CHAPTER 46
VALVES

2020 ASHRAE Handbook—HVAC Systems and Equipment

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NOTE: All information it has been extracted from 2020 ASHRAE Handbook—HVAC Systems and Equipment already, and any pictures will be added to this document will be taken from the internet for better understanding, furthermore any other information adopted from other standards, must be mentioned the names of standards here for your reference.

Other Standards for Your Reference:

- American Society of Plumbing Engineers (ASPE), **Volume 4 Chapter 3**.

Table of Contents

What is the valve?

The valve is elements put it on the pipeline for controlling of the fluid properly.

Functions of valves:

There are many different uses of valves such as:

- Starting, stopping, and directing flow.
- Regulating, controlling, or throttling flow.
- Preventing backflow.
- Relieving or regulating pressure.

Types of Valves:

There are many types of valves, and we will be mentioned here generally without any more details, then we will explain all of them:

- Manual Valves.
- Automatic Valves.
- Balancing Valves.
- Multiple Purpose Valves.
- Safety Devices.
- Pressure Reducing Valves.
- Check Valves.
- Stop-Check Valves.
- Backflow Prevention Devices.

Manual Valves:

Any valve it has controlled by hands it's called **manual valves**, and we have 5 types of manual valves**:**

- Globe Valve.
- Gate Valva.
- Butterfly Valve.
- Ball Valve.
- Plug Valve.

Globe Valves:

- Globe valves are used to stop or control the flow of fluids in a pipeline.
- Globe valves are most frequently used in smaller diameter pipes **but are available in sizes up to 12 in.**
- They are used for throttling duty where positive shutoff is required.
- Globe valves have a *relatively high pressure drop when fully open and therefore* **should be used for throttling (flow control) rather than shutoff (stop flow) applications.**
- Three-way globe valves are also *selected* ***based on flow pattern*** (either mixing or diverting).
- Globe valves for controlling service **should be selected by class**, *and whether they are of the* straight-through or angle type, composition disk, union or gasketed bonnet, threaded, and solder or grooved ends.

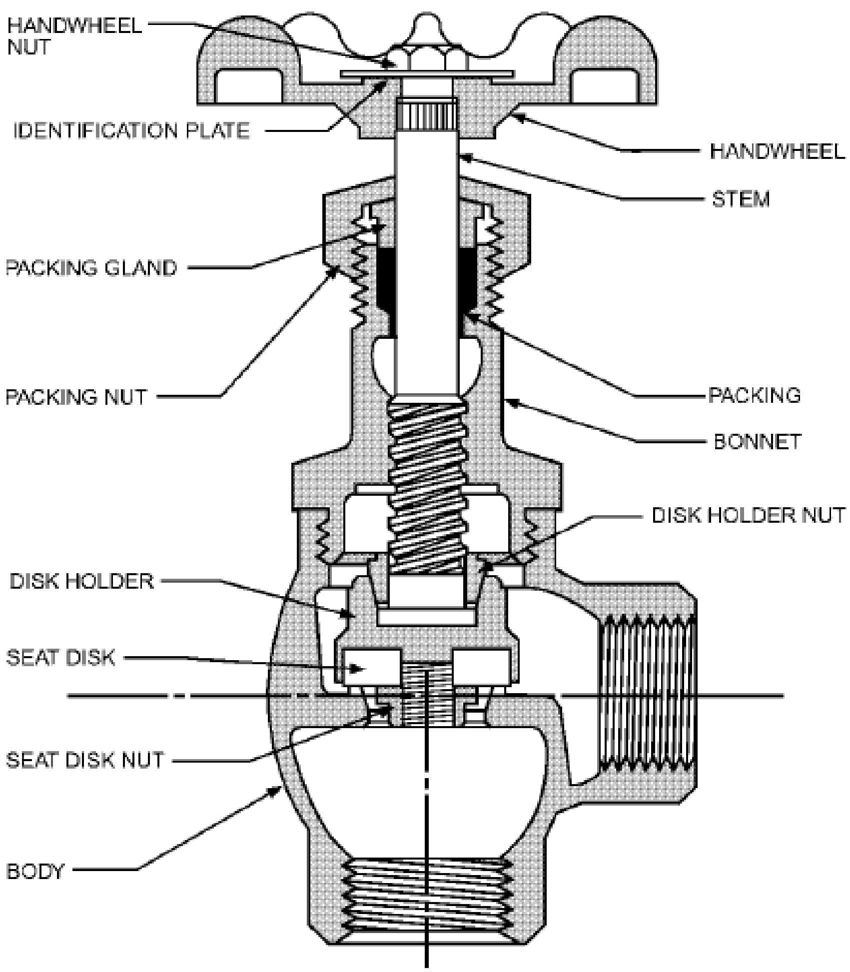


Fig. 3 Globe Valve
(Courtesy Anvil International)

Figure 1 Globe valve angle type

Figure 2 Globe valve straight-through type

Figure 3 Globe valve Y- pattern type

Methods of joining for globe valve:

Figure 3 Threaded globe valve.

Figure 4 Solder globe valve

Figure 5 Flanged globe valve

Gate Valves:

- Gate valves *are intended* to be fully open or completely closed and for maintenance.
- **They are designed to** allow or stop flow and **should not be used to regulate or control flow.**
- Various wedges for gate valves are available for specific applications.
- When we can't reach the valve because the location is not suitable in this case, we must provide chain wheel or hummer blow – operator with valve.

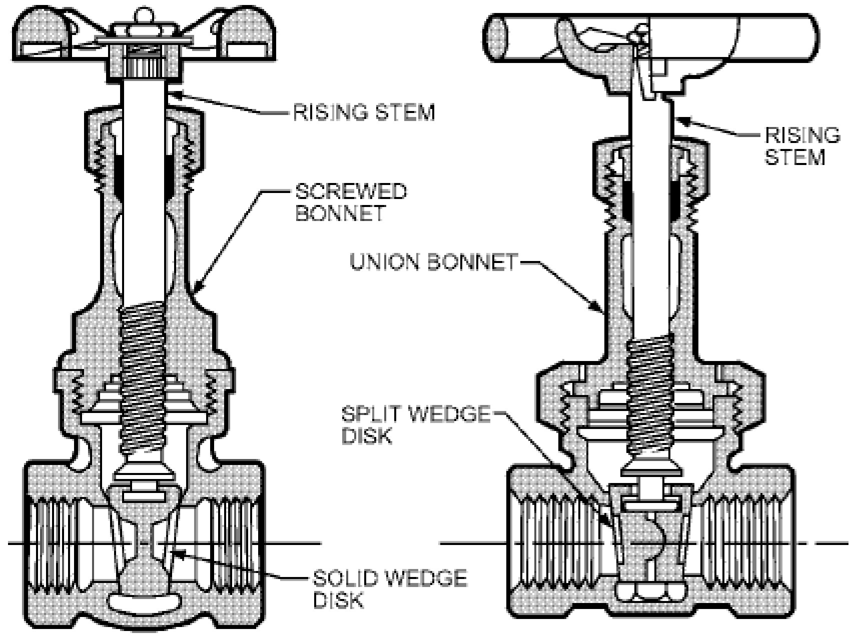


Fig. 4 Two Variations of Gate Valve

Plug Valves:

- A plug valve is a manual flow control device for fluid.
- It operates from **fully open to completely shut off within a 90° turn**.
- Lubricated plug valves are usually furnished **in gas applications**.

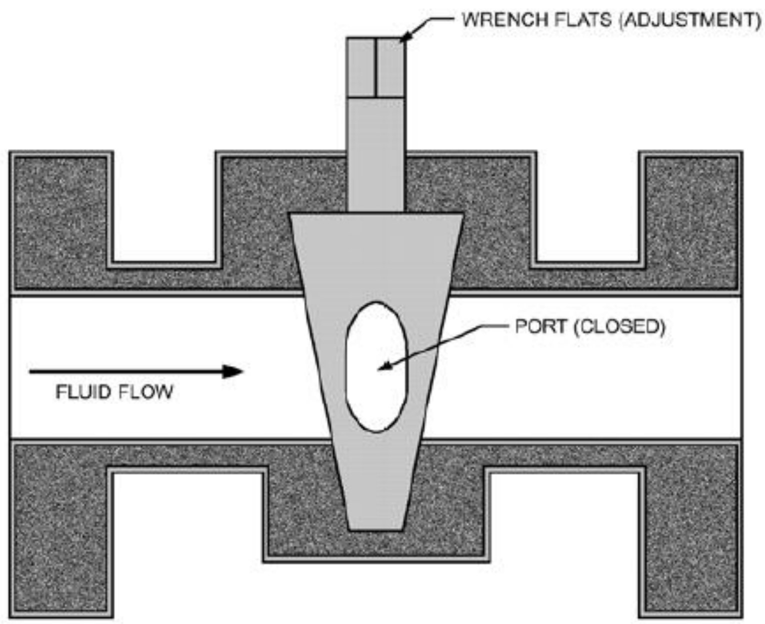


Fig. 5 Plug Valve

Ball Valves:

- A 90° turn of the handle changes operation from fully open to fully closed.
- Ball valves **for shutoff** service may be fully ported.
- Ball valves **for throttling** or **controlling** and/or **balancing** service **should have a reduced port with a plated ball and valve handle memory stop.**
- Ball valves may be of one-, two-, or three-piece body design (Figure 6).

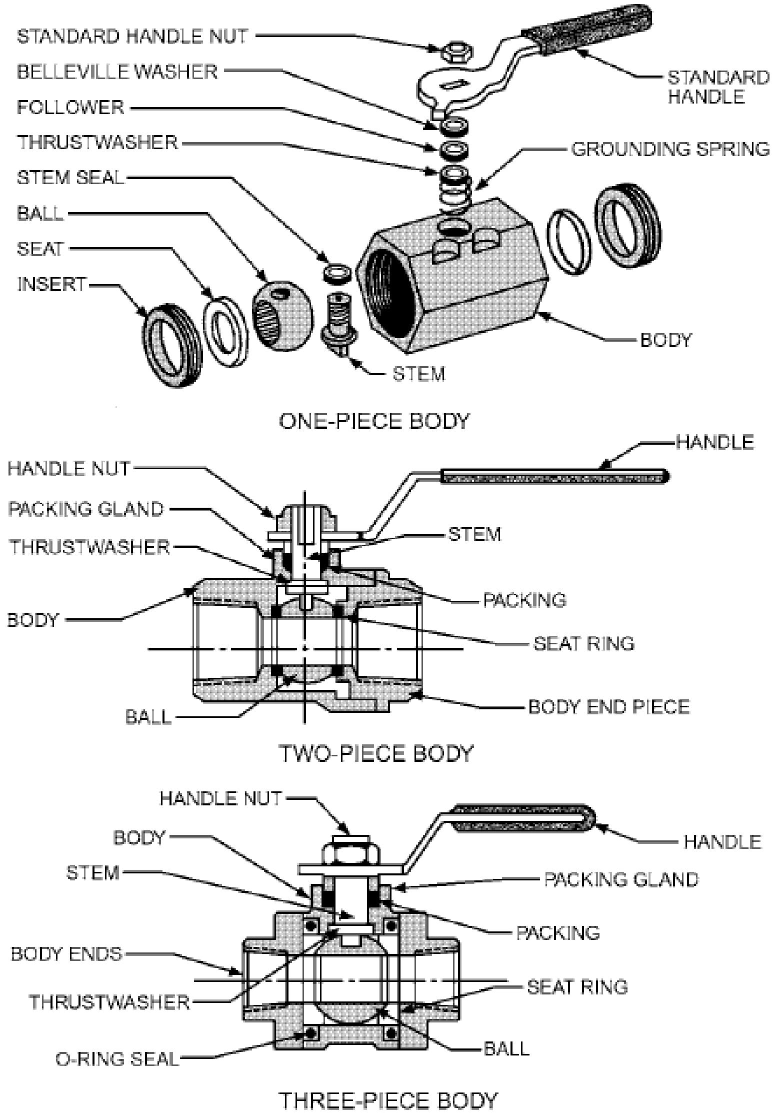


Fig. 6 Ball Valve

Butterfly Valves:

- Only a 90° turn of the valve disk is required to change from the full-open to the closed position.
- Butterfly valves may be ***manually operated*** with hand quadrants (levers) or gear wheel operators, **which are commonly used on larger valves**.
- Butterfly valve bodies may be ***wafer style*** or ***lugged style***.
- Butterfly valves may be provided with an extended shaft **for automatic operation by an actuator**.
- Special attention **should be paid to manufacturers' recommendations for sizing an actuator to handle the torque requirements**.

- *Butterfly valve characteristics include* simple and compact design, **a low corresponding pressure drop**, and **fast operation**. Quick operation makes them suitable for automated control, and the low-pressure drop is suitable for high flow.
- Butterfly valve sizing **for on/ off applications should be limited to pipe sizing velocities given in** Chapter 22 of the 2017 ASHRAE Handbook—Fundamentals.
- Butterfly valve **for throttling control applications,** the valve coefficient sizing presented in the section on **Automatic Valves** must be followed.

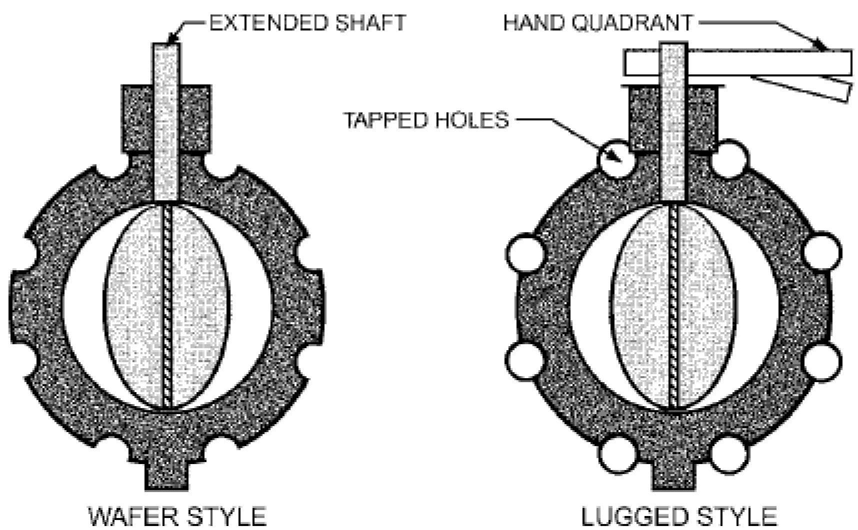


Fig. 7 Butterfly Valve

Figure 6 Butterfly Valve with extended shaft and electric actuator

Figure 8 Wafer Style

Figure 7 Butterfly valve with gear wheel

Figure 9 Lug Style

Automatic Valves:

Automatic valves are commonly considered as control valves and **consist of two things:** a valve body and an actuator.

The valve body and actuator may be designed **so that the actuator is removable and/or replaceable**, or **the actuator may be an integral part of the valve body.**

This section covers the most **common types of valve actuators** and **control valves** with the following classifications:

- Two-way globe valve bodies (single- and double-seated).
- Three-way globe valve bodies (mixing and diverting).
- Ball valves (two- and three-way).
- Butterfly valves (two- and three-way).

Actuators:

The valve actuator converts the controller’s output, such as an electric or pneumatic signal, into the rotary or linear action required by the valve (stem), **which changes the control variable (flow).**

Sizes of Actuators:

Selection of the actuator takes into account the design requirement for the **control signal**, **fail-safe operation**, **ambient conditions**, and **required close-off pressure rating of the valve assembly**.

Types of Actuators:

The most common types of actuators used on automatic valve applications are **solenoid**, **thermostatic radiator**, **pneumatic**, **electric gear train motor**, **electronic**, and **electrohydraulic**.

Solenoids:

- Solenoid valves are used to control the flow of **hot or chilled water** and **steam** and **range in size from 1/8 to 2 in. pipe size.**

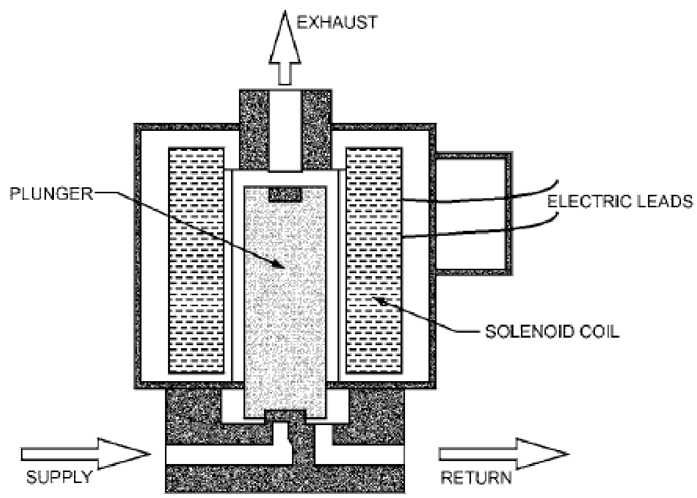


Fig. 10 Electric Solenoid Valve

Thermostatic Radiator Valves:

Thermostatic radiator valves are self-powered and do not require external energy source radiator valves are available for a variety of installation requirements with remote-mounted sensors or integral-mounted sensor and remote or integral set point adjustment (Figure 11).

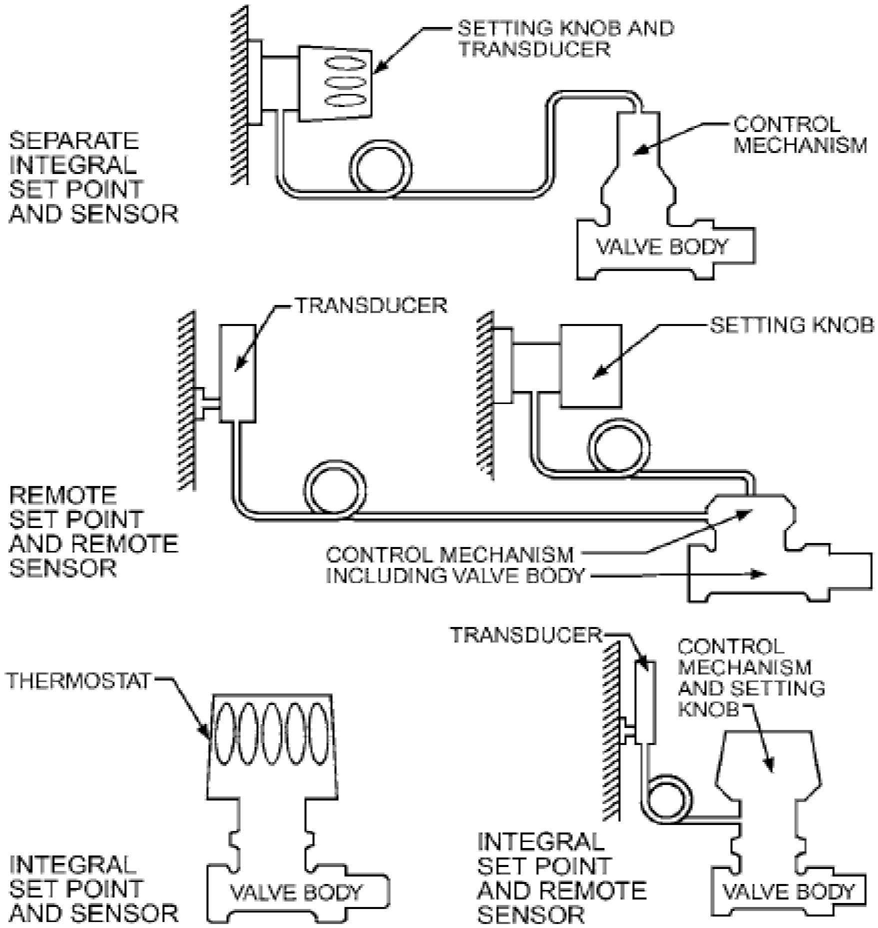


Fig. 11 Thermostatic Valves

Two-Way Valves:

- *In a two-way automatic valve*, **the fluid enters the inlet port and exits the outlet port either at full or reduced volume**, depending on the position of the stem and the disk in the valve.
- Two-way globe valves may be single- or double-seated.
- ***In the single-seated globe valve***, one seat and one plug-disk close against the stream. The style of the plug-disk varies depending on the requirements of the designer and the application. For body comparison, see Figure 9 in Chapter 7 of the 2017 *ASHRAE Handbook— Fundamentals*.
- ***In the double-seated globe valve*** is a special application of the two-way valve with two seats, plugs, and disks, and is **generally applied where the close-off pressure is too high for the single-seated valve.**

Three-Way Valves:

- Three-way valves either **mix** or **divert** streams of fluid. Figure 12 shows some common applications for three-way valves. Figure 8 in Chapter 7 of the 2017 *ASHRAE Handbook—Fundamentals* shows typical cross sections of three-way mixing and diverting globe valves.
- In some limited applications, such as a cooling tower control, **a diverting or bypass valve <u>must be used in place of a mixing valve</u>**.
- In most cases, a mixing valve can perform the same function as a diverting or bypass valve <u>if the companion actuator has a very high spring rate</u>.
- Otherwise, <u>water hammer</u> or <u>noise **may occur when operating near the seat**</u>.

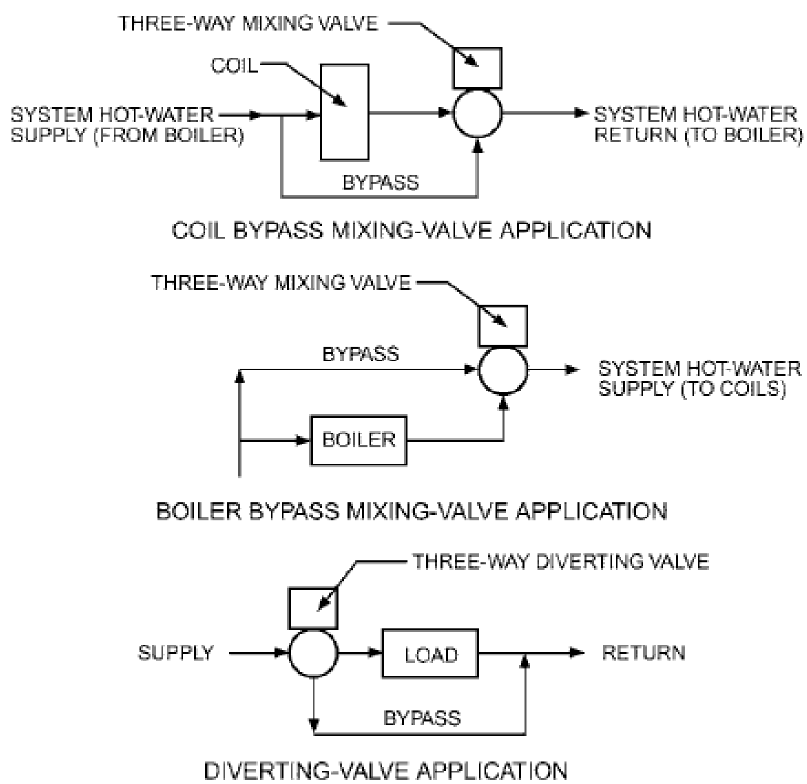


Fig. 12 Typical Three-Way Control Applications

Ball valves (two- and three-way):

- Ball valves coupled with electronic direct-coupled actuators **are common in HVAC** control applications because it is easy to match the movement of the 90° actuator travel to the quarter-turn movement of the ball valve.

Butterfly valves (two- and three-way):

- Butterfly valves are used in two-position and modulating applications.
- Advantages of butterfly valves are their ability **to provide a bubble tight close off against higher pressures**, **their lighter weight**, and **compact size**.
- Butterfly valves **are manufactured as two-way valves**. In some applications where there is a need for a **three-way valve application**, two butterfly valves are connected to a piping tee and cross-linked to operate as either three-way mixing or three-way bypass valves (Figure 14).
- **When sizing a butterfly valve for a modulating application**, use the *Cv* rating at 60° or 70° rotation; for two-position (on/off) applications, use the 90° *Cv* rating. ***It is also important to follow the manufacturer's guideline for the butterfly valve rating for maximum fluid velocity, because exceeding this figure can shorten the valve's life expectancy.***

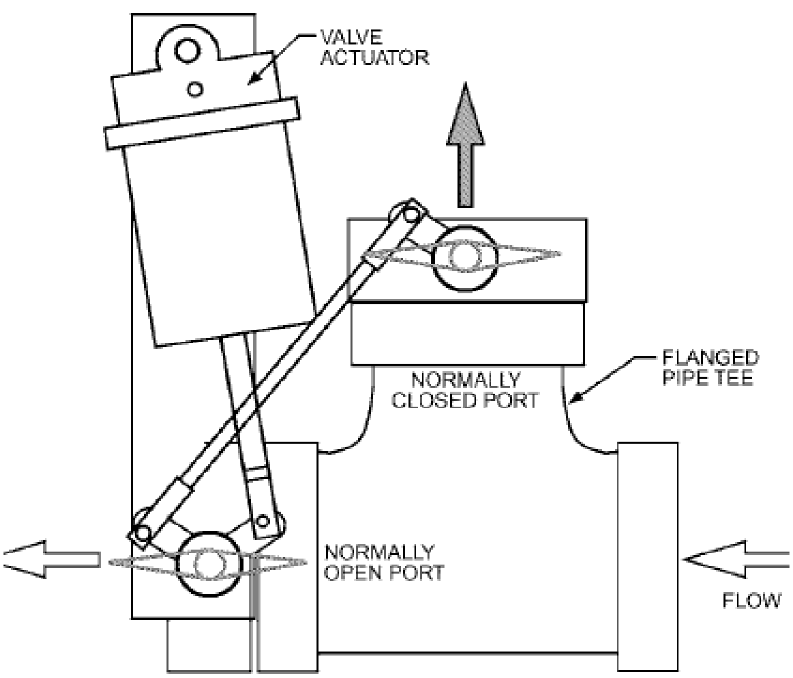


Fig. 14 Butterfly Valves, Diverting Tee Application

Pressure-Independent Control Valves:

- Pressure-independent control valves (PICVs; Figure 15) are control valves coupled with an internal method of differential pressure regulation to eliminate variances of flow caused by differential pressure fluctuations across the valve assembly.

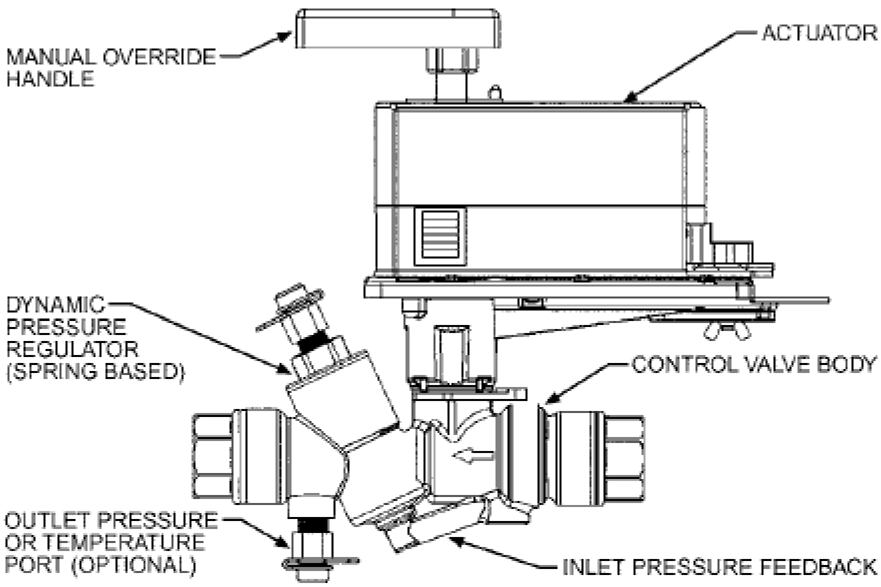
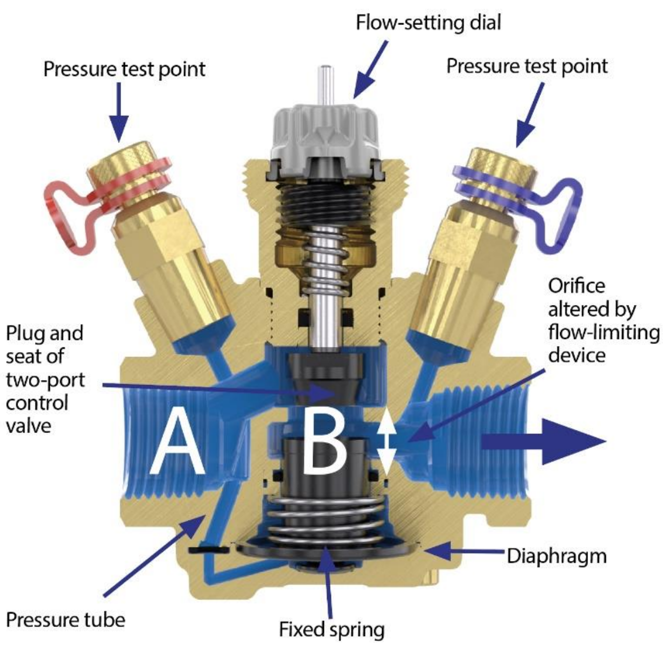


Fig. 15 Pressure-Independent Control Valve



Special-Purpose Valves:

- One type of four-way valve **is used to allow separate circulation in the boiler loop and a heated zone.**
- Another type of four-way valve body is **used as a changeover refrigeration valve in heat pump systems to reverse the evaporator to a condenser function.**
- Six-way valves **are commonly used with four-pipe chilled-beam systems having two coil connections (supply and return), which limits output to the chilled beam to either heating, cooling, or neither.**
- Float valves are **used to supply water to a tank or reservoir** or **serve as a boiler feed valve to maintain an operating water level at the float level location** (Figure 13).

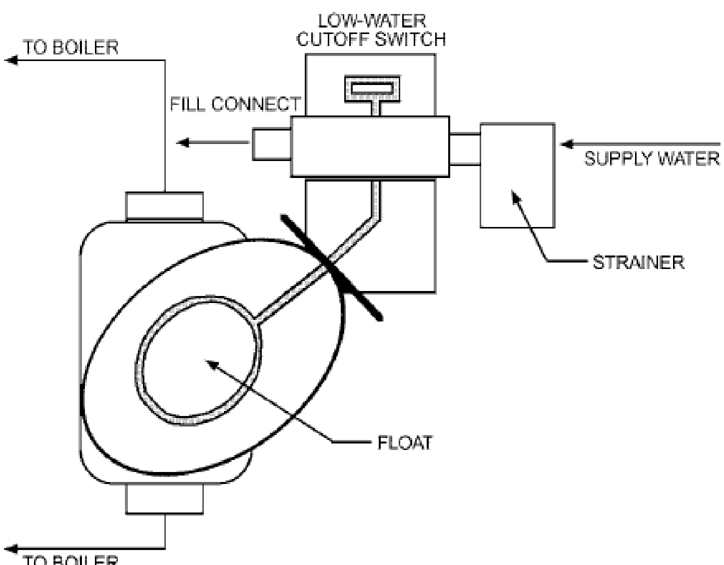


Figure 10 This Figure 13

Figure 11 Six Way Valves

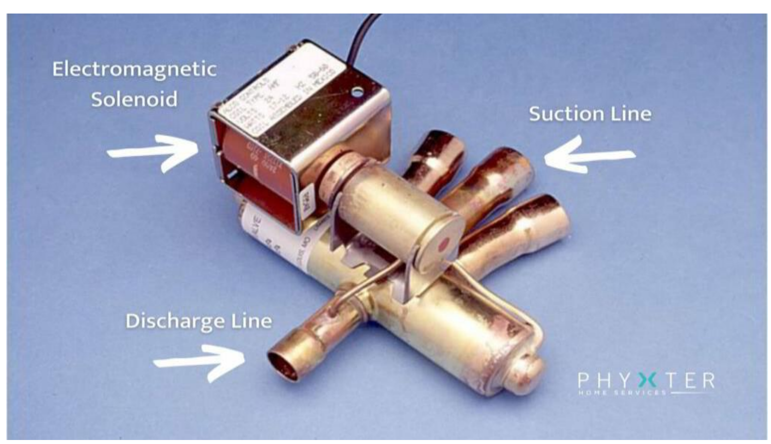
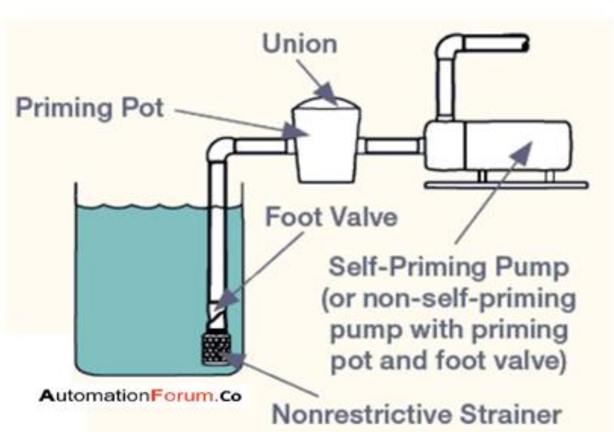


Figure 12 Four Way Valves

Foot Valves:

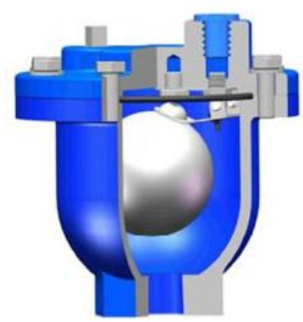
The basic function of a foot valve is to **prevent water from flowing back down the pipe**. It can also be described as a foot valve that would only allow the pump to pull water up but does not allow the water to flow back down.

Foot valves are used to prevent the backward flow of water through the pipe when the water pump is turned off then the water still inside of the pipe.



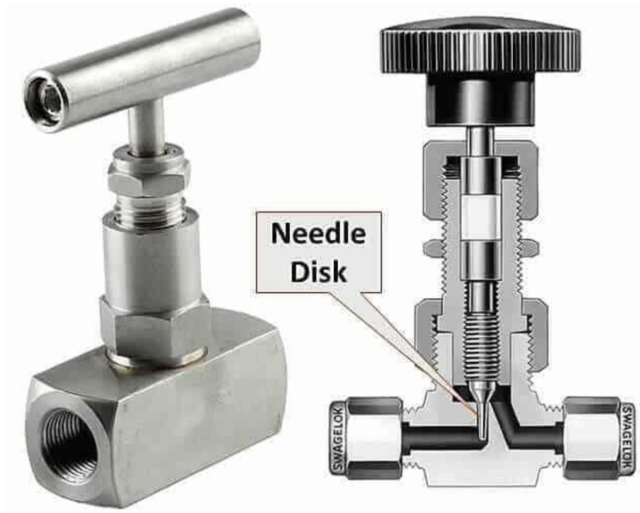
Automatic Air Vent Valve:

An automatic valve for the removal of air from fluid transport lines. All air that enters the valve body is discharged.



Needle valves:

Needle valves are commonly used to control flow and protect delicate gauges from damage caused by sudden pressure surges of liquids and gases. **They're ideal for systems using lighter and less viscous materials with low flow rates.**



BALANCING VALVES:

- Balancing valves are **placed in the distribution system to adjust water flow to a terminal, branch, zone, riser, or main.**
- The valve **should be located on the leaving side of the hydronic branch.**
- Flow Balance Valve Location: Supply or Return Side of the Coil.
- Balancing valves **should be placed on the return side of coils whenever possible**. Why? Because this location helps reduce air and noise problems within the system.

Two approaches are available for balancing hydronic systems:

1- **A manual valve** with integral pressure taps and a calibrated port, which allows field proportional balancing to the design flow conditions.

2- **Automatic flow-limiting valve selected to limit the circuit's maximum flow to the design flow.**

Pictures on a manual balancing valve:

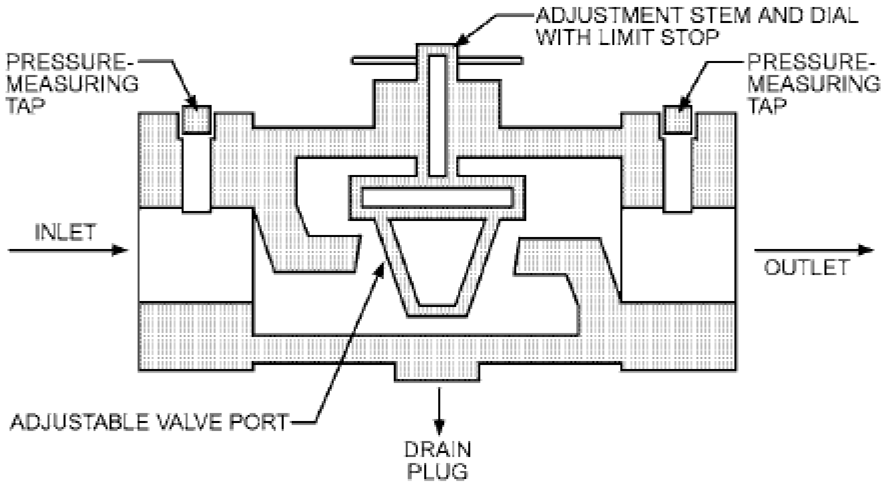
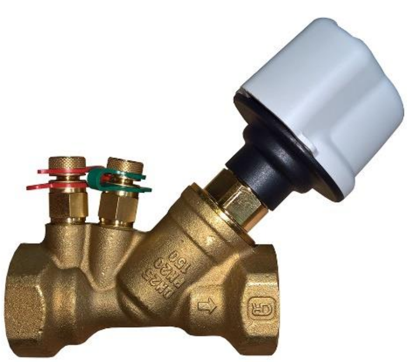


Fig. 20 Manual Balancing Valve

Automatic Flow-Limiting Valves:

- A **differential pressure-actuated flow control valve**, <u>also called an automatic flow-limiting valve</u> (Figure 21), **<u>regulates the flow of fluid to a preset value when the differential pressure across it is varied.</u>** *This regulation prevents an overflow condition in the circuit where it is installed, even when other system components are changing (modulating valves, pump staging, etc.).*
- A typical performance curve for the valve is shown in Figure 22.
- The flow rate for the valve is set.
- ***<u>The flow curve is divided into three ranges of differential pressure:</u>*** the start-up range, the control range, and the above-control range.



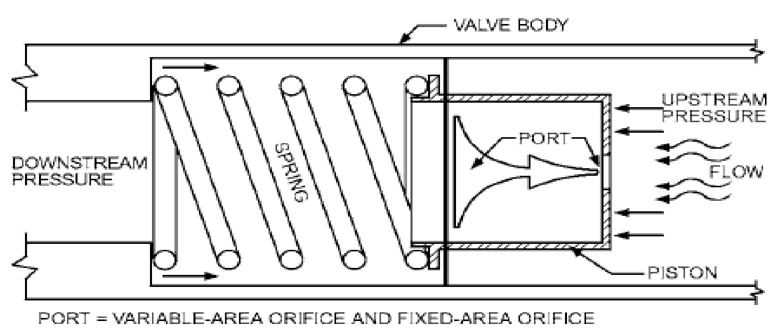


Fig. 21 Automatic Flow-Limiting Valve

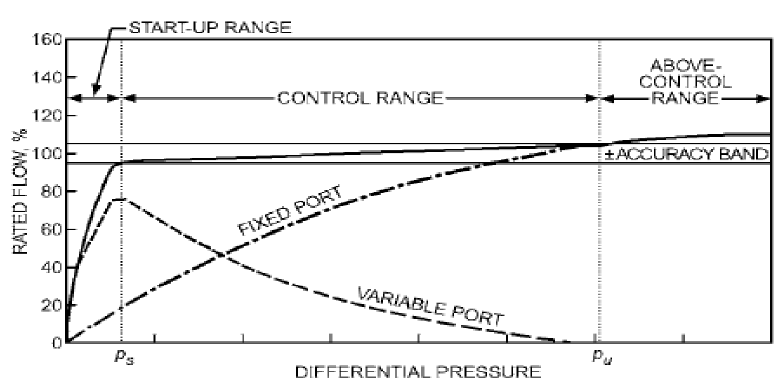


Fig. 22 Automatic Flow-Limiting Valve Curve

Balancing Valve Selection:

- Balancing valves should be selected with 0.45 to 1 psi pressure drop at the branch design flow when fully open.
- **Too small pressure drops** affect the accuracy of the flow measurements, causing inadequate balancing.
- **Too-high pressure drops** reduce the control valve's authority, affecting the controlled variable (e.g., room temperature) stability, and produce unnecessary friction losses.
- See **Chapter 39 of the 2019 *ASHRAE Handbook—HVAC Applications*** for balancing details.

MULTIPLE-PURPOSE VALVES:

- Multiple-purpose valves are made in straight pattern or angle pattern.
- The valves can provide shutoff for servicing or can be partially closed for balancing.
- **Pressure gage** connections to read the pressure drop across the valve *can be used with the manufacturer's calibration chart or meter to estimate the flow.*
- **Means are provided to return the valve to its as-balanced position after shutoff for servicing.**
- The valve also ***acts as a check valve to prevent backflow when*** parallel pumps are used and one of the pumps is cycled off.
- Figure 23 shows a straight pattern multiple-purpose valve designed to be installed **5 to 10 pipe diameters from the pump discharge of a hydronic system.**
- Figure 24 shows an angle pattern multiple-purpose valve installed **5 to 10 pipe diameters downstream of the pump discharge with a common gage and a push button trumpet valve manifold to measure the differential pressure across the strainer, pump, or multiple-purpose valve. From this, the flow can be estimated.**
- The differential pressure across the pump suction strainer can also be estimated to determine whether the strainer needs servicing.

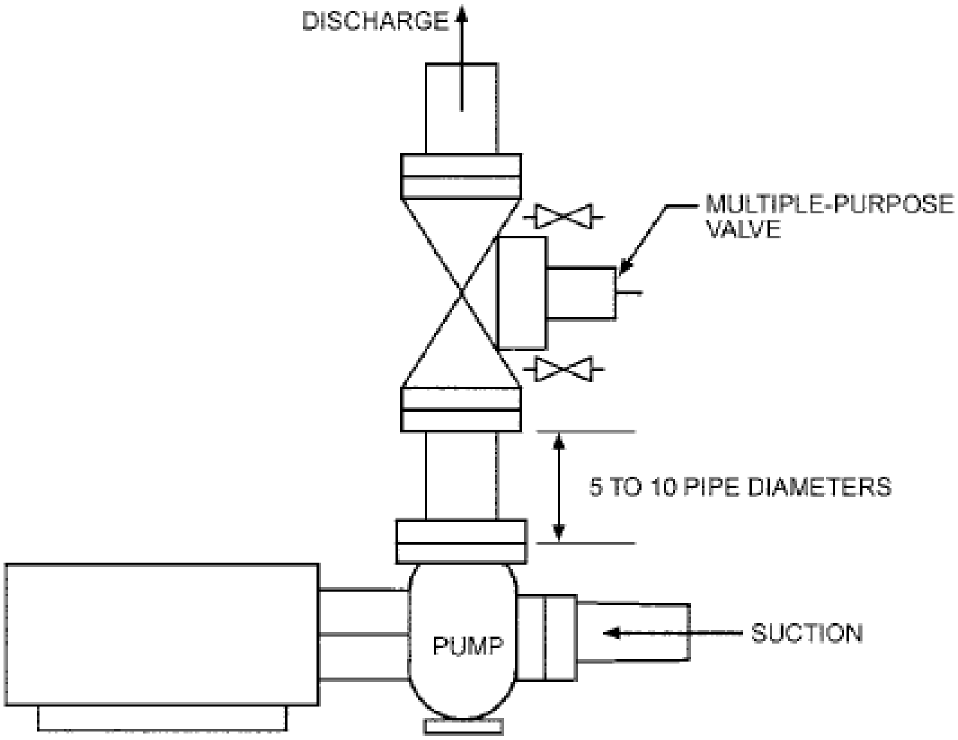
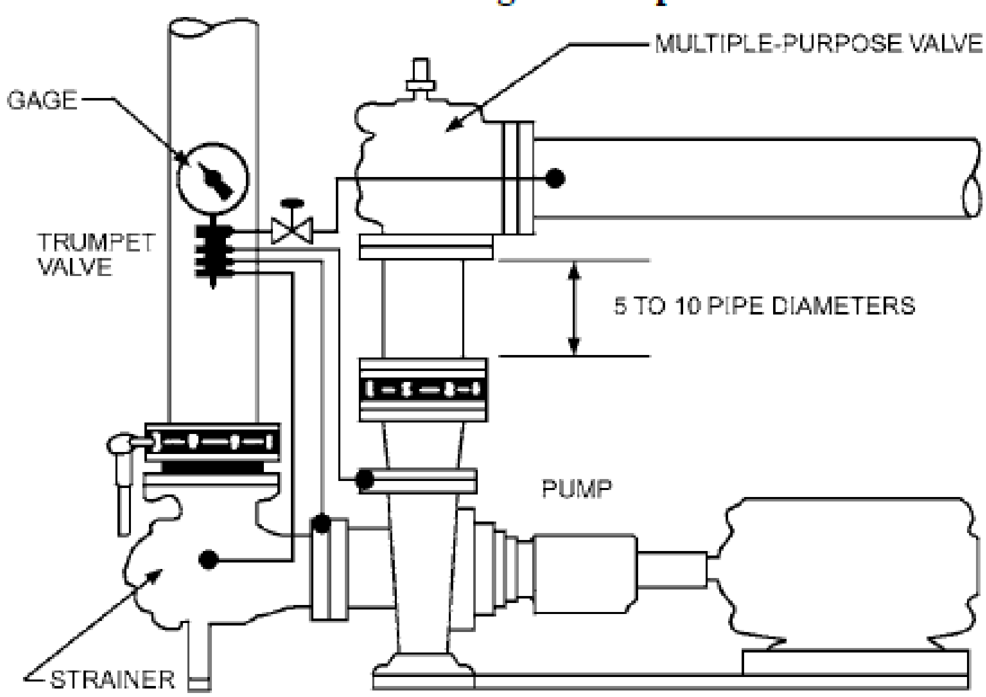


Fig. 23 Typical Multiple-Purpose Valve (Straight Pattern) on Discharge of Pump



SAFETY Devices:

- The terms safety valve, relief valve, and safety relief valve are sometimes used interchangeably, although the devices generally provide a similar function (safety).
- **They have important differences in their modes of operation and application in HVAC systems**.

- **Safety valves** **open rapidly (pop-action).** They are used for gases and vapors (e.g., compressed air and steam).
- **Relief valves** **open or close gradually in proportion to excessive pressure**. They are used for liquids (e.g., unheated water).
- **Safety relief valves** perform a dual function: they open rapidly (pop-action) for gases and vapors and gradually for liquids. **Typical HVAC application is for heating water**.
- **Temperature-actuated pressure relief valves** (or temperature and pressure safety relief valves) are **activated by excessive temperature or pressure**. They are commonly used for potable hot water.
- Application of these safety **devices must comply with building codes and the ASME *Boiler and Pressure Vessel Code*.**
- Safety valve construction, capacities, limitations, operation, and repair are **covered by the ASME *Boiler and Pressure Vessel Code***.
- For **pressures above 15 psig, refer to Section I**. **Section IV covers steam boilers for pressures less than 15 psig**. **Unfired pressure vessels (such as heat exchange process equipment or pressure-reducing valves) are covered by Section VIII.**
- The capacity of a safety valve is affected by the equipment on which it is installed and the applicable code.
- Valves are chosen **based on accumulation**, which is the pressure increase above the maximum allowable working pressure of the vessel during valve discharge.
- **Section I** valves are based on 3% accumulation.
- Accumulation may be as high as 33.3% for **Section IV valves** and **10% for Section VIII.**
- To properly size a safety valve, **the required** capacity and set pressure must be known.
- On a pressure-reducing valve station, the safety valve **must have sufficient capacity to prevent an unsafe pressure rise if the reducing valve fails in the open position.**

- The safety valve set pressure **should be high enough to allow the valve to remain closed during normal operation yet allow it to open and reseat tightly when cycling.**
- A minimum differential of 5 psi or 10% of inlet pressure (whichever is greater) **is recommended.**

When installing a safety valve, consider the following:

- Install the valve vertically with the drain holes open or piped to drain.
- The seat can be distorted if the valve is overtight, or the weight of the discharge piping is carried by the valve body. A drip-pan elbow on the discharge of the safety valve prevents the weight of the discharge piping from resting on the valve (Figure 25).
- Use a moderate amount of pipe thread lubricant (first two to three threads) on male threads only.
- Install clean flange connections with new gaskets, properly aligned and parallel, and bolted with even torque to prevent distortion.
- Wire cable or chain pulls attached to the test levers should allow for a vertical pull, and their weight should not be carried by the valve.

Testing of safety valves varies between facilities depending on operating conditions:

- *Under normal conditions*, safety valves with a working pressure under 400 psig **should be tested manually once per month and pressure-tested once each year.**
- For higher pressures, the test frequency **should be based on operating experience.**
- When steam safety valves require repair, adjustment, or set pressure change, **the manufacturer or approved stations holding the ASME V, UV, and/or VR stamps must perform the work**. **Only the manufacturer is allowed to repair Section IV valves.**

Figure 13 Pressure and Temperature Relief Valves

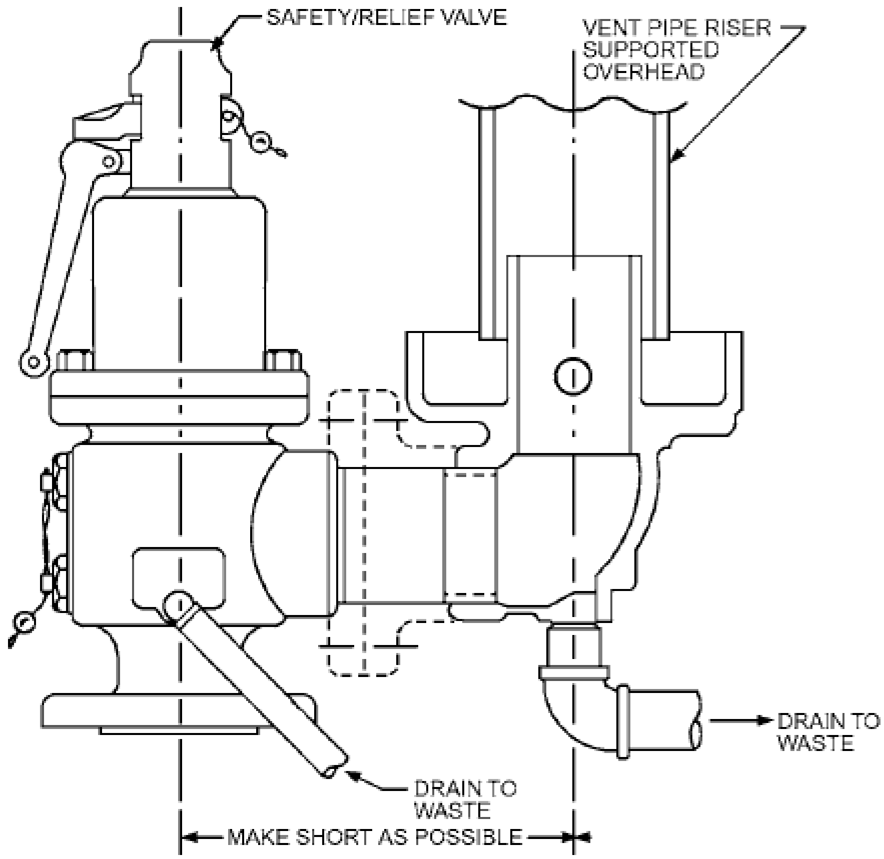


Fig. 25 Safety/Relief Valve with Drip-Pan Elbow

PRESSURE-REDUCING VALVES:

- **A Pressure Reducing Valve (PRV) is an Automatic Control Valve** designed to reduce a higher unregulated inlet pressure to a constant, reduced downstream (outlet) pressure regardless of variations in demand and/or upstream (inlet) water pressure.
- The amount of pressure drops below the set pressure that causes the valve to react to a load change is called **droop**.
- **To properly size these valves**, only the mass flow of steam, the inlet pressure, and the required outlet pressure **must be known.**
- Valve line size **can be determined by consulting manufacturers' capacity charts**.
- Because of their construction, simplicity, accuracy, and ease of installation and maintenance, **these valves have been specified for most** steam-reducing stations.

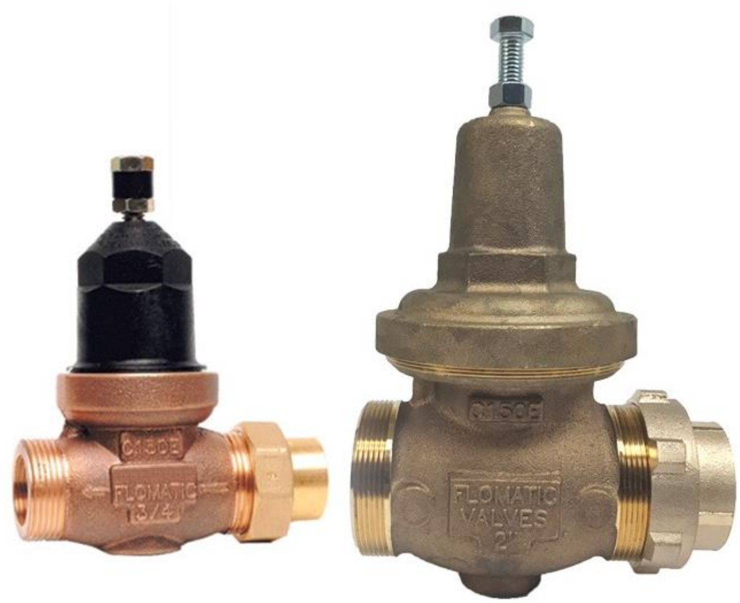
Makeup Water Valves:

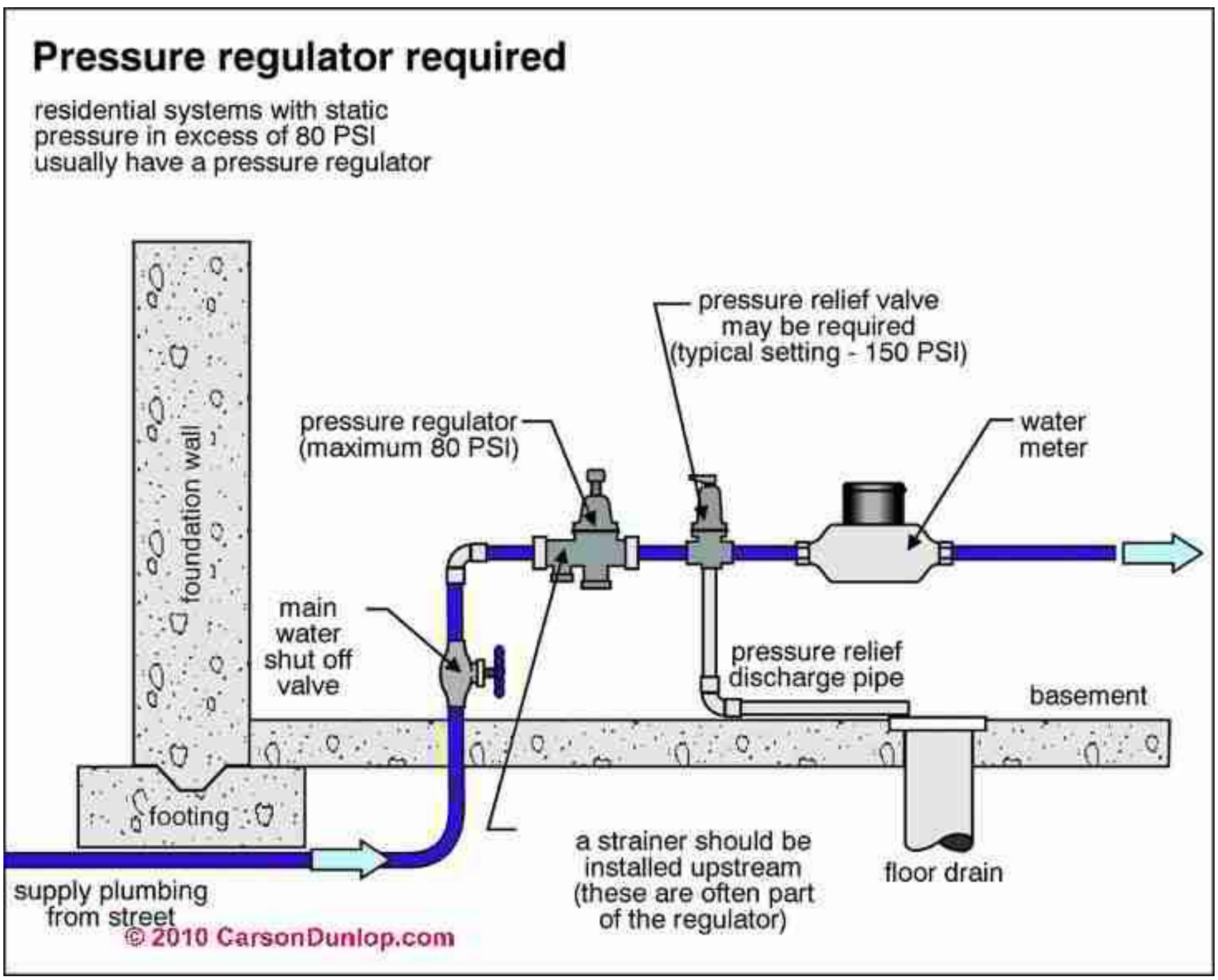
- A pressure-reducing valve is normally provided on a hydronic heating or cooling system **to automatically fill the system with domestic** or **city water to maintain a minimum system pressure.**
- **This valve may be referred to as a** fill valve, PRV fill valve, or automatic PRV makeup water valve, **and is usually located at or near the system expansion tank.**
- **Local plumbing codes may require** a backflow prevention device where the city water connects to the building hydronic system (**see the section on Backflow Prevention Devices).**

Figure 16 PRV Valve

Figure 15 PRV Valve

Figure 14 PRV Valve





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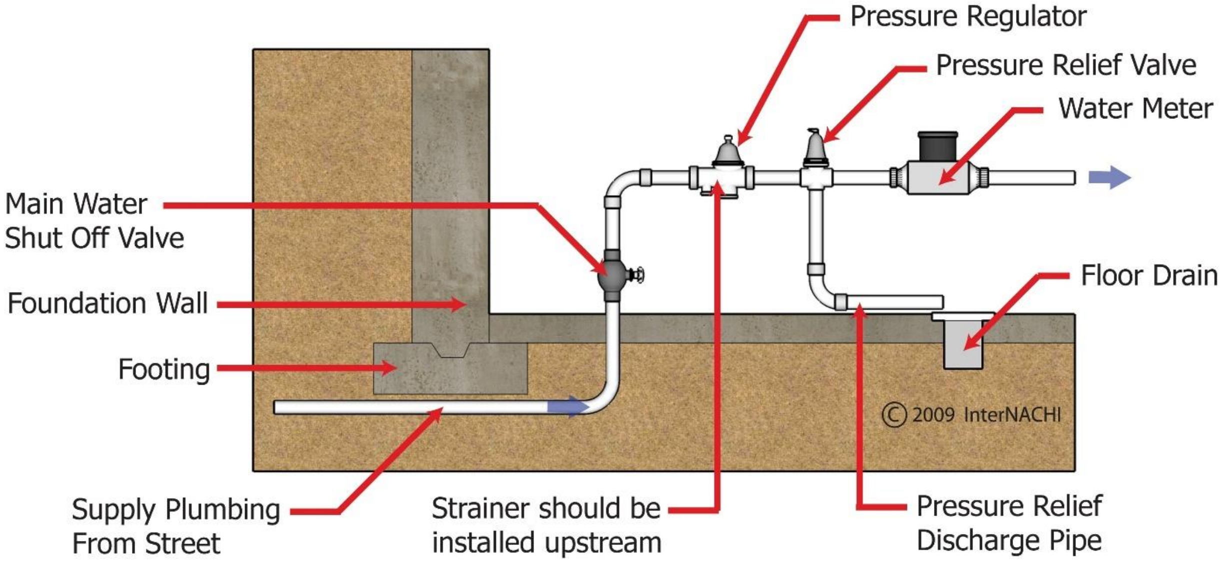
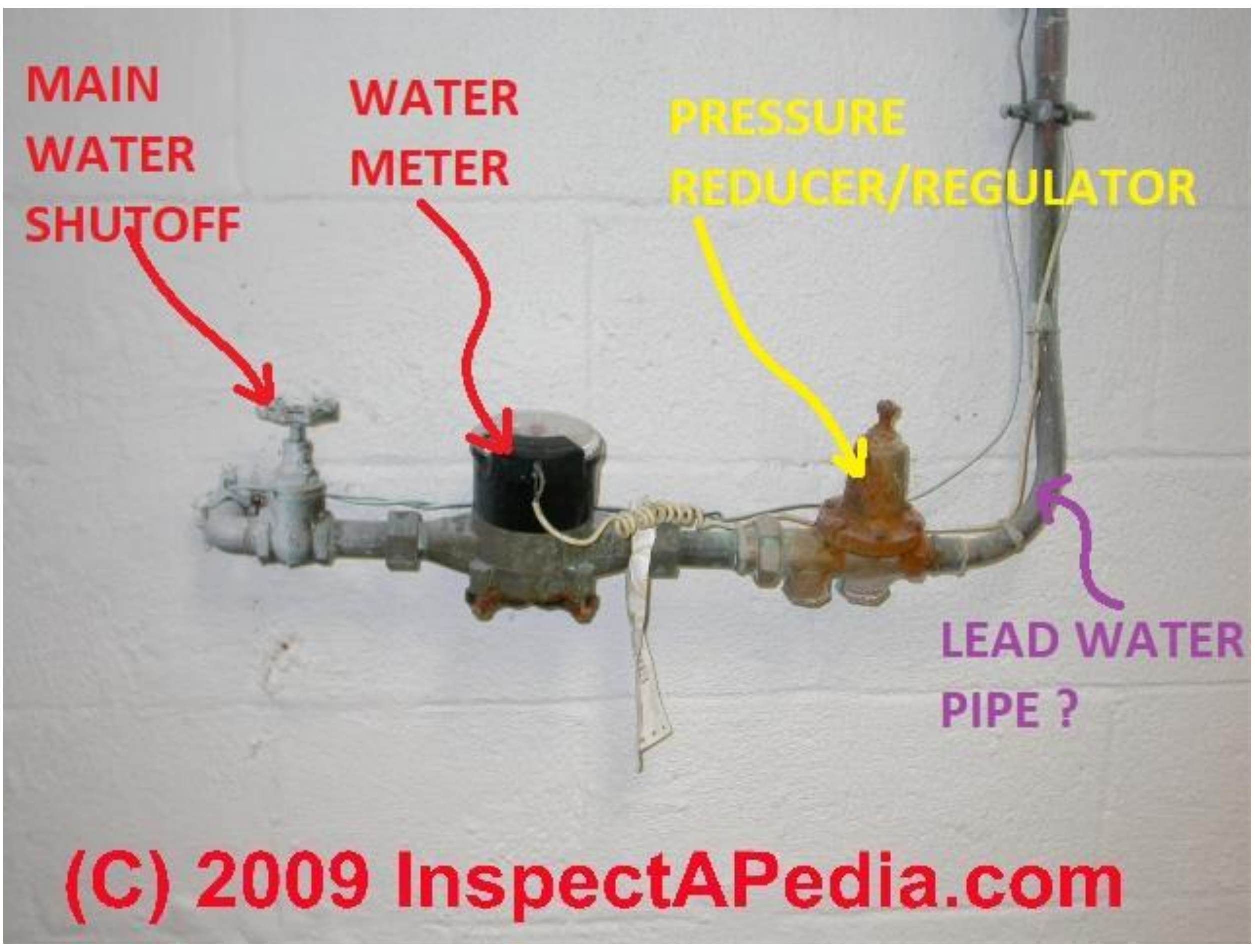
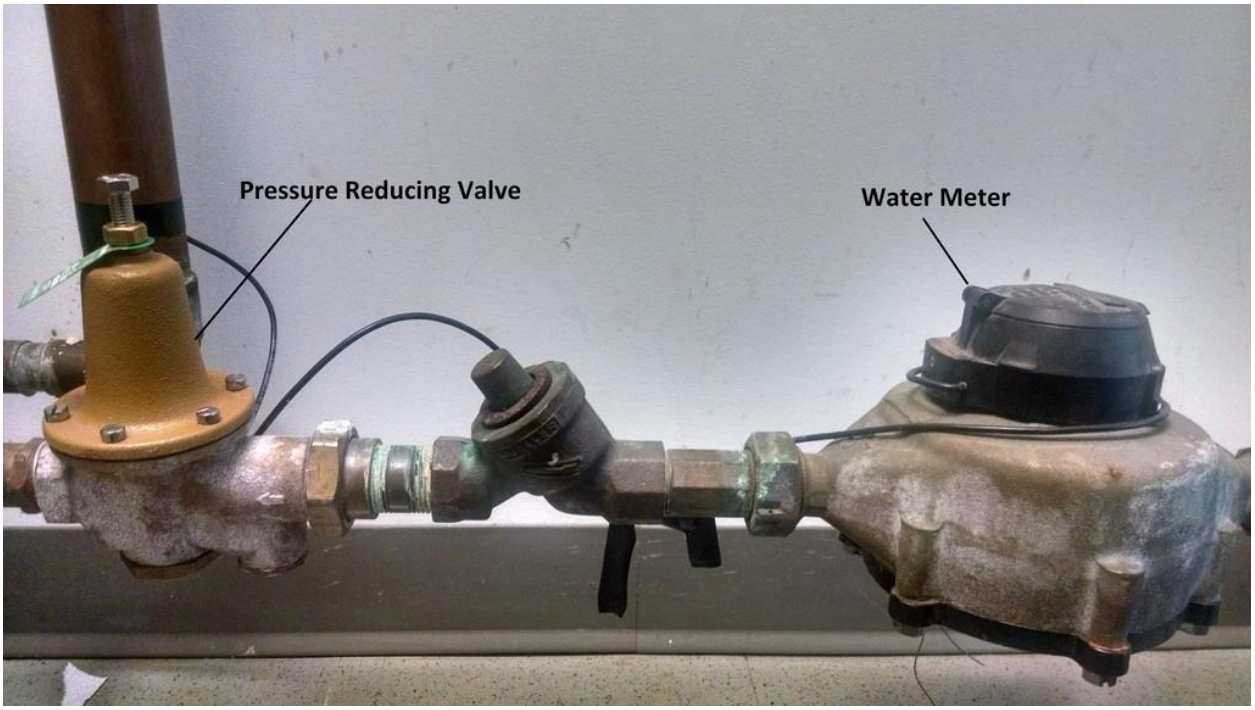
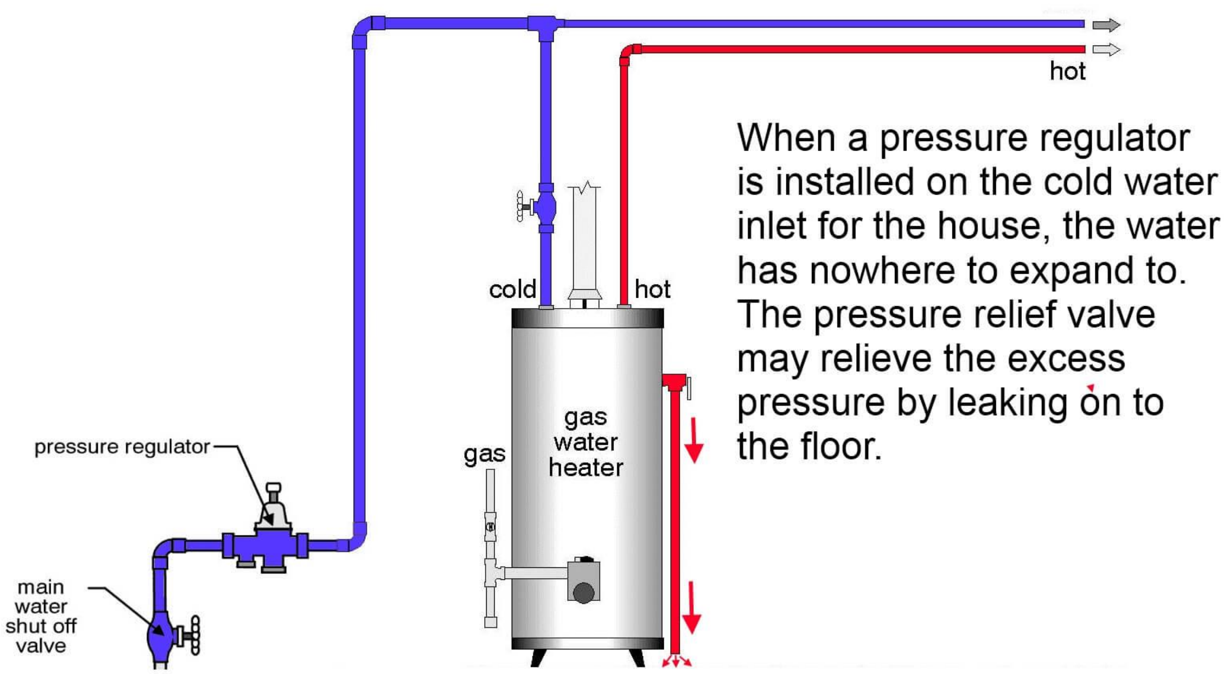
Pressure Regulator









CHECK VALVES:

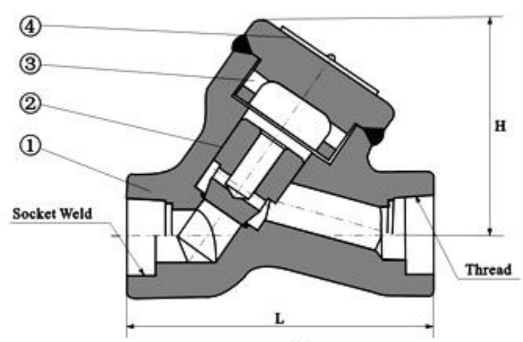
- **Check valves** prevent reversal of flow, controlling the direction of flow rather than stopping or starting flow.
- **Some basic types include** Lift check, swing check, ball check, wafer check, silent check, and stop-check valves.
- Most check valves are available in screwed and flanged body styles.

Swing check valves:

- Have hinge-mounted disks that open and close with flow (Figure 28).
- **The seats are generally made of** metal, **whereas the disks may be of** metallic or nonmetallic composition materials.
- **Nonmetallic disks** are recommended for fluids containing dirt particles or where tighter shutoff is required.
- **The Y-pattern check valve** *has an access opening to allow cleaning and regrinding in place.*
- Pressure drop through swing check valves **is lower than** that through lift check valves because of the straight-through design.

Welded Y Type Check

Bolted Y Type Check



YC8P$\frac{4}{5}$Y

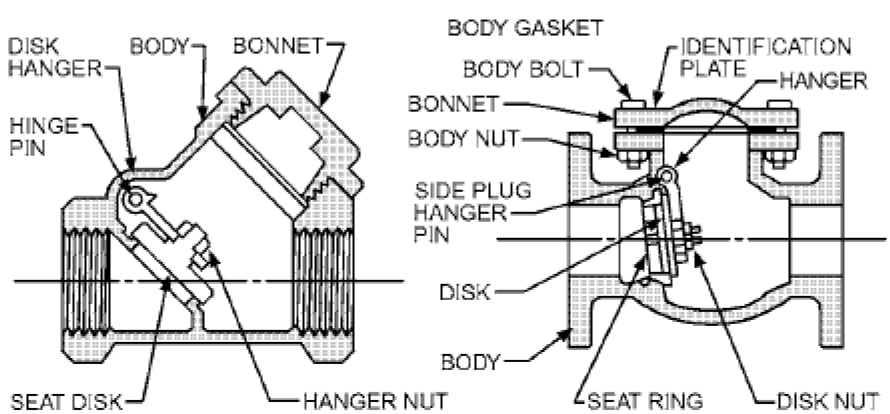


Fig. 28 Swing Check Valves
(Courtesy Anvil International)

Lift Check Valves:

- have a body similar in **design to** a globe or angle valve body with a similar disk seating.
- The guided valve disk is forced open by the flow and closes when the flow reverses. Because of the body design, **the pressure drop is higher than that of a swing check valve.**
- Lift check valves **are recommended for gas or compressed air or in fluid systems not having critical pressure drops.**

Figure 17 Lift Check Angle Valve

Ball Check Valves:

- Are similar to lift checks, except that they use a ball rather than a disk to accomplish closure.
- *Some ball checks* **are specifically designed for horizontal flow or vertical up flow installation.**

Wafer Check Valves:

- **Are designed to** fit between pipe flanges similar to butterfly valves and are used in **larger piping (4 in. diameter and larger).**
- **Wafer check valves have two basic designs**: (1) dual spring-loaded flapper, which operates on a hinged center post, and (2) single flapper, which is similar to the swing check valve.

Figure 18 Dual Spring Wafer Check Valve

Figure 19 Single flapper Wafer Check

Silent or spring-loaded check valves:

- This valve greatly reduces water hammer, which may occur with slow-closing check valves like the swing check.
- Silent check valves **are recommended for use in pump discharge lines.**

C.I SPRING LOADED CHECK VALVE
(SILENT CHECK)

STOP-CHECK VALVES:

- Stop-check valves **can operate as both a check valve and a stop valve.**
- Stop-check valves are **used for shutoff service on multiple steam boiler installations, in accordance with the** ASME *Boiler and Pressure Vessel Code*, **to prevent backflow of steam or condensate from an operating boiler to a shutdown boiler.**
- They are mandatory in some jurisdictions. Local codes **should be consulted.**



BACKFLOW PREVENTION DEVICES:

- Backflow prevention devices **prevent reverse flow of the supply in a water system**.
- A **vacuum breaker** prevents back siphonage in a non-pressure system, whereas a **backflow preventer** prevents backflow in a pressurized system (Figure 29).

Backflow Prevention Devices Selection:

Vacuum breakers and backflow preventers **should be selected based on the local plumbing codes,** the water supply impurities involved, and the type of cross-connection.

1- **Impurities are classified as:**
- contaminants (substances that could create a **health hazard** if introduced into potable water).
- Pollutants (substances that could create objectionable **conditions but not a health hazard**).

2- Cross-connections are classified as:

- Non pressure or pressure connections.
- **In a non-pressure cross-connection**, a potable-water pipe connects or extends below the overflow or rim of a receptacle at atmospheric pressure. **When this type of connection is not protected by a minimum air gap, it should be protected by an appropriate vacuum breaker or an appropriate backflow preventer.**
- **In a pressure cross-connection**, a potable-water pipe is connected to a closed vessel or a piping system that is above atmospheric pressure and contains a nonportable fluid. This connection should be protected by an appropriate backflow preventer only. **Note that a pressure vacuum breaker should not be used alone with a pressure cross-connection**.
- Vacuum breakers **should be corrosion resistant**.
- Backflow preventers, including accessories, components, **and fittings that are 2 in. and smaller**, **should be made of bronze with threaded connections.**
- **Those larger than 2 in**. **should be made of bronze, galvanized iron, or fused epoxy-coated iron inside and out, with flanged connections.**
- **All backflow prevention devices should meet applicable standards of the American National Standards Institute, the Canadian Standards Association, or the required local authorities.**

Backflow Prevention Devices Installation:

- *Vacuum breakers and backflow preventers equipped* with atmospheric vents, or with relief openings, **should be installed and located to prevent any vent or relief opening from being submerged.**
- **They should be installed in the position recommended by the manufacturer**.
- Backflow preventers may be double check valve (DCV) or reduced pressure zone (RPZ) types. **Refer to manufacturers' information for specific application recommendations and code compliance.**

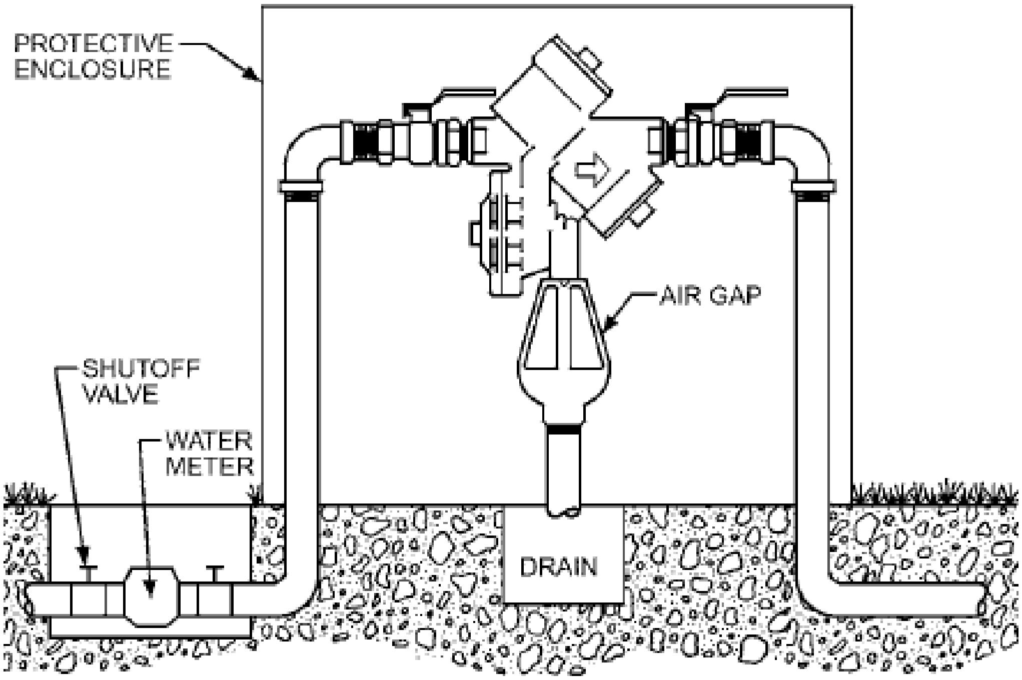


Fig. 29 Backflow Prevention Device

Figure 20 Double Check Valve

Figure 21 Double Check Valve

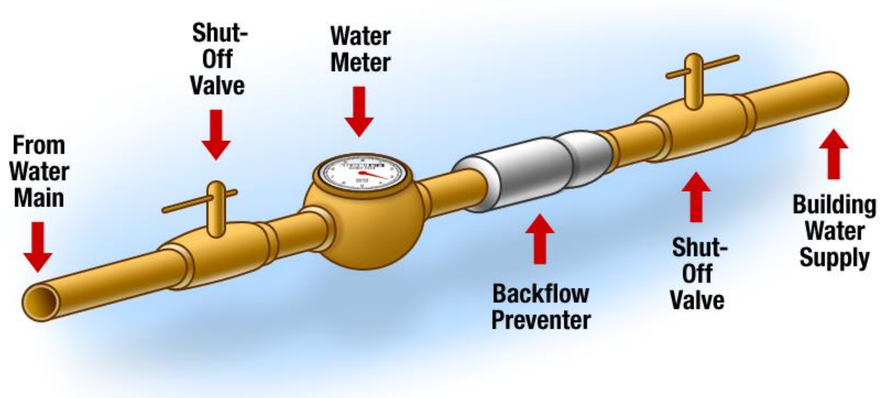


Figure 24 PRZ Valve

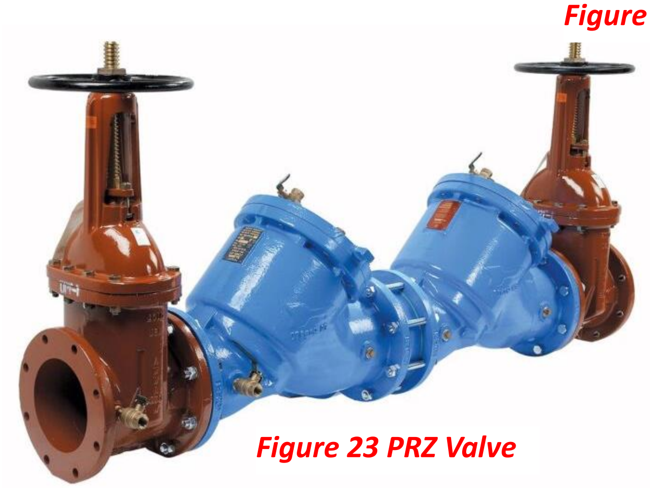


Figure 23 PRZ Valve

Figure 22 PRZ Valve

Selection and the conditions that should be following before selecting valves:

Each valve style has advantages and disadvantages for the application. **The questions listed in the section on Fundamentals must be evaluated carefully.**

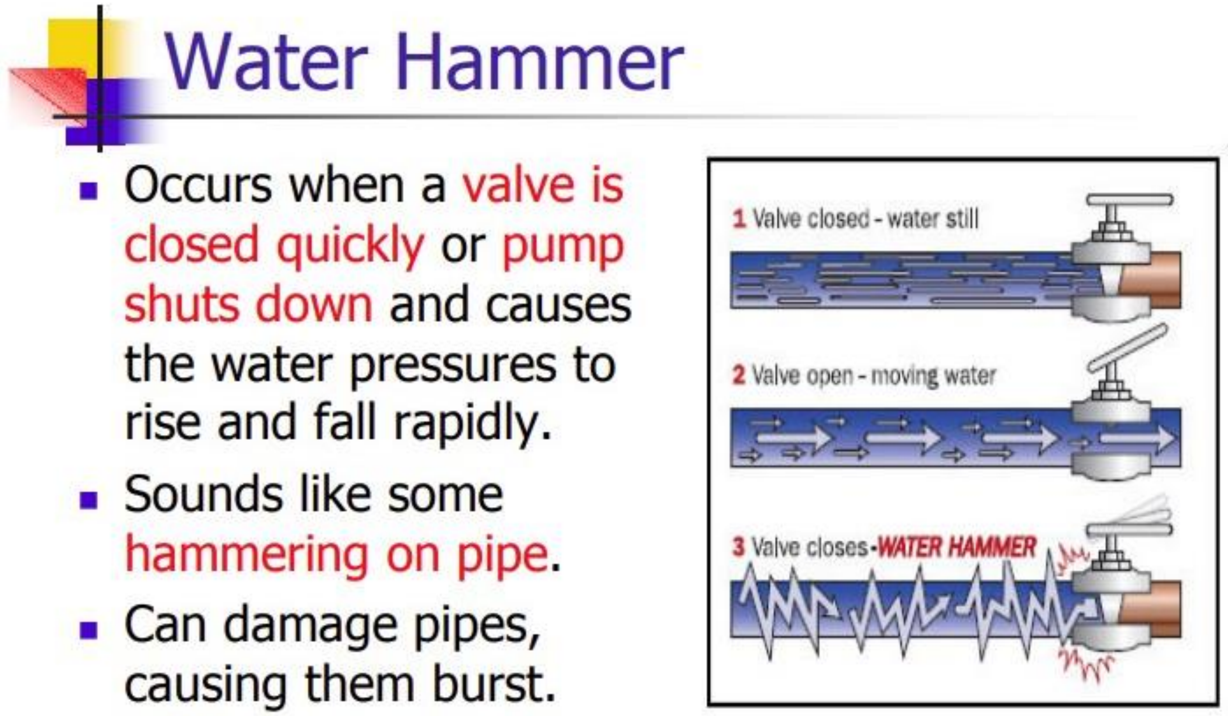
The following service conditions should be considered before specifying or selecting a valve:

1. Type of liquid, vapor, or gas
   - Is it a true fluid or does it contain solids?
   - Does it remain a liquid throughout its flow or does it vaporize?
   - Is it corrosive or erosive?
2. Pressure and temperature
   - Will these vary in the system?
   - Should worst case (maximum or minimum values) be considered in selecting correct valve materials?
3. Flow considerations
   - Is pressure drop critical?
   - Does the valve conform to the required pressure ratings?
   - Is the valve to be used for simple shutoff or for throttling flow?
   - Is the valve needed to prevent backflow?
   - Is the valve to be used for directing (mixing or diverting) flow?
4. Frequency and speed of operation
   - Will the valve be operated frequently?
   - Will the valve need to reposition itself quickly?
   - Should it move slowly?
   - Does the valve have a required default position if there is no power (e.g., fail to normal position or fail in place)?
   - Will valve normally be open with infrequent operation?
   - Will operation be manual or automatic?

Nomenclature for basic valve components may vary from manufacturer to manufacturer and according to the application.

Water Hummer:

- When flow stops because of closing the valve quickly and suddenly, the pressure increase is independent of the working pressure of the system. **For example, if water is flowing at 5 fps and a valve is instantly closed, the pressure increase is the same whether the normal pressure is 100 psig or 1000 psig.**
- **In general, it is important to avoid quickly closing valves in an**
- **HVAC system to minimize the occurrence of water hammer.**



Cavitation:

- Cavitation occurs when the pressure of a flowing fluid drops below the vapor pressure of that fluid (Figure 2).
- Cavitation happens in the pump on the suction line aslo.

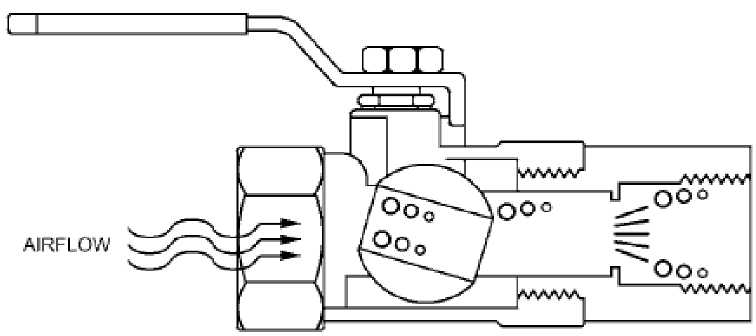
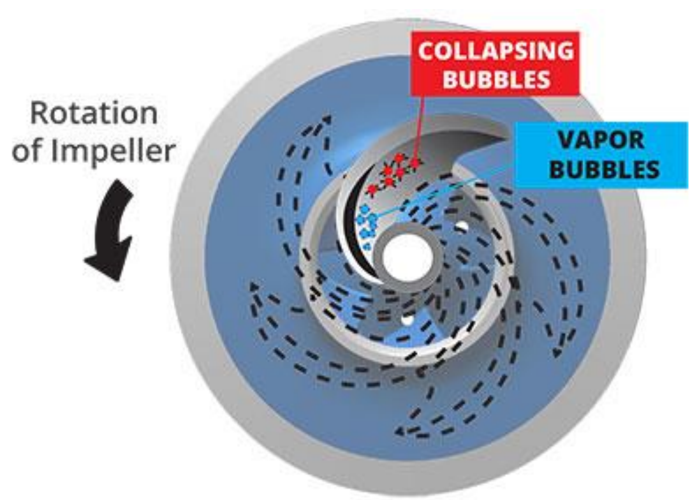


Fig. 2 Valve Cavitation at Sharp Curves



Noise:

- **Chapter 22 of the 2017 *ASHRAE Handbook—Fundamentals* points** out that limitations are imposed on pipe size to control the level of pipe and valve noise, erosion, and water hammer pressure.
- **ISA *Standard* 75.01** compiles prediction correlations t**o develop control valves for reduced noise levels.**

The materials that made of valves:

Materials

ASME *Standard* B16.34 addresses requirements for valves made from forgings, castings, plate, bar stock and shapes, and tubular products. This standard identifies acceptable materials from which valves can be constructed. In selecting proper valve materials, the valve body-bonnet material should be selected first and then the valve plug and seat trim.

Other factors that govern the basic materials selection include

- Pressure-temperature ratings
- Corrosion-resistance requirements
- Thermal shock
- Piping stress
- Fire hazard

Types of materials typically available include

- Carbon steel
- Ductile iron
- Cast iron
- Stainless steels
- Brass
- Bronze
- Polyvinyl chloride (PVC) plastic

Style body of valves:

Body Styles

Valve bodies are available in many configurations, depending on the desired service. Usual functions include stopping flow, allowing full flow, modulating flow between extremes, and directing flow. The operation of a valve can be automatic or manual.

The shape of bodies for automatic and manual valves is dictated by the intended application. For example, angle valves are commonly provided for radiator control. The principle of flow is the same for angle and straight-through valve configurations; the manufacturer provides a choice in some cases as a convenience to the installer.

The type or design of body connections is dictated primarily by the proposed conduit or piping material. Depending on material type, valves can be attached to piping in one of the following ways:

- Bolted to the pipe with companion flange.
- Screwed to the pipe, where the pipe itself has matching threads (male) and the body of the valve has threads machined into it (female).
- Welded, soldered, or sweated.
- Flared, compression, and/or various mechanical connections to the pipe where there are no threads on the pipe or the body.
- Valves of various plastic materials are fastened to the pipe if the valve body and the pipe are of compatible plastics.

Body Ratings:

Body Ratings

The rating of valves defines the pressure-temperature relationship within which the valve may be operated. The valve manufacturer is responsible for determining the valve rating. ASME *Standard* B16.34 should be consulted, and a valve pressure class should be identified. Inlet pressure ratings are generally expressed in terms of the ANSI/ASME class ratings (ranging from ANSI Class 125 to 2500) or based on the body vessel pressure rating, depending on the style, size, and materials of construction, including seat materials. Tables in ANSI/ASME *Standard* B16.34 and in various books show pressure ratings at various operating temperatures.

Characterized ball valves do not use ANSI/ASME class ratings, but are given gage body pressure ratings (e.g., 600 psi). Many non-characterized ball valves are rated as **water, oil, or gas (WOG)** body pressure rating based on the ambient temperature limit.

Control Valve Flow Characteristics:

Based on the characteristics of the valve, three distinct flow conditions are possible (Figure 16):

- **Quick Opening.** When started from the closed position, a quick-opening valve allows a considerable amount of flow through a small opening of the valve. As the valve moves toward the full open position, the rate at which the flow is increased is reduced in a nonlinear fashion. This characteristic is used in two-position or on/off applications, because it is very difficult to position the stem accurately enough for low and medium flows in modulating applications.
- **Linear.** Linear valves produce equal flow increments per equal increments of the valve moving towards the full open position. This characteristic is commonly used on steam coil terminals, bypass applications, and sometimes in the bypass port of three-way valves.
- **Equal Percentage.** This type of valve produces an exponential flow increase as the valve moves from the closed to the open position. For equal increments of the valve opening, the flow increases by an equal percentage. For example, in Figure 16, if the valve modulates from 50 to 70% of full stroke, the percentage of full flow changes from 10 to 25%, an increase of 150%. Then, if the valve modulates from 80 to 100% of full stroke, the percentage of full flow changes from 40 to 100%, again, an increase of 150%. This characteristic is recommended for control of hot- and chilled-water coils to linearize the output of the coil-valve combination, which makes control tuning easier and typically results in more stable systems.

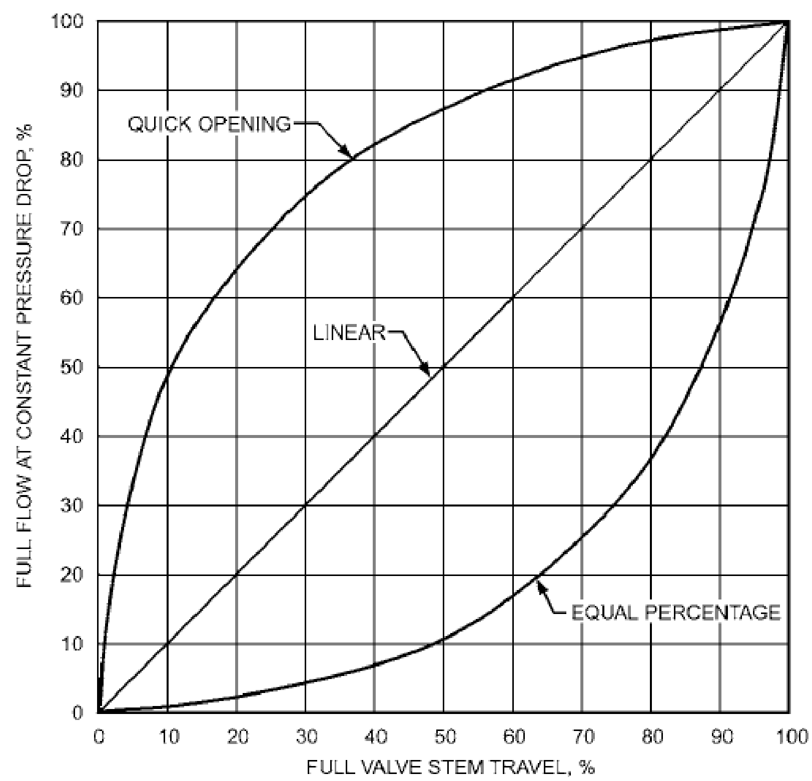


Fig. 16 Control Valve Flow Characteristics

The designer combines the valve flow characteristic with the coil performance curve (heating or cooling) to ensure the proper heat transfer characteristic. (Figure 17). The coil output (Figure 17A) of a heating or cooling coil increases rapidly and begins to slow as it nears the design point. Mating this coil output with its mirror image in flow percentage (i.e., the equal percentage flow characteristic) as shown in Figure 17B results in a linear coil output (Figure 17C).

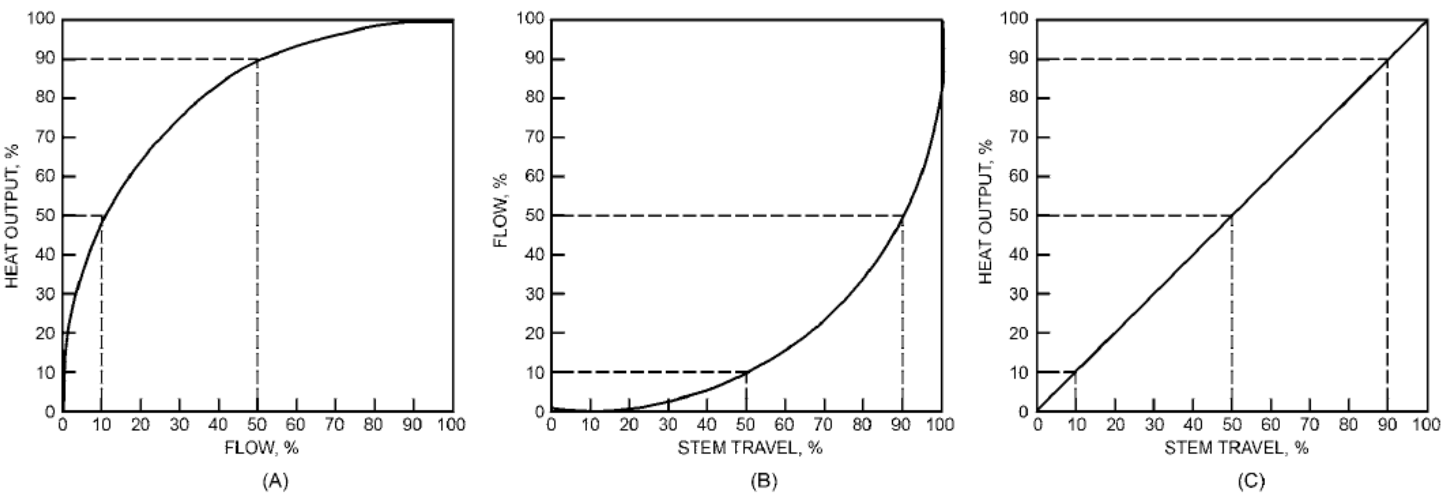


Fig. 17 Heat Output, Flow, and Stem Travel Characteristics of Equal-Percentage Valve

The three flow patterns are obtained by imposing a constant pressure drop across the modulating valve, but in actual conditions, the pressure drop across the valve varies between a maximum (when it is controlling) and a minimum (when the valve is near full open). The ratio of these two pressure drops is known as authority. Figures 18 and 19 show how linear and equal-percentage valve flow characteristic are distorted as the control valve authority is reduced because of a reduction in valve pressure drop. The quick-opening characteristic (not shown) is distorted to the point that it approaches two-position or on/off control. The selection of the control valve pressure drop directly affects the valve authority and should be at least 25 to 50% of the branch pressure drop (i.e., the pressure drop from the branch connection from the supply main to return main, including the piping, fittings, coil, balancing device, and control valve). The location of the control valve in the system results in unique pressure drop selections for each control valve. A higher valve pressure drop allows a smaller valve size and better control, but also higher friction energy losses.

Authority ranges between 0.0 and 1.0. A low authority can cause the coil output to be quick opening instead of providing the desired linear coil output, causing the flow, temperature, and pressure oscillations discussed previously. Low valve authority leads to unstable flow through the control valve during low-load conditions. An authority of 1.0 will cause the valve to operate along its theoretical curve. A high authority value results in high pressure losses, even when the valve is full open. In modulating applications, an authority between 0.25 and 0.5 usually provides the right balance between controllability and energy performance.

Authority = Differential pressure of valve/
(Differential pressure of valve + Differential pressure of branch)

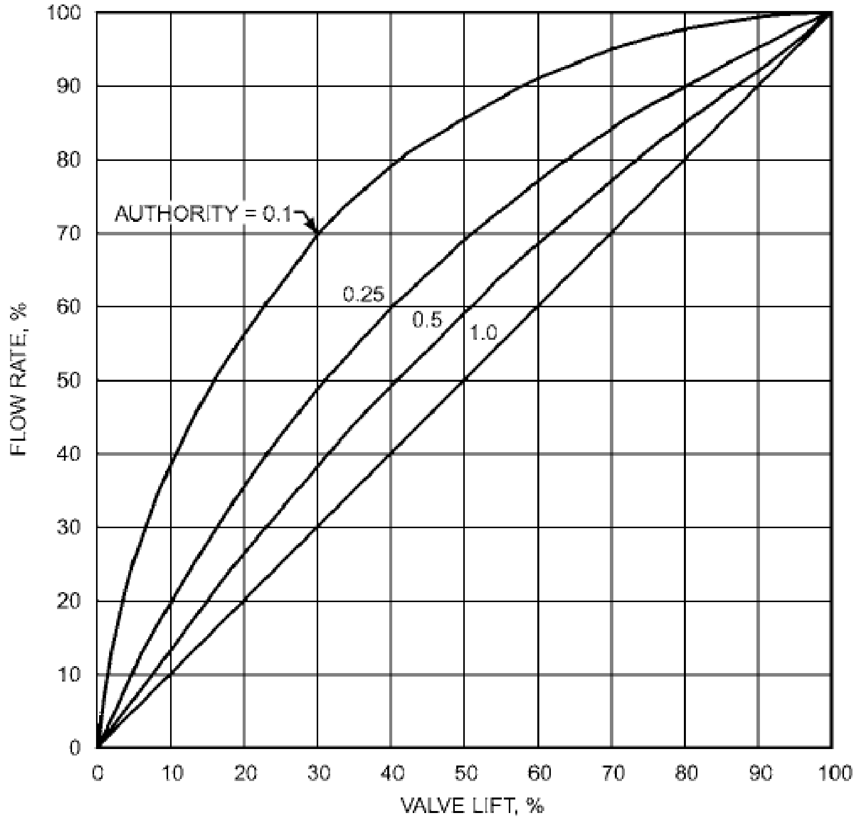


Fig. 18 Authority Distortion of Linear Flow Characteristics

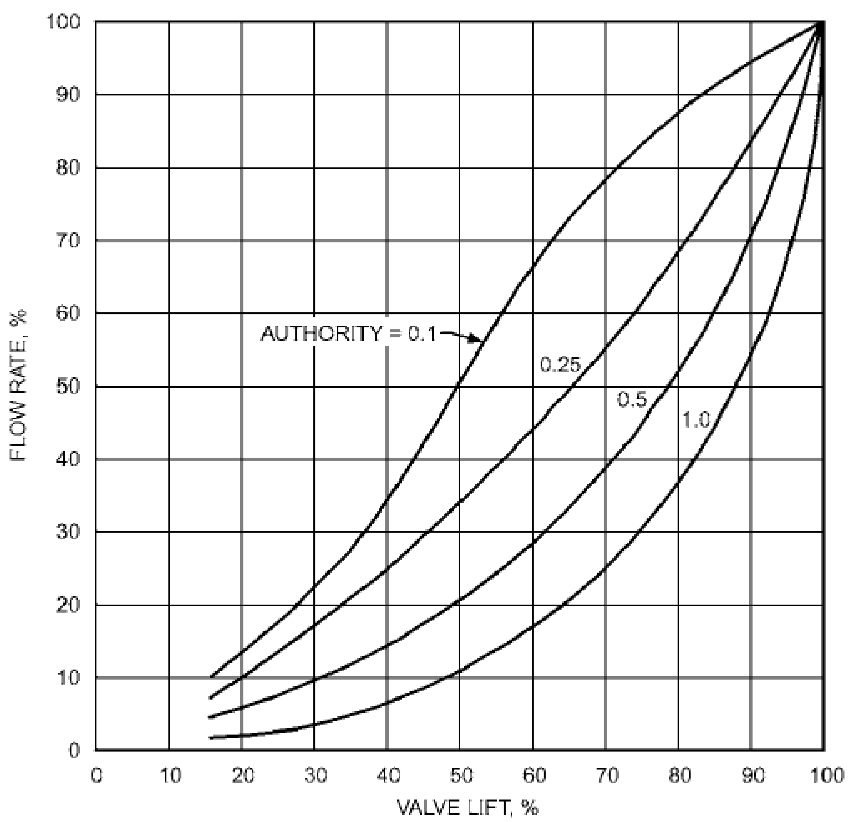


Fig. 19 Authority Distortion of Equal-Percentage Flow Characteristic

Control Valve Sizing:

Control Valve Sizing

Liquids. Two-position valves are generally selected to be the same size as the pipe; however, the C_v should be verified to ensure proper flow capacity: a wide range of flow capacities is available, especially in the smaller valve sizes. The flow characteristic (e.g., linear, equal percentage) does not matter in this application, so any type can be used. Ball valves should be selected without a characterizing disc and for the largest port size (largest C_v).

Sizing modulating pressure-dependent valves is based on the

$$C_v = Q(\mathrm{SG}/\Delta p)^{0.5} \tag{1}$$

where

C_v = flow coefficient

Q = flow, gpm

SG = specific gravity of fluid = 1 (for water), dimensionless

Δp = pressure drop, psi

Note that C_v (used with I-P units) and the SI equivalent K_v are not numerically equal. Therefore, before selecting valves from a catalog expressed in the other unit system, convert the calculated value as follows: $C_v = 1.16K_v$; $K_v = 0.862C_v$.

To determine the flow coefficient C_v of a control valve, the flow rate and the pressure drop desired across the control valve must be known.

The flow rate should be obtained from the design, shop drawings, the equipment itself, or other available data. The desired pressure drop is required to provide reasonable authority as discussed in the previous section.

Pressure drop and, ultimately, the valve sizing itself are based on the valve in a fully open state, because the valve capacity must be large enough to handle the design flow conditions. To estimate the desired pressure drop, first determine whether the valve is a two-position (on/off) or modulating (floating/proportional) type of control.

Two-position (on/off control) valves are sized with a 1 psi (2.31 ft head) pressure drop. Thus, if flow is 10 gpm, the desired C_v for the two-position control valve is

$$\begin{aligned} C_v &= Q(\mathrm{SG}/\Delta p)^{0.5} = Q(1/\Delta p)^{0.5} = Q/(\Delta p)^{0.5} = 10/(1)^{0.5} \\ &= 10/1 = 10 \end{aligned} \tag{2}$$

The selected control valve should have a C_v as close as possible to that calculated using this equation, without going below this value.

Caution: in a two-position application, the “rule of thumb” historically has been to select a line-sized control valve. However, with many more selections of C_v values now available across the range of control valves, specifying a 1/2 in. control valve for a 1/2 in. line without specifying the C_v could result in the installation of a valve with a C_v below 1.

Often, designers will specify a pressure drop higher than 1 psi for a two-position control valve. For example, with a maximum flow required of 10 gpm, but using a 4 psi pressure drop across the control valve instead of 1 psi,

$$C_v = 10/(4)^{0.5} = 10/2 = 5 \tag{3}$$

This result indicates that the valve will have only half the capacity at 4 psi pressure differential as it would at the 1 psi differential used in the previous calculation.

Modulating valves are sized using the same flow coefficient equation. However, because the control valve is modulating the pressure across the valve, the pressure differential will be higher than that of a two-position control valve. As stated previously, the pressure drop across the control valve should be 25 to 50% of the branch pressure. Many factors affect the branch pressure, and it varies as other valves in the system open and close. To avoid the complexity of hydraulic circuit analysis, a rule of thumb for desired control valve pressure drop is 4 to 5 psi.

For example, the C_v for a modulating control valve in a reheat coil application with a flow rate of 3 gpm and 5 psi, pressure drop is

$$C_v = 3/(5)^{0.5} = 3/2.24 = 1.3 \tag{4}$$

Note that installed flow coefficients may vary from catalog values because of pipe geometry factors, particularly with low-pressure drop valves such as full-port ball valves and butterfly valves. The greater the difference in valve and piping line size, the larger the impact on installed (corrected) flow coefficient. Where multiple flow coefficients are available for a given valve line size, such as with ball valves, the valve should be selected to match the pipe line size where available. Where the valve must be smaller than the line size, consult the manufacturer for flow coefficient adjustments. Typically, if the valve is no more than one size smaller than the pipe line size, the impact will be negligible for globe and characterized ball valves.

Steam. For steam flow, the inlet and outlet pressures of the steam, and the type of control (modulating or two-position) must be taken into account:

$$Q = 2.1C_v/K[\Delta p(P_1 + P_2)]^{0.5} \quad (5)$$

where

Q = steam mass flow, lb/h

$K = 1 + 0.0007 \times$ (°F superheat). Typically, this value is 1 for nonsuperheated steam.

C_v = flow coefficient

P_1 = differential pressure (inlet pressure – outlet pressure), psi

P_2 = outlet steam pressure (absolute), psia

There are two cases for selecting the differential pressure across the steam control valve:

1. Inlet steam pressure $\leq$ 15 psig.
   a. Two-position (on/off) control: differential pressure = 10% of inlet steam gage pressure.
   b. Proportional control: differential pressure = 80% of inlet steam gage pressure
2. Inlet steam pressure > 15 psig.
   a. Two-position (on/off) control: differential pressure = 10% of inlet steam absolute pressure.
   b. Proportional control: differential pressure = 25% of inlet steam absolute pressure.

Whenever possible, avoid selecting the differential pressure higher than 42% (saturated steam), because this takes the steam in the valve into critical or sonic velocity operation. In this case, the flow and C_v do not follow Equation (5), instead conforming to the following equation:

$$w_s = 1.6C_vP_1 \quad (6)$$