CHAPTER A10

PART 1 SELECTION AND APPLICATION OF VALVES

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INTRODUCTION

Valves are an essential part of any piping system that conveys liquids, gases, vapors, slurries and mixtures of liquid, and gaseous phases of various flow media. Starting with primitive means for stopping, allowing, or diverting water-flow from a source through shallow or deep channels, such as wooden or stone wedges stuck between the edges of a water passage, man has developed several different types of simple and sophisticated valve designs. Different types of valves include: gate, globe, check, ball, plug, butterfly, diaphragm, pinch, pressure relief, and control valves. Each of these types has several categories and designs, each offering different features and functional capabilities. Some valves are self-actuated while others are manually operated or have actuators that are powered with electric motors, are pneumatic or hydraulic, or a combination to operate the valve. Valves are manufactured with metals and nonmetals. Valves are used in industrial piping systems, transportation and distribution pipelines, building services piping, civic facilities, and irrigation piping systems. The piping systems of industrial, commercial, residential, and other civic facilities carry the lifeblood of modern civilization, like arteries and veins. And the valves in those piping systems serve the functions of allowing, stopping, regulating, and controlling the flow, to fulfill the intended objectives of the system. When fluid pressure builds up beyond a set limit, the valves relieve the overpressure to safeguard the integrity of the piping system or a component. Valves help in maintaining or breaking a vacuum. Valves also assist in maintaining the pressure or temperature of the flow medium within the desired range or limit. In order to select a suitable valve for a particular application, the user must evaluate the valve characteristics, including the design features, materials of construction, and performance, in light of specific application requirements: flow medium, process design requirements, piping design criteria, and economic factors. This chapter provides a brief discussion of topics considered in the selection and application of commonly used valves.

VALVE TERMINOLOGY

Actuator: A device that operates a valve by utilizing electricity, pneumatics, hydraulics, or a combination of one or more of these energies. Sometimes actuators are referred to as *operators.* In this chapter, the word operator will be used for a person who operates any equipment, machine, plant, or system.

Ambient conditions: The pressure and temperature of the environment surrounding a valve.

Backflow: The flow that occurs in the opposite direction of the normal or expected fluid flow.

Back pressure: The static pressure existing at the outlet of a pressure-relief device due to pressure in the discharge system.

Backseat: A seat on the bonnet or bonnet bushing which contacts a corresponding seating surface of the stem or disc holder when the stem is fully retracted. It provides a seal between the stem and the inside of the bonnet. It prevents leakage of flow medium and allows replacement of valve packing while the valve is open and under pressure.

Block-and-bleed valve: A valve with two seating surfaces which provide simultaneous blockage of flow from both valve ends, and means for draining or venting the cavity between the seating surfaces. When the valve is closed (blocked) the drain is opened, allowing the trapped fluid between the seats to drain (bleed).

Block valve: A valve that is used to start or stop the flow. It is also referred to as an *on-off valve.*

Blowdown: The difference between the set pressure and the disc-reseating pressure of a pressure-relief valve, which is expressed as a percentage of the set pressure.

Blowdown valve: A valve used to release the pressurized contents of a pressure vessel or piping.

Bonnet: A valve body closure component that contains an opening for the stem.

Bore: The diameter of the smallest opening through a valve. It is also called *port.*

Bubble tight: A valve is termed *bubble tight* when the upstream side of the valve is pressurized with air and the downstream side is filled with water and no air bubbles are detected on the downstream side with the valve in fully closed position.

Bypass: A piping loop provided to permit flow around the flow control element (disc, plug, etc.) of a valve in its closed position. A stop valve installed in the bypass loop is called the *bypass valve.*

Cavitation: This occurs when the fluid pressure at the *vena contracta* falls below the vapor pressure, followed by pressure recovery above the vapor pressure. The pressure below vapor pressure causes vapor bubbles to form, which then collapse as the pressure recovers. Collapsing bubbles can cause erosion of valve and downstream pipe metal surfaces. The phenomena of fluid pressure falling below and recovering above vapor pressure, combined with forming and collapsing of bubbles, is termed *cavitation.*

Chatter: Abnormal rapid reciprocating motion of the movable parts of a pressure-relief valve in which the disc contacts the seat.

Choked flow: When the flow rate cannot be increased even if the downstream pressure is decreased. In liquid applications, it is caused by vapor bubbles, formed by cavitation or flashing, choking the flow passage. In the case of gases, choked flow is caused when the flow velocity reaches sonic proportions and a reduction in downstream pressure cannot increase the gas flow.

Closing pressure: The pressure equal to the valve of decreasing inlet static pressure at which the valve disc reestablishes contact with the seat or at which lift becomes zero.

Coefficient of discharge: The ratio of the measured relieving capacity to the theoretical relieving capacity of a pressure-relief valve.

Coefficient of flow: The flow rate that passes through the fully open valve at unit pressure differential. It is measured in gal (3.8 liters) per minute of 60°F (16°C) water with 1 psi (6.9 kPa) pressure differential. It is also referred to as *flow coefficient* or *valve coefficient.*

Cold working pressure (CWP): This is the maximum flow-medium pressure at the ambient temperature to which the valve may be subjected during normal service. This is also referred to as *water-oil-gas* (WOG) rating.

Control valve: A valve serving as a control element in a system, providing means for varying the rate of flow of the fluid passing through the valve.

Cracking pressure: The upstream fluid pressure at which a closed check valve starts to open and allow the flow through the valve.

Cryogenic valve: A valve used in applications with fluid temperatures below −50°F (−45°C). A cryogenic valve is provided with an extended stem contained in an extension tube so that the valve packing and operator remain at ambient temperature when the cryogenic fluid is in the valve body. The valve is oriented so that the packing is at a higher elevation than the valve body. It allows a vapor-gas pocket to form inside the extension tube, thereby making the extension tube more effective at insulating the packing from cryogenic fluid cold temperature.

Disc: The part of the valve which is positioned in the flow stream to permit or to obstruct flow, depending on closure position. In specific designs, it may also be called a wedge, plug, ball, gate, or other functionally similar expression. In international standards it is referred to as obturator.

Double-disc: A two-piece disc or two separate discs that mate with two seating surfaces. Double discs are used in some designs of gate valves.

Double-seated valve: A valve with two separate seating surfaces that come in contact with two separate seating surfaces of a disc or a double disc.

Flow characteristic: Defines the relationship between the Flow Coefficient and the valve *stroke.*

Flow coefficient: See *Coefficient of flow.*

Flow control element: The part of the valve that allows, stops, obstructs, and controls the fluid flow through the valve. See *Disc.*

Fugitive emission: The amount of leakage of hazardous and toxic flow medium (fluids) from a valve to the environment.

Full bore: When valve *bore (port)* is approximately of the same size as the inside diameter of the connecting pipe, it is called *full bore (full port).*

Fully stellited: A valve is termed fully stellited when seating surfaces of the valve seat(s) and the disc(s) are hard faced with wear and corrosion-resistant material (*Stellite* or other such material).

Half stellited: A valve is termed half stellited when only the seating surfaces of the valve seat(s) are hard faced with wear and corrosion-resistant material (Stellite or other such material).

Hard facing: Application or deposit of hard, wear, and corrosion-resistant material on soft surfaces subject to wear.

Inside screw–nonrising stem (ISNRS): Threads on the stem are inside the valve body. The valve disc travels up and down the stem threads when the stem is rotated. Stem does not rise.

Inside screw–rising stem (ISRS): Threads on the stem are inside the valve body and exposed to the flow medium. The stem rises when it is rotated, thus opening the valve. Position of the stem indicates the position of the valve disc.

Iron body–bronze mounted (IBBM): A valve having cast iron body and bronze trim.

Lantern ring: A spacer ring used in the *lantern ring* type of packing chamber to permit lubrication of the packing, purging of the shaft or stem, or a leak-off system.

Leak-off connection: A pipe or tube connected to a hole in the stuffing box at the level of lantern ring. It is used to collect leakage past a lower set of lantern ring–type of packing or to inject lubricant into the stuffing box.

Linear-flow characteristics: A flow characteristic of the valve when the flow is directly proportional to the position of the flow control element.

Liner: Lining of protective materials applied on the inside surfaces of valve body (or valve trim) to enhance resistance to corrosion, erosion, or contamination.

Nonreturn valve: Stop-check valve, a check valve in which the closure member can be mechanically closed.

Nonrising stem: Refer to *Inside screw, nonrising stem (ISNRS).*

Outside-screw-and-yoke (OS&Y): A valve design in which the threaded portion of the stem is outside the pressure boundary of the valve. The valve bonnet has a yoke, which holds a nut through which the rotating stem rises as the valve is opened. The stem part inside the valve is smooth and is sealed so that stem threads are isolated from the flow medium.

Pilot operated pressure relief valve: A pressure-relief valve in which the major relieving device is combined with and controlled by a self-actuated auxiliary pressure-relief valve.

Port: See *bore.*

Power actuated pressure-relief valve: A pressure-relief valve in which the major relieving device is combined and controlled by a device requiring an external source of energy.

Quarter-turn valve: A valve whose closure member rotates approximately a quarter turn (90°) to move from full-open to full-closed position.

Reduced port: Valve port smaller than the inside diameter of the end-connecting pipe. It is approximately equal to the inside diameter of the one pipe size smaller than the end size for gate valves, and 60 percent of full bore on ball valves.

Regular port: A valve port smaller than the full bore, approximately 75 to 90 percent of full bore on ball valves and 60 to 70 percent on plug valves.

Relief valve: A pressure-relief valve actuated by inlet static pressure and having a gradual lift generally proportional to the increase in pressure over the opening pressure (set pressure).

Rotary motion valve: A valve that involves a quarter-turn motion to open or close the valve closure element.

Rupture disc: A nonclosing pressure-relief device actuated by inlet static pressure and designed to function by the bursting of a pressure-containing disc.

Safety-relief valve: A pressure-relief valve characterized by rapid opening pop action, or by opening generally proportional to the increase in pressure over the opening pressure.

Safety valve: A pressure-relief valve actuated by inlet static pressure and characterized by rapid opening or pop action.

Seat: The portion of the valve against which the closure member presses to effect shutoff.

Seat ring: A separate piece inserted in the valve body to form a seat against which the valve-closure member engages to effect shut-off.

Set pressure: The inlet static pressure of the system at which a relief valve starts to open, or safety valve pops open.

Short pattern valve: A valve that has face-to-face or end-to-end dimension for a short pattern design according to standard ASME B16.10.

Steam working pressure (SWP): The maximum rated or working pressure corresponding to the steam temperature that must not be exceeded when valve is used in steam service. It is marked with S, SP, or SWP on the valve.

Stroke: The amount of travel the valve-closure member is capable of from a fully closed position to a fully open position or vice versa. In linear-motion valves it is expressed in in (mm) and in degrees, 0 to 90, for rotary motion valves.

Throttling: The process of regulating the fluid flow rate or pressure by controlling the position of the closure member between the full-open and full-closed positions.

Trim: Functional parts of a valve which are exposed to the line fluid. Usually refers to the stem, closure member and, seating surfaces. The removable or replaceable valve metal internal parts that come in contact with the flow medium are collectively known as valve trim. Valve parts such as body, bonnet, yoke, and similar items are not considered trim.

Venturi port: A valve bore or port that is substantially smaller than the full port, approximately 40 to 50 percent of full port. It is normally found in plug valves.

Wafer body: A valve body that has a short face-to-face dimension in relation to pipeline diameter and is designed to be installed between two flanges using special length studs and nuts.

Wedge: A gate valve–closure member with inclined sealing surfaces which come in contact with valve-seating surfaces that are inclined to the stem centerline. Wedge is available in solid, split, and flex designs.

Yoke: That part of the valve assembly used to position the stem nut or to mount the valve actuator.

Yoke bushing, yoke nut: Yoke nut, yoke bushing, or *stem nut* is the valve part that is held in a recess at the top of the yoke through which the stem passes. It converts rotary-actuating effort into thrust on the valve stem.

REFERENCE CODES AND STANDARDS

The following is a list of commonly used valve standards in the United States. Based upon the scope, each of these standards contains rules and requirements for design, pressure-temperature ratings, dimensions, tolerances, materials, nondestructive examinations, testing, and inspection and quality assurance. Compliance to these and other standards is invoked by reference to codes of construction, specifications, contracts, or regulations.

ASME Standards

B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.33	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (Sizes ½ Through 2)
B16.34	Valves—Flanged, Threaded, and Welding End
B16.38	Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum)
B16.40	Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems
B16.44	Manually Operated Metallic Gas Valves for Use in House Piping Systems
N278.1	Self-Operated and Power-Operated Safety-Related Functional Specification Standard

ASME Performance Test Code

PTC 25.3	Safety and Relief Valves

ANSI Guides/Manuals

1003	Performance Requirements for Water Pressure Reducing Valves for Domestic Water Supply Systems
1029	Performance Requirements for Water Supply Valves; Mixing Valves and Single Control Mixing Valves
1032	Performance Requirements for Dual Check Valve Type Backflow Preventers for Carbonated Beverage Dispensers

AWWA Standards and Specifications

C500-93	Metal-Seated Gate Valves for Water Supply Service
C501-92	Cast-Iron Sluice Gates

C504-94	Rubber-Seated Butterfly Valves
C507-91	Ball Valves, 6 in Through 48 in (150 mm Through 1200 mm)
C508-93	Swing Check Valves for Waterworks Service
C509-94	Resilient-Seated Gate Valves for Water Supply Service
C510-92	Double Check Valve Backflow Prevention Assembly
C511-92	Reduced Pressure Principle Backflow Prevention Assembly
C512-92	Air-Release, Air-Vacuum, and Combination Air Valves for Waterworks Service
C540-93	Power-Actuating Devices for Valves and Sluice Gates
C550-90	Protective Epoxy Interior Coatings for Valves and Hydrants

ARI (Air-Conditioning and Refrigeration Institute) Standards

720	Refrigerant Access Valves and Hose Connectors
760	Solenoid Valves for Use with Volatile Refrigerants
770	Refrigerant Pressure Reducing Valves

ASSE (American Society of Sanitary Engineers) Standards

1001	Performance Requirements for Pipe Applied Atmospheric Type Vacuum Breakers.

Standards 1003, 1029 and 1032 are listed as ANSI Guides/Manuals above.

American Petroleum Institute (API) Specifications

6D-94	Specification for Pipeline Valves (Gate, Plug, Ball, and Check Valves)
6FA-94	Specification for Fire Test for Valves
6FB-92	Specification for Fire Test for End Connections
6FC-94	Specification for Fire Test for Valves with Automatic Backseats
6FD-95	Specification for Fire Test for Check Valves

14A-94	Specification for Subsurface Safety Valve Equipment
14D-94	Specification for Wellhead Surface Safety Valves and Underwater Safety Valve for Offshore Service

API Standards

526-95	Flanged Steel Pressure Relief Valves
527-91	Seat Tightness of Pressure Relief Valves
589-93	Fire Test for Evaluation of Valve Stem Packing
594-91	Wafer and Wafer-Lug Check Valves
598-90	Valve Inspection and Testing
599-94	Metal Plug Valves–Flanged and Welding Ends
600-91	Steel Gate Valves–Flanged and Butt-Welding Ends
602-93	Compact Steel Gate Valves—Flanged, Threaded, Welding, and Extended-Body Ends
603-91	Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves
607-93	Fire Test for Soft-Seated Quarter-Turn Valves
608-95	Metal Ball Valves—Flanged, Threaded, and Welding Ends
609-91	Lug- and Wafer-Type Butterfly Valves

The International Society for Measurement and Control (ISA) Recommended Practices (RP)

RP 75.06-81	Control Valve Manifold Design
RP 75.18-89	Control Valve Position Stability
RP 75.21-89	Process Data Presentation for Control Valves

Standards

S75.01-85	Flow Equations for Sizing Control Valves
S75.02-88	Control Valve Capacity Test Procedure
S75.03-92	Face-to-Face Dimensions for Integral Flanged Globe-Style Control Valve Bodies

S75.04-95	Face-to-Face Dimensions for Flangeless Control Valves
S75.05-83	Control Valve Terminology
S75.07-87	Laboratory Measurement of Aerodynamic Noise Generated by Control Valves
S75.08-85	Installed Face-to-Face Dimensions for Flanged Clamp or Pinch Valves
S75.11-85	Inherent Flow Characteristics and Rangeability of Control Valves
S75.12-93	Face-to-Face Dimensions for Socket Weld-End and Screwed-End Globe-Style Control Valves
S75.14-93	Face-to-Face Dimensions for Buttweld-End Globe-Style Control Valves (ANSI Classes 150, 300, 600, 900, 1500, and 2500)
S75.16-94	Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (ANSI Classes 900, 1500, and 2500)
S75.17-89	Control Valve Aerodynamic Noise Prediction
S75.19-89	Hydrostatic Testing of Control Valves (Formerly ASME/ANSI B16.37–80)
S75.20-91	Face-to-Face Dimensions for Separable Flanged Globe-Style Control Valves (ANSI Classes 150, 300, and 600)
S75.22-92	Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (ANSI Classes 150, 300, and 600)

MSS Standards

MSS-SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
MSS-SP-25	Standard Marking System for Valves, Flanges and Fittings
MSS-SP-42	Class 150 Corrosion Resistant Gate, Globe, Angle, and Check Valves with Flanged and Butt Weld Ends
MSS-SP-45	Bypass and Drain Connection Standard
MSS-SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components—Magnetic Particle Examination Method

MSS-SP-54	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components—Radiographic Examination Method
MSS-SP-55	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components—Visual Method
MSS-SP-60	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
MSS-SP-61	Pressure Testing of Steel Valves
MSS-SP-67	Buttefly Valves
MSS-SP-68	High Pressure-Offset Seat Butterfly Valves
MSS-SP-70	Cast Iron Gate Valves, Flanged and Threaded Ends
MSS-SP-71	Cast Iron Swing Check Valves, Flanged and Threaded Ends
MSS-SP-72	Ball Valves with Flanged or Butt-Welding Ends for General Service
MSS-SP-78	Cast Iron Plug Valves, Flanged and Threaded Ends
MSS-SP-80	Bronze Gate, Globe, Angle and Check Valves
MSS-SP-81	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
MSS-SP-82	Valve Pressure Testing Methods
MSS-SP-84	Valves—Socket-Welding and Threaded Ends
MSS-SP-85	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
MSS-SP-86	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
MSS-SP-88	Diaphragm Type Valves
MSS-SP-91	Guidelines for Manual Operation of Valves
MSS-SP-92	MSS Valve User Guide
MSS-SP-93	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components—Liquid Penetrant Examination Method
MSS-SP-94	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fit-

	tings and Other Piping Components—Ultrasonic Examination Method
MSS-SP-96	Guidelines on Terminology for Valves and Fittings
MSS-SP-98	Protective Epoxy Coatings for the Interior of Valves and Hydrants
MSS-SP-99	Instrument Valves
MSS-SP-100	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
MSS-SP-101	Part–Turn Valve Actuator Attachment—Flange and Driving Components Dimensions and Performance Characteristics
MSS-SP-102	Multi-Turn Valve Actuator Attachment—Flange and Driving Component Dimensions and Performance Characteristics
MSS-SP-105	Instrument Valves for Code Applications
MSS-SP-108	Resilient Seated-Eccentric Cast Iron Plug Valves

Refer to Chapter A.4 of this handbook for additional information on codes of construction and other standards. See App. E.10 for a listing of British, DIN, Japanese, and ISO codes, standards, and specifications related to piping, valves, flanges, fittings, and bolting.

CLASSIFICATION OF VALVES

The following are some of the commonly used valve classifications:

Classification Based on Mechanical Motion

Based on the mechanical or cyclical motion of the valve closure member, valves are classified as follows:

Linear Motion Valves. The valves in which the closure member, as in gate, globe, diaphragm, pinch, and lift check valves, moves in a straight line to allow, stop, or throttle the flow. Table A10.1 lists the valves based on motion of valve-closure member.

Rotary Motion Valves. When the valve-closure member travels along an angular or circular path, as in butterfly, ball, plug, eccentric- and swing check valves, the valves are called rotary motion valves. See Table A10.1.

TABLE A10.1 Classification of Valves Based on Motion

Valve type	Linear motion	Rotary motion	Quarter turn
Gate valve	X		
Globe valve	X		
Swing check valve		X	
Lift check valve	X		
Tilting-disc check valve		X	
Folding-disc check valve		X	
In-line check valve	X		
Stop check valve	X	X	
Ball valve		X	X
Pinch valve	X		
Butterfly valve		X	X
Plug valve		X	X
Diaphragm valve	X		
Safety valve	X		
Relief valve	X		

Notes: Tilting-disc check valves are in the same category as swing check valves in regard to motion of the disc.

When a swing check valve is provided with the external means to close and maintain the valve disc in a closed position, it can be used as a stop check valve.

Quarter Turn Valves. Some rotary motion valves require approximately a quarter turn, 0 through 90°, motion of the stem to go to fully open from a fully closed position or vice versa. Refer to Table A10.1.

Classification Based on Valve Size

Valve Size. Valve size is denoted by the nominal pipe size (NPS), which is equal to the size of valve-connecting ends or the flange-end size. In the metric system, valve size is designated by the nominal diameter (DN) of connecting pipe or the connecting flange ends. When a valve is installed with reducers on each end, the size of the valve will be equal to the size of the reducer-connecting ends attached to the valve. The valve size is not necessarily equal to the inside diameter of the valve.

It is a normal industry practice to categorize valves, based upon size, in two classification: small and large.

Small Valves. NPS 2 (DN 50) and smaller valves are called small valves. At times, NPS 2½ (DN 65) and smaller valves are referred to as small valves. As such, the size classification can vary and, therefore, it should not be considered a uniform industry practice.

Large Valves. NPS 2½ (DN 65) and larger valves are classified as large valves. As indicated earlier, NPS 2½ (DN 65) valves may be designated as small valves, depending on the criteria used in classifying small valves.

Classification Based on Pressure-Temperature Rating

Class Ratings. Pressure-temperature ratings of valves are designated by class numbers. Based on the material(s) of construction, the pressure-temperature ratings for each class are tabulated to provide the maximum allowable working pressures, expressed as gauge pressures, at the temperature shown. The temperature shown

TABLE A10.2 ASME B16.34 Classification of Valves and Limitations

Class	150	300	400	600	900	1500	2500	4500[1]
Standard[2]	X	X	X	X	X	X	X	X
Special[3]	X	X	X	X	X	X	X	X
Limited[4,5]	X	X	X	X	X	X	X	X
Intermediate[6]	X	X	X	X	X	X	X	X
Butt welding	X	X	X	X	X	X	X	X
Socket welding[4,7]	X	X	X	X	X	X	X	X
Flanged[8]	Std	Std	Std	Std	Std	Std	Std	
Threaded[4,7,9]	X	X	X	X	X	X	X	

[1] Class 4500 applies only to welding end valves.

[2] Valves conforming to the requirements of ASME B16.34, for standard class valves. Ratings shall not exceed the values shown in those Tables 2 having an identifying suffix ''A.'' (ASME B16.34).

[3] Threaded or welding-end valves which have successfully passed the examination required by Section 8 (of ASME B16.34) may be designated Special Class valves. Ratings shall not exceed the values shown in those Tables 2 having an identifying Suffix ''B.'' (ASME B16.34). Special Class ratings shall not be used for flanged-end valves.

[4] Welding- or threaded-end valves in sizes NPS 2-1/2 and smaller that conform to the requirements of Annex G (ASME B16.34) may be designated Limited Class valves. Limited Class ratings shall not be used for flanged end valves.

[5] Threaded-end valves rated above Class 2500 and socket-end valves rated above Class 4500 are not within the scope of ASME B16.34.

[6] A welding- or threaded-end valve may be assigned an intermediate pressure and temperature rating or Class, either Standard or Special, in accordance with paragraph 6.1.4 of ASME B16.34, provided all applicable requirements of this standard are met.

[7] Threaded and socket-welding-end valves larger than NPS 2-1/2 are beyond the scope of ASME B16.34.

[8] Flanged-end valves shall be rated as Standard Class.

[9] A class designation greater than Class 2500 or a rating temperature greater than 1000°F applied to threaded-end valves is beyond the scope of ASME B16.34.

TABLE A10.3 Valves Covered by MSS Standards

MSS Standard	Rating/class	Valve types	Size (NPS)	Material
MSS SP–42 Class 150 Corrosion Resistant Gate, Globe, Angle, and Check Valves with Flanged and Butt-Weld Ends	Class 150	a. Gates, (OS&Y)[1]	a. NPS ¼–24	A351; CF8, CF8M, CF8C, CF3, CF3M Alloy 20, CN7M A182 A240 A276 A479
		b. Globes, tee-, wye-pattern and angle, (OS&Y)	b. • NPS ¼–24 Globe and angle ■ NPS ½–24 wye-Pattern Globe	
		c. Check, lift, swing and wye-pattern	c. • NPS ¼–24 Lift check ■ NPS ½–24 Swing check	
MSS SP–67 Butterfly Valves	a. Class 25, 125, 150, 300, 400, 600, 900, 1500, 2500	a. Flangeless (wafer type), Single flange (lug type), and flanged-end valves	a. NPS 1½–72	Bronze (B16.24) Cast Iron (B16.1) Ductile Iron (B16.42) Materials per ASME B16.34
	b. Class[2] C606 rating	b. Grooved-end and shouldered-end valves	b. Pressure rating per ASME B16.34, B16.1, B16.24, B16.42, B16.47	
MSS SP–68 High-Pressure Butterfly Valves with Offset Design	ASME B16.34 ratings	Wafer, lug type	NPS 3–24 (DN 80–600) NPS 30–48 (DN 750–1200)	A126, Class B Brass Or Bronze
MSS SP–70 Cast-Iron Gate Valves, Flanged and Threaded Ends	125, 250 and 800 Hydraulic	Type I—Solid-wedge disc Type II—Split-wedge disc Type III—Double disc, parallel seat	a. NPS 2–48, flanged end b. NPS 2–6, threaded end	A126, Class B Brass Or Bronze
MSS SP–71 Gray-Iron Swing Check Valves, Flanged and Threaded Ends	125 and 250	Type I—Full waterway, metal to metal seats[3] Type II—Full waterway, composition to metal seats Type III—Clear waterway, metal to metal seats Type IV—Clear waterway, composition to metal seats	a. 2–24 (DN 50–600) flanged end b. 2–6 (DN 50–150)[4] threaded end	A126, Class B trim: Bronze Cast Iron Stainless Steel
MSS SP–72 Ball Valves with Flanged or Butt-Welding Ends for General Service	150, 300, 400, 900 per ASME B16.24 and ASME B16.5 150 & 300 per ASME B16.42	Ball valves Full port Regular port Reduced port	½ through 36	Carbon steel, alloy steel, stainless steel, ductile iron and bronze
MSS SP–78 Cast-Iron Plug Valves, Flanged and Threaded Ends	125, 250 and 800	Plug valves Flanged Threaded Lubricated Nonlubricated	• NPS 2–2 Flanged • NPS 2–6 Threaded	A126, A48, B62, B584, A47, A536, A197, A283

TABLE A10.3 Valves Covered by MSS Standards (Continued)

MSS Standard	Rating/class	Valve types	Size (NPS)	Material
MSS SP–80 Bronze Gate, Globe, Angle, and Check Valves	a. 125, 150, 200, 300, and 350 b. 150 and 300	a. Threaded and soldered ends b. Flanged ends	a. Threaded ends—⅛–3 Soldered ends—¼–3 b. Flanged ends—½–3	Bronze B61, B62, B124, B584, B371, B99, B16, B140, A494
MSS SP–81 Stainless-Steel, Bonnetless, Flanged Knife-Gate Valves	Valves for pressure not exceeding 150 psig @ temperature 32 to 150° F	Bonnetless, flanged knife-gate valves	2–24	Stainless steel or stainless-lined cast or fabricated A290, A351, A276, A743, A216, B62, A126
MSS SP–85 Cast-Iron Globe and Angle Valves, Flanged and Threaded Ends	125 and 250	Globe, angle, threaded, and flanged	NPS 2–12 flanged NPS 2–6 threaded	Cast iron A126, Class B
MSS SP–88 Diaphragm Type[5] Valves	Cat. A, 125 and 150 Cat. B ½–1 (200 psig) 1¼–2 (175 psig) 2½–4 (150 psig) 5 & 6 (125 psig) 8 (100 psig) 10 & 12 (65 psig) 14 & 16 (50 psig) Cat. C, Mfr. rating	Diaphragm type valves	½–16	Bronze B62 Cast iron A126, C1.B Malleable iron A47 Carbon steel A216, WCB Stainless steel A351 Ductile iron A395 Aluminum B26
MSS SP–99 Instrument Valves[6]	10,000 psi and lower @ 100°F	Valves needle, packless, ball, plug, check, and manifold	1 in and smaller	Steel and alloy Materials per ASME B16.34
MSS SP–105 Instrument Valves[6] for Code Applications	10,000 psi and lower @ 100°F	Valves needle, packless, ball, plug, check, and manifold	1 in and smaller	Steel and alloy Materials per ASME B16.34, B31.1, B31.3 ASME Section III
MSS SP–108 Resilient–Seated Cast-Iron, Eccentric Plug Valves	• 175 psig CWP[7], (NPS –112) • 150 psig CWP (NPS 14–72)	Plug valves, flanged, threaded, mechanical joint or grooved-end connection	3–72	Cast iron A126, Class B A48, Class 40 A536

[1] Outside screw and yoke.
[2] Valve ends shall conform to ANSI/AWWA C-606.
[3] Refer to figures in MSS SP–71.
[4] For equivalent metric (DN) sizes, refer to App. E2, E2M, and Table A1.1 (Chapter A1).
[5] Tables and annexes referenced are the ones in the standard.
[6] The application of valve type, size, rating, material of construction, and suitability for service are the responsibility of the purchaser and are outside the scope of this standard.
[7] Cold working pressure.

for a corresponding pressure rating is the temperature of the pressure-containing shell of the component. Items such as a piping system or a portion thereof, a pump, tank, heat exchanger, pressure vessel, valves, et cetera are considered components.

ASME B16.34, Valves—Flanged, Threaded, and Welding End is one of the most widely used valve standards. It defines three types of classes: standard, special, and limited. ASME B16.34 covers Class 150, 300, 400, 600, 900, 1500, 2500, and 4500 valves. It also allows valves to be classified as intermediate whose pressure-temperature ratings may fall within those listed for the standard and special class valves. See Table A10.2 for valve classifications and their limitations covered by ASME B16.34. Refer to Table A1.2 in Chapter A1 for metric equivalent (PN) of valve classifications.

Tables A10.3 and A10.4 provide a listing of valve classes covered by various commonly used valve standards published by the Manufacturers Standardization Society (MSS) and the American Petroleum Institute (API). Table A10.5 provides a brief summary of valves covered by AWWA standards.

Cold Working Pressure (CWP) Rating. Valves are also rated by the CWP rating. This rating represents the maximum allowable working pressure at the ambient temperature to which the valve may be subjected in normal service. Sometimes it is referred to as cold rating. The pressure rating of a valve at −20 to 100°F (−29 to 38°C), as listed in ASME B16.34 and other valve standards, is considered cold working pressure (CWP) or cold rating. CWP is also designated as the water-oil-gas (WOG) rating. Valves marked with CWP or WOG rating are primarily intended for applications in which the flow medium is maintained at ambient temperature, such as, but not limited to, water, oil, and gas distribution and transmission systems.

NFPA Rating. Valves to be used in fire protection systems in the United States are required to be rated for fire service. These valves are rated for 175 and 250 psi (1210 and 1725 kPa), and they are designated as UL (Underwriters Laboratories) listed and FM (Factory Mutual) approved. A valve rated for 175 psi (1210 kPa) for fire protection service may also be rated for higher pressure marked as CWP or Water Working Pressure (WWP) for general service. As such, a fire-rated valve may be used at pressures higher than fire service rating in applications termed as general service.

General Service Rating. The general service rating may be considered to be the equivalent of the CWP rating. Some valve manufacturers assign two ratings, fire rating and general service rating, to a valve. A UL-listed and FM-approved valve rated for 175 psig (1210 kPa) may have a general service rating of 400 psig (2760 kPa) at ambient temperature. It means that this valve can be used in a fire protection system having a maximum allowable working pressure of 175 psi (1210 kPa) or less, whereas it can be used in other services termed as general services and be subjected to a maximum allowable working pressure of 400 psig (2760 kPa). One must classify the service in accordance with the code of construction, as required. If the service does not fall within the jurisdiction of a code, then prudent engineering judgment may be followed in selecting the valve.

Steam Working Pressure (SWP) Rating. The SWP rating of a valve is intended to define the maximum working pressure corresponding to the steam temperature. A valve assigned a SWP rating must not be used in steam service at pressures and temperatures exceeding the rating.

Dual or Multiple Ratings. A valve may be assigned one or more ratings by the valve manufacturer. Ratings assigned must be marked on the valve. The marking

TABLE A10.4 Valves Covered by API Standards

API Standard	Rating/class	Valve types	Size	Materials
API Standard 526 Flanged Steel–Pressure Relief Valves	150, 300, 600, 900, 2500	a. Spring loaded b. Pilot-operated pressure relief valves (PORV)	a. Table 2–15 for spring-loaded Valves b. Table 16–29 for PORV	SA 216, Gr. WCB SA 217, Gr. WC SA 351, Gr. CF8M
API Standard 599 Metal Plug Valves, Flanged, and Welding Ends	150, 300, 400, 600, 900, 1500 and 2500 per ASME B16.34	Plug valves with flanged or butt-welding ends	NPS 1–24	Ductile iron (B16.42) A395, A126 and ASME B16.34 materials
API Standard 600 Steel Gate, Valves—Flanged and Butt-Welding Ends, Bolted, and Pressure-Seal Bonnets	150 through 2500	Gate valves	NPS 1–24	Material listed in ASME B16.34 A182, A217, A276, A351, A439, B473
API Standard 602 Compact Steel Gate Valves-Flanged, Threaded, Welding, and Extended-Body Ends	• Threaded-end, socket-welded end, or extended-body valves 800 or 1500 • Flanged end valves 150, 300, 600, or 1500 • Butt-welded end valves 150, 300, 600, 800, 1500	Gate valves a. Flanged and butt-welding b. Threaded and socket-welding	a. NPS 4 and smaller b. NPS 2½ and smaller	A105, A106, A182, A216, A217, A276, A312, A333, A335, A350, A351, A352, A582, B473
API Standard 594 Check Valves: Wafer, Wafer-Lug, and Double-Flanged Type	a. Class 125 and 250 b. Class 150 & 300 c. Class 400 & 600 d. Class 900 & 1500 e. Class 2500	Check valves	a. NPS 2–48 b. NPS 2–60 c. NPS 2–42 d. NPS 2–24 e. NPS 2–12	A182, A217, A351, A494, B473, B564
API Standard 603 Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves	150	Gate valves	NPS ½–12	ASME B16.34 Group 2 or 3 materials
API Standard 608 Metal Ball Valves—Flanged, Threaded, and Welding-End	a. 150 and 300 b. 150, 300, and 600	a. Butt-welding or flanged ends b. Threaded or socket-welding ends	a. NPS ½–12 b. NPS ½–2	Per ASME B16.34
API Standard 609 Butterfly Valves: Double-Flanged, Lug-and-Wafer Type	a. 125 or 150 b. 150, 300, and 600	a. Category A[1] b. Category B[2]	a. NPS 2–48 b. NPS 3–24	Ductile iron copper alloys B16.34 materials
API 6D Specification for Pipeline Valves	150, 300, 400, 600, 900, 1500, 2500	Gate, plug, ball, check flanged, or welded ends	Class 2500 (NPS 2–16) Class 1500 (NPS 2–16) Class 900 (NPS 2–36) Class 150–600 (NPS 2–60)	A216, A217, A351, A352, A487, A757, A105, A182, A350, A541, A181, A707

[1] Manufacturer's rated cold working pressure (CWP) butterfly valves, usually with concentric disc and seat configuration.
[2] Pressure-temperature rated butterfly valves that have an offset seat and either eccentric or concentric disc configuration.

TABLE A10.5 Valves Covered by AWWA Standards

AWWA[1] Standard	Rating/class	Valve types	Size	Material
AWWA C500a-95 Addendum to ANSI/ AWWA C500-93 AWWA Standard for Metal-Seated Gate Valves for Water Supply Service	200 psig (1380 kPa) for valves 12 in (300 mm) NPS and smaller, and 150 psig (1050 kPa) for valves with diameter 16 in (400 mm) NPS and larger[2]	a. NRS gate valves	a. 3 in (75 mm)–48 in (1200 mm)[4]	Iron body A126, A395, A536, A27
		b. (OS&Y) rising stem gate valves[3]	b. 3 in (75 mm)–12 in (300 mm)	
AWWA C501-92 AWWA Standard for Cast-Iron Sluice Gates		Sluice gate		Cast iron A126, A48
AWWA C504-94[5] AWWA Standard for Rubber-Seated Butterfly Valves	a. Class 150	a. Wafer valves	a. 3–20 in (75–500 mm)	Cast iron Ductile iron Alloy—cast iron A48, A126, A216, A436, A439, A536
	b. All classes	b. Short-body flanged valves	b. 3–72 in (75–1800 mm)	
	c. Class 75A, Class 75B, Class 150A and Class 150B[6]	c. Long-body flanged valves	c. 3–72 in (75–1800 mm)	
	d. ▪ Class 150B ▪ All classes	d. Mechanical joint-end valves	d. ▪ 3–24 in (75–600 mm) ▪ All sizes 30–48 in (750–1200 mm)	
AWWA C507-91 AWWA Standard for Ball Valves 6 in–48 in (150 mm–1200 mm)	150–300	Flanged end, tight shut-off, shaft or trunnion-mounted, full port, double- and single-seated ball valves	6 in–48 in (150 mm–1200 mm)	Gray iron Ductile iron Cast steel A27, A48, A126, A216, A351, A395

TABLE A10.5 Valves Covered by AWWA Standards (Continued)

AWWA[1] Standard	Rating/class	Valve types	Size	Material
AWWA C508-93 AWWA Standard for Swing-Check Valves for Waterworks Service, 2 in (50 mm) through 24 in (600 mm) NPS	a. 175 psig (1200 kPa) b. 150 psig (1030 kPa)	Swing check with mechanical joint or flanged ends	a. 2 in (50 mm)–12 in (300 mm) b. 16 in (400 mm)–24 in (600 mm)	Iron body A27, A47, A126, A395, A536
AWWA C509a-95 Addendum to ANSI/ AWWA C509-94 AWWA Standard for Resilient-Seated Gate Valves for Water Supply Service	• 200 psig (1380 kPa) for 3–12 in (75–300 mm size) • 150 psig (1034 kPa for 16 and 20 in (400 and 500 mm size)	Gate with a. Flanged end b. Mechanical joint ends c. Push-on joint ends d. Tapping-valve ends	3, 4, 6, 8, 10, 12, 16, 20 in (75, 100, 150, 200, 250, 300, 400, 500 mm)	Gray or ductile iron A27, A126, A395, A536
ANSI/AWWA C510-92 AWWA Standard for Double-Check Valve Black-Flow Prevention Assembly	150 psig (1034 kPa)	Double check valve	¾ in (19 mm) 10 in (254 mm)[7]	Bronze and gray iron B61, B62, B139, B584 A126, A276, A395, A536
ANSI/AWWA C512-92 AWWA Standard for Air-Release, Air Vacuum, and Combination Air Valves for Waterworks Service	Maximum working pressure of 300 psig (2070 kPa)	Air-release, air-vacuum, and combination air valves flanged or threaded ends	½ in (13 mm)–16 in (400 mm)	Gray cast iron or ductile iron A48, A126, A536

1. For detail scope, refer to applicable AWWA Standard.
2. Valves for operating pressure outside these limits are beyond the scope of this standard.
3. Gate valves with either double-disc gates having parallel or inclined seats, or solid-wedge gates. Flanges and mechanical joints per section 3.5 of this standard.
4. Valves 14 in (350 mm) NPS and 18 in (450 mm) are not covered by this standard.
5. Standard cover valves suitable for a maximum steady state fluid–working pressure of 150 psig (1034 kPa), a maximum steady state ΔP of 150 psi (1034 kPa) and maximum velocity 16 ft/sec (4.9 m/sec).
6. For classification A and B, reference section for definition of classification.
7. Reference Table 1 of the standard for complete details.

on the valve must be in accordance with the applicable valve standard or standards. A valve may comply with one or more valve standards. For example, a Class 600, NPS 4 (DN 100), butt-welding end, steel gate valve complying with ASME B16.34 may be marked as Class 800 valve in accordance with API Standard 603, provided the valve complies with the design and construction requirements of both ASME B16.34 and API 603. Some valve manufacturers may have proprietary design valves that are rated for specialty applications.

Dual- or multiple-rated valves may be used within the pressure-temperature rating(s) conforming to the valve standard referenced in the code of jurisdiction under which the system is designed and constructed. Dual- or multiple-rated valves have increased utility and broad market. The manufacturer benefits from reduced design and production costs.

MAJOR VALVE PARTS

Pressure Retaining Parts

Valve body, bonnet or cover, disc, and body-bonnet bolting are classified as pressure-retaining parts of a valve. The following provides a brief description of these parts:

Body. The valve body houses the internal valve parts and provides the passage for fluid flow. The valve body may be cast, forged, fabricated, or made by a combination of cast, forged, or fabricated portions. Valve bodies can be and are made from a variety of metals and alloys. Also, valve bodies can be and are made of nonmetals; however, these must be within certain size and pressure-rating limits.

The valve-body ends are designed to connect the valve to the piping or equipment nozzle by different types of end connections, such as butt or socket-welded, threaded, flanged or bolted, soldered, brazed, solvent cement joint, mechanical joint, or coupling. Refer to Table A10.6.

Bonnet or Cover. The bonnet or cover is fastened to the valve body to complete the pressure-retaining shell. In case of gate, globe, stop check, and diaphragm valves, it contains an opening for the valve stem to pass through. Usually, it contains a stuffing box. It provides access to valve internals, especially when the valve is installed. The top works of valves include bonnet, yoke, and operating mechanism. The bonnet is the base that supports the valve top works.

The valve bonnet is attached to the valve body by many different types of joints: bolted, pressure-seal joints—breach lock and standard pressure seal joints—threaded, welded, union joint, and clamp seal. Some valves have a bonnetless design in which valve body and bonnet are combined into one. This is also known as an integral bonnet.

The bolted bonnet design is commonly used with cast or ductile iron, cast or forged steel, and alloy valves, which are rated NPS 2½ (DN 65) and larger, and Class 600 and below. Valves with a pressure seal–bonnet design are usually manufactured in Class 600 and higher rating classifications and are considered superior in regard to the leaktightness of the body bonnet joint. Bolted bonnet designs are also produced in valves rated Class 900 and higher. The user needs to consider the potential consequences of flow-medium leakage through body bonnet joints and take the necessary measures to prevent or contain the leakage.

TABLE A10.6 Valves Body Materials and Available End Connections

Remarks	Flanged (FD)[1]	Welding BW	Welding SW	Threaded	Soldered	Brazed	Mechanical joint	Solvent cement	Remarks
Carbon steels	X	X	X	X			X		See Tables A10.2, 3, 4 & 5
Stainless steels	X	X	X	X			X		See Tables A10.2, 3, 4 & 5
Alloy steels	X	X	X	X			**X**		See Tables A10.2, 3, 4 & 5
Cast iron	X			X					See Tables A10.3, 4 & 5
Ductile iron	X			X					See Tables A10.3, 4 & 5
Bronze	X			X	X	X	X		See Tables A10.3, 4 & 5
Brass	X			X	X	X	X		
Copper	X			X	X	X	X		
Thermoplastics	X						X	X	Refer to ASME B16.40

[1] Flanged-end valves include flanged, wafer-and-lug–style valves, which are installed between flanges.

Bonnet or Cover Bolting. Bolting includes bolts, nuts, and washers. The bolting to be used must be made from materials acceptable for the application in accordance with the applicable code, standard, specification, or the governing regulation. Refer to the applicable valve standard for acceptable bolting materials.

Disc. The disc is the part which allows, throttles, or stops flow, depending on its position. In the case of a plug or a ball valve, the disc is called plug or a ball. A valve disc could be cast, forged, or fabricated. A disc is seated against the stationary valve seat or seats when the valve is in the closed position. It can be moved away from the valve seat(s) by motion of the valve stem, with the exception of check and safety-relief valves, in which the disc is moved away from its seat(s) by fluid flow and pressure.

At times some users do not consider the valve disc to be a pressure-retaining or -containing part. The reasoning advanced is that when the valve is in an open position, the disc does not perform a pressure-retaining or -containing functions. However, when the same valve is closed, the disc performs pressure-retaining functions. Refer to Table A10.7 for disc materials.

Valve Trim. The removable and replaceable valve internal parts that come in contact with the flow medium are collectively termed as valve trim. These parts include valve seat(s), disc, glands, spacers, guides, bushings, and internal springs. The valve body, bonnet, packing, et cetera that also come in contact with the flow medium are not considered valve trim.

TABLE A10.7 Selected Materials of Construction for Valves

Material nominal designation	Forgings		Castings		Bars		Tubular	
	Spec. No.	Grade	Spec. No.	Grade	Spec. No.	Grade	Spec. No.	Grade
C	A105		A216	WCB	A675 A105	70	A672	B70
C-Si 3 1/2Ni	A350	LF3	A216	WCC	A350	LF3	A106	C
C-1/2Mo			A217	WC5	A182	F2	A691	CM-75
1 1/4Cr-1/2Mo	A182	F11 Cl.2	A217	WC6	A182	F11 Cl.2		
2 1/4Cr-1Mo	A182	F22 Cl.3	A217	WC9	A182	F22 Cl.3		
5Cr-1/2Mo	A182	F5	A217	C5	A182	F5		
9Cr-1Mo	A182	F9	A217	C12	A182	F9		
18Cr-8Ni	A182 A182	F304 F304H	A351 A351	CF3 CF8	A182 A182	F304 F304H	A312 A312	TP304 TP304H
9Cr-1Mo-V	A182	F91	A217	C12A	A182	F91	A335	P91
16Cr-2Ni-2Mo 16Cr-12Ni-2Mo	A182	F316	A351 A351	CF3M CF8M	A182	F316	A312 A312	TP316 TP317
18Cr-8Ni 16Cr-12Ni-2Mo	A182 A182	F304L F316L			A182 A479 A182 A479	F304L 304L F316L 316L	A312 A312	TP304L TP316L
18Cr-10Ni-Ti	A182 A182	F321 F321H			A182 A479 A182	F321 321 F321H	A312 A312	TP321 TP321H
35Ni-35Fe-20Cr-Cb 28Ni-19Cr-Cu-Mo	B462	N08020	A351	CN7M	B473	N08020	B464 B468	N08020 N08020
33Ni-42Fe-21Cr	B564	N08800			B408	N08800	B163	N08800
54Ni-16Mo-15Cr 42Ni-21.5Cr-3Mo-2.3Cu	B574 B425	N10276 N08825			B574 B425	N10276 N08825	B622 B423	N10276 N08825

Valve trim parts may be constructed of assorted materials because of the different properties needed to withstand different forces and conditions. Bushings and packing glands do not experience the same forces and conditions as do the valve disc and seat(s). Flow-medium properties, chemical composition, pressure, temperature, flow rate, velocity and viscosity are some of the important considerations in selecting suitable trim materials. Trim materials may or may not be the same material as the valve body or bonnet.

API has standardized trim materials by assigning a unique number to each set of trim materials. Refer to Table A10.8 for API trim materials.

Nonpressure Retaining Parts. Valve seat(s), stem, yoke, packing, gland bolting, bushings, handwheel, and valve actuators are some of the major nonpressure-retaining parts of a valve.

Valve Seat(s). A valve may have one or more seats. In the case of a globe or a swing-check valve, there is usually one seat, which forms a seal with the disc to stop the flow. In the case of a gate valve, there are two seats; one on the upstream side and the other on the downstream side. The gate-valve disc or wedge has two seating surfaces that come in contact with the valve seats to form a seal for stopping the flow. Multiport plug and ball valves may have several seats, depending upon the number of ports in the plug or ball.

The valve leakage rate is directly proportional to the effectiveness of the seal between the valve disc and its seat(s). The valve standards MSS SP 61, API 598, and ASME B16.34 specify acceptable leak rates. A user may specify more or less restrictive leak rates to satisfy the application requirements.

Valve manufacturers have developed several designs of combination valve seats involving elastomer and metal seats that are effective in achieving the desired leaktightness, which is not readily accomplished with metal seats.

Valve seats may be integral, replaceable, or renewable seat rings. Small valves generally are provided with screwed-in, swaged-in, welded, or brazed-in valve seats. Large valves may have any of the seat designs listed for small valves, or have seats integrally cast or forged with the valve body and hardened by heat treatment or surfaced with hard material such as Stellite. Stellite is a trade name of the Deloro Company. There are other metals that can be used for hardening the seating surfaces.

Galling Prevention. In order to prevent or minimize galling of the valve disc and valve seats, it is common industry practice to maintain a hardness differential between the stationary seating surfaces of valve seats and the moving seating surfaces of the valve disc. The stationary valve seats are hardened slightly more than the disc-seating surfaces. When both the valve seats and the disc are hardened by use of Stellite, the valve is termed fully stellited. When only the seats are hardened by use of Stellite, the valve is called half stellited. Heat treatment is another method of hardening.

Valve Stem. The valve stem imparts the required motion to the disc, plug, or the ball for opening or closing the valve. It is connected to the valve handwheel, actuator, or the lever at one end and the valve disc on the other. In gate or globe valves, linear motion of the disc is needed to open or close the valve, while in plug, ball, and butterfly valves, the valve disc is rotated to open or close the valve. With the exception of stop-check valves, check valves do not have valve stems.

Rising Stem with Outside Screw and Yoke. The outermost part of the stem is threaded, while the portion of stem inside the valve is smooth. The stem threads are isolated from the flow medium by the stem packing. Two different styles of this design are available: one having the handwheel fixed to the stem so that they rise together, and the other having a threaded sleeve that causes the stem to rise through the handwheel. The rising stem with outside screw and yoke (O. S. & Y.) is a common design for NPS 2 (DN 50) and larger valves. Some codes, such as ASME B31.1, Power Piping, require that an outside screw-and-yoke design be used

TABLE A10.8 API Trim Materials

Trim number	Nominal trim	Seat surface material type (b)	Seat surface Typical specification (grade)			Stem/Bushing	
			Cast	Forged	Welded	Material type (b)	Typical specifications type
1	F6	13Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410	13Cr	ASTM A276 T410 or T420
2	304	18Cr-8Ni	ASTM A351 (CF8)	ASTM A182 (F304)	AWS A5.9 ER308	18Cr-8Ni	ASTM A276 T304
3	F310	25Cr-20Ni	*	ASTM A182 (F310)	AWS A5.9 ER310	25Cr-20Ni	ASTM A276 T310
4	Hard F6	Hard 13Cr	*	(f)	*	13Cr	ASTM A276 T410 or T420
5	Hardfaced	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	13Cr	ASTM A276 T410 or T420
5A	Hardfaced	Ni-Cr	*	*	(h)	13Cr	ASTM A276 T410 or T420
6	F6 and	13Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410	13Cr	ASTM A276 T410 or T420
	Cu-Ni	Cu-Ni	*	(k)	*	*	*
7	F6 and	13Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410	13Cr	ASTM A276 T410 or T420
	Hard F6	Hard 13Cr	*	(f)	*	*	*
8	F6 and	13Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410	13Cr	ASTM A276 T410 or T420
	Hardfaced	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	*	*
8A	F6 and	13Cr	ASTM A217 (CA15)	ASTM A182 (F6a)	AWS A5.9 ER410	13Cr	ASTM A276 T410 or T420
	Hardfaced	Ni-Cr	*	*	(h)	*	*
9	Monel	Ni-Cu alloy	*	MFG. Standard	*	Ni-Cu alloy	MFG. Standard

TABLE A10.8 API Trim Materials (Continued)

Trim number	Nominal trim	Seat surface material type (b)	Seat surface Typical specification (grade)			Stem/Bushing	
			Cast	Forged	Welded	Material type (b)	Typical specifications type
10	316	18Cr-8Ni	ASTM A351 (CF8M)	ASTM A182 (F316)	AWS A5.9 ER316	18Cr-8Ni	ASTM A276 T316
11	Monel and	Ni-Cu alloy	*	MFG. Standard	*	Ni-Cu alloy	MFG. Standard
	Hardfaced	Trim 5 or 5A	*	*	SEE TRIM 5 or 5A	*	*
12	316 and	18Cr-8Ni	ASTM A351 (CF8M)	ASTM A182 (F316)	AWS A5.9 ER316	18Cr-8Ni	ASTM A276 T316
	Hardfaced	Trim 5 or 5A	*	*	SEE TRIM 5 or 5A	*	*
13	Alloy 20	19Cr-29Ni	ASTM A351 (CN7M)	ASTM B473	AWS A5.9 ER320	19Cr-29Ni	ASTM B473
14	Alloy 20 and	19Cr-29Ni	ASTM A351 (CN7M)	ASTM B473	AWS A5.9 ER320	19Cr-29Ni	ASTM B473
	Hardfaced	Trim 5 or 5A	*	*	See trim 5 or 5A	*	*
15	Hardware	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	18Cr-8Ni	ASTM A276 T304
16	Hardfaced	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	18Cr-8Ni	ASTM A276 T316
17	Hardware	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	18Cr-10Ni	ASTM A276 T347
18	Hardfaced	Co-Cr A(g)	*	*	AWS A5.13E or R CoCrA	19Cr-29Ni	ASTM B473

Notes: (f) = Case hardened by nitriding to a thickness of 0.13 m (0.005 in) minimum. (h) = Manufacturer's standard hardfacing with a maximum iron content of 25%. (k) = Manufacturer's standard with 30 Ni minimum.

Trim Numbers and Alternate Trim Number

Specified trim numbers	Alternative trim number
1	8 or 8A
2	10
5A	5
6	8
8A	8

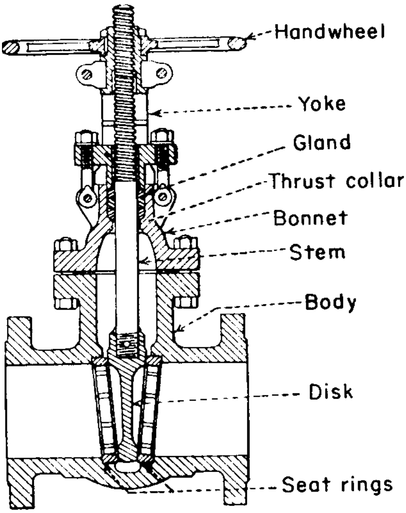


FIGURE A10.1 Rising-stem solid-wedge gate valve for 250-psig steam service.

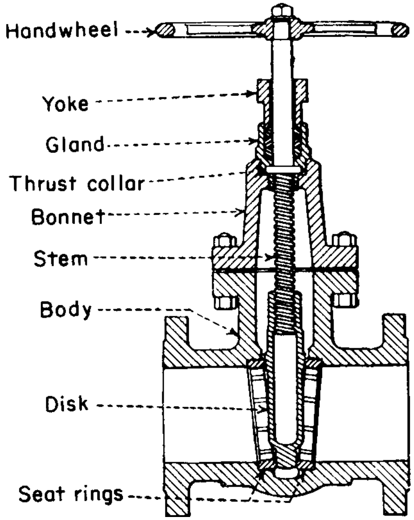


FIGURE A10.2 Nonrising stem gate valve for 250-psig steam service.

for NPS 3 (DN 80) and larger valves in pressures above 600 psi (4140 kPa). See Fig. A10.1.

Rising Stem with Inside Screw. The threaded part of the stem is inside the valve body, and the stem packing is along the smooth part that is exposed to the atmosphere outside. In this case the stem threads are in contact with the flow medium. When rotated, the stem and the handwheel rise together to open the valve. This design is commonly used in the smaller-sized low-to-moderate pressure gate, globe, and angle valves.

Nonrising Stem with Inside Screw. The threaded part of the stem is inside the valve and does not rise. The valve disc travels along the stem like a nut when the stem is rotated. Stem threads are exposed to the flow medium and, as such, are subjected to its impact. Therefore, this design is used where space is limited to allow linear stem movement, and the flow medium does not cause erosion, corrosion, or wear and tear of stem material. See Fig. A10.2.

Sliding Stem. This stem does not rotate or turn. It slides in and out of the valve to close or open the valve. This design is used in hand-lever–operated quick-opening valves. It is also used in control valves that are operated by hydraulic or pneumatic cylinders.

Rotary Stem. This is a commonly used design in ball, plug, and butterfly valves. A quarter-turn motion of the stem opens or closes the valve.

Stem Packing. Stem packing performs one or both of the following two functions, depending on the application:

- Prevent leakage of flow medium to the environment
- Prevent outside air from entering the valve in vacuum applications

Stem packing is contained in a part called the stuffing box. Packing rings are packed and compressed by tightening a packing nut or packing gland bolts. Compression must be adequate to achieve a good seal. Sometimes it requires regular inspection and tightening of packing rings, if required, to stop leakage. If this does not stop the leakage, the packing may need to be replaced. Belleville washers are used to maintain *live loading,* or the required compression of packing to achieve an effective seal against leakage.

A stuffing box may be provided with some or all of the following features as dictated by the valve application:

- Two sets of packing rings separated by an intermediate lantern ring
- A bottom junk ring
- A leak-off connection which detects leakage past the lower set of packing rings and is piped off to a leakage collection tank
- A blow-off connection for removal of packing rings using compressed air
- Belleville washer, live loading
- A steam-seal connection, where an external steam supply is used to prevent leakage from the packing chamber
- As an alternate to steam-seal connection, a grease or sealant-seal connection used to prevent loss of vacuum within the valve
- Inverted-V packing for vacuum service

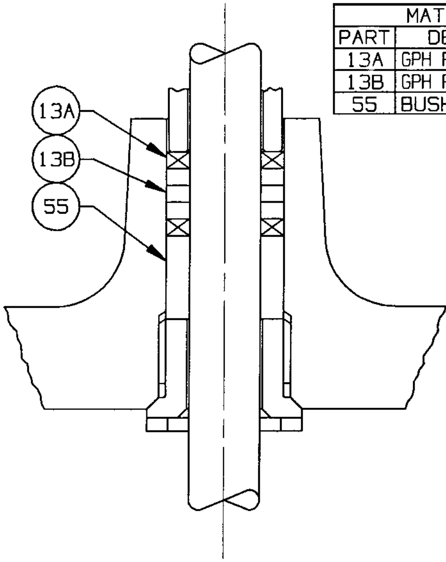
Figure A10.3a shows a standard graphite packing arrangement; Figure A10.3b depicts the inverted Teflon packing arrangement for vacuum service; Figure A10.3c reflects a lantern-ring packing arrangement; and Figure A10.3d shows a live-loading packing system.

Stem Protector. In the case of outside-screw-and yoke rising-stem gate and globe valves, a portion of the threaded valve stem is exposed to the outside environment when the valve is in the open position. Airborne dirt and other substances may be deposited on the exposed portion of the threaded stem and impair its smooth operation or shorten its stem-bushing life. A stem protector in the form of a clear plastic sleeve, tubing, or a pipe with a cap at the end is installed to protect the stem. The length of the stem protector must be adequate to allow full stem travel.

Back Seat. Back seat is comprised of a shoulder on the stem and a mating surface on the underside of the bonnet. It forms a seal when the stem is in the fully open position. It prevents leakage of flow medium from the valve shell into the packing chamber and consequently to the environment. Back seat enables dismantling of the valve beyond the bonnet, without disrupting the fluid flow through the valve. In addition, it allows the replacing of the stuffing box while the valve is in service.

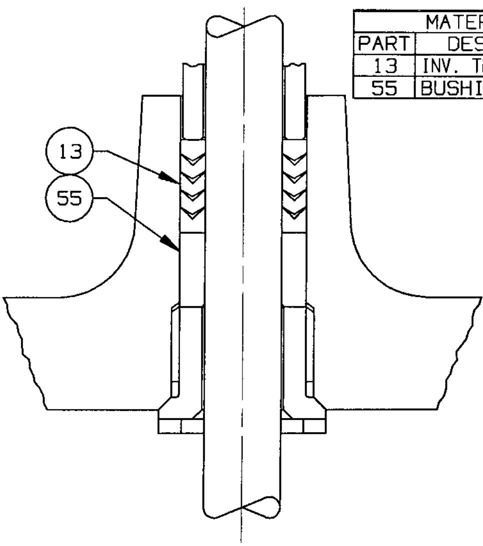
Yoke. Yoke is also called yoke arms. It connects the valve body or bonnet with the actuating mechanism. In some cases, it provides support for the gland-pull-down bolts. On many valves, the yoke and bonnet are designed as one-piece construction. The top of the yoke holds a yoke nut, stem nut, or yoke bushing and the valve stem passes through it. See Fig. A10.1.

For power-actuated valves, the yoke arms are of a heavier construction to provide adequate support to the actuator. The yoke usually has openings or windows to allow access to the stuffing box, position-switch dogs, actuator couplings, et cetera.



MATERIAL LIST		
PART	DESCRIPTION	QTY
13A	GPH PACKING BRAIDED	2
13B	GPH PACKING RIBBON	3
55	BUSHING	1

FIGURE A10.3a Standard graphite packing arrangement. *(Courtesy of Velan.)*



MATERIAL LIST		
PART	DESCRIPTION	QTY
13	INV. TEFLON PACKING	5
55	BUSHING	1

FIGURE A10.3b Inverted Teflon packing arrangement for vacuum service. *(Courtesy of Velan.)*

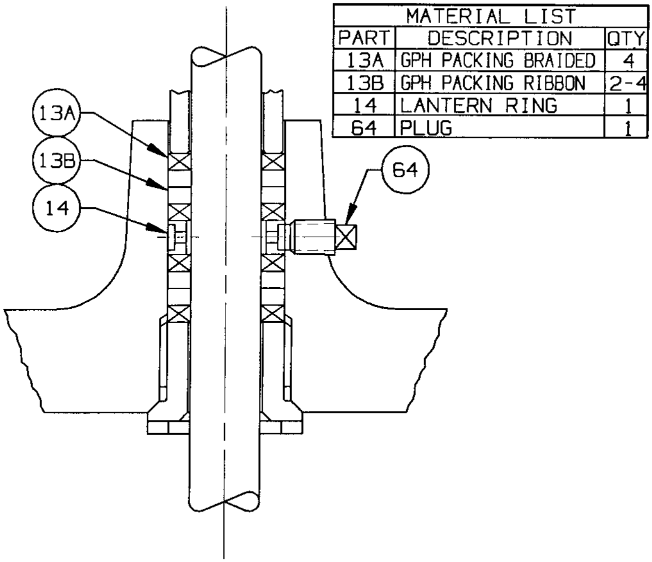


FIGURE A10.3c Lantern ring packing arrangement. *(Courtesy of Velan.)*

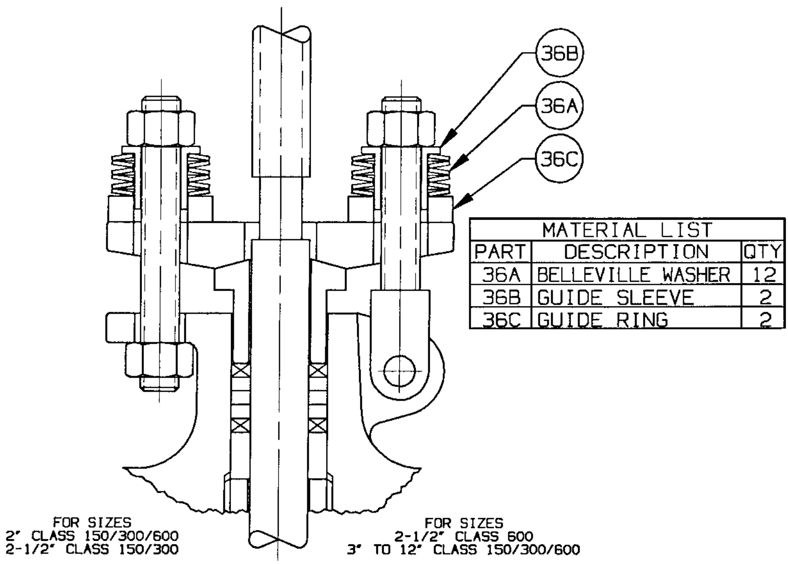


FIGURE A10.3d Live-loading packing arrangement. *(Courtesy of Velan.)*

Structurally, a yoke must be sturdy enough to withstand forces, moments, and torque developed by the actuator.

Yoke Bushings. An internally threaded nut held in the top of a yoke through which the valve stem passes. In gate and diaphragm valves, the yoke nut is turned and the stem travels up or down depending upon the direction of rotation of the nut. In the case of globe valves, the nut is held fixed and the stem is rotated through it. Usually, the yoke nut or yoke bushing is made of softer material than the stem for valves requiring medium effort to actuate. Valves which require greater effort to open or close are provided with anti-freeze yoke-sleeve bearings that minimize the friction between the hardened stem and the yoke bushing.

MATERIALS

Each of the valve standards listed in the beginning of this chapter lists material specifications which are acceptable for construction of valves covered by the standard. At times, a valve standard may make reference to other standard(s) which list the acceptable materials. One of the most widely used valve standards is ASME B16.34. It lists three groups of acceptable materials that are further subdivided into several subgroups.

Valve bodies, discs, and bonnets may be made from forgings, castings, or fabricated from combination of plate materials and others. Stems are usually produced from bar stock. Stems may be heat treated to provide needed hardness. Tubular materials are also used to make valve parts.

Valve bodies and trim materials may be totally different. For example, cast iron body valve may have stainless steel or bronze trim. Sometimes, the discs may be electroplated or lined to provide protection against corrosion.

Refer to Tables A10.3, A10.4, A10.5, A10.7, and A10.8 for lists of valve materials. For additional listing of acceptable valve materials, refer to valve standards and the code of jurisdiction.

VALVE CATEGORIES

Stop (Isolation) Valves

As the name implies, stop valves are used to stop flow or isolate a portion of the system until it is desirable to achieve flow downstream of the valve. The basic design requirement of stop valves is to offer minimum resistance to flow in the fully open position and to exhibit tight shut-off characteristics when fully closed. Gate, globe, ball, butterfly, plug, and diaphragm valves satisfy the above requirements in varying degrees and, therefore, are widely used in shut-off service. The actual type of valve selected is dictated by several parameters, including:

- Pressure drop
- Seat leakage
- Fluid properties

- System leakage
- Actuation requirements
- Initial cost
- Maintenance

Regulating Valves

Regulating valves are used extensively in piping systems to regulate the flow of fluid. Whether the desired effect is to control flow, pressure, or temperature, the task is accomplished by increasing or decreasing the flow through the valve in response to a signal from a pressure, flow, or temperature controller.

The primary requirement of a flow-control valve is to predictably regulate the flow with respect to its open position and impart the required pressure drop without sustaining damage. Specially designed globe, needle, butterfly, ball, plug, and diaphragm valves are capable of satisfying these requirements in varying degrees. The manufacturer's literature should be consulted for the limitations placed on a particular valve.

Backflow Prevention

Valves are generally used for the prevention of backflow. The valves are self-actuating and the valve disc is kept open by the forward flow of fluid. The valve disc is quickly closed by reverse flow. In certain applications, pneumatic actuators may be used to assist in the rapid closure of the valves on reversal of flow.

Pressure-Relief Devices

Pressure-relief devices are used to protect piping and equipment from being subjected to pressures that exceed their design pressures. Generally, the seating of relief valves is accomplished by a compressed spring, which exerts a force on the valve disc, pressing it against the valve seat. When the force exerted by the fluid on the valve disc exceeds the spring force, the valve automatically opens to release the excess pressure. Other designs incorporate a pilot valve, which uses system pressure to control the movement of the disc. Another type of pressure-relieving device, although not a valve, is a rupture disc. See Fig. A10.4. The rupture disc is designed to burst open at a predetermined pressure. A rupture disc cannot be reseated and, therefore, must be replaced once it has performed its relieving function. Rupture discs have the advantage of being leak tight up to the rupture pressure and of being capable of relieving large rates of flow. The set pressure of rupture discs cannot be adjusted.

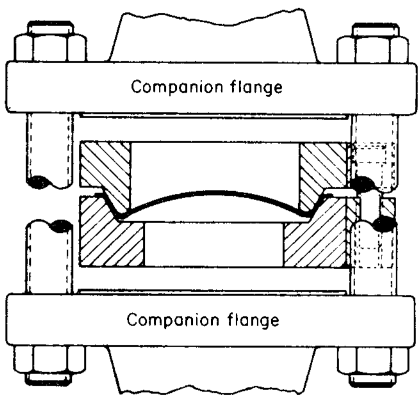


FIGURE A10.4 The rupture disc, a type of relief device.

VALVE TYPES

Gate Valves

Gate valves are primarily designed to serve as isolation valves. In service, these valves generally are either fully open or fully closed. When fully open, the fluid or gas flows through the valve in a straight line with very little resistance. Gate valves should not be used in the regulation or throttling of flow because accurate control is not possible. Furthermore, high-flow velocity in partially opened valves may cause erosion of the discs and seating surfaces. Vibration may also result in chattering of the partially opened valve disc. An exception to the above are specially designed gate valves that are used for low-velocity throttling; for example, guillotine gate valves for pulp stock.

Advantages of Gate Valves

1. They have good shutoff characteristics.
2. They are bidirectional.
3. The pressure loss through the valve is minimal.

Disadvantages of Gate Valves

The following are some of the disadvantages of gate valves that must be considered when selecting a gate valve for an application:

1. Gate valves are not quick opening or closing valves. Full-stem travel to open or close a gate valve requires many turns of its handwheel or an actuator.
2. Gate valves require large space envelope for installation, operation, and maintenance.
3. The slow movement of the disc near the full-closed position results in high-fluid velocities, causing scoring of seating surfaces, referred to as wire drawing. It also causes galling of sliding parts.
4. Some designs of gate valves are susceptible to thermal or pressure binding, depending upon the application.
5. In systems experiencing high-temperature fluctuations, wedge-gate valves may have excessive leakage past the seats due to changes in the angular relationship between the wedge and the valve seats caused by piping loads on the valve ends.
6. Repair or machining of valve seats in place is difficult.

Construction of a Gate Valve

Gate valves consist of three major components: body, bonnet, and trim. The body is generally connected to the piping by means of flanged, screwed, or welded connections. The bonnet, containing the moving parts, is joined to the body, generally with bolts, to permit cleaning and maintenance. The valve trim consists of the stem, the gate, the wedge, or disc, and the seat rings.

Two basic types of gate valves are the manufactured-wedge type and the double-disc type, and there are several variations within each of these types. A third type of gate valve, called conduit valve, is shown in Fig. A10.5.

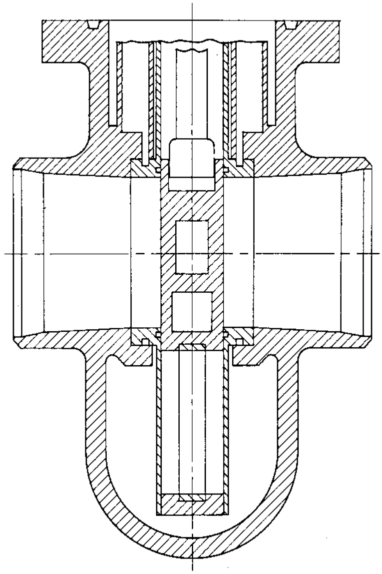


FIGURE A10.5 Conduit valve.

Wedge Type

There are four types of wedges: *solid, hollow, split, and flexible wedge.* The solid wedge is a single-piece solid construction. It does not compensate for changes in seat alignment due to pipe-end loads or thermal fluctuations. As such it is most susceptible to leakage. Except for NPS 2 (DN 50) and smaller, solid-wedge discs are generally not recommended for use in applications having temperatures in excess of 250°F (121°C). Solid-wedge gate valves are considered the most economical. Almost all small, NPS 2 (DN 50) and smaller, gate valves are solid-wedge gate valves. Solid-wedge gate valves are generally used in moderate to lower pressure-temperature applications. It is common practice to use cast iron or ductile iron solid-wedge gate valves in cold or ambient water lines.

A hollow wedge is a variation of solid wedge with the exception of a hole in the center. The hollow wedge travels along the stem when the threaded stem is rotated, thus opening or closing the valve port.

The flexible wedge is also one-piece construction like a solid wedge, but areas behind the seating surfaces are hollowed out to provide flexibility. This construction compensates for changes in seat alignment for improved seating while maintaining the strength of a solid wedge in the middle. This design offers better leaktightness and improved performance in situations with potential for thermal binding.

The split wedge consists of two-piece construction which seats between the tapered seats in the valve body. The two pieces of split wedge seat flat against the valve seats as the stem is moved downward, and they move away from the valve seats when the stem is pulled upward.

In the wedge or disc-wedge types either a tapered solid or tapered split wedge is used. In the rising stem valves (Fig. A10.1), the operating threads are out of direct contact with the fluid or gas. The nonrising stem type (Fig. A10.2) is preferred where space is limited and where the fluid passing through the valve will not corrode or erode the threads or leave deposits on the threads. Also, the nonrising stem valve is preferred for buried service. When the valve is closed, the gate disc is wedged on both sides against the seat. In split-wedge gate valves (Fig. A10.6), the two-piece wedge disc is seated between matching tapered seats in the body. This type is preferred where the body seats might be distorted due to pipeline strain.

In the rising-stem type of valve, the upper part of the stem is threaded and a nut is fastened solidly to the handwheel and held in the yoke by thrust collars. As the handwheel is turned, the stem moves up or down. In the nonrising stem valve, the lower end of the stem is threaded and screws into the disc, vertical motion of

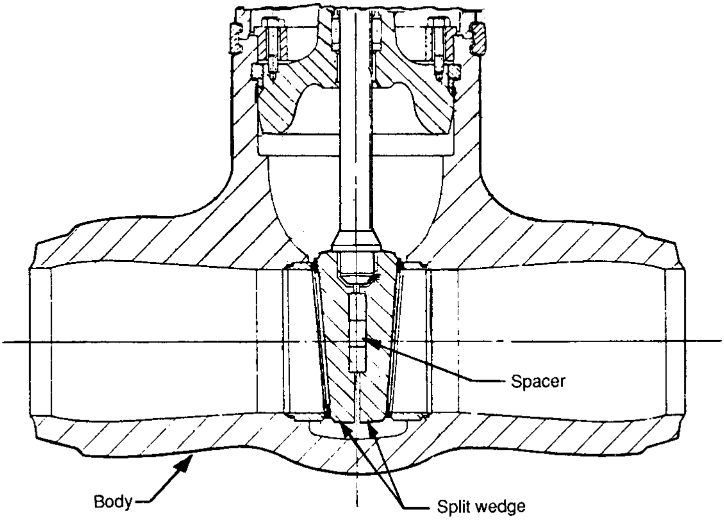


FIGURE A10.6 Split-wedge gate valve.

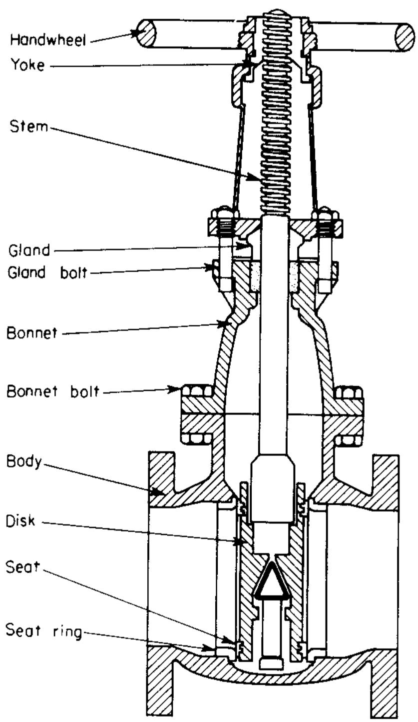


FIGURE A10.7a Double-disc rising-stem flanged-end gate valve for 150-psig service.

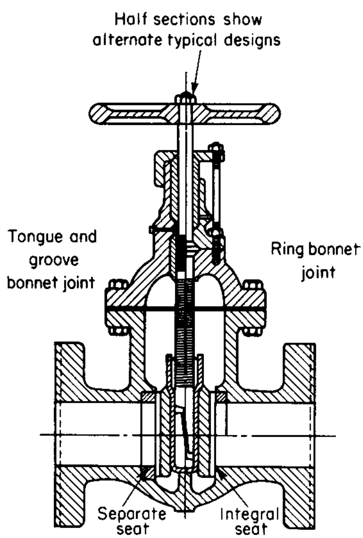


FIGURE A10.7b Double-disc nonrising-stem gate valve.

the stem being restrained by a thrust collar. The rising-stem valve requires a greater amount of space when opened. However, it is generally preferred because the position of the stem indicates at once whether the valve is open or closed. Nonrising stem valves are sometimes provided with an indicator for this purpose.

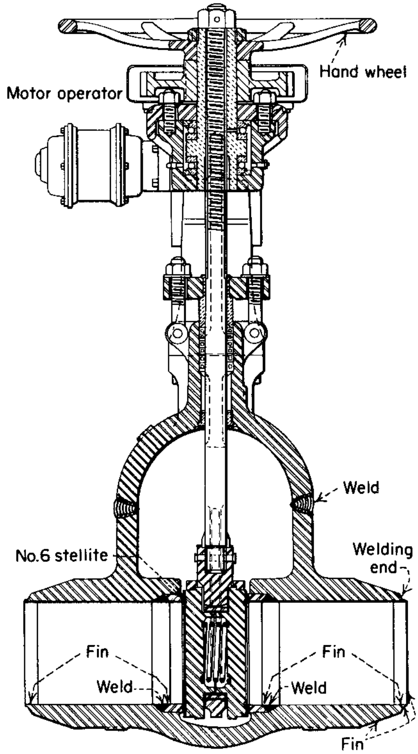


FIGURE A10.7c Parallel-seat gate valve showing welded construction for high-temperature service with welded-in seat ring.

Double-Disc Type

In the double-disc parallel-seat valves (Figs. A10.7a, A10.7b, and A10.7c), the discs are forced against the valve seats by a wedging mechanism as the stem is tightened. Some double-disc parallel-seat valves employ a design which depends mainly upon the fluid pressure exerted against one side of the disc or the other for its tightness. The major advantage of this type is that the disc cannot be jammed into the body, an action that might make it difficult to open the valve. This is particularly important where motors are used for opening and closing the valve.

Unlike the wedge in a wedge-gate valve, which only comes into contact with the seat rings when the valve is nearly closed, each disc in the parallel-seat valve slides against its seat while the valve is being opened or closed. Consequently, these components must be made of metals, which do not gall or tear when in sliding contact with each other. The double-disc parallel-seat gate valve is often favored for high-temperature steam service because it is less likely to stick in the closed position as a result of change in temperature.

Conduit Gate Valve

It is also referred to as a slide valve or parallel slide. The disc surfaces are always in contact with the body seats. Like the double-disc or parallel-seated gate valve, its disc seats against the downstream seat, depending on the flow direction. The inside diameter of a conduit gate valve is equal to the inside diameter of the connecting pipe. These valves are used in pipelines where pigs are run through the piping to perform cleaning of builtup deposits or debris. The typical applications of conduit valves include dirty river water with suspended solids or water with sludge or debris.

Conduit gate valves require a large-space envelope because of their longer disc proportions to accommodate both the blank and the spacer halves of the disc assembly. The valve is closed by moving the blank half downward to block the valve port. The spacer is accommodated in the sump part of the valve body. Refer to Fig. A10.5.

Conduit valves with Teflon (PTFE) seats can be used for low to intermediate temperatures (to 450°F or 232°C). Metal-seated valves may be used for temperatures up to 1000°F (538°C).

Thermal Binding

Thermal binding occurs when a valve is tightly shut off while the high temperature system is in operation. Later when the system is shut down and allowed to cool, thermal contraction of the valve seats move inward more than the wedge shrinkage. This can bind the wedge and seats tight enough to not allow the wedge to unseat or move when the handwheel or the valve actuator is activated to open the valve.

Parallel seated gate valves are most suitable for applications having potential for thermal binding. Split-wedge or flexible-wedge type gate valves are expected to perform better than solid-wedge gate valves when thermal binding is a concern.

Pressure Binding

Sometimes in high-temperature applications, the flow medium, such as water or steam, is trapped in the valve bonnet area when the valve is closed for system shutdown. The valves that do not permit this trapped liquid or the condensate to

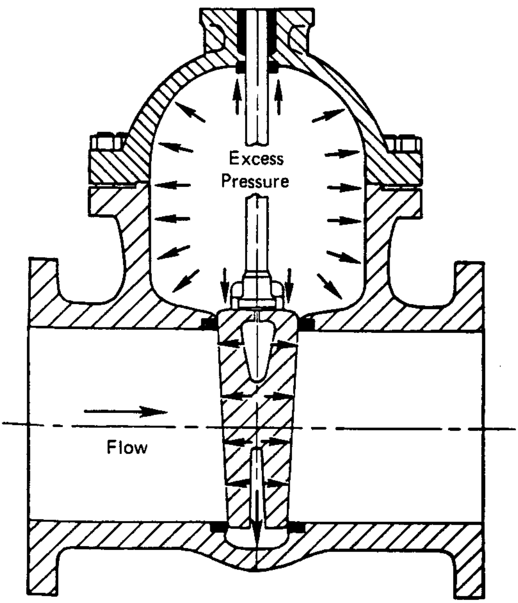


FIGURE A10.8a Pressure binding caused by built-up pressure in bonnet cavity.

reenter the piping either upstream or downstream may experience excessive pressures in the bonnet cavity when the system returns to operating temperature. This built-up pressure in the bonnet cavity can prevent the valve from opening and may cause damage to valve parts. See Fig. A10.8a.

Pressure binding may not occur if the leakage past the upstream seat is adequate to prevent overpressurization of the valve bonnet cavity. The following options offer solutions to this problem:

- Drill a small hole on the upstream side of the disc. See Fig. A10.8b.
- Install a small manual stop valve between the valve bonnet-neck and the upstream end of the valve. This valve shall be opened during startup.
- Install a small relief valve in the bonnet.
- Edward valves offer a new valve called ACEVE to solve this problem.

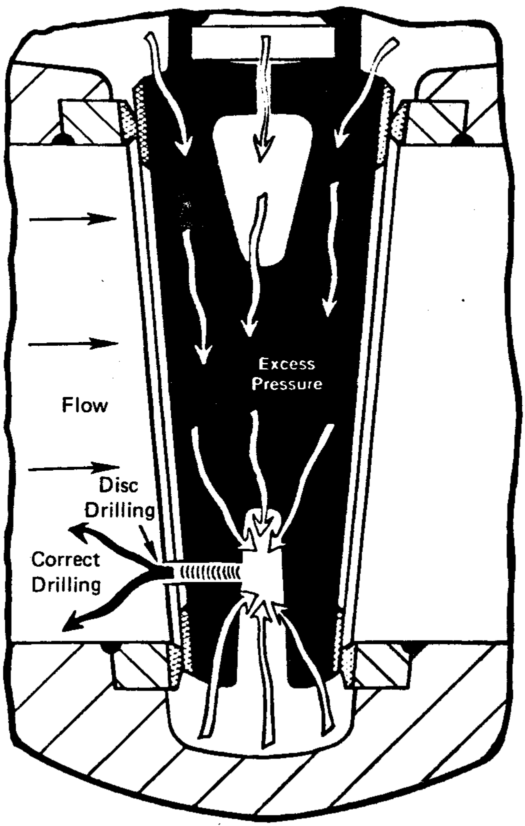


FIGURE A10.8b A hole on the upstream side of wedge to release built-up pressure in bonnet cavity.

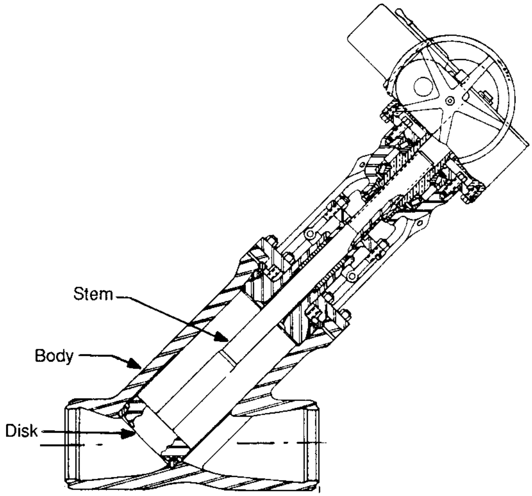


FIGURE A10.9 Large wye-pattern globe valve (with gear actuator).

Typical Gate Valve Applications

Socket or butt-welding end-gate valves in air, fuel gas, feedwater, steam, lube oil, and other systems are typical applications. Threaded-end gate valves may be used in air, gaseous, or liquid systems. Concern for leakage from threaded connection can be addressed by seal welding the threaded connection or by using thread sealants, as appropriate. In low-pressure and low-temperature systems such as fire protection systems' water piping or water distribution pipelines, flanged gate valves are commonly used.

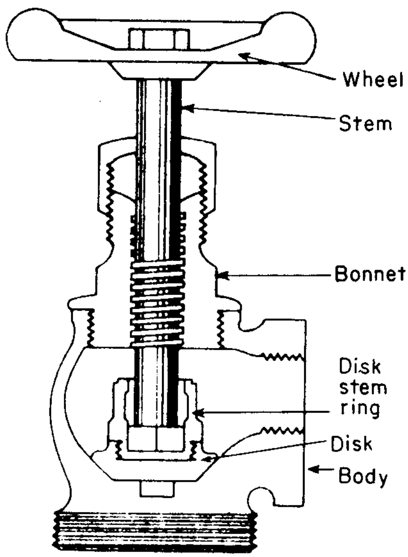


FIGURE A10.10 Angle globe valve with screwed ends.

Globe Valves

Conventional globe valves may be used for isolation and throttling services. Although these valves exhibit slightly higher pressure drops than straight-through valves (e.g., gate, plug, ball, etc.), they may be used where the pressure drop through the valve is not a controlling factor. Also, wye-pattern (Fig. A10.9) and angle-pattern (Fig. A10.10) globe valves exhibit improved flow characteristics over the tee-pattern (Fig. A10.11) globe valve. Because the entire system pressure exerted on the disc is transferred to the valve stem, the practical size limit for these valves is NPS 12 (DN 300). Globe valves larger than NPS 12 (DN 300) are an exception rather than the rule. Larger valves would require that enormous forces be exerted on the stem to open or close the valve under pressure. Globe valves in sizes up to NPS 48 (DN 1200) have been manufactured and used.

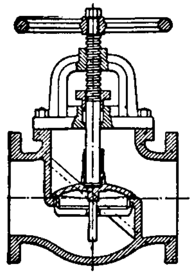


FIGURE A10.11 A typical large globe valve with flanged ends.

Globe valves are extensively employed to control flow. The range of flow control, pressure drop, and duty must be considered in the design of the valve to avert premature failure and to assure satisfactory service. Valves subjected to high-differential pressure-throttling service require specially designed valve trim. Generally the maximum differential pressure across the valve disc should not exceed 20 percent of the maximum upstream pressure or 200 psi (1380 kPa), whichever is less. Valves with special trim may be designed for applications exceeding these differential pressure limits.

Types of Globe Valves

Tee Pattern globe valves have the lowest coefficient of flow and higher pressure drop. They are used in severe throttling services, such as in bypass lines around a control valve. Tee-pattern globe valves may also be used in applications where pressure drop is not a concern and throttling is required. Refer to Fig. A10.11.

Wye Pattern globe valves, among globe valves, offer the least resistance to flow. They can be cracked open for long periods without severe erosion. They are extensively used for throttling during seasonal or startup operations. They can be *rod through* to remove debris when used in drain lines that are normally closed. Refer to Fig. A10.9.

Angle Pattern globe valves turns the flow direction by 90 degrees without the use of an elbow and one extra weld. They have a slightly lower coefficient of flow than wye-pattern globe valves. They are used in applications that have periods of pulsating flow because of their capability to handle the slugging effect of this type of flow. Refer to Fig. A10.10.

Construction of a Globe Valve

A typical large globe valve with flanged ends is illustrated in Fig. A10.11, and a large wye-pattern globe is illustrated in Fig. A10.9. Globe valves usually have rising stems, and the larger sizes are of the outside screw-and-yoke construction. Components of the globe valve are similar to those of the gate valve. This type of valve has seats in a plane parallel or inclined to the line of flow.

Maintenance of globe valves is relatively easy, as the discs and seats are readily refurbished or replaced. This makes globe valves particularly suitable for services which require frequent valve maintenance. Where valves are operated manually, the shorter disc travel offers advantages in saving operator time, especially if the valves are adjusted frequently.

The principal variation in globe-valve design is in the types of discs employed. Plug-type discs have a long, tapered configuration with a wide bearing surface. This type of seat provides maximum resistance to the erosive action of the fluid stream. In the composition disc, the disc has a flat face that is pressed against the seat opening like a cap. This type of seat arrangement is not as suitable for high differential pressure throttling.

The conventional disc, in contrast to the plug type, provides a thin contact between the taper of the conventional seat and the face of the disc. This narrow contact area tends to break down hard deposits that may form on the seats and facilitates pressure-tight closure. This arrangement allows for good seating and moderate throttling.

In cast-iron globe valves, disc and seat rings are usually made of bronze. In steel-globe valves for temperature up to 750°F (399°C), the trim is generally made of stainless steel and so provides resistance to seizing and galling. The mating faces are normally heat-treated to obtain differential hardness values. Other trim materials, including cobalt-based alloys, are also used.

The seating surface is ground to ensure full-bearing surface contact when the valve is closed. For lower pressure classes, alignment is maintained by a long disc locknut. For higher pressures, disc guides are cast into the valve body. The disc turns freely on the stem to prevent galling of the disc face and seat ring. The stem bears against a hardened thrust plate, eliminating galling of the stem and disc at the point of contact.

Advantages of a Globe Valve

The following summarizes the advantages of globe valves:

1. Good shutoff capability
2. Moderate to good throttling capability
3. Shorter stroke (compared to a gate valve)
4. Available in tee, wye, and angle patterns, each offering unique capabilities
5. Easy to machine or resurface the seats
6. With disc not attached to the stem, valve can be used as a stop-check valve.

Disadvantages of a Globe Valve

The following are some shortcomings inherent in globe valves:

1. Higher pressure drop (compared to a gate valve)
2. Requires greater force or a larger actuator to seat the valve (with pressure under the seat)
3. Throttling flow under the seat and shutoff flow over the seat

Typical Applications of Globe Valves

The following are some of the typical applications of globe valves:

1. Cooling water systems where flow needs to be regulated
2. Fuel oil system where flow is regulated and leaktightness is of importance.

3. High-point vents and low-point drains when leaktightness and safety are major considerations.
4. Feedwater, chemical feed, condenser air extraction, and extraction drain systems.
5. Boiler vents and drains, main steam vents and drains, and heater drains.
6. Turbine seals and drains.
7. Turbine lube oil system and others.

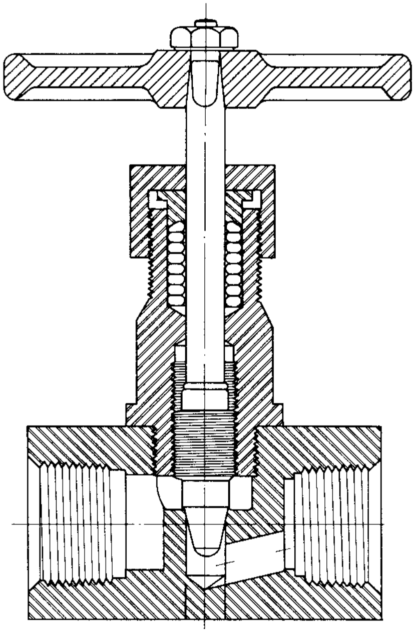


FIGURE A10.12 Needle valve for accurate throttling of flow.

Needle Valves

Needle valves generally are used for instrument, gauge, and meter line service. Very accurate throttling is possible with needle valves and, therefore, they are extensively used in applications that involve high pressures and/or high temperatures. In needle valves (Fig. A10.12), the end of the stem is needle point.

Check Valves

Check valves are designed to pass flow in one direction with minimum resistance and to prevent reverse or backflow with minimal leakage. The principal types of check valves used are the tee-pattern lift check, the swing check, the tilting-disc check, the wye-pattern lift check, and the ball check, illustrated in Figs. A10.13 to A10.17, respectively.

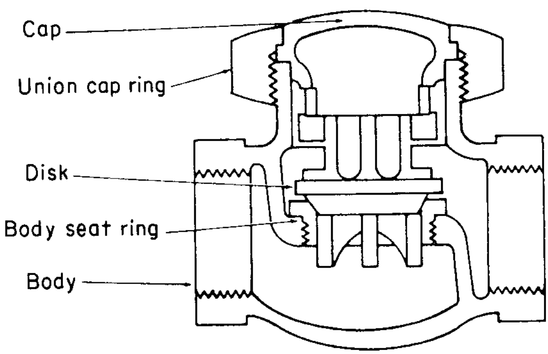


FIGURE A10.13 Lift check valve.

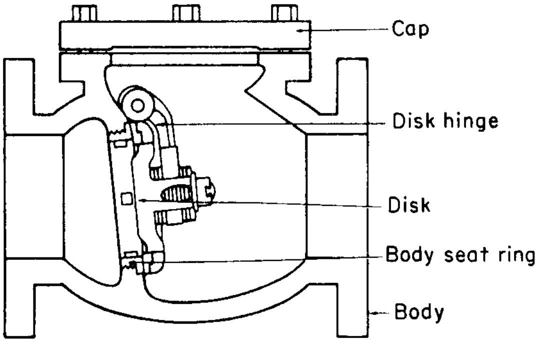


FIGURE A10.14 Swing check valve.

Construction of a Check Valve

A basic check valve consists of a valve body, bonnet or cover, and a disc which is attached to a hinge and swings away from the valve seat to allow fluid to flow in the forward direction, as in a swing- or tilting-disc check valve, and returns to valve seat when upstream flow is stopped. Thus, reverse flow is prevented. In folding-disc check valves, the disc consists of two halves attached in the middle. The two halves fold backward when upstream flow is initiated. Activated by a spring, the two halves quickly close the flow path when upstream flow ceases. In the case of lift-check valves, the disc is in the form of a piston which is moved out of the flow path by upstream flow and returns to the valve seat by gravity to stop back flow. Ball-check valves have a disc in the form of a ball.

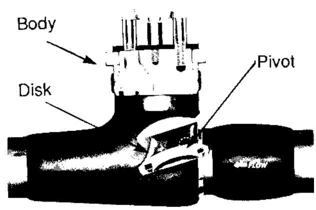


FIGURE A10.15 Tilting-disc check valve. (*Courtesy BTR Inc./Edward Valve*)

Check valves are available in sizes from NPS ¼ (DN 6) through NPS 72 (DN 1800). Other sizes may be made available to meet specific size requirements. Depending upon the design requirements of a piping system, a check valve may have butt welding, socket welding, threaded, or flanged ends.

Advantages of Check Valves

They are self-actuated and require no external means to actuate the valve either to open or close. They are fast acting.

Disadvantages of Check Valves

The following are some of the disadvantages that are attributed to check valves:

1. Since all moving parts are enclosed, it is difficult to determine whether the valve is open or closed. Furthermore, the condition of internal parts cannot be assessed.

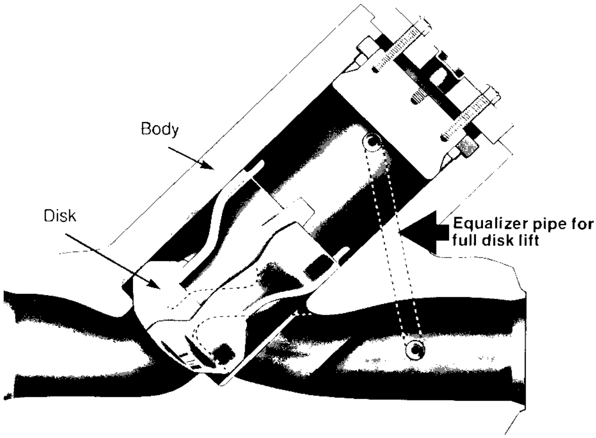


FIGURE A10.16 Wye-pattern lift check valve. (*Courtesy, BTR Inc./ Edward Valve*)

2. Each type of check valve has limitations on its installation configurations.

3. Valve disc can stick in open position.

Types of Check Valves

There are several types of check valves having varying body configurations. The following are some commonly used types of check valves:

Swing Check Valve. In swing check valves, the disc is unguided when it moves to fully open position or to fully closed position. Many different disc and seat designs are available to satisfy requirements of varying applications. Soft-seated–swing check valves provide improved leaktightness compared to metal-to-metal seating surfaces. Combination seats consisting of a metal seat ring with resilient insert also offer better leaktight characteristics. The seating angle, the angle between the seat and the vertical plane, may vary from 0 to 45 degrees. Vertical seats have a 0° angle. Larger seat angles reduce the disc travel, resulting in quick closing, thus minimizing the possibility of water hammer. Usually the seat angles are in the range of 5 to 7 degrees.

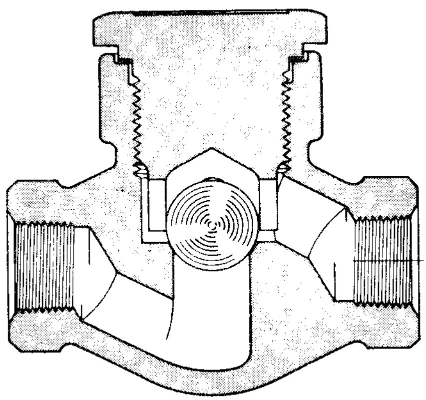


FIGURE A10.17 Ball check valve.

Lift Check Valve. Lift check valves are particularly adapted for high-pressure service where velocity of flow is high. In lift check valves, the piston disc is accurately guided by long contact and a close sliding fit with the perfectly centered dash pot. The walls of the piston and dash pot are of approximately equal thickness. Large steam jackets are located outside of the dash pot and inside the piston to eliminate sticking because of differential expansion. The seat ring is of a barrel-type design of heavy uniform cross-section. It is normally screwed in and seal welded. The flow opening is full port size. Refer to Figs. A10.13 and A10.16.

The seat design of a lift-check valve is similar to a globe valve. The disc is usually in the form of a piston or a ball. The ball-lift check valves are used in highly viscous fluid service. These valves have superior leaktight characteristics to those of swing-check valves.

The piston type lift check valves have a tendency to stick in the open position when service fluid has sediment trapped above the piston. Large lift check valves are furnished with an equalizer line between the chamber above the disc and the downstream side of the valve.

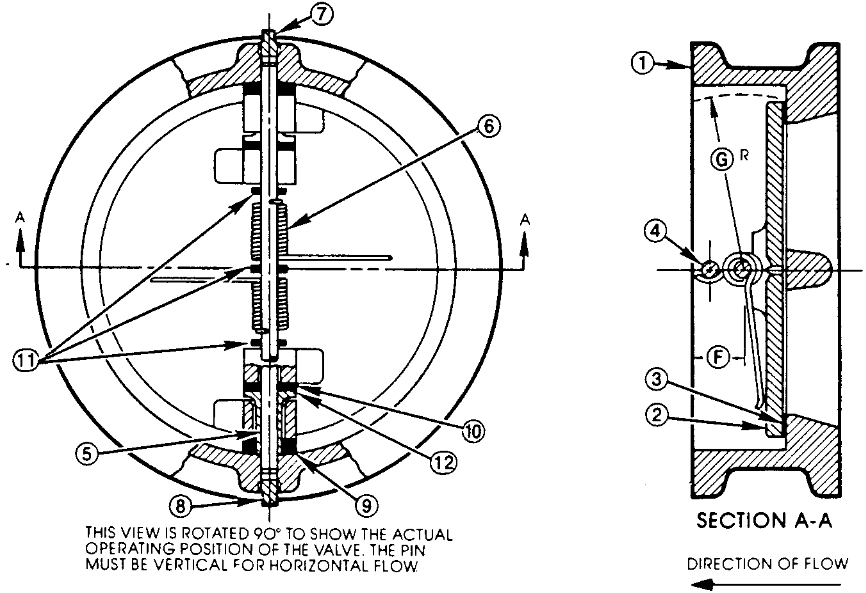
Tilting Disc Check Valve. The tilting-disc check valve is designed to overcome some of the weaknesses inherent in conventional swing check valves. A combination of design features enables the valve to open fully and remain steady at lower flow velocities and to close quickly upon cessation of forward flow. The dome-shaped disc floats in the flow with fluid on both bottom and top of its surfaces, thus it has minimum dashpot effect. It performs well in pulsating, turbulent, and high-velocity flows. These attributes prolong the valve's lift and reduce flow-induced dynamic loads on the piping system. Refer to Fig. A10.15.

Folding Disc Check Valves. This valve is also referred to as *double-disc* or *split-disc* check valve. Refer to Fig. A10.18. It is manufactured in wafer-body pattern and is available with soft or hard seats. It is very popular in low-pressure liquid and gaseous services. Its lightweight compact construction makes it a preferable check valve when space and convenience are important.

Vertical or In-Line Check Valve. These valves are available in two configurations: in-line ball check and fully guided disc with soft or hard seats. In-line ball check valves can be used in both vertical and horizontal lines. The fully guided disc in-line check valves must be provided with a spring-assist closure when used in horizontal lines. In vertical lines, the guided disc in-line check valves may or may not be provided with spring-assist closure. The spring-assist closure not only assists in closing the valve quickly, it minimizes the possibility of water hammer by preventing flow reversal.

They can be used in applications having pulsating flows, such as in a discharge line of a reciprocating compressor. Because they are compact in size, they are ideal for application in tight spaces.

Stop Check Valve. A stop check valve can either be used as a unidirectional check valve or as an isolation (stop) valve like a gate or globe valve. During normal operation of a system, these valves are used as a regular check valve; however, when needed, these valves can be closed with the help of a screw-down stem which is not fastened to the valve disc. The stem, when fully screwed down, holds the free-floating disc against the valve seat, just as in a gate or a globe valve. These valves are available in tee-pattern, wye-pattern, angle-pattern, and inclined pattern. The swing-and-piston lift-disc design check valves are commonly used as stop check valves. Refer to Figs. A10.19a and A10.19b.



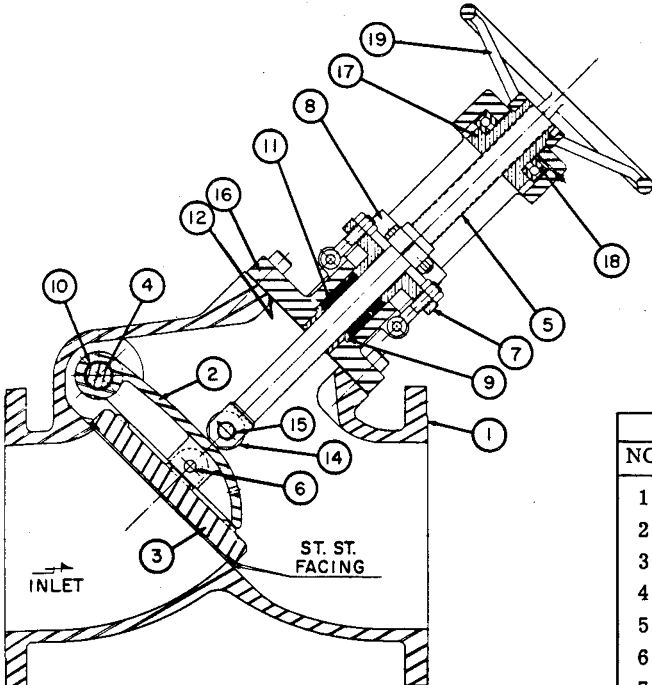
ITEM NO	PART NAME
1	BODY
2	PLATE
3	SEAL*
4	STOP PIN
5	HINGE PIN
6	SPRING**
7	STOP PIN RET.
8	HINGE PIN RET.
9	BODY BEARING
10	PLATE BEARING
11	SPRING BEARING
12	SUP. SLEEVE***

*Integral part of body.

**Independent springs available in valve sizes 6″ and larger only.

***Independent plate suspension available in valve sizes 24″ and larger only.

FIGURE A10.18 Folding-disc check valve.



LIST OF PARTS

NO.	NAME OF PART	NO.	NAME OF PART
1	Body	11	Packing
2	Disc Arm	12	Gasket
3	Disc	13	Shaft Plug (Not Shown)
4	Shaft	14	Roller
5	Stem	15	Roller Pin
6	Disc Pin	16	Comb. Cover & Yoke
7	Gland	17	Stem Nut
8	Anti-Rotation Device	18	Thrust Bearing
9	Cover Bushing	19	Handwheel
10	Shaft Bushing		

FIGURE A10.19a Swing-disc stop check.

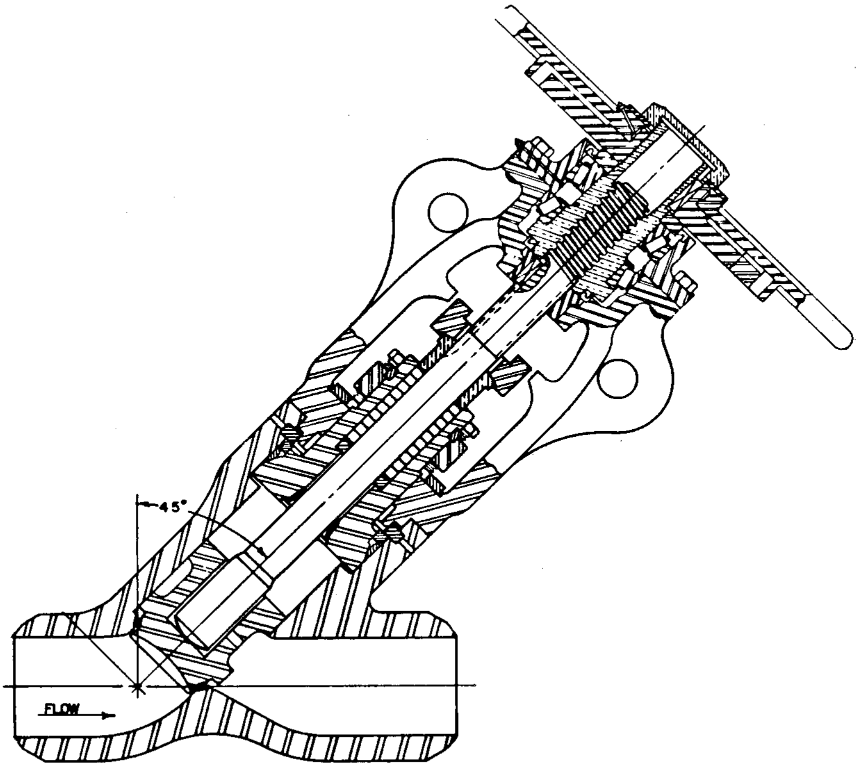


FIGURE A10.19b Wye-pattern stop check.

Application Considerations

The force of gravity plays an important role in the functioning of a check valve and, therefore, the location and orientation of the check valve must always be given consideration. Lift and ball check valves must always be placed so that the direction of lift is vertical. Swing checks must be located to ensure that the disc will always be closed freely and positively by gravity.

The flow velocity of the fluid through the valve has a significant effect on the life of the check valve. The valve should be sized such that the fluid velocity under normal conditions is sufficient to keep the disc fully open and pressed against the stop. This minimizes disc fluttering, which is the primary cause of valve failure.

Also, a check valve should not be located immediately downstream of a source of turbulence, such as a pump, elbow, control valve, or a tee-branch connection. It is recommended that manufacturer's recommendations be followed to provide the required straight run of pipe upstream of the check valve. Some manufacturers recommend 8-to-10 pipe-diameter length of straight run of pipe upstream of the valve. Sometimes, the layout and the space available may not allow compliance to manufacturer's recommendations. Alternatives must be evaluated and the most reasonable and feasible approach be implemented.

A swing check valve may be used in the vertical run of a pipe only when the

TABLE A10.9 Application of Check Valves

Type flow	Media type	Velocity range FPS (m/s)	Recommended check valve type
Uniform with insignificant reversal	Water or oil	1 to 6 (0.3 to 2)	Swing check w/ lever and ctr wt.
	Steam, water, gas	7 to 100 (2 to 30)	Simple swing
Uniform	Water or oil	5 to 10 max (1.5 to 3)	In-line guided disc
Pulsating	Air or gas	5 to 10 max (1.5 to 3)	In-line guided disc with cushion chamber
Uniform with normal reversal	Water or oil	7 to 10 (2 to 3)	Swing with spring assist to close
Uniform with severe reversal	Water or oil	7 to 10 (2 to 3)	Swing with dashpot
Uniform or pulsating	Steam, water or gas	8 to 160 (2.5 to 50)	Tee- or inclined-pattern lift
Uniform or pulsating (severe reversal)	Steam, water or gas	10 to 160 (3 to 50)	Tee-pattern lift with dashpot
Uniform	Steam, water or gas	12 to 250 (4 to 75)	Tilting disc
Uniform or pulsating	Steam, water, gas, oil	20 to 250 (6 to 75)	Wye-pattern lift
Uniform or pulsating (severe reversal)			Wye-pattern lift with dashpot

flow is upward. In addition, the flow velocity and the fluid pressure must be adequate to overcome the disc weight and swing it to the fully open position. In-line ball check valves are suitable for application in horizontal or vertical lines.

When the flow is suspected to be pulsating and low, use of a swing check valve is not recommended. Due to the continuous flapping of the swing disc against the seat, valves suffer considerable damage, and at times the swing discs can come loose.

Table A10.9 summarizes preliminary application guidelines for selection of a suitable type of check valve. The user must evaluate specific application features to determine the right valve for the application.

Typical Applications of Check Valves. Table A10.9 provides a brief summary of different types of check valves and their typical applications. The preliminary guidelines of this table may be used to determine the suitable check valve for an application, considering the specifics of the application.

Ball Valves

The ball valve (Fig. A10.20) is a quarter-turn valve suitable for clean gas, compressed air, and liquid service. They also can be used for slurry service, but provisions for

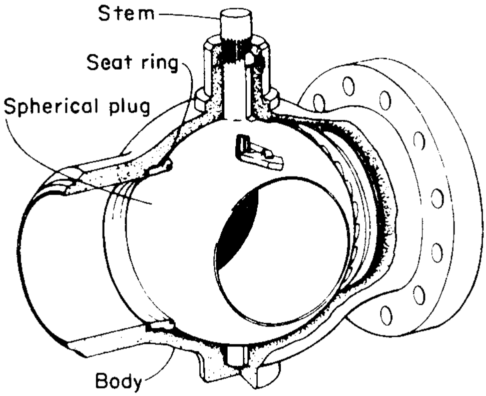


FIGURE A10.20 Ball valve in closed position.

prevention of *crud* buildup must be made. The use of soft-seat materials such as nylon, delrin, synthetic rubbers, and fluorinated polymers imparts excellent sealing ability. With fluorinated polymer seats, ball valves can be used for service temperatures ranging from −450 to 500°F (−270° to 260°C); with graphite seats, service temperatures to 1000°F (538°C) or even higher are possible. Also, with metal-backing seats, the valves can be used in fire-safe services. Ball valves are similar to plug valves in operation. They are nonbinding and provide leak-tight closure. The valves exhibit negligible resistance to flow because of their smooth body and port.

Construction of a Ball Valve

Major components of the ball valve are the body, spherical plug, and seats. Ball valves are made in three general patterns: *venturi port, full port,* and *reduced port.* The full-port valve has an inside diameter equal to the inside diameter of the pipe. In the venturi and reduced-port styles, the port is generally one pipe size smaller than the line size. Stem sealing is accomplished by bolted packing glands and O-ring seals. Valves are also available with a lubricant-seal system that is similar to that available for plug valves. A typical lubrication system is illustrated in Fig. A10.21.

A ball valve may be unidirectional, bidirectional, or multidirectional, depending on the number of valve ports and the number of valve seats. Therefore, ball valves are referred to as 2-way, 3-way, 4-way, or 5-way multiport valves. A 2-way ball valve with a single seat will be unidirectional with the flow direction indicated. Even a 3-way, 4-way, or 5-way ball valve can be unidirectional when flow must

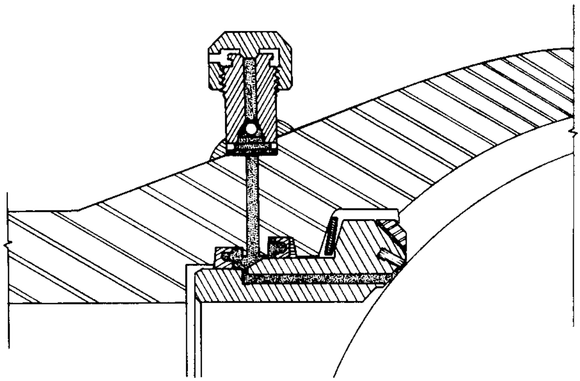


FIGURE A10.21 Lubricant-seal system in a ball valve.

enter through a designated port. A 2-way ball valve provided with two seats, one on the upstream side and the other on the downstream side of the ball, is termed a bidirectional valve. Multiple-port ball valves permit flows in more than one direction, thus eliminating the need for several valves.

Ball valves are manufactured in several different body configurations: *top entry, side entry, split body,* and *three-piece body.* The valve ends are available as butt-welding, socket welding, flanged, threaded, soldering, or brazing ends.

Ball valves are manufactured in high- and low-pressure classifications. The advances in ball valve designs have made it possible to use these valves in high-pressure and high-temperature applications.

Types of Ball Valves

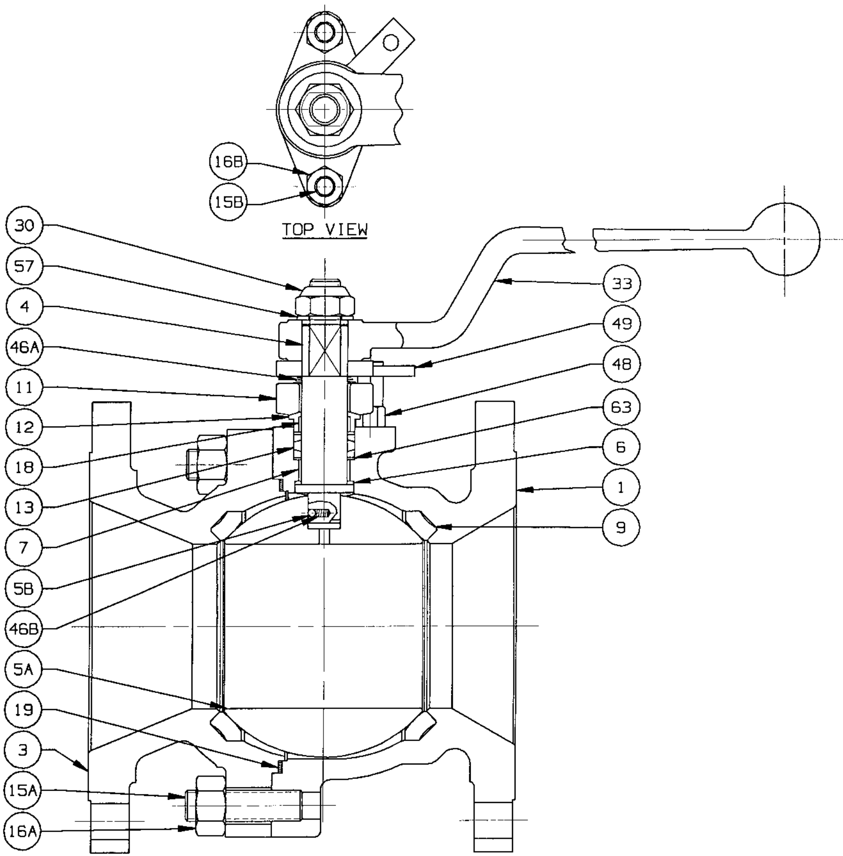
The following provides a brief description of types of ball valves:

Split-Body Ball Valve. The split body design consists of a two-part body, a cover, ball, seat rings, stem, and other internals. The two-part body is held together by a flange connection. One body part is smaller than the other. The ball is inserted in the larger body part, and the smaller body part is assembled by a bolted connection. The stuffing box is constructed integral with the larger body part. On smaller size split-body ball valves, the two-part body is joined by threaded connection. The flanged or threaded joint between the two-part body is an added source of potential leakage.

Flanged end connections are commonly available on all sizes; however, they are standard for large size valves. NPS 2 (DN 50) and smaller split-body ball valves are furnished with screwed ends. The split-body ball valves are manufactured in sizes ranging from NPS ½ (DN 15) through NPS 36 (DN 900). Refer to Fig. A10.22.

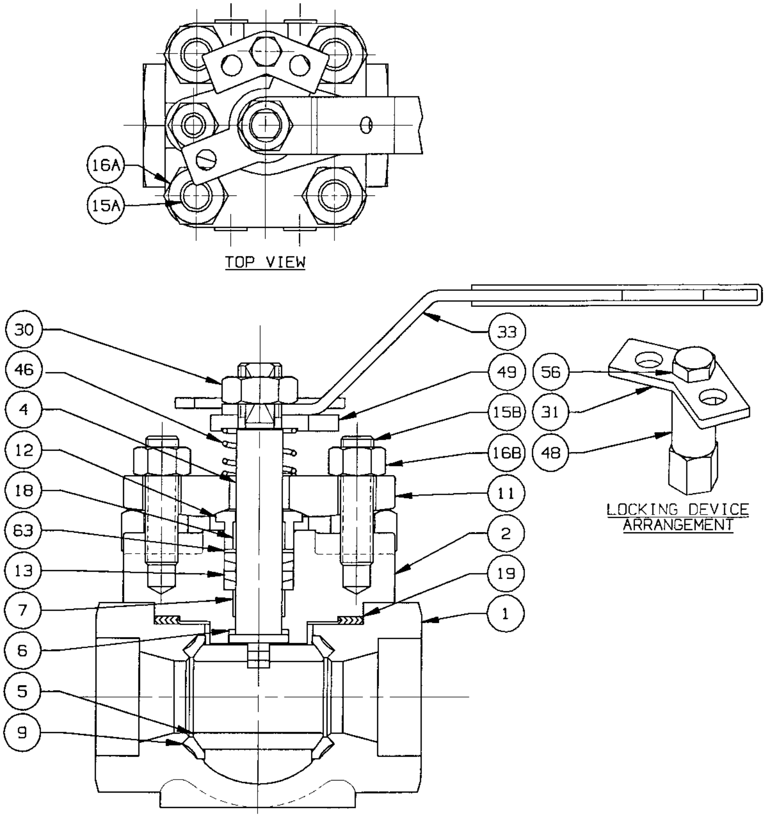
Top-Entry Ball Valve. Top-entry ball valves allow access to valve internals for assembly, disassembly, repair, or maintenance by removal of the valve bonnet-cover. The valve is not required to be removed from the pipeline. Refer to Fig. A10.23.

End-Entry Ball Valve. End-entry ball valves have a single-piece body. The ball is inserted from one end and is retained by an insert. These valves have flange- or



MATERIAL LIST		
PART	DESCRIPTION	QTY
1	BODY	1
3	BODY END	1
4	STEM	1
5A	BALL	1
5B	GROUNDING BALL	1
6	THRUST WASHER	1
7	STEM BUSHING	1
9	SEAT	2
11	PACKING FLANGE	1
12	GLAND BUSHING	1
13	PACKING RING	3
15A	STUD	-
15B	STUD	2
16A	NUT	-
16B	NUT	2
18	GLAND BSHG SLV	1
19	BODY SEAL	1
30	HANDLE NUT	1
33	HANDLE	1
46A	SPRING	1
46B	SPRING	1
48	STOP PIN	2
49	STOP PLATE	1
57	WASHER	1
63	PACKING WASHER	2

FIGURE A10.22 Ball valves, split body, regular port, flanged ends. *(Courtesy of Velan.)*



MATERIAL LIST		
PART	DESCRIPTION	QTY
1	BODY	1
2	BONNET	1
4	STEM	1
5	BALL	1
6	THRUST WASHER	1
7	STEM BUSHING	1
9	SEAT	2
11	PACKING FLANGE	1
12	GLAND BUSHING	1
13	PACKING RING	4
15A	STUD	4
15B	STUD	2
16A	NUT	4
16B	NUT	2
18	GLAND BSHG SLV	1
19	BONNET SEAL	1
30	HANDLE NUT	1
31	LOCK PLATE	1
33	HANDLE	1
46	SPRING	1
48	STOP PIN	1
49	STOP PLATE	1
56	SCREW	1
63	PACKING WASHER	1

FIGURE A10.23 Ball valves, top entry, regular port, socket weld ends. *(Courtesy of Velan.)*

screwed-end connections. This design is commonly used for inexpensive small valves. They are also available in larger sizes up to NPS 6 (DN 150).

Three-Piece—Body Ball Valve. The middle part of the valve is the major part that holds all valve internals, and the stem passes through a hole in the top. Two end caps are held together with the middle body by bolts or studs and nuts. The end connections are part of the end caps, and they may be butt-welding, socket-welding, threaded, or flanged. This design is available in sizes ranging from NPS ½ (DN 15) through NPS 36 (DN 900). The two end cap joints are two additional sources of potential leakage.

Double Trunnion Ball Valves. In this ball-valve design, the ball is provided with two integral short-shaft extensions called the top and the bottom trunnions. These trunnions are fitted in bearings and rotate freely when the shaft installed in the top trunnion is turned to open or close the valve. The ball is held firmly in place, unlike the ball in other designs where the ball is supported by the two seat rings and is allowed to float in the direction of the slot on top of the ball. A shaft installed in the top slot is turned to open or close the valve.

The trunnion-mounted ball-valve design is used with split-body large size valves, whereas the floating-ball design is the most common design for all other types of ball valves. The torque required to actuate a trunnion-mounted ball valve is substantially smaller than the torque required for a floating-ball design.

Lubricated or Nonlubricated Ball Valves. Like other valves, the stem sealing is usually accomplished by bolted packing glands and O-ring seals. Some valve designs are available with a lubricant-seal system similar to the one used in plug valves. Such a design is shown in Fig. A10.21. The valves with lubrication seal systems are termed lubricated ball valves, while others are called nonlubricated.

Advantages of Ball Valves

The following are the advantages of ball valves:

1. Provides bubble-tight service.
2. Quick to open and close.
3. Smaller in size than a gate valve.
4. Lighter in weight than a gate valve.
5. Multiport design offers versatility not available with gate or globe valves. It reduces the number of valves required.
6. Several designs of ball valves offer flexibility of selection.
7. Can be used in clean and slurry applications.
8. High-quality ball valves provide reliable service in high-pressure and high-temperature applications.
9. Force required to actuate the valve is smaller than that required for a gate or a globe valve.

Disadvantages of Ball Valves

1. They are not suitable for sustained throttling applications.
2. In slurry or other applications, the suspended particles can settle and become trapped in body cavities causing wear, leakage, or valve failure.

Typical Applications of Ball Valves

The following are some typical applications of ball valves:

1. Air, gaseous, and liquid applications requiring bubble-tight service
2. Low-point drains and high-point vents in liquid, gaseous, and other fluid services
3. Instrument root valves
4. Cooling water and feedwater systems
5. Steam service

Plug Valves

Plug valves, also called *cocks*, generally are used for the same full-flow service as gate valves, where quick shutoff is required. They are used for steam, water, oil, gas, and chemical liquid service. Plug valves are not generally designed for the regulation of flow. Nevertheless, in some applications, specially designed plugs are used for this purpose, particularly for gas-flow throttling.

Plug valves generally can be readily repaired or cleaned without necessitating removal of the body from the piping system. They are available for pressure service from vacuum to 10000 psi (69000 kPa) and temperatures from −50 to 1500°F (−46 to 816°C). Also, plug valves are available with a wide variety of linings suitable for many chemical service applications.

Construction of a Plug Valve

The basic design of plug valves is illustrated in Fig. A10.24. Full flow is obtained when the opening in the tapered plug is aligned in the direction of flow. When the plug is rotated a quarter turn, flow is terminated. The body and tapered plug represent the essential features in plug valves. Careful design of the internal contours of the valve produces maximum flow efficiency. The port in the tapered plug is generally rectangular. However, valves are also available with round ports. Major valve patterns or types are identified as *regular, venturi, short, round-port,* and *multiport.*

Plugs are usually tapered downward, while in some cases they are tapered upward. Most of the plug valves are top entry. In top-entry plug valves, the tapered plug is installed from the top of the valve. In some cases the plug is tapered upwards and is installed from the bottom opening in the valve body. Such a plug is called bottom entry or *inverted* plug valve.

Plug valves are also available with cylindrical plugs. The cylindrical plugs provide for larger port openings equal to or greater than the pipe flow area.

The regular pattern employs the tapered form of port openings, the area of which is from 70 to 100 percent of the internal pipe area. In some cases, the face-

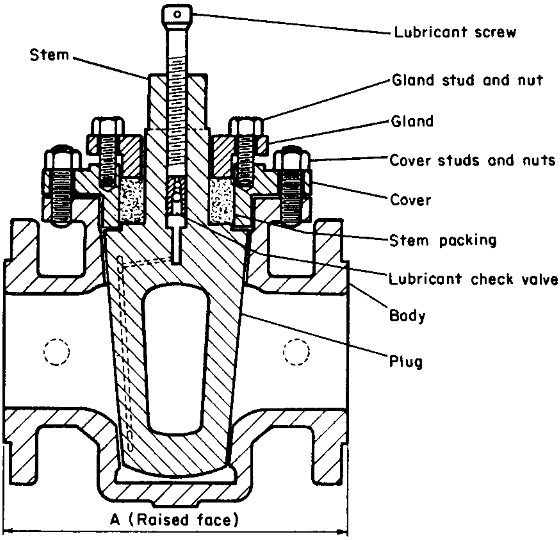


FIGURE A10.24 Plug valve with lubricant system, as specified in API Standard 600.

to-face lengths are greater than those of standard gate valves. The venturi pattern provides streamlined flow and thus permits reduction in the port size. The port opening area is approximately 40 to 50 percent of the internal pipe area. In most of the plug valves, the port opening varies from 60 to 70 percent of the pipe area. The round-port full-bore pattern has a circular port through the plug and body equal to or greater than the inside diameter of the pipe or fitting. Operating efficiency is equal to or greater than that of gate valves of the same size.

Use of multiport valves is advantageous in many installations because it provides simplification of piping and convenience in operation. One three-way or four-way multiport valve may be used in place of two, three, or four straightway valves. Refer to Fig. A10.25.

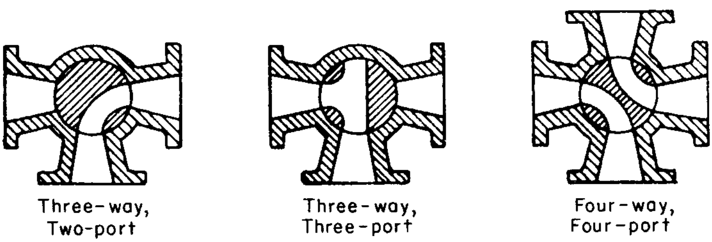


FIGURE A10.25 Multiport valves: (*a*) three-way, two-port; (*b*) three-way, three-port; (*c*) four-way, four-port.

Types of Plug Valves

The following describes salient features of different types of plug valves:

Lubricated Plug Valves. The plug in a lubricated plug valve is provided with a cavity in the middle along its axis. This cavity is closed at the bottom and fitted with a sealant-injection fitting at the top. The sealant is injected into the cavity, and a check valve below the injection fitting prevents the sealant from flowing in the reverse direction. The sealant oozes out from the center cavity through radial holes into lubricant grooves that extend along the length of the seating surface of the plug. The sealant or the lubricant performs the following functions:

1. Establishes a renewable seal between the plug and the body. As a result, internal leakage is prevented or minimized.
2. Protects the seating surfaces against corrosion.
3. Acts as a lubricant, thus reducing the force required to open or close the valve.

The lubricant pressure developed by a turn of the lubricant screw or injection of lubricant with a pressure gun exerts a powerful hydraulic jacking action on the plug, momentarily lifting it from the seat and making it easy to turn. Since the lubricant pressure is greater than the line pressure, it is virtually impossible for solids to lodge between the valve body and plug.

The type of sealant to be used must be compatible with the flow medium in the pipe. The sealant must not dissolve or be washed away by the flow medium. The washed-away or dissolved sealant could contaminate the fluid, and the seal between the plug and the body would be destroyed, resulting in leakage. In addition, the sealant used must be able to withstand the flow-medium temperature.

Lubricated plug valves are normally manufactured in sizes ranging from NPS ½ through 36 (DN 15 through 900). They can be used in applications with pressures over 2500 psi (17250 kPa). They have been used in services involving air, gases, acids, alkalis, water, steam, oils, fuels, among others. Lubricated plug valves are less subject to seizing or wear and may exhibit somewhat greater resistance to corrosion in some service environments.

Nonlubricated Plug Valves. Nonlubricated plug valves contain an elastomeric body liner or a sleeve, which is installed in the body cavity. The tapered and polished plug acts like a wedge and presses the sleeve against the body. Thus, the nonmetallic sleeve reduces the friction between the plug and the body.

Nonlubricating plug valves are used where maintenance must be kept to a minimum. Like lubricating plug valves, these valves also provide a bubble-tight closure and are of compact size.

Lubricants

The word *lubricant* does not precisely define the part this material plays in the efficient functioning of lubricated plug valves. More properly such valves might be called *plastic sealed valves,* and the lubricant could better be designated *plastic sealant.* The use of an effective lubricant is important, as, in operation, the valve structure and plastic scaling film are an integral unit, and each component is dependent on the other for ultimate performance.

The lubricant in effect becomes a structural part of the valve, as it provides a flexible and renewable seat. This eliminates the necessity of *force fits* and metal-to-metal *distortable-seat* contacts to effect a seal. For this purpose, the lubricant must exhibit proper elasticity as well as resistance to solvents and chemicals to avoid the destructive action of the line fluid and to form an impervious seal around each body port, even under pressure. The film of lubricant also protects the metal surfaces between the plug and body from corrosion. The seal formed by the lubricant transmitted in a system of lubricant grooves circuiting each port aids in maintaining the essential film on the metal, closure surfaces.

Advantages of Plug Valves

The following summarizes the advantages of plug valves:

1. Simple design with few parts.
2. Quick to open or close.
3. Can be serviced in place.
4. Offers minimal resistance to flow.
5. Provides reliable leaktight service. Seal can be maintained by injection of sealant or by replacement of sleeve, in addition to utilizing the wedging action of a tapered plug.
6. Multiple port design helps reduce number of valves needed and permits change in flow direction.

Disadvantages of Plug Valves

The disadvantages include:

1. Requires greater force to actuate, due to high friction.
2. NPS 4 (DN 100) and larger valves require use of actuators.
3. Reduced port, due to tapered plug.
4. Typically, plug valves may cost more than ball valves.

Typical Applications of Plug Valves

As indicated earlier, the plug valves can be and have been used in many different fluid services. They perform well in slurry applications. They are primarily used in bubble-tight services as on-off stop valves. The wiping-off action of a plug does not permit suspended particles to accumulate and form crud. The following are some typical applications of plug valves:

1. Air, gaseous, and vapor services
2. Natural gas piping systems
3. Coal slurries, mineral ores, mud, and sewage applications
4. Oil piping systems
5. Vacuum to high-pressure applications

Diaphragm Valves

All diaphragm valves are bidirectional. They can be used as on-off and throttling valves. Diaphragm valves offer advantages in certain low-pressure applications not possible with other types of valves. Their fluid passages are smooth and streamlined, minimizing pressure drop. They are suitable for moderate throttling applications, and they exhibit excellent leak-tight characteristics, even when conveying liquids containing suspended solids. The fluid stream is isolated from the working parts of the valve, preventing contamination of the fluid and corrosion of the operating mechanism. Since there is no leak path around the valve stem, the valve is virtually leak tight. This feature makes the valve indispensable where leakage into or out of the system cannot be tolerated.

The maximum pressure that these valves can be subjected to is a function of the diaphragm material and the service temperature. Also, the rated design life of the valve is influenced by the service conditions. Furthermore, the system hydrostatic test pressure must not exceed the maximum pressure rating of the diaphragm.

Construction of a Diaphragm Valve

Diaphragm valves (Fig. A10.26) consist of a rigid body formed with a weir placed in the flow path, a flexible diaphragm which forms the upper pressure boundary

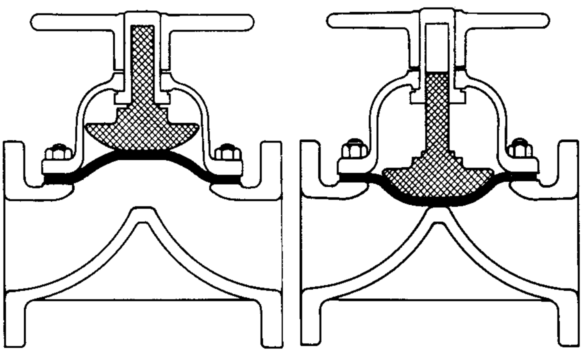


FIGURE A10.26 Sketch of a weir-type of diaphragm valve in open and closed positions.

of the valve, a compressor which is used to force the diaphragm against the weir, and the bonnet and handwheel which secure the diaphragm to the body and actuate the compressor.

Diaphragm valves are manufactured in a variety of end connections: welding-end socket or butt welding; flanged, screwed, or threaded; clamp ends or grooved ends; solvent cement joint ends for themoplastic valves; and male sanitary threaded ends.

The valve body is available in two patterns: tee-pattern and angle pattern.

Diaphragm valves are available in a wide choice of body, diaphragm, and lining materials that are suitable for service with a wide variety of chemicals. For severe corrosive applications, diaphragm valves are made of stainless steel or PVC plastics,

TABLE A10.10 Typical Materials Used for Diaphragms

Valve type	Service	Material	Temp, °F (°C)	
			Min	Max
Conventional weir	Abrasive	Soft natural rubber	−30 (−34)	180 (82)
	Water	Natural rubber	−30 (−34)	180 (82)
	Food and beverage	White natural rubber	0 (−18)	160 (71)
	Weak chemical, air, oil	Neoprene	−30 (−34)	200 (93)
	Weak chemical, high vacuum	Reinforced Neoprene	−30 (−34)	200 (93)
	Other chemicals, gases	Black chlorinated butyl	−20 (−29)	250 (121)
	Food and beverage	White chlorinated butyl	−10 (−23)	225 (107)
	Special for hydrogen peroxide	Clear Tygon	0 (−18)	150 (66)
	Oils and gasoline	Hycar (gen. purpose)	10 (−12)	180 (82)
	Oxidizing services	Hypalon	0 (−18)	225 (107)
	Brewery services	Pure gum rubber	−30 (−34)	160 (71)
	Special service on temperature	Silicone	50 (10)	350 (177)
	Radioactive conditions	G.R.S.	−10 (−23)	225 (107)
	Severe chemicals, solvents	Teflon	−30 (−34)	325 (163)
	Severe chemicals	Kel-F	60 (16)	250 (121)
	Specific acids	Polyethylene	10 (−12)	135 (57)
Full flow	Cold beer	White rubber	−30 (−34)	160 (71)
	Hot wort and cold beer	White chlorinated butyl	−10 (−23)	225 (107)
	Cold beer	Pure gum rubber	−30 (−34)	160 (71)
Straightway	Water	Natural rubber	−30 (−34)	180 (82)
	Chemical, air, oil	Neoprene	0 (−18)	180 (82)
	Oils and gasoline	Hycar (gen. purpose)	10 (−23)	180 (82)
	Fatty acids	Black chlorinated butyl	0 (−18)	225 (107)
	Oxidizing services	Hypalon	0 (−18)	200 (93)
	Food and beverage	White chlorinated butyl	−10 (−23)	200 (93)

or they are lined with glass, rubber, lead, plastics, titanium, or still other materials. Some of the common materials used for diaphragms are listed in Table A10.10.

Adjustable travel stops are used to prevent excessive compression of the diaphragm. The adjustable travel stop can be enclosed in a temper-proof housing. The temper-proof housing prevents inadvertent mishandling after the travel length is set. It requires a special tool to open the housing and to make an adjustment in the travel length.

When an actuator is required, it should be sized and tested by the valve manufacturer and furnished with the valve as an assembled unit with settings made and verified in the shop.

Types of Diaphragm Valves

Primarily there are two basic designs of diaphragm valves: *weir* and *straight-through* types. The body interior and the end flanges can be lined to make the diaphragm valves suitable for corrosive applications. Various lining materials can be used, depending upon the application.

Weir-Type Diaphragm Valves. As shown in Fig. A10.26, a weir is provided as an integral part of the valve body. The weir acts as the valve seat against which the diaphragm is compressed to stop the flow. This type of diaphragm valve is generally produced in large sizes. The raised weir reduces the amount of diaphragm travel from the fully open to the fully closed position, thus reducing the amount of stress and strain in the diaphragm.

Straight-Through Diaphragm Valves. Variations of the weir diaphragm valve are the *straightway* (Fig. A10.27) and the *full-bore* types (Fig. A10.28). When the straightway valve is open, its diaphragm lifts high for full streamline flow in either direction. When the valve is closed, the diaphragm seals tight for positive closure even with gritty or fibrous materials in the line.

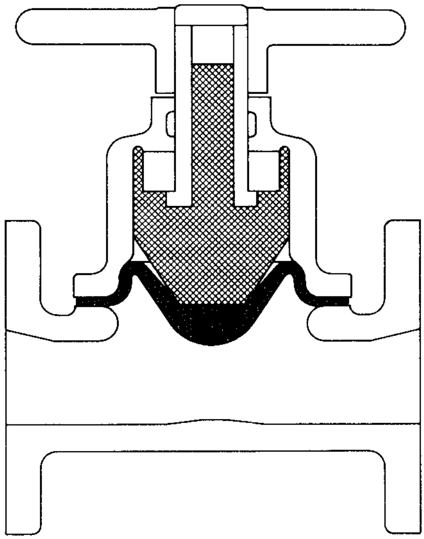


FIGURE A10.27 Straightway-type diaphragm valve.

The full-bore type of valve is most extensively used in the beverage industry. It permits ball-brush cleaning with either steam or caustic soda, without opening or removing the valve from the line.

Advantages of Diaphragm Valves

The following summarizes some distinct advantages of diaphragm valves:

1. Can be used as on-off and throttling service valves.
2. Offer good chemical resistance due to variety of linings available.
3. Stem leakage is eliminated.
4. Provides bubble-tight service.
5. Does not have pockets to trap solids, slurries, and other impurities. It is suitable for slurries and viscous fluids.
6. These valves are particularly suitable for hazardous chemicals and radioactive fluids.
7. These valves do not permit contamination of flow medium, thus they are used extensively in food processing, pharmaceutical, brewing, and other applications which cannot tolerate any contamination.

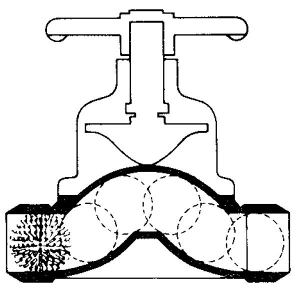


FIGURE A10.28 Full-bore-type diaphragm valve illustrating passage of ball-brush cleaner through valve.

Disadvantages of Diaphragm Valves

1. The weir may prevent full drainage of piping.
2. Working temperatures and pressures are limited by the diaphragm material. Generally the pressures are limited to 200 psi (1380 kPa) and temperatures up to 400°F (204°C).
3. The diaphragm may also limit the hydrostatic pressure.
4. The diaphragm may experience erosion when used extensively in severe throttling service containing impurities.
5. Diaphragm valves are available in limited sizes, usually NPS ½ to 12 (DN 15 to 300).

Typical Applications of Diaphragm Valves

1. Clean or dirty water and air service applications
2. Demineralized water systems
3. Corrosive applications
4. Radwaste systems in nuclear facilities
5. Vacuum service
6. Food processing, pharmaceutical, and brewing systems

Butterfly Valves

Butterfly valves are used to control and regulate or throttle the flow. They are characterized by fast operation and low-pressure drop. They require only a quarter-turn from closed to full-open position. A typical flanged butterfly valve is illustrated in Fig. A10.29. Butterfly valves are produced in sizes ranging from NPS 1½ (DN 40) to over NPS 200 (DN 5000). They are usually manufactured in flanged, wafer, and lug, or single-flange-type designs. The welding-end style is a specially engineered valve for a specific application. Threaded-end, grooved-end, and shouldered-end butterfly valves are also available to satisfy the joint type selected for the piping system. Butterfly valves are produced with metal-to-metal seats, soft seats, and with fully lined body and disc. The soft seats permit bubble-tight shutoff and the full lining enhances erosion and corrosion resistance.

Butterfly valves are suitable for low-pressure and low-temperature applications as well as high-pressure and high-temperature applications. The term *high-performance butterfly valve* is intended to signify their suitability for moderate- to high-pressure and temperature services.

The butterfly valves have a low-pressure drop and high-pressure recovery factor. They are suitable for low-pressure drop applications. These valves are extensively used in large water transmission, distribution, and cooling water lines.

Construction of a Butterfly Valve

A butterfly valve has a short circular body, a round disc, shaft, metal-to-metal or soft seats, top and bottom shaft bearings, and the stuffing box. The valve body may

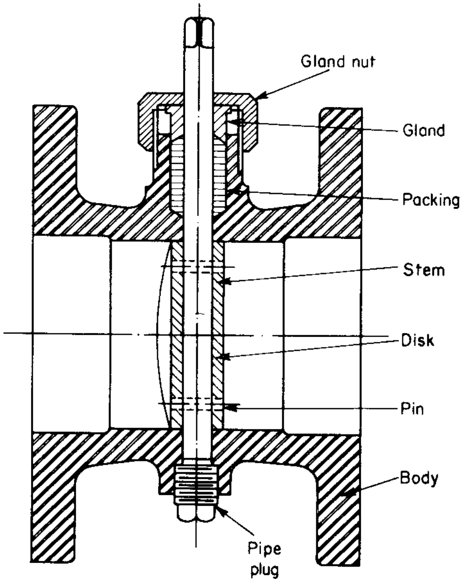


FIGURE A10.29 Typical flanged-end butterfly valve.

have flanged ends, lugs, or wafer style (Fig. A10.30) configurations to be installed between pipe flanges. The welding-end (Fig. A10.31) butterfly valves are usually large and have butt-welding ends. Sometimes butterfly valves are manufactured in rectangular or square configurations.

The wafer-style butterfly valves are usually available in sizes NPS 12 (DN 300) or smaller. The limitation on size is essentially imposed by the difficulty of holding the larger weight valve in place between the flanges. The lug and flanged-end butterfly valves are available in all sizes and pose no problem in installation between flanges except for the normal problems associated with warped-flanged surfaces and uneven torquing of bolts.

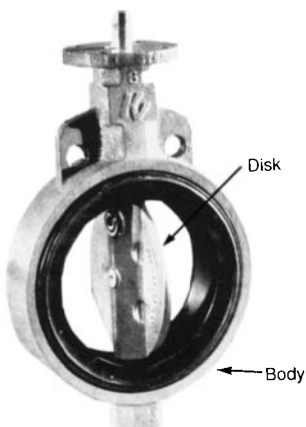


FIGURE A10.30 Wafer butterfly valve. (*Courtesy, Keystone International, Inc.*)

Types of Butterfly Valves

Low Pressure or Concentric Butterfly Valves. In low pressure and low temperature designs of a butterfly valves, the disc and shaft axes are concentric. In open position, the disc divides the flow in two equal halves, with the disc in the middle and parallel to the flow. These valves are provided with resilient seats. These valves are available as *lined* or *unlined*. Most commonly used lining and seating materials include: Buna N, Neoprene, Fluorcel, Hypalon, EPDM, TFE, Viton, among others. The application temperature is limited by the temperature capability of the resilient material. These valves are generally produced in Classes 150 and 300.

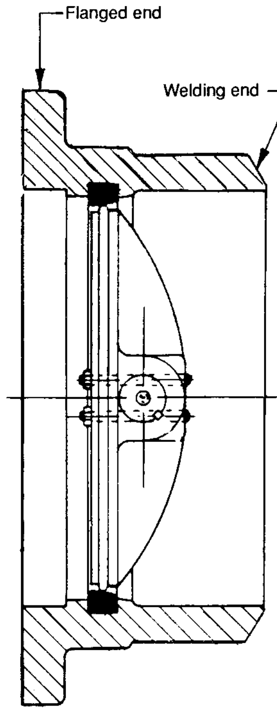


FIGURE A10.31 Butterfly valve; welding end on one end.

High-Performance or Eccentric Butterfly Valves. The disc in high performance butterfly valves is offset from the center of the valve, and the shaft is also offset from the center of the disc. The offsets provided allow the disc to move eccentrically uninterrupted away from or toward the valve seat. Thus, the uninterrupted motion of the disc until it seats against the valve seat prevents unwanted wear and tear of the valve seat and disc due to friction and rubbing of the seating surfaces. The high-performance butterfly valves are used for on-off and throttling services. Some butterfly valve manufacturers produce high performance butterfly valves with triple offset, which enhances their actuation and leak-tightness.

Advantages of Butterfly Valves

The following summarizes the advantages of butterfly valves:

1. The compact design requires considerably less space, compared to gate, globe, or other valves.
2. Light in weight.
3. Quick acting; as a quarter-turn valve, it requires less time to open or close.
4. It is available in large sizes, ranging from NPS 1½ (DN 40) to over NPS 200 (DN 5000).
5. They have low-pressure drop and high-pressure recovery.
6. Provide bubble-tight service.

Disadvantages of a Butterfly Valve

1. Throttling service is limited to low differential pressure.
2. Throttling is restricted to a 30- to 80-degree disc opening. Location of valve,

pipe routing, free, and closed discharge are to be considered while using a butterfly valve in a throttling application.

3. Cavitation and choked flow are two potential concerns.
4. The disc movement is unguided and affected by flow turbulence.

Typical Applications of Butterfly Valves

Concentric or low-pressure and low-temperature butterfly valves, the high-performance butterfly valves, cover a wide range of applications. These applications include:

1. Cooling water, air, gases, and other similar applications, such as fire protection, circulating water, et cetera
2. Corrosive services requiring lined valves
3. Food processing, chemical, and pharmaceutical services
4. Slurry and similar services
5. High-pressure and high-temperature water and steam services
6. Throttling service involving low differential pressures, as in cooling water or air supply systems
7. Vacuum service

Application Considerations for Butterfly Valves

1. It is noted that the disc of butterfly valve is unguided; therefore, operability of the valve is affected by the flow characteristics. A butterfly valve should not be located just downstream of a source of flow turbulence, such as pump-discharge nozzle, elbow, control valve, or a tee-branch. To minimize the effects of flow turbulence on the valve, attempts should be made to
   - Locate the valve 4 to 6 diameters downstream of the source of flow turbulence.
   - Orient the valve shaft in the same plane as the elbow or the pump outlet configuration. When there is more than one component on the upstream side of the valve, then the component adjacent to the valve is to be considered in determining the valve-shaft orientation.
2. When used in throttling applications, an attempt must be made to provide an adequate straight length of pipe downstream of the valve to allow the flow turbulence to subsidize prior to diverting the flow.
3. Butterfly valves are essentially bidirectional. In the case of high-performance butterfly valves, and sometimes in the case of low-pressure and low-temperature butterfly valves, the valve design may require more actuating torque to open or close the valve when the flow is reversed. In such cases, the valve manufacturer must be contacted to ensure that the valve is designed and the actuator is sized for flow in both directions.

PRESSURE-RELIEF DEVICES

Safety Valves and Pressure-Relief Devices

Safety valves and pressure-relief valves are automatic pressure-relieving devices used for overpressure protection of piping and equipment. Safety valves (Fig. A10.32) are generally used in gas or vapor service because their opening and reseating characteristics are commensurate with the properties and potential hazards of compressible fluids. The valves protect the system by releasing excess pressure. Under normal pressure, the valve disc is held against the valve seat by a preloaded spring. As the system pressure increases, the force exerted by the fluid on the disc approaches the spring force. As the forces equalize, fluid begins to flow past the seat. The valve disc is designed in such a way that the escaping fluid exerts a lifting pressure over an increased disc surface area, thereby overcoming the spring force and enabling the valve to rapidly attain near-full lift. An added benefit to the safety-valve disc design is that the pressure at which the valve reseats is below the initial set pressure, thereby reducing the system pressure to a safe level prior to resealing. The ratio of the difference between the set pressure and the resealing pressure to the set pressure is referred to as the *blowdown.*

Pressure-relief valves (Fig. A10.33) are used primarily in liquid service. These valves function in a way similar to safety-relief valves, except that as liquids do not

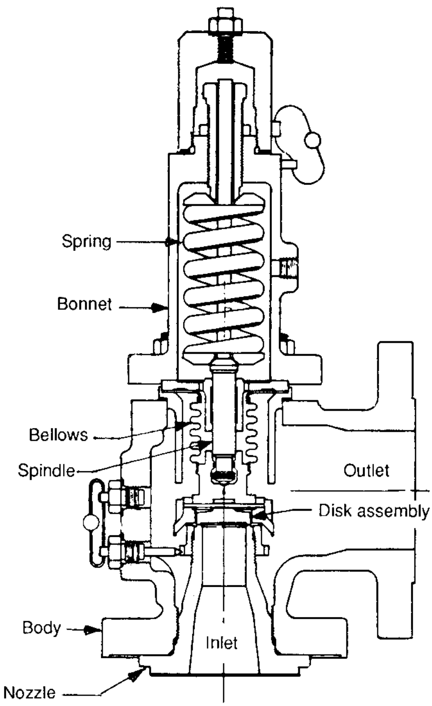


FIGURE A10.32 Safety valve.

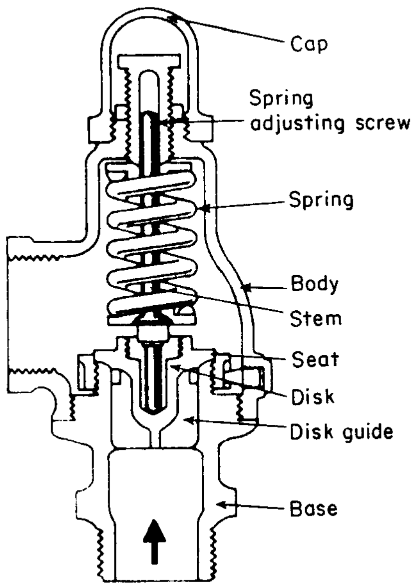


FIGURE A10.33 Relief valve opens when line pressure exceeds preset loading on the spring.

expand, there is no additional lifting force on the disc and, therefore, the valve lift is proportional to the system pressure. Also, the valves reseat when the pressure is reduced below the set pressure.

A third type of pressure-relieving valve is a safety-relief valve, which can be used with both compressible and incompressible fluids. It combines the design features of a safety- and a relief-valve into one. Therefore, when it is used with compressible fluids, such as steam or a gas, it pops open to release the overpressure, and when used with incompressible fluids, such as water or other liquids, it opens gradually, proportional to the increase in pressure over the set pressure, to safeguard the vessel, tank, heat exchanger, piping, or other equipment.

ACTUATORS

A brief discussion is provided to assist the user in understanding the considerations affecting the selection of the type of actuators required for an application. Manually actuated valves do not change position due to a change in the mode of system operation or an accident. As such, a manually operated valve remains in the last position it was placed in. Manually operated valves are usually furnished with a handwheel attached to the valve stem or yoke nut which is rotated clockwise or counter-clockwise to close or open a valve such as a gate or globe valve. Manually operated quarter-turn valves, such as a ball, plug, or butterfly valve, is provided with a lever to actuate the valve. There are applications in which the force required to actuate the valve is more than the force manually imparted through a handwheel or a lever. These applications include:

- Large valves and valves required to be operated against high-fluid pressure
- When the time required to open, close, throttle, or regulate the valve manually is longer than that required by system-design criteria
- When the valve is required to be operated from a remote location
- When the valve must attain a position (open or close) in the event of an accident or in a particular mode of system operation

The valves to be furnished with an actuator utilizing external source(s) of energy, such as electricity, pneumatics, hydraulics, mechanical springs, or a combination of one or more of these energies, are called actuated valves. Upon failure of the external source of energy, a valve may not be in the required position for accomplishing the design function. One must be aware of failure modes prior to selecting a valve actuator.

Failure Modes

Fail-As-Is (FAI): The valve remains in its last position following upon an external power failure.

Fail-Closed: The valve is provided with external source(s) of energy to place it in the closed position, regardless of valve position before power failure.

Fail-Open: The valve is provided with external source(s) of energy to place it in the open position, regardless of valve position before power failure.

Fail-Locked: Air or inert gas actuators may be provided with a device or devices to seal in actuator pressure upon the loss of normal pneumatic source control.

Types of Actuators

The following are some of the commonly used valve actuators:

Gear Actuators. Spur, bevel, or worm-gear actuators are used to reduce the manual force required to operate a valve. Spur gears are used with globe, angle, and nonreturn valves. Bevel-gear actuators are used on gate valves. Worm-gear actuators are usually used on quarter-turn valves. The use of a gear actuator is warranted when the rim pull force required to manually actuate a valve exceeds a given value, which varies from 50 lb (22 kgf) to 250 lb (113 kgf).

Electric Motor Actuators. An electric motor provides the actuating energy to place the valve in the desired position. Upon loss of power, the failure mode is fail-as-is. The stem speed may vary from 12 in/min (30 cm/min), known as manufacturer's standard, to 60 in/min (150 cm/min). Special features are required to accomplish stem speeds over 45 in/min (112 cm/min).

Pneumatic Actuators. Pneumatic actuators utilize the motive force provided by a compressed gas such as air, nitrogen, or other inert gas. There are many different types of pneumatic actuators. These include linear, rotary, and linear-to-rotary. Linear-type actuators are used with valves having translating stems. Rotary and linear-to-rotary pneumatic actuators are used on valves having rotating stems.

Pneumatic actuators can generate very high thrust and an extremely high torque. The length and speed of stroke may vary considerably, depending upon the type of pneumatic actuator. These actuators are capable of providing either fail-open or fail-close failure mode upon loss of air. Piston-type air actuators are furnished with springs to open or close the valve upon air failure. Diaphragm air actuators have limited thrust and torque generation capabilities due to limits on air pressure because of diaphragm strength. In addition, the diaphragm actuators have limited stroke ranging from 1 to 4 in (25 to 100 mm).

Air-vane pneumatic actuators are used with quarter-turn valves, and they can be directly mounted on the valve stem.

Hydraulic Actuators. Hydraulic actuators utilize pressurized liquids, usually oils but sometimes water, or the process liquid is used to provide the motive force for actuating the valve. Like pneumatic actuators, these actuators can help achieve fail-open or fail-close failure modes.

Solenoid Actuators. Solenoid actuators have short-stroke and low-thrust capabilities. Two types of actuating methods are used in solenoid valves: direct acting and pilot operated. In the direct acting solenoid valve, the disc is lifted off the seat to a fully open position by magnetic flux generated by energizing the coil, and the disc is returned to its seat by deenergizing the coil. The pilot-operated solenoid valve utilizes the system pressure to provide the actuating force.

Solenoid valves can accomplish all failure modes.

SELECTION AND APPLICATION GUIDELINES

The following guidelines are provided to assist in selecting a suitable valve for any application. These guidelines are intended to cover all physical features and capabilities or limitations of different types of valves and which may be suitable for one particular application. The user must fully evaluate the pros and cons of using a particular type of valve and arrive at the most suitable selection, taking into consideration the life span expected and costs involved.

Identify Application Characteristics

1. Identify the system and various modes of system operation: startup, normal operation, accident condition, standby, shutdown, et cetera.

2. Identify the flow medium and its properties, flow rate during all modes of system operation, system design pressure, and design temperature.

3. Identify the pipe size, pipe wall thickness, piping material, piping joint(s) to be used, and any other information which relates to valves in the system.

4. Establish the code of jurisdiction, which governs the construction of the system, component, or equipment. The codes related to piping systems are discussed in Chap. A4. The applicable code (ASME B31.1, B31.3, B31.5, B31.8, B31.9, B31.11, ASME Sec. I, Sec. III, Sec. VIII, etc.) does contain requirements for valves. Become familiar with the code requirements for valves in general and for the system under consideration in particular.

5. Identify the valve standards referenced in the code of jurisdiction. Each code lists the valve standards that are acceptable for construction of valves to be used in piping within the jurisdiction of the code. Use valves complying with the valve standards listed in the code of jurisdiction. The most commonly used valve standards are listed in the beginning of this chapter.

6. Establish the pressure drop through the valve that can be critical on overall system performance. For example, the pressure drop through the stop valve(s) in the main steam system of a power facility is critical to achieve the guaranteed performance of the plant.

Select Type of Valve Required

1. In reference to the various modes of system operation, determine the function(s) a valve has to perform.

2. Based upon the valve functions, the valve type(s) can be selected. The valve needed may be an isolation valve or a stop valve. What are the choices available?

3. Similarly, the valve required may be a check valve or the valve required to stop the flow in reverse direction. There are many different types of check valve. Which is the most suitable?

4. Does flow need to be throttled? Based upon the amount of throttling required, one may select a globe valve, butterfly valve, or a needle valve. Size limitations also play a role in the availability of these valves.

5. If flow has to be regulated and controlled based on variation in pressure, temperature, fluid level, or the design limitations of a component or equipment,

TABLE A10.11 Valve Types and Typical Applications

Valve type	Service/Function			
	Isolation or stop	Throttling	Pressure relief	Directional change
Gate	yes	no	no	no
Globe	yes	yes	no	yes (note 1)
Check	note 2	no	no	no
Stop check	yes	no	no	no
Butterfly	yes	yes	no	no
Ball	yes	note 3	no	yes (note 4)
Plug	yes	note 3	no	yes (note 4)
Diaphragm	yes	no	no	no
Safety/relief	no	no	yes	no

Notes:
1. Only angle-globe valves can be used for a 90-degree change in direction of flow.
2. Check valves (other than the stop-check valves) stop flow only in one (reverse) direction. Stop-check valves can be and are used as stop, block, or isolation valves, in addition to being used as a check valve.
3. Some designs of ball-and-plug valves (contact the valve manufacturer) are suitable for throttling service.
4. Multiport ball-and-plug valves are used for changing the direction of flow and mixing flows.

the valve required would be a control valve. Refer to selection and application of control valves section at the end of this chapter.

6. The first step is to determine the valve type: *isolation, check*, or a *control valve.* If the component or the piping system is required to be protected against overpressure built up, then one of the pressure-relief devices ought to be selected.

7. To begin the selection process, Table A10.11 provides a good starting point.

8. The next step is to narrow down the choices of valves to be used. As discussed earlier, there are several different designs available in different categories of valves. For example, large-size butterfly valves are preferred to large-size gate valves as stop valves in low-pressure and low-temperature cooling water systems, due to space, weight, actuator, and cost considerations.

Select Valve Size

1. Pipe size will indicate the valve size unless there are other requirements that may make it necessary to install a smaller- or larger-than-pipe-size valve.

2. The valve availability is one of those factors. In addition, some valves are not manufactured in certain small or large sizes. Refer to valve vendor catalogs and evaluate application requirements and valve features in addition to space, cost and, operational concerns.

Select Valve-End Connection

1. Types of piping joints to be used depend upon several considerations, such as ease of removal and replacement of components in the piping system, frequency of repairs and replacements, life span of valves, and trim items. For example, the power plants utilize welded joints, whereas the petroleum refineries and chemical plants use flanged joints predominantly. Use of threaded, soldering, and brazing joints is common in plumbing piping systems.

2. Check code requirements concerning piping joints. At times codes prohibit or restrict the use of different types of joints based upon size, pressure, temperature, materials of construction, flow medium, and other criteria. When leakage through joints is a concern, use of a threaded joint may be prohibited or limited by the code or by prudent engineering.

3. When valve-body material is different from the pipe material, transition pieces may be needed to attach the valve to piping.

4. To prevent galvanic corrosion between valve and pipe flanges, insulating flanges may be needed.

Select Valve-Body, Bonnet, and Trim Materials

1. Flow medium and its characteristics will help in selecting the valve-body and valve-trim materials. The flow-medium characteristics include: liquid, gaseous, vapor or two-phase flow, viscosity, clean fluid, dirty fluid, suspended impurities, pH-value (0 to 14), and pressure, and temperatures during different modes of system operation. Nonmetallic, stainless steel, or high-alloy piping may be utilized. Accordingly, valve materials should be selected keeping in mind the manufacturing limitations and availability of valve types and sizes required.

2. Flow rate will dictate requirements for the valve-flow coefficient. Should the valve be full port, standard port, reduced port, et cetera?

3. Valve materials for pressure-retaining parts must be in accordance with the applicable code and acceptable valve standard.

4. Materials for valve parts other than pressure retaining parts must be suitable for withstanding all conditions of loading and assist the valve in performing its design functions.

Identify Seat-Leakage Criteria

1. Determine the minimum and maximum acceptable seat leakage across the valve seat when the valve is in closed position during various modes of system operation. In some cases the seat leakage may not be of concern, while in other applications, such as in piping handling cryogenic fluids, radioactive materials (liquids, gases, and mixtures) or toxic and hazardous waste materials may be a serious concern and must be limited to an acceptable level.

2. The applicable valve standard may specify the acceptable seat leakage when the valve is tested in the shop. Alternatively, more stringent criteria may be specified. Refer to the valve standard, such as MSS SP-61 and API 598.

Identify Requirements for Valve-Stem Packing Arrangement

1. If the valve is to be connected to a piping system or to equipment which is continuously maintained at vacuum, the stem packing must be suitable to prevent inward air leakage. Inverted–V Teflon packing is used to temperatures up to 400°F. Graphite packing may be specified at temperatures above 400°F. Contact the valve manufacturer to ensure effectiveness of the packing.

2. When fugitive emission is a concern, specify the requirements for a suitable packing arrangement.

3. In cryogenic applications the leakage of fluid across the valve seat must not come in contact with the stem packing. Refer to Chap. C8.

Be Aware of Piping Layout and Valve Orientation

1. If a valve is located near or close to an elbow, tee-branch connection, or another source of turbulence, precautions must be taken to select the valve that can withstand flow conditions or modify the layout. It is particularly true for swing check and butterfly valves.

2. If a gate valve is installed with its stem in a horizontal plane, the bonnet cavity may not fully drain after hydrostatic testing, be filled with condensed vapor when the system is shut down, or contain chemicals if the system was cleaned using chemicals. Such situations may result in damage to the valve due to pressure binding or chemical reaction. A drain or vent in the bonnet may be needed to alleviate potential problems.

Take into Consideration Maintenance Requirements

1. Maintenance considerations are important for the selection of valves. The plant designer must provide for access, assembly, and disassembly of valves.

2. Space limitations may impose restrictions on the use of a particular type of valve even though it may be the most suitable valve for the application. Select an alternative valve.

3. When plants are designed for long life, the valves selected must not require frequent maintenance, with the exception of items such as the replacement of packing or lubrication.

Initial Cost

1. A low-initial-cost valve may necessitate frequent repairs or replacements of the valve or valve parts. Be aware of future costs involved.

2. High initial costs may be prohibitive. Therefore, a compromise may be made to choose the right valve for the application.

Actuation Requirements

1. Does the valve require an actuator? If needed, select the proper actuator, keeping in mind the facilities and utilities available at the location.

2. Failure mode desired will dictate the type of power actuator.

3. Gear-actuated valves require special attention with regard to the size of the actuator. The actuator size would depend on the maximum rim pull that can be applied without use of crowbars, rods, or hammers. The rim pull may vary from as low as 50 lb (22 kgf) to 250 lb (113 kgf). Consideration must be given to the plant-operating individuals and their safety and health. A high rim pull may result in injury to an operator.

The above-stated guidelines are provided to assist the user in arriving at a reasonable solution for selecting and applying valves. They are not to be considered the only guidelines. They are for initiating the thought process and offering users critical information for making a final decision.

CHAPTER A10

PART 2 SELECTION AND APPLICATION OF CONTROL VALVES

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DEFINITION OF CONTROL VALVES

Unlike valves in a piping system that primarily serve to shut off, drain, fill, or divert, control valves are a part of an automated control system. They are considered the ''final control element'' in an automated and usually very sophisticated ''control loop.'' Aside from the control valve, the ''loop'' consists of a transmitter that measures the variable to be controlled (usually pressure, flow, level, or temperature) and a controller (nowadays a computer of sorts). Following an error in the variable to be controlled (such an error being sensed by the transmitter), the controller sends a signal change to the control valve which, in turn, responds by altering the flow rate through the valve sufficiently to restore the desired variable (such as pressure, for example).

Control valves have basically three interactive components: (1) a valve body subassembly (either with a reciprocating or rotating stem), (2) an actuating device (usually a spring diaphragm type), (3) a valve positioner (an instrument that converts an electronic control signal from a controller, or computer, into an air signal to control the position of the control valve stem), and (4) an airset or regulator to supply air pressure to the positioner (see Figure A10.34).

HOW TO SPECIFY CONTROL VALVES

The first step in specifying a control valve is to define its function in the given application. In some, it will operate as an on-off valve that opens or closes following the commands of a programmable controller on, say, a batch process. In others, it will be used to remotely set a flow rate in a process—that is, it will be used as a manually controlled variable orifice in a pipe (an open-loop application). Finally, in more sophisticated applications, the control valve will serve as the final control

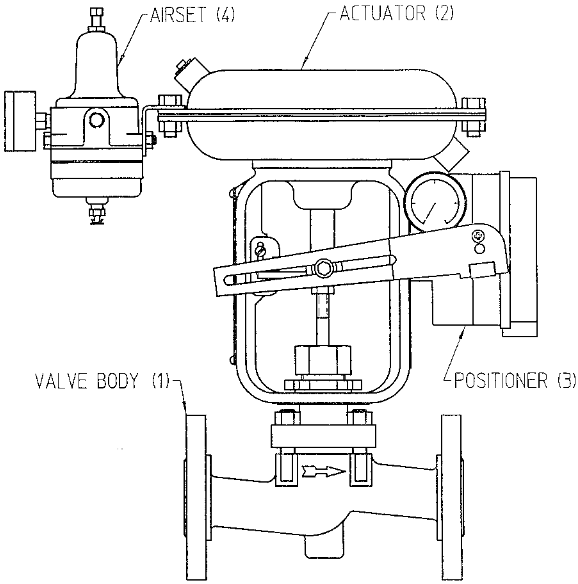

FIGURE A10.34 Typical globe-style control-valve assembly with various components. *(Courtesy of H.D. Baumann, Inc.)*.

element in a process control loop and respond to the sometimes infinitely small variations of a signal coming from a controller (typically a computer). The signal will be generated in response to a deviation in the desired temperature, pressure, or level of a process fluid as measured by a transmitter.

Application Classes

In the first type of application, any on-off valve with a pneumatic or electrical actuator (say, for example, a ball valve) may suffice. The requirements are to provide tight shutoff (perhaps with a Teflon® seat) to withstand the pressure, temperature, and corrosiveness of the fluid, and, finally, to have sufficient flow capacity. No valve positioner is required (see Figure A10.35).

Open-loop control requires a higher level of sophistication, such as a characterized valve plug and good repeatability. The latter calls for a valve/actuator combination with low dead band (low friction). A valve positioner, a device that is essentially a stem position controller with an accuracy between 0.5 and 1.0 percent of stem position, may be required. Controlling the stem position may not always assure that the valve plug or ball moves the required amount unless the stem or shaft is pinned or welded to the ball, vane, or plug (unless fluid pressure assures constant contact). See Figure A10.36.

The modulating control valve that is part of a control loop is the most sophisticated device. Typical features are plug or ball with either linear or equal percentage flow characteristic, low-friction packing and actuating devices, and, if required, low-

FIGURE A10.35 Typical automated ball valve *(Courtesy of XOMOX Corp).*

noise or anticavitation features. These are in addition to the previously stated requirements.

Figure A10.37 shows an eccentric rotary plug valve with a low noise restrictor in the valve outlet port. Part of the pressure drop at moderate to high flow rates occurs across this slotted device. The smaller jets created by the slots produce about 10 to 15 dBA less noise than the valve itself.

Flow control is only possible if the control valve can reduce some of the fluid pressure. Such pressure reduction (also used for valve sizing) typically amounts to 5 to 10 percent of the maximum pump pressure. This makes a streamlined valve trim (highly desirable for on-off valves) actually less desirable for control purposes. It takes much higher velocities with a streamlined trim or valve (hence, more noise or cavitation) to achieve a certain pressure drop than with a nonstreamlined valve.

Signals from controllers to control valves are 3 to 15 psi (0.2 to 1.0 bar) if pneumatic or 4 to 20 mA if electronic. Digital signals will be used in the future once the question of fieldbus standardization has been resolved.

Control Valve Styles. Let's take a look at the characteristics of some of the most commonly used control valve types:

- *Globe valve* The globe valve (see Figure A10.34), which is the most widely used type of control valve, has a screwed-on, integrally attached, or cage-supported seat ring, and typically a lathe-turned, single-seated valve plug. Larger valves or

FIGURE A10.36 Section of V-ball showing pinned stem to ball. *(Courtesy of Fisher Controls International, Inc.).*

high-pressure valves may have designs such that the valve plug is cage-guided and pressure-balanced to reduce actuator force requirements. Globe valves are cost effective in sizes NPS 2 (DN 50) and below and are available in sizes as small as NPS ¼ (DN 6) for research applications. End connections are flanged or threaded. High-pressure or high-temperature valves can be welded to the piping. NPS 2 (DN 50) and smaller can be provided with socket-welding or threaded ends. NPS 2½ (DN 65) and larger are generally butt-welded or flanged.

- *Angle valves* Angle valves are a special variety of globe valves typically having an inlet port at a right angle to the valve stem and a discharge port in line with the valve orifice. Typical applications include flashing and erosive fluids.
- *Three-way valves* As the name implies, three-way valves are globe valves (or some rotary valves) that have three access ports and two plugs and orifices opposed to each other. Depending on the flow direction, three-way valves may serve as either mixing valves (where two different fluids enter the valve through two of the ports, and discharge as a mixture through the third), or diverting valves around heat exchangers (for example, where a fluid enters at one port and discharges through either the second or the third port).
- *Eccentric rotary plug valves* Eccentric rotary plug valves are designed especially for modulating control (i.e., they have solid stem connections, low or constant operating torque, a good flow characteristic, and tight shutoff). They feature a

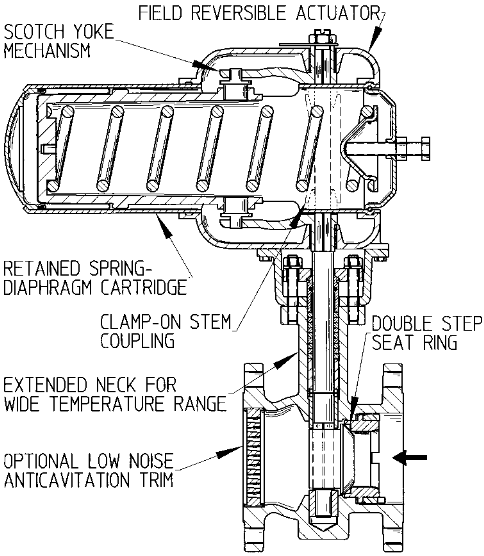

FIGURE A10.37 Eccentric rotary plug valve with low noise restrictor built into the valve outlet port. *(Courtesy of H.D. Baumann Inc.).*

lower weight than globe valves and, therefore, have a cost advantage in sizes NPS 3 (DN 80) and above. They are either flanged or wafer-style for installation between flanges (Figure A10.37).

- *Characterized semispherical ball valves* The characterized semispherical ball valve is another form of ''designed for modulation'' rotary control valve with a backlash-free stem connection. Here, the seal is a thin metal or plastic ring that engages a segmented rotating ball. A V-notch in the ball surface gives a good repeatable flow characteristic. This valve type is popular in the paper industry and is available in either flanged or wafer-style (Figure A10.36).
- *Ball valves* Ball valves have a good shutoff characteristic and high flow capacity. As a result, they are a good choice for on-off or sequencing control. End connections are flanged or wafer-style. Metal-seated ball valves are designed for high temperature applications and can be provided with welded connections. Soft-seated ball valves are used for normal liquid or gaseous fluids up to 482°F (250°C) and where tight shutoff is required (Figure A10.35).
- *Butterfly valves* Except for some special designs with low-torque and low-noise features, butterfly valves for modulating control have to be selected with care. This is because their high-torque (both seating and dynamic) and high-pressure recovery tend to encourage noise and cavitation. A lower-cost valve choice in sizes NPS 6 (DN 150) and above, butterfly valves are typically wafer-style due to their narrow profile.

Actuators. More than 90 percent of all control valves use pneumatic actuating devices—either spring-opposed diaphragm types or piston actuated.

The *spring/diaphragm actuator* is by far the most popular due to its simplicity and ability to fail-safe (that is, the spring force will drive the valve either to close [fail-close] or in the open position [fail-open], depending on process safety requirements, should the air pressure be lost).

Piston actuators provide more dynamic stiffness. In addition, because they use higher air pressures, they are more compact than spring-opposed diaphragm actuators. Other forms of actuation are electric or hydraulic. They are used more for special applications and their use is limited due to higher cost and limited reliability.

Materials of Construction. For noncorrosive use, the material of choice is carbon steel (ASTM A216 Grade WCB, if cast; and A105 when forged). Valve plugs and seat rings are typically ASTM A 351, CF8M (316 stainless steel).

For mild, corrosive applications, valve housings are made from type CF8M (316 stainless steel). However, Teflon®-lined housings and exotic alloys, such as Hastelloy®, monel, or titanium are available for highly corrosive fluids.

For additional information, refer to: Hans D. Baumann, *Control Valve Primer, A User's Guide*, ISA, Research Triangle Park, 1998.

How to Size Control Valves

The flow capacity of control valves is expressed by the coefficient C_v. This is a combination of valve flow area and the valve's headloss coefficient K. It is expressed as

$$C_v = \frac{A \times N_1}{\sqrt{K}} \tag{A10.1}$$

where A is the "vena contracta" area of the valve's orifice, typically 70 percent of the orifice area. C_v is expressed in the flow of U.S. gallons per minute of water when the pressure drop is one psi. N_1 is a numerical constant = 0.059 if A is in mm^2, or 38.1 if A is in $inch^2$. For example, if $K = 1$ and $A = 25\ mm^2$, then the $C_v = 25 \times 0.059/\sqrt{1} = 1.475$.

While C_v was initially a liquid flow coefficient, this term can also be used for gases or steam with the proper conversion coefficients as shown below.

We have to distinguish two modes of flow in a control valve which, in turn, governs the use of the correct equation.

1. *Normal Flow* This occurs when the pressure drop across the valve lies below the following limits:

$$\text{For liquids:} \quad \Delta p_{\text{lim}} = F_L{}^2(p_1 - p_v) \tag{A10.2}$$

$$\text{For gases:} \quad \Delta p_{\text{lim}} = F_L{}^2(0.5 \times p_1) \tag{A10.3}$$

where Δp_{lim} is the limited pressure drop across the valve (see equations), p_1 is the valve's inlet pressure, and p_v is the vapor pressure of the respective fluid and at the flowing temperature (all pressures absolute).

2. *Choked Flow* This occurs if the actual pressure drop exceeds Δp_{lim}. CAUTION: Such conditions could cause cavitation in valves handling liquids, or high sound levels with gas or steam. Consult your control valve supplier.

FOR LIQUID SERVICE

Normal Flow	Choked Flow	Remarks
When Δp is less than $F_L^2(\Delta p_s)$, use equations in this column.	When Δp is more than $F_L^2(\Delta p_s)$, use equations in this column.	Δp_s = Maximum Δp for sizing. Use $p_1 - p_v$ when outlet pressure is higher than vapor pressure, or use $P_1 - \left(0.96 - 0.28\sqrt{\frac{P_v}{P_c}}\right)P_v$ (A10.4) when outlet pressure is equal to or lower than vapor pressure.
Volumetric Flow		
$C_v = N_2 q\sqrt{\frac{G_f}{\Delta p}}$ (A10.5)	$C_v = N_2\frac{q}{F_L}\sqrt{\frac{G_f}{\Delta p_s}}$ (A10.6)	
Flow by Weight		
$C_v = N_3\frac{W}{500\sqrt{G_f\Delta p}}$ (A10.7)	$C_v = N_3\frac{W}{500F_L\sqrt{G_f\Delta p_s}}$ (A10.8)	

where F_L = pressure recovery factor (dimensionless)
G_f = specific gravity @ flowing temperature (water = 1 @ 16°C)
$\Delta p = p_1 - p_2$, psia (kPa)
N_2 = 11.7 if q is in m^3/h and p in kPa; N_2 = 1 is q is in gpm and p is in psia.
N_3 = 5.32 if W is kg/h and p in kPa; N_3 = 1 if W is lb/h and p is in psia.
P_c = pressure at thermodynamic critical point, water is 3206 psia (21,370 kPa)
P_v = vapor pressure of liquid at flowing temperature, psia (kPa)
q = liquid flow rate, m^3/h (U.S. gpm)
W = flow in kg/h (lb/h)

FOR GAS AND STEAM SERVICE

Surprising as it may sound, the basic C_v equation can also be applied to gases and steam. The difference here is that the density of the gas changes with Δp, and, since this is a gradual process, the relationship $\sqrt{\Delta p}$ to flow is no longer linear but curved. However, the following simplified equations give reasonable accuracy.

Normal Flow	Choked Flow
When Δp is less than $F_L^2(p_1/2)$, use equations in this column.	When Δp is more than $F_L^2(p_1/2)$, use equations in this column.
Volumetric Flow	
$C_v = \frac{N_4 q}{963}\sqrt{\frac{G_g T}{\Delta p(p_1 + p_2)}}$ (A10.9)	$C_v = \frac{N_4 q\sqrt{G_g T}}{834 F_L p_1}$ (A10.10)
Flow by Weight	
$C_v = \frac{N_5 W}{3.22\sqrt{\Delta p(p_1 + p_2)G_g}}$ (A10.11)	$C_v = \frac{N_5 W}{2.8 F_L p_1\sqrt{G_g}}$ (A10.12)

TABLE A10.12 Application Guide for Modulating Control Valves (d = mm)

Valve Type	Pipe size		Relative cost[4]	Typical flow capacities, C_v/d^2		Flow chara.	Max. temp. °C	Min. temp. °C	Max. press. ratings	Special service conditions			
	DN	NPS		Low Δp[1]	High Δp[1]					Cavitation	Fiberous	Viscous	Abrasive
Global Valve	8–600	¼–24	1	0.018	0.016	G	400	−268[5]	Class 2500	N[6]	N	N	N
Angle Valve[3]	25–300	1–12	1.1	0.029	0.016	G	400[5]	−268[5]	Class 2500	Y	N	N	Y
3-Way Valve (Globe)	15–150	½–6	1.3	0.016	N	A	200	−30	Class 300	N	N	N	N
Eccentric Rotary Plug Valve	25–300	1–12	0.7	0.021	0.018	G	250	−200	Class 600	N[6]	N	Y	Y[7]
Charac. Segmented Ball Valve	25–300	1–12	0.8	0.04	0.024	G	250	−110	Class 300	N	Y	Y	N
Full Ball Valve	15–600	½–24	0.7	0.05	0.026	A	250	−268[5]	Class 2500	N	Y	Y	Y[7]
Butterfly Valve at 70° open	50–900	2–36	0.6	0.04	0.028	A	250	−30	Class 300	N	N	Y	N

Notes:

[1] Low pressure drops are typically less than 20% of the inlet pressure.

[2] High Δp's are defined as those higher than 40% of the inlet pressure. The valve's flow capacity is restricted due to the onset of vaporization of liquids and sonic flow for gases.

[3] Flow to close.

[4] Relative to Globe valve price (DN 150).

[5] With special bonnets.

[6] Except anticavitation trim.

[7] With ceramic trim.

G = good, N = not recommended, A = acceptable, Y = recommended.

Note:

C_v is a standardized (ISA-S75.01) term to denote the flow capacity of a valve expressed in gallons per minute of water at 60°F when the pressure drop (Δp) is 1 psi. Thus, the flow in gpm = $C_v\sqrt{\Delta p/G_f}$ where G_f is the specific gravity (water @ 16°C (60°F) = 1) and d is the valve diameter in mm. For example, a typical DN 150 globe valve will have a C_v of $0.018 \times 150^2 = 405$ at low Δp. **Caution: Do not select a valve size less than half of the pipe diameter.**

For Saturated Steam

$$C_v = \frac{N_5 W}{2.1\sqrt{\Delta p(p_1 + p_2)}} \qquad \text{(A10.13)}$$

$$C_v = \frac{N_5 W}{1.83 F_L p_1} \qquad \text{(A10.14)}$$

For Superheated Steam

$$C_v = \frac{N_5 W(1 + 0.0007 T_{sh})}{2.1\sqrt{\Delta p(p_1 + p_2)}} \qquad \text{(A10.15)}$$

$$C_v = \frac{N_5 W(1 + 0.0007 T_{sh})}{1.83 F_L p_1} \qquad \text{(A10.16)}$$

where C_v = valve coefficient
F_L = pressure recovery factor
G_g = gas specific gravity (air = 1.0)
N_4 = 323 if q is in m^3/h, p is in kPa, and T is °K; N_4 = 1 if q is in scfh, p is in psia, and T is in °R.
N_5 = 14.8 if q is in m^3/h, p is in kPa; N_5 = 1 if q is in scfh, and p is in psia
p_1 = upstream pressure, psia (kPa)
p_2 = downstream pressure, psia (kPa)
Δp = pressure drop $p_1 - p_2$, psi (kPa)
q = gas flow rate at 100 kPa and 16°C, m^3/h (scfh)
T = flow temperature [°R = (460 + °F)], (°K = 273 + °C)
T_{sh} = steam superheat, °F (°C)
W = flow rate, pounds per h (kg/h)

Application Guide. Table A10.12 summarizes application guidelines for modulating control valves.