Liquid Process Piping

Part 5: Valves

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Chapter 10
Valves

10-1. General

For liquid piping systems, valves are the controlling element. Valves are used to isolate equipment and piping systems, regulate flow, prevent backflow, and regulate and relieve pressure. The most suitable valve must be carefully selected for the piping system. The minimum design or selection parameters for the valve most suitable for an application are the following: size, material of construction, pressure and temperature ratings, and end connections. In addition, if the valve is to be used for control purposes, additional parameters must be defined. These parameters include: method of operation, maximum and minimum flow capacity requirement, pressure drop during normal flowing conditions, pressure drop at shutoff, and maximum and minimum inlet pressure at the valve. These parameters are met by selecting body styles, material of construction, seats, packing, end connections, operators and supports.

a. Body Styles

The control valve body type selection requires a combination of valve body style, material, and trim considerations to allow for the best application for the intended service.

Valve body styles have different flow characteristics as they open from 0 to 100%. The flow rate through each type or body style will vary according to different curves with constant pressure drops. This is referred to as the valve flow characteristics. A quick opening flow characteristic produces a large flow rate change with minimal valve travel until the valve plug nears a wide open position. At that point, the flow rate change is minimal with valve travel. A linear flow characteristic is one that has a flow rate directly proportional to valve travel. An equal percentage flow characteristic is one in which a flow rate change is proportional to the flow rate just prior to the change in valve position. Equal increments of valve travel result in equal percentage changes to the existing flow rate. That is, with a valve nearly closed (existing flow rate is small), a large valve travel will result in a small flow rate change, and a large flow rate change will occur when the valve is almost completely open, regardless of the amount of valve travel. The purpose of characterizing control valves is to allow for relatively uniform control stability over the expected operating range of the piping system. A design goal is to match a control valve flow characteristic to the specific system. Figure 10-1 illustrates some typical flow characteristic curves for control valves.

Table 10-1 provides guidelines for the selection of proper flow characteristics. There are exceptions to these guidelines, and a complete dynamic analysis is performed on the piping system to obtain a definite characteristic. Quick opening valves are primarily used for open/close applications (or on/off service) but may also be appropriate for applications requiring near linear flow. For processes that have highly varying pressure drop operating conditions, an equal percentage valve may be appropriate.

b. Material of Construction

The selection of valve body material and trim material is typically based on pressure, temperature, corrosive and erosive properties of the liquid. Table 10-2 provides basic information on typical castable materials used for control valve bodies. Certain service conditions require other alloys and metals to withstand corrosive and erosive properties of the liquid. The materials that can be used for these situations are similar to the piping materials; therefore, the material fluid matrix found in Appendix B can be used as a guide to select materials for these special conditions. The use of non-standard materials is much more expensive than the use of standard valve body materials.

c. Seats

Valve seats are an integral part of a valve. The materials for valve seats are specified under valve trim for each valve. As such, valve seats are manufacturer specific and should not be interchanged. Seat material is selected for compatibility with the fluid. Valve seats can be either metallic or non-metallic. The fluid/material matrix found in Appendix B may be used to assist in material selection. Table 10-3 provides a wear and galling resistance chart for different metallic valve plug and seat combinations. Table 10-4 provides general information for elastomers used in valve seats.

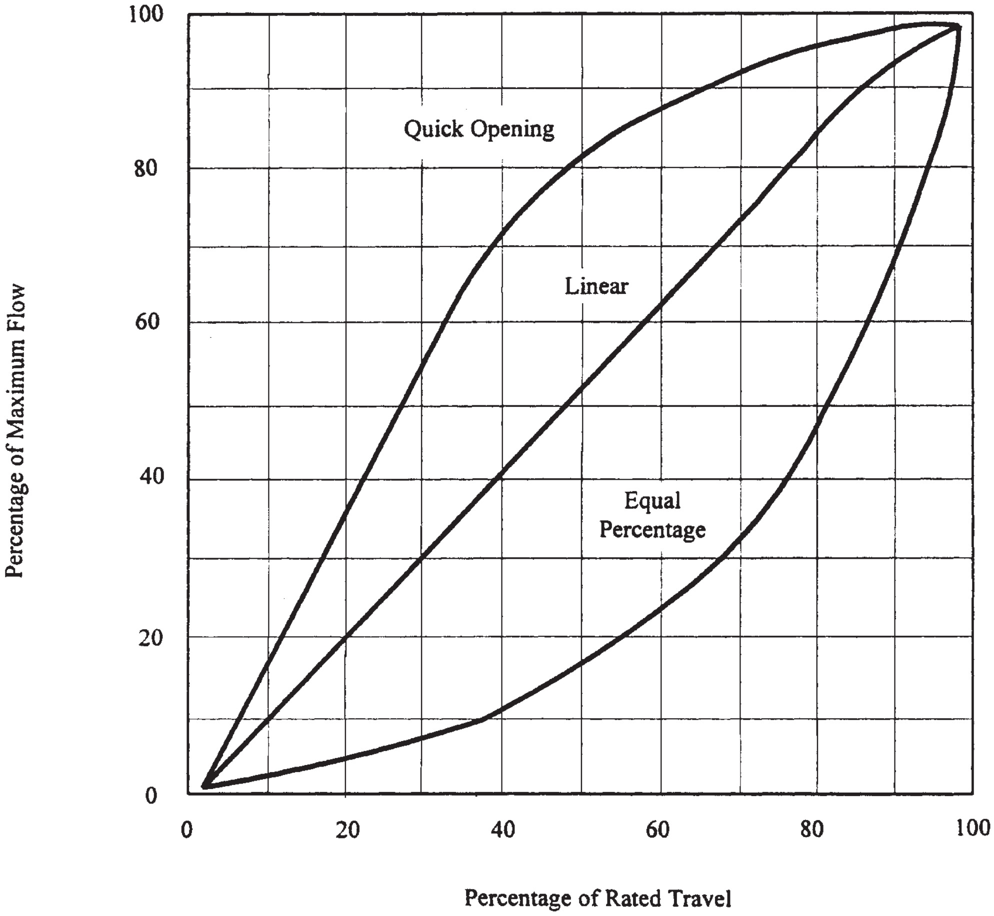

Figure 10-1. Valve Flow Characteristics
(Source: Fisher, Control Valve Handbook, 2nd Ed., p. 60.)

Table 10-1
Recommended Flow Characteristics

Control System	Application	Recommended Flow Characteristic
Liquid Level	Constant ΔP.	Linear
Liquid Level	Decreasing ΔP with increasing flow; $\Delta P_{min} > 20\% \Delta P_{max}$.	Linear
Liquid Level	Decreasing ΔP with increasing flow; $\Delta P_{min} < 20\% \Delta P_{max}$.	Equal Percentage
Liquid Level	Increasing ΔP with increasing flow; $\Delta P_{max} < 200\% \Delta P_{min}$.	Linear
Liquid Level	Increasing ΔP with increasing flow; $\Delta P_{max} > 200\% \Delta P_{min}$.	Quick Opening
Flow	Measurement signal proportional to flow; valve in series with measurement device; wide range of flow required.	Linear
Flow	Measurement signal proportional to flow; valve in series with measurement device; small range of flow required with large ΔP change for increasing flow.	Equal Percentage
Flow	Measurement signal proportional to flow; valve in parallel (bypass) with measurement device; wide range of flow required.	Linear
Flow	Measurement signal proportional to flow; valve in parallel (bypass) with measurement device; small range of flow required with large ΔP change for increasing flow.	Equal Percentage
Flow	Measurement signal proportional to flow squared; valve in series with measurement device; wide range of flow required.	Linear
Flow	Measurement signal proportional to flow squared; valve in series with measurement device; small range of flow required with large ΔP change for increasing flow.	Equal Percentage
Flow	Measurement signal proportional to flow squared; valve in parallel (bypass) with measurement device; wide range of flow required.	Equal Percentage
Flow	Measurement signal proportional to flow squared; valve in parallel (bypass) with measurement device; small range of flow required with large ΔP change for increasing flow.	Equal Percentage
Pressure	All.	Equal Percentage

Source: Control Valve Handbook, Fisher Controls Company, pp. 61-62.

Table 10-2
Standard Control Valve Body Materials

Cast Material	Standard	Comments
Carbon Steel	ASTM A 216 Gr. WCB	Moderate services such as non-corrosive liquids. Higher pressures and temperatures than cast iron. Check codes for suitability at extended high temperatures.
Chrome-Moly Steel	ASTM A 217, Gr. C5	Used for mildly corrosive fluids such as sea water, oils. Resistant to erosion and creep at high temperatures. Can be used to 595°C (1,100°F).
Type 304 Stainless Steel	ASTM A 351, Gr. CF8	Used for oxidizing or very corrosive fluids (see Appendix C). Can be used above 540°C (1,000°F).
Type 316 Stainless Steel	ASTM A 351, Gr. CF8M	Used for oxidizing or very corrosive fluids, resistant to corrosion pitting and creep (see Appendix C). Provides greater strength than 304 S.S.
Monel	ASTM A 494 Gr. M35-1	Resistant to nonoxidizing acids. Used with seawater and other mildly corrosive fluids at high temperatures. Expensive.
Hastelloy-C	ASTM A 494 Gr. CW2N	Used particularly with chlorine and chloride compounds. Expensive.
Iron	ASTM A 126 Class B	Inexpensive and non-ductile. Used for water and non-corrosive liquids.
Bronze	ASTM B 61 and B 62	ASTM B 61 typically used for trim. ASTM B 62 typically used for valve body. Can be used for water and dilute acid service (see Appendix B).

Note: Gr. = grade; grade designation pursuant to the referenced standard.
Source: Compiled by SAIC, 1998.

Table 10-3
Wear and Galling Resistance Chart of Material Combinations

	304 SS	316 SS	Bronze	Inconel	Monel	Hastelloy B	Hastelloy C	Titanium 75A	Nickel	Alloy 20	Type 416 Hard	Type 440 Hard	Alloy 6 (Co-Cr)	Cr-Plate	Al-Bronze
304 SS	P	P	F	P	P	P	F	P	P	P	F	F	F	F	F
316 SS	P	P	F	P	P	P	F	P	P	P	F	F	F	F	F
Bronze	F	F	S	S	S	S	S	S	S	S	F	F	F	F	F
Inconel	P	P	S	P	P	P	F	P	F	F	F	F	F	F	S
Monel	P	P	S	P	P	P	F	F	F	F	F	F	S	F	S
Hastelloy B	P	P	S	P	P	P	F	F	S	F	F	F	S	S	S
Hastelloy C	F	F	S	F	F	F	F	F	F	F	F	F	S	S	S
Titanium 75A	P	P	S	P	F	F	F	P	F	F	F	F	S	F	S
Nickel	P	P	S	F	F	S	F	F	P	P	F	F	S	F	S
Alloy 20	P	P	S	F	F	F	F	F	P	P	F	F	S	F	S
Type 416 Hard	F	F	F	F	F	F	F	F	F	F	F	F	S	S	S
Type 440 Hard	F	F	F	F	F	F	F	F	F	F	S	F	S	S	S
17-4 PH	F	F	F	F	F	F	F	F	F	F	F	S	S	S	S
Alloy 6 (Co-Cr)	F	F	F	F	S	S	S	S	S	S	S	S	F	S	S
ENC*	F	F	F	F	F	F	F	F	F	F	S	S	S	S	S
Cr Plate	F	F	F	F	F	S	S	F	F	F	S	S	S	P	S
Al Bronze	F	F	F	S	S	S	S	S	S	S	S	S	S	S	P

* Electroless nickel coating

S - Satisfactory
F - Fair
P - Poor

Source: Control Valve Handbook, Fisher Controls Company, p. 49.

Table 10-4
Elastomer General Properties

Property		Natural Rubber	Buna-S	Nitrile	Neoprene	Butyl	Thiokol	Silicone	Hypalon	Viton[2,3]	Polyurethane[3]	Ethylene Propylene[4]
Tensile Strength, psi (Bar)	PureGum	3000 (207)	400 (28)	600 (41)	3500 (241)	3000 (207)	300 (21)	200-450 (14-31)	4000 (276)	---	---	---
	Reinforced	4500 (310)	3000 (207)	4000 (276)	3500 (241)	3000 (207)	1500 (103)	1100 (76)	4400 (303)	2300 (159)	6500 (448)	2500 (172)
Tear Resistance		Excellent	Poor-Fair	Fair	Good	Good	Fair	Poor-Fair	Excellent	Good	Excellent	Poor
Abrasion Resistance		Excellent	Good	Good	Excellent	Fair	Poor	Poor	Excellent	Very Good	Excellent	Good
Aging:	Sunlight Oxidation	Poor Good	Poor Fair	Poor Fair	Excellent Good	Excellent Good	Good Good	Good, Very Good	Excellent, Very Good	Excellent Excellent	Excellent Excellent	Excellent Good
Heat (Max. Temp.)		93°C (200°F)	93°C (200°F)	121°C (250°F)	93°C (200°F)	93°C (200°F)	60°C (140°F)	232°C (450°F)	149°C (300°F)	204°C (400°F)	93°C (200°F)	177°C (350°F)
Static (Shelf)		Good	Good	Good	Very Good	Good	Fair	Good	Good	---	---	Good
Flex Cracking Resistance		Excellent	Good	Good	Excellent	Excellent	Fair	Fair	Excellent	---	Excellent	---
Compression Set Resistance		Good	Good	Very Good	Excellent	Fair	Poor	Good	Poor	Poor	Good	Fair
Low Temperature Flexibility (Max.)		-54°C (-65°F)	-46°C (-50°F)	-40°C (-40°F)	-40°C (-40°F)	-40°C (-40°F)	-40°C (-40°F)	-73°C (-100°F)	-29°C (-20°F)	-34°C (-30°F)	-40°C (-40°F)	-45°C (-50°F)
Permeability to Gases		Fair	Fair	Fair	Very Good	Very Good	Good	Fair	Very Good	Good	Good	Good
Resilience		Very Good	Fair	Fair	Very Good	Very Good	Poor	Good	Good	Good	Fair	Very Good
Elongation (Max.)		700%	500%	500%	500%	700%	400%	300%	300%	425%	625%	500%

Notes:
[1] Trademark of Thiokol Chemical Co.
[2] Trademark of E.I. DuPont Co.
[3] Do not use with ammonia.
[4] Do not use with petroleum base fluids. Use with ester base nonflammable hydraulic oils and low pressure steam applications to 300 °F (140°C).
See Appendix B for more details regarding fluid compatibility with elastomers.

Source: Control Valve Handbook, Fisher Controls Company, p. 57.

In addition, the amount of valve leakage is determined based on acceptability to process and design requirements. Control valve seats are classified in accordance with ANSI/FCI 70-2-1991 for leakage. These classifications are summarized in Table 10-5 and Table 10-6.

Table 10-5
Valve Seat Leakage Classifications

Leakage Class Designation	Maximum Allowable Leakage
I	---
II	0.5% of rated capacity
III	0.1% of rated capacity
IV	0.01% of rated capacity
V	5×10^{-12} m^3/s of water per mm of seat diameter per bar differential (0.0005 ml/min per inch of seat diameter per psi differential)
VI	Not to exceed amounts shown in Table 10-6 (based on seat diameter)

Source: ANSI/FCI 70-2-1991

Table 10-6
Class VI Seat Allowable Leakage

Nominal Port Diameter mm (in)	Allowable Leakage Rate (ml per minute)
≤25 (≤1)	0.15
38 (1½)	0.30
51 (2)	0.45
64 (2½)	0.60
76 (3)	0.90
102 (4)	1.70
152 (6)	4.00
203 (8)	6.75

Source: ANSI/FCI 70-2-1991

d. Packing

Most control valves use packing boxes with the packing retained and adjusted by flange and stud bolts. Several packing materials are available for use, depending upon the application. Table 10-7 provides information on some of the more typical packing arrangements.

e. End Connections

The common end connections for installing valves in pipe include screwed pipe threads, bolted gasketed flanges, welded connections, and flangeless (or wafer) valve bodies.

Screwed end connections are typically used with small valves. Threads are normally specified as tapered female National Pipe Thread (NPT). This end connection is limited to valves 50 mm (2 in) and smaller and is not recommended for elevated temperature service. This connection is also used in low maintenance or non-critical applications.

Flanged end valves are easily removed from piping and, with proper flange specifications, are suitable for use through the range of most control valve working pressures. Flanges are used on all valve sizes larger than 50 mm (2 in). The most common types of flanged end connections are flat faced, raised faced, and the ring joint. Flat faced flanges are typically used in low pressure, cast iron or brass valves and have the advantage of minimizing flange stresses. Raised faced flanges can be used for high pressure and temperature applications and are normally standard on ANSI Class 250 cast iron and on all steel and alloy steel bodies. The ring-type joint flange is typically used at extremely high pressures of up to 103 MPa (15,000 psig) but is generally not used at high temperatures. This type of flange is furnished only on steel and alloy valve bodies when specified.

Welding ends on valves have the advantage of being leak tight at all pressures and temperatures; however, welding end valves are very difficult to remove for maintenance and/or repairs. Welding ends are manufactured in two styles: socket and butt.

Flangeless valve bodies are also called wafer-style valve bodies. This body style is common to rotary shaft control valves such as butterfly valves and ball valves.

TABLE 10-7
Packing

Type	Application
PTFE	Resistant to most chemicals. Requires extremely smooth stem finish to seal properly. Will leak if stem or packing is damaged.
Laminated/Filament Graphite	Impervious to most liquids and radiation. Can be used at high temperatures, up to 650°C (1,200°F). Produces high stem friction.
Semi-Metallic	Used for high pressures and temperatures, up to 480°C (900°F).
Fiberglass	Good for general use. Used with process temperatures up to 288°C (550°F). Ferritic steel stems require additive to inhibit pitting.
Kevlar and Graphite	Good for general use. Used with process temperatures up to 288°C (550°F). Corrosion inhibitor is included to avoid stem corrosion.

Source: Compiled by SAIC, 1998

Flangeless bodies are clamped between two pipeline flanges by long through-bolts. One of the advantages of a wafer-style body is that it has a very short face-to-face body length.

f. Operators

Valve operators, also called actuators, are available in manual, pneumatic, electric, and hydraulic styles.

Manual operators are used where automatic control is not required. These valves may still result in good throttling control, if control is necessary. Gate, globe and stop check valves are often supplied with hand wheel operators. Ball and butterfly valves are supplied with hand levers. Manual operators can be supplied with direct mount chain wheels or extensions to actuate valves in hard-to-reach locations. Manually operated valves are often used in a three-valve bypass loop around control valves for manual control of the process during down time on the automatic system. Manual operators are much less expensive than automatic operators.

For sliding stem valves, that is, valves that are not rotary, the most common operator type is a pneumatic operator. A pneumatic operator can be a spring and diaphragm type or a pneumatic piston. While these pneumatic operators are also available for rotary shaft valves, electrical operators tend to be more common on the rotary valves.

Spring and diaphragm operators are pneumatically operated using low pressure air supplied from a controller position or other source. Styles of these operators include direct acting, in which increasing air pressure pushes down the diaphragm and extends the actuator stem; reverse acting, in which increasing air pressure pushes up the diaphragm and retracts the actuator stem; and direct acting for rotary valves. Pneumatic operators are simple, dependable, and economical. Molded diaphragms can be used to provide linear performance and increase travel. The sizes of the operators are dictated by the output thrust required and available air pressure supply.

Pneumatic piston operators are operated using high pressure air. The air pressure can be up to 1.03 MPa (150 psig), often eliminating the need for a pressure regulator that is required on a diaphragm actuator. The best design for piston actuators is double acting. This allows for the maximum force in both directions on the piston. Piston actuators can be supplied with accessories that will position the valve in the event of loss of air supply. These accessories include spring return, pneumatic trip valves, and lock-up type systems. It is common to include manual operators along with pneumatic piston operators in a design. These manual operators can then act as travel stops to limit either full opening or full closing of the valve.

Electric and electro-hydraulic operators are more expensive than pneumatic actuators; however, they offer advantages when no existing air supply source is available, where low ambient temperatures could affect pneumatic supply lines, or where very large stem forces or shaft forces are required. Electrical operators only require electrical power to the motors and electrical input signal from the controller in order to be positioned. Electrical operators are usually self-contained and operate within either a weather-proof or an explosion-proof casing.

An auxiliary positioner or booster is sometimes used on pneumatic operating systems when it is necessary to split the controller output to more than one valve, to amplify the controller above the standard range in order to provide increased actuator thrust, or to provide the best possible control with minimum overshoot and fastest possible recovery following a disturbance or load change. Determination of whether to use a positioner or a booster depends on the speed of the system response. If the system is relatively fast, such as is typical of pressure control and most flow control loops, the proper choice is a booster. If the system is relatively slow, as is typical of liquid level, blending, temperature and reactor control loads, the proper choice is a positioner[1].

Hydraulic snubbers dampen the instability of the valve plug in severe applications and are used on pneumatic piston and direct acting diaphragm actuators.

Limit switches can be used to operate signal lights, solenoid valves, electric relays, or alarms. The limit switches are typically provided with 1 to 6 individual switches and are operated by the movement of the valve stem. It is common for each switch to be individually adjustable and used to indicate the full open or full closed position on a valve.

Electro-pneumatic transducers and electro-pneumatic positioners are used in electronic control loops to position pneumatically operated control valves. The positioner or transducer receives a current input signal and then supplies a proportional pneumatic output signal to the pneumatic actuator to position the valve.

g. Supports

Specific pipe material design recommendations are followed when designing supports for valves. In general, one hanger or other support should be specified for each side of a valve, that is, along the two pipe sections immediately adjacent to the valve. The weight of the valve is included in the calculation of the maximum span of supports.

10-2. Valve Types

The main valve types have many variations and may have different names depending upon manufacturer. Careful selection and detailed specifications are required to insure that design and performance requirements are met.

a. Check Valves

Check valves are self-actuated. These valves are opened, and sustained in the open position, by the force of the liquid velocity pressure. They are closed by the force of gravity or backflow. The seating load and tightness is dependent upon the amount of back pressure. Typical check valves include swing check, tilting disc check, lift check, and stop check. Other check valve types are available, however.

Swing check valves are used to prevent flow reversal in horizontal or vertical upward pipelines (vertical pipes or pipes in any angle from horizontal to vertical with upward flow only). Swing check valves have discs that swing open and closed. The discs are typically designed to close on their own weight, and may be in a state of constant movement if velocity pressure is not sufficient to hold the valve in a wide open position. Premature wear or noisy operation of the swing check valves can be avoided by selecting the correct size on the basis of flow

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[1] Fisher Control Company, p. 35.

conditions. The minimum velocity required to hold a swing check valve in the open position is expressed by the empirical formula[2]:

$$V = j\sqrt{v}$$

where:
V = liquid flow, m/s (ft/s)
v = specific volume of the liquid, m^3/N (ft^3/lb)
j = 133.7 (35) for Y-pattern
= 229.1 (60) for bolted cap
= 381.9 (100) for U/L listed

Tilting disc check valves are pivoted circular discs mounted in a cylindrical housing. These check valves have the ability to close rapidly, thereby minimizing slamming and vibrations. Tilting disc checks are used to prevent reversals in horizontal or vertical-up lines similar to swing check valves. The minimum velocity required for holding a tilting check valve wide open can be determined by the empirical formula[3]:

$$V = j\sqrt{v}$$

where:
V = liquid flow, m/s (ft/s)
v = specific volume of the liquid, m^3/N (ft^3/lb)
j = 305.5 (80) for a 5° disc angle (typical for steel)
= 114.6 (30) for a 15° disc angle (typical for iron)

Lift check valves also operate automatically by line pressure. They are installed with pressure under the disc. A lift check valve typically has a disc that is free floating and is lifted by the flow. Liquid has an indirect line of flow, so the lift check is restricting the flow. Because of this, lift check valves are similar to globe valves and are generally used as a companion to globe valves. Lift check valves will only operate in horizontal lines. The minimum velocity required to hold a lift check valve open is calculated using the following empirical formula[4]:

$$V = j\beta^2\sqrt{\nu}$$

where:
V = liquid flow, m/s (ft/s)
v = specific volume of the liquid, m^3/N (ft^3/lb)
j = 152.8 (40) for bolted cap
= 534.7 (140) for Y-pattern
β = ratio of port diameter to inside pipe diameter

Stop check valves are typically used in high pressure and hazardous applications. Stop check valves have a floating disc. Sizing of these valves is extremely important because of the floating disc, and manufacturer's recommended procedures should be used. Stop check valves typically have a manual operator and, in this manner, can be forced closed to prevent any backflow of materials. The minimum velocity required for a full disc lift in a stop check valve is estimated by the following empirical formula[5]:

$$V = j\beta^2\sqrt{\nu}$$

where:

V = liquid flow, m/s (ft/s)
v = specific volume of the liquid, m^3/N (ft^3/lb)
j = 210.0 (55) globe, OS&Y blocked bonnet
= 286.4 (7S) angle, OS&Y blocked bonnet
= 229.1 (60) Y-pattern, OS&Y bolted bonnet
= 534.7 (140) Y-pattern, threaded bonnet
β = ratio of port diameter to inside pipe diameter

Use of these empirical methods may result in a check valve sized smaller than the piping which is used. If this is the case, reducers are used to decrease pipe size to the smaller valve. The pressure drop is no greater than that of the larger valve that is partially open, and valve life is extended[6].

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[2] Crane Valves, Engineering Data, p. 53.
[3] Ibid., p. 53.
[4] Ibid., p. 53.
[5] Ibid., p. 54.
[6] Crane Valves, Cast Steel Valves, p. 14.

b. Ball Valves

Ball valves with standard materials are low cost, compact, lightweight, easy to install, and easy to operate. They offer full flow with minimum turbulence and can balance or throttle fluids. Typically, ball valves move from closed to full open in a quarter of a turn of the shaft and are, therefore, referred to as quarter turn ball valves. Low torque requirements can permit ball valves to be used in quick manual or automatic operation, and these valves have a long reliable service life. Ball valves can be full ball or other configurations such as V-port.

Full ball valves employ a complete sphere as the flow controlling member. They are of rotary shaft design and include a flow passage. There are many varieties of the full ball valves, and they can be trunion mounted with a single piece ball and shaft to reduce torque requirements and lost motion.

One of the most popular flow controlling members of the throttling-type ball valves is a V-port ball valve. A V-port ball valve utilizes a partial sphere that has a V-shaped notch in it. This notch permits a wide range of service and produces an equal percentage flow characteristic. The straight-forward flow design produces very little pressure drop, and the valve is suited to the control of erosive and viscous fluids or other services that have entrained solids or fibers. The V-port ball remains in contact with the seal, which produces a shearing effect as the ball closes, thus minimizing clogging.

c. Gate Valves

The gate valve is one of the most common valves used in liquid piping. This valve, as a rule, is an isolation valve used to turn on and shut off the flow, isolating either a piece of equipment or a pipeline, as opposed to actually regulating flow. The gate valve has a gate-like disc which operates at a right angle to the flow path. As such, it has a straight through port that results in minimum turbulence erosion and resistance to flow. However, because the gate or the seating is perpendicular to the flow, gate valves are impractical for throttling service and are not used for frequent operation applications.

Repeated closure of a gate valve, or rather movement toward closure of a gate valve, results in high velocity flow. This creates the threat of wire drawing and erosion of seating services. Many gate valves have wedge discs with matching tapered seats. Therefore, the refacing or repairing of the seating surfaces is not a simple operation. Gate valves should not, therefore, be used frequently to avoid increased maintenance costs. In addition, a slightly open gate valve can cause turbulent flow with vibrating and chattering of the disc.

A gate valve usually requires multiple turns of its hand wheel manual operator in order to be opened fully. The volume of flow through the valve is not in direct proportion to the number of turns of the hand wheel.

d. Globe and Angle Valves

Liquid flow does not pass straight through globe valves. Therefore, it causes an increased resistance to flow and a considerable pressure drop. Angle valves are similar to globe valves; however, the inlet and outlet ports are at 90° angles to one another, rather than at 180° angles. Because of this difference, the angle valves have slightly less resistance to flow than globe valves. However, both valve types operate similarly in principle and, for the purposes of this document, discussion of globe valves will also pertain to angle valves.

There are a number of common globe valve seating types. Table 10-8 presents some of the more common seating types, along with advantages and disadvantages of each.

The seating of the plug in a globe valve is parallel to the line of liquid flow. Because of this seating arrangement, globe valves are very suitable for throttling flow with a minimal seat erosion or threat of wire drawing.

A globe valve opens in direct proportion to the number of turns of its actuator. This feature allows globe valves to closely regulate flow, even with manual operators. For example, if it takes four turns to open a globe valve fully, then approximately one turn of a hand wheel will release about 25% of the flow, two turns will release 50%, and three turns will release 75%. In addition, the shorter travel saves time and work, as well as wear on valve parts.

Maintenance is relatively easy with globe valves. The seats and discs are plugs, and most globe valves can be repaired without actually removing the valve from the pipe.

Table 10-8
Common Globe Valve Seating

Type	Comments
Plug	Long taper with matching seat provides wide seating contact area. Excellent for severe throttling applications. Resistant to leakage resulting from abrasion. With proper material selection, very effective for resisting erosion.
Conventional Disc	Narrow contact with seat. Good for normal service, but not for severe throttling applications. Subject to erosion and wire drawing. Good seating contact if uniform deposits (such as from coking actions) occur. Non-uniform deposits make tight closure difficult.
Composition Disc	“Soft” discs provided in different material combinations depending upon liquid service. Good for moderate pressure applications except for close throttling, which will rapidly erode the disc.
Needle	Sharp pointed disc with matching seat provides fine control of liquid flow in small-diameter piping. Stem threads are fine, so considerable stem movement is required to open or close.

Source: Compiled by SAIC, 1998

e. Butterfly Valves

Butterfly valves provide a high capacity with low pressure loss and are durable, efficient, and reliable. The chief advantage of the butterfly valve is its seating surface. The reason for this advantage is that the disc impinges against a resilient liner and provides bubble tightness with very low operating torque. Butterfly valves exhibit an approximately equal percentage of flow characteristic and can be used for throttling service or for on/off control.

Typical butterfly bodies include a wafer design, a lug wafer design (a wafer with the addition of lugs around the bodies), and a flanged design. In all designs, butterfly valves are typically made with standard raised face piping flanges. Butterfly valves are available standard in sizes up to 72 inches for many different applications. The operators can be either pneumatic or electric.

f. Pinch Valves

Pinch valves, as the name suggests, pinch an elastomeric sleeve shut in order to throttle the flow through the pipeline. Because of the streamlined flow path, the pinch valve has very good fluid capacity. Pinch valves typically have a fairly linear characteristic. However, some manufacturers offer field reversible cam-characterizable positioners. These positioners will vary the rate of stem change as a function of position in order to match the flow characteristics desired. In some instances, the cams are set up to provide an equal percentage flow characteristic through a pinch valve.

The pinch valve sleeve is available in various elastomer materials in order to adjust for chemical resistance. In addition, because the throttling takes place in the elastomer sleeve, and elastomers typically have very good abrasion resistance; pinch valves are often used for slurries or liquids that contain high amounts of solids.

g. Plug Valves

Plug valves are another type of isolation valve designed for uses similar to those of gate valves, where quick shutoff is required. They are not generally designed for flow regulation. Plug valves are sometimes also called cock valves. They are typically a quarter turn open and close. Plug valves have the capability of having multiple outlet ports. This is advantageous in that it can simplify piping. Plug valves are available with inlet and outlet ports with four-way multi-port valves which can be used in place of two, three or four straight valves.

h. Self-Contained Automatic Valves

Self-contained automatic valves are used for pressure-reducing stations. The valve body itself is normally a globe-type valve. It is normally diaphragm actuated and hydraulically operated. The valves are capable of maintaining constant downstream pressure regardless of the fluctuations in flow or upstream pressure by internal hydraulic controllers.

10-3. Valve Sizing and Selection

Valve sizing and type selection is a critical component of a piping design. Valve type is shown on P&IDs, and valve size is commonly provided on valve schedules. The sizing and selection procedures are different for non-control and control valves.

a. Non-Control Valves

Non-control valves used for isolation are the same size as the connecting pipe. This sizing reduces pressure loss. Check valves may be smaller than the connecting pipe, provided that the valves are properly sized to ensure full open operation without flow restriction. Materials of construction, wetted or otherwise, and end connections are in compliance with applicable codes and standards and address the fluid application for corrosivity (see Paragraph 10-1).

b. Control Valves

Control valves are sized and selected to optimize application. Valves that are sized too small will not pass the required flow. Control valves that are sized too large or are arbitrarily sized to match the connecting pipe, will result in increased capital costs, decreased valve life (due to the throttling and erosion effects when operating near to the closed position), and decreased performance (by limiting rangeability). Control valves are optimally selected by identifying the flow characteristic required, then calculating an expected flow coefficient and the maximum allowable pressure drop. These factors are then compared to manufacturers' data for specific valve types and sizes.

To select a control valve, the process application must be understood. Minimum information considered includes desired flow characteristics; type, temperature, viscosity, and specific gravity of the liquid; minimum and maximum flow capacity; minimum and maximum valve inlet pressure; and minimum and maximum valve outlet pressure.

For example, Figure 10-2 depicts a piping system curve, with and without the control valve, and an overlying pump curve. Typically, a valve differential pressure (ΔP) of approximately 33% of the total piping system friction drop at maximum flow is desired (as shown on Figure 10-2). For systems that require low turndown, or face abrasion or other problems, the valve ΔP may be as low as 15%[7].

Once a desired ΔP is determined, the valve flow coefficient (C_v) and allowable pressure drop (ΔP_{allow}) are calculated for a fully open valve in accordance with the flow chart depicted on Figure 10-3. The valve recovery factor (R_m) and cavitation index (K_c) are determined from manufacturers' data for a specific type and size of valve.

The sizing formulas for incompressible flow without mixed-phase fluids, dense slurries, dry solids or non-Newtonian liquids are as follows[8]:

$$C_v = \frac{Q}{N_1}\sqrt{\frac{s.g.}{\Delta P}}$$

where:
C_v = valve flow coefficient
Q = flow, m^3/hour (gpm)

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[7] Gardellin, p. 4.
[8] ISA-S75.01, pp. 15-18, 33-35.

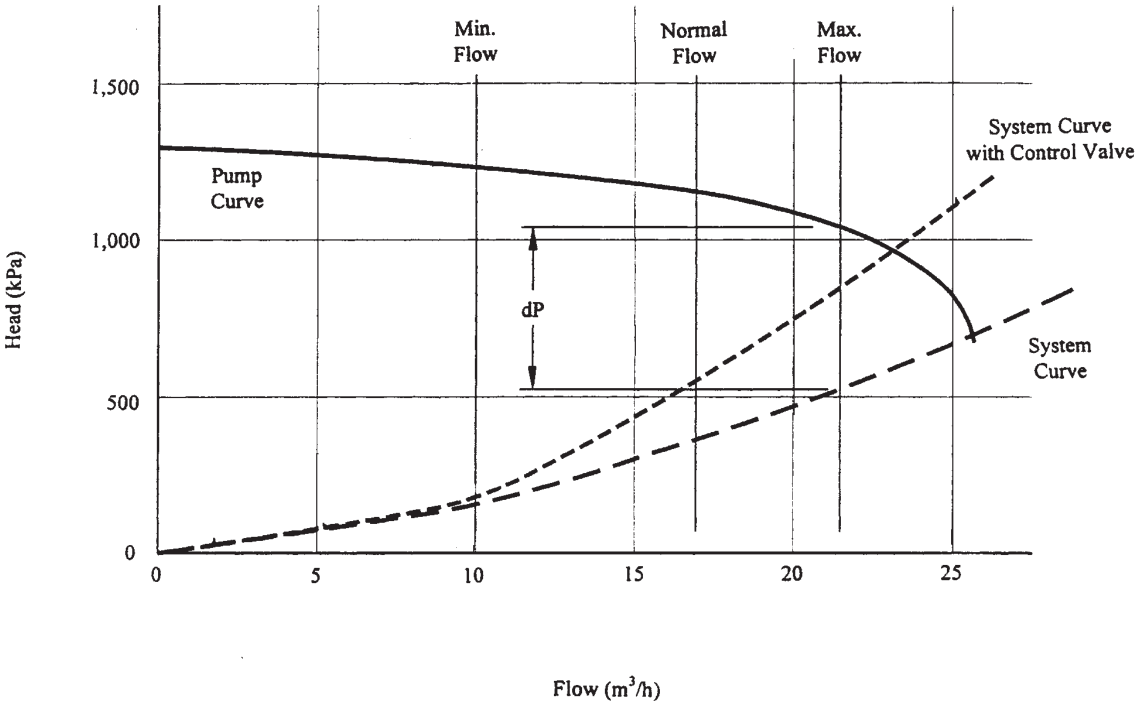


Figure 10-2. Control Valve Pressure Drop Curve
(Source: SAIC, 1998)

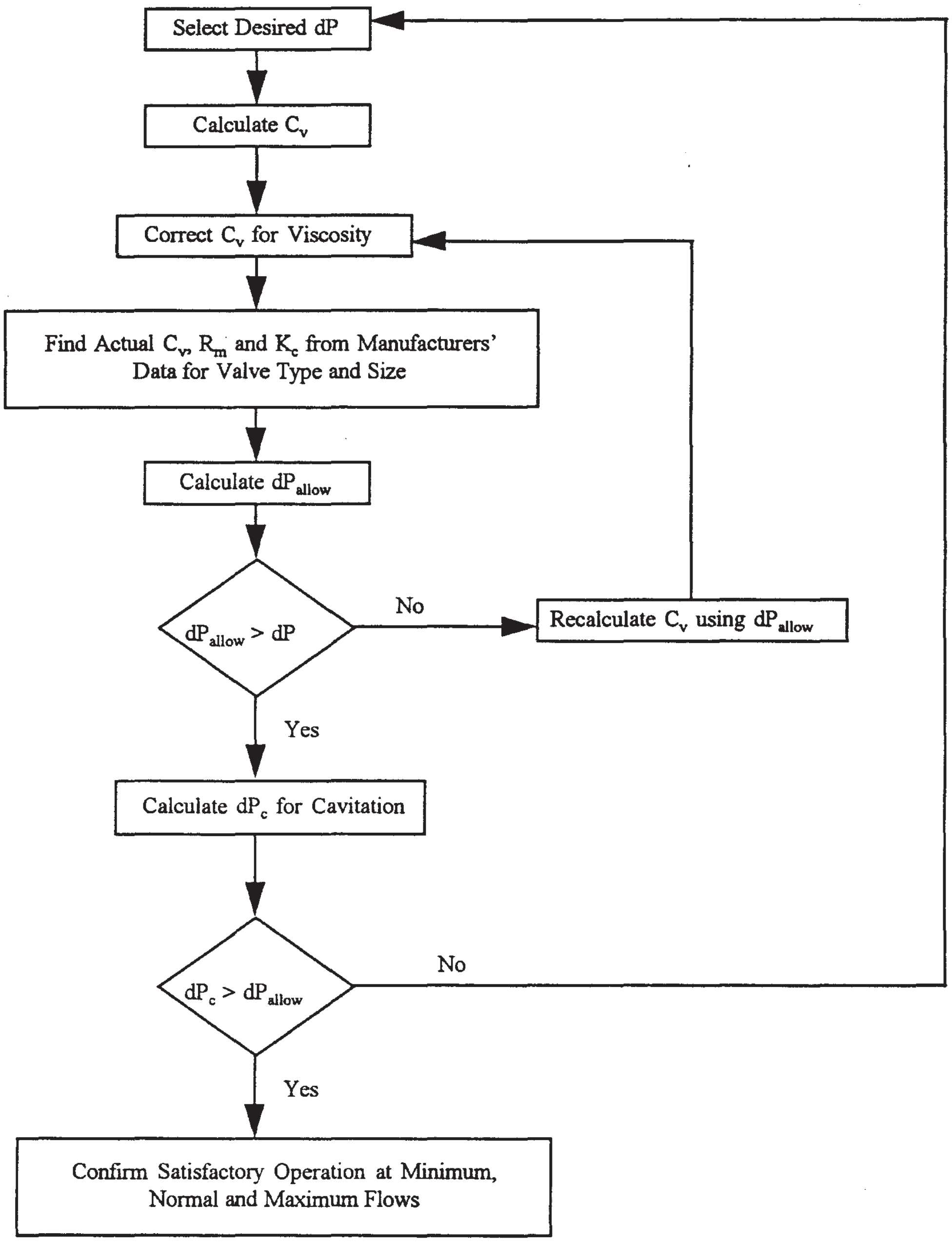


Figure 10-3. Control Valve Sizing
(Source: SAIC, 1998)

N_1 = Conversion factor, 0.085 when Q is in m^3/hour and ΔP is in kPa (1.00 when Q is in gpm and ΔP is in psi)
s.g. = specific gravity of liquid
ΔP = differential pressure across valve, kPa (psi)

$$Re_v = \frac{N_4 F_d Q}{\nu R_m^{1/2} C_v^{1/2}} \left[\frac{R_m^2 C_v^2}{N_2 d^4} + 1 \right]^{1/4}$$

where:
Re_v = valve Reynolds number
N_4 = conversion factor, 76,000 when Q is in m^3/hour and d is in mm (17,300 when Q is in gpm and d is in inches)
F_d = valve style modifier, see Table 10-9
Q = volumetric flow rate, m^3/hour (gpm)
ν = kinematic viscosity, mm^2/sec (centistoke)
R_m = valve recovery factor, from manufacturers' data (see Table 10-9)
C_v = valve flow coefficient
N_2 = conversion factor, 0.00214 when d is in mm (890 when d is in inches)
d = valve inlet diameter, mm (in)

$$C_{vc} = \frac{C_v}{F_R}$$

where:
C_{vc} = valve flow coefficient corrected for viscosity
F_R = valve Reynolds number factor (see Figure 10-4)

$$\Delta P_{allow} = R_m^{\ 2} (P_i - r_c P_v)$$

where:
ΔP_{allow} = maximum valve ΔP to avoid choked flow, kPa (psi)
R_m = valve recovery factor, from manufacturers' data (see Table 10-9)
P_i = valve inlet pressure, kPa (psi)
r_c = critical pressure ratio, calculation as follows or see Figure 10-5
P_v = liquid vapor pressure, kPa (psia)

$$r_c = 0.96 - 0.28 \left(\frac{P_v}{P_c} \right)^{1/2}$$

where:
r_c = critical pressure ratio
P_v = liquid vapor pressure, kPa (psi)
P_c = absolute thermodynamic critical pressure, kPa (psi)

$$\Delta P_c = K_c (P_i - P_v)$$

where:
ΔP_c = valve ΔP at which cavitation damage occurs, kPa (psi)
K_c = cavitation index, from manufacturers' data
P_i = value inlet pressure, kPa (psi)
P_v = liquid vapor pressure, kPa (psi)

Example Problem 8:
Figure 10-2 represents the process to be controlled and control valve is for flow control purposes with an orifice plate flow measurement device. The liquid is water with trace hydrocarbons. The pipe size is 100 mm and the operating conditions are: T = 15.6°C; P_i = 517 kPa, 172.4 kPa, and 1030 kPa for normal, minimum, and maximum operating conditions, respectively.

Solution:
Step 1. From Figure 10-2, ΔP at max. flow = 496 kPa and Q = 17 m^3/hour normal
10 m^3/hour minimum
21.5 m^3/hour maximum

Step 2. The flow measurement device is proportional to flow squared so that an equal percentage for characteristic is desired. Assume a butterfly valve will be used so F_d = 0.7, and R_m = 0.7 (from Table 10-9)

Step 3. From common fluid mechanics reference materials: s.g. = 1.0; P_v = 1.85 kPa; P_c = 22.09 MPa; ν = 1.13 mm^2/sec.

Step 4. Therefore, the valve calculations are:

TABLE 10-9
Example Values of Valve Capacity Factors

Valve Type	Trim Type	Flow Direction*	R_m	F_d**	C_v/d^2***
Globe - Single port	Ported plug	Either	0.9	1.0	6,129 (9.5)
	Contoured plug	Open	0.9	1.0	7,098 (11)
		Close	0.8	1.0	7,098 (11)
	Characterized cage	Open	0.9	1.0	9,032 (14)
		Close	0.85	1.0	10,322 (16)
	Wing guided	Either	0.9	1.0	7,098 (11)
- Double port	Ported plug	Either	0.9	0.7	8,065 (12.5)
	Contoured plug	Either	0.85	0.7	8,387 (13)
	Wing guided	Either	0.9	0.7	9,032 (14)
- Rotary	Eccentric Spherical plug	Open	0.85	1.0	7,742 (12)
		Close	0.68	1.0	8,710 (13.5)
Angle	Contoured plug	Open	0.9	1.0	10,968 (17)
		Close	0.8	1.0	12,903 (20)
	Characterized cage	Open	0.85	1.0	7,742 (12)
		Close	0.8	1.0	7,742 (12)
	Venturi	Close	0.5	1.0	14,194 (22)
Ball	Segmented	Open	0.6	1.0	16,129 (25)
	Standard port (diameter ≅ 0.8d)	Either	0.55	1.0	14,194 (22)
Butterfly	60-Degree aligned	Either	0.68	0.7	11,290 (17.5)
	Fluted vane	Either	0.7	0.7	16,129 (25)
	90-Degree offset seat	Either	0.60	0.7	18,710 (29)

* Flow direction tends to open or close the valve: i.e., push the closure member away from or towards the seat.

** In general, an F_d value of 1.0 can be used for valves with a single flow passage. An F_d value of 0.7 can be used for valves with two flow passages, such as double-ported globe valves and butterfly valves.

*** In this table, d may be taken as the nominal valve size, mm (in).

NOTE: The values are typical only for the types of valves shown at their rated travel for full-size trim. Significant variations in value may occur because of any of the following reasons: reduced travel, trim type, reduced port size, and valve manufacturer.

Source: ISA -S75.01, p. 31; Copyrighted material reprinted by permission of the Instrument Society of America, all rights reserved.

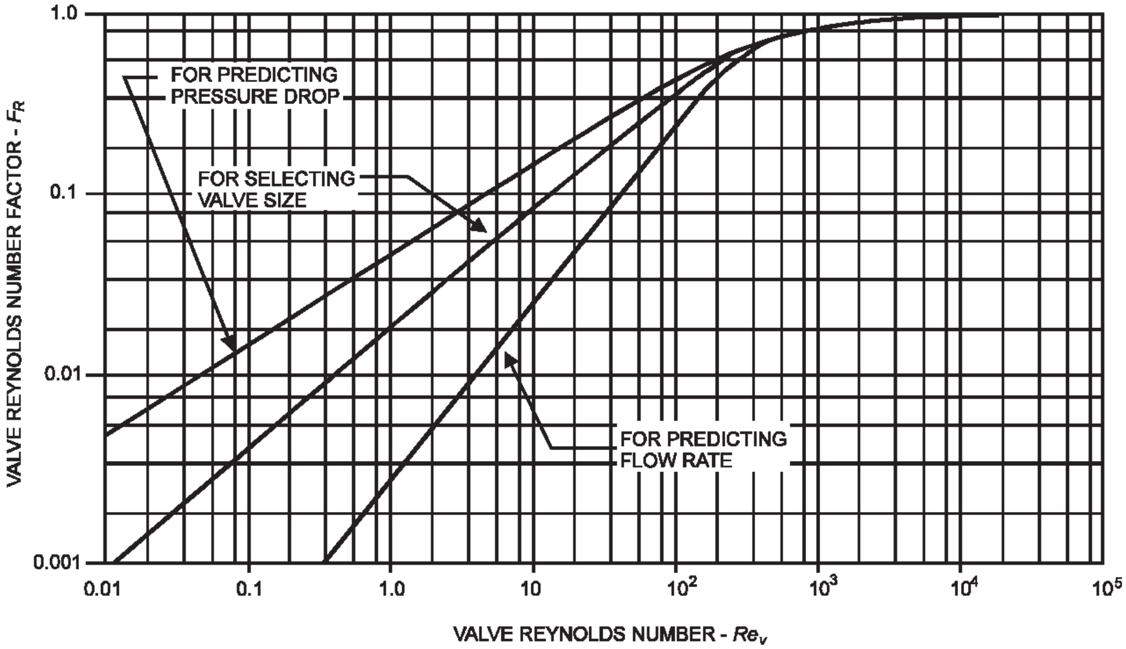
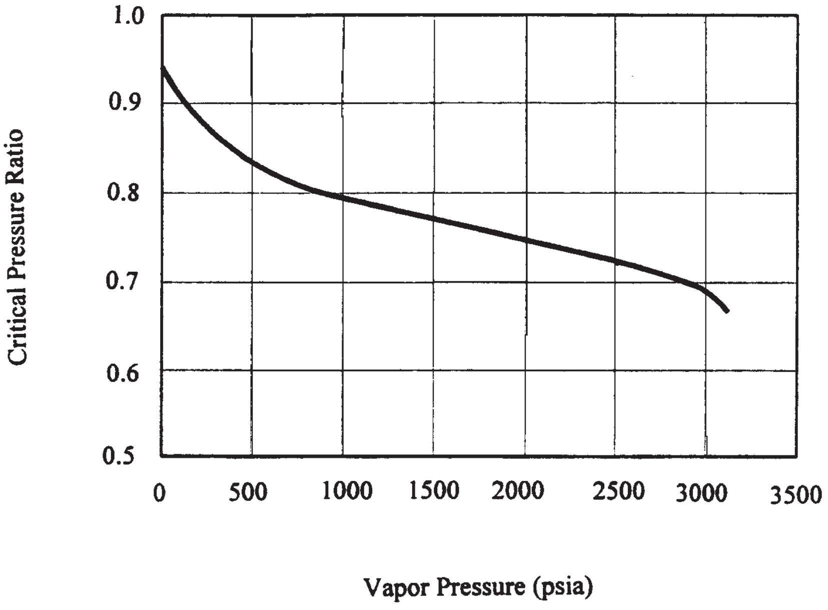
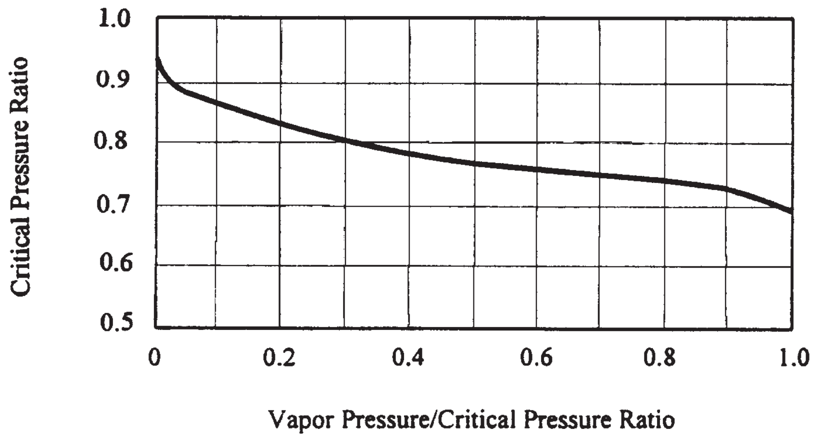


Figure 10-4. Valve Factor Diagram
(Source: ISA-S75.01-1985 (R 1995), p. 34.)



a. Curve to be Used for Water



b. Curve for Liquids Other Than Water

Figure 10-5. Critical Pressure Ratio
(Source: Fisher, Control Valve Handbook, 2nd Ed., p. 67)

$$C_v = \frac{Q}{N_1}\sqrt{\frac{s.g.}{\Delta P}}$$

$$C_v = \frac{21.5\ m^3/hour}{0.085}\sqrt{\frac{1.0}{496\ kPa}} = 11.4$$

$$Re_v = \frac{N_4\ F_d\ Q}{\nu\ R_m^{1/2} C_V^{1/2}}\left[\frac{R_m^2\ C_v^2}{N_2\ d^4} + 1\right]^{1/4}$$

$$Re_v = \frac{(76{,}000)(0.7)(21.5)}{(1.13)(0.7)^{1/2}(11.4)^{1/2}}\left[\frac{(0.7)^2(11.4)^2}{(0.00214)(100)^4} + 1\right]^{1/4}$$

$$Re_v = 3.57\ x\ 10^5$$

F_R = 1.0 from Figure 10-4 (a viscosity correction is not required due to the high Reynolds number).Therefore, C_{vc} = 11.4.

Step 5. From manufacturer's data, a 25 mm, 60° V-port ball valve at full open in a 50 mm pipe has a C_v of 11.2 and a R_m of 0.75. Therefore, neck the connecting piping down to 50 mm, and select a 25 mm V-port ball valve (has an equal percentage flow characteristic).

Step 6. The allowable pressure drop of the system is compared to the actual valve differential pressure to confirm that the valve will operate satisfactorily.

$$r_c = 0.96 - 0.28\left(\frac{P_v}{P_c}\right)^{1/2}$$

$$= 0.96 - 0.28\left(\frac{1.85kPa}{22{,}090kPa}\right)^{1/2}$$

$$r_c = 0.96$$

$$\Delta P_{allow} = R_m^2\ (P_i - r_c\ P_v)$$

$$= (0.75)^2[1030\ kPa - (0.96)(1.85\ kPa)]$$

$$\Delta P_{allow} = 578\ kPa\ at\ \text{max.}\ flow\ (full\ open)$$

$\Delta P_{allow} \geq \Delta P$ at maximum flow, therefore, the valve is acceptable.

10-4. Valve Schedule

Many manufacturers have PC-based sizing programs that will size and select their optimum valve for a specific application. In addition, computerized piping system design programs may also have valve sizing and selection routines that will select the optimum valve in their databases. Although these sizing programs can provide useful data, the optimum valve for a particular application may be found elsewhere. For design purposes, contract drawings include a valve schedule to aid in the bidding and proper supply of valves.

a. Valve Schedule

Table 10-10 presents a valve schedule that is included in the contract drawings for liquid process piping design.

b. Valve Operators Schedule

Table 10-11 is a valve operator schedule that is sometimes included in the contract drawings. This schedule is used when additional information, beyond that shown on a valve schedule, is required.

Table 10-10
Valve Schedule

Valve Tag/Ref	Description	Size Range	Flange Rating	Screwed Ends	Design Rating	Body Materials	Trim Materials	Bolting Materials	Operation	Service	Remarks
V120	Ball Valve, Full Port Positive Shut-off	50 mm & Smaller	- -	Taper ANSI B2.1	1.39 MPa	316 SS	316 SS Ball & Stem Glass Filled TFE Seats, TFE Seals	- -	Lever	IWW, SLG, WPS	
V121	Ball Valve, Full Port Positive Shut-off	80 mm	ANSI B16.5 Class 150	- -	689 kPa	316 SS	316 SS Ball & Stem Glass Filled TFE Seats, TFE Seals	CS ASTM A 307 Gr B	Lever	SW, ALT, RO, AL, SWW, RL	Instrument Isolation Valves Only
V122	Ball Valve, Full Port Positive Shut-off	40 mm & Smaller	ANSI B16.5 Class 300	- -	1.03 MPa	316 SS	316 SS Ball & Stem Glass Filled TFE Seats, TFE Seals	CS ASTM A 307 Gr B	Lever	WCR	
V123	Solid Wedge Gate Valve O.S. & Y., Rising Stem	50 mm & Larger	ANSI B16.5 Class 300	- -	1.03 MPa	CS ASTM A 216 GR WCB	13% Cr Steel Seats & SS Stem	CS ASTM A 307 Gr B	Handwheel	SLP	
V124	Double Disc Gate Valve O.S. & Y., Rising Stem	50 mm & Larger	ANSI B16.5 Class 150	- -	689 kPa	CS ASTM A 216 GR WCB	UT Trim 316 SS Stem	CS ASTM A 307 Gr B	Handwheel	SL	
V150	Swing Check Valve	50 mm to 300 mm	ANSI B16.5 Class 150	- -	689 kPa	CS ASTM A 216 GR WCB	13% Cr Steel Seats & Disc	CS ASTM A 307 Gr B	- -	XLT, ALT, RL, AL, SLO, PLO	All Drain Points to be Threaded & Plugged
V151	Swing Check Valve	50 mm & Smaller	- -	Taper ANSI B2.1	1.39 MPa	Bronze	Bronze	- -	- -	PW	All Drain Points to be Threaded & Plugged
V152	Y-Pattern Check Valve	50 mm & Smaller	- -	Socket Weld	17.2 MPa	CS ASTM A 105	13% Cr Steel Seats & 302 SS Spring	- -	- -	FWH	
V153	Lined Wafer Check Valve	250 mm	Fit Between Class 150	- -	689 kPa	PFA Coated CS	PFA Coated Steel	- -	- -	DWH	
V154	Wafer Style Check Valve	100 mm to 250 mm	Fit Between Class 150	- -	689 kPa	410 SS ASTM A 276	302 SS	- -	- -	AP	All Drain Points to be Threaded & Plugged
PCV-452	Globe Valve, Bolted Bonnet, O.S. & Y., Rising Stem	100 mm	ANSI B16.5 Class 150	- -	689 kPa	CS ASTM A 216 GR WCB	SS	CS ASTM A 307 Gr B	Pneumatic Diaphragm R.A.	RCY	
FCV-501	Butterfly Valve	100 mm	Fit Between Class 150	- -	689 kPa	PFA Lined D.I.	PFA Lined D.I. & SS Stem	- -	Electric	AG, AV	
FCV-625	Butterfly Valve	300 mm	Fit Between Class 150	- -	689 kPa	PFTE Lined CS	PTFE Lined CS & SS Stem	- -	Electric, Enclosed Gear	DWH	

Source: Example Schedule by SAIC, 1998.

Table 10-11
Valve Operator Schedule

Operator Tag/Ref	Description	Type	Maximum Air Pressure	Electrical Supply	Action	Materials of Construction	Failure Mode	Enclosure Rating	Accessories	Associated Valve	Remarks
V120	Ball Valve, Full Port Positive Shut-off	Pneumatic, Diaphragm	103 kPa	- -	R.A	Manufacturer’ s Standard with Epoxy Coating	F.O.	Weather Proof	Positioner, Filter/Regulator, Handwheel	PCV-452	
V121	Ball Valve, Full Port Positive Shut-off	Pneumatic, Piston	1.03 MPa	- -	D.A.	Manufacturer’ s Standard with Epoxy Coating	F.C.	Weather Proof	Positioner, Filter, Handwheel	PCV-1013	
V122	Ball Valve, Full Port Positive Shut-off	Pneumatic, Rotary	1.03 MPa	- -	D.A.	Aluminum	F.L.	NEMA 4	I/P, Filter	FCV-485	
V123	Solid Wedge Gate Valve O.S. & Y., Rising Stem	Electric, Rotary	- -	120 V, 20 A, 1 ph	D.A.	Manufacturer’ s Standard with Epoxy Coating	F.L.	NEMA 4		FCV-501	
V124	Double Disc Gate Valve O.S. & Y., Rising Stem	Electric, Rotary	- -	120 V, 20 A, 1 ph	D.A.	Manufacturer’ s Standard	F.C.	NEMA 4X	Enclosed Gear,	FCV-625	

Source: Example Schedule by SAIC, 1998.