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of Process Equipment Design

ISOLATION AND BLOCK VALVE, SELECTION, SIZING AND TROUBLESHOOTING

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INTRODUCTION

Scope

This design guideline covers the selection, sizing methods and troubleshooting for Block Valves. It assists engineers, operations, personnel and maintenance personnel to understand the basic designs of different types of Valves. By definition, valves are mechanical devices specifically designed to direct, start, stop, mix, or regulate the flow, pressure, or temperature of a process fluid. Valves can be designed to handle either liquid or gas applications.

Prior to the development of even simple irrigation systems, crops cultivated by early civilizations were at the mercy of whims of weather, water levels of rivers or lakes, or the strength of humans and animals to transport water in primitive vessels. Because of the unpredictability or hardship associated with the methods, early farmers sought a number of ways to control the flow of nearby water sources. The main idea of the valve most likely came about when these humble farmers noticed that fallen trees or debris were diverting, or even stopping, the flow of rivers and so came the concept of using artificial barriers to divert water to nearby fields. Eventually, this idea expanded into simple irrigation using a planned series of ditches and canals, which by using gravity could transport, store, and widen the reach of the water source.

Generally, valves during the Middle Ages were raw, carved from wood, and is used primarily as a cake in wine and beer casks. Valve design changed very little until the Renaissance when the principles of modern hydraulic engineering began to develop. In an effort to improve the channel lock performance, Leonardo da Vinci analyzed the voltage will occur at different key gates with varying water levels both sides of the gate. Early studies of this concept of pressure drop helped define the basis for modern fluid dynamics, namely important to understand and calculate valve performance.

Based on their design, function and application, the intake valve various styles, sizes and pressure classes. The smallest industrial valves can weigh as little as 1 lb (0.45 kg) and can be installed conveniently human hands, while the largest can weigh up to 10 tons (9070 kg) and extends to over 24 feet (6.1 m). Industrial process valves can be used in pipe sizes from 0.5 in [nominal diameter (ON 50) to exceeds 48 in (ON 1200), even though more than 90 percent of valves used in process systems are installed in piping measuring 4 in (ON 100) and smaller. The valve can be used in pressures from vacuum to over 13,000 psi (897 bar).

The spectrum of valves available today extends from simple water faucet to control valve equipped with a microprocessor, which provides one-turn process control. The most commonly used types today is gate, plug, ball, butterfly, check, pressure-relief, and globe valve. Valves can be made from a number of materials, with most valves made of steel, iron, plastic, brass, bronze, or some special alloy.

GENERAL DESIGN CONSIDERATIONS

There are many types of valves available, each with its advantages and limitations. Basic requirements and selection depend on their ability to perform certain functions such as:

1. Ability to throttle or control the rate of flow;
2. Lack of turbulence or resistance to flow when fully open - turbulence reduces head pressure;
3. Quick opening and closing mechanism - rapid response is many times needed in an emergency or for safety;
4. Tight shut off - prevents leaks against high pressure;
5. Ability to allow flow in one direction only - prevents return;
6. Opening at a pre-set pressure - procedure control to prevent equipment damage; and
7. Ability to handle abrasive fluids - hardened material prevents rapid wear.

This guideline will discuss the selection process and provide the basic principles of sizing the control valves.

BASIC VALVE TYPES

Valves are available with a wide variety of valve bodies in a variety of styles, materials, connections and sizes. The selection mainly depends on the service conditions, duty and load characteristics of the application. The most common types are ball valves, butterfly valves, globe valves, and gate valves.

A) Ball Valves

Ball valves are quick-open valves that provide a tight seal. When fully open, the ball valve creates little turbulence or resistance to flow. The valve stem rotates the ball containing the orifice. The ball opening can be positioned in the fully open or fully closed position but should not be used to throttle flow as abrasive wear on the ball will cause leakage when the valve is closed. Ball valves are considered high recovery valves, have low pressure drop and relatively high flow capacity.

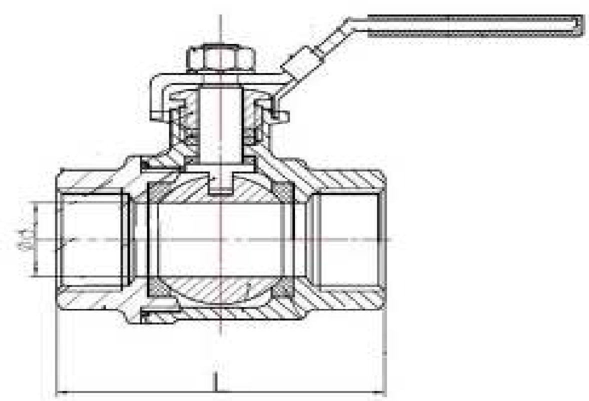

Figure 1 : Ball Valves

Best Suited Control: Quick opening, linear

Recommended Uses :

- Fully open/closed, limited-throttling
- Higher temperature fluids

Applications:

- Ball valves are excellent in chemical applications, including the most challenging services (e.g. dry chlorine, hydrofluoric acid, oxygen).
- General sizes available are 1/2" to 12".
- Compliant with ASME is the flange rating, either 150, 300, 600, 900# or occasionally higher classes, enabling high performance ball valves to withstand up to 2250 psi.
- The operating temperature which is primarily dependent on seats and seals may be rated as high as 550°F.
- Standard valves comply with ASME face-to-face dimensions, making the ball valve easy to retrofit and replace.

Advantages:

- Low cost
- High flow capacity
- High pressure/temperature capabilities
- Low leakage and maintenance
- Tight sealing with low torque
- Easy quarter turn operation- desirable to most operators
- Fairly easy to automate.

Disadvantages:

- Limited throttling characteristics
- Prone to cavitation
- Not suitable for slurry applications due to cavities around the ball and seats. Slurries tend to solidify or clog inside the cavities, greatly increasing the

operating torque of the valve and in some cases rendering the valve inoperable.

B) Butterfly Valves

Butterfly valves consist of a disc mounted on a shaft with bearings used to facilitate rotation. It is considered a high-recovery valve, as only the disc is blocking the flow path of the valve. The flow capacity is relatively high and the pressure drop across the valve is relatively low. Butterfly valves are used for limited throttling where tight closure is not required. When fully open, the butterfly creates little turbulence or resistance to flow.

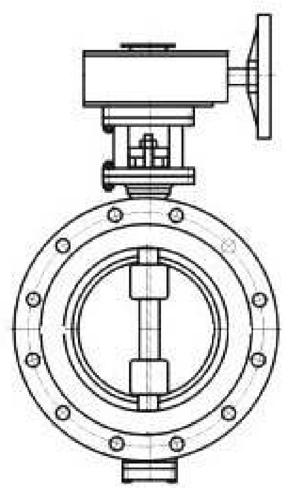

Figure 2 : Butterfly Valves

Best Suited Control : Linear, Equal percentage

Recommended Uses :

- Fully open/closed or throttling services
- Frequent operation
- Minimal fluid trapping in line
- Applications where small pressure drop is desired

Applications:

- Most economical for large lines in chemical services, water treatment, and fire protection systems. General sizes available are 2" to 48", although sizes up to 96" are available from certain manufacturers.
- Due to the valve design, incorporating a small face-to-face dimension and lower weight than most valve types, the butterfly valve is an economical choice for larger line sizes (i.e. 8" and above).
- The butterfly valve complies with ASME face-to-face dimensions and pressure ratings. This enables the valve to be easily retrofitted in line regardless of the manufacturer
- The ASME pressure classes adhered to by most manufacturers include 150, 300 and 600# allowing a maximum pressure of 1500 psi.

Applicable Standards:

- AWWA C504 for rubber-seated butterfly valves
- API 609 for lug and wafer type butterfly valves
- MSS SP-69 for general butterfly valves
- UL 1091 for safety butterfly valves for fire protection services

Advantages:

- Low cost and maintenance
- High capacity
- Good flow control
- Low pressure drop

Disadvantages:

- High torque required for control

- Prone to cavitation at lower flows
- Lack of cleanliness and inability to handle slurry applications.
- Generally not rated as bubble tight, and the cavities and leak paths around the disc stem are potential entrapments for fluids and slurries. Some high performance butterfly valves meeting ASME class VI leakage ratings are however available on demand.

C) Globe Valves

The globe valve consists of a movable disk type element and a stationary ring seat in a generally spherical body. The valve stem moves the globe plug relative to the valve seat. The globe plug can be in any position between fully open and fully closed to control flow through the valve. The globe and seat construction give the valve good flow control characteristics. Turbulent flow through the seat and plug, when the valve is open, results in a relatively high pressure drop, limited flow capacity and low recovery.

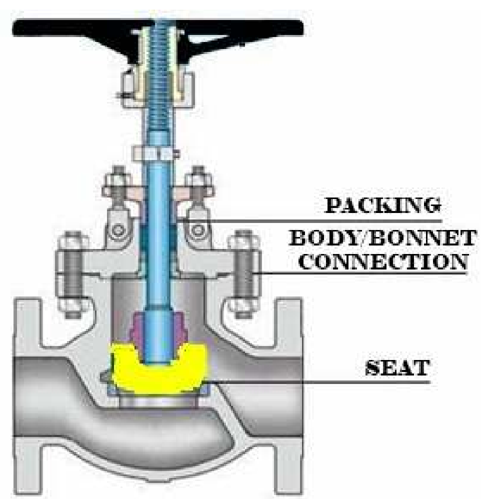

Figure 3 : Globe Valves

Best Suited Control: Linear and Equal percentage

Recommended Uses:

Applications requiring:

- Precise flow regulation
- Frequent and wide throttling operation
- Suited to very high pressure drops

Applications:

- Suitable for most liquids, vapor, gases, corrosive substances
- General sizes available are 1/2" to 8".
- Pressure limitations are relatively high, ranging from 1480 to 1500 psi, dependent on materials of construction, size and temperature.
- Minimum and maximum temperatures are also very broad ranging from -425°F to 1100°F, depending again on the materials of construction.
- Depending on the specific construction and application, the globe valve may comply with ASME class II, III, IV, V or VI shut-off requirements.
- Easily automated and available with positioners, limit switches, and other accessories

Advantages:

- Efficient and precise throttling
- Accurate flow control

Disadvantages:

- Low recovery and relatively low coefficient of flow (Cv).
- High pressure drop, higher pump capacity and system wear
- More expensive than other valves
- The sealing device is a plug that offers limited shut-off capabilities, not always meeting bubble tight requirements.

D) Gate Valves

The gate valve uses a type of linear stem movement to open and close the valve. These valves use a parallel or wedge-shaped disc as the closing member providing a tight seal.

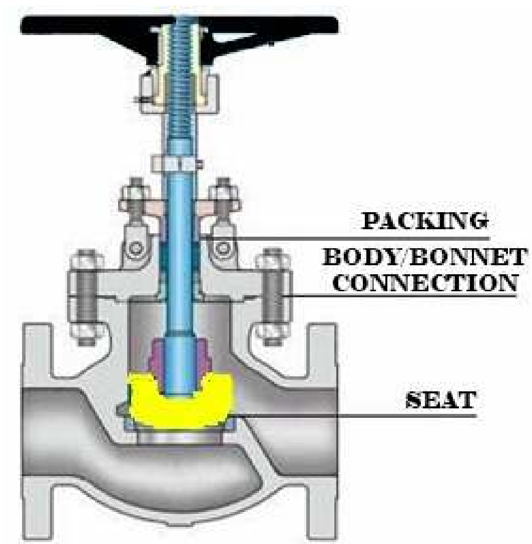

Figure 4 : Gate Valves

Best Suited Control: Quick Opening Recommended Uses:

- Fully open/closed, non-throttling
- Infrequent operation
- Minimal fluid trapping in line

Applications:

- Suitable for oil, gas, air, heavy liquids, steam, non-condensing gases, abrasive and corrosive liquids
- Sizes available range from standard cast configurations as small as 2" to special fabricated valves exceeding 100".

- Standard cast configurations have ASME 125/150 bolting patterns and are rated at 150 psi.

Advantages:

- High capacity
- Tight shutoff
- Low cost
- Little resistance to flow
- Ability to cut through slurries, scale and surface build-ups
- Provide unobstructed flow paths that not only provide high flow capacity (Cv), but even allows slurry, large objects, rocks and items routinely found in mining processes to safely pass through the valve.

Disadvantages:

- Poor control
- Cavitation at low pressure drops
- Cannot be used for throttling
- Relatively low pressure limitation - general pressure limitations are 150 psi at maximum.

Refer to the summary table at the end of this section to check more valves and their characteristics.

Valve Classification According to Function

i. On-Off Valves

On-off valves are typically used in applications where flow should be diverted around areas where maintenance is being carried out or where workers must be protected from potential safety hazards. They are also helpful in mixing applications where a number of liquids are combined for a predetermined amount of time and when precise measurement is not required. Safety management system too requires automatic on-off valve to immediately shut down the system when an emergency situation occurs. The pressure relief valve is a self-acting on-off valve that opens only when the set pressure is exceeded. Such a valve is divided into two families: relief valve and safety valve. The relief valve is used for guard against excess pressure from liquid service. Besides that, safety valves are applied in gas applications where the overpressure of the system presents a safety or process hazard and must be discarded.

ii. Non return valves

Non return valves allow the fluid to flow only in the desired direction. The design is such that any flow or pressure is in the opposite direction mechanically restricted from occurring. All check valves are one-way valves . A one-way valve is used to prevent backflow of liquid, which can damage equipment or disrupt processes. Such a valve especially useful in protecting pumps in liquid applications or compressors in gas application of backflow when pump or compressor is closed down. Non-return valves are also applied in process systems that have: various pressures, which must be kept separate.

iii. Throttling Valves

Throttling valves are used to regulate the flow, temperature, or pressure of the service. This valve can move to any position inside valve stroke and hold that position, including fully open or fully closed position. Hence, they can act as on-off valves as well. Although many throttling valve designs are equipped with a hand wheel or hand-operated manual lever, some are equipped with an torque or actuation system, which provides greater thrust and positioning capability, as well as automatic control.

The pressure regulator is a throttling valve that varies the valve position to maintain a constant pressure downstream. If the pressure build downstream, the regulator closes slightly to reduce pressure. If the pressure decreases downstream, the regulator opens to build pressure. As part of the family of throttling valves, automatic control valves, sometimes referred to simply as a control valve, is common terms used to describe valves capable of varying flow conditions for according to process requirements. To achieve automatic control, this : valves are always equipped with actuators. The actuator is designed for accept command signal and convert it to a certain valve position using an external power source (air, electrical, or hydraulic), which match the required performance for a given moment.

Classification According to Application

i. General Service Valves

General service valves are valves designed to most typical applications that have a lower pressure rating between American National Standards Institute Classes 150 and 600 (between PN 16 and PN 100), medium temperature rating between -50 and 650 °F (between -46 and 343 °C), non-corrosive liquid, and general pressure drop that does not result in cavitation or flashing. Common service valves have several levels of exchange and flexibility built into the design to allow them to be used more widely various applications. Their body material is defined as carbon or stainless steel.

ii. Special Service Valves

Specialized service valve is a term used for specially engineered valves which designed for a single application that is outside the normal process application. Due to its unique design and technique, it will only function within the parameters and service conditions associated with it specific application. Such valves usually handle demanding temperatures, high pressures, or corrosive media.

iii. Severe Service Valves

Associated with special service valves are heavy service valves, namely valves equipped with special features to handle volatile applications, such as a high pressure drop resulting in severe cavitation, flashing, choking, or high noise levels. Such valves may have highly engineered trim in globe style valves, or special discs or balls in rotary valves to minimize or prevent application effects. In addition, service conditions or process applications can be require special actuation to overcome the forces of the process. A heavy service valve designed to handle 1100°F (593°C) fluid-sodium applications with multistage trim to handle high pressure drops and a hood with special cooling fins. Electrohydraulic actuators are capable of producing 200,000lb (889,600N) of thrust.

Classification According to Port Size

i. Full-Port Valve

In process systems, most valves are designed to restrict the flow to some extent by allowing the flow passageway or area of the closure element to be smaller than the inside diameter of the pipeline. Besides that, some gate and ball valves can be designed so that internal flow passageways are large enough to pass flow without a significant restriction. Such valves are called full-port valves because the internal flow is equal to the full area of the inlet port. Full-port valves are used primarily with on-off and blocking services, where the flow must be stopped or diverted. Full-port valves also allow for the use of a pig in the pipeline. The pig is a self-driven (or flow-driven) mechanism designed to scour the inside of the pipeline and to remove any process build up or scale.

ii. Reduced-Port Valves

On the other hand, a valve with a reduced port is a valve that closes flow-limiting elements. The port flow area of the enclosure element is less than the pipe inner diameter area. For example, the seat on the linear globe valve or the arm aisle in the plug the valve will have the same flow area as the inside of the inlet and valve body outlet port. This restriction allows the valve to take pressure drop as the flow moves through the enclosure element, allowing a partial pressure recovery after the flow moves past the restriction. The main purpose of a valve with a reduced port is to control the flow through flow reduction or through throttling, which is defined as the arrangement of the enclosing elements to provide varying levels of flow at a given point valve opening.

DEFINITIONS

Actuator - is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a mover.

Ball Valve - is a flow control device which uses a hollow, perforated and pivoting ball to control liquid flowing through it. It is open when the ball's hole is in line with the flow inlet and closed when it is pivoted 90-degrees by the valve handle, blocking the flow.

Butterfly valve - is a quarter-turn rotational motion valve, that is used to stop, regulate, and start flow. Butterfly valves are easy and fast to open. A 90° rotation of the handle provides a complete closure or opening of the valve.

Block and Bleed Valve System - is a combination of one or more block/isolation valves, usually ball valves, and one or more bleed/vent valves, usually ball or needle valves.

Block Valve - A block and bleed valve system is a combination of one or more block/isolation valves, usually ball valves, and one or more bleed/vent valves, usually ball or needle valves.

Bypass System and Valve - One part of the control valve as well. As the name implies, this system is to bypass the flow when the control valve is in maintenance (when both block valves are working, the flow will go through this bypass).

Capacity – Rate of flow through a valve under stated conditions.

Choked flow - Condition at constant inlet pressure when no increase in flow rate is achieved for a decrease in downstream pressure.

Control Valve - is a valve used to control fluid flow by varying the size of the flow passage as directed by a signal from a controller. This enables the direct control of flow rate and the consequential control of process quantities such as pressure, temperature, and liquid level.

Dead Band - Is the range which an input can be varied without initiating observable response. (By referred to the amount of the diaphragm pressure it can be changed without initiating valve stem movement in a diaphragm actuated control valve. It is usually expressed as a percent of diaphragm pressure span.)

Diaphragm Pressure Span – Difference between the high and low values of the diaphragm pressure range. This may be stated as an inherent or installed characteristic.

Double-Acting Actuator – An actuator capable of operating in either direction, extending or retracting the actuator stem as dictated by the fluid pressure acting upon it.

Drain System - The drain system serves to remove the fluid flow that is in the control valve before maintenance. So before the control valve is completely removed, the drain is opened first so that the remaining fluid around the control valve directly falls through the drain so as not to be scattered.

Dynamic Unbalance - The net force produced on the valve plug in any stated open position by the fluid pressure acting upon it.

Eccentric Plug Control Valve - A style of rotary control valve with a plug-shaped, flow-restricting member that follows an eccentric path as it rotates. The plug has no contact with its seat until it turns within a few degrees of the shutoff position.

Effective Area - Part of the diaphragm area which is effective in producing a stem force in a diaphragm actuator. (The effective area of a diaphragm may change as it is stroked, usually being a maximum at the end of the travel range. Moulded diaphragms have less change in effective area than flat sheet diaphragms, and are recommended).

Electric Actuator - are in power and nuclear power industry, where high pressure water systems require smooth, steady and slow valve movement. The main advantages of electric actuators are the high degree of stability and constant thrust available to the user.

Electro Hydraulic Actuator - replace hydraulic systems with self-contained actuators operated solely by electrical power. EHAs eliminate the need for separate hydraulic pumps and tubing, because they include their own pump.

Equal Percentage Flow Characteristic – An inherent flow characteristic which produces equal percentage of changes in the existing flow for equal increments of rated travel. (Increasing sensitivity)

Fail-Closed - A condition wherein the valve port remains closed should the actuating power fail.

Fail-Open - A condition wherein the valve port remains open should the actuating power fail.

Fail-Safe - An actuator which will fully close, fully open, or remain in the fixed position upon loss of power supply. (May require additional auxiliary controls to be connected to the actuator)

Flashing - Condition where the cavitation vapor persists downstream of the region where bubble collapse normally occurs, ie, the cavitation process stops before the completion of the second stage defined in the above "Cavitation".

Flow Characteristic - Relationship between the flow of fluid through the valve and the percent of rated travel as the latter is varied from 0 – 100 percent. This term should always be designated as either inherent flow characteristic or installed flow characteristic.

Gate Valve - also known as a sluice valve, is a valve that opens by lifting a barrier (gate) out of the path of the fluid. Gate valves require very little space along the pipe axis and hardly restrict the flow of fluid when the gate is fully opened.

Globe Valve - is a type of valve used for regulating flow in a pipeline, consisting of a movable plug or disc element and a stationary ring seat in a generally spherical body.

High Recovery Valve - A valve design that dissipates relatively little flow stream energy due to streamlined internal contours and minimal flow turbulence. (Straight-through flow valves, such as rotary-shaft ball valves, are typically high-recovery valves.)

Inherent Diaphragm Pressure Range - The high and low values of pressure applied to the diaphragm to produce rated valve plug travel with atmospheric pressure in the valve body. (This range is often referred to as a “bench set” range since it will be the range over which the valve will stroke when it is set on the work bench.)

Inherent Flow Characteristic - Flow characteristic when constant pressure drop is maintained across the valve.

Inherent Rangeability - Ratio of maximum to minimum flow within which the deviation from the specified inherent flow characteristic does not exceed some stated limit. (A control valve that still does a good job of controlling when increases to

100 times the minimum controllable flow has a rangeability of 100 to 1. Rangeability might also be expressed as the ratio of the maximum to minimum controllable flow coefficients.)

Installed Diaphragm Pressure Range - The high and low values of pressure applied to the diaphragm to produce rated travel with stated conditions in the valve body. (It is because of the forces acting on the valve plug that the inherent diaphragm pressure range can differ from the installed diaphragm pressure range).

Installed Flow Characteristic - Flow characteristic when pressure drop across the valve varies as dictated by flow and related conditions in the system in which the valve is installed.

Leakage - Quantity of fluid passing through an assembled valve when the valve is in the closed position under stated closure forces, with pressure differential and pressure as specified.

Linear Flow Characteristic - An inherent flow characteristic which can be represented ideally by a straight line on a rectangular plot of flow versus percent rated travel. (Equal increments of travel yield equal increments of flow at a constant pressure drop.)

Low-Recovery Valve - A valve design that dissipates a considerable amount of flow stream energy due to turbulence created by the contours of the flow path. This results into a lower pressure recovery across the vena contracta and hence the valve will have a larger pressure drop. (Conventional globe-style valves generally have low pressure recovery capability).

Manual Actuator - employs levers, gears, or wheels to move the valve stem with a certain action. Manual actuators are powered by hand. Manual actuators are inexpensive, typically self-contained, and easy to operate by humans. However, some large valves are impossible to operate manually and some valves may be located in remote, toxic, or hostile environments that prevent manual operations in some conditions. As a safety feature, certain types of situations may require quicker operation than manual actuators can provide to close the valve.

Normally Closed Control Valve - A control valve which closes when the diaphragm pressure is reduced to atmospheric.

Normally Open Control Valve - A control valve which opens when the diaphragm pressure is reduced to atmospheric.

Piston Actuator - is a device that transforms raw energy into motion. In general, the actuator is connected to a piston which is contained inside an enclosure. Something that causes pressure will enter the enclosure and force the piston to move, which moves the actuator and whatever it is connected.

Pneumatic Actuator - the air signal from the external control device to make control action through the solenoid. These are usually available in two main forms: piston actuators and diaphragm actuators.

Push-Down-to-Close Construction - A globe-style valve construction in which the valve plug is located between the actuator and the seat ring. The valve closes when the extension of the actuator stem moves the valve plug toward the seat ring, finally closing the valve. This mechanism is also called Direct Acting. (For rotary-shaft, linear extension of the actuator stem moves the ball or disc toward the closed position).

Push-Down-to-Open - A globe type valve construction in which the seat ring is located between the actuator and the valve plug. The valve opens when the extension of the actuator stem moves the valve plug away from the seat ring. This mechanism is also called Reverse Acting. (For rotary-shaft valve, linear extension of the actuator stem moves the ball or disc toward the open position.

Quick Opening Flow Characteristic - An inherent flow characteristic in which there is maximum flow with minimum travel. (Decreasing sensitivity)

Rated Cv - The value of Cv at the rated full-open position.

Rated Travel - Linear movement of the valve plug from the closed position to the rated full-open position. (The rated full-open position refers to the maximum opening recommended by the manufacturer.)

Seat - The area of contact between the closure member and its mating surface that establishes valve shut-off.

Seat Load - The contact force between the seat and the valve plug. (In practice, the selection of an actuator for a given control valve will be based on how much force is required to overcome static, stem , and dynamic unbalance with an allowance made for seat load.)

Single Block and Bleed - The Single Block and Bleed Valve System consists of one block valve and one bleed valve. This system is sometimes referred to simply as the "Isolation Valve System".

Single Unit Double Block and Bleed - Single Unit Double Block and Bleed Valve provides double block and bleed in one valve. This force can isolate the pipe on both sides of the valve to vent/eject the valve cavity between the seats.

Spring Rate - Force change per unit change in length. (In diaphragm control valves, the spring rate is usually stated in pounds force per inch compression.)

Static Unbalance - The net force produced on the valve plug in its closed position by the fluid pressure action upon it.

Stem Unbalance - The net force produced on the valve plug stem in any position by the fluid pressure action upon it.

Trim - The internal components of a valve that modulate the flow of the controlled fluid. In a globe valve body, trim would typically include closure member, seat ring, cage, stem, and stem pin.

Valve Flow Coefficient (Cv) - The amount of 60oF water in US gallons per minute that will flow through a valve with a one pound per square inch pressure drop.

Vena Contracta - The point where the pressure and the cross-sectional area of the flow stream is at its minimum, whereas the fluid velocity is at its highest level. (Normally occurs just down stream of the actual physical restriction in a control valve.)

NOMENCLATURE

A	Cross-sectional area of plunger or piston, in^2
A	Cross-sectional area of piston rod, in^2
C	Constant for pump geometry
Cp	Specific heat of pumped liquid, Btu/lb.ºF
D	Diameter of impeller, in
D	Displacement of reciprocating pump, gpm
E	Pump efficiency, fraction
g	Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)
H_c	Total head developed from centrifugal pump, ft
H_d	Discharge head, ft (m)
H_s	Suction head, ft (m)
H_t	Total head, ft (m)
h_a	Acceleration for the reciprocating pump only for calculate the head losses due to pulsation in the flow, ft (m)
h_f	Head produce from pressure loss in pipe, fitting, and entrancement, ft (m)
$h_{f(d)}$	Head produce from pressure loss in pipe, fitting, and entrancement with depend the pipe diameter and type of flow from discharge to destination, ft (m)
$h_{f(s)}$	Head produce from pressure loss in pipe, fitting, and entrancement with depend the pipe diameter and type of flow at suction section, ft (m)
h_p	Absolute pressure head on surface of liquid, ft (m)
$h_{p(d)}$	Gauge pressure head on surface of liquid at destination, ft (m)
$h_{p(s)}$	Gauge pressure head on surface of liquid at suction point, ft (m)
h_{st}	Head from the elevation between distance from suction surface to pump centerline, ft (m)

$h_{st(d)}$	Head from the elevation between distance from destination surface to pump centerline, ft (m)
$h_{st(s)}$	Head from the elevation between distance from suction surface to pump centerline, ft (m)
h_{vp}	Vapor pressure of the liquid converted, ft (m)
K	A factor representing the relative compressibility of the liquid
L	Length of the suction line from the nearest upstream vessel (or suction stabilizer) to the pump, (ft or m)
M	The number of cylinders
n	Speed of rotation, RPM (Revolutions per minute)
N	Pumps speed for centrifugal pumps, rpm
Ns	Specific speed, dimensionless
P	Pressure in system, psi (kg/cm^2)
Q	Capacity, gal/min (m^3/min)
Q_1	Capacity, (m^3/s)
r	Radius of shaft (rad)
Sp	Pump speed for reciprocating pump, ft/min
Sss	Suction specific speed, dimensionless
S	Specific gravity
S	Stroke length, in
T_r	Shaft Torque (Nm)
V	Average velocity in the suction line, ft/s (m/s)
v	Velocity of periphery of impeller (tip speed), ft/s (m/s)
VE	Volumetric efficiency, dimensioness

Greek letters

η_p Pump efficiency, %

ρ Fluid density, lb/ft^3 (kg/m^3)

π pi (3.142)

ω Shaft angular velocity (rad/s)

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