Valves

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The plumbing valve, in its simplest definition, is any valve used to regulate the flow of water in a potable water or wastewater system. Valves come in many shapes, sizes, design types, and materials to accommodate different fluids, piping materials, pressure ranges, and types of service. No single valve is appropriate for all services, so the proper selection of a valve is important to ensure the most efficient, cost-effective, and long-lasting system. (Note: This chapter is limited to manually operated valves that start, stop, regulate, and prevent the reversal of flow.)

The following organizations publish standards and guidelines governing the use of valves:

- Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry
- Underwriters Laboratories (UL)
- FM Global
- American Petroleum Institute (API)

TYPES OF VALVES

A valve's primary function is to control the flow of liquids and gases. The selection of a valve 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 (i.e., free-flowing characteristics)?
- Does the fluid contain abrasive, granular, or fibrous particles?
- Is the fluid corrosive?
- What is the fluid's temperature (e.g., normal, elevated, 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?
- What are the relevant plumbing code requirements for the particular application?

The three main styles of valves are multi-turn (gate, globe, and angle), quarter-turn (ball, butterfly, and plug), and check (swing, list, and silent [non-slam]).

The following materials are used in manufacturing 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)

The federal Reduction of Lead in Drinking Water Act requires that all valves used in potable water systems have a weighted average lead content of no more than 0.25 percent.

Gate Valve

With starting and stopping flow as its primary function, the gate valve (see Figure 3-1) is intended to operate either fully open or fully closed.

The gate valve uses a gate-like disc actuated by a stem screw and a hand wheel that moves up and down at right angles to the path of flow and seats against two faces to shut off flow. Since the disc of the gate valve presents a flat surface to the oncoming flow, this valve should never be used to regulate or throttle flow. Flow through a partially open gate valve creates vibration and chattering and subjects the disc and seat to inordinate wear. Gate valves are manufactured in a wide range of materials including bronze, brass, cast iron, ductile iron, cast steel, and stainless steel.

Bypass valves should be provided where the differential pressure exceeds 200 pounds per square inch (psi) (1,378 kilopascals [kPa]) on valves sized 4 to 6 inches (101.6 to 152.4 mm)

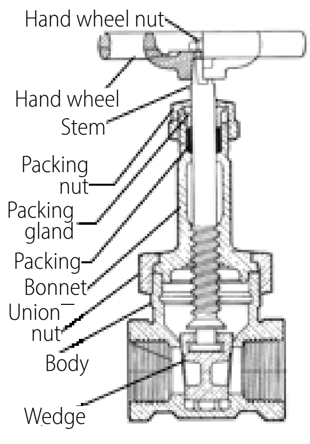

Figure 3-1 Gate Valve

and 100 psi (689 kPa) on valves 8 inches (203.2 mm) and larger. Bypass valves should be ½ inch (12.7 mm) for 4-inch (101.6-mm) valves and ¾ inch (19.1 mm) for 5-inch (127-mm) and larger valves.

Commercial, industrial, and institutional construction are major markets for gate valves. They are widely used by water utilities as they conform to American Water Works Association (AWWA) requirements. Other markets include the petroleum, gas, shipbuilding, chemical, metal, pulp, food and beverage, and power generation industries. Gate valves with electronic supervision are commonly found in fire protection piping mains. The electronic supervision, which is connected to the fire alarm system, helps prevent the fire protection service from being shut off without authorization, which could cause the system to fail to operate when needed.

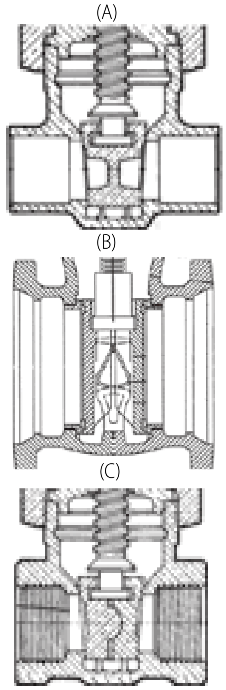

Figure 3-2 Gate Valve Discs: (A) Solid, (B) Double, and (C) Split Wedge

Disc and Seat Designs

Many different seats and discs suit the conditions under which the gate valve operates. For relatively low pressures and temperatures and for ordinary fluids, bronze and iron valves are preferred. Bronze and iron valves usually have bronze or bronze-faced seating surfaces; iron valves may be all iron. Stainless steel is used for high-pressure steam and erosive media. Nonmetallic composition discs are available for tight seatings or hard-to-hold fluids, such as air and gasoline. Hard-faced seats are available for steam and condensate services.

The four main types of discs in gate valves are solid wedge, double, parallel faced/split wedge, and flexible wedge (see Figure 3-2). The solid wedge is the most widely used disc design in gate valves. This design closes by descending between two tapered seats in the valve and is available in steel, brass, and iron gate valves. The double disc closes by descending between two parallel or tapered seats in the valve. When the parallel-faced double discs are lowered into position, they are seated by spreading against the body seats. A disc spreader then makes contact with a stop and forces the discs apart. The double disc application is widely used in the waterworks, sewage, and oil and gas industries.

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

Flexible discs were designed to overcome sticking in high-temperature service with extreme temperature changes. They are solid through the center but flexible around the outer portion and are very rare in plumbing applications.

Globe Valve

The globe valve (see Figure 3-3), which is named for the shape of its body, is much more resistant to flow than the gate valve, as can be seen by examining the path of flow through it. Its main advantages over the gate valve are its use as a throttling valve to regulate flow, positive bubble-tight shutoff when equipped with a resilient seating, and its ease of repair. It is also good for frequent operation. On the negative side, the flow path causes a significant pressure drop, and globe valves are typically more expensive than other valves.

Because all contact between the seat and the disc ends when flow begins, the effects of wire drawing (seat erosion) are minimized. The valve can operate just barely open or fully open with little change in wear. Also, because the disc of the globe valve travels a relatively short distance between fully open and fully closed with few turns of the wheel required, an operator can gauge the rate of flow by the number of turns of the wheel.

Globe valves are manufactured in a wide range of materials including bronze, cast iron, all iron, forged steel, cast steel, and corrosion-resistant alloys. Globe valves are typically specified for the following applications: frequent operation, throttling (flow regulation), positive shutoff of gases, and where a high pressure drop across the valve can be tolerated.

Disc and Seat Designs

As with the gate valve, many disc and seat arrangements are available (see Figure 3-4). These are classified as conventional, plug, and composition.

The conventional disc is constructed of metal and is relatively flat, with beveled edges. On closure, it is pushed down into a beveled, circular seat. This particular flow control is recommended for the positive shutoff of liquids. It is not recommended for throttling service.

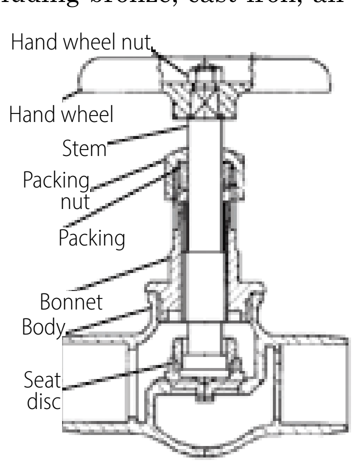

Figure 3-3 Globe Valve

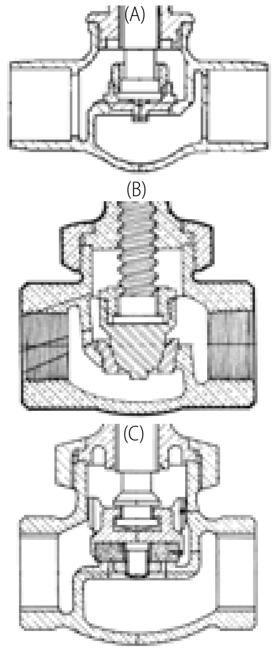

Figure 3-4 Globe Valve Discs: (A) Conventional, (B) Plug, and (C) Composition

Plug-type discs differ from conventional discs only in that they are far more tapered, thereby increasing the contact surface between the disc and the seat. This characteristic has the effect of increasing their resistance to the cutting effects of dirt, scale, and other foreign matter. The sliding action of the semi-plug disc assembly allows the valve to serve as a shutoff valve, throttling valve, or check valve.

The composition disc differs from the others in that it does not fit into the seat opening but over it—much as a bottle cap fits over the bottle opening. This seat adapts the valve to many services, and it is highly regarded for dependable, tight seating for hard-to-hold fluids such as gas and compressed air. It is not recommended for throttling service.

Resilient (soft) seat discs are preferred over metal-to-metal, except where temperature, very close throttling, or abrasive flow makes all-metal seating a better choice. Stainless steel trim is available for medium- to high-pressure steam and abrasive applications. Tetrafluoroethylene (TFE) is the most resilient disc material for most services, although rubber's softness provides good performance in cold water. TFE is good up to 400°F (204.4°C). Nitrile rubber (Buna-N) is good up to 200°F (93.3°).

Angle Valve

Akin to the globe valve, the angle valve (see Figure 3-5) can decrease piping installation time, labor, and materials by serving as both a valve and a 90-degree elbow. It is less resistant to flow than the globe valve, as flow must change direction twice instead of three times. It is also available with conventional, plug type, and composition discs.

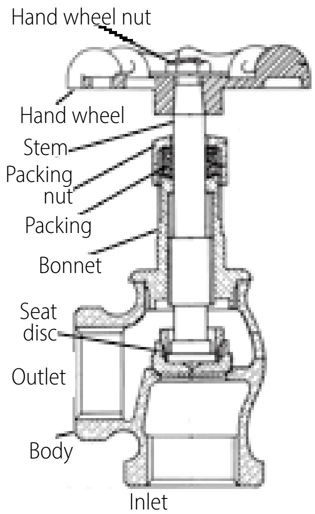

Figure 3-5 Angle Valve

Ball Valve

The ball valve derives its name from the drilled ball that swivels on its vertical axis and is operated by a handle. Its advantages are its straight-through flow, minimum turbulence, low torque, bubble-tight closure, and compactness. Also, a quarter turn of the handle makes it a quick-closing or quick-opening valve. Reliability, ease of maintenance, and durability have made the ball valve popular in industrial, chemical, and gas transmission applications. On the downside, the cavity around the ball traps media and does not drain the entrapped media. Ball valves are susceptible to freezing, expansion, and increased pressure due to increased temperature. Ball valves are not recommended for use in pharmaceutical, bio-processing, or food and beverage applications as they are hard to clean. Chemical or non-sterile applications would be the exception.

Body Styles

Ball valves are available in one-, two-, and three-piece body types, as shown in Figure 3-6. The one-piece body is machined from a solid bar of stock material or is a one-piece casing. The ball is inserted into 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. Not repairable, they are used primarily in chemical and refining plants.

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. Two-piece end entries are used most commonly in building services. They are the best-value valves and are available in full- or standard-port balls. They are recommended for on/off or throttling service and are 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 are easy to disassemble and offer the possibility of inline repair. They are available in full- or standard-port balls.

Figure 3-6 Ball Valve Body Types: (A) One Piece, (B) Two Piece, and (C) Three Piece

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) balls are up to one pipe size smaller than the nominal pipe size but 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. Reduced-port valves will have higher pressure drops than standard-port valves.

Both full-port and reduced-port valves are considered recovery valves. They are typically used in applications with a low pressure drop and a high flow coefficient.

V-notch control valves are designed with a contoured V-notch in the ball, producing an equal-percentage flow characteristic. They are used in the paper industry, chemical plants, and power industry due to their good rangeability (i.e., the ratio of the maximum controllable flow to the minimum controllable flow), control, and shutoff capability.

Handle Extensions

Insulated handle extensions or extended handles should be used to keep insulated piping systems intact.

Butterfly Valve

The butterfly valve is the valve most commonly used in place of a gate valve in cases where absolute, bubble-tight shutoff is required. It offers quick, 90-degree open and close and is easier to automate than multi-turn valves.

In addition to its tight closing, one of the valve's advantages is that it can be placed in a very small space between pipe flanges. It is available with several types of motorized and manual operators and a variety of component material combinations. A broad selection of trim materials is available to match different fluid conditions. Butterfly valves are very cost-effective compared to alternative valve choices, and they offer a long cycle life.

Butterfly valves cannot be used with steam, and gear operators are needed for 8-inch and larger valves to aid in operation and to protect against quick operation, which can cause destructive line shock.

Body Styles

The two most common body types are the wafer body and lug body (see Figure 3-7). The wafer body is placed between pipe flanges, and the flange bolts surround the valve body. They are easy to install but cannot be used as isolation valves. Lug-style valves have wafer bodies with tapped lugs matching the bolt circles of class 125/150-pound flanges. They are easily installed with cap screws from either side. Screwed lug valves can be provided so equipment may be removed without draining down the system.

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.

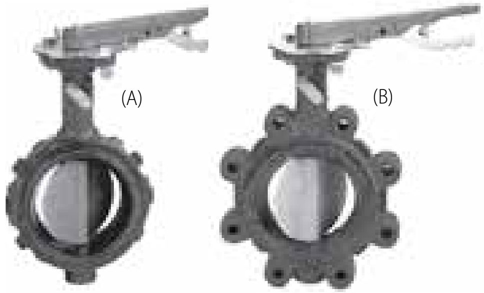

Figure 3-7 Butterfly Valve Body Types: (A) Wafer and (B) Lug

Check Valve

Actuated by line fluid, the check valve is the original truly automatic valve. It is designed to perform the single function of preventing the reversal of flow in a piping system. Swing checks and lift checks (see Figure 3-8) are the most common types of check valves. Both are designed to prevent the reversal of flow in a pipe. The swing check permits straight-through flow when open and is, therefore, less resistant to flow than the lift check. The lift check is primarily used with gases or compressed air or in fluid systems where pressure drop is not critical.

When installed in vertical installations and to ensure immediate closure upon the reversal of flow, the check valve should be of the spring-loaded (non-slamming) type (see Figure 3-8). If reverse flow is not stopped immediately, the backflow velocity could increase to a point that when closure occurs, the resulting shock could seriously damage the valve and system.

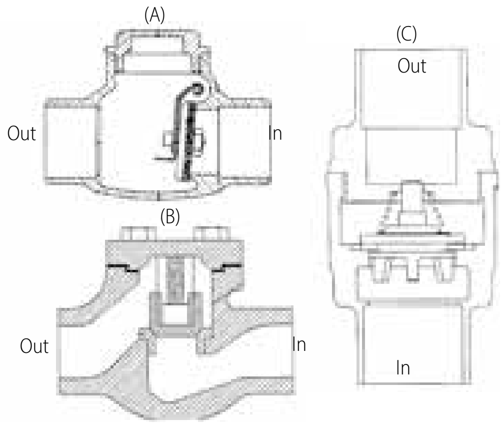

Figure 3-8 Check Valves: (A) Swing, (B) Lift, and (C) Spring Loaded

Design Details

Swing-type check valves offer the least pressure drop and simple automatic closure. When fluid flow stops, gravity and flow reversal close the valve. Many bronze valves offer a Y-pattern body with an angle seat for improved performance. Resilient Teflon seating is preferred for tight shutoff.

Lift checks come in inline and globe-style body patterns. Both cause greater pressure drop than the swing type, with the horizontal pattern similar in restriction to globe valves. Some styles are spring-actuated and center-guided for immediate closure when flow stops. The inline, spring-actuated lift check is also referred to as the silent check because the spring closes the valve before gravity and fluid reversal can slam the valve closed. Resilient seating is recommended.

Double-disc check valves have twin discs on a spring-loaded center shaft. These valves have better flow characteristics than lift checks and most often have a wafer body for low cost and easy installation. Resilient seating is recommended.

To increase protection against backpressure or backsiphonage, the industry has adopted the use of pre-engineered redundant check valves, including dual check valves, double check valve assemblies, and reduced pressure zone assemblies, each of which offers a different level of protection. These are commonly used to protect potable water systems against possible sources of contamination due to an unintended reversal of flow. Backflow prevention is discussed in Chapter 9 of this volume.

Plug Valve

The plug valve has a quarter-turn design similar to a ball valve, with the ball replaced by a plug. The plug can be round, diamond, or rectangular (standard). The plug valve typically requires a higher operating torque for closure, meaning specialized wrenches or expensive automation packages are required. However, it has a mechanism for power operation or remote control of any size and type to operate with air, oil, or water.

Plug valves offer bubble-tight shutoff from a stem seal of reinforced Teflon as well as quick, 90-degree open and close. Flow through the valve can be straight through, unobstructed, bidirectional, three way, or four way. Plug valves offer a long cycle life and an adjustable stop for balancing or throttling service.

Plug valves are available in lubricated, non-lubricated, and eccentric types. The lubricated, sealed valve and combination lubricant screw and button head fitting prevent foreign matter from being forced into the lubrication system. However, the temperature and pressure ranges are limited by the type of lubricant sealant and standard rating. The non-lubricating type eliminates periodic lubrication and ensures that the valve's lubrication does not contaminate the process media or affect any downstream instrumentation. The eccentric type is basically a valve with the plug cut in half. The eccentric design allows a high achieved seating force with minimal friction encountered from the open to closed positions.

VALVE MATERIALS

A valve may be constructed of several different materials. For example, it may have a bronze body, a monel seat, and an aluminum wheel. Metallic materials include brass, bronze, cast iron, malleable iron, ductile iron, steel, and stainless steel. Nonmetallic materials are typically thermoplastics. Material specifications depend on the operating conditions.

Brass and Bronze

Brass usually consists of 85 percent copper, 5 percent lead, 5 percent tin, and 5 percent zinc. Bronze has a higher copper content, ranging from 86 percent to 90 percent, with the remaining percentage divided among lead, tin, and zinc. Due to the federal lead-free legislation, manufacturers have decreased or eliminated the amount of lead in their products that are used in systems conveying water meant for human consumption.

Under certain circumstances, a phenomenon known as dezincification occurs in valves or pipes containing zinc. The action is a result of electrolysis; in effect, the zinc is actually drawn out and removed from the brass or bronze, leaving a porous, brittle, and weakened material. A higher zinc content leads to greater susceptibility to dezincification. To slow or prevent the process, tin, phosphorus antimony, and other inhibitors are added.

Brass valves should not be used for operating temperatures above 450°F (232.2°C). The maximum operating temperature for bronze is 550°F (287.8°C).

Iron

Iron used in valves usually conforms to ASTM A126: *Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings*. Although iron-bodied valves are manufactured in sizes as small as ¼-inch (6.4-mm) nominal diameter, they are most commonly stocked in sizes of 2 inches (50.8 mm) and above. In these larger sizes, they are considerably less expensive than bronze.

The higher weight of iron valves, as compared to bronze valves, should be considered when determining hanger spacing and loads. A typical 2-inch (50.8-mm) bronze screwed globe valve rated at 125 psi (861.3 kPa) weighs about 13 pounds (5.9 kg). The same valve in iron weighs 15 pounds (6.8 kg), and if specified with a yoke bonnet, it weighs about 22 pounds (10 kg).

Malleable Iron

Malleable iron valves are stronger, stiffer, and tougher than iron-bodied valves and hold tighter pressures. Their toughness is most valuable for piping subjected to stresses and shocks.

Stainless Steel

For highly corrosive fluids, stainless steel valves provide maximum corrosion resistance, high strength, and good wearing properties. Seating surfaces, stems, and discs of stainless steel are suitable where foreign materials in the fluids being handled could have adverse effects.

Thermoplastic

Many different types of thermoplastic materials are used for valve construction. Plastic valves generally are limited to a maximum temperature of 250°F (121.1°C) and a maximum pressure of 150 psi (1,035 kPa).

VALVE RATINGS

Most valve manufacturers rate their products in terms of saturated steam pressure, the pressure of non-shock cold water, oil, or gas (WOG), or both. These ratings usually appear on the body of the valve. For instance, a valve with the markings "125" and "200 WOG" will operate safely at 125 psi (861.3 kPa) of saturated steam or 200 psi (1,378 kPa) of cold water, oil, or gas.

The engineer should be familiar with the markings on the valves specified and should keep them in mind during construction inspection.

VALVE COMPONENTS

Stems

Stem designs fall into four basic categories: rising stem with outside screw, rising stem with inside screw, non-rising stem with inside screw, and sliding stem (see Figure 3-9).

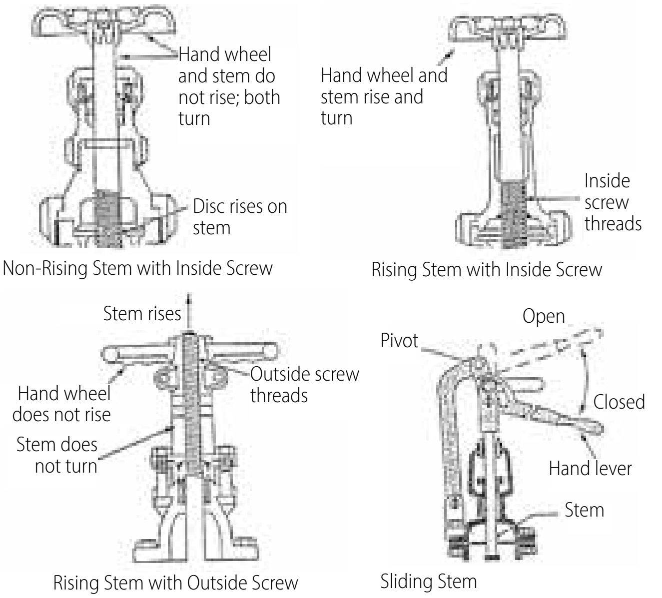

Figure 3-9 Valve Stem Designs

Rising Stem with Outside Screw

This design is ideal where the valve is used infrequently and the possibility of sticking constitutes a hazard, such as in a fire protection system. In this arrangement, the screws are not subject to corrosion or elements in the line fluid that might cause damage because they are outside the valve body. Also, being outside, they can be lubricated easily.

As with any other rising stem valve, sufficient clearance must be allowed to enable a full opening.

Rising Stem with Inside Screw

This design is the simplest and most common stem design for gate, globe, and angle valves. The position of the hand wheel indicates the position of the disc (opened or closed). The rising stem is a good indicator of the valve's position, whether open or closed.

Non-Rising Stem

These are ideal where headroom is limited, but they generally are limited to use with gate valves. In this type, the screw does not raise the stem, but rather raises and lowers the disc. As the stem only rotates and does not rise, wear on packing is lessened slightly.

Sliding Stem

These are applied where quick opening and closing are required. A lever replaces the hand wheel, and stem threads are eliminated.

Bonnets

The bonnet acts as a pressure boundary for the valve. In choosing valves, the service characteristics of the bonnet joint should not be overlooked. Bonnets and bonnet joints must provide leak-proof closure. Many modifications are available, but the three most common types are the screwed-in bonnet, screwed union-ring bonnet, and bolted bonnet.

Screwed-In Bonnet

This is the simplest and least expensive construction, frequently used on bronze gate, globe, and angle valves, and are recommended where frequent dismantling is not needed. When properly designed with running threads and carefully assembled, the screwed-in bonnet makes a durable, pressure-tight seal that is suitable for many services.

Screwed Union-Ring Bonnet

This construction is convenient where valves need frequent inspection or cleaning and also for quick renewal or changeover of the disc in composition disc valves. A separate union ring applies a direct load on the bonnet to hold the pressure-tight joint with the body. The turning motion used to tighten the ring is split between the shoulders of the ring and the bonnet. Hence, the point-of-seal contact between the bonnet and the body is less subject to wear from frequent opening of the joint. Contact faces are less likely to be damaged in handling. The union ring gives the body added strength and rigidity against internal pressure and distortion.

While ideal on small valves, the screwed union-ring bonnet is impractical on large sizes.

Bolted Bonnet Joint

A practical and commonly used joint for large valves or for high-pressure applications, the bolted bonnet joint has multiple boltings with small-diameter bolts that permit equalized sealing pressure without the excessive torque needed to make large threaded joints. Only small wrenches are needed.

End Connections

Valves are available with screwed, welded, brazed, soldered, flared, flanged, hub, and press-fitted ends.

Screwed End

The most widely used type of end connection is the screwed end. It is found in brass, iron, steel, and alloy piping materials. It is suited for all pressures but usually is confined to small pipe sizes as it is more difficult to make the screwed joint with large pipe sizes.

Welded End

Welded ends are available only in steel valves and fittings and are used mainly for high-pressure and high-temperature service. It is recommended for lines not requiring frequent dismantling. The two welded-end types are butt and socket welding. Butt-welding valves and fittings come in all sizes; socket-welding ends are limited to small sizes.

Brazed End

Brazed ends are available in brass materials because the ends of such materials are specially designed for the use of brazing alloys to make the joint. When the equipment and brazing material are heated with a welding torch to the temperature required by the alloy, a tight seal is formed between the pipe and the valve or fitting. While made in a manner similar to a solder joint, a brazed joint can withstand higher temperatures due to the brazing materials used.

Soldered Joint

Soldered joints are used with copper tubing for plumbing and heating lines and for many low-pressure industrial services. The joint is soldered by applying heat. Because of the close clearance between the tubing and the socket of the fitting or valve, the solder flows into the joint by capillary action. The use of soldered joints under high temperatures is limited because of the low melting point of the solder. Silver solder or sil-fos (silver-copper-phosphorus) is used for high pressures and temperatures.

Flared End

The flared end is commonly used on valves and fittings for metal and plastic tubing up to 2 inches (50.8 mm) in diameter. The end of the tubing is skirted or flared, and a ring nut is used to make a union-type joint.

Flanged End

Flanged ends generally are used when screwed or soldered ends become impractical because of cost, size, or the strength of the joint. They typically are used for large-diameter lines due to their ease of assembly and dismantling. Flanged facings are available in various designs depending on the service requirements. Facings should be matched—when bolting iron valves to forged steel flanges, the facing should be of the flat face design on both surfaces.

Hub End

The hub end generally is limited to valves for water-supply and sewage piping. The joint is assembled on the socket principle, with the pipe inserted into the hub end of the valve or fitting.

Press-Fitted End

In the press-fitting method, the ends are crimped with a crimping tool around an ethylene propylene diene monomer (EPDM) seal to form a water-tight connection.

THERMOSTATIC MIXING VALVES

A thermostatic mixing valve (TMV) blends hot water with cold water to ensure a constant outlet temperature. To prevent against waterborne pathogens such as Legionella, it is becoming increasingly common practice to store water at 140°F (60°C) and circulate or distribute it at a temperature less than 122°F (50°C). Installing the proper thermostatic mixing valve can ensure that the water is delivered at the required temperature, thus reducing the risk of scalding accidents.

The three main categories of water temperature controlling devices are heat source, group control, and point of use. Heat source controlling devices are used with central heating systems that use water as a medium. The tempering valves offer high flow rates suitable for use in under-floor (radiant) heating applications. They also allow water to be stored at a higher temperature.

Group control devices provide a uniform distribution temperature for all hot water outlets in a household. They are designed for multi-point applications, feature high flow rates (14 to 51 gallons per minute [gpm] at 45 psi), and offer temperature stability.

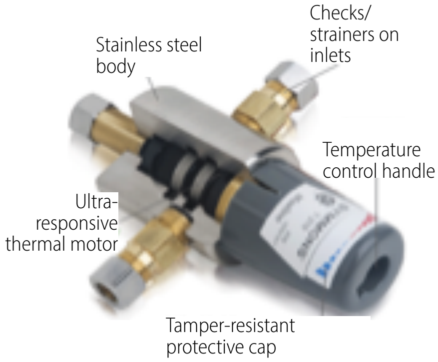

Figure 3-10 Point-of-Use TMV Valve
Photo Courtesy of Symmons Industries

Point-of-use devices (see Figure 3-10) are single-outlet thermostatic mixing valves that are designed for single-point applications, such as individual showers, handwash basin mixers, and bath or tub fillers. They offer a high level of protection against scalding and thermal shock. They are preferred in healthcare facilities, as they limit the maximum outlet temperature regardless of pressure or flow.

SOLENOID VALVES

Solenoid valves are highly engineered products that can be used in many diverse and unique system applications. They are electronically operated and are used to control the flow of liquids or gases in a positive, fully closed or fully open mode.

The valve is commonly used to replace a manual valve or where remote control is desired. In a solenoid valve, an orifice in the valve body opens or closes to permit or prevent flow through the valve. The solenoid assembly consists of a coil, plunger, and sleeve assembly. In a normally closed valve, the plunger return spring holds the plunger against the orifice, preventing flow through the valve. When the coil is energized, a magnetic field is produced, raising the plunger and allowing flow through the valve. In a normally open valve, when the coil is energized, the plunger seals off the orifice, stopping flow through the valve.

WATER PRESSURE REGULATORS

Water pressure regulators protect building plumbing systems from excessive damage by reducing incoming high water main pressures to a safe level. A pressure regulator is an automatic valve controlled by an inner valve connected to a diaphragm or piston or both. The diaphragm, held in the extreme travel (open) position by a pre-loaded spring, is positioned in the downstream portion of the valve and closes the valve when the desired pressure has been reached.

The effectiveness of the diaphragm and the amount of pre-loading must be related to allow the diaphragm to move the inner valve to the extreme opposite travel (closed) position immediately after the pressure on the diaphragm passes the desired operating pressure. To change the operating pressure, tension on the diaphragm is increased or decreased by turning the adjusting screw.

A regulator typically does not go from closed to fully open or from open to fully closed immediately, but moves between those extreme positions in response to system requirements. The regulator adjusts to a fully open position instantaneously only if maximum system demand is imposed quickly, which is not a common occurrence unless the regulator is undersized. The degree of valve opening, therefore, depends entirely on the regulator's ability to sense and respond to pressure changes.

A reducing pressure change that causes a valve to open is known as a reduced pressure fall-off, or droop, and is an inherent characteristic of all self-operated or pilot-operated regulators. Technically, fall-off is expressed as the deviation in pressure from the set value that occurs when a regulator strokes from the minimum flow position to a desired flow position. The amount of fall-off necessary to open a valve to its rated capacity varies with different types of valves.

It is important to realize that the installation of a regulator sets up a closed system; therefore, it is necessary to install a relief valve and an expansion tank to eliminate any excessive pressure caused by thermal expansion of the water in the water heater or hot water storage tank. Every manufacturer makes regulators with an integral bypass to eliminate relief valve dripping caused by thermal expansion. During normal operation, the bypass is held closed by high initial pressure. However, when the thermal expansion pressure equals the initial pressure, the bypass opens, passing the expanded water back into the supply line. The effectiveness of this feature is limited to systems where the initial pressure is less than the pressure setting of the relief valve. The integral bypass is not a replacement for the relief valve; it is used only to eliminate excessive drip from the relief valve.

Regulator Selection and Sizing

The selection of the correct type of regulator depends entirely on the accuracy of regulation required. The valve plug in oversized valves tends to remain close to the seat, causing rapid wire drawing and excessive wear. Unfortunately, no set standard for rating a pressure-regulating valve or for sizing it to the system capacity exists. The many methods proposed for selecting the proper valve are often a cause of confusion to the engineer.

The capacity rating of a pressure-regulating valve usually is expressed in terms of some single value. This value, to be useful, must specify all of the conditions under which the rating was established. Otherwise, it is impossible to adapt it to different system conditions.

Manufacturers attempt to recognize the inherent characteristics of their own design and to stipulate those factors that, in their opinion, must be considered in sizing the valve to the system. Some stress the importance of the difference between the initial and the reduced pressure (the differential pressure). The set pressure and the allowable reduced pressure fall-off are very important factors in sizing a valve. A fall-off of 15 to 17 psi (103.4 to 117.1 kPa) is considered reasonable for the average residential installation and, in well-designed valves, produces a good rating.

Another procedure for establishing valve performance is based on flow rate, with a reduced pressure fall-off of 15 to 17 psi (103.4 to 117.1 kPa) below the reduced lockup or no-flow pressure. For general use, this approach provides an adequate means of valve selection. However, it is not specific enough to enable the selection of the valve best suited to the particular conditions.

Other manufacturers rate their valves based on a stipulated flow rate at a specific pressure differential with the valve open to atmosphere, without regard to changes in pressure drop when the system demand is zero. This method does not provide ample information for proper judgment of valve behavior and capability, which could result in the selection of a valve that, under no-demand conditions, permits a reduction in pressure great enough to damage equipment in the system. The maximum pressure permitted under no-flow conditions is a very important factor, for both physical and economic reasons, and should be stipulated in the specification.

The rule of thumb frequently employed is a size-to-size selection—that is, using a valve with the same connection size as the pipeline in which it will be installed. This is a gamble inasmuch as the actual capacities of many valves are inadequate to satisfy the service load specified for a pipeline of corresponding size. Consequently, the system may be starved, and the equipment may operate in an inconsistent manner.

The only sound valve selection procedure to follow is to capacity size a valve on the basis of known performance data related to system requirements.

Common Regulating Valves

Direct Acting, Diaphragm Actuated

This valve is simple in construction and operation, requiring minimum attention after installation. The direct-acting, diaphragm-actuated pressure regulator does not regulate the delivery pressure with extreme accuracy.

Pilot Operated

The pilot-controlled valve operates efficiently because the pilot magnifies the control valve's travel for a given change in control pressure. This regulator consists of a small, direct-acting, spring-loaded valve and a main valve. The pilot valve opens just enough to supply the necessary pressure to operate the main valve. Extreme accuracy is affected as a constant load exists on the adjusting spring, and variations in initial pressure have little effect.

Direct Acting, Balanced Piston

This valve is a combination piston and diaphragm and requires little attention after installation. With the dependability of the diaphragm and the simplicity of direct action, this valve is only slightly affected by variations in initial pressure.

Booster Pump Control

This is a pilot-operated valve designed to eliminate pipeline surges caused by the starting and stopping of a booster pump. The pump starts against a closed valve, and after the pump starts a solenoid valve is energized, slowly opening the valve and allowing the line pressure to gradually increase to full pumping head. When the pump shuts off, the solenoid is de-energized, and the valve slowly closes as the pump continues to run. When the valve is fully closed, the pump stops.

Level Control

This non-modulating valve is used to accurately control the liquid level in a tank. The valve opens fully when a preset liquid low point is reached and closes drip-tight when the preset high point is reached. This is a hydraulically operated diaphragm valve with the pilot control and float mechanism mounted on the cover.

Common Types of Regulator Installations

Single Regulator in the Supply Line

This type of installation is most common in domestic service and is self-explanatory.

Two Regulators in Series in the Supply Line

This type of installation provides extra protection when the main pressure is so excessive that it must be reduced to two stages to prevent high-velocity noise in the system.

Multiple Regulators Used as a Battery in the Supply Line

In many instances, a battery installation is preferable to the use of a single valve, as it provides more precise regulation over a wide demand variation. This type of installation consists of a group of parallel regulators, all receiving water from a common manifold. After flowing through the battery of valves, water enters the common manifold, which is of sufficient size to service the system at the reduced pressure. The battery installation is advantageous because it allows maintenance work to be performed without turning off the entire system. It also provides better performance where demands vary from one extreme to the other.

For example, at a school with a 3-inch (76.2-mm) service, demand on drinking fountains during classes may be approximately 6 to 7 gpm (22.7 to 26.5 L/m). However, between classes, when all services are in use, the demand may be at a maximum. With a single 3-inch (76.2-mm) regulator in the system, when the faucet is turned on, the regulator must open to allow a small draw. Each time this is done, it cuts down on the service life of the large regulator. In comparison, with a battery installation of two or three regulators set at a graduated pressure, with the smallest valve set 2 to 3 psi (13.8- to 20.7-kPa) higher than the larger ones, the system is more efficient. For a small demand, only the smallest valve opens. As the demand increases, the larger valves also open, providing the system with the capacity of all valves in the battery.

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CE Questions — "Valves" (CEU 244)

1. Which of the following is an example of a multi-turn valve?
   a. swing
   b. angle
   c. ball
   d. butterfly

2. Which of the following end connections typically is used for large-diameter lines due to their ease of assembly and dismantling?
   a. flared
   b. flanged
   c. screwed
   d. soldered

3. Brass valves should not be used for operating temperatures above _______.
   a. 250°F
   b. 350°F
   c. 450°F
   d. 550°F

4. A _______ should never be used to regulate or throttle flow.
   a. gate valve
   b. globe valve
   c. check valve
   d. plug valve

5. Which of the following is an advantage of a plug valve?
   a. long cycle life
   b. adjustable stop for balancing or throttling service
   c. bubble-tight shutoff
   d. all of the above

6. The _______ stem design is applied where quick opening and closing are required.
   a. rising stem with outside screw
   b. rising stem with inside screw
   c. nonrising stem with inside screw
   d. sliding

7. The _______ is the original truly automatic valve.
   a. gate valve
   b. globe valve
   c. check valve
   d. plug valve

8. Which of the following is an advantage of a ball valve?
   a. easy to clean
   b. bubble-tight closure
   c. not likely to freeze
   d. all of the above

9. The _______ is the most widely used disc design in gate valves.
   a. double wedge
   b. split wedge
   c. flexible wedge
   d. solid wedge

10. The _______ acts as a pressure boundary for the valve.
   a. bonnet
   b. disc
   c. stem
   d. jacket

11. Which of the following valve materials offers maximum corrosion resistance, high strength, and good wearing properties?
   a. malleable iron
   b. plastic
   c. stainless steel
   d. bronze

12. In which of the following applications are globe valves typically specified?
   a. frequent operation
   b. flow regulation
   c. positive shutoff of gases
   d. all of the above