-slam check valve and a silent check valve. Although non-slam checks, as the name implies, eliminate slam, they do not eliminate the possibility of water hammer. Silent checks eliminate both slam and water hammer.

Installation

Swing checks can be installed in either the horizontal or vertical position. When installed in the vertical, the direction of flow must be up. Lift checks (except the vertical type) must be installed in the horizontal position only. Silent check valves can be installed in any position, and when vertical, the flow can be either up or down.

Sizing

The discs and any associated moving parts of a check valve may be in a state of constant movement if the velocity head is not sufficient to maintain the disc in the wide-open position. The size of the check valve should be selected on the basis of flow conditions to prevent premature wear, noisy operation, and vibration.

The following formulas can be utilized to determine the minimum velocity required to hold the discs in the wide-open and stable position.

Equation 6-3a: Bronze Valve, Swing Check

$$V = 35V_s^{1/2}$$

Equation 6-3b: Bronze Valve, Lift Check

$$V = 40V_s^{1/2}$$

Equation 6-3c: Cast Iron Valve, Swing Check

$$V = 48V_s^{1/2}$$

Equation 6-3d: Cast Iron Valve, Tilting-Disc Check

$$V = 30V_s^{1/2}$$

Equation 6-3e: Cast Iron Valve, Lift Check

$$V = 25V_s^{1/2}$$

where
V = Velocity of flow, feet per second (fps)
V_s = Specific volume of fluid, ft^3/lb

Sizing check valves on this basis often results in valves smaller than the pipe in which they are installed. The pressure drop through the valve will be no greater than that of a larger valve that operates partially open.

QUARTER-TURN VALVES

Plug, ball, and butterfly valves are referred to as quarter-turn valves because they move from the fully open to the fully closed position with a 90-degree rotation of the sealing member. They are unique in that the quantity of flow is indicated by the position of the operating handle. These valves are applicable to a broad range of services and are available in a wide selection of materials, end connections, seat materials, and sizes. They are popular due to their adaptability, relatively small overall size, simple construction, rapid operation, and tight shutoff.

Typically ball and butterfly valves utilize a resilient material to form the seats, whereas plug valves may be lined with a resilient coating or utilize metal-to-metal seats with a heavy grease or sealant.

Plug Valves

The plug valve (Figure 6-5) is probably the oldest type of valve in use today; they were used in the water systems of ancient Rome. The operation of the valve is extremely simple: a rotary cylindrical or tapered plug, with an opening through it, is fitted into an open body to permit or block the flow of liquids or gases. Rotation of the plug one-quarter turn from the closed position allows flow through the opening in the plug.

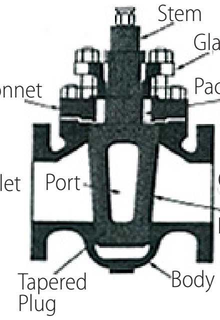

Figure 6-5 Plug Valve

Plug valves are simple to operate, exhibit fast response, and add relatively little internal disturbance to flow. Because of the valve's straight-through flow pattern, pressure loss through the valve is low. Plug valves are not typically used for throttling, but some designs are available for some throttling applications.

Plug valves come in lubricated and non-lubricated types. The lubricated valve should be specified for hard-to-seal substances and large gas lines. The plug is designed with grooves that retain a lubricant to seal and lubricate the valve. A disadvantage of the lubricated plug valve is the constant maintenance; lubrication is required at all times to maintain a tight seal between the body and the plug and to prevent the plug from sticking in place. Another disadvantage is that the lubrication could enter the product stream, so it is not recommended where purity is a primary concern.

Non-lubricated plug valves have two basic designs: lift type and sleeved. In the lift type, the plug is mechanically lifted while being turned to disengage it from the seating surface, thereby reducing seating force. The sleeve type generally has a fluorocarbon sleeve (retained in the body) that surrounds the plug, providing a continuous seal.

The three port sizes are 100, 70, and 40 percent of the inlet pipe size opening. The size of the port determines the physical size of the valve, with the larger port having the largest valve size. The 70 percent port is frequently supplied.

Seating mechanisms can be metal-to-metal resilient seats or lubricated seats. In metal-seated valves, the plugs are lapped and matched to their individual body. Because the plugs are typically tapered, the valve can be wedged into the body if a leak occurs, thus eliminating the leak path. Plug valves are available with either full- or reduced-port openings. They are also available with multiple ports.

The accumulation of sediment and scale in the valve is prevented by the straight passage through the port and the wiping action of the plug as it is rotated 90 degrees.

Ball Valves

Ball valves (Figure 6-6) are an adaptation of the basic plug valve. The closure member is a ball, instead of a plug, with a hole through it. In the open position, the port in the ball connects the inlet and outlet ports in the body. Ball valves are easily adapted to power actuation and are generally less expensive than equivalent sizes of gate and globe valves.

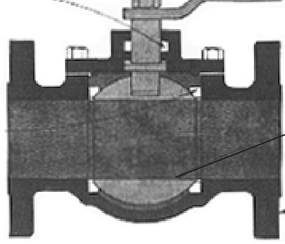

Figure 6-6 Ball Valve

The ball rotates between two resilient seats with concave seating surfaces. The most common design incorporates the floating ball concept. The ball is compressed between the seats, and when pressure is applied, the ball moves into the downstream seat, thus forming the seal. Available seat materials are nylon, neoprene, and Buna-N. Fluid flow is straight through in the open position. A 90-degree rotation from the open position completely blocks the flow of fluid.

Ball valves are available in reduced-port and full-port designs (see Figure 6-7). The full-port design allows full flow through the valve with negligible pressure loss.

Ball valves can be used for on/off and limited throttling. Like plug and gate valves, ball valves are not generally recommended for throttling service. Ball valves are quick opening, have low pressure drop, require minimum mounting space, require little maintenance, are tight sealing, and operate with the application of low torque.

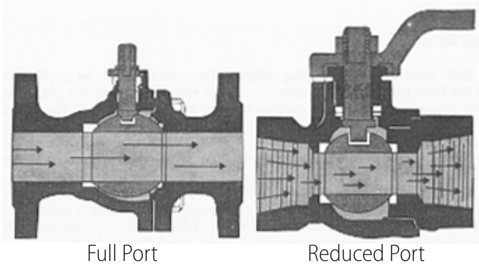

Figure 6-7 Full-Port and Reduced-Port Ball Valves

On the downside, the cavity around the ball traps media and does not drain it. Ball valves are susceptible to freezing, expansion, and increased pressure due to increased temperature. When the ball is closed to flow, media is trapped in the hole. If this could cause a problem due to expansion or vaporization, the ball can be purchased with a weep hole to the downstream side.

Body Styles

Ball valves are available in one-, two-, and three-piece body types. The one-piece body is machined from a solid bar of stock material or is a one-piece casing. The ball is inserted in the end for assembly, and the body insert that acts as the seat ring is threaded in against the ball. One-piece valves have no potential body leak path, but they do have a double reduced port; thus, significant pressure drop occurs. They are not repairable.

The two-piece body is the same as the one-piece valve, except that the body insert is larger and acts as an end bushing. It is available in full- and standard-port balls. It is not recommended to be repaired.

The three-piece body consists of a center body section containing the ball that fits between two body end pieces. Two or more bolts hold the assembly together. Three-piece valves are costly, but they are easy to disassemble and offer the possibility of inline repair. They are available in full- and standard-port balls.

End types available are screwed, soldered/brazed, flanged, and grooved.

Port Size

Full-port ball valves provide a pressure drop equal to the equivalent length of the pipe, slightly better than gate valves. Standard-port (conventional) ball valves are up to one pipe size smaller than the nominal pipe size, but they still have significantly better flow characteristics than globe valves.

Reduced-port ball valves have greater than one pipe size flow restriction and are not recommended in building service piping, but rather are used for process piping for hazardous material transfer.

Butterfly Valves

Butterfly valves control flow via a circular disc whose pivot axis is perpendicular to the direction of flow. When the plane of the disc lies parallel to the longitudinal axis of the pipe, the valve is fully open. When the disc is rotated 90 degrees, the valve is fully closed. As the disc is moved from the fully closed position, it offers progressively less resistance to flow until it reaches the position at which the plane of the disc is parallel to the longitudinal axis of the pipe.

The force required for actuation does not exhibit a simple linear pattern. In a semi-open position, the disc behaves like an airfoil, generating lift and drag forces that attempt to close it. When the disc reaches an open angle of approximately 67 degrees, the dynamic forces are at a maximum. Throttling is achieved by rotating the disc to an intermediate position and locking the handle in place or using a self-locking actuator (see Figure 6-8). It is essential to have this locking feature because of the dynamic forces acting on the disc.

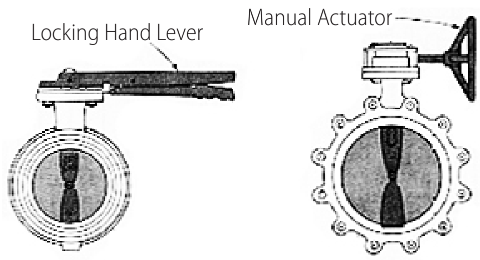

Figure 6-8 Butterfly Valve Actuators

Although a butterfly valve can be used for throttling, its primary function is full-open/full-closed service. Butterfly valves cannot be used with steam. Gear operators are needed for 8-inch and larger valves to aid in operation and to protect against operating too quickly and causing destructive line shock.

Resilient-seated butterfly valves range in size from 2 inches to 48 inches. Butterfly valves of this design can be bubble tight. Conventional metal-to-metal seated valves cannot make this claim.

The butterfly valve has gained acceptance in many industries due to the multiple liner and disc combinations. In a butterfly valve, the media is only exposed to the disc, liner, and sometimes the stem. Thus, by changing the materials of these components, the valve can be used in a wide range of applications. Because butterfly valves utilize elastomer materials for sealing surfaces, the pressures and temperatures are limited to that of the seat material.

Resilient-lined or rubber-lined styles are available in three basic disc configurations: vertical, offset, and angle. Vertical disc valves generally have a shorter cycle life than the other two types due to the scrubbing and compression set of the elastomer that occurs in the disc boss area. Offset discs eliminate this problem, but they have a reduced port diameter that results in a less-efficient valve. The angle disc configuration either minimizes or effectively eliminates both of these problems.

Figure 6-9 Lug-Type Butterfly Valve

The wafer-style butterfly valve is used almost exclusively in plumbing work and is available in three configurations: span (or wafer type), lug (sometimes called single flange), and double flange. The lug type (Figure 6-9) is popular because of its ease of installation and the ease of removing downstream pipe or equipment without the valve falling out. This is accomplished by the use of cap screws or machine bolts inserted from each side of the mating flanges to allow the valve body to be held against the single flange. The lug wafer butterfly valve is slipped between pipe flanges, but the bolts pass through the lugs on the body of the valve. The double-flange wafer valve is installed in the same manner as any other flanged valve.

The seats of many resilient-seated wafer valves are designed to extend beyond the valve body face to provide the sealing surface between the body and pipe flanges. Valves with other types of resilient seat designs must utilize flange gaskets to provide a leak-free joint.

Grooved butterfly valves directly connect to pipe using iron pipe size grooved couplings. While more costly than wafer valves, grooved valves are easier to install.

Butterfly valves generally provide positive shutoff up to 250 psi, and some designs are capable of handling pressures as high as 720 psi. Particular care must be exercised in closing butterfly valves to prevent water hammer. When closed too quickly (which can easily happen because of the quarter-turn feature), hydraulic shock will occur. When closed quickly, the disc is subjected to the full force of the high-pressure wave.

The bodies of butterfly valves are very short compared to the bodies of other valve types. They take up very little longitudinal space, and this compactness results in a valve that is much less in weight for a given capacity than other types of valves.

The advantages of butterfly valves include light weight, economy, simplicity of design, compact configuration, ease of installation and maintenance, quick operation, reliability, and versatility.

DIAPHRAGM VALVES

The two types of diaphragm valves are the straightaway and the weir type (see Figure 6-10). The fluid flow is isolated from all moving parts except the diaphragm, and there are no pockets to catch debris. The diaphragm can be made of several materials depending on the abrasiveness or chemical corrosivity and temperature/pressure of the fluid passing through the valve. Various body materials are also available.

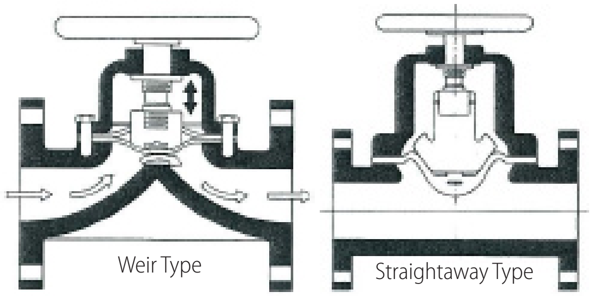

Figure 6-10 Diaphragm Valves

The diaphragm is pressed against the machined seat surface of the weir or the bottom of the body. A bubble-tight seal is possible. If of the weir type and drainability is desired, the valve must be pitched at least 15 degrees from the horizontal to drain. The weir type can be throttled.

These valves are U.S. Food and Drug Administration (FDA) approved for sanitary food processing applications. They are CIP (cleaned in place) and SIP (steamed in place) approved. They are rated as WSP and/or WOG.

STOP CHECK VALVES

Stop checks, or non-return valves as they are frequently called, are used on boilers where two or more units are connected to the same header. They automatically prevent backflow from the header if one boiler fails. They simplify the work of cutting out a boiler or bringing a cold boiler into operation. They protect boiler repair or inspection crews against steam backflow if the header valve is accidentally opened. They are available in straightway Y patterns, angle Y patterns, globe, and angle patterns, depending on the working pressure.

NEEDLE VALVES

Needle valves (Figure 6-11) are available in angle and straight-through patterns. They are used frequently for throttling or chemical feed lines as well as other throttling uses. The long conical seating surface provides close throttling capabilities.

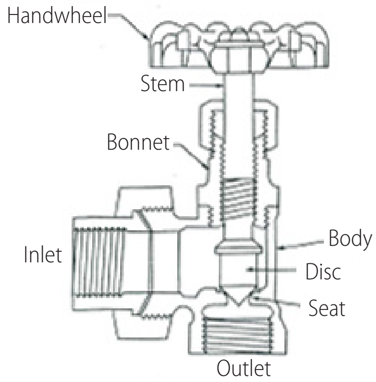

Figure 6-11 Needle Valve

LEAKAGE RATINGS AND TESTING

Typically, manufacturers test 100 percent of the valves they produce per the standard practice covering each particular type of valve. A bronze gate valve, for example, when tested per MSS SP-80 would be subjected to a shell test and a seat test. The shell test is designed to detect leakage in the pressure-containing parts. The shell test can be hydrostatic, pneumatic, or steam. No visible leakage is permitted in what is called the valve pressure-containing boundary, except at the stem packing (when adjustable) or at the test connection seal. The test pressure is determined by the valve class. Each valve is also subjected to a seat test. The test can be hydrostatic, pneumatic, or steam.

Because gate valves have metal-to-metal seating surfaces, they are allowed a maximum leakage rate of 10 milliliters of water per hour per inch of diameter of the nominal valve size, or 0.1 standard cubic foot of air per hour per inch of diameter of the nominal valve size for 1-inch and larger valves. For valves smaller than 1 inch, the test criteria is the same, except the rate of permissible leakage is multiplied by inch of nominal pipe diameter. The seat test pressures are also listed by valve class.

Because ball and butterfly valves in most cases have resilient seats, the test criteria is different than that of metal-to-metal seated valves. A good example is the test procedures outlined in MSS SP-72 for ball valves. Like the gate and globe valves, ball valves are also subjected to shell and seat tests. The shell test for a ball valve is a hydrostatic test at 1.5 times the rated cold working pressure of the valve. The duration of the shell test is also specified—for example, valves 2 inches and smaller are pressurized for a minimum of 15 seconds. The ball is partially opened during the test to ensure equalized pressure throughout the shell of the valve.

A seat test is also required. Seat tests for ball valves are performed at the rated cold working pressure of the valve. The seat test is performed on both seats of the valve if it will be used as a bi-directional valve. If the valve is a directional valve, the test is performed on the seat in the direction of flow as indicated on the valve. No visible seat leakage is allowed. An 80-psi air test is also an acceptable alternative. The seat test also has a specific duration after full pressurization.

Other test procedures are outlined in industry specifications, such as those by the American Petroleum Institute (API); however, at a minimum, valves that are produced to MSS standards are tested and can be certified as to the test by each particular manufacturer.

All valves for gases should be air tested bubble tight.

PRESSURE-REGULATING VALVES

Excessive pressure in a water distribution system is a major source of trouble. In addition to creating operational difficulties, excessive pressure is a prime contributor to the increased frequency of equipment breakdown and the resulting maintenance costs. Unless a specific high pressure is essential for the proper operation of certain system components, it is unwise to design a system where the building pressure will be in excess of 70 psi. When the pressure is greater than 70 psi, it is difficult to maintain the flow velocity (which is a function of pressure) below the critical velocity of 10 fps, and high pressure and velocity can have the following detrimental effects:

- Noise in the distribution system
- Accelerated erosion of piping
- Wire-drawing of valve seats
- Hydraulic shock (water hammer), with consequent over-stressing that can rupture pipe or damage equipment
- Damage to equipment not designed for high pressure or high velocity
- Reduced system life expectancy
- Excessive waste of water due to excessive flow rates at outlets

These problems can be avoided by maintaining the pressure below the recommended maximum level. When a higher pressure is required for a piece of equipment or operation, some separate means should be provided to boost the pressure for that specific function, such as a pressure-regulating valve (PRV) .

Automatic regulation of pressure in a water distribution system is a relatively simple process. Consider the setup shown in Figure 6-12, which will be used to demonstrate how a pressure-regulating valve functions. A globe valve (A) represents the pressure-regulating valve. Globe valve B represents the outlet at the fixture or equipment. Assume valves A and B are closed, and a pressure of 80 psi exists at the inlet of valve A. The objective is to maintain a steady, reduced pressure of 40 psi at B. Opening valve A slowly will admit water to the branch, and the pressure will rise. If valve A is then closed when the branch pressure reaches 40 psi, that pressure will be maintained as long as valve B remains closed and no leaks are present. As B is gradually opened to allow the water to flow, however, the pressure in the branch will immediately start to drop.

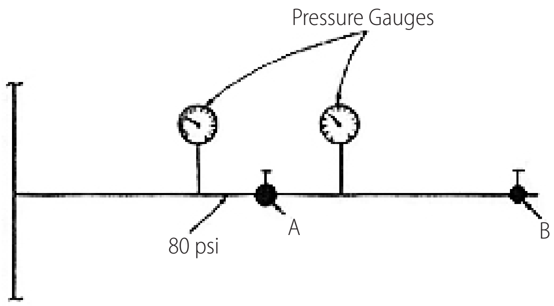

Figure 6-12 Operation of a Pressure-Reducing Valve

If, at the instant the pressure begins to drop, valve A is opened to a point that admits water into the branch at the same rate it is being discharged at B, the 40-psi pressure will be maintained. Opening valve B wider to simulate increased demand requires valve A to be opened wider to equalize flow in and out of the branch and to keep the pressure from dropping below 40 psi. Similarly, reducing the flow at valve B will cause a pressure rise, requiring an immediate throttling adjustment at valve A to reduce the inflow. In practice, a PRV performs the functions of valve A, except that it does it automatically.

Terminology

The following terms are commonly used in discussing the operation of a PRV.

- Set pressure is the pressure on the outlet (system) side of the PRV at which the valve begins to open.
- Dead-end service is a type of service in which the PRV is required to completely close during times of no demand.
- Sensitivity is the ability of a PRV to sense a change in pressure. If the valve is oversensitive and reacts too quickly, the result is over-control and a hunting effect. Inadequate sensitivity leads to sluggish operation and excessive variation in outlet pressure.
- Response is the ability of a PRV to react to a change in outlet pressure.
- Falloff is the pressure drop required from the set pressure to meet flow demand conditions. (Higher flows require greater falloffs.) A falloff of 20 psi is considered to be the maximum allowable for proper design.
- Accuracy is the falloff from the set pressure at full flow. It also is used to describe the capability of reproducing results under repetitive operation with identical conditions of flow.
- No-flow pressure is the pressure maintained in the system by the PRV when no water is flowing. In times of no flow, the PRV should shut tight to prevent the high-pressure fluid at the valve inlet from entering the system.
- Reduced-flow pressure is the outlet pressure maintained at the PRV outlet when water is flowing. This flow pressure is always less than the no-flow pressure by the amount of falloff. A PRV that is set to open at 45 psi would deliver a reduced-flow pressure of 30 psi at peak demand if the falloff were 15 psi.

Synonymous Terms

A number of synonymous terms are used to designate certain operating conditions of a PRV. The following groupings contain terms that are generally considered to be interchangeable:

- Inlet pressure; supply pressure; initial pressure; upstream pressure; line pressure
- Outlet pressure; reduced pressure; delivery pressure; downstream pressure; system pressure
- Capacity; peak demand; full flow; design flow rate

PRV Characteristics

Pressure-regulating valves fall into four general categories: single-seated, direct or pilot-operated, and double-seated, direct or pilot-operated (see Figure 6-13).

Single-seated PRVs are used for intermittent flow or dead-end service. Double-seated units find application primarily for continuous flow conditions; they are not suitable for dead-end service. One problem with single-seated valves is that pressure fluctuations are proportional to the seat area divided by the area of the pressure-sensing diaphragm or piston. With double-seated valves, variations in inlet pressure have little effect on outlet pressure because the pressure fluctuations act on opposing valve seats and balance each other.

Construction of the direct-operated valve is relatively simple. It has a pressure-adjusting screw that controls the valve's operation by regulating the action of a spring or weight-loaded pressure diaphragm or piston. Initial and maintenance costs are generally much lower for the direct-operated valve than for the pilot-operated type.

The pilot-operated valve is more complex because of the manner in which the pressure is regulated. Its design enables the valve to function efficiently over an extremely wide range of inlet pressures and flow rates. In the pilot-operated unit, downstream pressure acting on the diaphragm of the control causes flow through the ejector to vary as pressure changes. This action, in turn, alters the pressure in the main valve cover chamber, resulting in a corrective change by the main valve to hold a constant downstream pressure.

As a general rule, large-capacity, single-seated, direct-operated PRVs should not be used for large flows where a high initial pressure must be reduced to a low system pressure. Under such conditions, these valves are very inefficient due to the extreme unbalance in pressures across the valve seat. For applications of this type, the best choice is a pilot-operated PRV, which can handle large pressure reductions. The pilot-operated valve, however, is not well suited for operation with small pressure differentials.

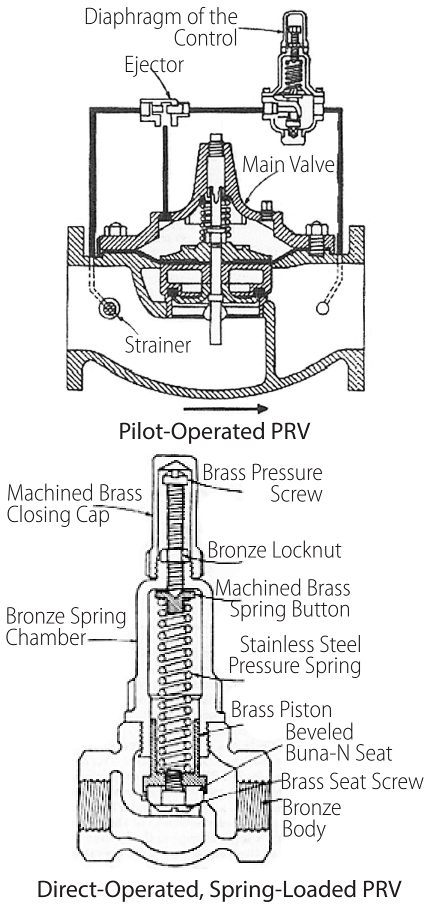

Figure 6-13 Pressure-Regulating Valves

Pressure on the outlet side of a direct-operated valve tends to decrease from the set pressure level as the rate of flow increases. This characteristic is particularly evident with spring-loaded PRVs, but it is less pronounced with the weight-loaded designs that provide a more constant outlet pressure. As the valve stem moves in a spring-loaded PRV, the motivating pressure required varies because of the characteristic of the spring action. In a weight-loaded PRV, the loading force (and the motivating pressure required) changes only slightly as the stem moves. Pilot-operated valves, on the other hand, regulate the pressure uniformly throughout their capacity range.

PRV Selection and Sizing

When the outlet pressure drops below the acceptable range of falloff, the demand requirements are greater than the rated capacity of the valve. The valve is simply too small for the job, and the outlet pressure drops excessively as the valve attempts to satisfy the flow requirements. Replacement of the valve with one that is properly sized is the only solution. On the other hand, a valve that is too large for the application can also create problems. If the valve must accommodate both small and large flows, the oversized unit will be noisy during operation. In addition, at minimum flow conditions the valve will operate close to its seat, causing wire-drawing and erosion.

Thus, careful selection and sizing of a PRV are essential for its efficient operation. The valve should never be sized solely on the basis of the size of the line in which it is to be installed. In general, a correctly sized valve is usually smaller than the line in which it is installed. Flow and pressure are the basic and all-important PRV selection factors. Furthermore, it is imperative that the outlet piping be sized to accommodate the full volume of flow at the required reduced pressure and suitable low velocity.

Manufacturer capacity tables should always be checked for guidance in the selection of a properly sized PRV for a specific application. A general rule of practice to obtain good pressure regulation and to keep maintenance to a minimum is to select a valve size just large enough to satisfy the required maximum flow. For example, if the flow demand is 20 gpm and the maximum allowable falloff is 15 psi, a ¾-inch PRV that provides 14-psi reduced-pressure falloff at 20 gpm will provide the required capacity at less than a 15-psi falloff; therefore, it will give excellent reduced-flow pressure service.

The volume of water that most direct-acting pressure-regulating valves will pass is governed by the pressure differential between the valve inlet and the outlet. As the differential increases, the quantity of flow increases. The maximum capacity of the valve is dictated by the differential pressure and the degree of regulation (falloff) that can be tolerated in the system pressure.

On the basis of regulating performance alone, higher inlet pressures tend to improve valve operation in terms of high rates of flow and less falloff of outlet pressure. Inlet pressures should always be a minimum of 70 psi (or higher) for best results. However, valves can handle only a maximum pressure differential efficiently before noise and chattering begin to occur due to cavitation. The following equation can be used to determine the pressure differential at which cavitation will occur:

Equation 6-4

$$K = \frac{P_2 + 14.7}{P_1 - P_2}$$

where

K = A dimensionless number

P_1 = Inlet pressure, psi

P_2 = Outlet pressure, psi

Cavitation will occur when K is less than 0.5 (see Figure 6-14).

Series Hookup

When the value of K drops into the cavitation zone, it is an indication that the pressure reduction is too great for one valve to handle, so the reduction must be accomplished in stages. This staging can be effectively handled by two (or more) valves in series. The primary valve reduces the pressure to a point at which the secondary valve completes the reduction to the required system pressure without causing cavitation.

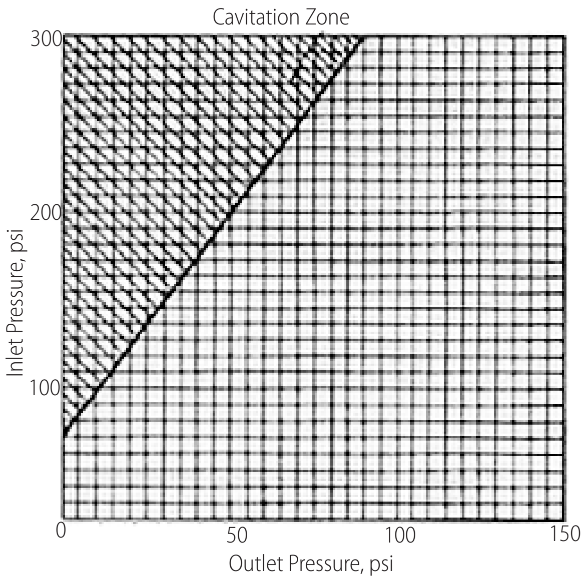

Figure 6-14 Cavitation Chart

Parallel Hookup

Where demand requirements vary widely and where it is vital to maintain a continuous water supply as well as provide greater capacity, parallel installation is recommended. Parallel installation is the use of two or more small PRVs serving a larger supply main. It has the advantage of providing increased capacity beyond that provided by a single valve where needed. This installation improves valve performance for widely variable demands and allows the servicing of an individual valve without completely shutting down the line, thus preventing costly stoppages.

For a two-valve parallel installation, the total capacity of the valves should equal or exceed the capacity required by the system. One valve should be set at a 10-psi higher delivery pressure than the other. Another possible choice is to install two PRV combinations of different sizes. This is practical on large installations where supply lines are 2 inches and larger and where frequent periods of small demand occur. The smaller PRV would have the 10-psi higher delivery pressure and thus operate alone to satisfy small demands, such as urinals and drinking fountains. When a larger volume is needed, the main PRV would open to satisfy the system demand.

Manufacturers provide tables indicating the recommended capacities and valve sizes for use in parallel installations.

PRV Installation

Pressure-regulating valves should always be installed in straight horizontal runs of piping (see Figure 6-15). Spring-loaded valves should be mounted with the stem in the vertical position whenever possible; weight-loaded valves must always be mounted in the vertical position. A strainer should be mandatory at the inlet to every PRV to protect the valve seat from dirt and other foreign matter. A valved bypass should also be provided to allow maintenance, inspection, or replacement of the PRV without interruption of service.

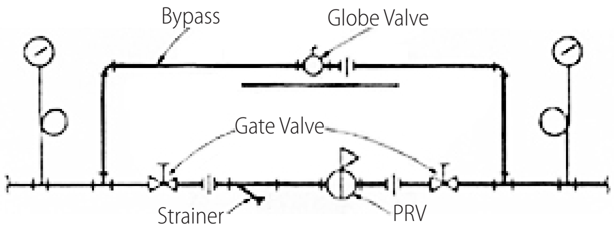

Figure 6-15 Typical PRV Assembly

RELIEF VALVES

Domestic hot water systems shall be protected from excessive temperatures and pressures by relief valves. Temperature and pressure relief valves are available either separately or combined. A combination temperature and pressure (T&P) relief valve offers economical and effective protection. If the water heater or storage tank malfunctions, the temperature relief valve releases an adequate amount of cold water to prevent overheating, while the pressure relief valve relieves water at a specified rate until the pressure stops rising. Both valves will close and reseat when the pressure and temperature drop. Figure 6-16 shows a typical T&P relief valve installation on a water heater.

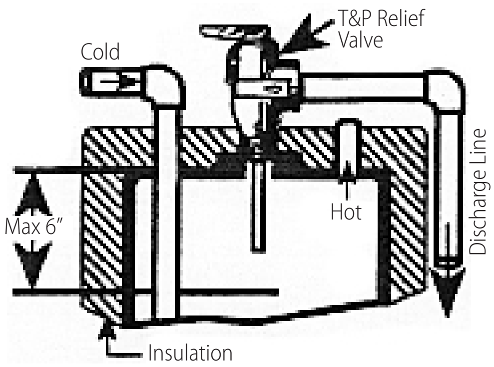

Figure 6-16 T&P Relief Valve Installation on a Water Heater

Typical T&P relief valve settings are 125 psi and 210°F. At 212°F, water has a volume of 0.01671 cubic feet per pound at sea level atmospheric pressure, and steam has a volume of 26.763 cubic feet per pound. If the water in the water heater increased to 212°F and a rupture or leak occurred that caused the pressure to drop to atmospheric, water in the system would immediately turn to steam (explode).

The temperature-sensing bulb must be in the location of the hottest water in the water heater.

All relief valves should have a discharge pipe connected to their outlet that terminates at a point where the discharge will cause no damage or injury. The discharge pipe shall be sized at least the same as the valve discharge outlet, be as short as possible, and run down to its terminal without sags or traps. Some codes prohibit the discharge from connecting to the building's drainage system, so check with the authority having jurisdiction for the relevant requirements.

A T&P relief valve is sized using the temperature steam rating, commonly called the AGA temperature steam rating. The rating of the T&P relief valve shall be equal to or exceed the energy input rating of the water heater. In addition, when the energy input rating exceeds 200,000 British thermal units per hour (Btuh), the T&P relief valve also shall be ASME pressure steam rated.

Typically, T&P relief valves are tested to comply with the standards of ASME International, the American Gas Association (AGA), or the National Board of Boiler and Pressure Vessel Inspectors and are so labeled. The designer should verify which agency's standards are applicable to the water-heating system being designed and follow those requirements for relief valve sizes, types, and locations.

TEMPERATURE CONTROL VALVES

Temperature control valves are located at the water heater or at the fixture to prevent excessively cold or hot water from being discharged and causing injury.

Mixing Valves

Mixing valves (Figure 6-17) provide tempered water to showers and other plumbing fixtures to prevent cold-water shock or hot-water scald. According to ASSE International, the three main types of mixing valves are:

- Temperature actuated mixing valve (ASSE 1017), which is installed at or near the outlet of a water heater to automatically temper the hot water to a preset temperature before it reaches the point of use, regardless of the water heater's thermostat setting (see Figure 6-18)
- Automatic compensating mixing valve (ASSE 1016), which is installed at a shower or tub faucet to automatically blend the hot water supply with sufficient cold water to deliver a safe water temperature, regardless of the position of the manual valve
- Temperature-limiting device (ASSE 1070), which is installed at fixtures to prevent the water temperature from exceeding a preset temperature

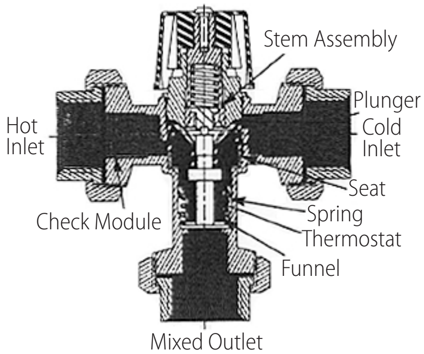

Figure 6-17 Temperature Mixing Valve
Courtesy of Watts

A thermostat in the valve automatically positions a seat assembly that controls the flow of hot and cold water supplied to the mixing chamber. If the mixed outlet temperature increases, the thermostat will expand, thus moving the seat assembly to allow the cold water inlet port to open more fully and at the same time restricting the hot water inlet port. Conversely, if the mixed outlet temperature decreases, the thermostat will contract, moving the seat

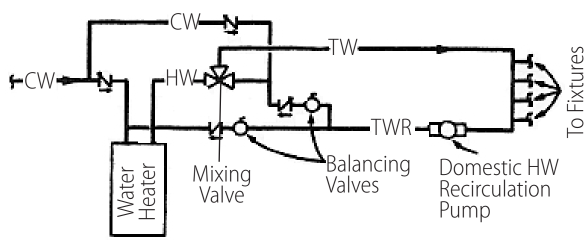

Figure 6-18 Temperature-Actuated Mixing Valve Installation
Courtesy of Ron George

assembly to allow the hot water inlet port to open more fully and at the same time restrict the cold water inlet port. In both cases, the mixed outlet water temperature is automatically and continually maintained at the preset temperature within the tolerances of the valve. In the event of a cold or hot water supply failure, the seat assembly moves to an extreme position to shut off the hot or cold inlet water port.

Mixing valves need continuous flow at the thermostat at all times to provide safe, tempered water.

Shower Valves

Shower valves must be thermostatic mixing, pressure balancing, or a combination of thermostatic mixing and pressure balancing and conform to ASSE 1016. Shower valves control the flow and temperature of the water. These valves protect against scalding and sudden changes in water temperature, which can cause slips and falls.

A pressure-balancing valve maintains a constant temperature of the shower water by constantly adjusting the pressure of the hot and cold water supplies. If the pressure on the cold water supply changes, the hot water supply balances to the equivalent pressure setting. When tested, a pressure-balancing valve cannot have a fluctuation in temperature that exceeds 3°F. If the cold water shuts off completely, the hot water shuts off as well.

Thermostatic mixing valves adjust the temperature of the water by maintaining a constant temperature once the water temperature is set. This is accomplished by thermally sensing controls that modify the quantity of hot and cold water to keep the set temperature.

Mixing Valves for Emergency Showers and Eyewashes

For emergency shower and eye/facewash applications, special mixing valves are designed to function at tepid or lukewarm temperatures, generally considered in the 60°F to 100°F range. Standard mixing valves are designed to work well above this range and do not offer the performance features necessary for emergency fixtures. For example, when the hot water supply to an emergency mixing valve is interrupted, the emergency valve is designed to pass a minimum flow of cold water (20 gpm) to a drench shower. A standard mixing valve would shut down the cold water supply if the hot failed, so virtually no water would reach the fixture. The bypass is one of the unique features of the emergency mixing valve.

THERMOSTATICALLY CONTROLLED MIXING UNIT

Steam/water mixing valves are usually used in food and dairy processing plants for cleanup of floors and equipment. They provide safe, automatic control of hot water mixing via a thermostatically controlled safety shutoff valve that prevents the unit from overheating. The valve automatically compensates for water pressure fluctuations to maintain the desired temperature setting. The thermostat is hydraulically formed with liquid-filled bellows.

FLOW CONTROL VALVES

Most control systems are pneumatic or electronic or a combination of both, which usually involves electronic sensing, analyzing, diagnostics, and sending a signal to a device that is electric, such as a variable-frequency drive, or a device driven by pneumatic (or electric) power, such as a control valve.

Control valves are sized for a certain pressure drop (usually equal to the device's pressure drop). As it is desirable to reduce flow to the device, the control valve must replace the pressure drop of the device as well as be able to accept the pump shutoff pressure (dead head).

Control valves come in the following types:

- On-off: Gate, solenoid
- Rising stem: Globe, diaphragm
- Rotary: Ball, butterfly, plug

Globe valves account for a good share of the flow control and HVAC markets. They have various plug shapes (e.g., quick-opening, linear, and equal percentage)to offer different flow control patterns, are easily made bubble tight, and offer a good selection of trims for corrosion control. Their biggest disadvantage is size (cost). Also, the flow path might cause seat erosion due to abrasive material and the hanging up of stringy material. However, they handle cavitation better than ball and butterfly valves.

Rotary valves offer the following advantages in flow control:

- Light weight
- High turndown (up to 100:1) (globe = 50:1)
- Straight-through path
- Low emissions
- Long packing service life
- Easy on actuator
- Can be bubble tight
- Easy to service

Flow Control Terminology

Valve gain is the incremental change in flow rate produced by an incremental change in plug position. This gain is a function of valve size and type, plug configuration, and system operating conditions. The gain at any point in the stroke of a valve is equal to the slope of the characteristic curve at that point.

The close-off rating of a valve is the maximum allowable pressure to which the valve can be subjected while fully closed. It is usually a function of the power available from the valve actuator to hold the valve closed against pressure, but structural parts such as the stem sometimes are the limiting factor. The close-off rating is independent of the actual valve body rating.

The linear characteristic is when flow capacity changes linearly with valve travel.

The equal percentage flow characteristic is when a change in flow capacity for a change in valve position is equal in percentage to the flow capacity just before the change was made.

Rangeability is a calculation of the maximum rated Cv over the minimum controllable Cv.

Turndown is the maximum expected flow over the minimum controllable flow.

Choked flow is when lowering the downstream pressure no longer causes an increase in flow at 100 percent open.

Flow Control Valve Selection

As noted previously, valves are selected using their Cv factor, which is provided by the manufacturer. Cv is the amount of water flow through a fully open valve that will produce a 1-psi pressure drop.

Using the differential pressure (pressure drop) desired and the flow rate, a valve can be selected using a manufacturer's valve data sheet. When the Cv selection falls between two consecutive sizes of valves, care must be exercised in deciding which of the two valves to use. Judgment must be used to determine whether the pressure drop is too great or not. If the actual pressure drop is too great for the system, use the larger valve. If not, use the smaller valve.

If the pressure at the outlet of the valve orifice is below the vapor pressure of the liquid flowing at the corresponding temperature, the liquid will flash to a vapor. When it regains pressure in the discharge, the vapor bubbles will collapse, causing cavitation. To determine if cavitation will exist for a selected valve, use the following formula:

Equation 6-5

$$\Delta P_{Allow} = FL^2(P_1 - F_F P_V)$$

where

ΔP_{Allow} = Allowable pressure drop, psi

FL^2 = Square of the liquid recovery factor found on a Cv table (To use these tables, find the FL corresponding to Cv_{min}, which is calculated using the maximum pressure drop.)

P = Inlet pressure, pounds per square inch absolute (psia)

F_F = Critical pressure ratio (see Figure 6-19)

P_V = Vapor pressure, psia

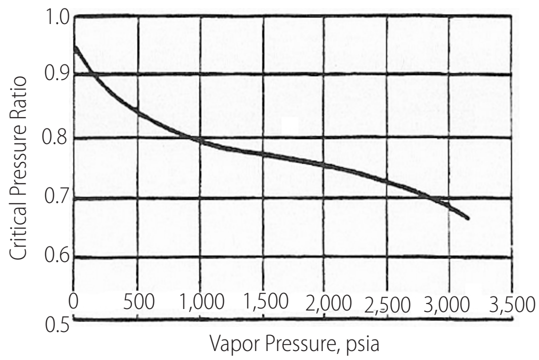

Figure 6-19 Critical Pressure Ratio

If the calculated ΔP_{Allow} is greater than the ΔP used to determine the valve Cv, cavitation won't be a problem. If ΔP_{Allow} is smaller than the ΔP used to determine the valve Cv, cavitation will exist. To prevent cavitation, use the ΔP_{Allow} to size the valve as follows:

Equation 6-6

$$Cv = Q_{max}\sqrt{(G/\Delta P_{Allow})}$$

where

Q_{max} = Maximum flow rate, gpm

G = Specific gravity of the fluid

Basically, ΔP_{Allow} should be used to check for cavitation in the following situations:

- If the inlet pressure is relatively close to the vapor pressure
- If the outlet pressure is relatively close to the vapor pressure
- If the actual pressure drop is large when compared to the inlet pressure

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Expiration date: Continuing education credit will be given for this examination through **January 31, 2020**.

CE Questions — "Valves" (CEU 267)

1. Globe valves are specified for which of the following applications?
   a. frequent operation
   b. throttling
   c. positive shutoff for gases and air
   d. all of the above

2. Shower valves must conform to which standard?
   a. ASSE 1016
   b. ASSE 1017
   c. ASSE 1070
   d. MSS SP-72

3. Which of the following valves is FDA approved for sanitary food processing applications?
   a. needle
   b. diaphragm
   c. butterfly
   d. ball

4. Typical temperature and pressure relief valve settings are ________ and ________.
   a. 125 psi; 212°F
   b. 125 psi; 210°F
   c. 120 psi; 210°F
   d. 120 psi; 212°F

5. Which disc is the most widely used type in gate valves?
   a. solid wedge
   b. split wedge
   c. flexible wedge
   d. double disc, parallel faced

6. If the calculated allowable pressure drop is greater than the pressure drop used to determine the valve Cv, ________ won't be a problem.
   a. seat erosion
   b. turndown
   c. cavitation
   d. choked flow

7. If the pressure is greater than 70 psi in a water distribution system, which of the following could occur?
   a. excessive waste of water due to excessive flow rates at outlets
   b. accelerated erosion of piping
   c. water hammer
   d. all of the above

8. Which of the following check valves eliminates both slam and water hammer?
   a. silent
   b. lift
   c. slanting disc
   d. double disc

9. A ________ is a cover for the valve and acts as the pressure boundary.
   a. seal
   b. bonnet
   c. liner
   d. disc

10. Regarding pressure-regulating valves, ________ is the pressure drop required from the set pressure to meet flow demand conditions.
   a. turndown
   b. sensitivity
   c. falloff
   d. accuracy

11. A ________ valve is a quarter-turn valve.
   a. butterfly
   b. needle
   c. check
   d. angle

12. Which of the following valves is not generally recommended for throttling service?
   a. plug
   b. gate
   c. ball
   d. all of the above