PROCESS CONTROL VALVE ENGINEERING

ENG / ISLAM DEIF

OUTLINE

- Introduction to Control Valve Terminology
- Control Valve Types
- Actuators types
- Valve Accessories
- Phenomena Associated to the Control Valve
- Valve Selection and Sizing
- Testing and Installation

INTRODUCTION

CONTROL VALVE TERMINOLOGY

CONTROL VALVE

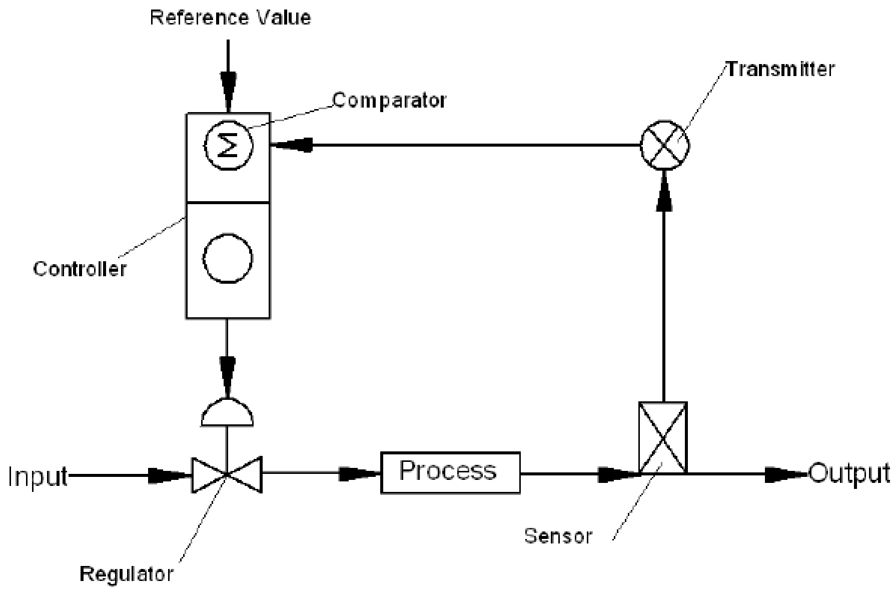
- A power actuated device which modifies the fluid flow rate in a process control system. It consists of a valve connected to an actuator mechanism (including all related accessories) that is capable of changing the position of a closure member in the valve in response to a signal from the controlling system.
- Control valve is considered the most important final control element in a process control loops

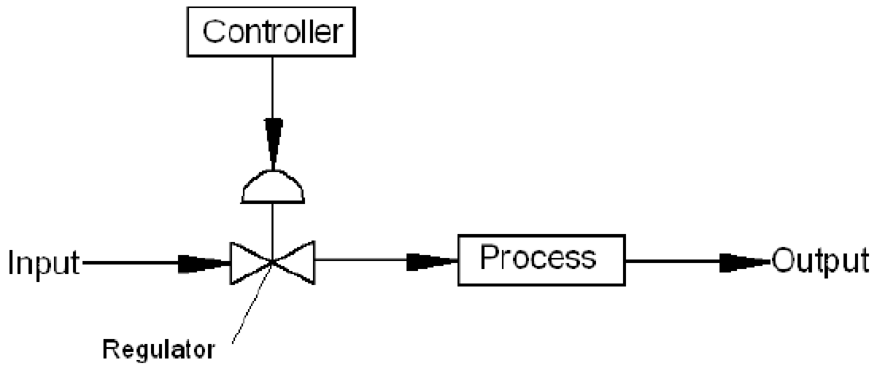
CONTROL VALVE TERMINOLOGY

BASIC CONTROL LOOP

There are 2 types of control loops

- ➢ Open-Loop Control System
- ➢ Closed-Loop Control System

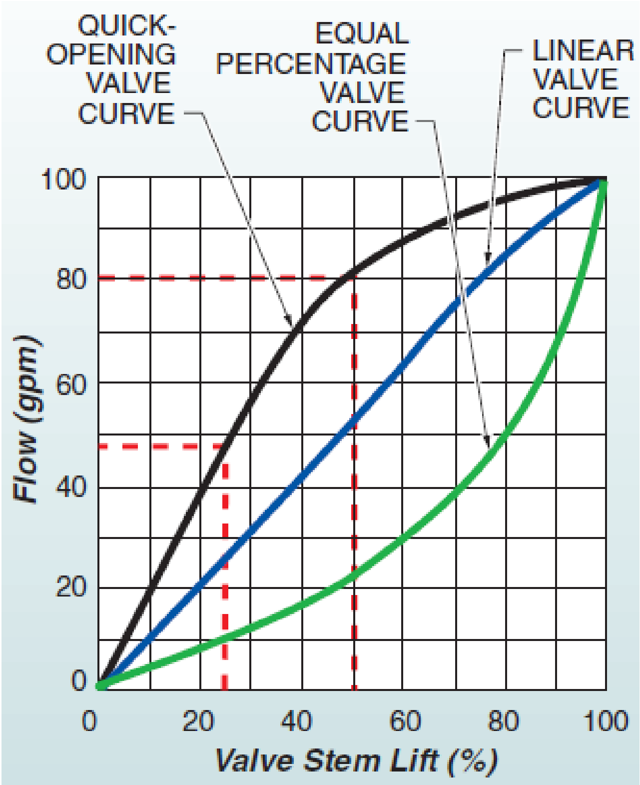




CONTROL VALVE TERMINOLOGY

CONTROL VALVE GAIN

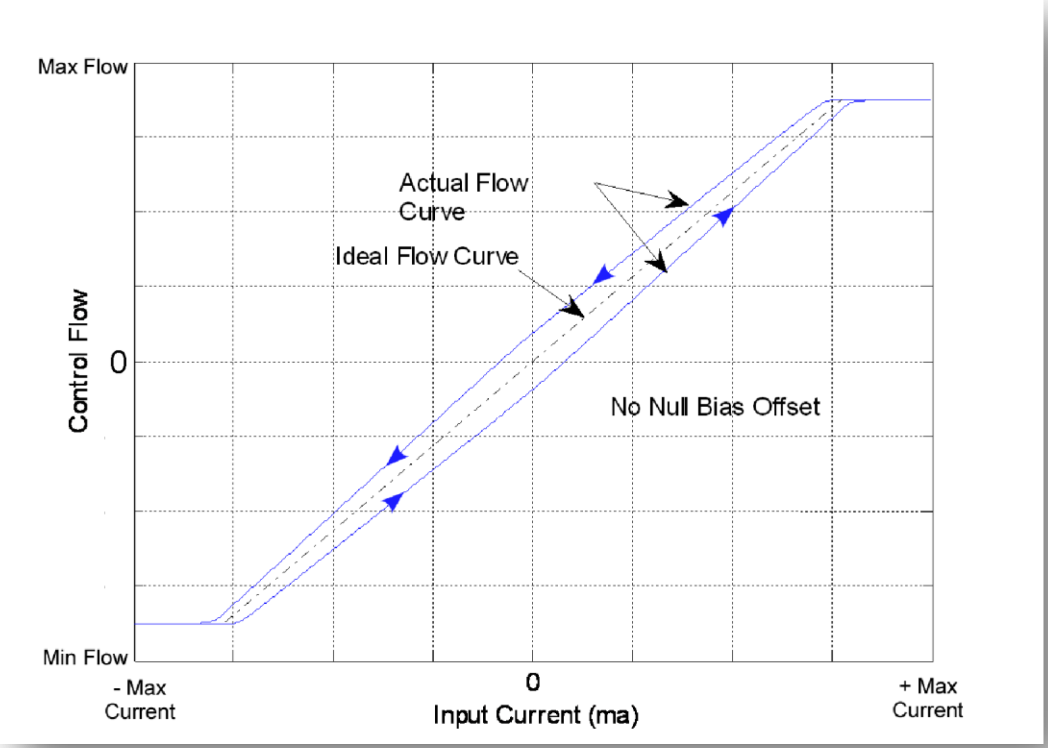
- The change in the flow rate as a function of the change in valve travel. It is the slope of the installed flow characteristic curve.



CONTROL VALVE TERMINOLOGY

HYSTERESIS

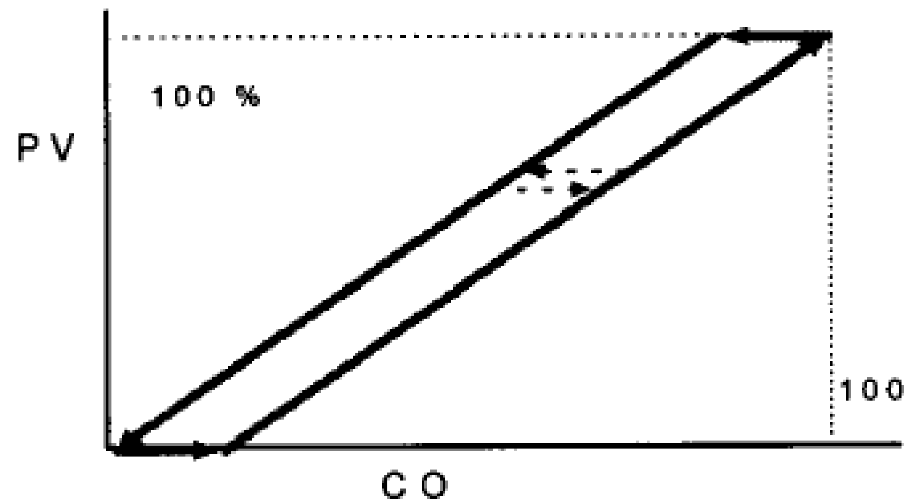
- The maximum difference in output value for any single input value during a calibration cycle, excluding errors due to dead band.



CONTROL VALVE TERMINOLOGY

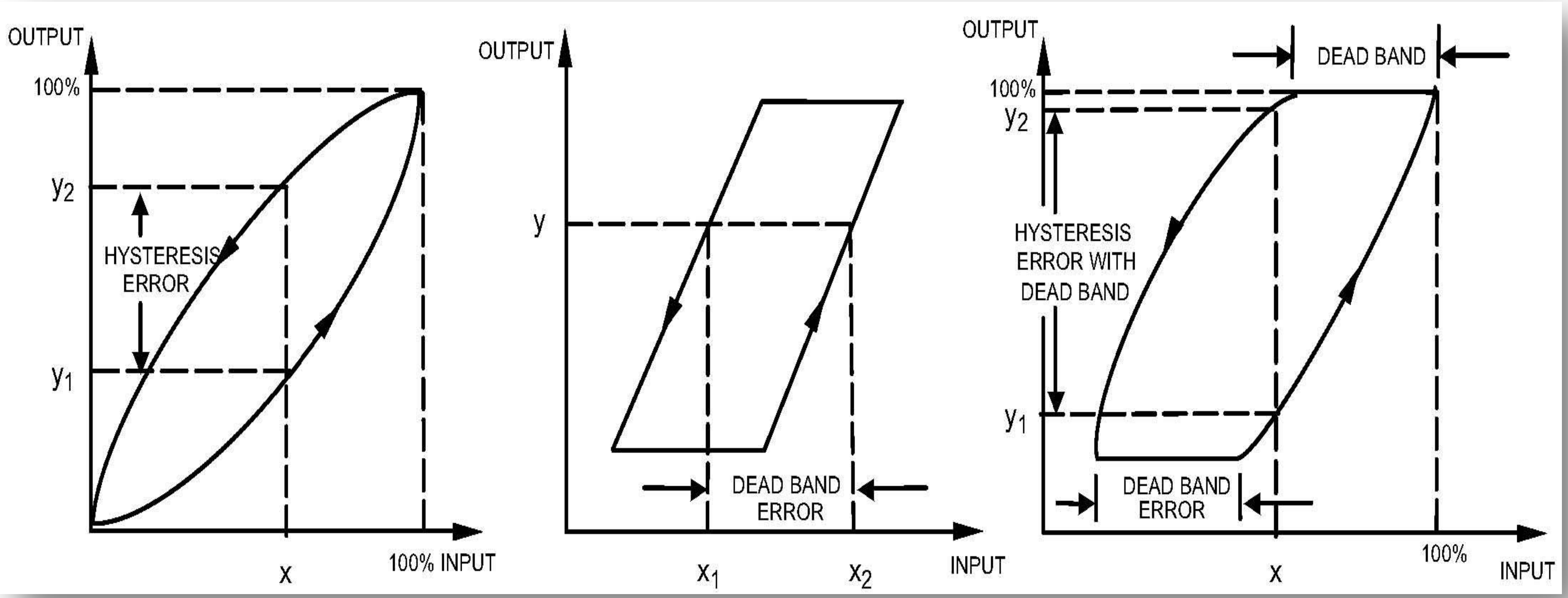
DEAD BAND (BACKLASH)

- The range through which an input signal can be varied, upon reversal of direction, without initiating an observable change in the output signal. Dead band is the name given to a general phenomenon that can apply to any device. For the valve assembly, the controller output (CO) is the input to the valve assembly and the process variable (PV) is the output of the control valve .



CONTROL VALVE TERMINOLOGY

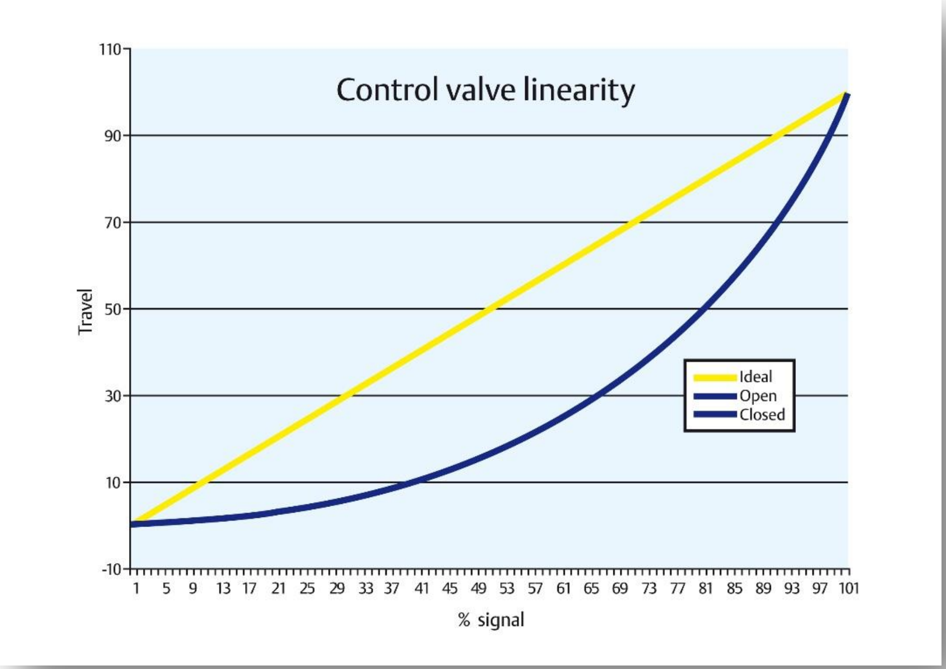
HYSTERESIS & DEAD BAND EFFECTS



CONTROL VALVE TERMINOLOGY

LINEARITY

➢ The closeness to which a curve relating to two variables approximates a straight line. (Linearity also means that the same straight line will apply for both upscale and downscale directions. Thus, dead band as defined above, would typically be considered a non-linearity)



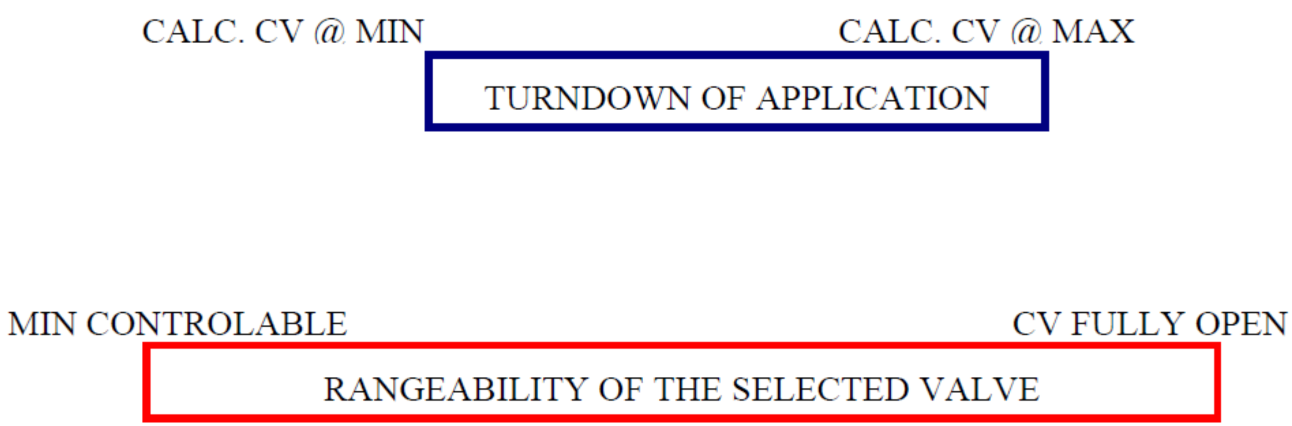
CONTROL VALVE TERMINOLOGY

Rangeability

- The ratio of the largest flow coefficient (Cv or Kv) to the smallest controllable flow coefficient (Cv or Kv) within which the deviation from the specified flow characteristic does not exceed the stated limits.

Turndown

- Turndown applies to the application and is the ratio of the calculated Cv at maximum conditions to the calculated Cv at minimum.



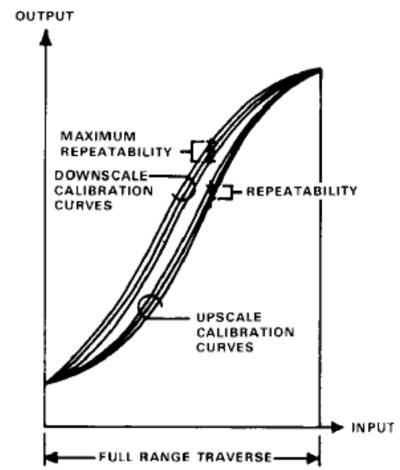
CONTROL VALVE TERMINOLOGY

ACCURACY

- the degree of conformity of an indicated value to a recognized accepted standard value or ideal value.

REPEATABILITY

- The closeness of agreement among a number of consecutive measurements of the output for the same value of input under the same operating conditions, approaching from the same direction, for full range traverses. It does not include hysteresis.



REPEATABILITY

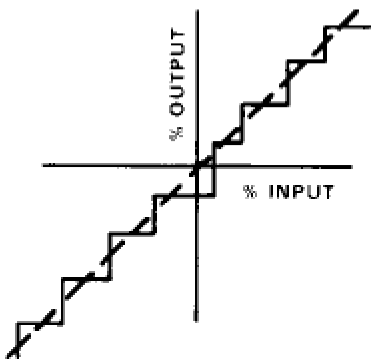
CONTROL VALVE TERMINOLOGY

LOOP GAIN:

- The combined gain of all the components in the loop when viewed in series around the loop Sometimes referred to as open-loop gain.

RESOLUTION:

- The minimum possible change in input required to produce a detectable change in the output when no reversal of the input takes place. Resolution is typically expressed as a percent of the input span.



RESOLUTION

CONTROL VALVE TERMINOLOGY

Dead Time

- The time interval (Td) in which no response of the system is detected following a small (usually 0.25% - 5%) step input. It is measured from the time the step input is initiated to the first detectable response of the system being tested. Dead Time can apply to a valve assembly or to the entire process

DRIFT

- An undesired change in the output/input relationship over a period of time.

CAPACITY (VALVE)

- The rate of flow through a valve under stated conditions (Cv).

CONTROL VALVE TERMINOLOGY

FRICTION

- A force that tends to oppose the relative motion between two surfaces that are in contact with each other. The friction force is a function of the normal force holding these two surfaces together and the characteristic nature of the two surfaces. Friction has two components: static friction and dynamic friction. Static friction is the force that must be overcome before there is any relative motion between the two surfaces. Once relative movement has begun, dynamic friction is the force that must be overcome to maintain the relative motion.

"Stiction" is terms that are sometimes used to describe **static friction.**

CONTROL VALVE TERMINOLOGY

Principles of valve throttling processes

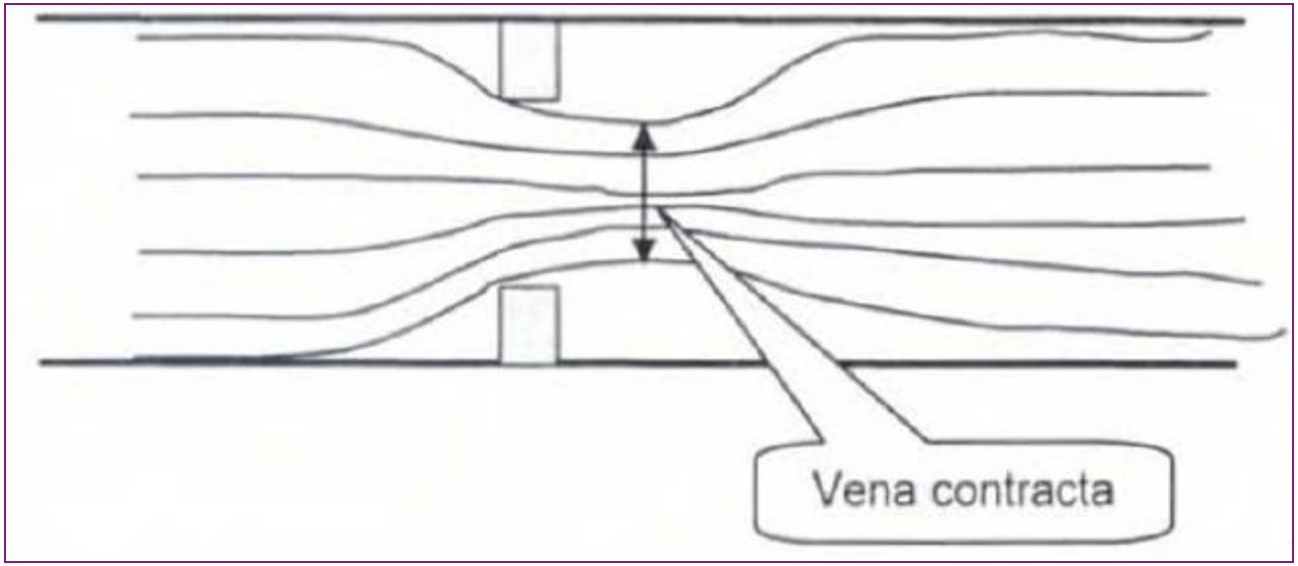
- A control valve modifies the fluid flow rate in a process pipeline by providing a means to change the effective cross sectional area at the valve.

- This in turn forces the fluid to increase its velocity as passes through the restriction. Even though it slows down again after leaving the valve, some of the energy in the fluid is dissipated through flow separation effects and frictional losses, leaving a reduced pressure in the fluid downstream of the valve.

CONTROL VALVE TERMINOLOGY

Principles of valve throttling processes

- To display the general behavior of flow through a control valve the valve is simplified to an orifice in a pipeline as shown in Figure



CONTROL VALVE TERMINOLOGY

Principles of valve throttling processes

- it is important to understandhow the pressure conditions change In the fluid as it passes through the restriction and the vena contracta and then how the pressure partially recovers as the fluid enters the downstream pipe area.

- The first point to note is that the velocity of the fluid must increase as the flow area decreases.

This is given by the continuity of flow equation;

$$V1.A1=V2.A2$$

CONTROL VALVE TERMINOLOGY

Principles of valve throttling processes

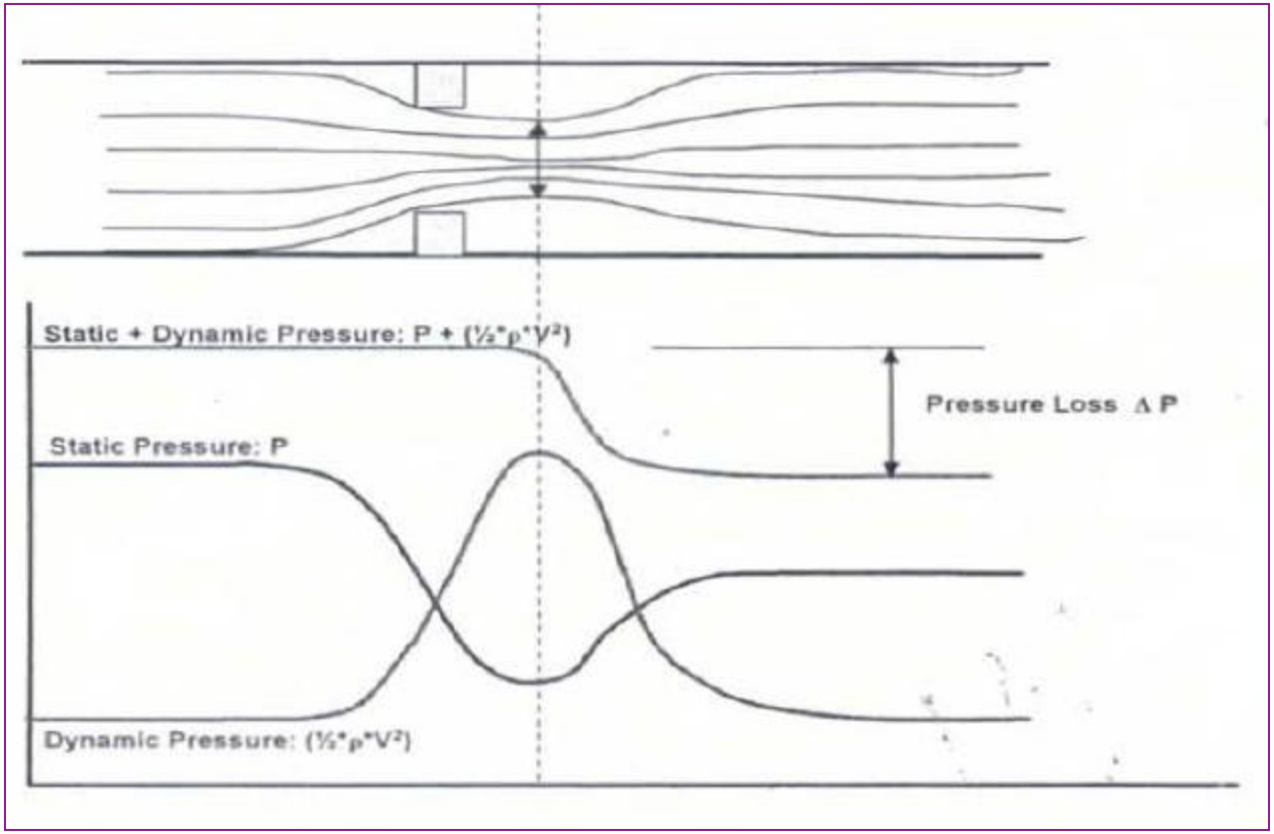
- Now to consider the pressure conditions we apply Bernoulli's equation ,which demonstrates the balance between dynamic, hydrostatic pressure and Static. Energy must be balanced each side of the flow restriction so that:

$$\left(\tfrac{1}{2} \times \rho_1 \times V_1^2\right) + \left(\rho_1 \times g \times H_1\right) + P_1 = \left(\tfrac{1}{2} \times \rho_2 \times V_2^2\right) + \left(\rho_2 \times g \times H_2\right) + P_2 + \Delta P$$

P	=	static pressure
ρ	=	density
ΔP	=	pressure loss (due to losses through the restrictor)
H	=	relative height
g	=	acceleration of gravity

CONTROL VALVE TERMINOLOGY

Principles of valve throttling processes



CONTROL VALVE STANDARDS

Control Valve Standards

- Numerous standards are applicable to control valves. International and global standards are becoming increasingly important for companies that participate in global markets. Following is a list of codes and standards that have been or will be important in the design and application of control valves.

- It covers the following issues
  1-face to face dimensions.
  2-Materials of construction.
  3-Pressure-temperature ratings.
  4-Design of some components to ensure adequate strength.
  5-Testing procedures.

CONTROL VALVE STANDARDS

Well Known Valve Standards

ISA	Instrument Society of America
ASME	American Society of Mechanical Engineers
CEN	European Committee for Standardization
API	American Petroleum Institute
IEC	International Electrotechnical Commission
ISO	International Standards Organization
ANSI	American National Standards Institute

CONTROL VALVE STANDARDS

Instrument Society of America (ISA)

S51.1, Process Instrumentation Terminology

S75.01, Flow Equations for Sizing Control Valves

S75.02, Control Valve Capacity Test Procedures

S75.03, Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (Classes 125, 150, 250, 300, and 600)

S75.04, Face-to-Face Dimensions for Flangeless Control Valves (Classes 150, 300, and 600)

S75.05, Terminology

S75.07, Laboratory Measurement of Aerodynamic Noise Generated by Control Valves

S75.08, Installed Face-to-Face Dimensions for Flanged Clamp or Pinch Valves

S75.11, Inherent Flow Characteristic and Rangeability of Control Valves

S75.12, Face-to-Face Dimensions for Socket Weld-End and Screwed-End Globe-Style Control Valves (Classes150, 300, 600, 900, 1500, and 2500)

S75.13, Method of Evaluating the Performance of Positioners with Analog Input Signals

CONTROL VALVE STANDARDS

Instrument Society of America (ISA)

S75.14, Face-to-Face Dimensions for Buttweld-End Globe-Style Control Valves (Class 4500)

S75.15, Face-to-Face Dimensions for Buttweld-End Globe-Style Control Valves (Classes 150, 300, 600, 900, 1500, and 2500)

S75.16, Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (Classes 900, 1500, and 2500)

S75.17, Control Valve Aerodynamic Noise Prediction

S75.19, Hydrostatic Testing of Control Valves

S75.20, Face-to-Face Dimensions for Separable Flanged Globe-Style Control Valves (Classes 150, 300, and 600)

S75.22, Face-to-Centerline Dimensions for Flanged Globe-Style Angle Control Valve Bodies (Classes 150, 300, and 600)

RP75.23, Considerations for Evaluating Control Valve Cavitation

CONTROL VALVE STANDARDS

ANSI -American National Standards Institute

B16.34:	"Valves - Flanged, Threaded, and Welding End"
	- Design basis for all kinds of valves, including pressure-temperature ratings, dimensions, materials, and testing.
	- Cast and forged flanged, threaded, and welding end valves.
	- Class 150 thru Class 4500.
B16.10:	"Face-to-Face and End-to-End Dimensions of Valves"
	- Face-to-Face dimensions for flanged end valves and end-to-end dimensions for welding end valves.
	- Gate, globe, angle, check, plug, and ball valves.
	- Class 150 thru Class 2500.
B 16.5:	"Pipe Flanges and Flanged Fittings"
	- Design basis for all kinds of flanges such as raised face, ring joint face, tongue and groove face.
	- Class 150 thru 2500, NPS (Nominal Pipe Size) 1/2" thru 24".

CONTROL VALVE STANDARDS

API - American Petroleum Institute

600:	"Bolted Bonnet Steel Gate Valve for Petroleum and Natural Gas Industries"
	- Specific and detailed design requirements.
	- 1"-24" Sizes, Class 150 thru 2500 flange and butt welding ends.
602:	"Compact Steel Gate Valves - Flanged, Threaded, Welding, and Extended-Body Ends"
	- Specific and detailed design requirements for compact gate valves.
	- 2 1/2" and smaller, Class 800 and 1500, threaded and socket ends.
	- 4" and small, Class 150 thru 1500, flanged and butt welding ends.
	- Cast and forged, Carbon Steel and Stainless Steel.
598:	"Valve Inspection and Testing"
	- Pressure test requirements and acceptance criteria for shell, backseat, and closure tests.

CONTROL VALVE STANDARDS

ASME-American Society of Mechanical Engineers

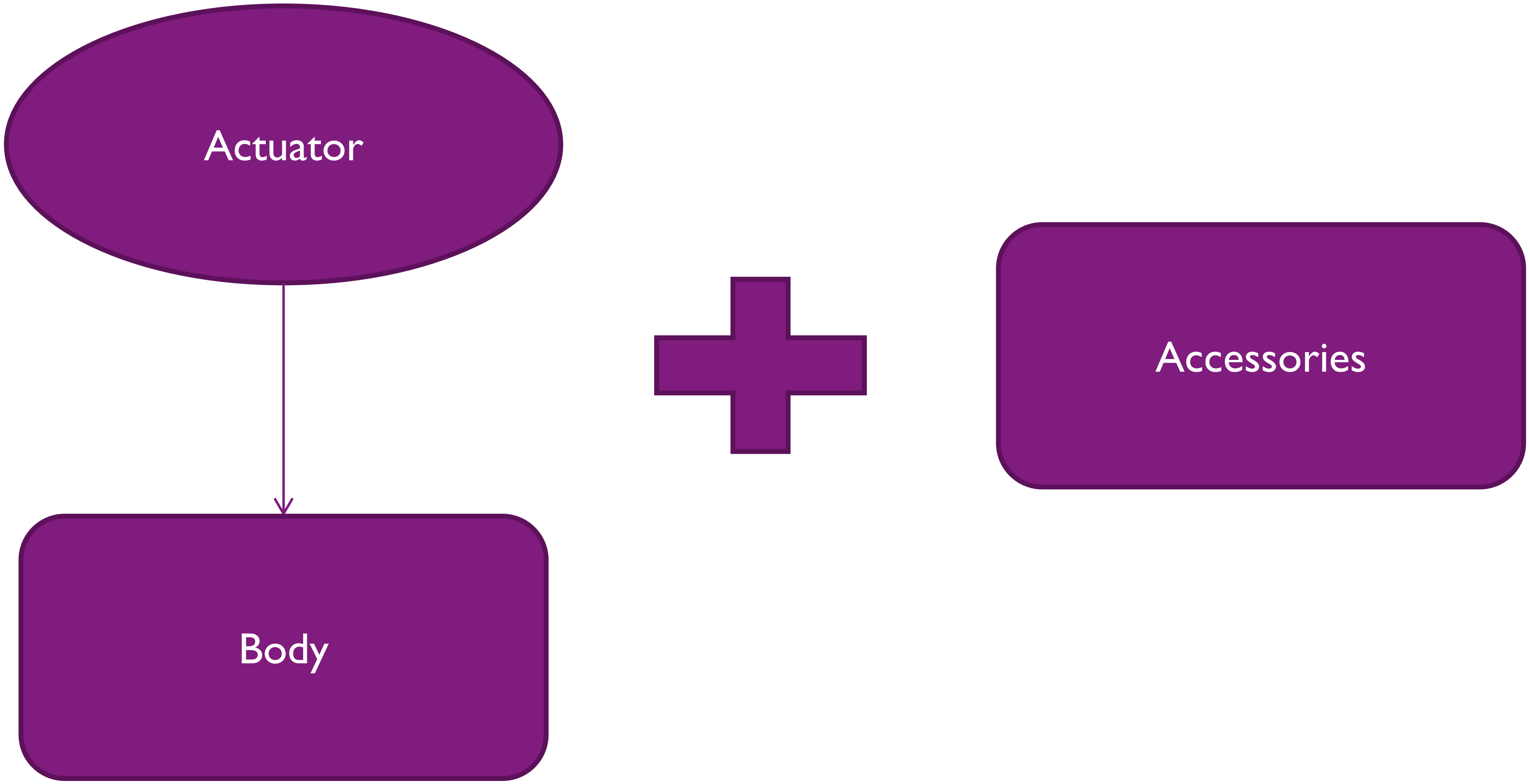
ASME Boiler and Pressure Vessel Code	
Section IX:	"Welding and Brazing Qualifications"
	- Requirements for qualification of welders and procedures employed in welding. ASME Code for Pressure Piping, B31
ASME Code for Pressure Piping, B31	
B31.3:	"Chemical Plant and Petroleum Refinery Piping"
	- Requirements for material, design, fabrication, and testing of piping, including valves and specialty components

NACE-National Association of Corrosion Engineers

MR0175:	"Standard Material Requirements-Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment"
	- Material requirements for components exposed to sour environment (H_2S-bearing hydrocarbon service)
	- Selected material and limited hardness.

CONTROL VALVE COMPONENTS

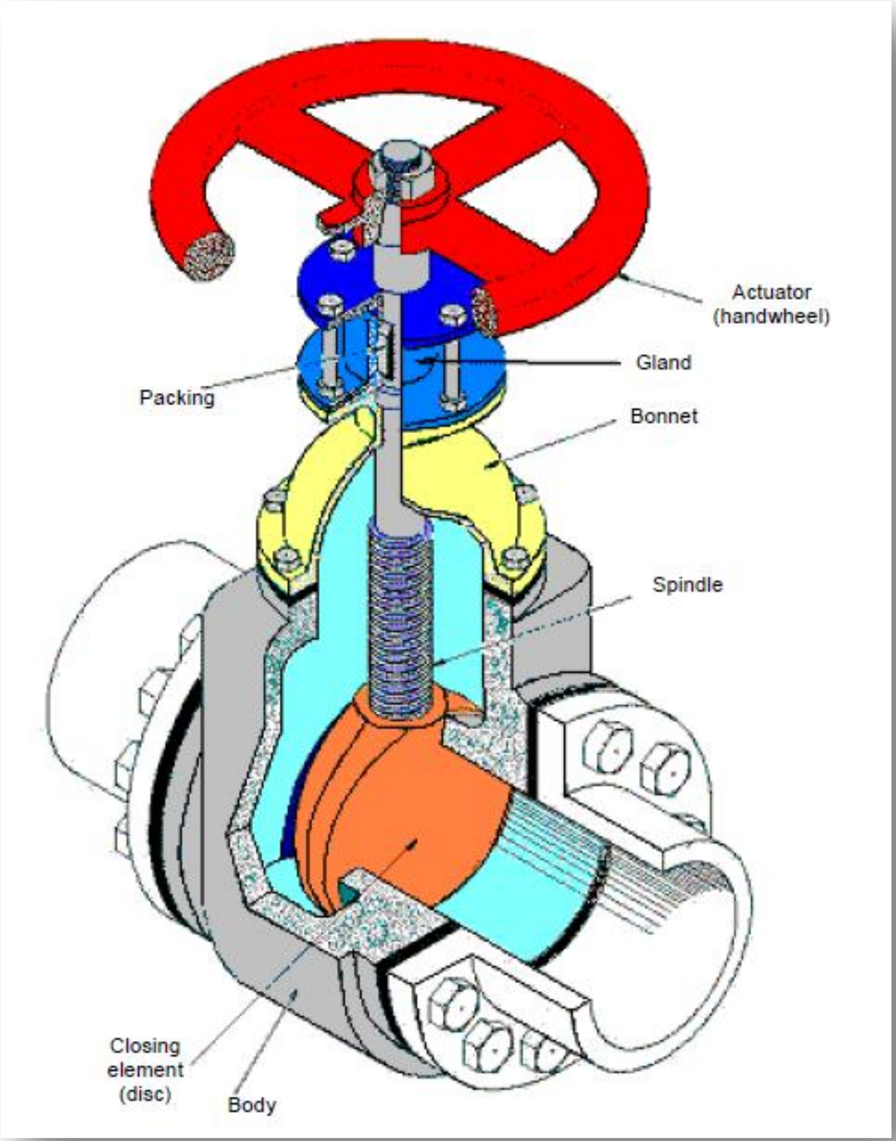
CONTROL VALVE COMPONENTS



CONTROL VALVE COMPONENTS

Basic Valve Components

- BODY
- BONNET
- TRIM
- PACKING
- ACTUATOR



CONTROL VALVE COMPONENTS

Body

- Is the main part of the valve. All other parts fit onto the body.
- It is usually *cast* or *forged* and the shape varies with the type of valve.
- Inlet and outlet pipes fit onto the valve body through threaded, bolted (flanged) or welded joints.
- The fluid passes through the valve body when the valve is open.
- The valve body must be strong enough to take the maximum pressure of the process fluid. It must also be made of a material that is not attacked by the fluid.

Bonnet

- Is a removable cover fitted to the body. Some bonnets support the moving parts of the valve. Others just close the hole in the body through which the moving parts pass for assembly and dismantling.

CONTROL VALVE COMPONENTS

Trim (Plug and Seat)

Is the name given to the parts inside a valve. This normally includes:

- The opening/closing element—closes the fluid path through the valve body
- The valve stem—connects the actuator to the closing element
- The valve seat—makes a seal with the closing element when the valve is closed

Packing

- It allows the valve stem to pass into the valve body without loss of fluid or fluid pressure from the valve. It forms a dynamic seal between the valve stem and the bonnet.

Actuator

- Operates the stem and closing element assembly.

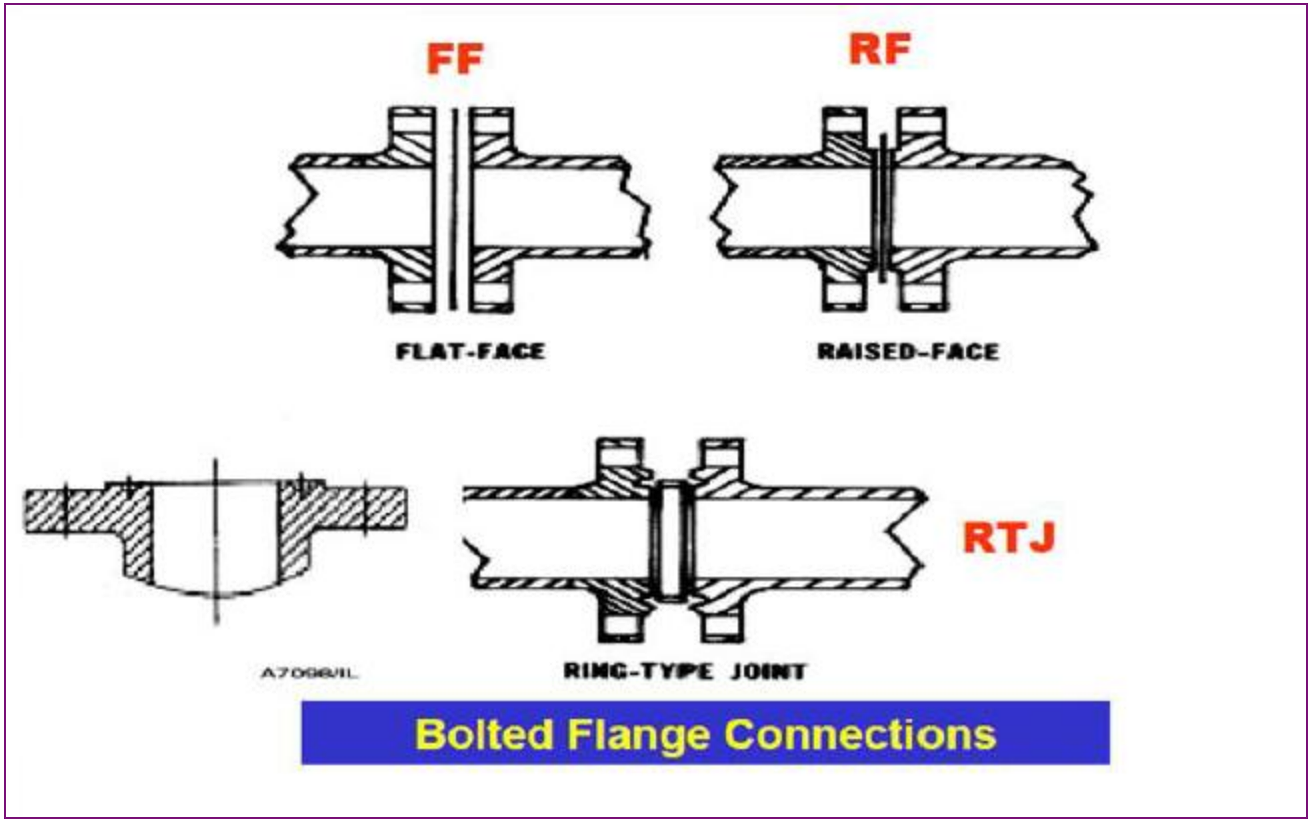
CONTROL VALVE COMPONENTS

End Connections

Must be specified when buying the valve – butt weld end, compression flange, pipe thread, quick disconnect

CONTROL VALVE COMPONENTS

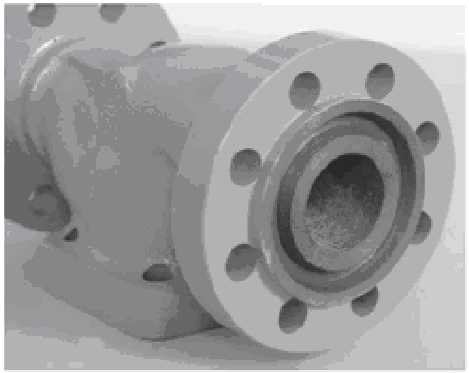
End Connections



CONTROL VALVE COMPONENTS

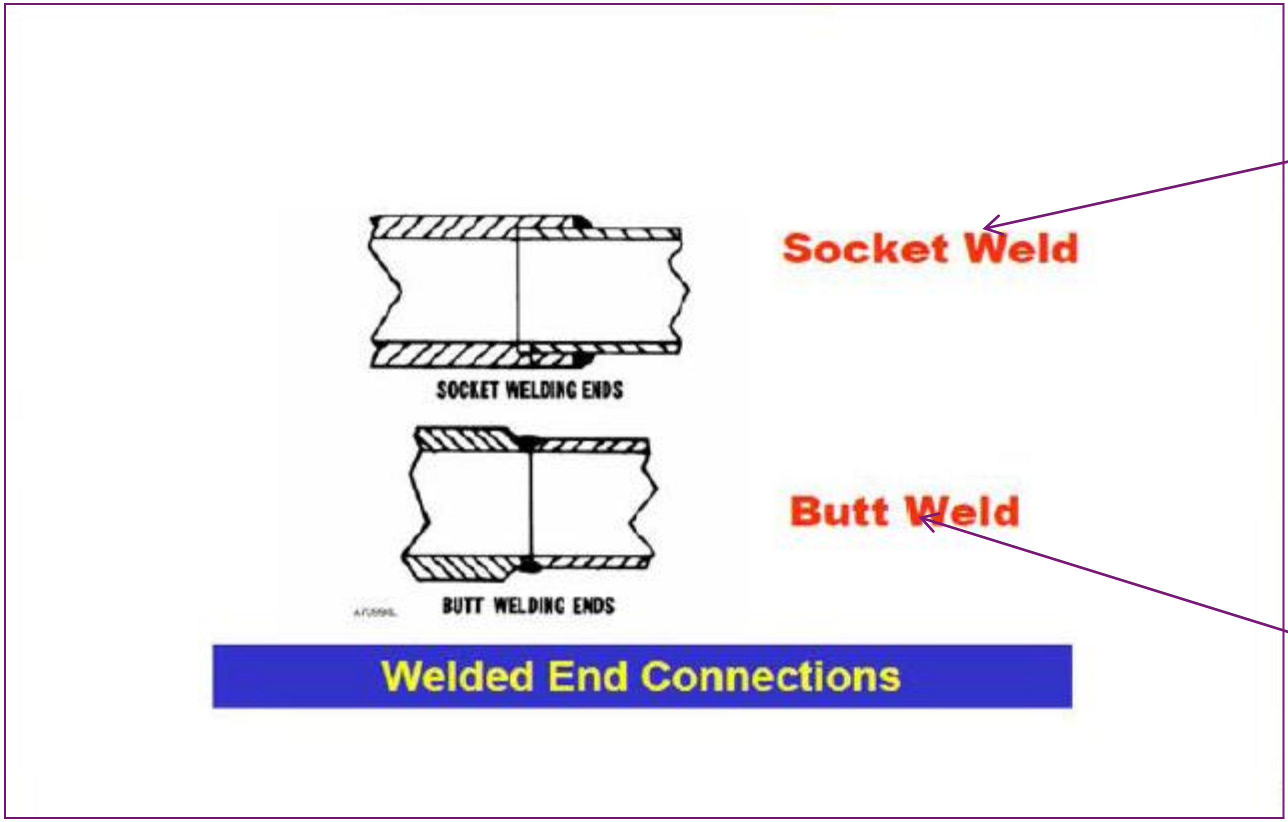







CONTROL VALVE COMPONENTS

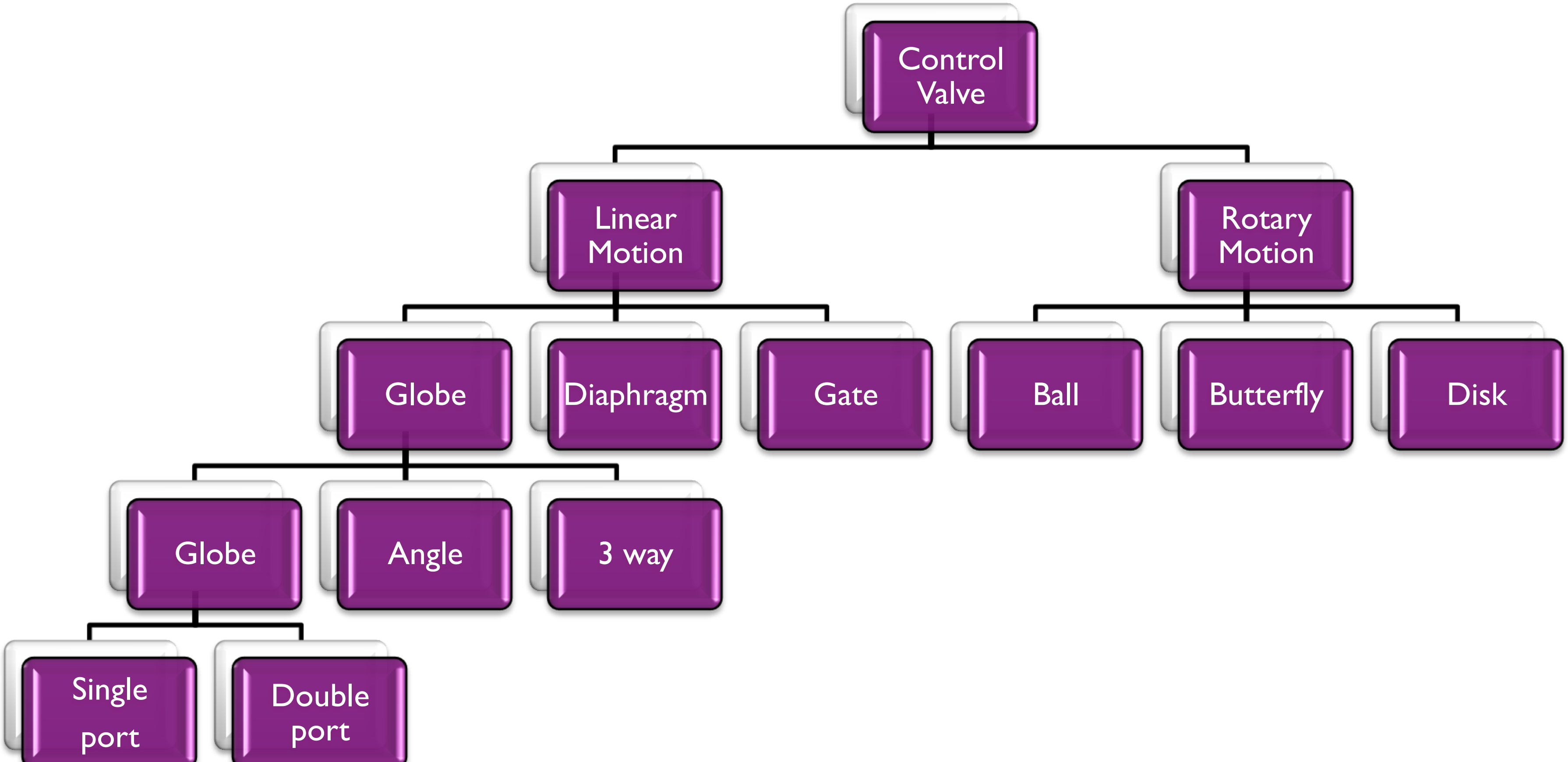
End Connecions



CONTROL VALVE BODY

CONTROL VALVE BODY

Control Valve Classification



CONTROL VALVE BODY

LINEAR (SLIDING STEM VALVES)

A sliding-stem valve body is one where the moving parts slide with a linear motion.

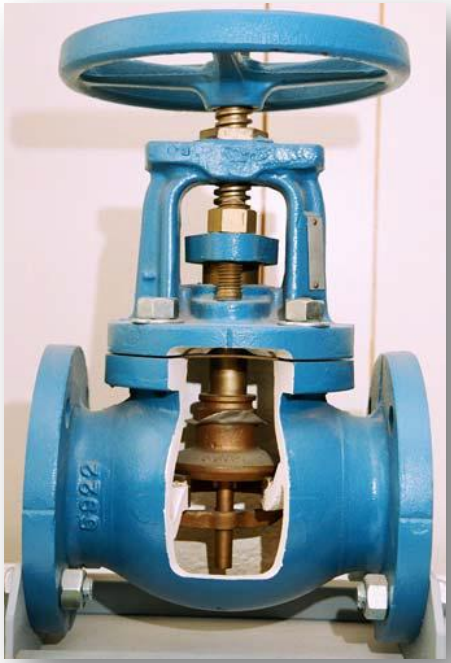
Main types of linear valves :

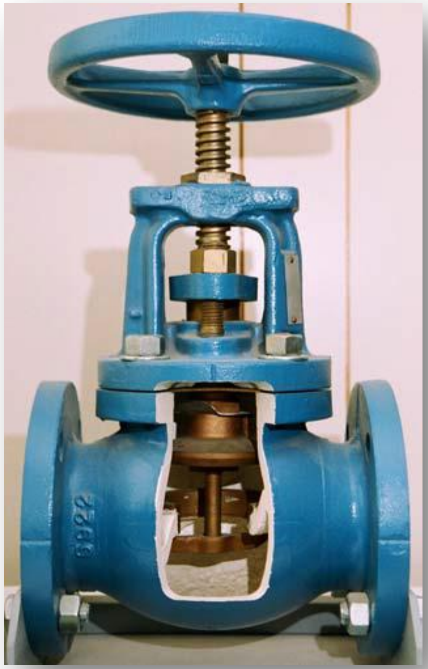
- Globe Valves
- Diaphragm Valves
- Gate Valves

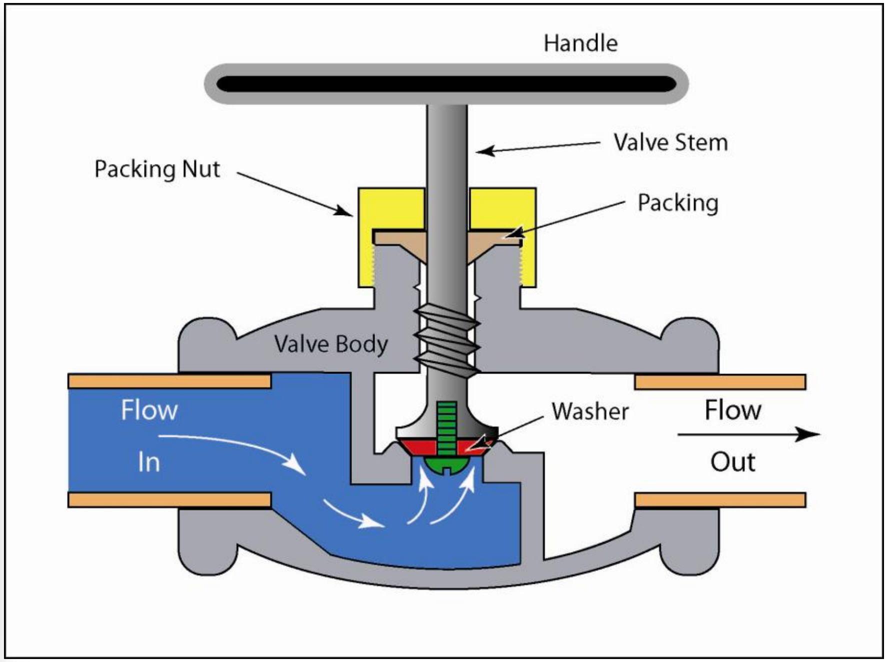
CONTROL VALVE BODY

Globe Valves

- Globe valves restrict the flow of fluid by altering the distance between a movable plug and a stationary seat (in some cases, a pair of plugs and matching seats). Fluid flows through a hole in the center of the seat, and is more or less restricted by how close the plug is to that hole. The globe valve design is one of the most popular sliding-stem valve designs used in throttling service.



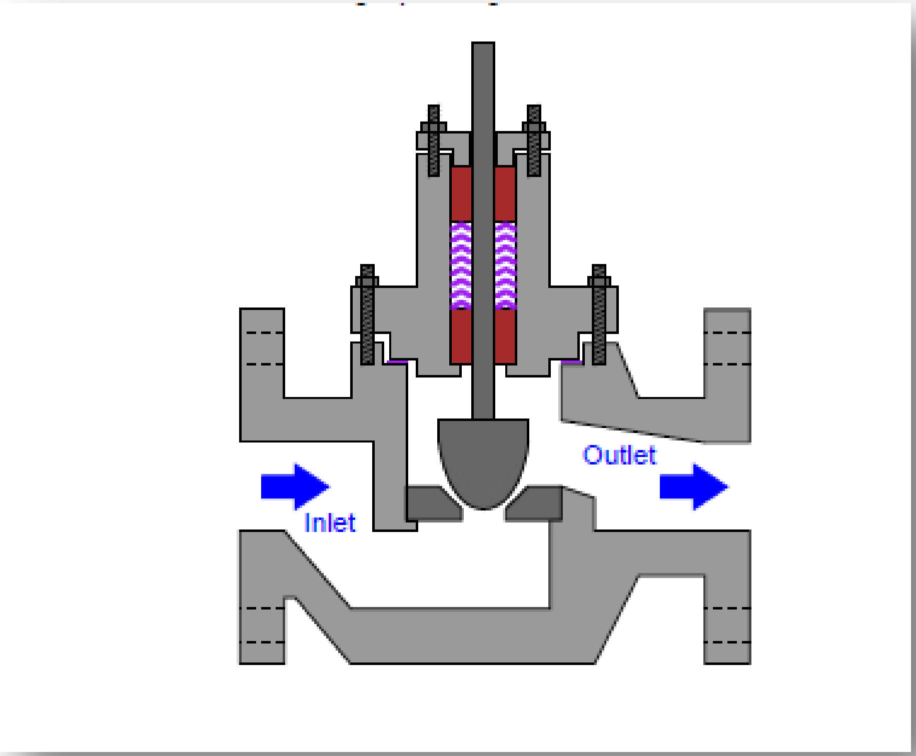




CONTROL VALVE BODY

SINGLE-PORTED GLOBE

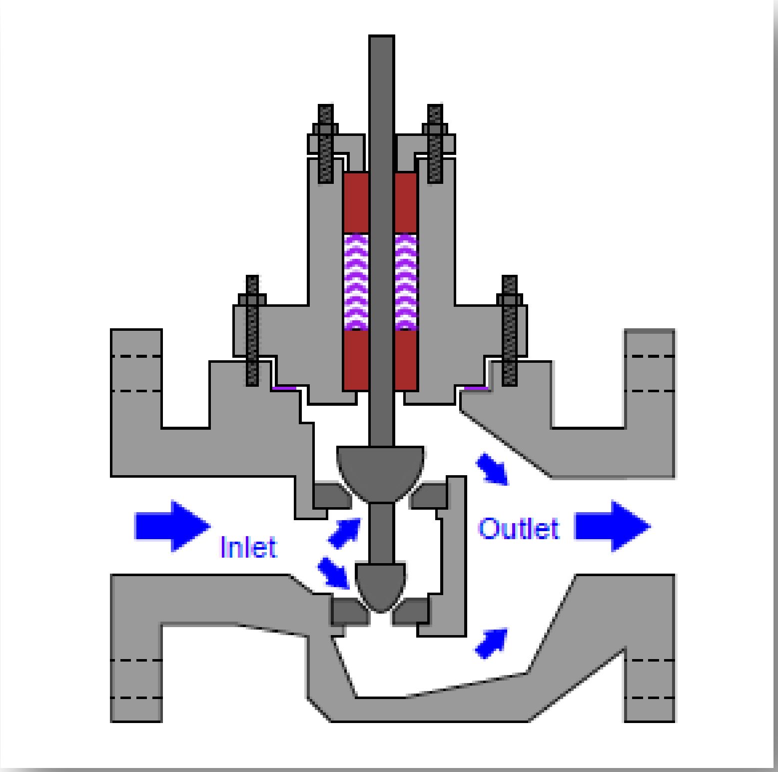
- Large amount of force required to drive the stem
- Tight shut off
- Used in small diameter applications



CONTROL VALVE BODY

DOUBLE-PORTED GLOBE VALVE

- The purpose of a double-ported globe valve is to minimize the force applied to the stem by process fluid pressure across the plugs which comes in trade of tight shutoff of the valve



CONTROL VALVE BODY

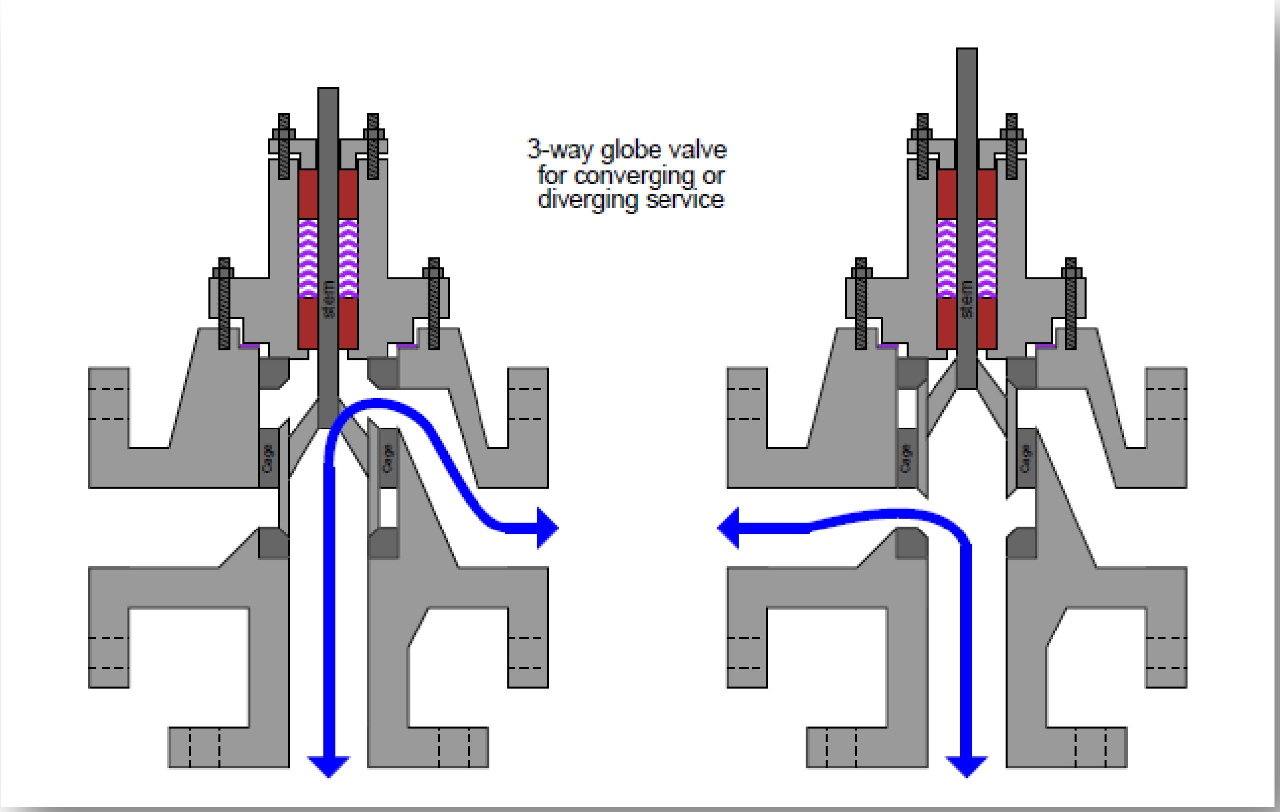
Application
Throttling general purpose flow control valve

Advantages	Disadvantages
Faster than gate, seat less wear and tear, high pressure drop for pressure control. Minimizes disassembly for maintenance. Streamlined flow path with a minimum of parts and no irregular cavities.	High pressure drop, require considerable power to operate (gears and levers), heavy. Valves cannot be welded in-line since the valve body is required to be split.

CONTROL VALVE BODY

3-WAY VALVES

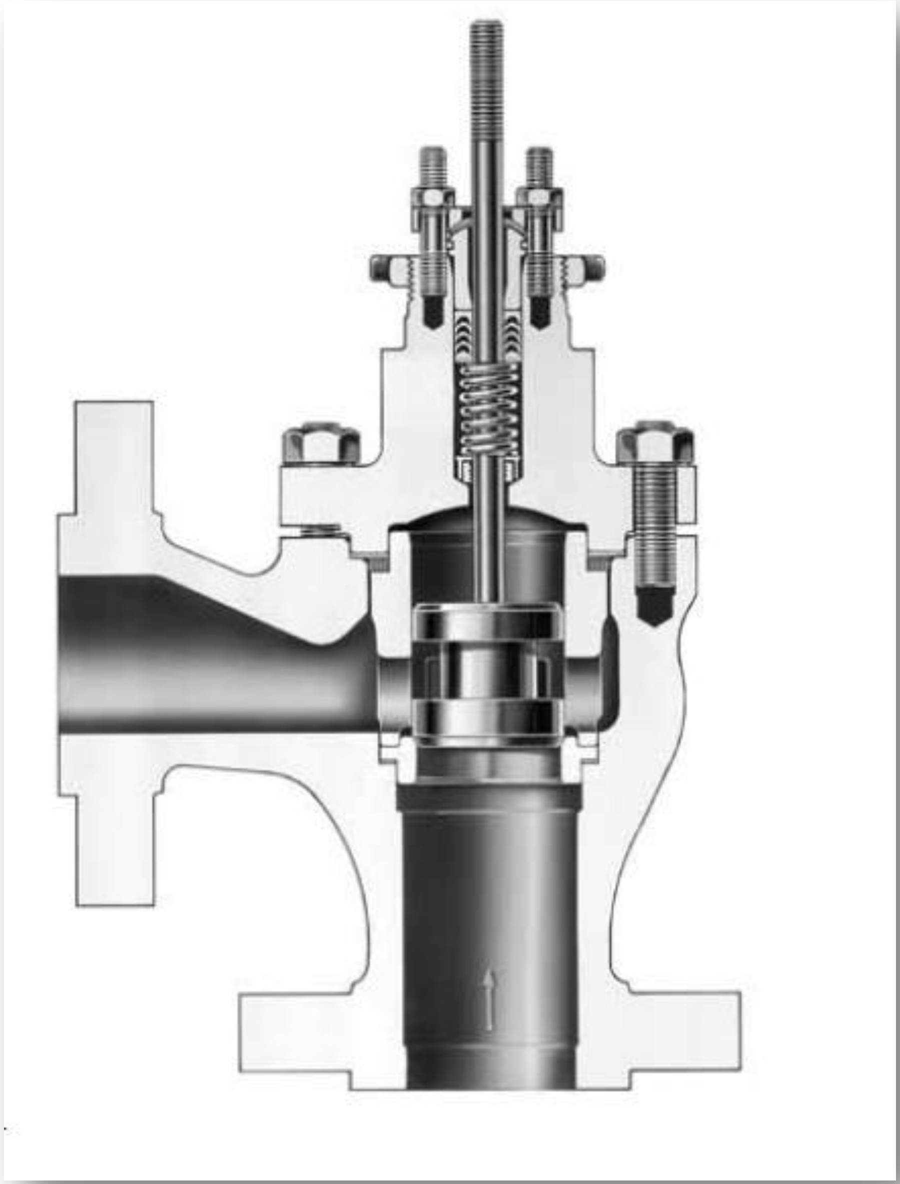
➢ Three-way valves are useful in services where a flow stream must be diverted (split) between two different directions, or where two flow streams must converge (mix) within the valve to form a single flow stream.



CONTROL VALVE BODY

ANGLE VALVES

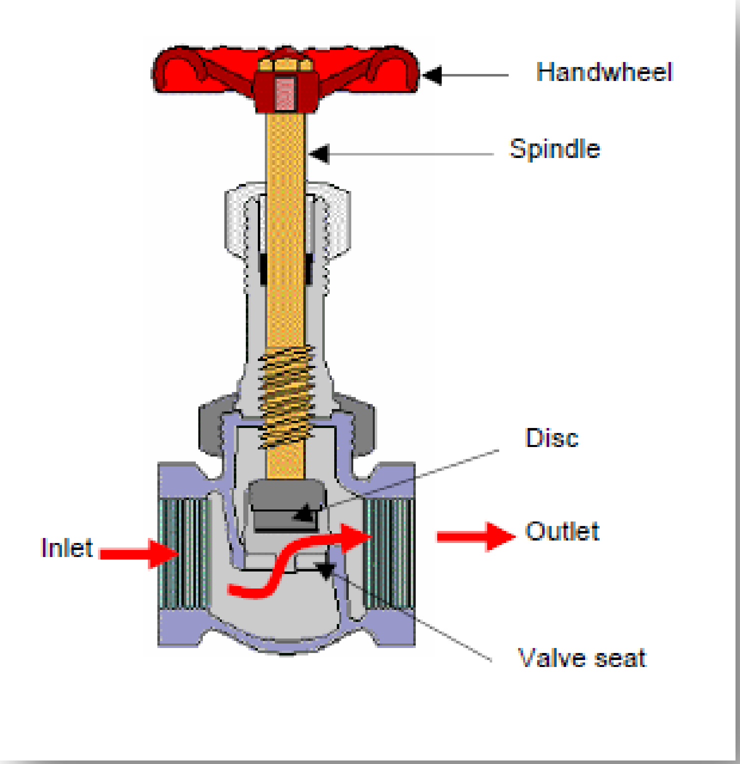
- The inlet and outlet ports are at right angle to each other .
- Can be installed in case of no inline globe valve can be installed



CONTROL VALVE BODY

Z GLOBE VALVE

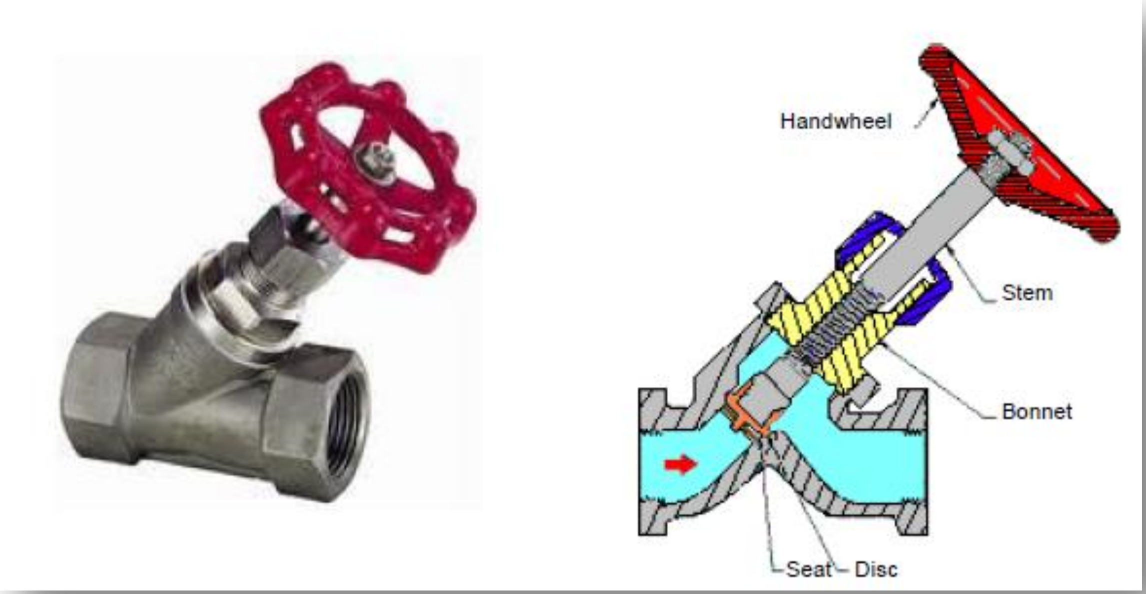
- The name is given because of the path the fluid has to take as it passes through the valve. It changes direction twice, like the letter Z.
- Z-type globe valves are used mainly for small-size, low-pressure applications. In large, high-pressure lines, the changes of flow direction cause a large pressure drop and turbulence that can damage the trim.



CONTROL VALVE BODY

Y GLOBE VALVE

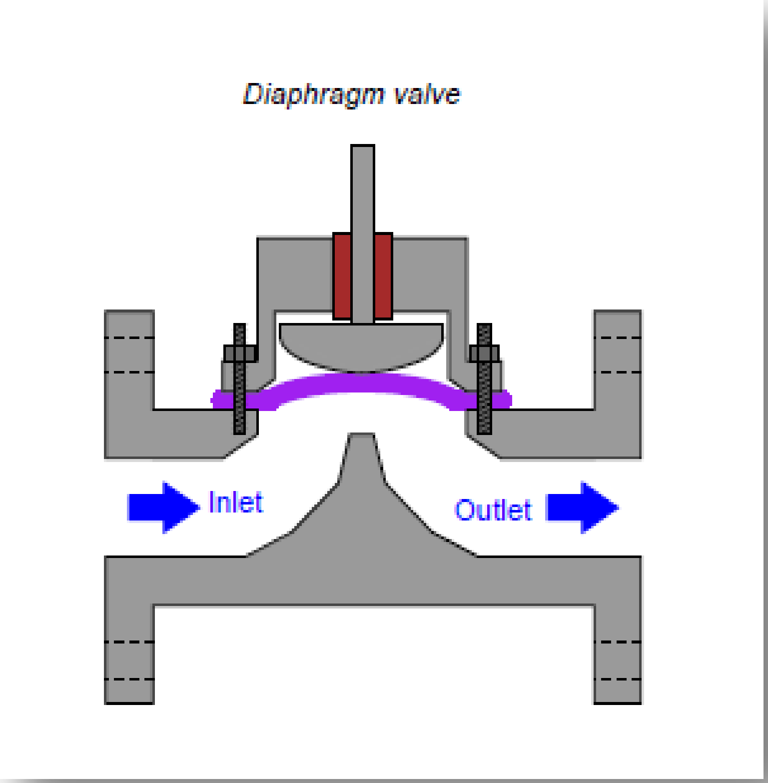
- Having the seat at about 45 to the flow direction straightens the flow path and reduces the pressure drop. This type of valve can be used for high-pressure applications.
- Have the property of self drain useful in high temperature application



CONTROL VALVE BODY

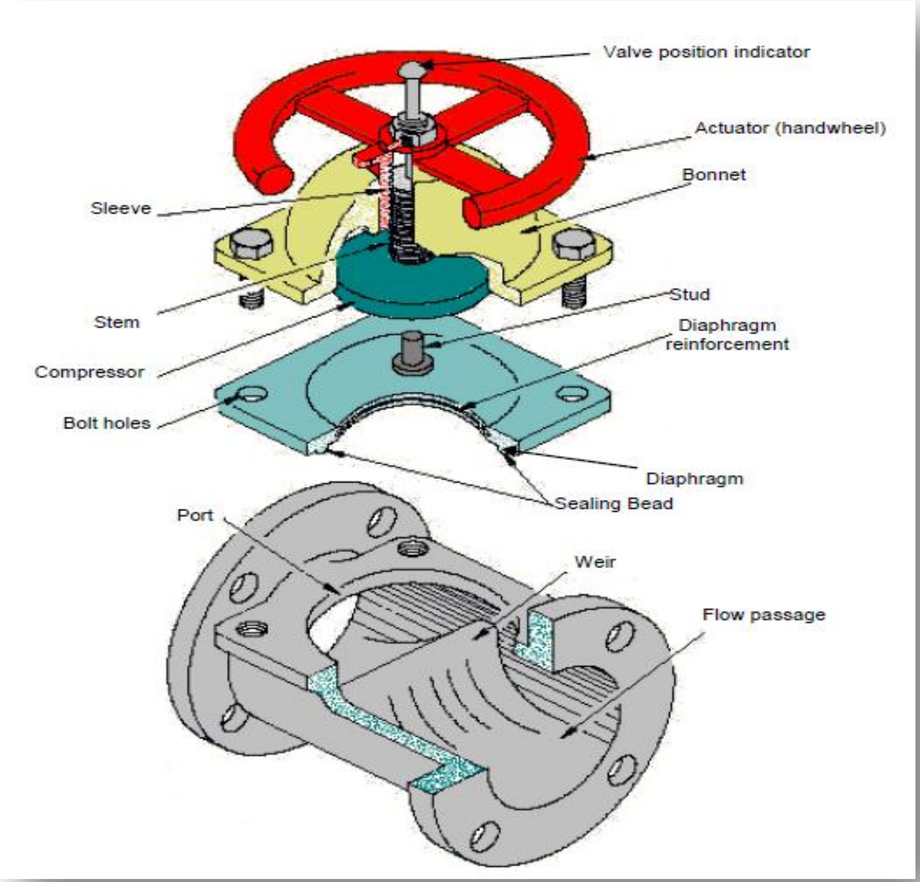
DIAPHRAGM VALVE

- Diaphragm valves use a flexible sheet pressed close to the edge of a solid dam to narrow the flow path for fluid. These valves are well suited for flows containing solid particulate matter such as slurries.
- Precise throttling may be difficult to achieve due to the elasticity of the diaphragm.
- This diaphragm completely separates the valve trim from the fluid flowing through the valve. This means that the fluid does not contact the trim and the stem does not need any gland packing.



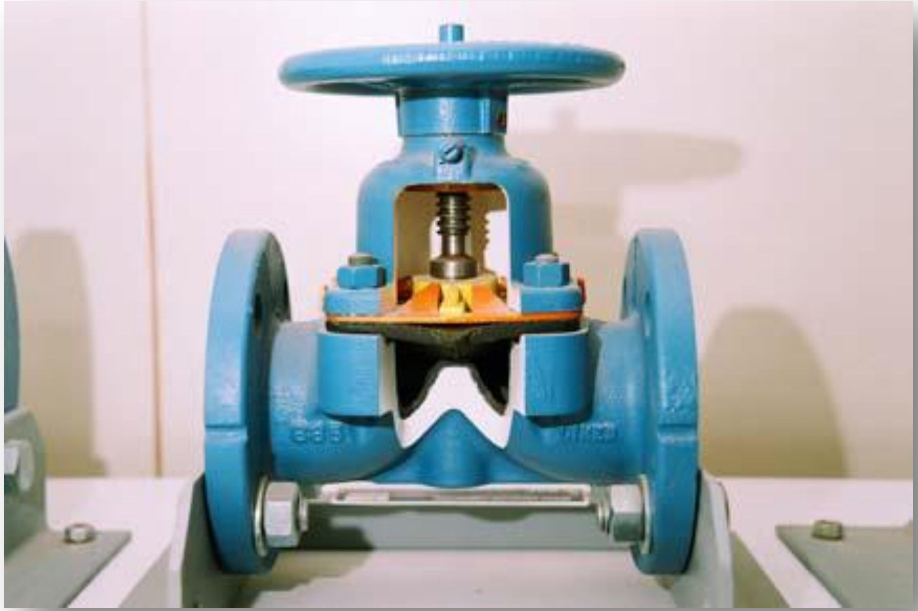
CONTROL VALVE BODY

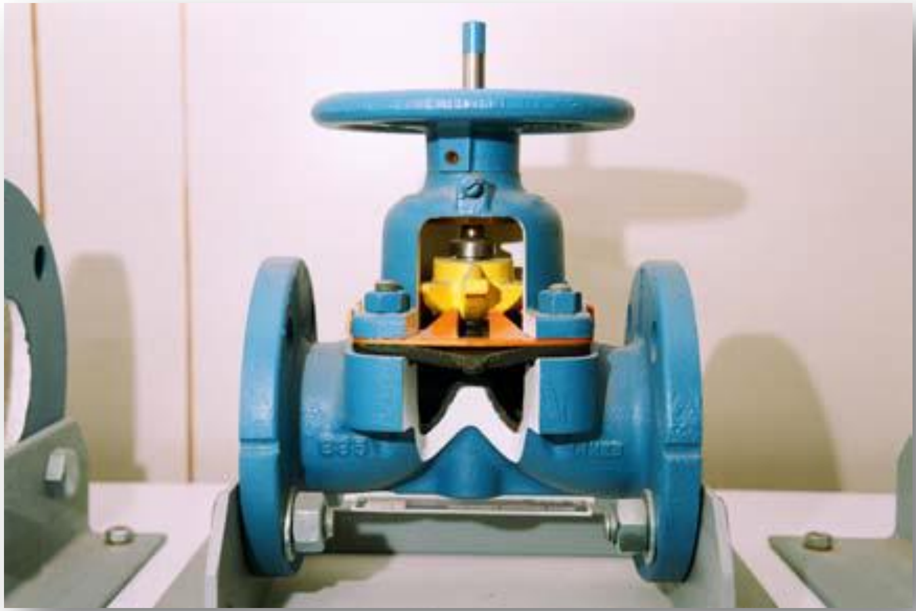
DIAPHRAGM VALVE ASSEMBLY



CONTROL VALVE BODY

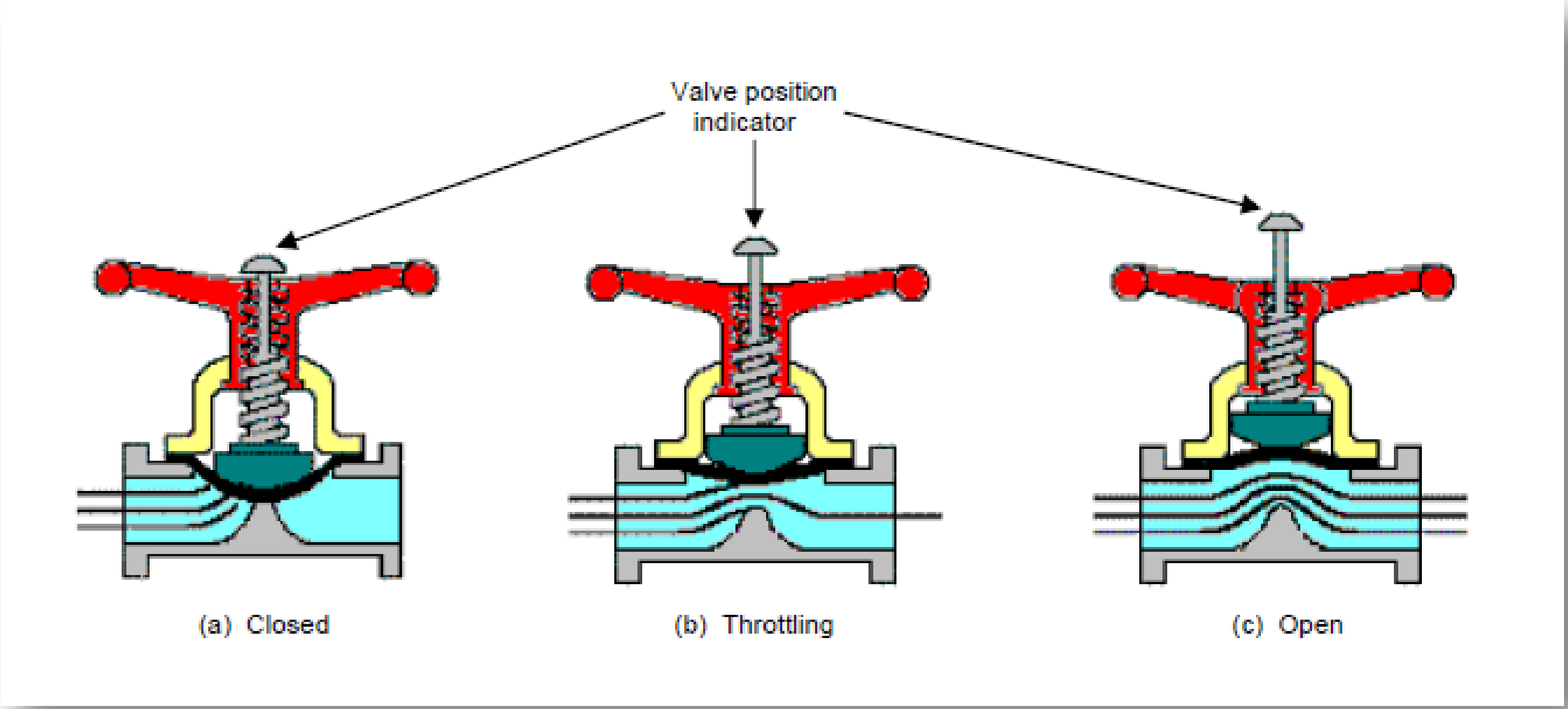
Diaphragm Valve positions (on-off)





CONTROL VALVE BODY

DIAPHRAGM VALVE POSITIONS (THROTTLING)



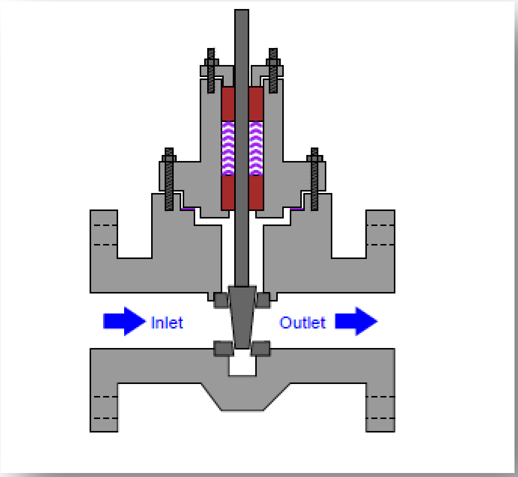
CONTROL VALVE BODY

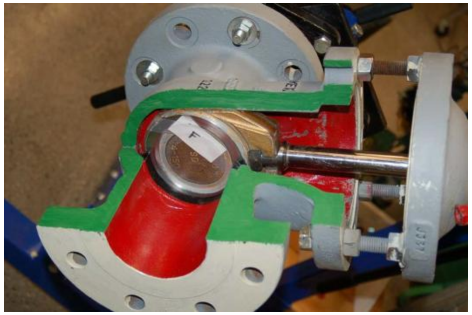
Application Used for biochemical processes. used for regulation of most gases and liquids	
Advantages	Disadvantages
Valve components can be isolated from the process fluid. Valve construction prevents leakage ofthe fluid without the use of a gland seal (packing)	The diaphragm becomes worn more easily and regular maintenance is necessary. These types of valves are generally not suited for very high temperature fluids and are mainly used on liquid systems.

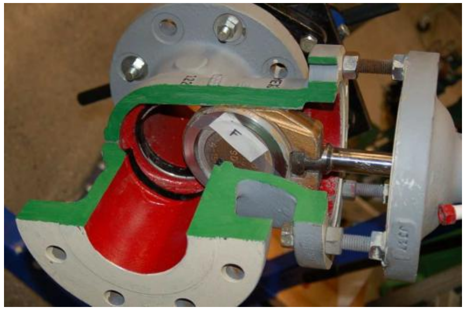
CONTROL VALVE BODY

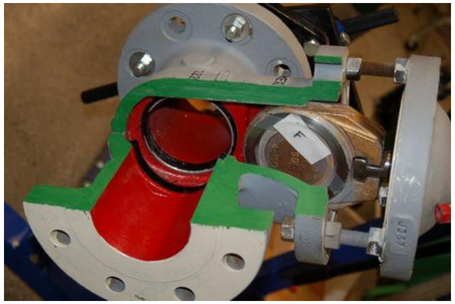
GATE VALVE

- Gate valves work by inserting a dam (gate) into the path of the flow to restrict it, in a manner similar to the action of a sliding door. Gate valves are more often used for on/off control than for throttling.



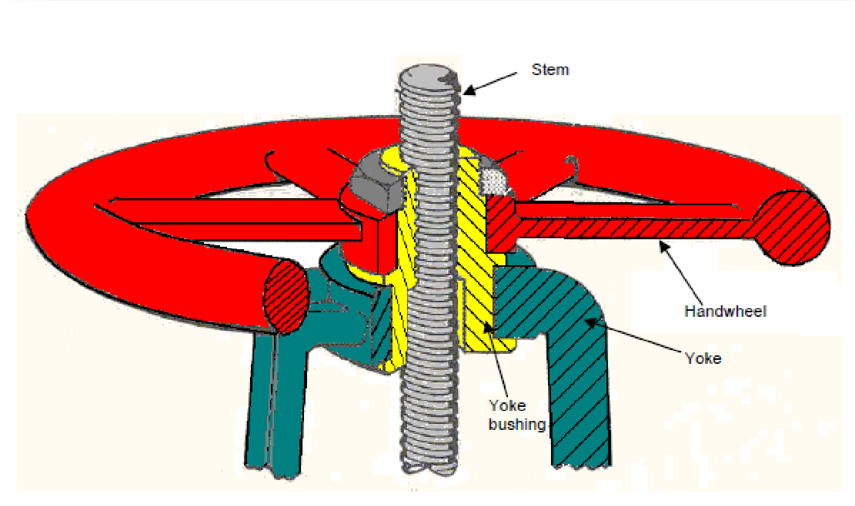


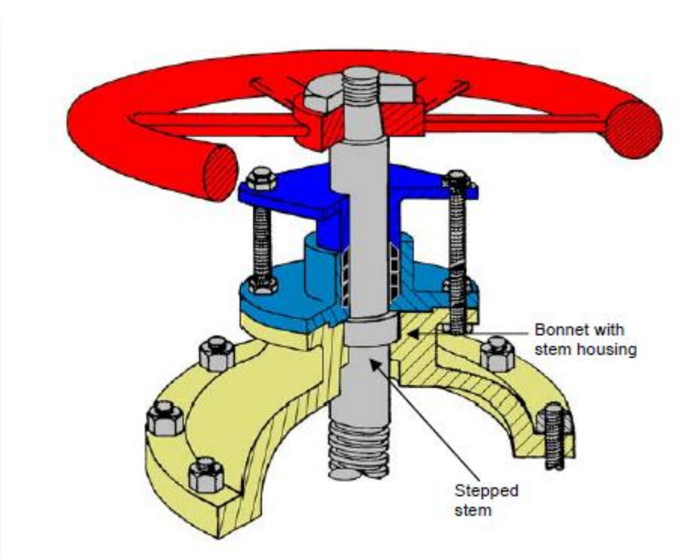




CONTROL VALVE BODY

Rising and Non Rising stem

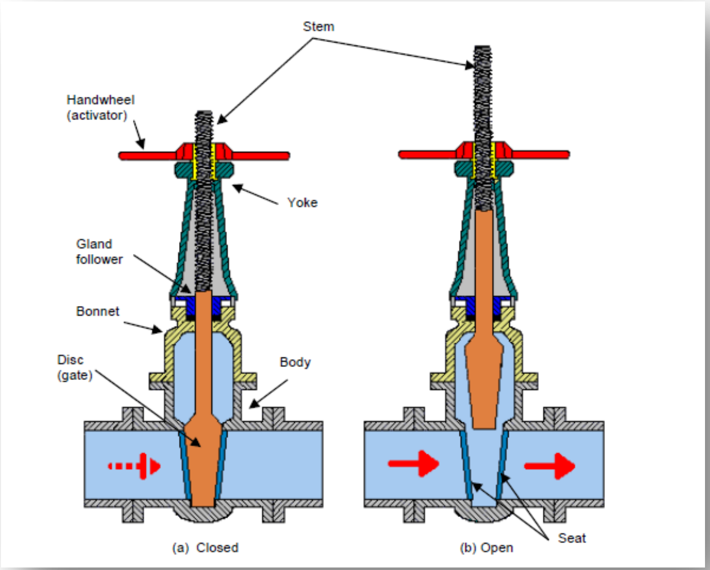


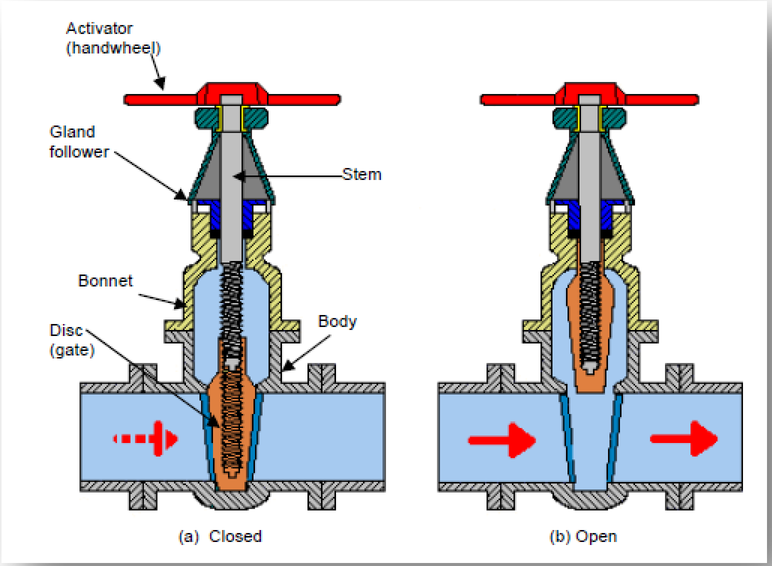


CONTROL VALVE BODY

GATE VALVE WITH HANDWHEEL

- Turning the hand wheel raises and lowers the gate.
- When the gate valve is fully closed, the gate fills the passage and stops the flow through the valve completely.
- When the valve is fully opened, the gate is positioned above the passage in the valve body. This allows full flow through the valve, with little or no obstruction. There is very little pressure drop across the valve.





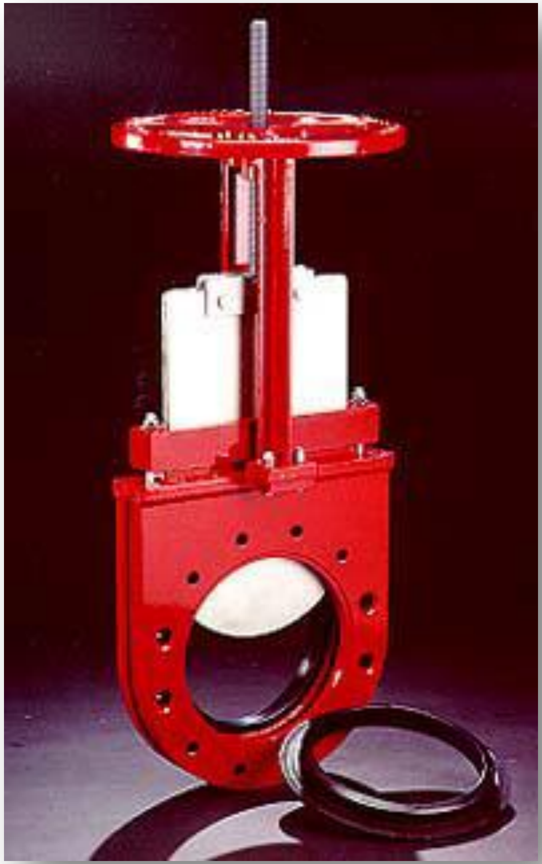
CONTROL VALVE BODY

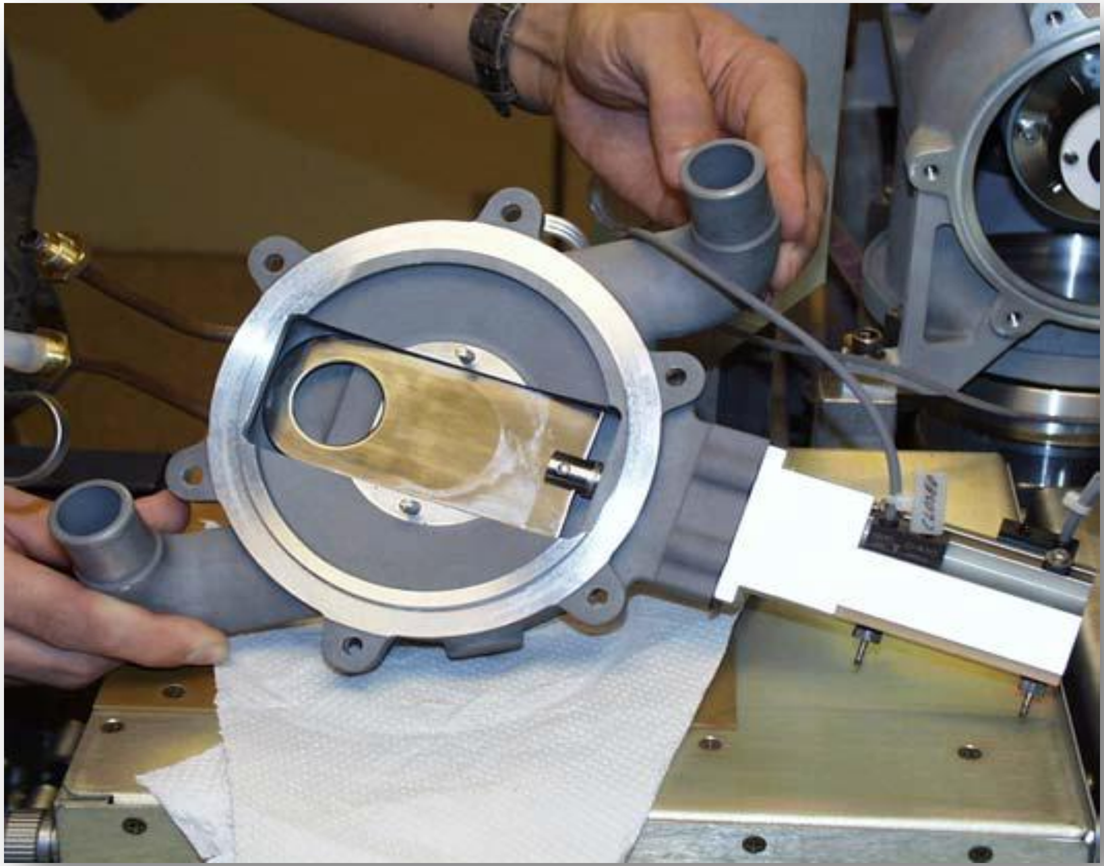
Application **stop valves, (not throttling), high pressure and temp, not for slurries, viscous fluids**	
Advantages	Disadvantages
low pressure drop when fully open, tight seal when closed, free of contamination buildup.	vibration when partially open, slow response and large actuating force

CONTROL VALVE BODY

Knife Gate valve

- Knife gate valves, have a simple, one-piece closing element. It is a parallel-sided plate that may move clear of the flow path to open or may have a hole that moves into the flow path.





CONTROL VALVE BODY

ROTARY VALVES

- A different strategy for controlling the flow of fluid is to insert a rotary element into the flow path. Instead of sliding a stem into and out of the valve body to actuate a throttling mechanism, rotary valves rely on the rotation of a shaft to actuate the trim. An important advantage of rotary control valves over sliding-stem designs such as the globe valve and diaphragm valve is a virtually obstruction less path for fluid when the valve is wide-open.

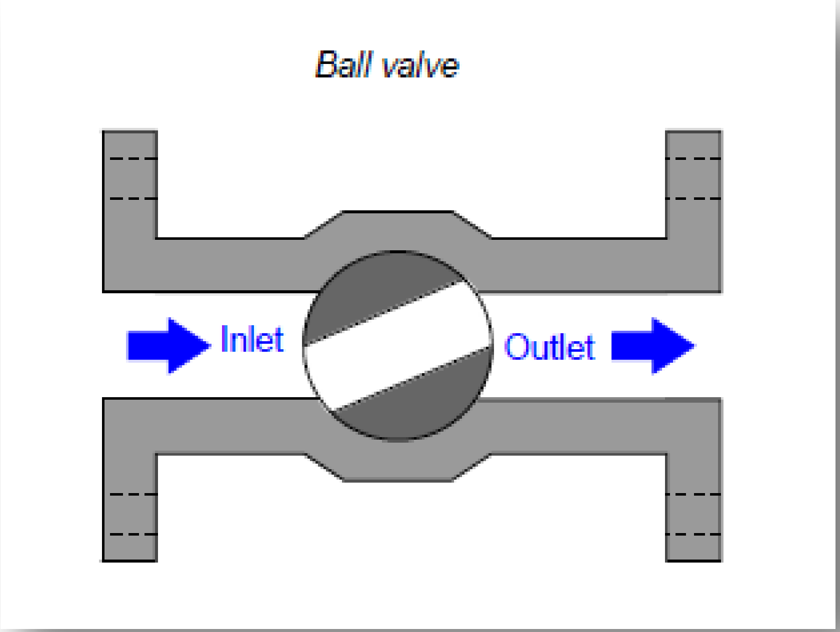
MAIN TYPES OF ROTARY VALVES

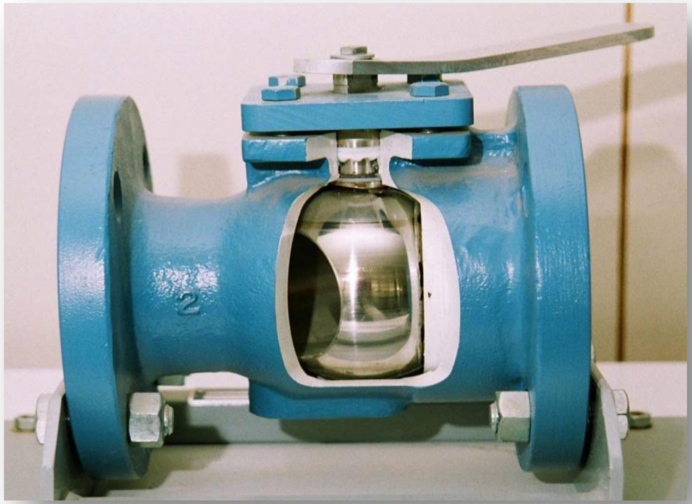
- Ball Valves
- Butterfly Valves
- Disc Valves

CONTROL VALVE BODY

BALL VALVE

- In the ball valve design, a spherical ball with a passageway cut through the center rotates to allow fluid more or less access to the passageway. When the passageway is parallel to the direction of fluid motion, the valve is wide open; when the passageway is aligned perpendicular to the direction of fluid motion, the valve is fully shut (closed).

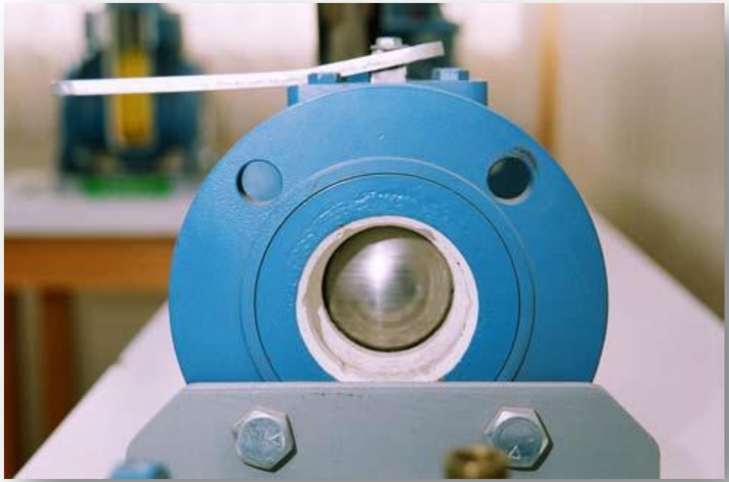




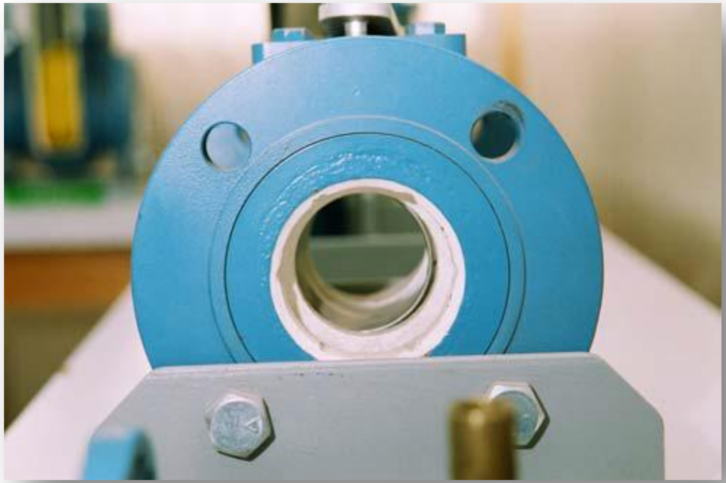
CONTROL VALVE BODY

BALL VALVES OPEN / CLOSE STATES

CLOSE



OPEN



CONTROL VALVE BODY

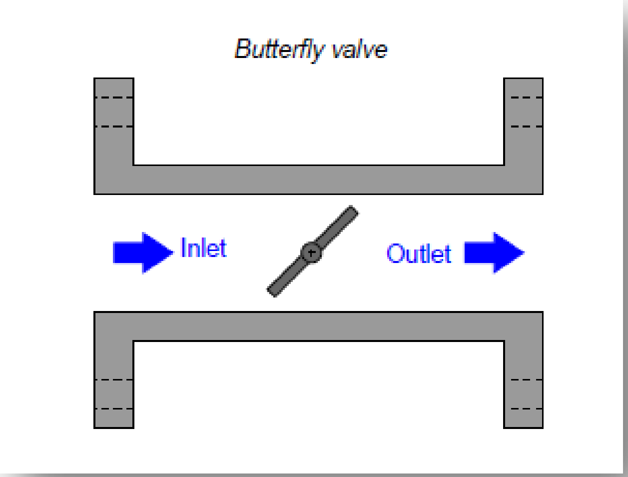
Application
Flow control, pressure control, shutoff, corrosive fluids, liquids gases, high temp.

Advantages	Disadvantages
Low pressure drop, low leakage, small, rapid opening. Low cost and weight relative to globes as size increases High flow capacities (2 to 3 times that of globe valves) Tight shutoff Low stem leakage Easily fitted with quarter turn actuators	Seat can wear if used for throttling, quick open may cause hammer. Over sizing. High cost in large sizes compared to butterfly valves.

CONTROL VALVE BODY

BUTTERFLY VALVES

- Butterfly valves are quite simple to understand: the "butterfly" element is a disk that rotates perpendicular to the path of fluid flow. When parallel to the axis of flow, the disk presents minimal obstruction; when perpendicular to the axis, the disk completely blocks any flow. Fluid-tight shutoff is difficult to obtain in the classic butterfly design unless the seating area is lined with a soft (elastic) material.

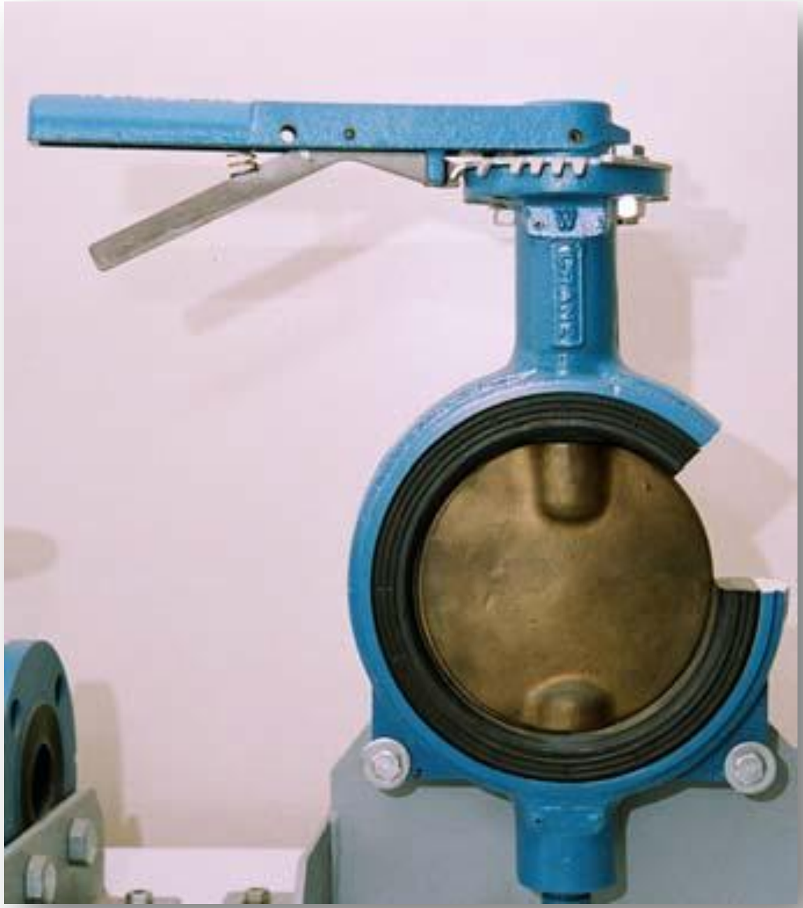


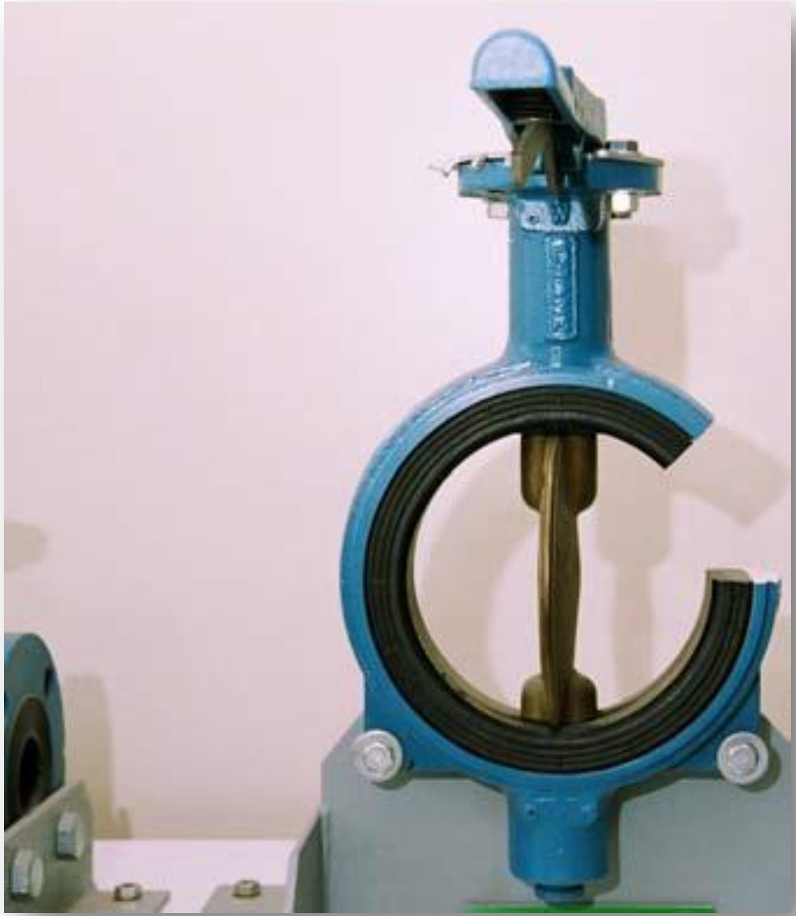
- The disc turns to open and close the valve. The disc or seat may be made of a polymer (plastic) to give a better seal.

- Butterfly valves are simple and take up little space. This makes them especially good for use in large pipelines or where there is not much space. Operating a butterfly valve can take a lot of force as you have to push it against the fluid pressure. Larger valves usually have geared actuators to make operation easier.

CONTROL VALVE BODY

BUTTERFLY POSITIONS

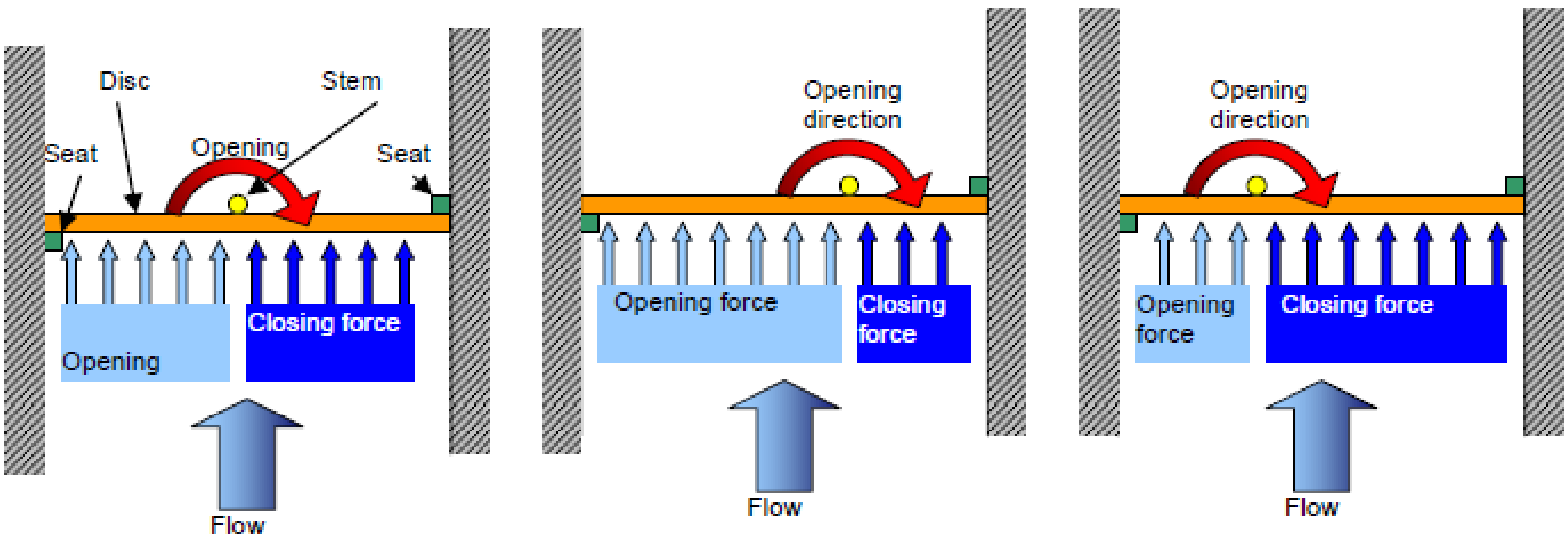




CONTROL VALVE BODY

BUTTERFLY POSITIONS

- Most butterfly discs turn on a stem that passes through the center of the disc along a diameter. When the valve is closed, fluid pressure pushes equally on both sides of the stem: half the force is pushing in the closing direction and half in the opening direction



(a) Central Stem—equal pressure (b) Offset Stem—quick open (c) Offset Stem—quick close

CONTROL VALVE BODY

Application Low pressure, large diameter lines where leakage is unimportant	
Advantages	Disadvantages
Low pressure drop, small and lightweight. Low cost and weight relative to globes as size increases High flow capacities Low stem leakage	High leakage, high actuation forces so limited to low pressures. Over sizing

CONTROL VALVE BODY

DISC VALVE

➢ Disk valves (often referred to as eccentric disk valves, or as high-performance butterfly valves) are a variation on the butterfly design intended to improve seat shut-off. The disk's center is offset from the shaft centerline, causing it to approach the seat with a "cam" action that results in high seating pressure. Thus, tight shut-off of flow is possible even when using metal seats and disks.

SPECIAL VALVES

SPECIAL VALVES

Pressure relief valves

- Pressure relief valves are used mainly to relieve overpressure of liquids. This often happens when a liquid in a closed container or pipeline expands as its temperature increases.
- Under normal operating conditions, a spring holds the PRV closed. Fluid pressure pushes against the spring to open the valve. The fluid pressure needed to push the valve open is called the set point pressure. The set point pressure is usually the maximum normal operating pressure of the liquid.

SPECIAL VALVES

Pressure relief valves

- An adjustment screw changes the spring force for different set point pressures. When the liquid pressure exceeds the set point pressure, the valve opens slowly. It releases just enough liquid to bring the pressure down to the normal operating pressure. The spring then closes the valve slowly so that normal operations can continue.

SPECIAL VALVES

Pressure safety valves

- Pressure safety valves are used mainly to relieve overpressure of gases and vapors (e.g. steam). The set point pressure is greater than the maximum normal operating pressure of the process fluid but less than the maximum safe working pressure of the equipment.
- When the fluid pressure exceeds the set point pressure, the valve pops fully open. This happens very quickly to release overpressure as quickly as possible. The pressure at which the valve closes again is lower than the opening set point pressure. The difference between opening and closing pressures is called the blow down.

SPECIAL VALVES

Pressure safety valves

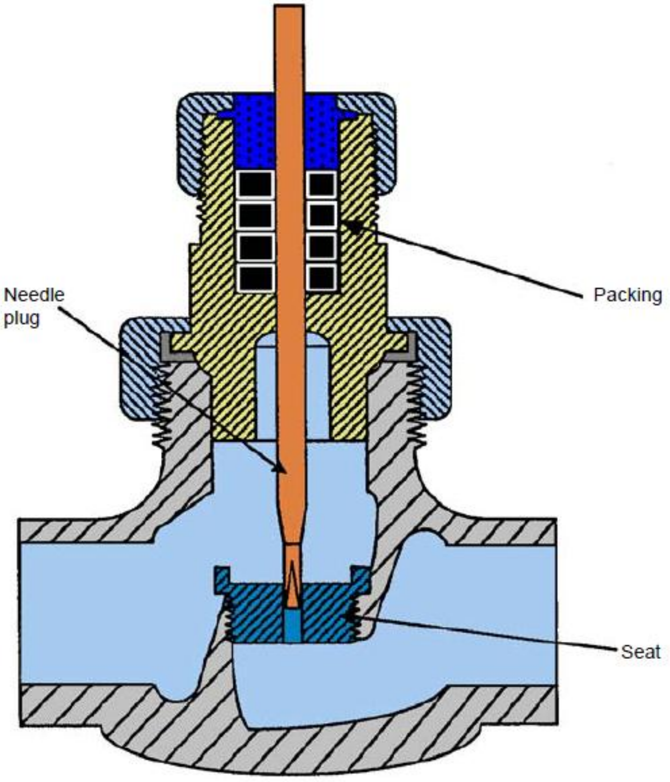
- Blow down is given as a percentage of opening setpoint pressure.
  EXAMPLE a valve may open at 15bar with a blowdown of 10%.
  10% of 15bar is 1.5bar
  the valve will close at a pressure that is 1.5bar lower than 15bar
  15bar – 1.5bar = 13.5bar.
- PSVs on gas processing systems normally vent to flare—the valve outlet is connected to the flare system where the gas burns off.

- PSVs on steam systems vent to atmosphere—the steam is released into the air.

SPECIAL VALVES

Needle Valves

- Needle valves are linear-motion valves. They can make very small adjustments to flow rate. Their name comes from the long, tapered shape of the bottom of the spindle that forms the closing element.



SPECIAL VALVES

Needle valve Positions

SPECIAL VALVES

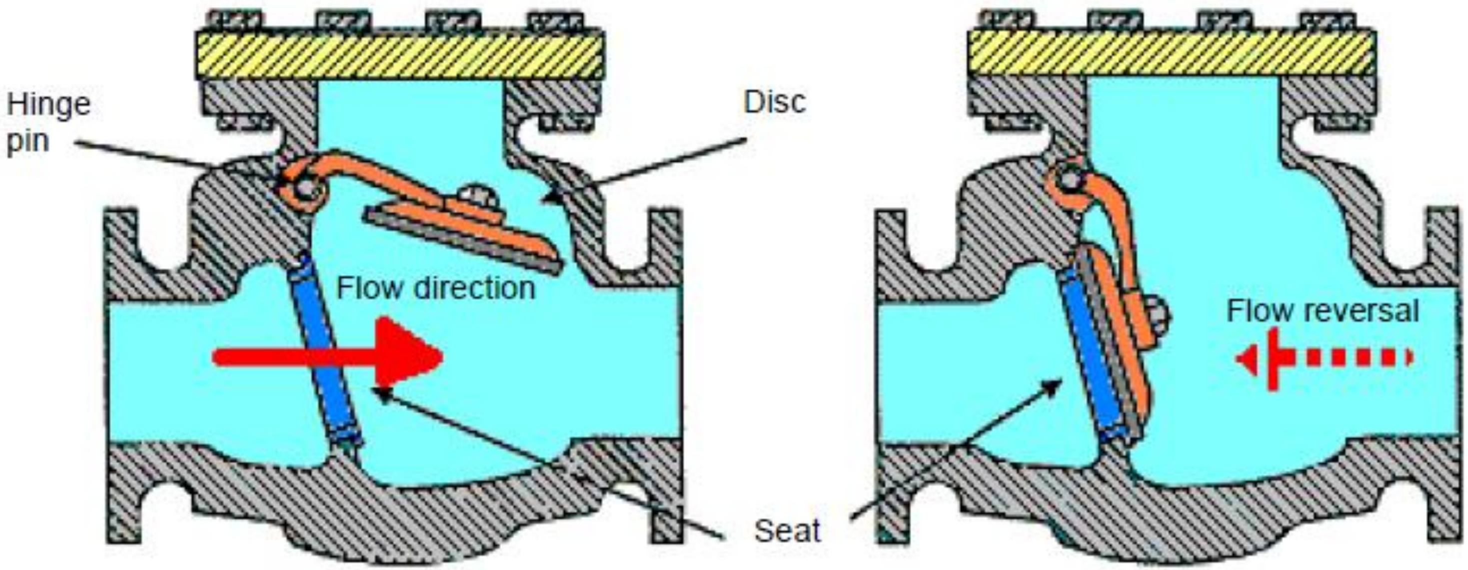
Check Valves

- Non-return valves, also called check valves, stop flow reversal in a pipe. They only allow fluid to flow in one direction.
- The pressure of the fluid passing through the valve in the correct direction opens it automatically. If the flow tries to reverse, the valve closes automatically. They have an arrow on the body that shows the correct flow direction,. Make sure that you mount non-return valves the correct way round.

SPECIAL VALVES

Swing Check valve

- In this type, the valve disc is hinged at the top. When there is no flow, the weight of the disc closes the valve.

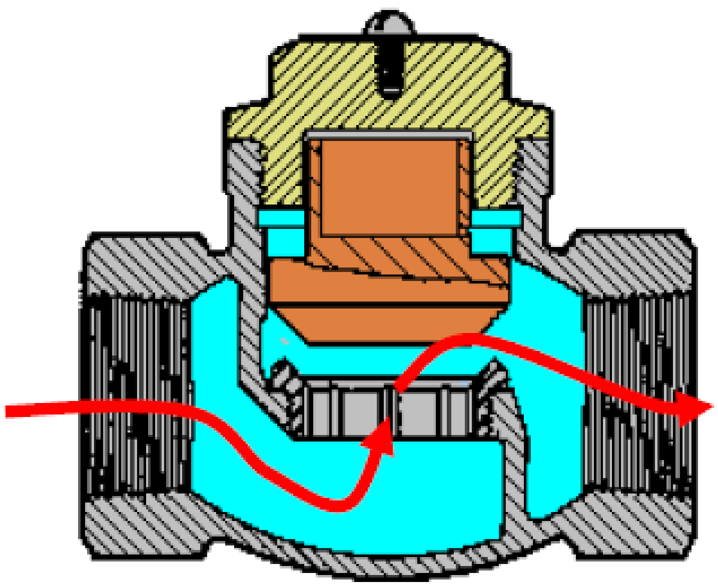


(a) Open—flow (b) Closed—no flow

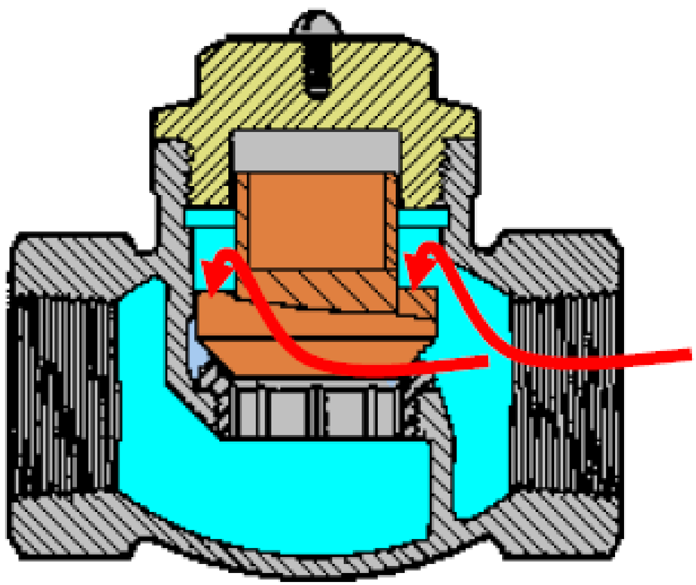
SPECIAL VALVES

Lift Check Valves

- These valves have a similar valve body and seating arrangement to globe valves.
- Flow must enter from under the seat to lift the closing element. Flow in the reverse direction pushes the closing element against its seat.



(a) Flow

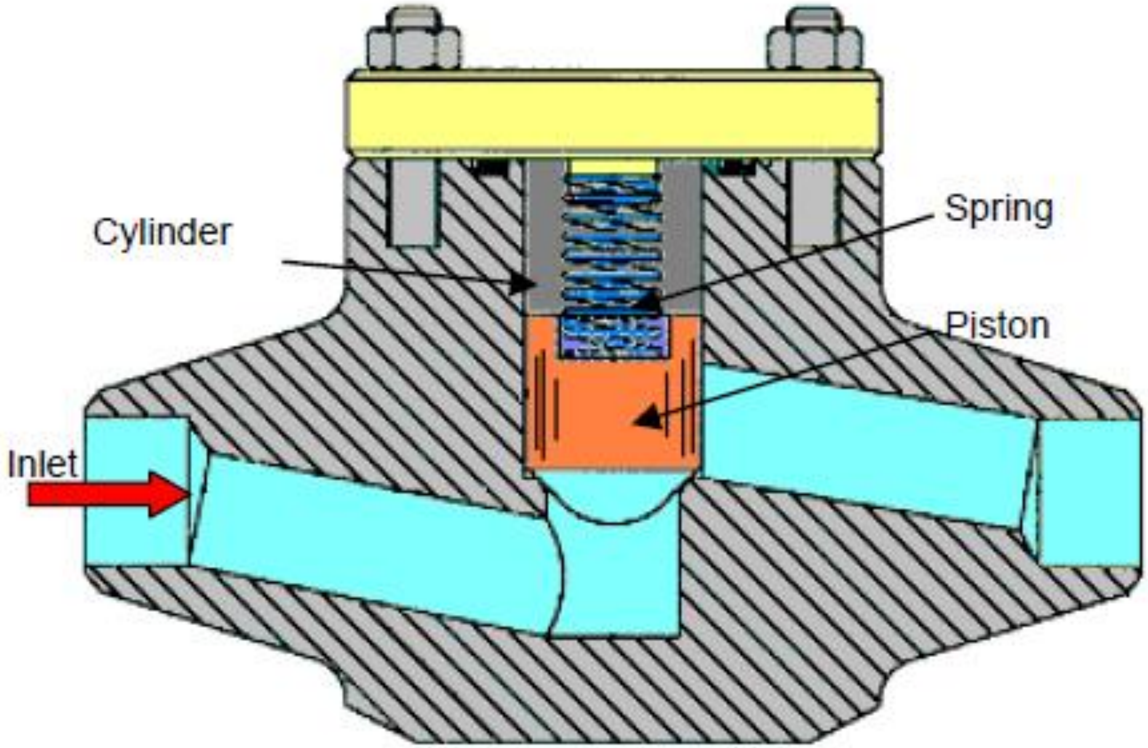


(b) No Flow

SPECIAL VALVES

Piston Check Valves

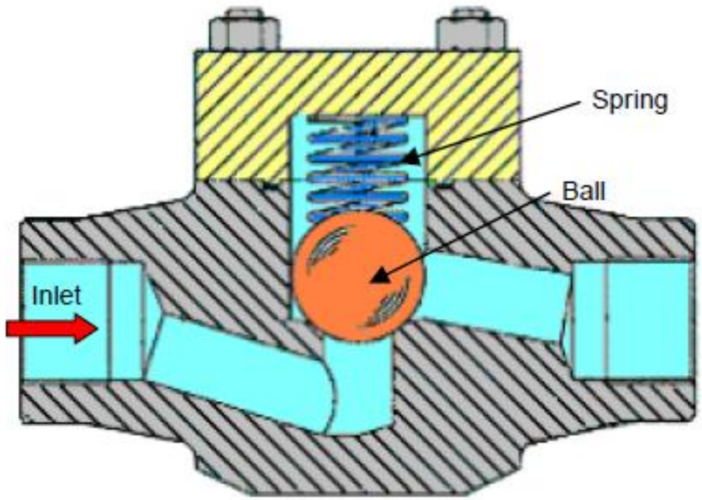
➢ Piston check valves are similar to lift check valves. Instead of a valve disc there is a piston that slides in a cylinder. This gives a smoother motion during operation.



SPECIAL VALVES

Ball Check Valves

➢ These have a spherical (ball-shaped) closing element. Like the other check valves, the closing element may operate by gravity or the flow pressure or it may be spring loaded.



(a) Spring-loaded Ball Check Valve

(b) Flow-activated Ball Check Valve

CONTROL VALVE BODY SELECTION

CONTROL VALVE BODY SELECTION

Globe (Plug and Seat)

- These are the most traditionally used control valves - generally available from 12 to 400mm in all castable materials. Larger sizes are available but it becomes more common to move to an angle construction on these sizes.

- Pressure ratings up to ANSI 2500# and higher are available.

- The globe valve is very versatile offering reduced trim options as well as a variety of special trims for severe high pressure drop applications. This style of valve is easily adapted for use on cryogenic temperatures, and for high temperature duties.

- Turndown capability of 50:1 is available.

CONTROL VALVE BODY SELECTION

Butterfly

- The least expensive of all control valves. Sizes range from 50 to 3000mm.
- Pressure ratings are generally up to 1600 kpa(G).
- Temperatures are up to 100C. This valve is good for corrosive applications but does not handle high pressure drops well. It is the lightest valve available - size for size. Turndown is 75:1.

CONTROL VALVE BODY SELECTION

Diaphragm / Pinch

- These valves are inexpensive and very simple in operation. They are used extensively in the mining industry for control of slurries and water.
- The characteristic is basically quick opening and so these valves do not give precise control or high turndown but function particularly well on level control. Very good for low pressure abrasive applications.
- Sizes are available from 25 to 350mm in pressure ratings up to 1000kPa on the smaller sizes and 350kPa above 200mm. Special pinch valves can handle pressures up to 100 bar.
- Temperature limitation is about 100C. Turndown is 10:1.

CONTROL VALVE BODY SELECTION

Ball

- Ball valves naturally have a good control characteristic and give high turndown of 100:1 for standard ball valves and up to 500:1 for vee ported valves.
- High pressure valves are available to ANSI 2500# and higher - most valves working at greater than 3000kPa have trunnion mounted balls.
- Sizes range from 10mm to 500mm.
- High temperatures are handled by valves with metal seats.
- Full ball valves are not recommended for slurries due to the solids settling out in the body cavity.
- High pressure drops are not handled well due to the ball causing high velocity jets of fluid directed into the seat and body - resulting in erosion.
- This design of valve is particularly suitable for use with ceramic materials and can be used on abrasive throttling duties where the pressures and temperatures are too high for pinch or diaphragm valves.

CONTROL VALVE BODY SELECTION

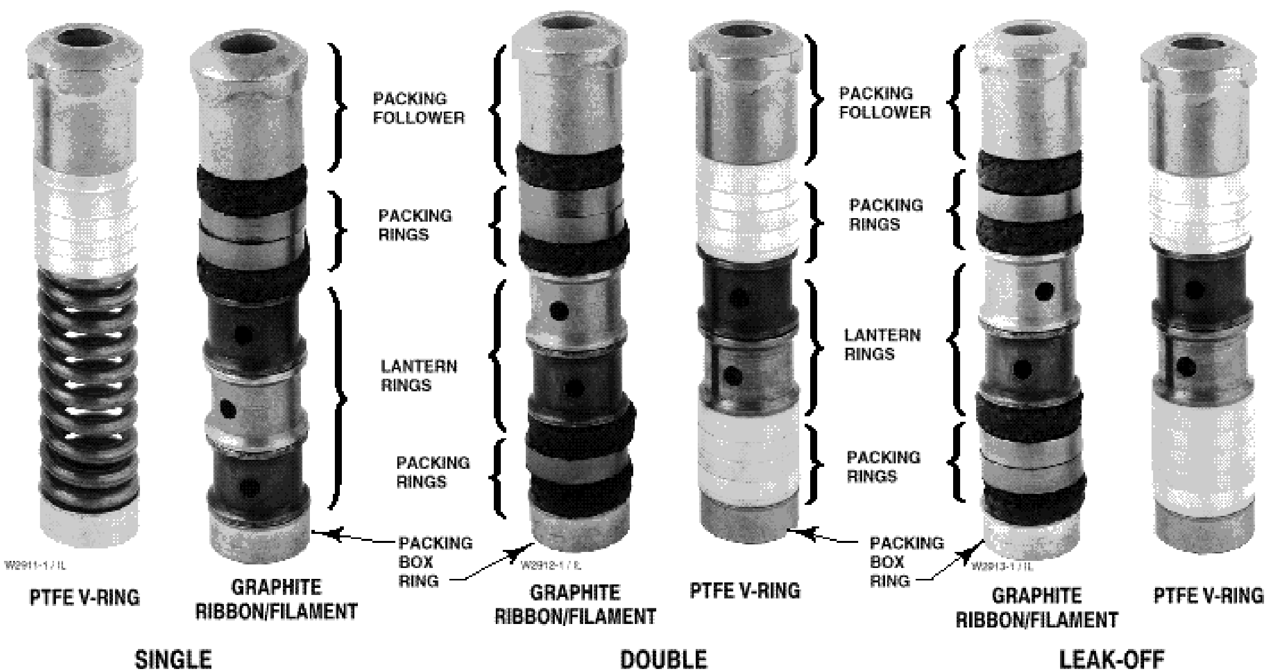
	Type of Valve				
	Gate	Plug (Ball)	Globe	Butterfly	Diaphragm
Type of Service	On/off (Sliding)	On/off (Rotary)	Throttling	Throttling	Throttling
Advantages	Virtually no pressure loss across the valve face Can be used when the fluid contains suspended solids	Similar properties to gate valves Lightweight, compact design High capacity Good rangeability Tight shut-off	Good sealing characteristics Can be used in frequent open/ closing service Quick change of trim without removing valve from line High capacity God rangeability Low-noise trim available Smooth control	Lightweight, compact design Minimal pressure loss across valve face Low cost High throughput capacity Smaller shaft and actuator	Almost no leakage; process fluid is isolated from valve stem Self-cleaning
Disadvantages	Poor sealing characteristics	Sealability poor with metal seats used at high temperatures Limited-temperature range with resilient seats Choke flow problems Cavitation problems Requires removal for maintenance	High-pressure losses due to contorted path through the valve Low-noise trim reduces capacity	Poor sealing characteristics Good control limited to 60-deg. opening Tight shut-off requires special lining: plus over-sized shaft and actuators Lining imposes temperature limitations	Limited operating pressure Limited temperature High wear and tear Poor control over 50%-opening
Sealing Method	Gate face slides parallel to the seal surface. Gate and seal in constant shear contact	Radial seal, shaped to conform with ball surface	Disk motion is perpendicular to valve seat. Only contact is in fully closed position	Throttle blade is mashed into mated seal	Diaphragm material is forced onto valve seat. Only contact is in fully closed position
Recommendations	Not for frequent valve opening/ closing service Not for when throttling control is required	Not for service with highly corrosive fluids Most suitable for handling slurries	For flow regulation When tight shut-off is required	Low-pressure applications	Water-treatment service Chemical and abrasive service

PACKING

CONTROL VALVE PACKING

WHAT IS PACKING ?

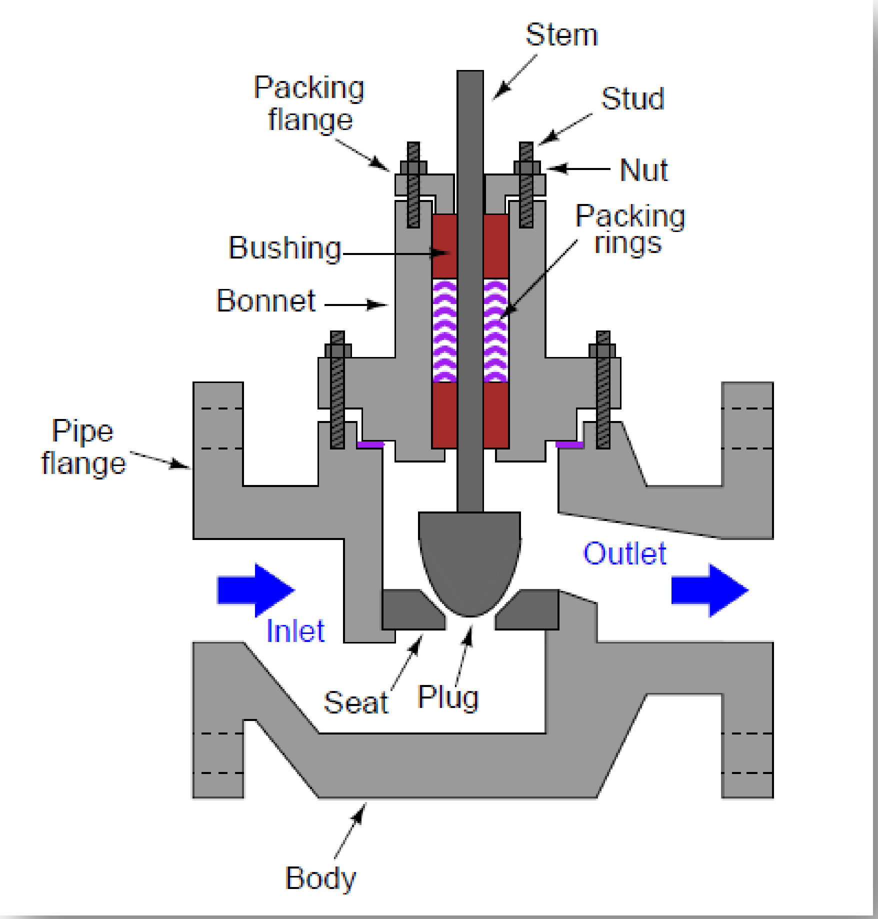
- All stem-actuated control valves require some form of seal allowing motion of the stem from some external device (an actuator) while sealing process fluid so no leaks occur between the moving stem and the body of the valve. The general term for this sealing mechanism is packing.



CONTROL VALVE PACKING

PACKING IN SLIDING STEM VALVE

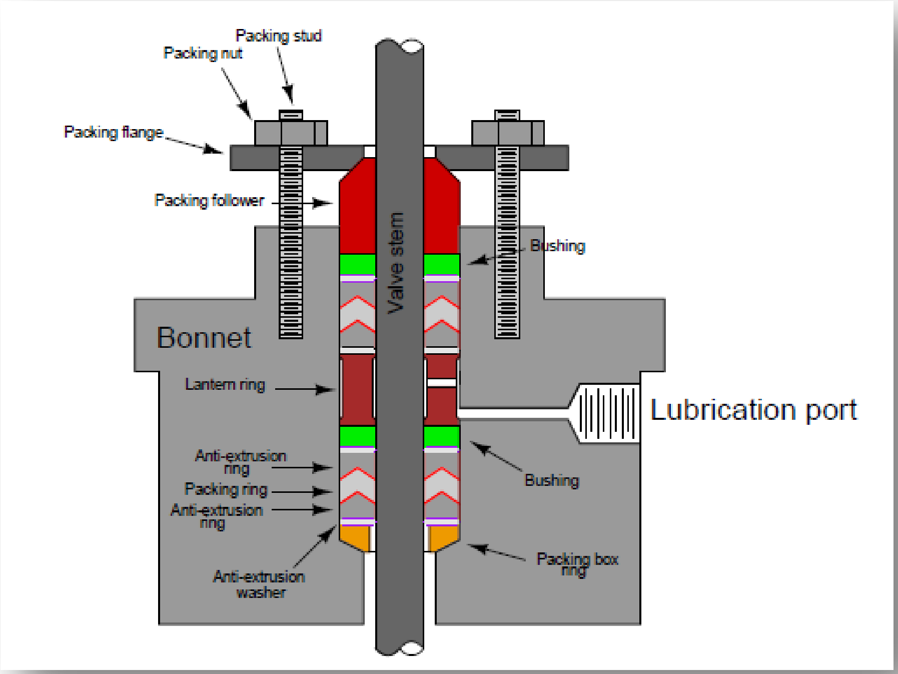
- The packing material takes the form of several concentric rings, stacked on the valve stem like washers on a bolt. These packing rings are forced down from above by the packing flange to apply a compressive force around the circumference of the valve stem. This compressive force is necessary to generate mechanical stress in the packing material to make it seal tightly against the stem of the valve and the interior wall of the bonnet.



CONTROL VALVE PACKING

STATIONARY LOADING

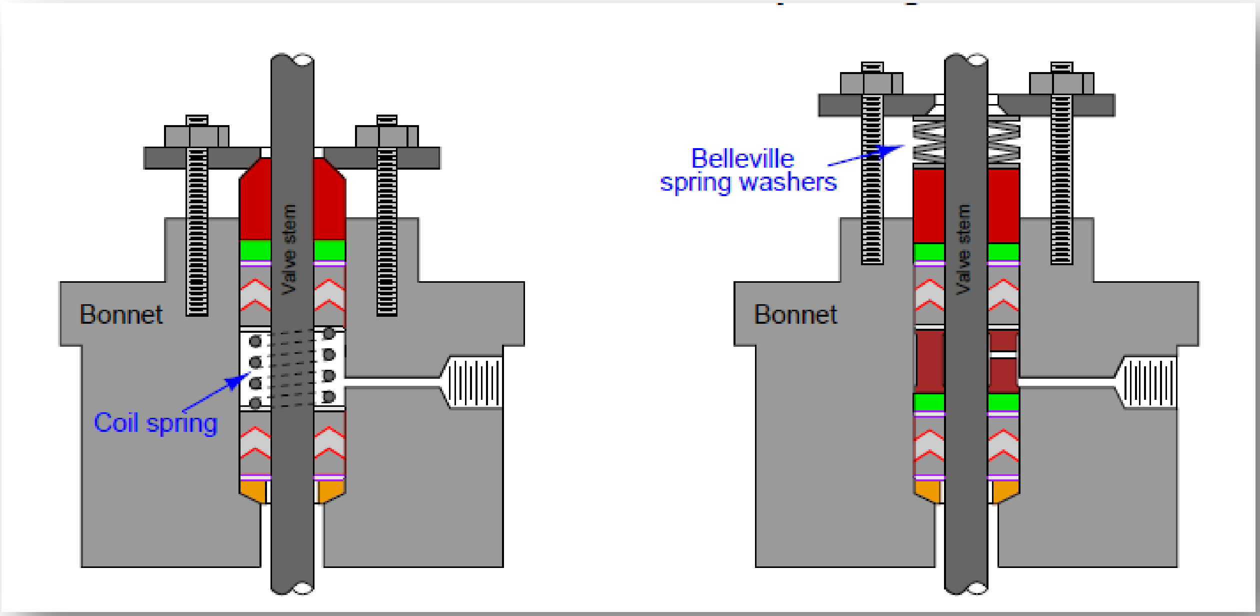
- The packing shown here is "loaded" by the compressive force exerted by the packing follower.
- The only elasticity in this particular system resides in the packing material itself. This is called stationary loading, otherwise known as jam packing.
- Over time, as the packing material wears and fatigues, the packing follower must be re-compressed by carefully tightening the packing nuts.



CONTROL VALVE PACKING

LIVE-LOADED VALVE STEM PACKING

- An alternative to "stationary" loading is to insert a metal spring into the packing assembly, so that the elasticity of the spring helps to maintain an appropriate amount of packing stress as the packing material wears and ages. This is called live loading



CONTROL VALVE PACKING

ADJUSTING PACKING ASSEMBLE

CONTROL VALVE PACKING

PACKING MATERIAL SELECTION

- The two most common packing materials in use today are Teflon (PTFE) and graphite. Teflon is the better of the two with regard to fluid sealing, stem friction, and stem wear. Teflon is also quite resistant to attack from a wide variety of chemical substances.

- Unfortunately, it has a limited temperature range and cannot withstand intense nuclear radiation. Graphite is another self-lubricating packing material, and it has a far greater temperature range than Teflon as well as the ability to withstand harsh nuclear radiation, but creates much more stem friction than Teflon.

CONTROL VALVE PACKING

PACKING MATERIAL SELECTION

- Graphite packing also has the unfortunate property of permitting galvanic corrosion between the stem and bonnet metals due to its electrical conductivity. Sacrificial zinc washers are sometimes added to graphic packing assemblies to help mitigate this corrosion, but this only postpones rather than prevents corrosive damage to the stem.

- Hybrid packing materials, such as carbon-reinforced Teflon, also exist in an attempt to combine the best characteristics of both technologies.

CONTROL VALVE PACKING

Typical Packing friction values

Typical Packing Friction Values

STEM SIZE (INCHES)	CLASS	PTFE PACKING		GRAPHITE RIBBON/ FILAMENT
		Single	Double	
5/16	All	20	30	- - -
3/8	125	38	56	- - -
	150			125
	250			- - -
	300			190
	600			250
	900			320
	1500			380
1/2	125	50	75	- - -
	150			180
	250			- - -
	300			230
	600			320
	900			410
	1500			500
	2500			590
5/8	125	63	95	- - -
	150			218
	250			- - -
	300			290
	600			400
3/4	125	75	112.5	- - -
	150			350
	250			- - -
	300			440
	600			660
	900			880
	1500			1100
	2500			1320
1	300	100	150	610
	600			850
	900			1060
	1500			1300
	2500			1540
1-1/4	300	120	180	800
	600			1100
	900			1400
	1500			1700
	2500			2040
2	300	200	300	1225
	600			1725
	900			2250
	1500			2750
	2500			3245

CONTROL VALVE PACKING

PACKING MATERIAL SPECIFICATION

Temp. Range	Common use	Suitablity for Oxygen /Oxidizing Service	Packing material	Description	Stem friction	Special consideration
-73 to 232C	Non-Radioactive	Yes	PTFE impregented composition	Split rings of braided composition impregented with PTFE	Low	-
-40 to 232C	All chemicals (Except Molten alkali) Non radioactive	No	single PTFE V - Ring	Solid rings of molded PTFE	Low	Required 2 to 4 micro inch RMS valve plug stem finish
	Vacuum Pressure / Vacuum	No	Double PTFE V - Ring	Solid rings of molded PTFE	Low	
-84 to 232C	Vacuum, All chemicals (Except molten alkali)	Yes	Chesterton 324	Split rings of braided, preshrunk PTFE yarn impregented with PTFE; available with copper rings at top and bottom of packing box to meet UOP specification 6-14-0 for acid service.	Low	-
-18 to 538C	Water, Stem Petroleum products, Radiactive and Non-radiactive nuclear	Yes but upto 371C	Graphite/ Ribbon/Filament	Ribbon style graphite rings and rings of braided graphite fibers with sacrificial zinc washer	High	Low chloride content (less then 100ppm) chrome plated stem not necessary for high temperature service
371 to 649C	High temperature oxidizing service	Yes	Ribbon - Style graphite	Solid rings of ribbon-style graphite with sacrificial zinc washers	High	-

SHUTOFF CLASSES

SHUTOFF CLASSES

VALVE SEAT LEAKAGE

- In some process applications, it is important that the control valve be able to completely stop fluid flow when placed in the "closed" position.
- Many control valves spend most of their operating lives in a partially-open state, rarely opening or closing fully. Additionally, some control valve designs are notorious for the inability to completely shut off (e.g. double-ported globe valves).
- Given the common installation of manual "block" valves upstream and downstream of a control valve, there is usually a way to secure zero flow through a pipe even if a control valve is incapable of tight shut-off. For some applications, however, tight control valve shut-off is a mandatory requirement.
- A control valve's ability to shut off has to do with many factors as the type of valves for instance. A double seated control valve have very poor shut off capability. The guiding, seat material, actuator thrust, pressure drop, and the type of fluid can all play a part in how well a particular control valve shuts off.

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class I - Valve Leakage Classifications

Identical to Class II, III, and IV in construction and design intent, but no actual shop test is made. Class I is also known as dust tight and can refer to metal or resilient seated valves.

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class II - Valve Leakage Classifications

Intended for double port or balanced singe port valves with a metal piston ring seal and metal to metal seats.

0.5% leakage of full open valve capacity.

Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125 F.

Test medium air at 45 to 60 psig is the test fluid.

Typical constructions:

- Balanced, single port, single graphite piston ring, metal seat, low seat load
- Balanced, double port, metal seats, high seat load

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class III - Valve Leakage Classifications

Intended for the same types of valves as in Class II.

0.1% leakage of full open valve capacity.

Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125 oF.

Test medium air at 45 to 60 psig is the test fluid.

Typical constructions:

- Balanced, double port, soft seats, low seat load
- Balanced, single port, single graphite piston ring, lapped metal seats, medium seat load

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class IV - Valve Leakage Classifications

Intended for single port and balanced single port valves with extra tight piston seals and metal to-metal seats.

0.01% leakage of full open valve capacity.

Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125 oF.

Test medium air at 45 to 60 psig is the test fluid.

Typical constructions:

- Balanced, single port, Teflon piston ring, lapped metal seats, medium seat load
- Balanced, single port, multiple graphite piston rings, lapped metal seats
- Unbalanced, single port, lapped metal seats, medium seat load
- Class IV is also known as metal to metal

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class V - Valve Leakage Classifications

Intended for the same types of valves as Class IV.

The test fluid is water at 100 psig or operating pressure.

Leakage allowed is limited to 5 x 10 ml per minute per inch of orifice diameter per psi differential.

Service dP at 50 to 125 oF.

Typical constructions:

- Unbalanced, single port, lapped metal seats, high seat load
- Balanced, single port, Teflon piston rings, soft seats, low seat load
- Unbalanced, single port, soft metal seats, high seat load

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class VI - Valve Leakage Classifications

Class VI is known as a soft seat classification. Soft Seat Valves are those where the seat or shut-off disc or both are made from some kind of resilient material such as Teflon. Intended for resilient seating valves.

The test fluid is air or nitrogen.

Pressure is the lesser of 50 psig or operating pressure.

The leakage limit depends on valve size and ranges from 0.15 to 6.75 ml per minute for valve sizes 1 through 8 inches.

Typical constructions:

- Unbalanced, single port, soft seats, low load

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

- Class VI - Valve Leakage Classifications

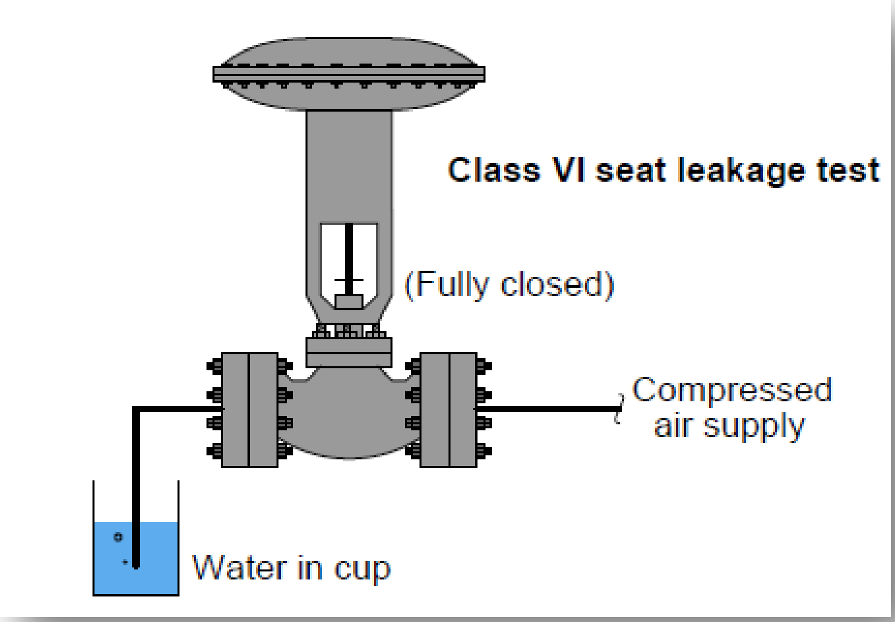
Port Diameter		Bubbles per minute	ml per minute
inches	Millimeters		
1	25	1	0.15
1 1/2	38	2	0.30
2	51	3	0.45
2 1/2	64	4	0.60
3	76	6	0.90
4	102	11	1.70
6	152	27	4.00
8	203	45	6.75
10	254	63	9
12	305	81	11.5

SHUTOFF CLASSES

VALVE LEAKAGE CLASSIFICATIONS

Class VI - Valve Leakage Classifications

- The "bubble test" used for Class VI seat leakage is based on the leakage rate of air or nitrogen gas past the closed valve seat as measured by counting the rate of gas bubbles escaping a bubble tube submerged under water.



- It is from this leakage test procedure that the term bubble-tight shut-of originates.

SHUTOFF CLASSES

Control Valve Leakage Classification - Overview

Leakage Class Designation	Maximum Leakage Allowable	Test Medium	Test Pressure	Testing Procedures Required for Establishing Rating
I	x	x	x	No test required
II	0.5% of rated capacity	Air or water at 50 - 125° F (10 - 52°C)	45 - 60 psig or maximum operating differential whichever is lower	45 - 60 psig or maximum operating differential whichever is lower
III	0.1% of rated capacity	As above	As above	As above
IV	0.01% of rated capacity	As above	As above	As above
V	0.0005 ml per minute of water per inch of port diameter per psi differential	Water at 50 to125°F (10 to 52°C)	Maximum service pressure drop across valve plug not to exceed ANSI body rating	Maximum service pressure drop across valve plug not to exceed ANSI body rating
VI	Not to exceed amounts shown in the table above	Air or nitrogen at 50 to 125° F (10 to 52°C)	50 psig or max rated differential pressure across valve plug whichever is lower	Actuator should be adjusted to operating conditions specified with full normal closing thrust applied to valve plug seat

CONTROL VALVE ACTUATORS

CONTROL VALVE ACTUATORS

ACTUATORS

These are the main types of actuator:

Manual

Pneumatic

Electric motor

Hydraulic

Self-actuated

CONTROL VALVE ACTUATORS

PNEUMATIC ACTUATORS

They are basically of two types

1. Diaphragm actuator
2. Piston actuator

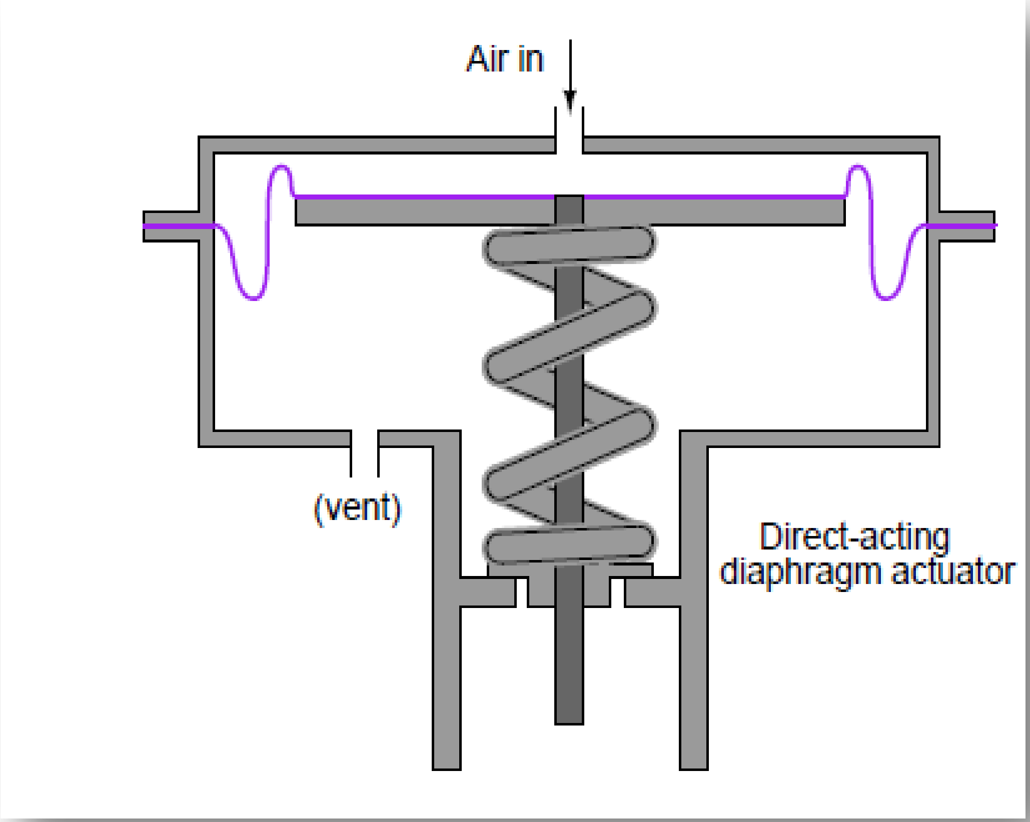
These actuators are designed so that with a specific change of air pressure, the spindle will move sufficiently to move the valve through its complete stroke from fully-closed to fully-open.

CONTROL VALVE ACTUATORS

DIAPHRAGM ACTUATORS

They have compressed air applied to a flexible membrane called the diaphragm.

They are single acting i.e. air is supplied from single side of the diaphragm.



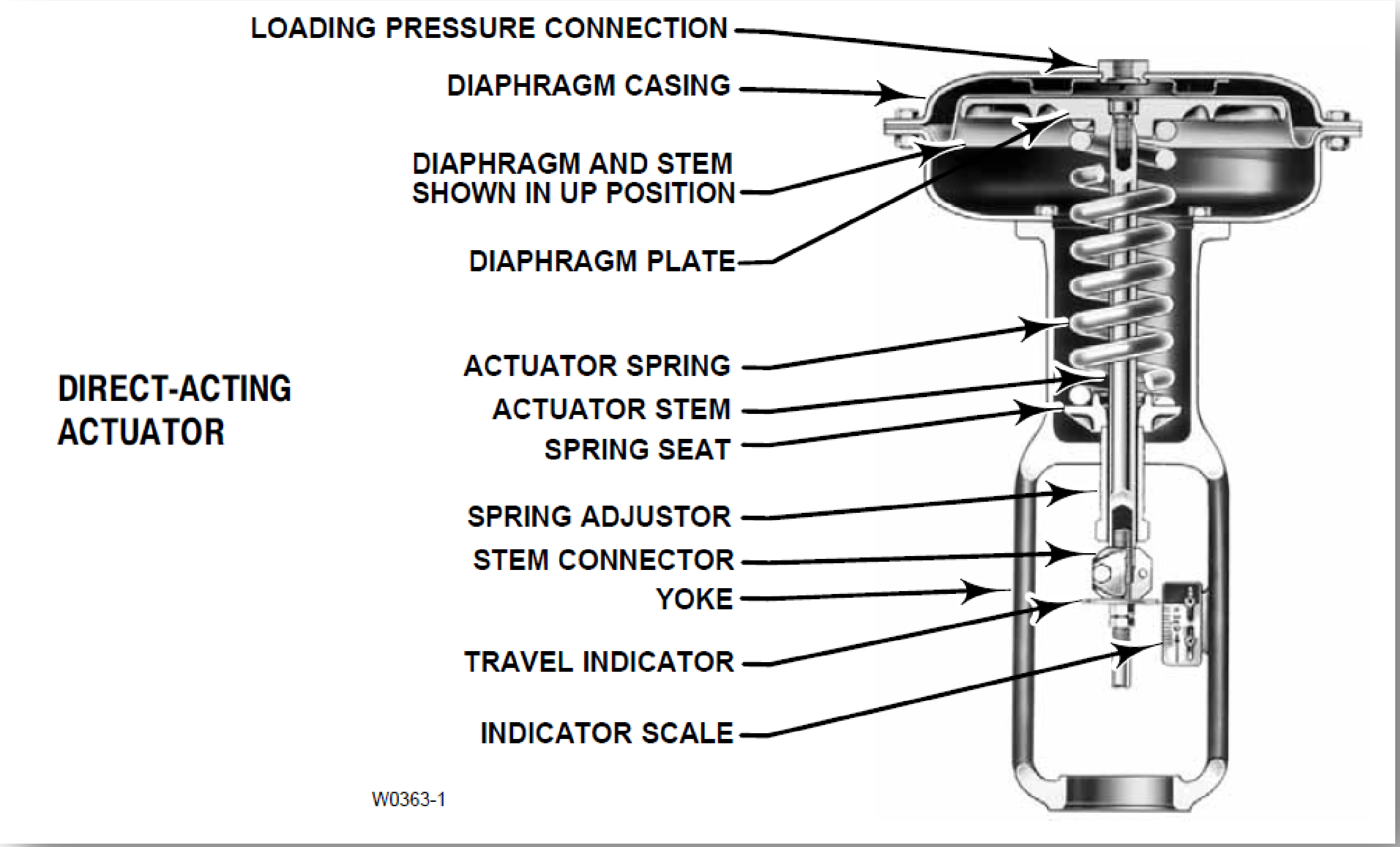
CONTROL VALVE ACTUATORS

WHAT IS THE FORCE REQUIRED TO ACT ON THE DIAPHRAGM ?

The amount of force (F) in units of pounds generated by any fluid pressing against any surface is equal to the fluid's pressure (P) in units of PSI multiplied by the surface area (A) in units of square inches (F = PA). In the case of a circular diaphragm, with area equal to πr2, the complete formula for force is F = Pπr2. For example, a control valve diaphragm 14 inches in diameter (radius = 7 inches) with an applied air pressure of 15 PSI generates a linear force of 2309 pounds.

CONTROL VALVE ACTUATORS

DIAPHRAGM ACTUATORS ASSEMBLY



CONTROL VALVE ACTUATORS

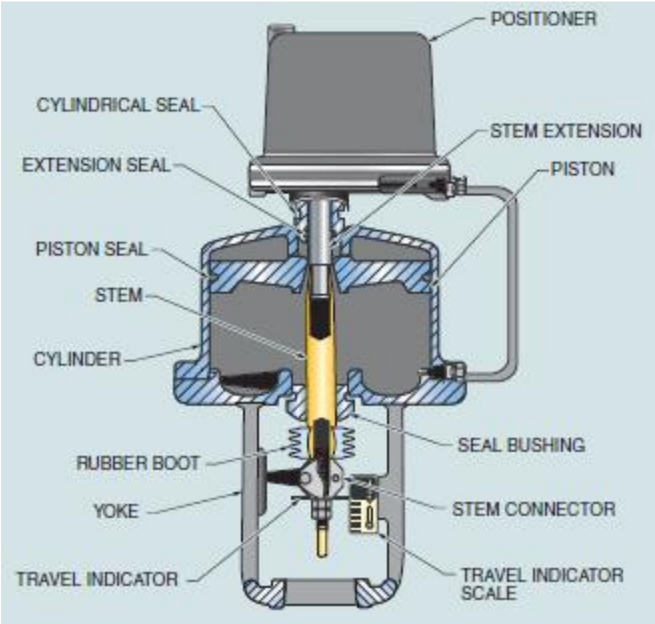
PISTON ACTUATORS

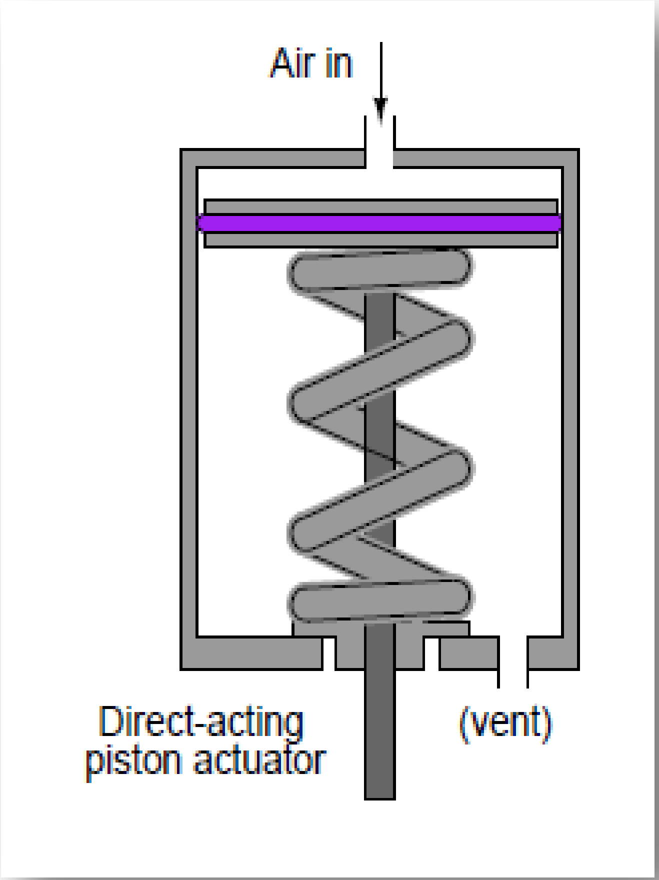
Pneumatic actuators may take the form of pistons rather than diaphragms.

They can withstand higher input pressures.

Can offer small cylinder volumes.

Can be Single Acting or Double Acting





CONTROL VALVE ACTUATORS

HOW CAN MORE PRESSURE ENHANCE FORCE GENERATED ?!

Piston actuators generally have longer stroke lengths than diaphragm actuators, and are able to operate on much greater air pressures. Since actuator force is a function of fluid pressure and actuator area (F = PA), this means piston actuators are able to generate more force than diaphragm actuators of the same diameter. A 14 inch diaphragm operating at a maximum pressure of 35 PSI generates 5388 pounds of force, but the same size piston operating at a maximum pressure of 150 PSI generates 23091 pounds of force.

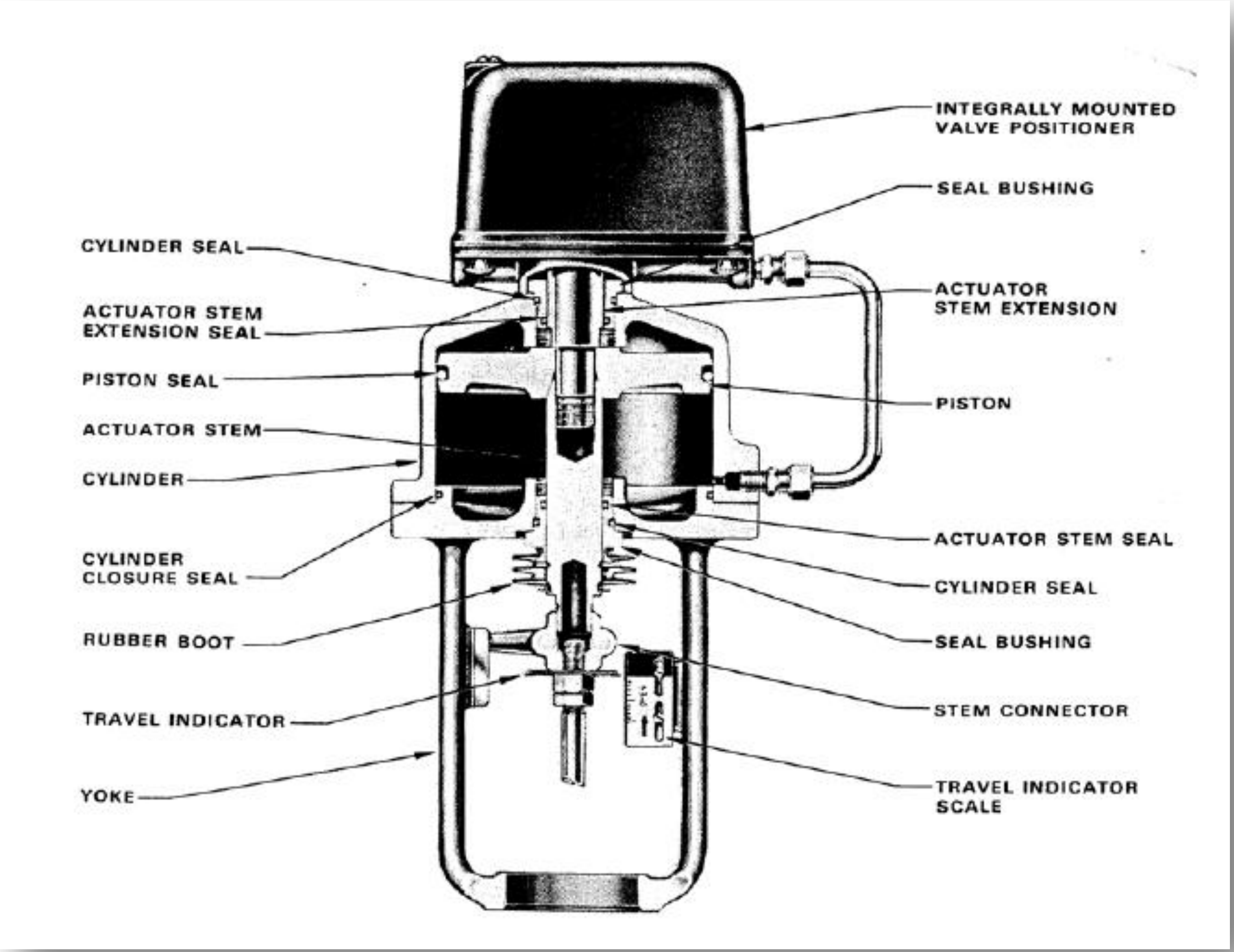
CONTROL VALVE ACTUATORS

WHY PISTON ACTUATORS CAN BEAR MORE PRESSURE ?!

The greater pressure rating of a piston actuator comes from the fact that the only "soft" component (the sealing ring) has far less surface area exposed to the high pressure than a rolling diaphragm. This results in significantly less stress on the elastic ring than there would be on an elastic diaphragm exposed to the same pressure. There really is no limit to the stroke length of a piston actuator as there is with the stroke length of a diaphragm actuator. It is possible to build a piston actuator miles long, but such a feat would be impossible for a diaphragm actuator, where the diaphragm must stretch (or roll) the entire stroke length.

CONTROL VALVE ACTUATORS

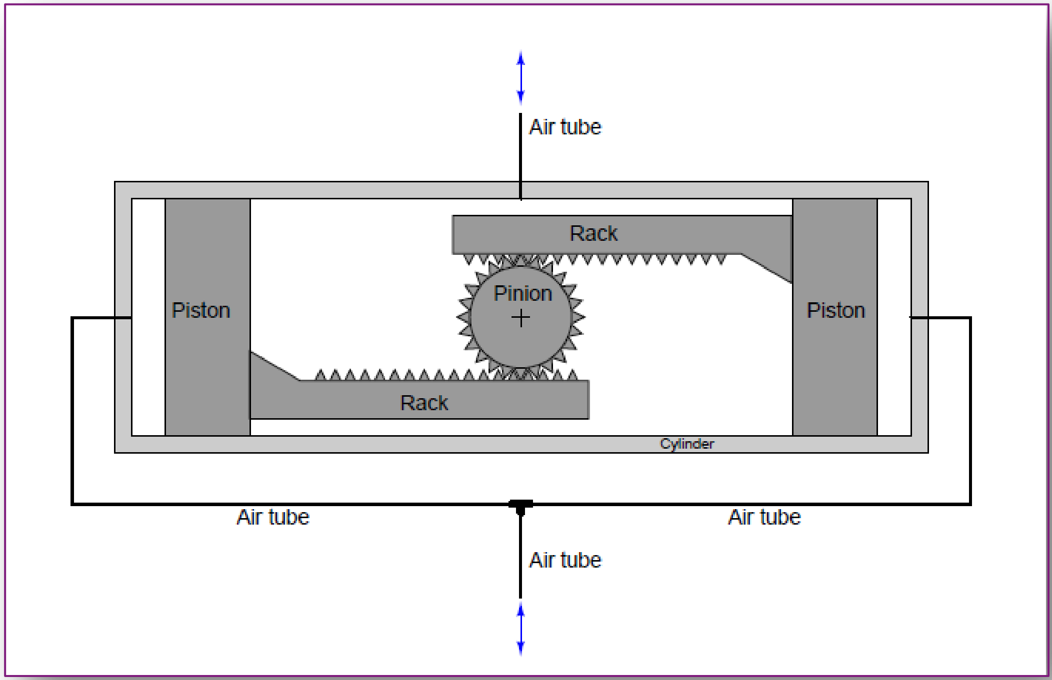
DOUBLE ACTING PISTON

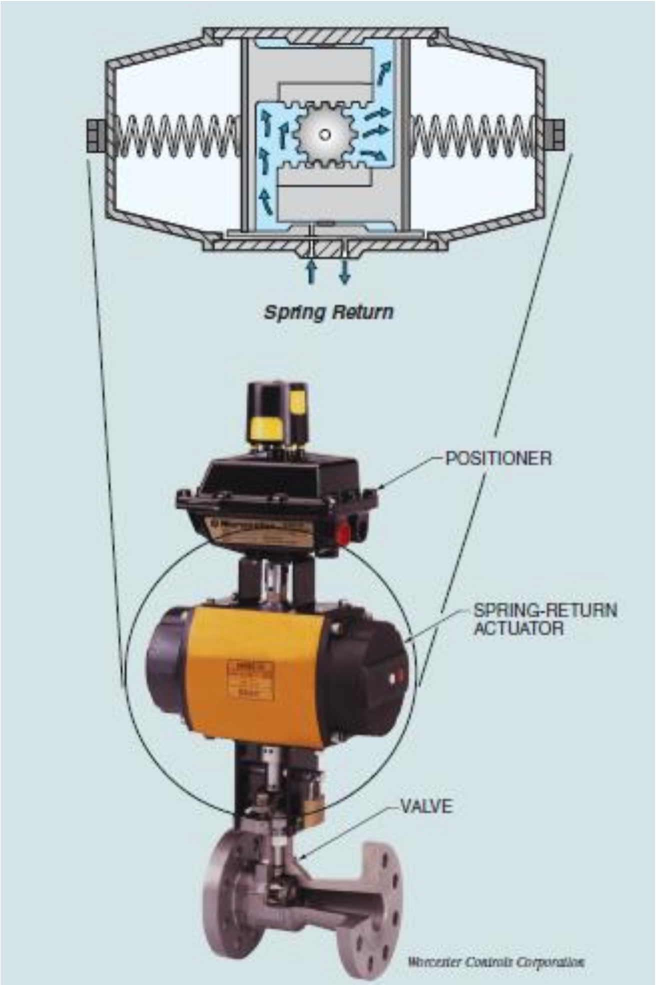


CONTROL VALVE ACTUATORS

Rotating Actuators (RACK-AND PINION MECHANISM)

A pair of pneumatically-actuated pistons move a rack and pinion mechanism to convert linear piston motion into rotary shaft motion to move the butterfly trim.





CONTROL VALVE ACTUATORS

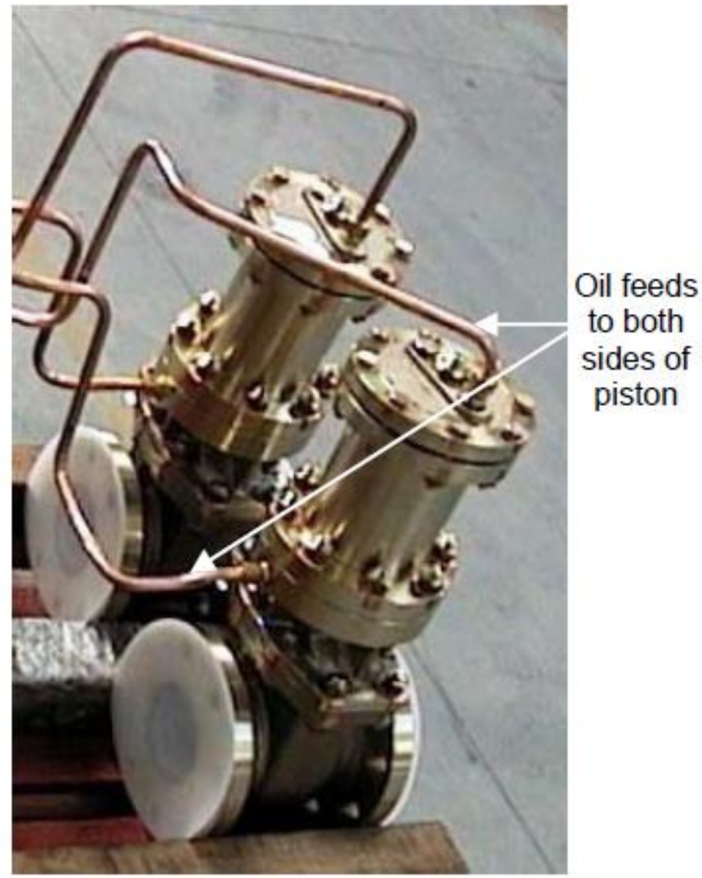
HYDRAULIC ACTUATORS

Hydraulic actuators use liquid pressure rather than gas pressure to move the valve mechanism. Nearly all hydraulic actuator designs use a piston rather than a diaphragm to convert fluid pressure into mechanical force. The high pressure rating of piston actuators lends itself well to typical hydraulic system pressures, and the lubricating nature of hydraulic oil helps to overcome the characteristic friction of piston-type actuators. Given the high pressure ratings of most hydraulic pistons, it is possible to generate tremendous actuating forces with a hydraulic actuator, even if the piston area is modest.

CONTROL VALVE ACTUATORS

Examples

(a) Single-acting Spring Return Hydraulic Actuator



(b) Double-acting Hydraulic Actuators

CONTROL VALVE ACTUATORS

TECHNICAL NOTES ABOUT HYDRAULIC ACTUATORS

They exhibit very stable positioning owing to the non-compressibility of hydraulic oil. Unlike pneumatic actuators, where the actuating fluid (air) is "elastic," the oil inside a hydraulic actuator cylinder does not yield appreciably under stress. If the passage of oil to and from a hydraulic cylinder is blocked by small valves, the actuator will become firmly "locked" into place. This is an important feature for certain valve-positioning applications where the actuator must firmly hold the valve position in one position.

Some hydraulic actuators contain their own electrically-controlled pumps to provide the fluid power, so the valve is actually controlled by an electric signal. Other hydraulic actuators rely on a separate fluid power system (pump, reservoir, cooler, hand or solenoid valves, etc.) to provide hydraulic pressure on which to operate.

CONTROL VALVE ACTUATORS

Hydraulic pressure supply systems, however, tend to be more limited in physical span than pneumatic distribution systems due to the need for thick-walled tubing (to contain the high oil pressure), the need to purge the system of all gas bubbles and the problem of maintaining a leak-free distribution network.

Another disadvantage of hydraulic systems compared to pneumatic is lack of intrinsic power storage. Compressed air systems, by virtue of air's compressibility (elasticity), naturally store energy in any pressurized volumes, and so provide a certain degree of "reserve" power in the event that the main compressor shut down. Hydraulic systems do not naturally exhibit this desirable trait.

CONTROL VALVE ACTUATORS

PRACTICAL ASSEMBLY

A hydraulic piston actuator attached to a large shut-off valve (used for on/off control rather than throttling). Two hydraulic cylinders may be seen above the round valve body, mounted horizontally. Like the pneumatic piston valve shown earlier, this valve actuator uses a rack-and-pinion mechanism to convert the hydraulic pistons' linear motion into rotary motion to turn the valve trim

CONTROL VALVE ACTUATORS

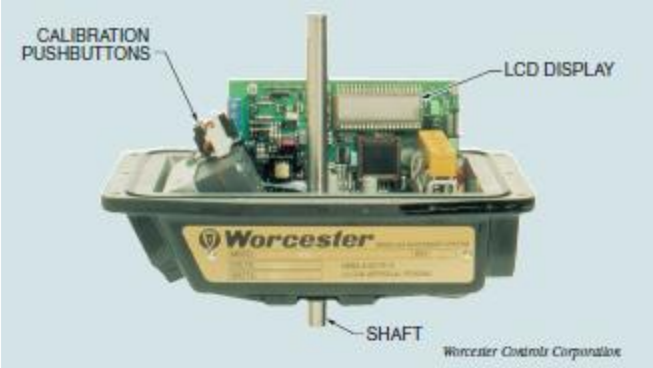
Electric Actuators (MOV)

Electric operators with proportional or infinite positioning control have limited use in the process industries. Their primary use has been in remote areas, such as tank farms and pipeline stations, where no convenient air supply is available. Slow operating speeds, maintenance problems in hazardous areas and economics have prevented wide acceptance for throttling applications.

Electric motors have long been used to actuate large valves, especially valves operated as on/off ("shutoff") devices. Advances in motor design and motor control circuitry have brought motor operated valve (MOV) technology to the point where it now competes with legacy actuator technologies such as pneumatic in actuating throttling valves as well.

CONTROL VALVE ACTUATORS

An electric actuator providing on/off rotary actuation to a ball valve. This particular electric actuator comes with a hand crank for manual operation, in the event that the electric motor (or the power provided to it) fails



CONTROL VALVE ACTUATORS

Electric motors require no external fluid power system to function, unlike pneumatic or hydraulic actuators. All they require is a source of electrical power (often 480 volts AC, three-phase). Some electric valve actuators even have the capability of operating from the power of an electric battery pack, for reliable operation in the event of a power system outage. Virtually all electric valve actuators require some form of feedback to indicate the valve's position.

At minimum, this consists of limit switches to indicate when the valve is fully shut and fully open. For throttling services, an electric actuator requires an actual valve position sensor so that it may precisely adjust the valve to any desired state. This sensor may take the form of a potentiometer, or a variable differential transformer (LVDT or RVDT)

CONTROL VALVE ACTUATORS

Hand Actuators

The most common manual actuators are:

Hand wheel—for linear motion valves: gate valves, globe valves.

lever—for rotational motion valves: ball valves, butterfly valves.

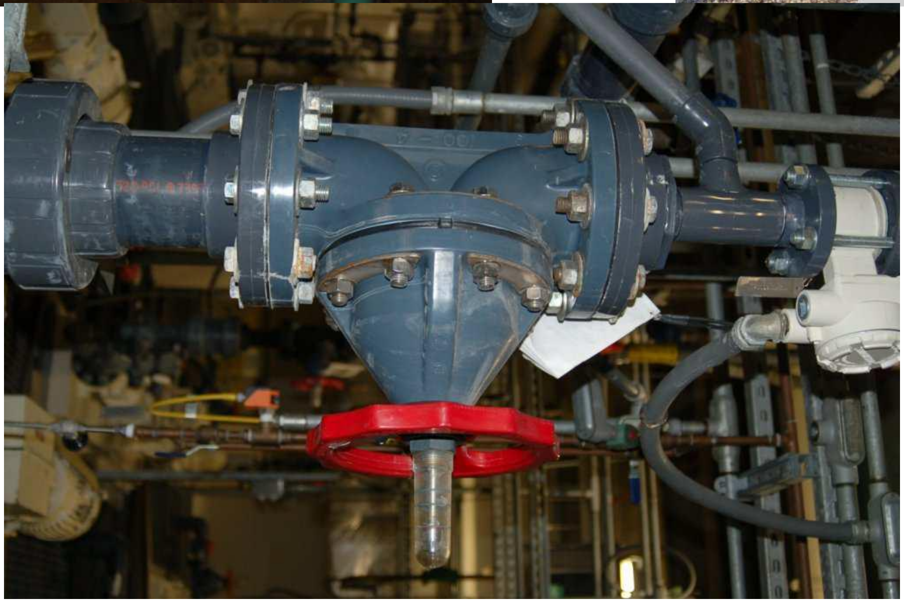
It can be operate normally with all type of valves

(a) Handwheel-actuated Gate Valve

(b) Lever-actuated Ball Valve

CONTROL VALVE ACTUATORS

Some examples for manual actuator



CONTROL VALVE ACTUATORS

Self Actuated Valves

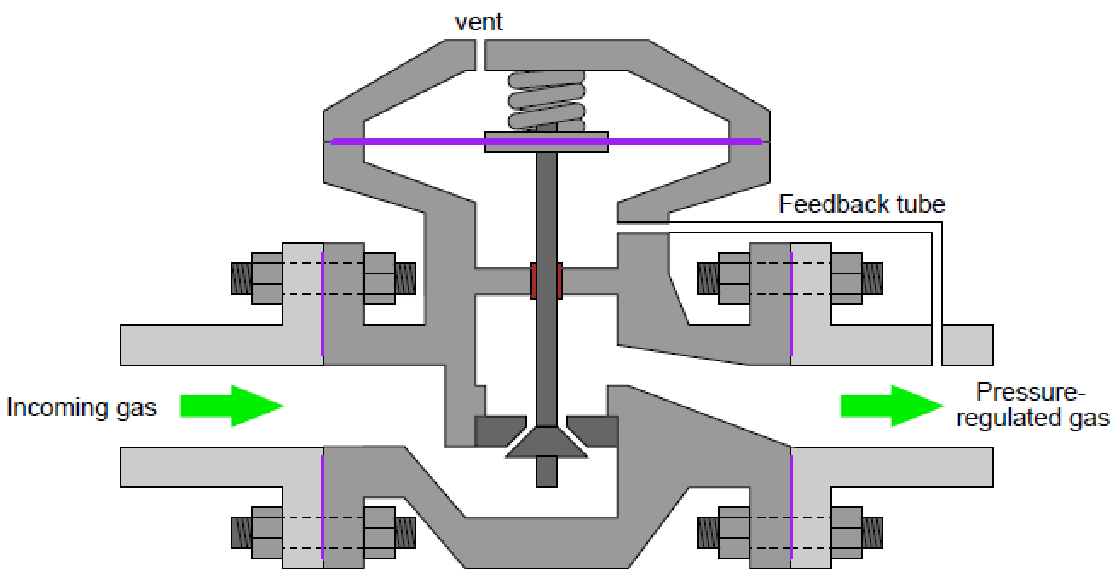
Although not a type of actuator itself, a form of actuation worthy of mention is where the process fluid pressure itself actuates a valve mechanism. This self-operating principle may be used in throttling applications or on/off applications, in gas or liquid services alike. The process fluid may be directly tubed to the actuating element (diaphragm or piston), or passed through a small mechanism called a pilot to modulate that pressure before reaching the valve actuator. This latter design allows the main valve's motion to be controlled by an adjustable device (the pilot).

CONTROL VALVE ACTUATORS

Self-operated, spring-loaded gas pressure regulating valve

A spring tries to force the plug off the seat, while "feedback" gas pressure from the downstream side of the valve acts against a flexible diaphragm to move the plug toward the seat.

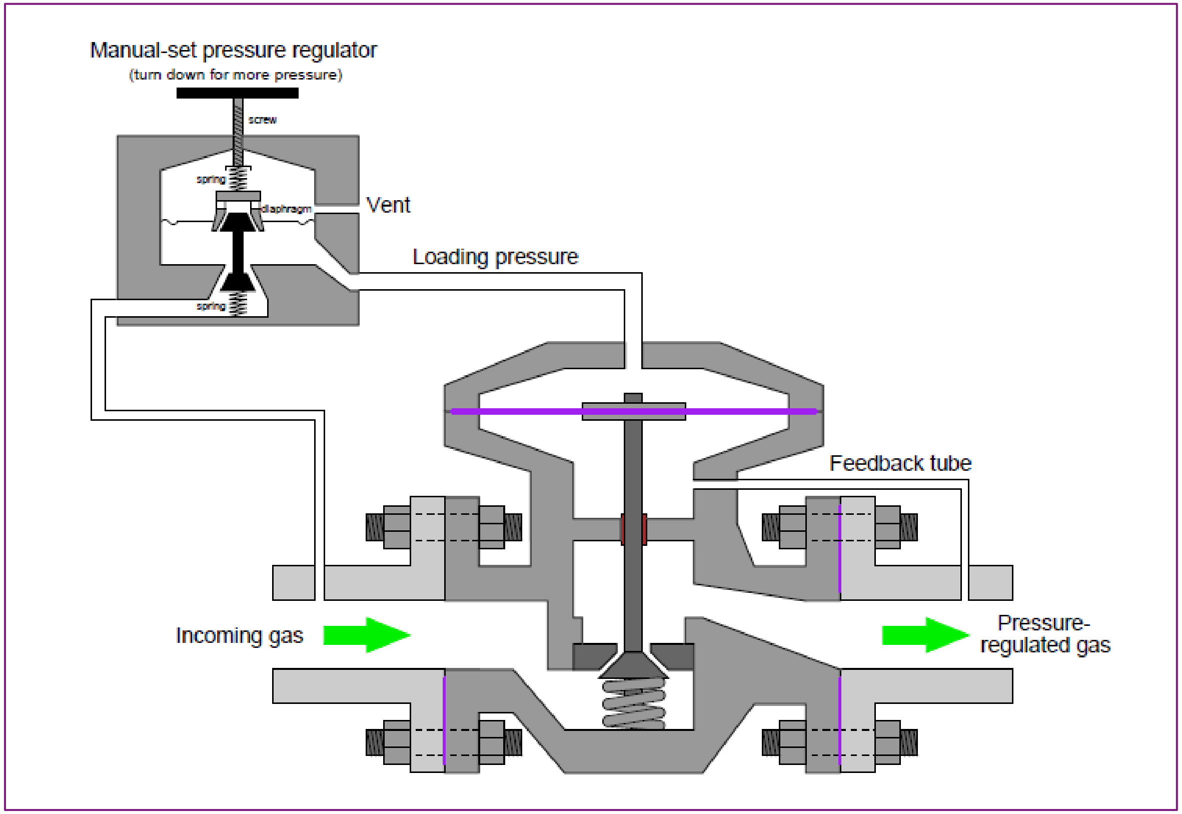
The less downstream pressure, the more the trim opens up; the more downstream pressure, the more the trim shuts off. This spring establishes the pressure-regulating "setpoint" value for the regulator.



CONTROL VALVE ACTUATORS

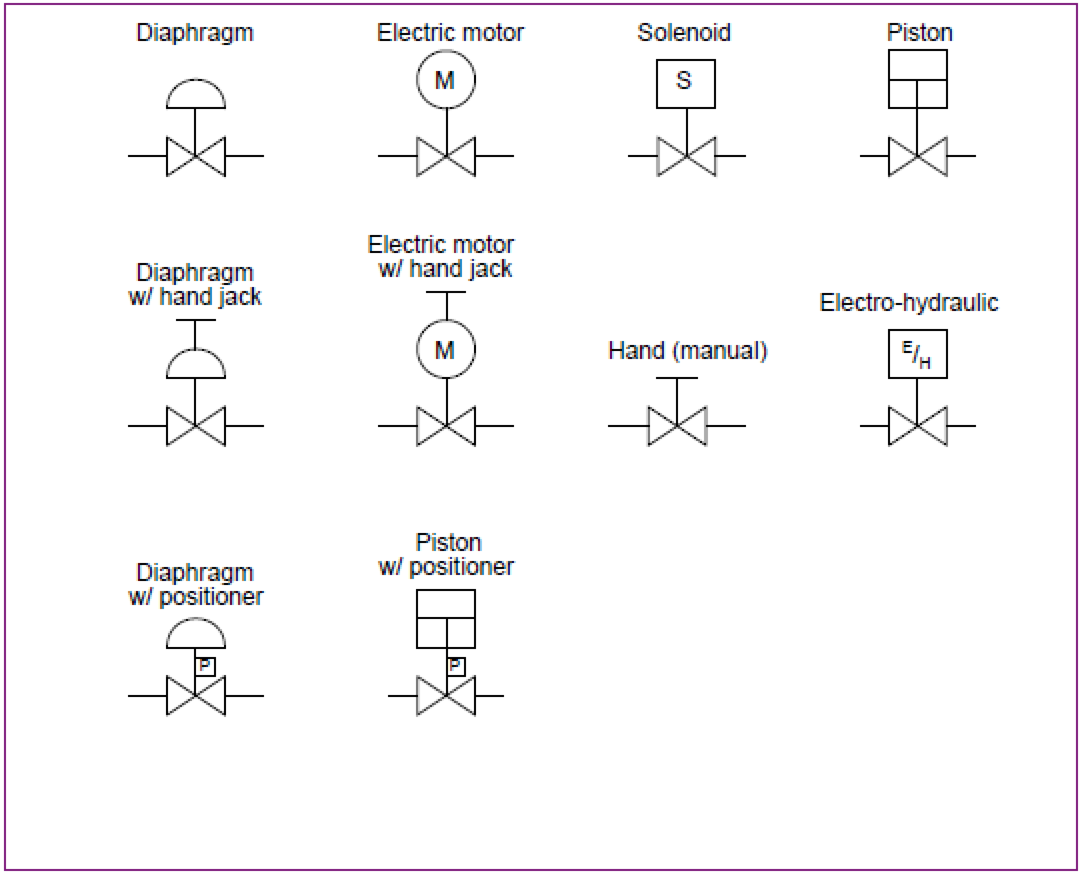
Pilot-loaded or externally-loaded pressure regulator

Externally supplied loading pressure does that. Since this loading pressure is easily adjusted by turning the knob on the manual-set pressure regulator, the main regulator now becomes adjustable as well. The pilot mechanism controls the main gas throttling mechanism, hence the name pilot.



CONTROL VALVE ACTUATORS

Actuator types symbols



VALVE FAILURE MODES

VALVE FAILURE MODES

What is the meaning Failure ?!

By failure we mean the loss of the source of the actuating power supplied to the valve body .

For electrically actuated valves, this is typically the last position the valve was in before loss of electric power.

For pneumatic and hydraulic actuated valves, the option exists of having a large spring provide a known “fail-safe” position (either open or closed) in the event of fluid pressure (pneumatic air pressure or hydraulic oil pressure) loss.

VALVE FAILURE MODES

Direct/Reverse actions

The fail-safe mode of a pneumatic/spring valve is a function of both the actuator's action and the valve body's action.

For sliding-stem valves

1st Actuator :

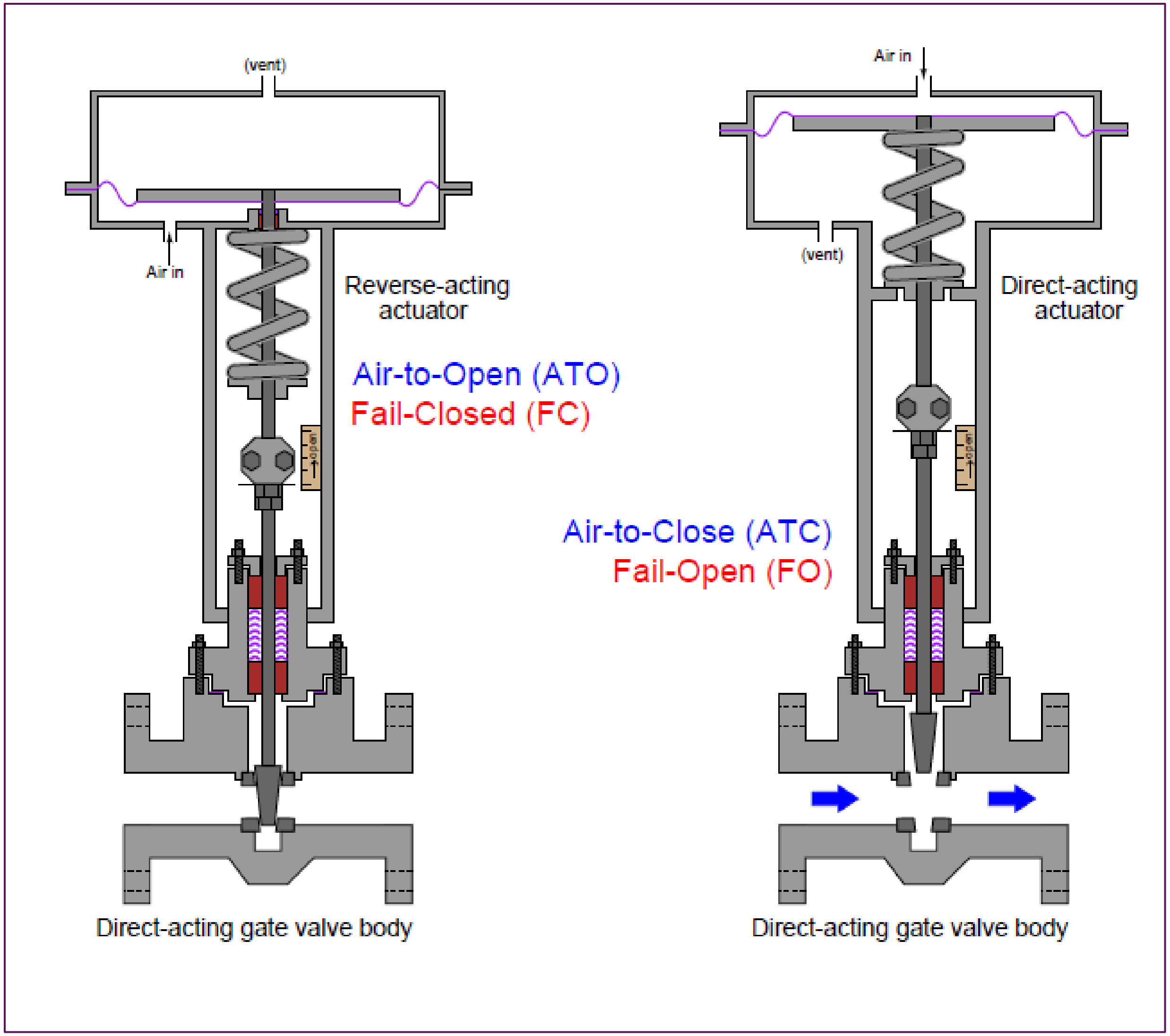
A direct-acting actuator pushes down on the stem with increasing pressure while a reverse-acting actuator pulls up on the stem with increasing pressure.

2nd Valve Body

Sliding-stem valve bodies are classified as direct-acting if they open up when the stem is lifted, and classified as reverse-acting if they shut off (close) when the stem is lifted.

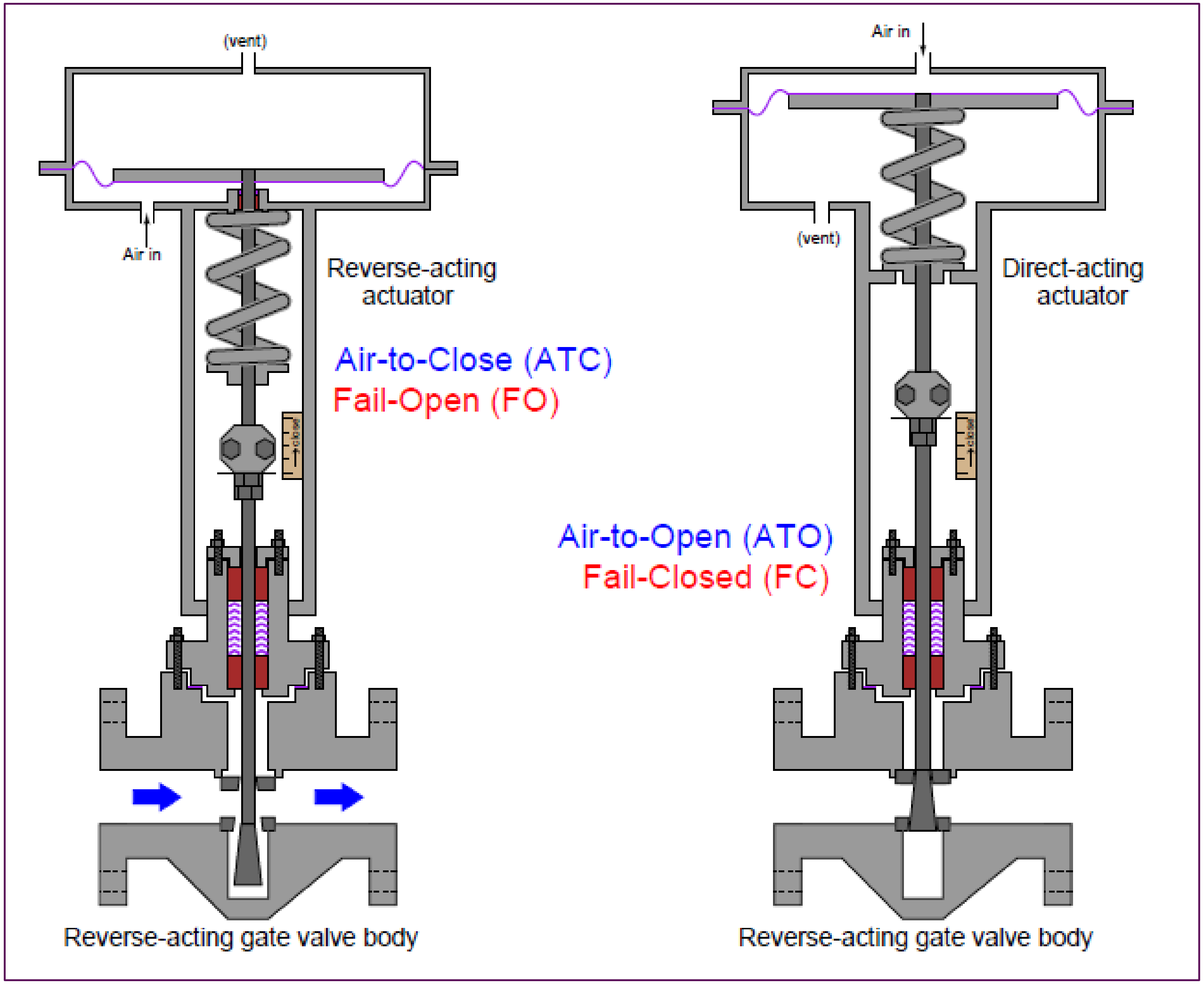
VALVE FAILURE MODES

Direct Body



VALVE FAILURE MODES

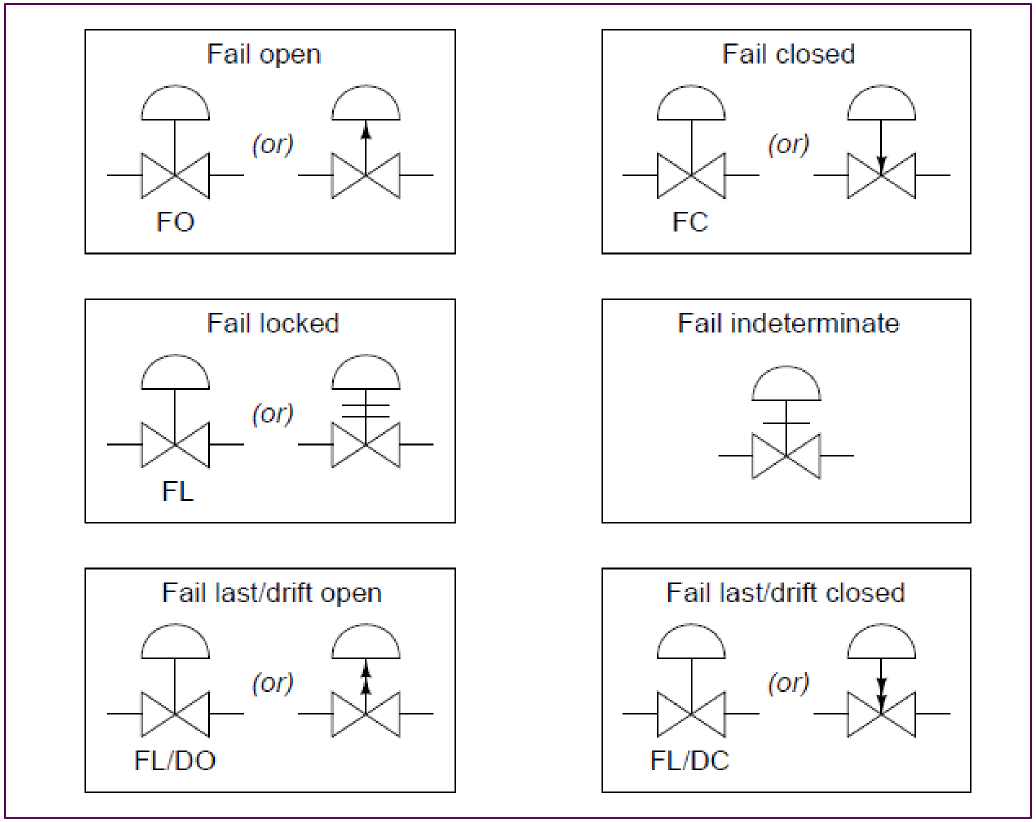
Reverse Body



VALVE FAILURE MODES

Failure modes Symbols

Valve fail mode may be shown in instrument diagrams by either an arrow pointing in the direction of failure (assuming a direct-acting valve body where stem motion toward the body closes and stem motion away from the body opens the valve trim) and/or the abbreviations "FC" (fail closed) and "FO" (fail open).

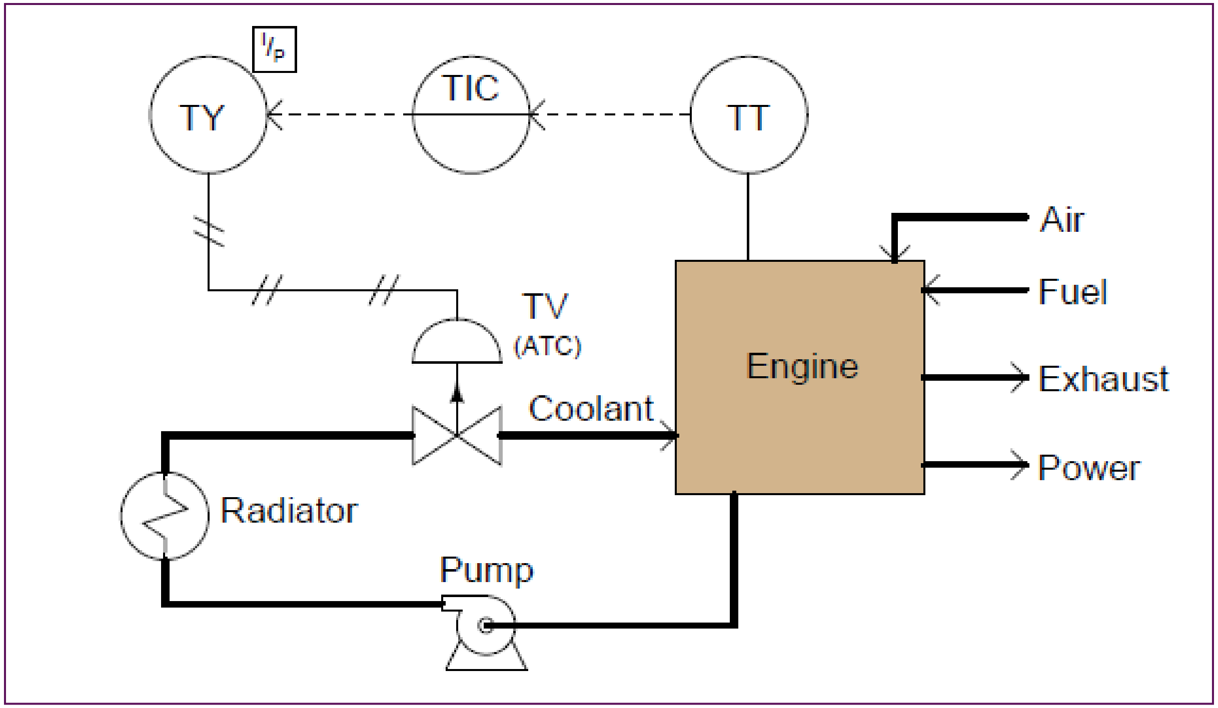


VALVE FAILURE MODES

How to select failure mode for a control valve

In fact, this basic principle forms the basis of decisions made for all instrument actions in critical control loops: first determine the safest mode of valve failure, then select and/or configure instrument actions in such a way that the most probable modes of signal path failure will result in the control valve consistently moving to that (safest) position.

Practical Example



ACTUATOR BENCH-SET

ACTUATOR BENCH-SET

Valve actuators provide force to move control valve trim. For precise positioning of a control valve, there must be a calibrated relationship between applied force and valve position. Most pneumatic actuators exploit Hooke's Law to translate applied air pressure to valve stem position.

$$F = kx$$

Where,

F = Force applied to spring in newtons (metric) or pounds (British)

k = Constant of elasticity, or "spring constant" in newtons per meter (metric) or pounds perfoot (British)

x = Displacement of spring in meters (metric) or feet (British)

ACTUATOR BENCH-SET

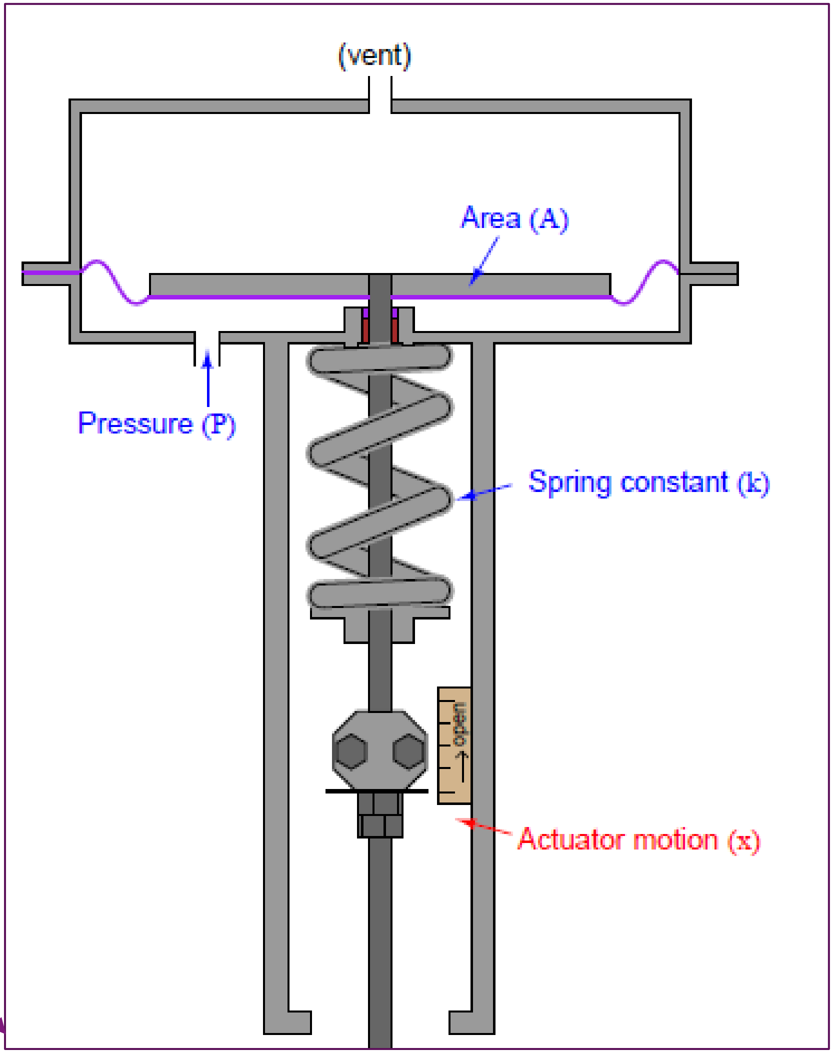
Hooke's Law is a linear function, which means that spring motion will be linearly related to applied force from the actuator element (piston or diaphragm). Since the working area of a piston or diaphragm is constant, the relationship between actuating fluid pressure and force will be a simple proportion ($F = PA$). By algebraic substitution, we may alter Hooke's Law to include pressure and area:

$$F = kx$$
$$PA = kx$$

ACTUATOR BENCH-SET

Bench-Set Adjust

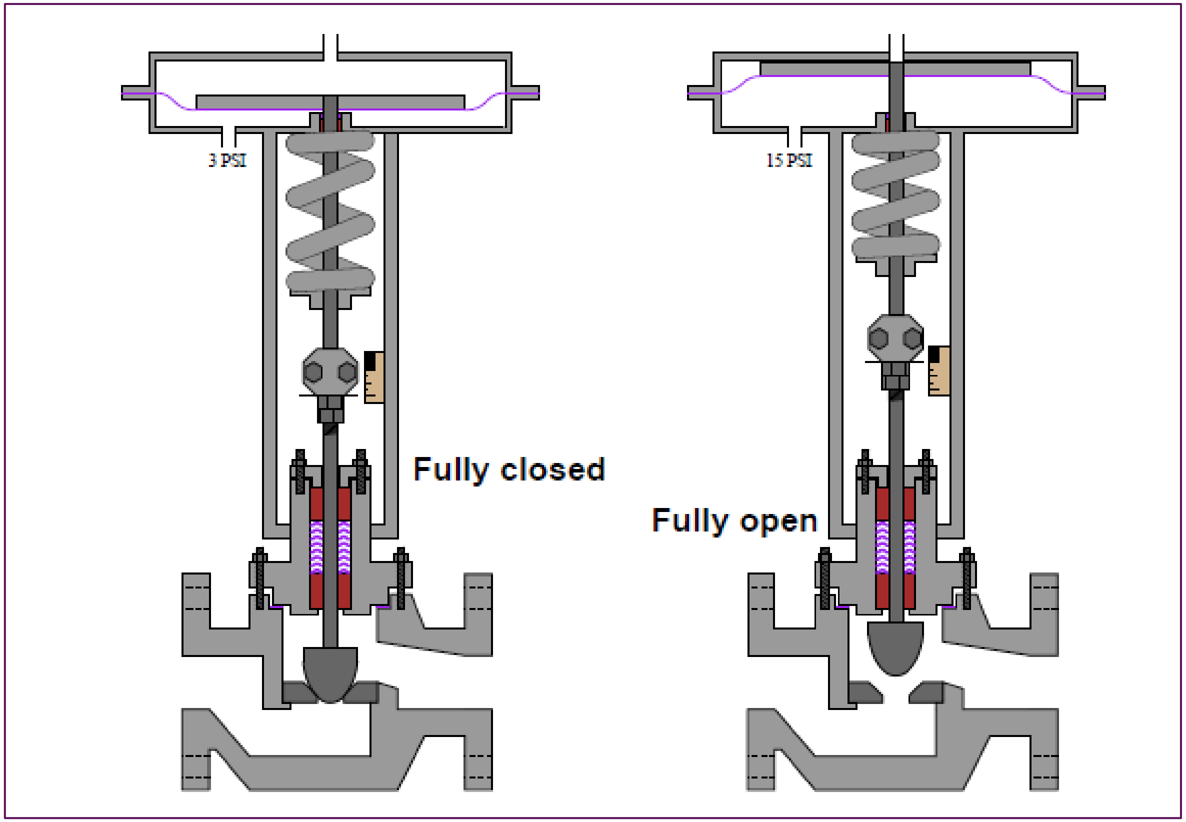
$$x = \frac{PA}{k}$$



ACTUATOR BENCH-SET

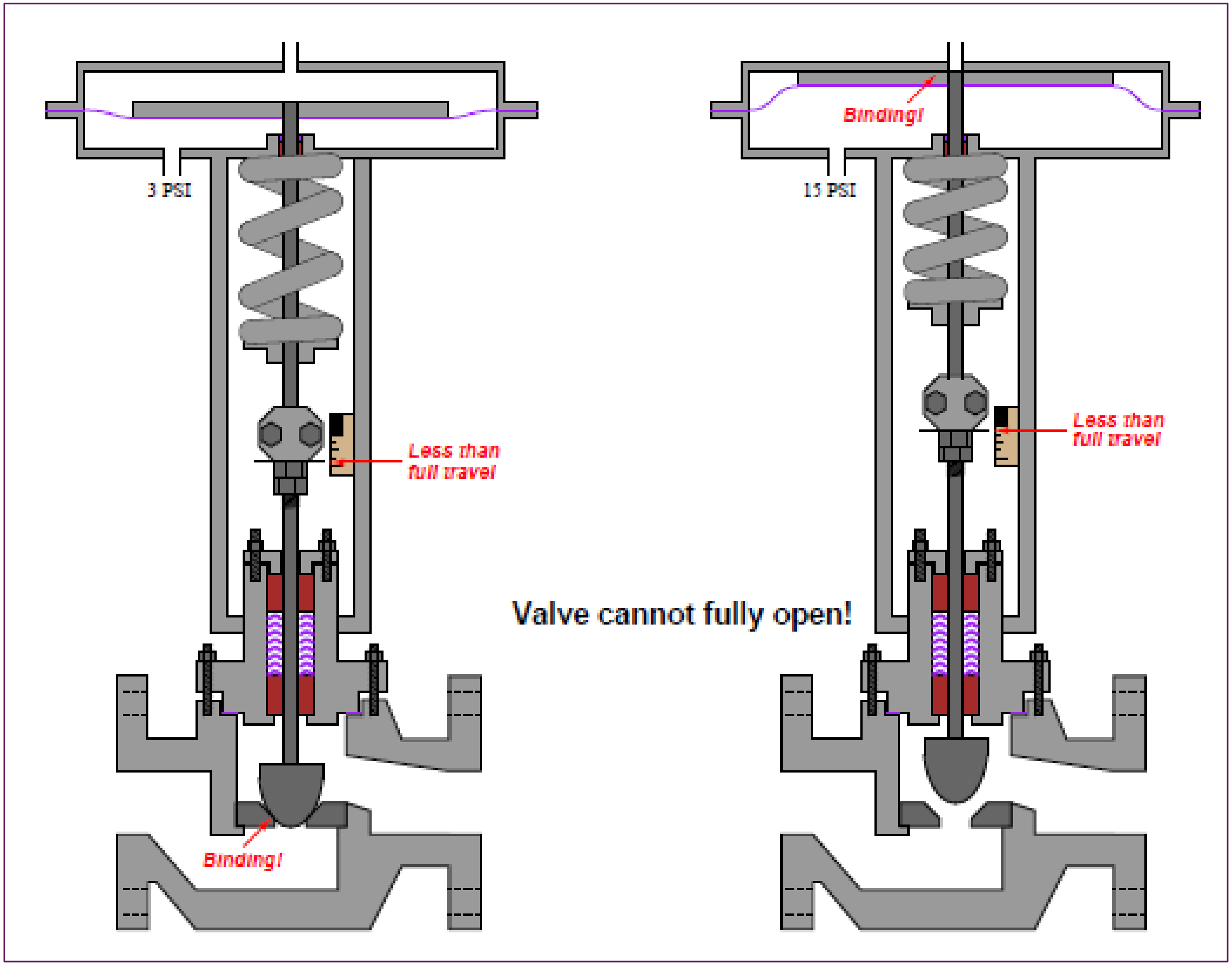
Bench-Set Adjust

There are really only two mechanical adjustments that need to be made when coupling a pneumatic diaphragm actuator to a sliding-stem valve: the stem connector and the spring adjuster.



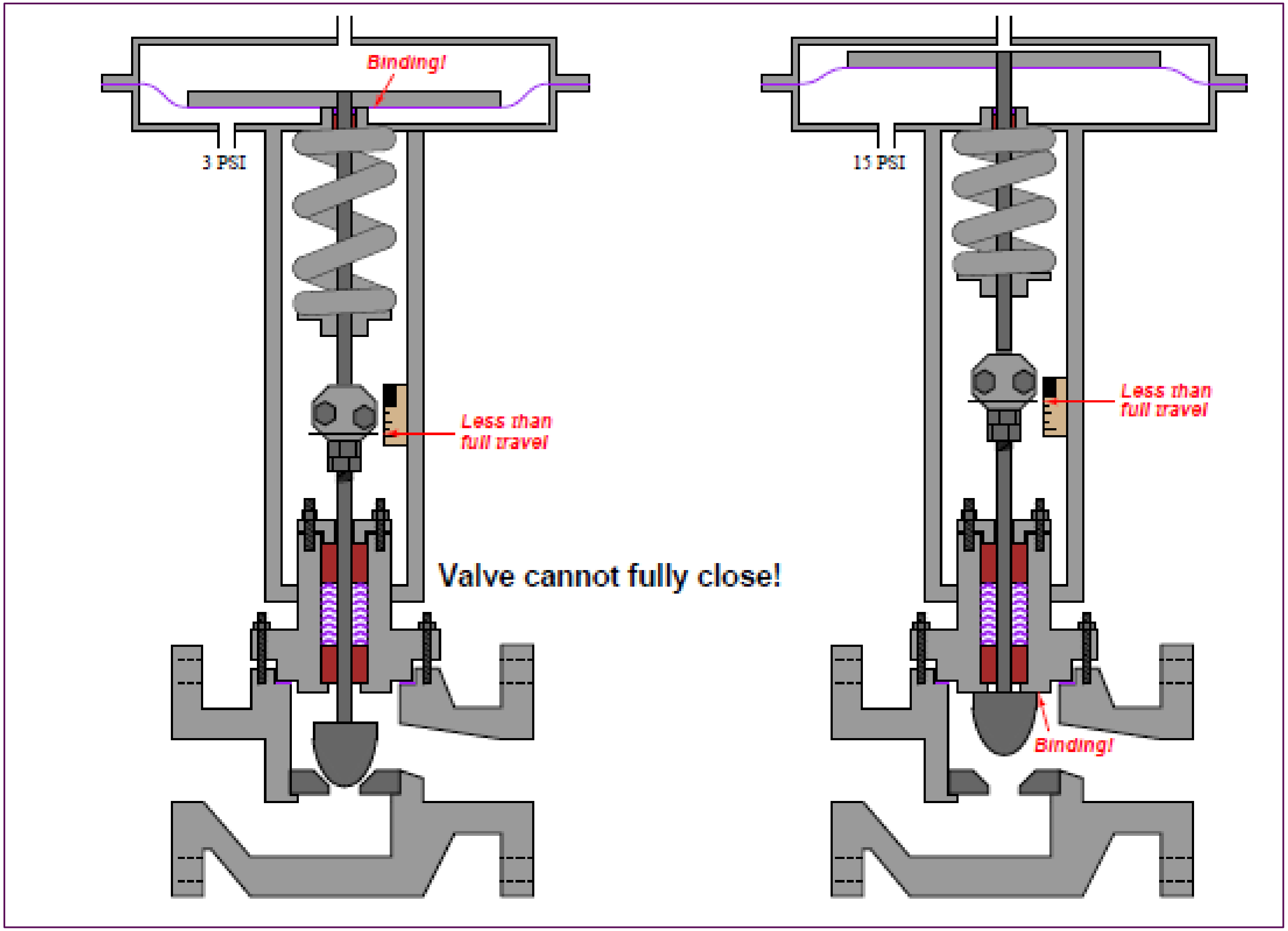
ACTUATOR BENCH-SET

Case 1



ACTUATOR BENCH-SET

Case 2



ACTUATOR BENCH-SET

Summary

Once the stem length has been properly set by adjusting the stem connector, the spring adjuster must be set for the proper bench set pressure. This is the pneumatic signal pressure required to lift the plug off the seat. For an air-to-open control valve with a 3 to 15 PSI signal range, the "bench set" pressure would be 3 PSI.

Bench set is a very important parameter for a control valve because it establishes the seating force of the plug against the seat when the valve is fully closed. Proper seating pressure is critical for tight shut-off, which carries safety implications in some process services.

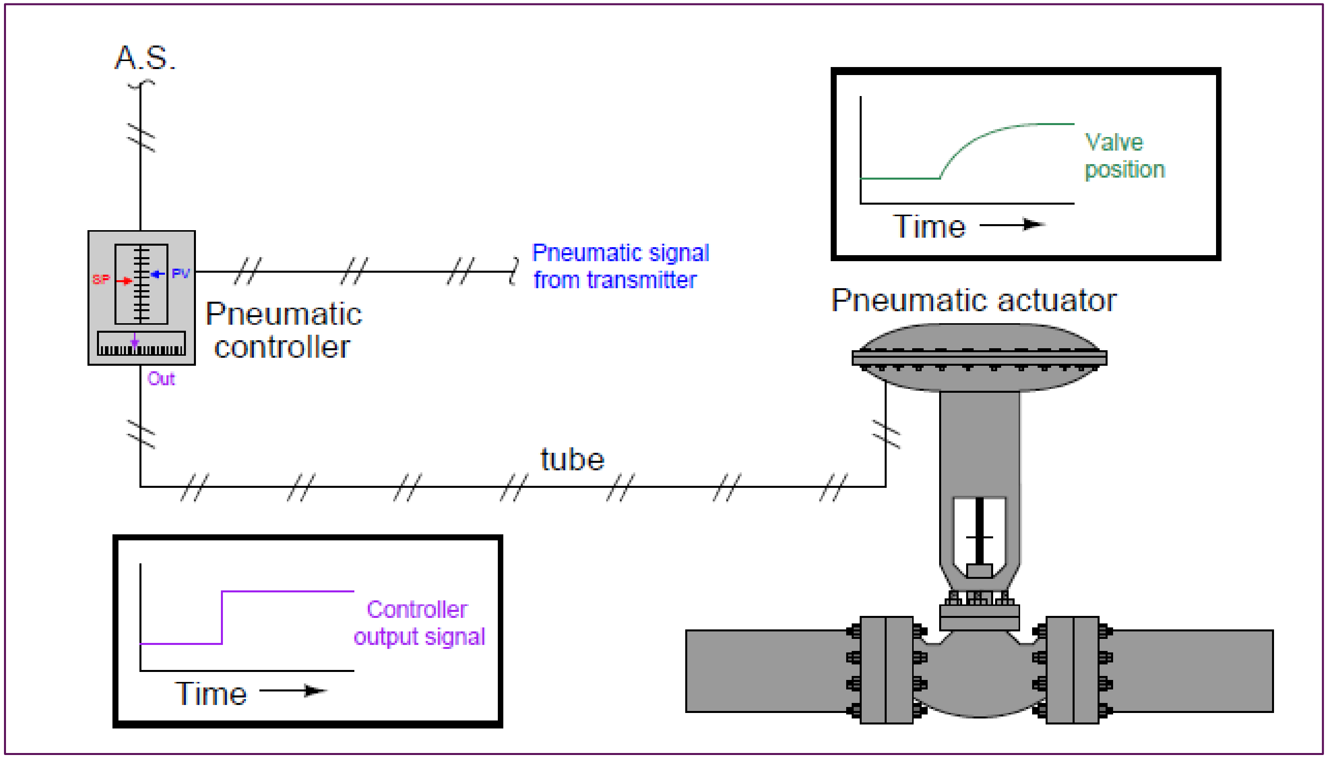
ACTUATOR RESPONSE

ACTUATOR RESPONSE

Actuator response problem

A limitation inherent to pneumatic valve actuators is the amount of air flow required to or from the actuator to cause rapid valve motion. This is an especially acute problem in all-pneumatic control systems, where the distance separating a control valve from the controller may be large.

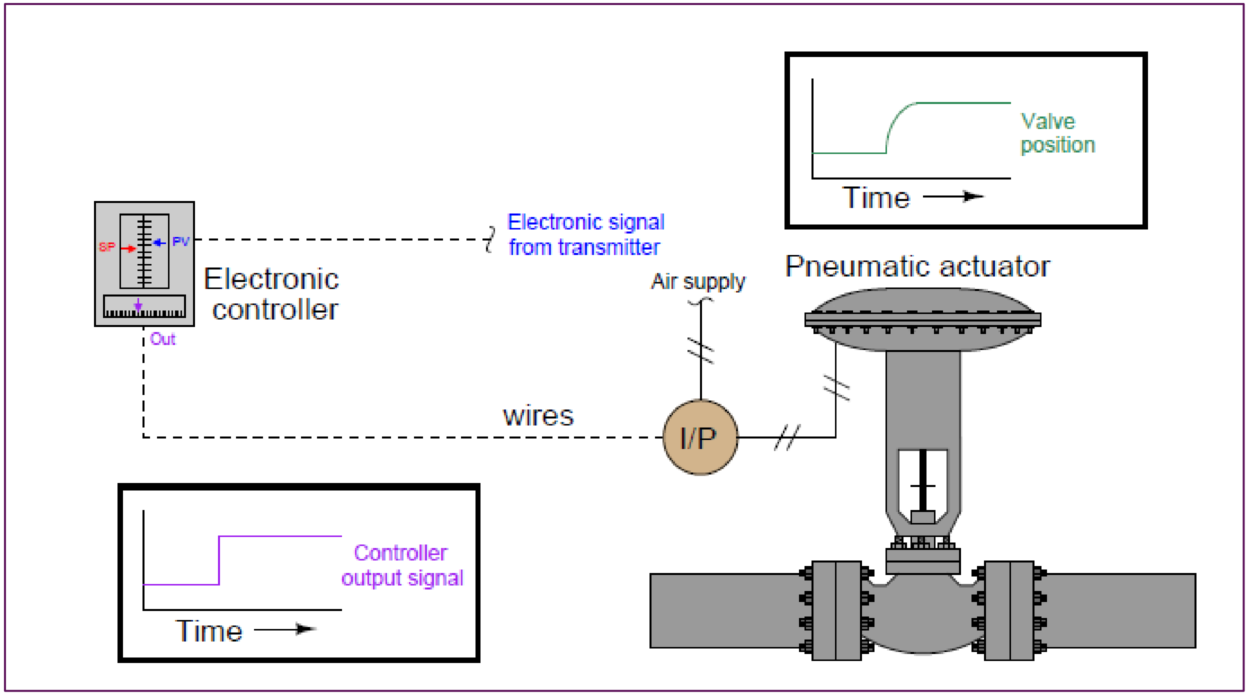
This was serious problem in pneumatic control systems .



ACTUATOR RESPONSE

1st Using I/P transducer

If the pneumatic valve actuator is driven by an I/P transducer instead of directly by a pneumatic controller, the problem is lessened by the ability to locate the I/P close to the actuator, thus greatly minimizing tube friction and thus minimizing the "time constant" (τ) of the control valve's response if the pneumatic actuator is particularly large in volume, an I/P transducer may experience trouble supplying the necessary air flow rate to rapidly actuate the control valve.

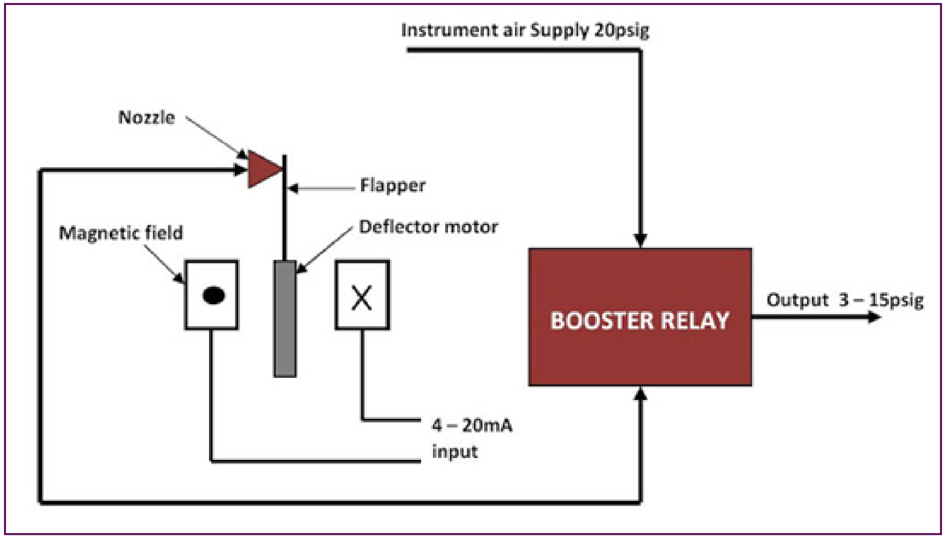


ACTUATOR RESPONSE

I/P transducer

A "current to pressure" transducer (I/P) converts an analog signal (4 to 20 mA) to a proportional linear pneumatic output (3 to 15 psig). Its purpose is to translate the analog output from a control system into a precise, repeatable pressure value to control pneumatic actuators.

The I/P converter uses an electromagnetic force balance principle to change electrical signals into pneumatic signals. Typically, a 4 – 20mA input is converted into a 3 – 15pisg output.

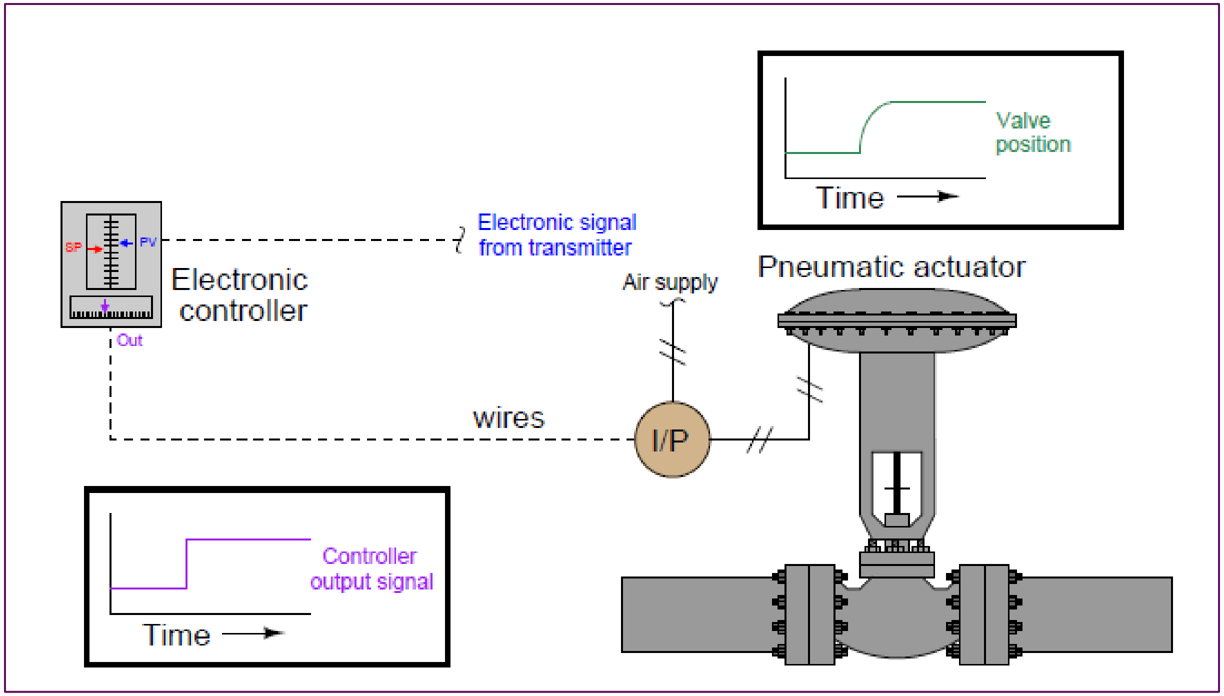


ACTUATOR RESPONSE

2nd Using Volume booster

One way to improve valve response in either type of system is to use a device known as a volume booster to source and vent compressed air for the valve actuator.

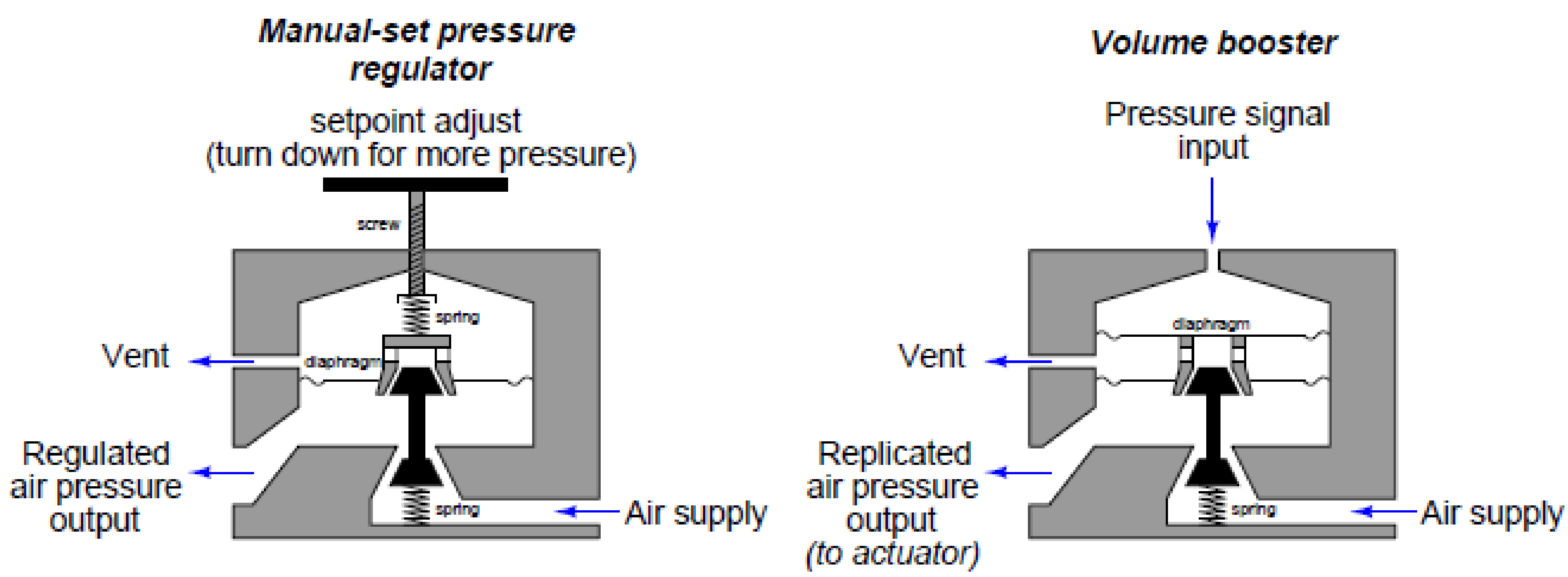
A "volume booster" is a pneumatic device designed to reproduce a pneumatic pressure signal (1:1 ratio), but with far greater output flow capacity. A 3 to 15 PSI pneumatic pressure signal applied to the input of a volume booster will result in an identical output signal but with greatly enhanced flow capacity.



ACTUATOR RESPONSE

Volume booster VS Pressure regulator

In either mechanism, an internal diaphragm senses output pressure and acts against a restraining force to position an air flow throttling/venting mechanism.

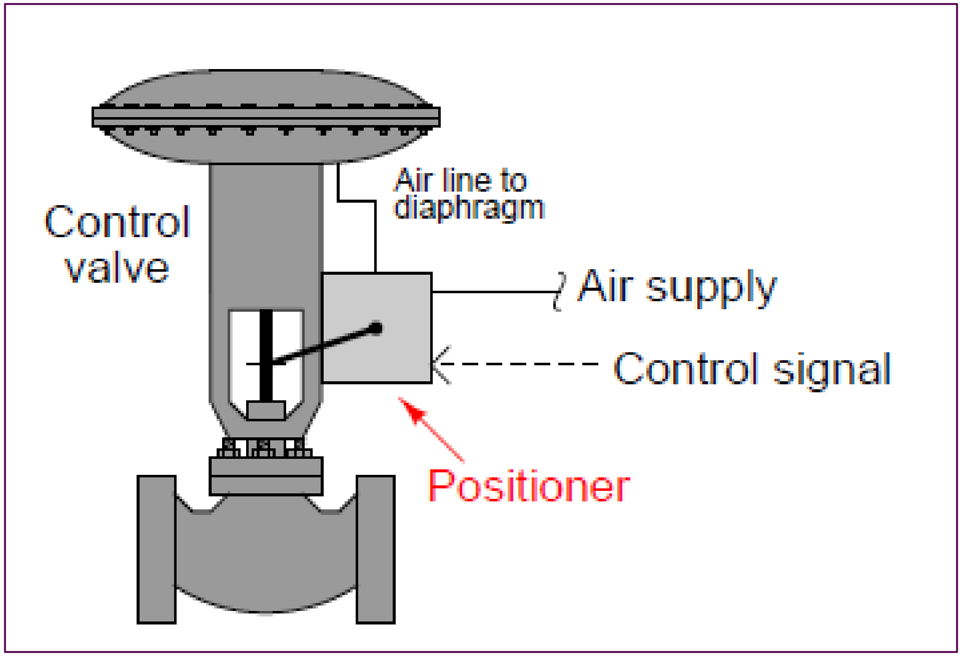


CONTROL VALVE POSITIONER

CONTROL VALVE POSITIONER

Why do we need a positioner ?

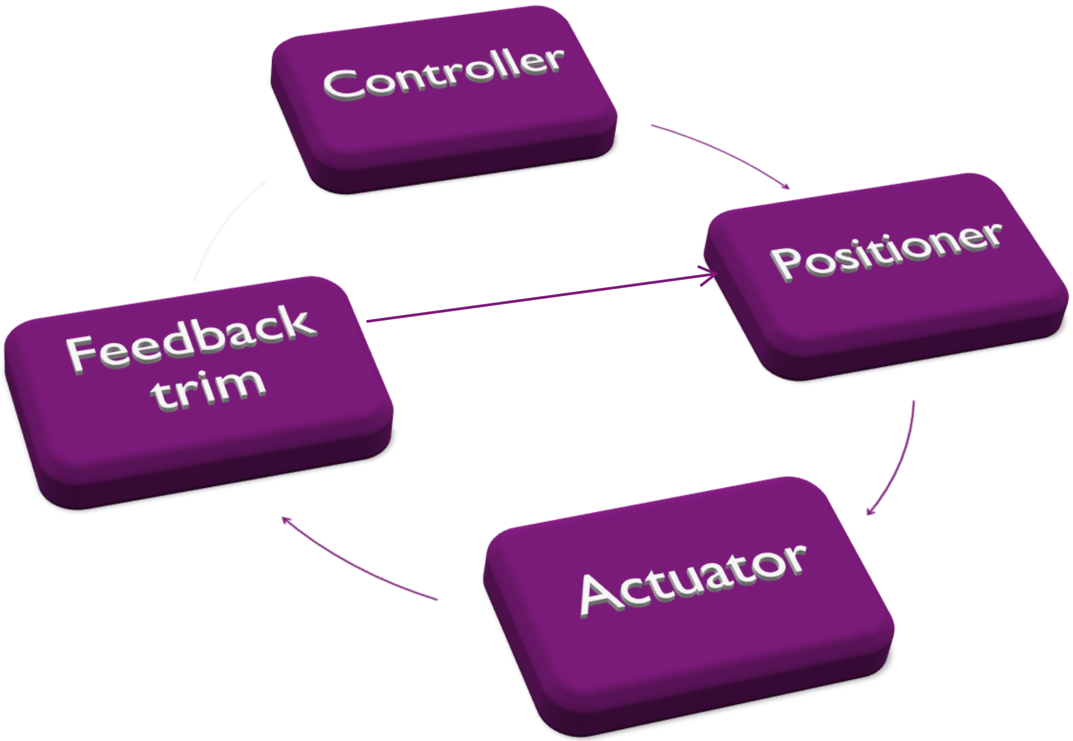
Springs work quite nicely to convert mechanical force into mechanical motion (Hooke's Law – F = kx) for valve actuators if and only if the sole forces involved are the diaphragm or piston force against the spring's resistance force. If any other force acts upon the system, the relationship between actuating fluid pressure and valve stem travel will not necessarily be proportional.



CONTROL VALVE POSITIONER

Positioner is a control system ?!!!!

Positioners essentially act as control systems within themselves the valve's stem position is the process variable (PV), the command signal to the positioner is the set point (SP), and the positioner's signal to the valve actuator is the manipulated variable (MV) or output.



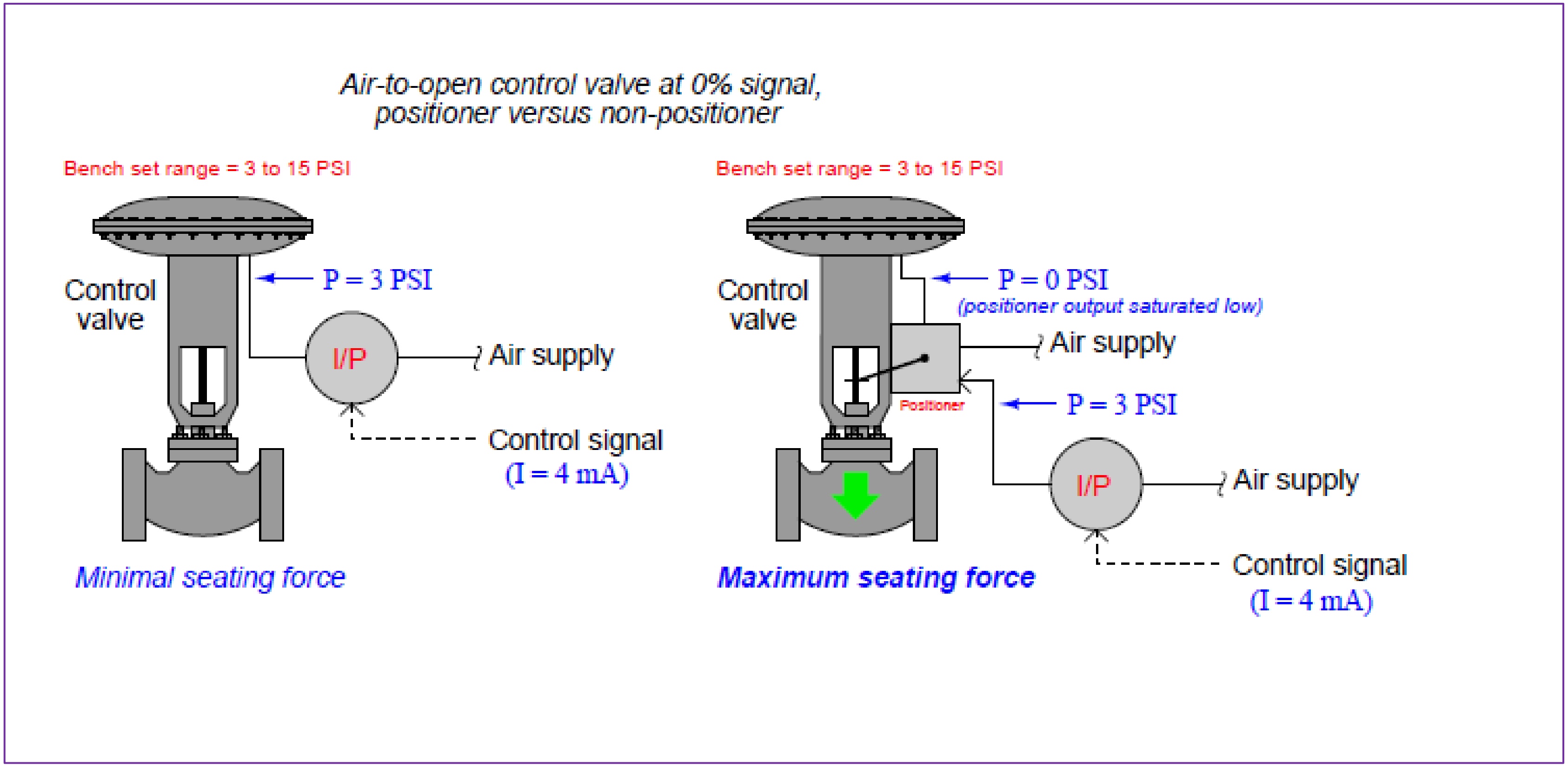
CONTROL VALVE POSITIONER

Advantages of adding positioner

Accurate positioning of the valve stem
Ability to change the valve characteristics
Increase the speed of response (acting like volume booster)
Reverse the action of a valve
Tight shutoff (improve valve seating)

CONTROL VALVE POSITIONER

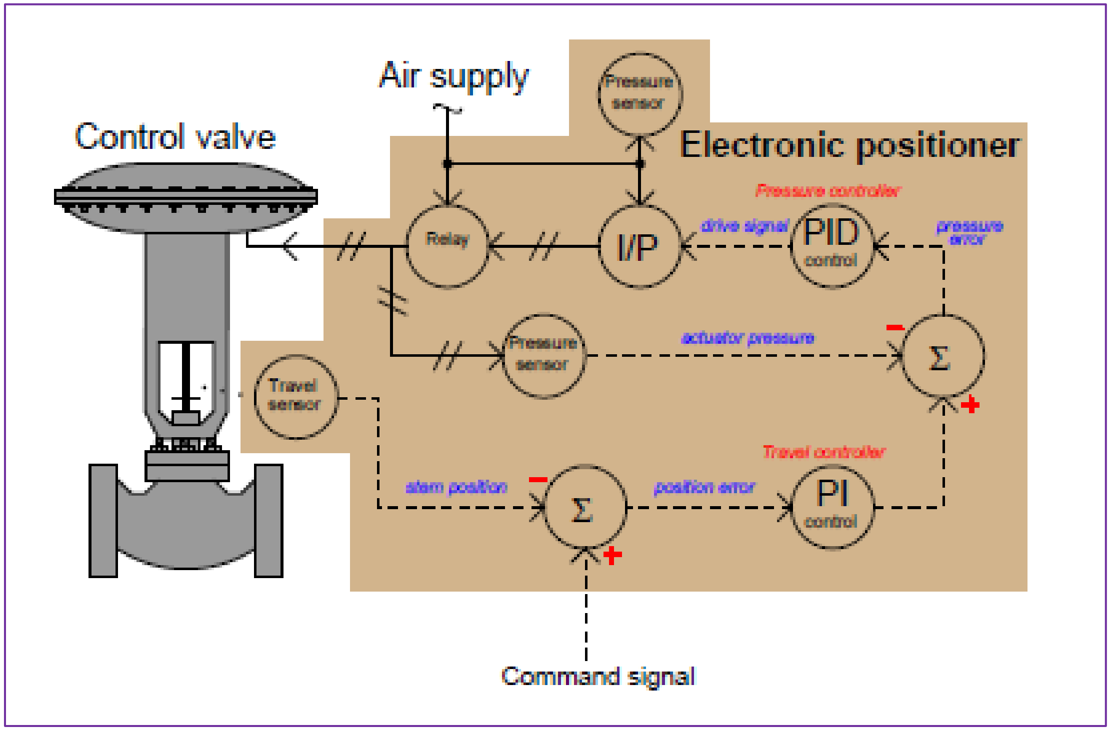
How can Positioner increase valve seating



CONTROL VALVE POSITIONER

Electronic positioners

Electronic valve positioners, such as the Fisher model DVC6000, use an electronic sensor to detect valve stem position, microprocessor to compare that sensed stem position against the control
signal by mathematical subtraction (error = position − signal), then a pneumatic signal converter and relay(s) to send air pressure to the valve actuator.

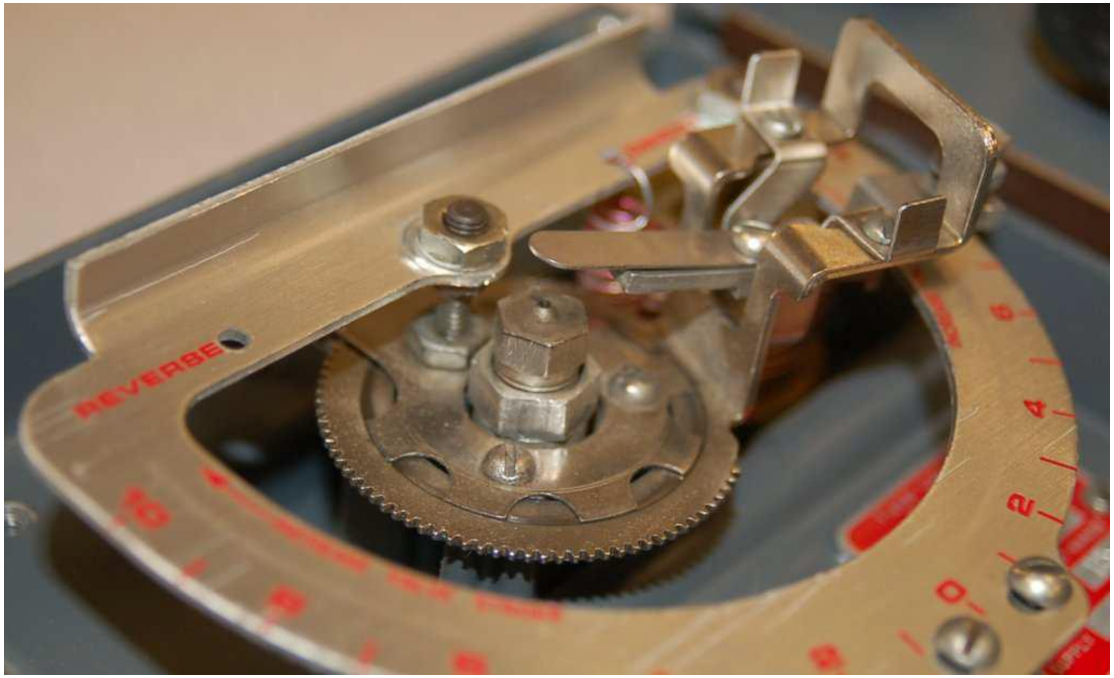


CONTROL VALVE POSITIONER

Examples for electronic positioner

CONTROL VALVE POSITIONER

Examples for Pneumatic positioner



SOLENOID VALVES

Solenoid Valve

A very common form of on/off valve used for pneumatic and hydraulic systems alike is the solenoid valve.

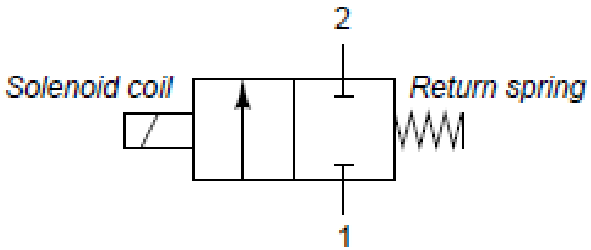
A "solenoid" is nothing more than a coil of wire designed to produce a magnetic field when energized. Solenoid actuators work by attracting a movable iron armature into the center of the solenoid coil when energized, the force of this attraction working to actuate a small valve mechanism. Solenoid-actuated valves are usually classified according to the number of ports ("ways"). A simple on/off solenoid valve controlling flow into one port and out of another port is called a 2-way valve. Another style of solenoid valve, where flow is directed in one path or to another path – much like a single-pole double-throw (SPDT) electrical switch – is called a 3-way valve because it has three fluid ports.

SOLENOID VALVES

2-way solenoid valve

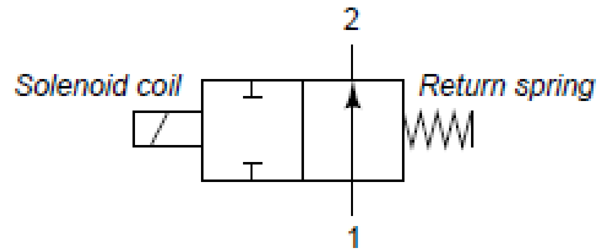
2-way solenoid valves operate in a manner analogous to single-pole single-throw (SPST) electrical switches: with only one path for flow.

2-way solenoid valve
(normally closed)



Blocks flow when de-energized ("normal")
Passes flow when energized

2-way solenoid valve
(normally open)



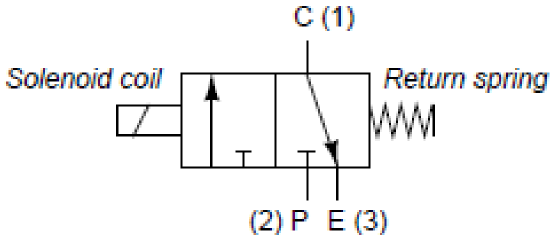
Passes flow when de-energized ("normal")
Blocks flow when energized

SOLENOID VALVES

3-way solenoid valves

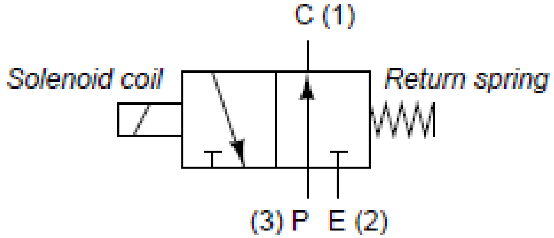
3-way solenoid valves operate in a manner analogous to single-pole double-throw (SPDT) electrical switches: with two paths for flow sharing one common terminal.

3-way solenoid valve
(normally closed)



Vents cylinder when de-energized
Pressurizes cylinder when energized

3-way solenoid valve
(normally open)



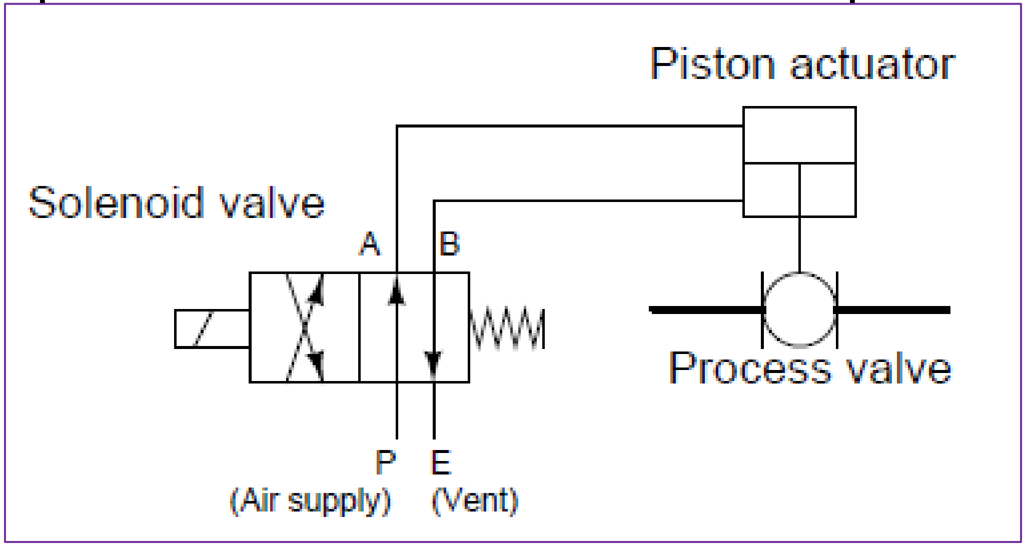
Pressurizes cylinder when de-energized
Vents cylinder when energized

SOLENOID VALVES

4-way solenoid valves

When a pneumatic actuator requires air pressure applied to two different ports in order to move two different directions (such as the case for cylinders lacking a return spring), the solenoid valve supplying air to that actuator must have four ports: one for air supply (P), one for exhaust (E), and two for the cylinder ports (typically labeled A and B).

the solenoid valve forces the piston-actuated valve stem to move down (shut off) when the solenoid is de-energized. When the solenoid is energized, air is directed to the bottom of the piston (with the top of the piston becoming vented to atmosphere), causing the piston-actuated valve stem to move up (open wide).



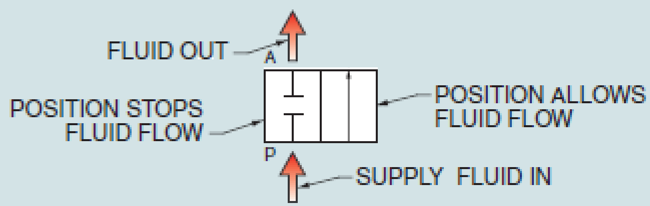
SOLENOID VALVES

Summary

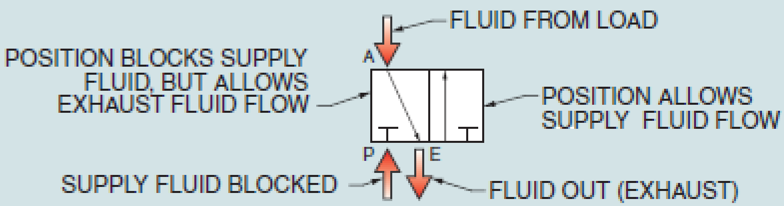
Solenoid Valves

Standard Port Markings

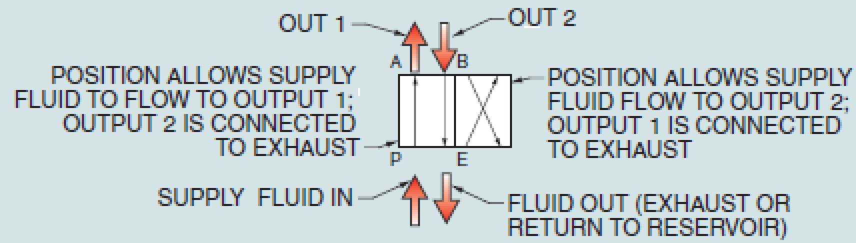
P = PRESSURE
E = EXHAUST
D = DRAIN
T = TANK
A + B = OUTLETS TO LOAD



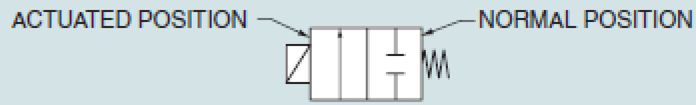
2-Way Valve



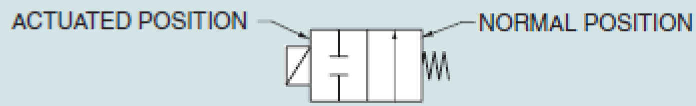
3-Way Valve



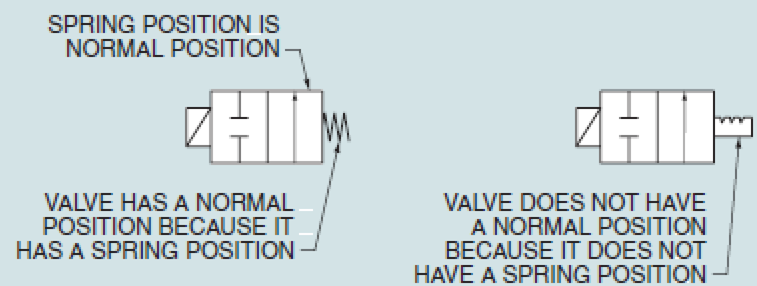
4-Way Valve



Normally Closed Valve



Normally Open Valve

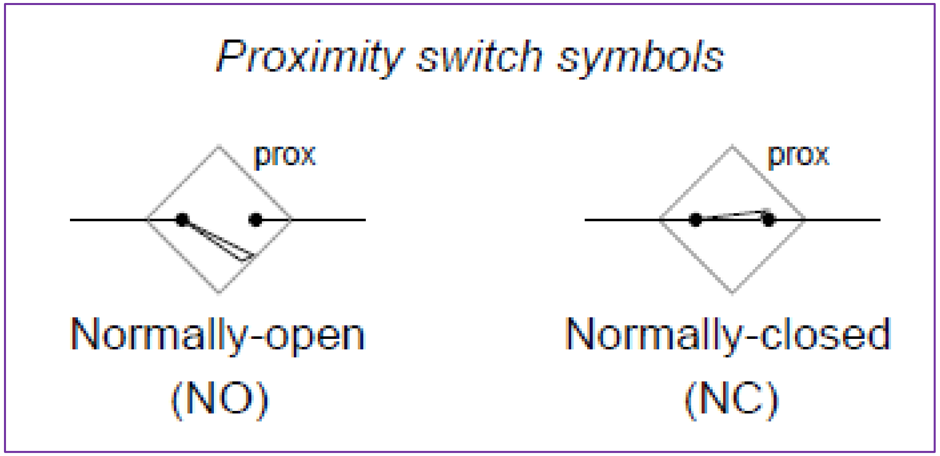


PROXIMITY SWITCH

Proximity (limit) switch

A proximity switch is one detecting the proximity (closeness) of some object. By definition, these switches are non-contact sensors, using magnetic, electric, or optical means to sense the proximity of objects.

Inductive proximity switches sense the presence of metallic objects through the use of a high-frequency magnetic field. Capacitive proximity switches sense the presence of non-metallic objects through the use of a high-frequency electric field. Optical proximity switches detect the interruption of a light beam by an object. Ultrasonic proximity switches sense the presence of dense matter by the reflection of sound waves.



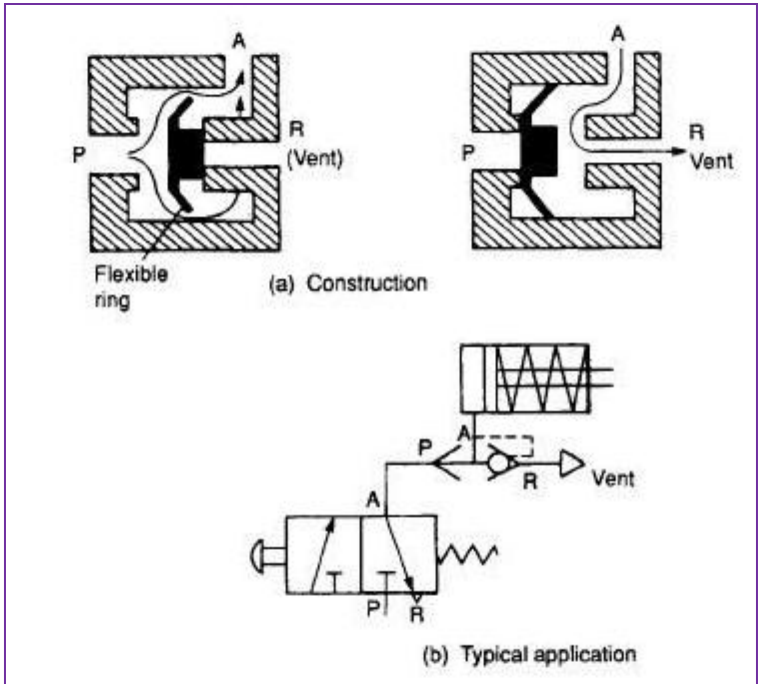
PROXIMITY SWITCH

Proximity (limit) switch

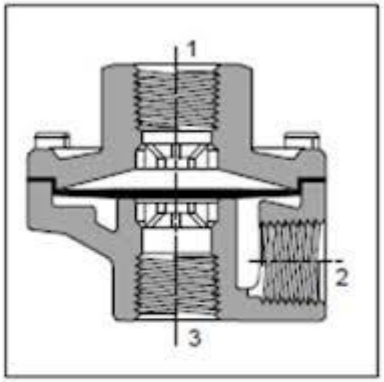
PROXIMITY SWITCH

Quick Exhaust valve

It is used in case of quick venting is important in a control valve .



Fast exhaust valve



SPLIT RANGE CONTROL

Basic Control Strategies

Open loop control

Single feedback control

Cascade control

Ratio control

Split range control

SPLIT RANGE CONTROL

Split range Control

There are many process control applications in industry where it is desirable to have multiple control valves respond to the output of a common controller. Control valves configured to follow the command of the same controller are said to be split-ranged, or sequenced. Split-ranged control valves may take different forms of sequencing.

A few different modes of control valve sequencing are commonly seen in industry:

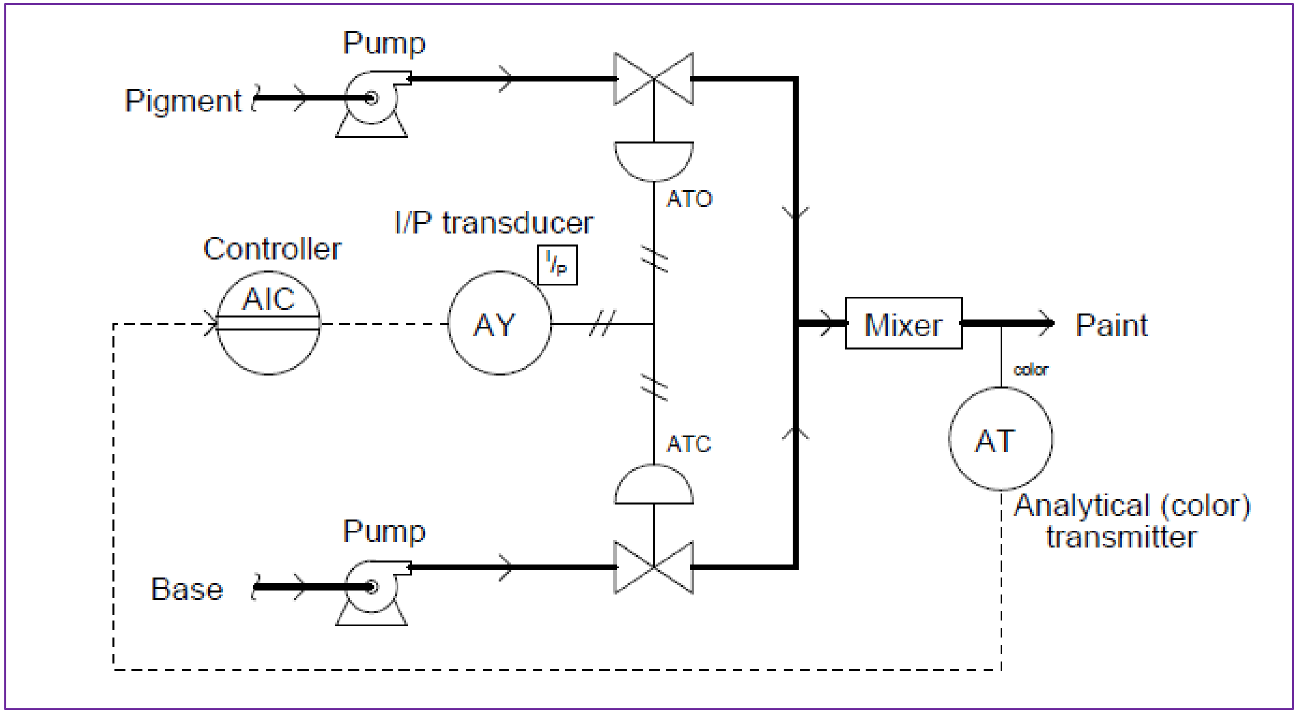
- Complementary
- Exclusive
- Progressive

SPLIT RANGE CONTROL

Complementary valve sequencing

A mode where two valves serve to proportion a mixture of two fluid streams.

Controller output (%)	I/P output (PSI)	Pigment valve (stem position)	Base valve (stem position)
0 %	3 PSI	fully shut	fully open
25 %	6 PSI	25% open	75% open
50 %	9 PSI	half-open	half-open
75 %	12 PSI	75% open	25% open
100 %	15 PSI	fully open	fully shut

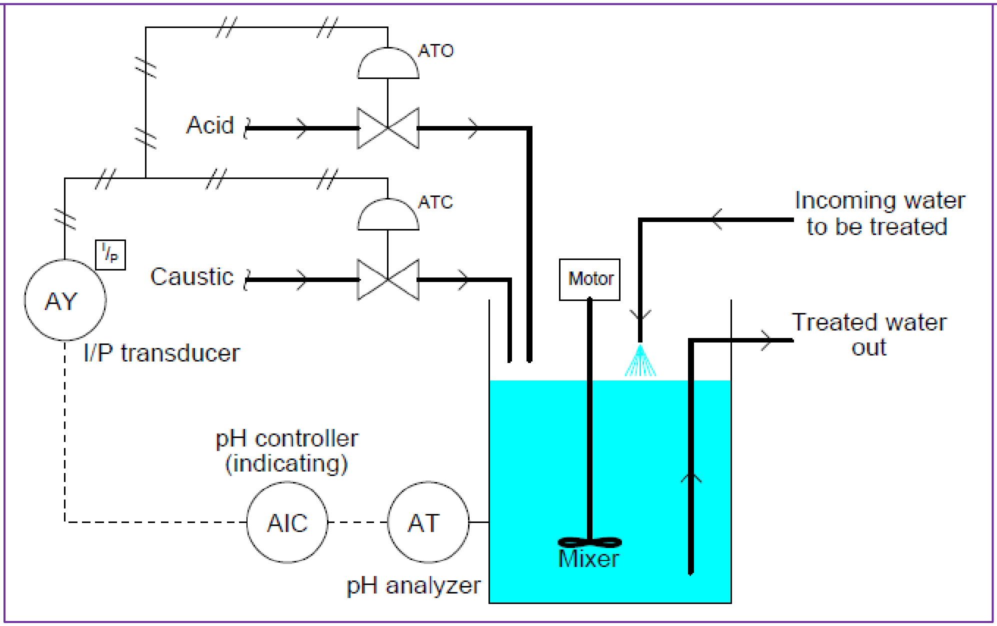


SPLIT RANGE CONTROL

Exclusive valve sequencing

The nature of this valve sequencing is to have an "either-or" throttled path for process fluid. That is, either process fluid flows through one valve or through the other, but never through both at the same time.

Controller output (%)	I/P output (PSI)	Acid valve (stem position)	Caustic valve (stem position)
0 %	3 PSI	fully shut	fully open
25 %	6 PSI	fully shut	half-open
50 %	9 PSI	fully shut	fully shut
75 %	12 PSI	half-open	fully shut
100 %	15 PSI	fully open	fully shut

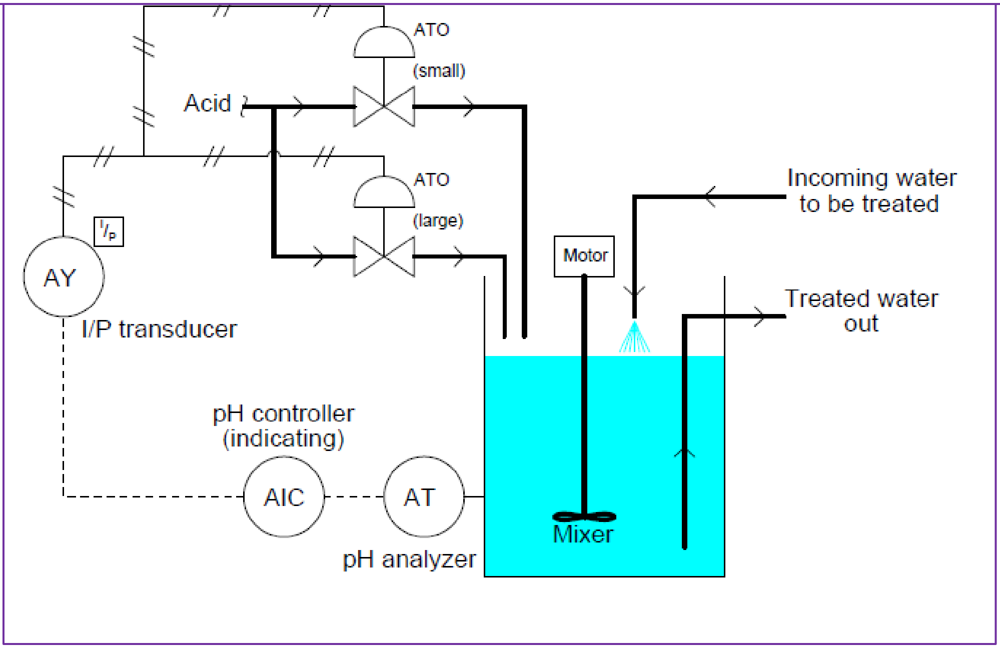


SPLIT RANGE CONTROL

Progressive valve sequencing

This mode used to expand the operating range of flow control for some fluid beyond that which a single control valve could muster.

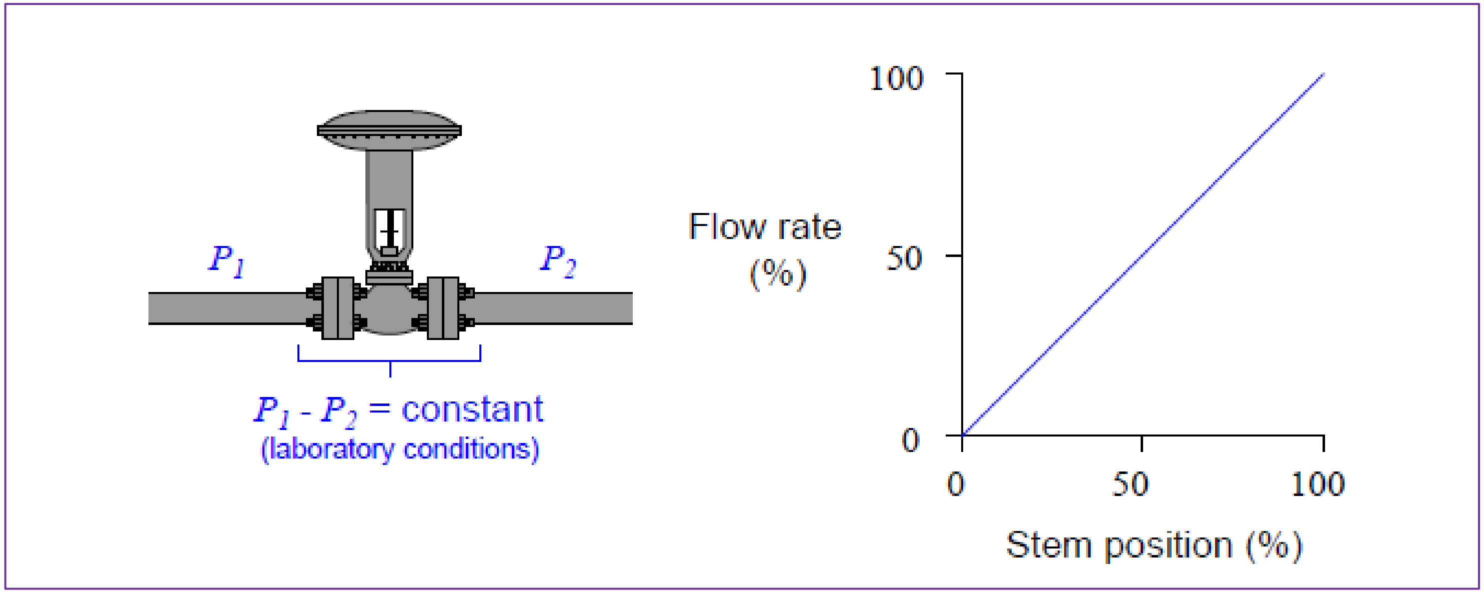
Controller output (%)	I/P output (PSI)	Small acid valve (stem position)	Large acid valve (stem position)
0 %	3 PSI	fully shut	fully shut
25 %	6 PSI	half-open	fully shut
50 %	9 PSI	fully open	fully shut
75 %	12 PSI	fully open	half-open
100 %	15 PSI	fully open	fully open



CONTROL VALVE CHARACTERIZATION

Inherent versus installed characteristics

When control valves are tested in a laboratory setting, they are connected to a piping system providing a nearly constant pressure difference between upstream and downstream (P1 −P2). With a fluid of constant density and a constant pressure drop across the valve, flow rate becomes a direct function of flow coefficient (Cv).



CONTROL VALVE CHARACTERIZATION

Installed characteristics

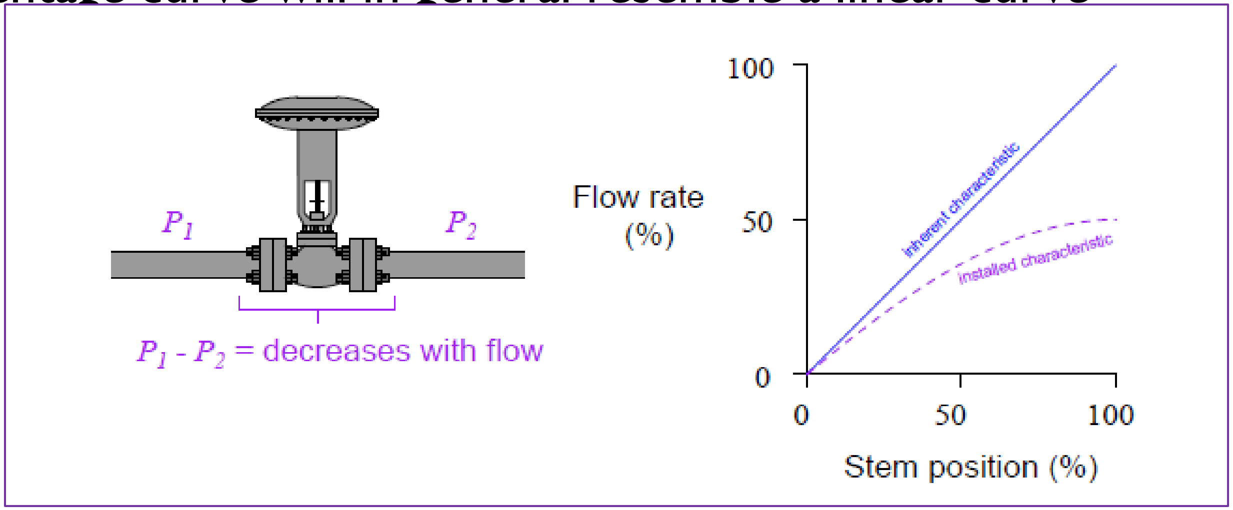
When valves are installed with pumps, piping and fittings, and other process equipment, the pressure drop across the valve will vary as the plug moves through its travel.

When the actual flow in a system is plotted against valve opening, the curve is called the **Installed Flow Characteristic**.

In most applications, when the valve opens, and the resistance due to fluids flow decreases the pressure drop across the valve. This moves the inherent characteristic:

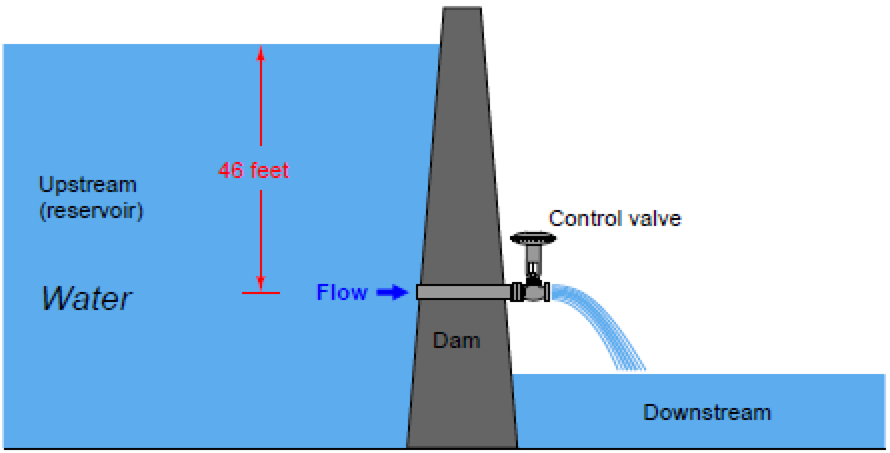
A linear inherent curve will in general resemble a quick opening characteristic

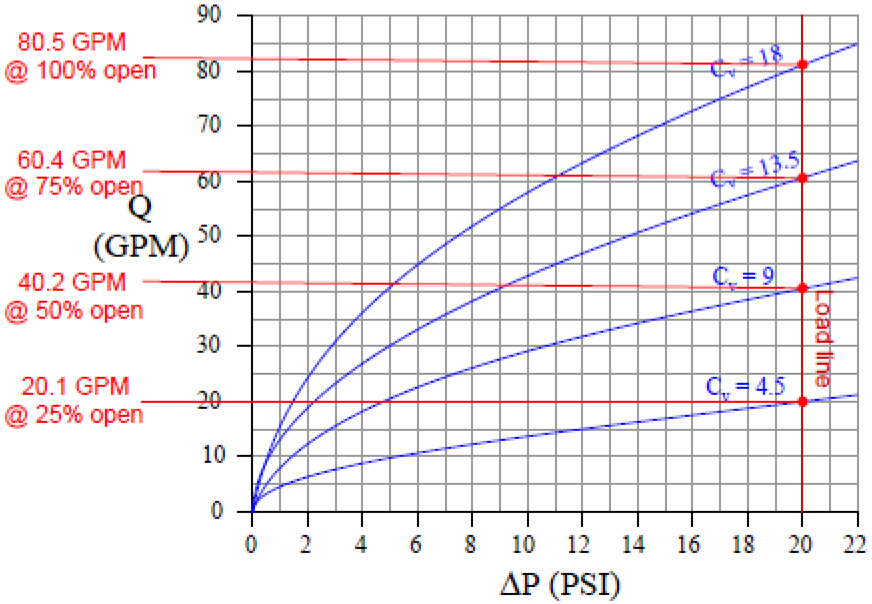
An equal percentage curve will in general resemble a linear curve



CONTROL VALVE CHARACTERIZATION

Installed characteristics
Case 1

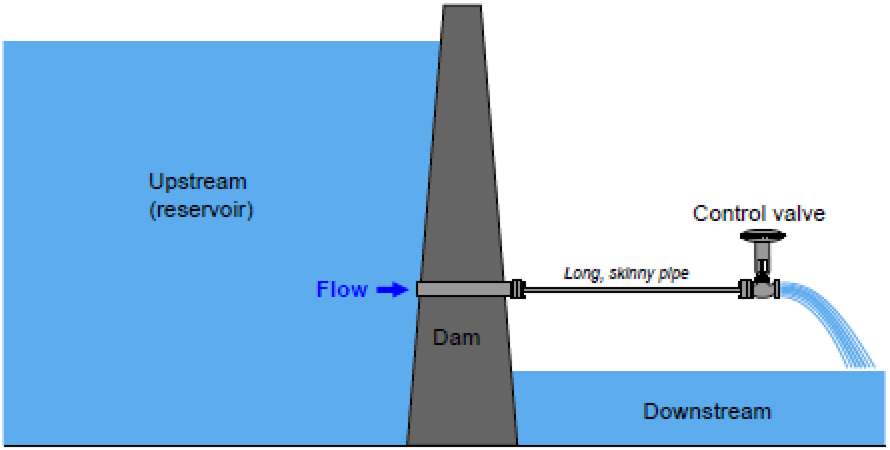


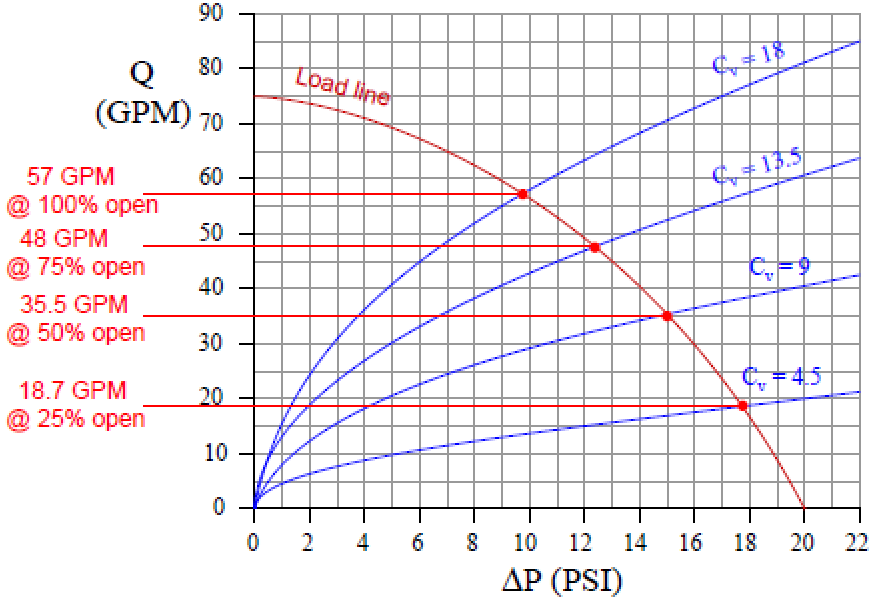


Opening (%)	C_v	Flow rate (GPM)
0	0	0
25	4.5	20.1
50	9	40.2
75	13.5	60.4
100	18	80.5

CONTROL VALVE CHARACTERIZATION

Installed characteristics
Case 2

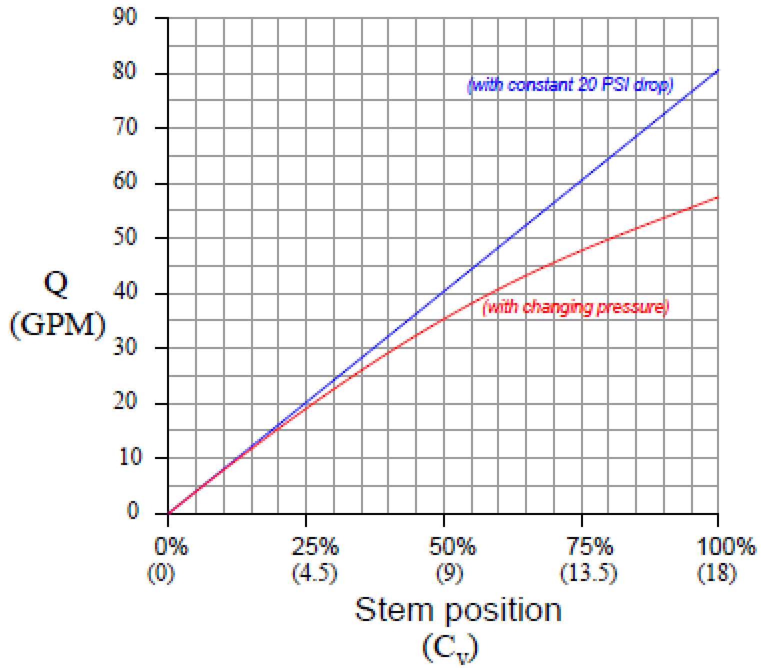




Opening (%)	C_v	Flow rate (GPM)
0	0	0
25	4.5	18.7
50	9	35.5
75	13.5	48
100	18	57

CONTROL VALVE CHARACTERIZATION

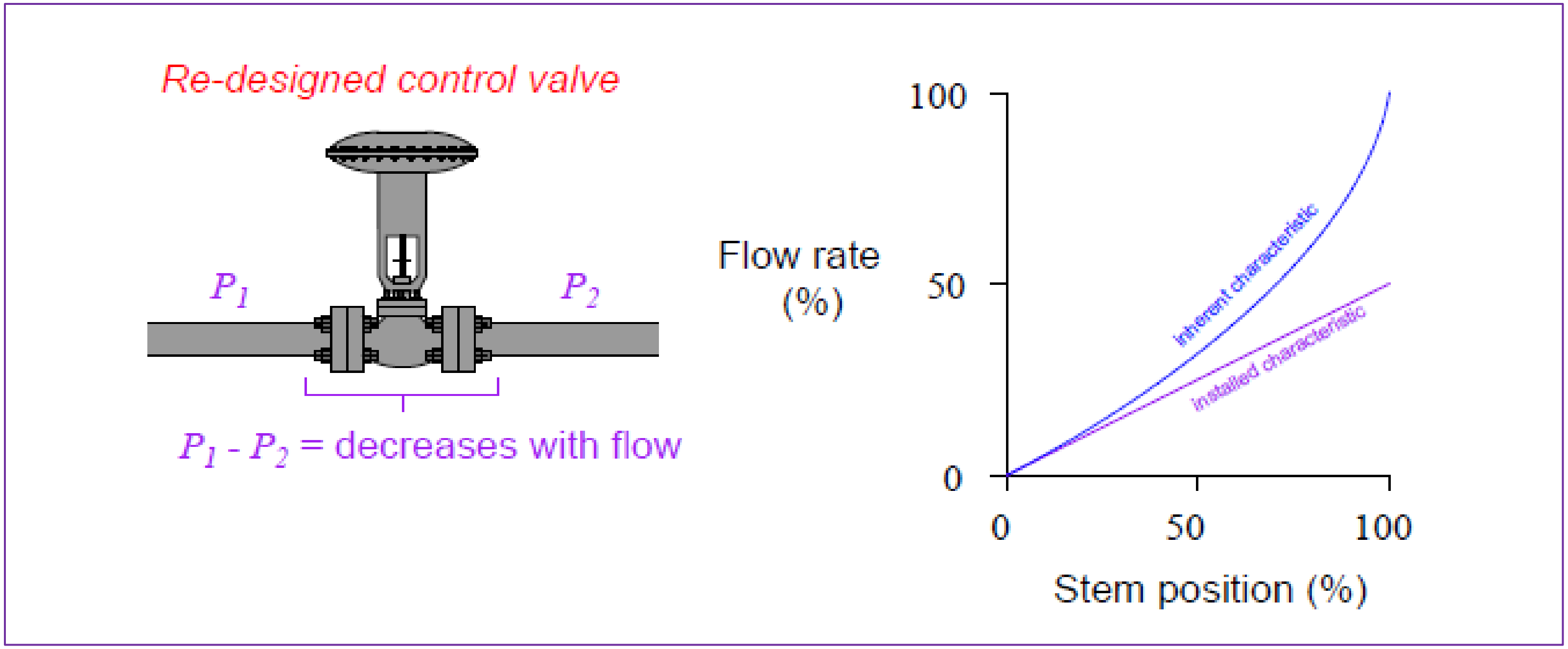
Result



CONTROL VALVE CHARACTERIZATION

Solving linearity problems

we design the control valve trim so it opens up gradually during the initial stem travel (near the closed position), then opens up more aggressively during the final stages of stem travel (near the full-open position). With the valve made to open up in a nonlinear fashion inverse to the "droop" caused by the installed pressure changes, the two non-linearities should cancel each other and yield a more linear response.



CONTROL VALVE CHARACTERIZATION

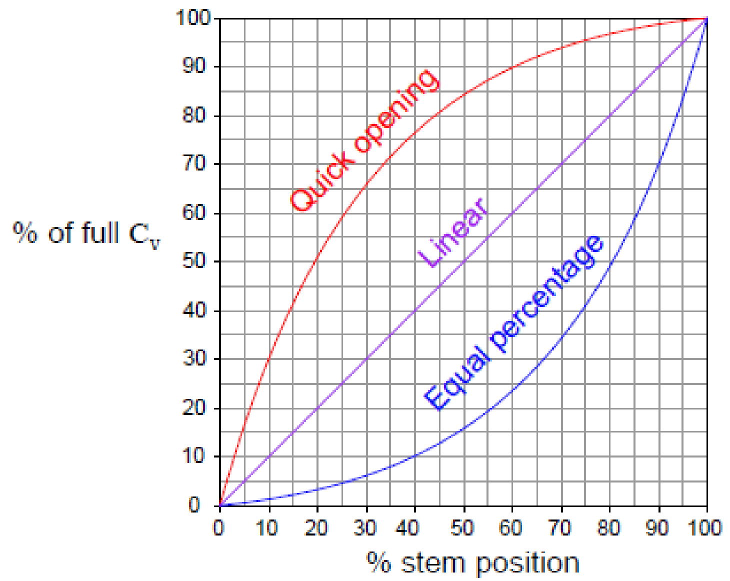
Ideal Characteristic curves

Linear - flow capacity increases linearly with valve travel.

Equal percentage flow capacity increases **exponentially** with valve trim travel. Equal increments of valve travel produce equal percentage changes in the existing C_v.

Quick opening provides large changes in flow for very small changes in lift. It usually has too high a valve gain for use in modulating control. So it is limited to on-off service, such as sequential operation in either batch or semi-continuous processes.

$C_v = xC_{vm}$	Linear trim
$C_v = C_{vm}R^{(x-1)}$	Equal percentage trim



CONTROL VALVE CHARACTERIZATION

Example

LINEAR CHARACTERISTIC CURVE

$$Cv_{Actual} = Cv_{Max}\left\{\left[\frac{\%Travel}{100} \times \left(1 - \frac{1}{Rangeability}\right)\right] + \left(\frac{1}{Rangeability}\right)\right\}$$

% Travel	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
{ }	.020	.118	.216	.314	.412	.510	.608	.706	.804	.902	1.000
Cv Actual	2.0	11.8	21.6	31.4	41.2	51.0	60.8	70.6	80.4	90.2	100.0

Valve with - Cv = 100, Rangeability = 50:1

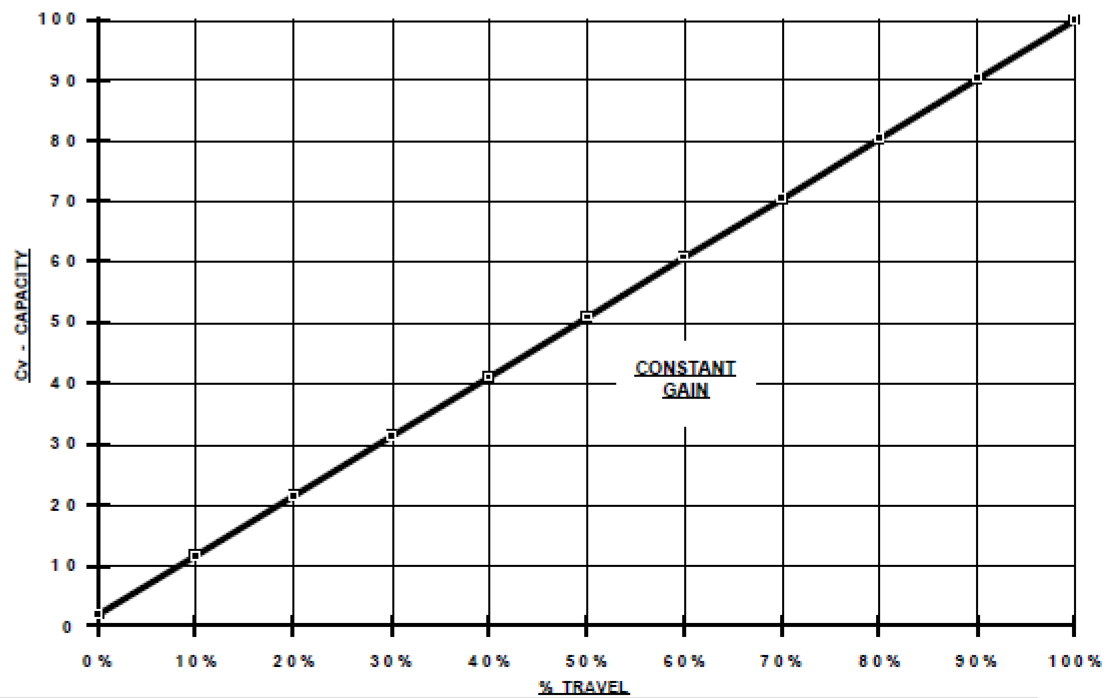
Cv @ 30% = 31.4
Cv @ 40% = 41.2

$$\% \text{ Change} = \frac{(41.2 - 31.4)}{31.4} \times 100\% = \boxed{31.2\%}$$

* * * % change is NOT equal !!

Cv @ 70% = 70.6
Cv @ 80% = 80.4

$$\% \text{ Change} = \frac{(80.4 - 70.6)}{70.6} \times 100\% = \boxed{13.9\%}$$



CONTROL VALVE CHARACTERIZATION

Example

Equal percentage

$$Cv_{Actual} = \frac{Cv\ @\ 100\%}{Rangeability} \times e^{\left[\frac{(\%Travel) \times LN(Rangeability)}{100}\right]}$$

% Travel	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
[%TRAVEL*LN(RGBLTY)]/100	0.00	0.39	0.78	1.17	1.56	1.96	2.35	2.74	3.13	3.52	3.91
EXP(LN Function)	1.00	1.48	2.19	3.23	4.78	7.07	10.46	15.46	22.87	33.81	50.00
[Cv_{Max}/(RGBLTY)]*[EXP(LN Function)]	2.00	2.96	4.37	6.47	9.56	14.14	20.91	30.92	45.73	67.62	100.00

Valve with - Cv = 100, Rangeability = 50:1

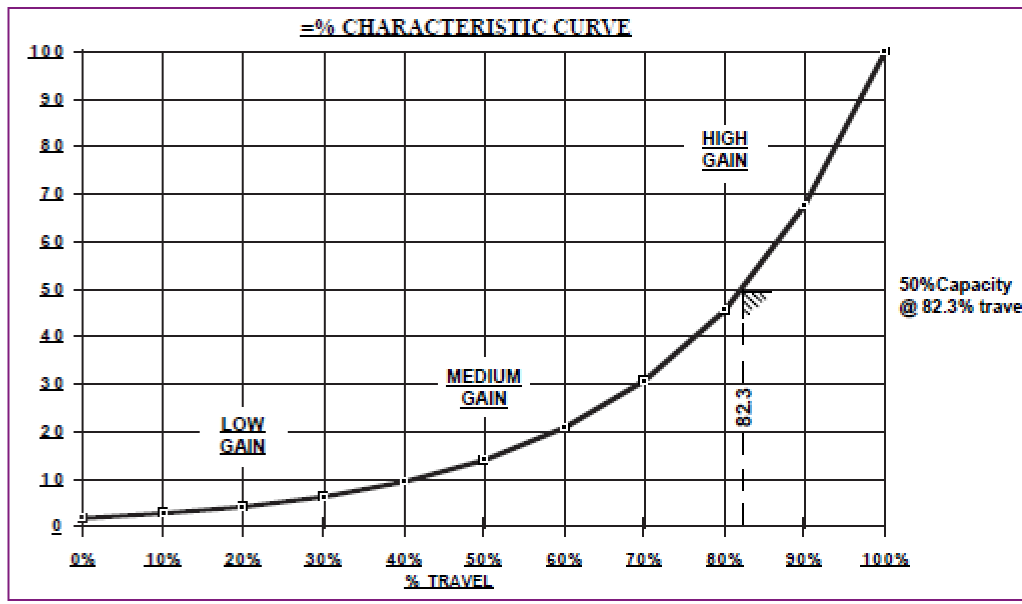
Cv @ 30% = 6.47
Cv @ 40% = 9.56

$$\%\ Change = \frac{(9.56 - 6.47)}{6.47} \times 100\% = \boxed{47.8\%}$$

Cv @ 70% = 30.92
Cv @ 80% = 45.73

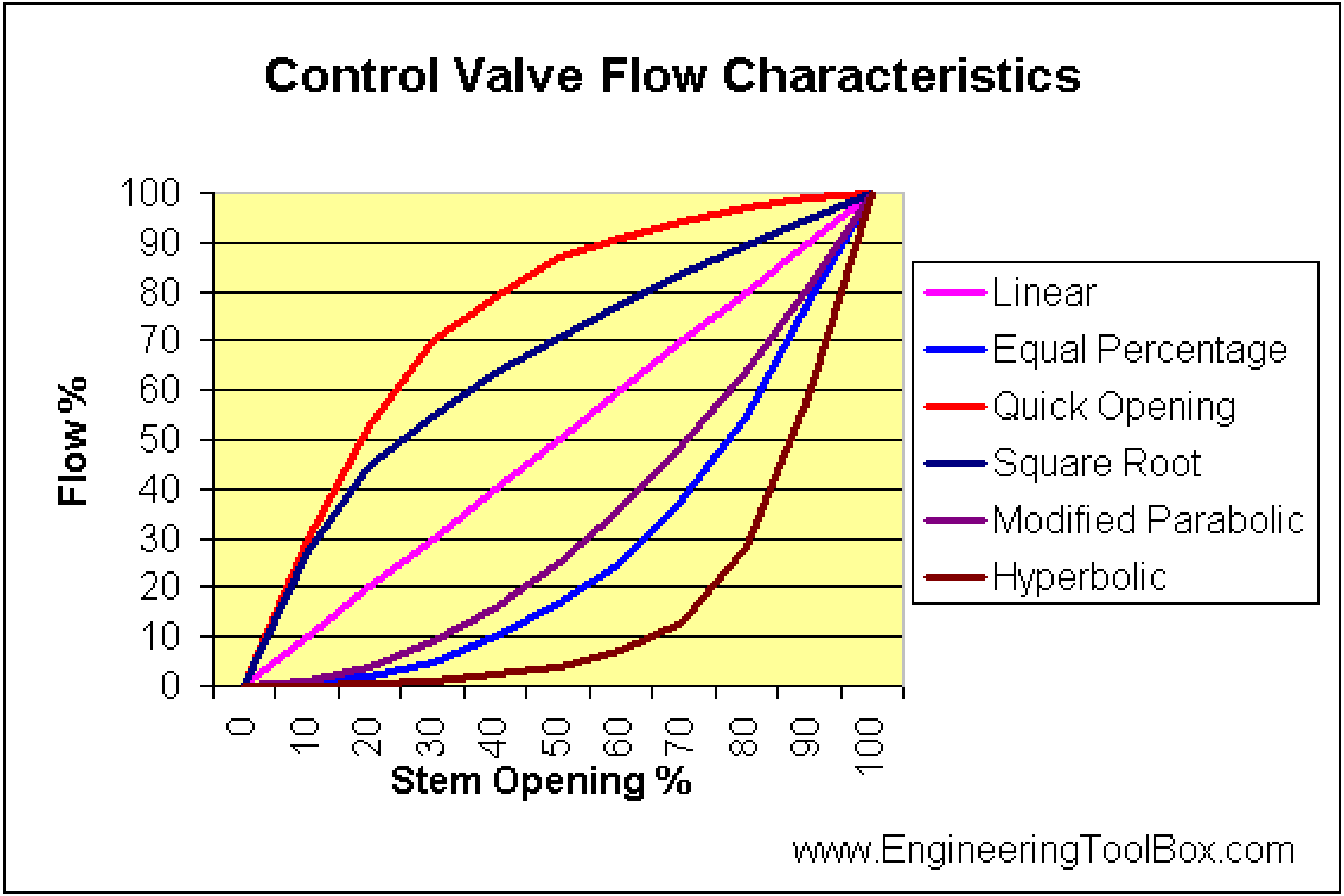
$$\%\ Change = \frac{(45.73 - 30.92)}{30.92} \times 100\% = \boxed{47.9\%}$$

* * * "Equal %" change along the curve!



CONTROL VALVE CHARACTERIZATION

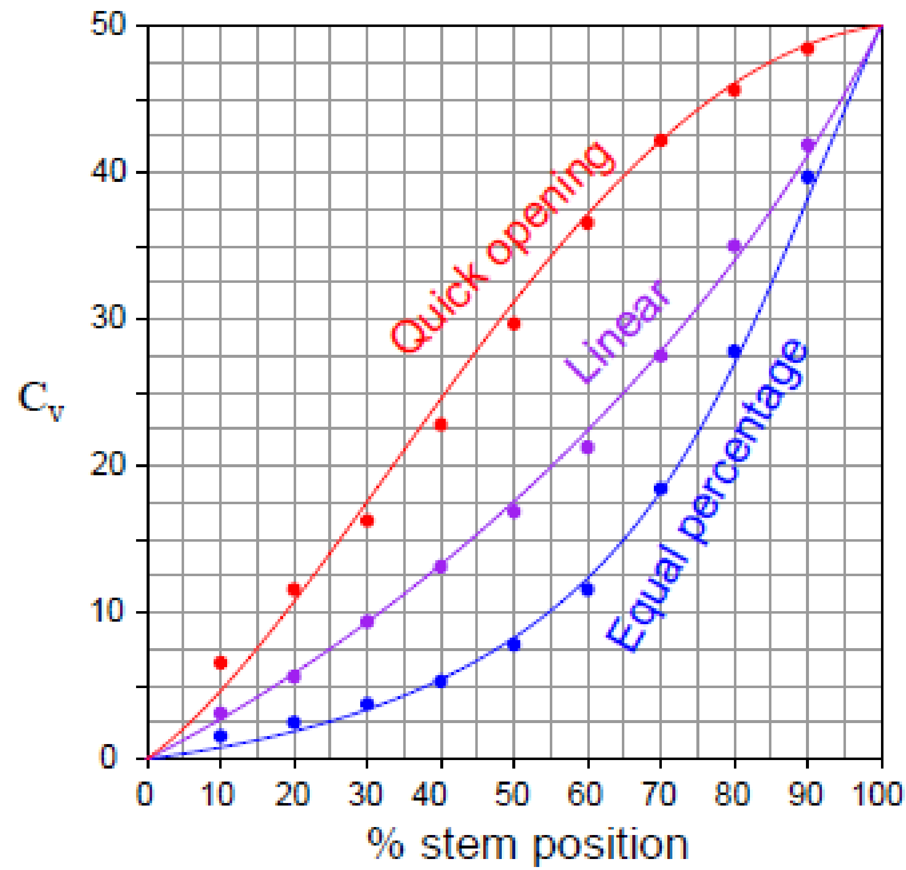
Modified characteristic curves



CONTROL VALVE CHARACTERIZATION

Practical Characteristic curves from manufacturers data

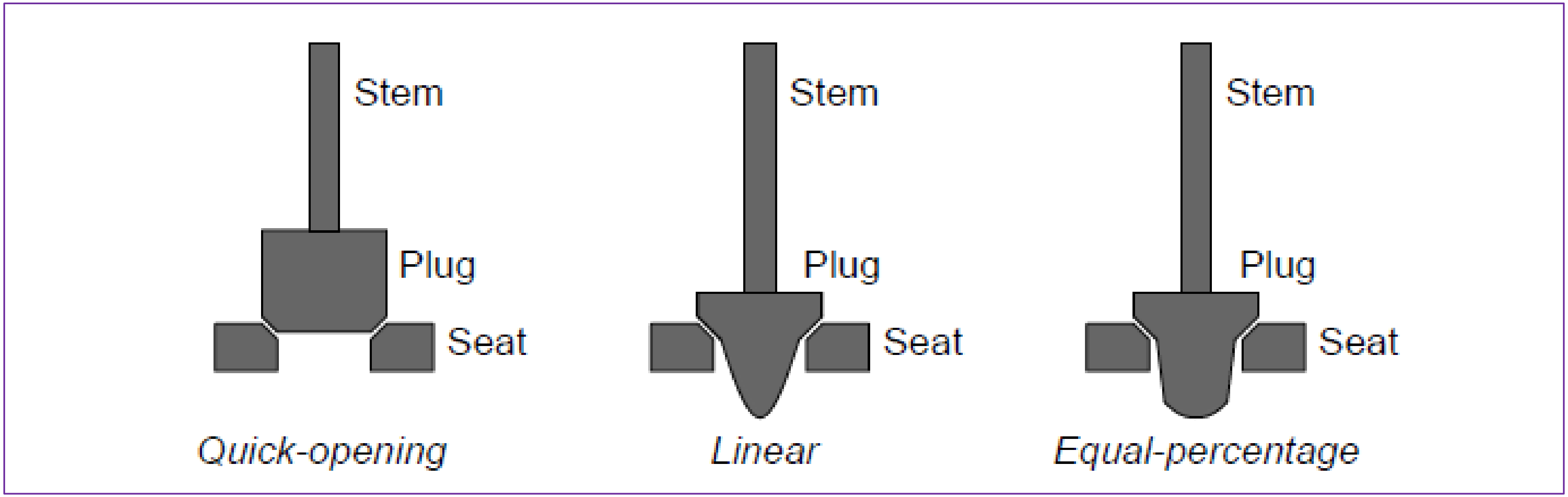
A graph showing valve characteristics taken from actual manufacturers' data on valve performance



CONTROL VALVE CHARACTERIZATION

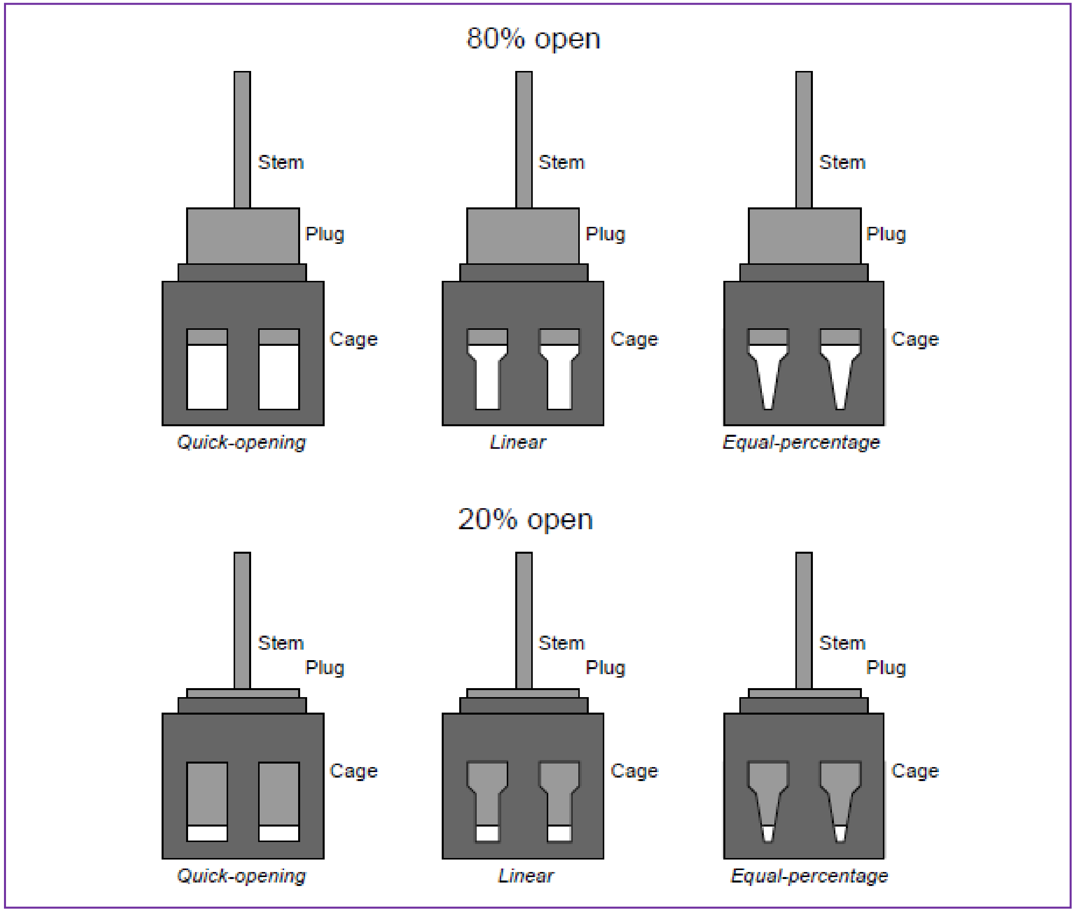
Valve trim Assignments

Plug profiles of a single-ported, stem-guided globe valve may be modified to achieve the common quick-opening, linear, and equal-percentage characteristics



CONTROL VALVE CHARACTERIZATION

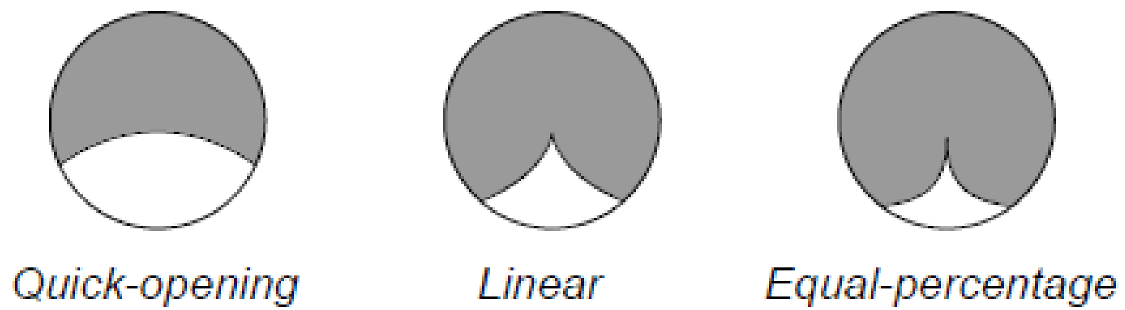
Cage guided



CONTROL VALVE CHARACTERIZATION

Ball valve trim

Ball Valve notch shapes in case of 50 % open



SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Notes about selection

When speaking of valves, it's easy to get lost in the terminology. Valve types are used to describe the mechanical characteristics and geometry (Ex/ gate, ball, globe valves). We'll use valve control to refer to how the valve travel or stroke (openness) relates to the flow:

1. Equal Percentage: equal increments of valve travel produce an equal percentage in flow change

2. Linear: valve travel is directly proportional to the valve stoke

3. Quick opening: large increase in flow with a small change in valve stroke

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Equal Percentage (most commonly used valve control)

a. Used in processes where large changes in pressure drop are expected
b. Used in processes where a small percentage of the total pressure drop is permitted by the valve
c. Used in temperature and pressure control loops

Linear
a. Used in liquid level or flow loops
b. Used in systems where the pressure drop across the valve is expected to remain fairly constant (ie. steady state systems)

Quick Opening
a. Used for frequent on-off service
b. Used for processes where "instantly" large flow is needed (ie. safety systems or cooling water systems)

SELECTION GUIDE
(CRACTERSISTIC CURVE & BODY TYPE

Gate valve

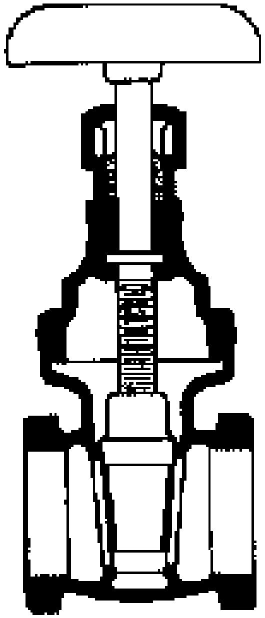
Gate Valves Best Suited Control: Quick Opening

Recommended Uses:

1. Fully open/closed, non-throttling
2. Infrequent operation
3. Minimal fluid trapping in line

Applications: Oil, gas, air, slurries, heavy liquids, steam, non condensing gases, and corrosive liquids

Advantages:	*Disadvantages*
• *High capacity* • *Tight shutoff* • *Low cost*	• *Poor control* • *Cavitate at low pressure drops* • *Cannot be used for throttling*



Gate Valve

SELECTION GUIDE
(CRACTERSISTIC CURVE & BODY TYPE

Globe Valve

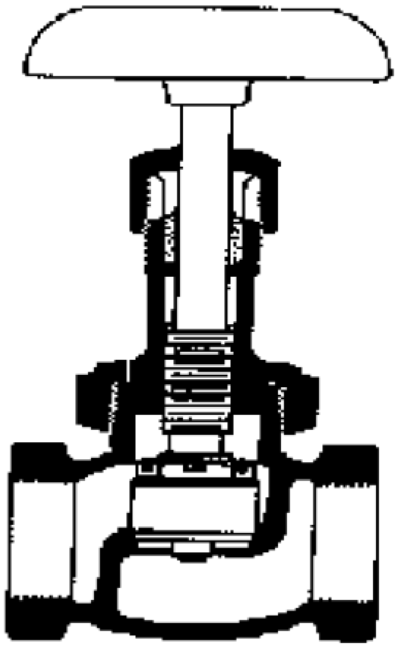
Best Suited Control: Linear and Equal percentage

Recommended Uses:

1. Throttling service/flow regulation
2. Frequent operation

Applications: Liquids, vapors, gases, corrosive substances, slurries

Advantages:	*Disadvantages*
• *Efficient throttling* • *Accurate flow control* • *Available in multiple ports*	• *High pressure drop* • *More expensive than other valves*



Globe Valve

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

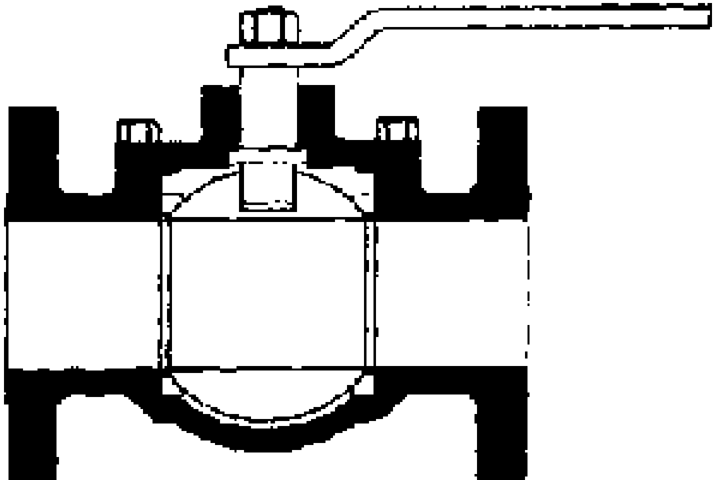
Ball valve

Best Suited Control: Quick opening, linear

1. Fully open/closed, limited-throttling
2. Higher temperature fluids

Applications: Most liquids, high temperatures, slurries suited Control: Quick opening, linear

Advantages:	*Disadvantages*
• *Low cost* • *High capacity* • *Low leakage and maint.* • *Tight sealing with low torque*	• *Poor throttling characteristics* • *Prone to cavitation*



Ball Valve

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Butterfly valve

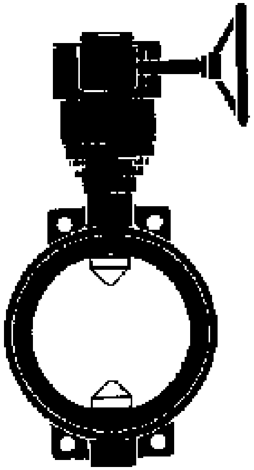
Best Suited Control: Linear, Equal percentage

Recommended Uses:

1. Fully open/closed or throttling services
2. Frequent operation
3. Minimal fluid trapping in line

Applications: Liquids, gases, slurries, liquids with suspended solids

Advantages:	*Disadvantages*
• *Low cost and maint.* • *High capacity* • *Good flow control* • *Low pressure drop* Other Valves	• *High torque required for control* • *Prone to cavitation at lower flows*



Butterfly Valve

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Selection Steps

- Valve & Trim Type and Style
- Valve Flow Characteristics
- End Connections Type and P&T Rating
- Body & Trim Material
- Seat Leakage Class
- Bonnet Style and Packing
- Fail safe position
- Valve Calculations (valve sizing, flashing & cavitation check and noise prediction)
- Actuator Type / size

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Selection Steps

Valve Type is selected on basis of :

- service function (on-off or throttling, mixing, diversion,… etc),
- size,
- pressure drop, and :
- cost.

Trim Type is selected based on:

- pressure drop
- flow characteristics
- anticipated service conditions (flashing / cavitation and noise)
- tight shut-off requirements (seat leakage class)

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Selection Steps

End Connections is selected on basis of :

- Service conditions (P, T ratings) and fluid properties (degree of hazard)
- Piping specifications.

Body & Trim Materials are selected on basis of :

- Service conditions (P & T limits of materials and possible flashing / cavitation conditions)
- Fluid corrosive properties

Valve Flow Characteristics is selected such that :

- It provides a constant gain as much as possible within the actual operating range noting that the valve characteristics change as the pressure drop changes.

SELECTION GUIDE (CRACTERSISTIC CURVE & BODY TYPE

Selection Steps

Seat Leakage Class is selected to meet the specific process requirements and shut-off ΔP.

Note that some designs are not suitable for tight shut-off requirements (e.g., double port unbalanced trim design).

Bonnet Style & Packing is selected based on the service temp. and the degree of hazard of the process fluid.

- STD, extended (plain surface or finned surface) bonnets are used for normal, low or high service temp., respectively.
- Single, duplex or bellows seal packing are used depending on the service P&T as well as degree of hazard of the service fluid.
- Packing material is selected in view of the temp. limits of the different seal materials.

SELECTION GUIDE
(CRACTERSISTIC CURVE & BODY TYPE

Selection Steps

Seat Leakage Class is selected to meet the specific process requirements and shut-off ΔP.

Note that some designs are not suitable for tight shut-off requirements (e.g., double port unbalanced trim design).

Bonnet Style & Packing is selected based on the service temp. and the degree of hazard of the process fluid.

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CONTROL VALVE SIZING

CONTROL VALVE SIZING

What is Valve Sizing?

It is a procedure by which the dynamics of a process system are matched to the performance characteristics of a valve.

This is to provide a control valve that will best meet the needs of managing flow within that process system.

CONTROL VALVE SIZING

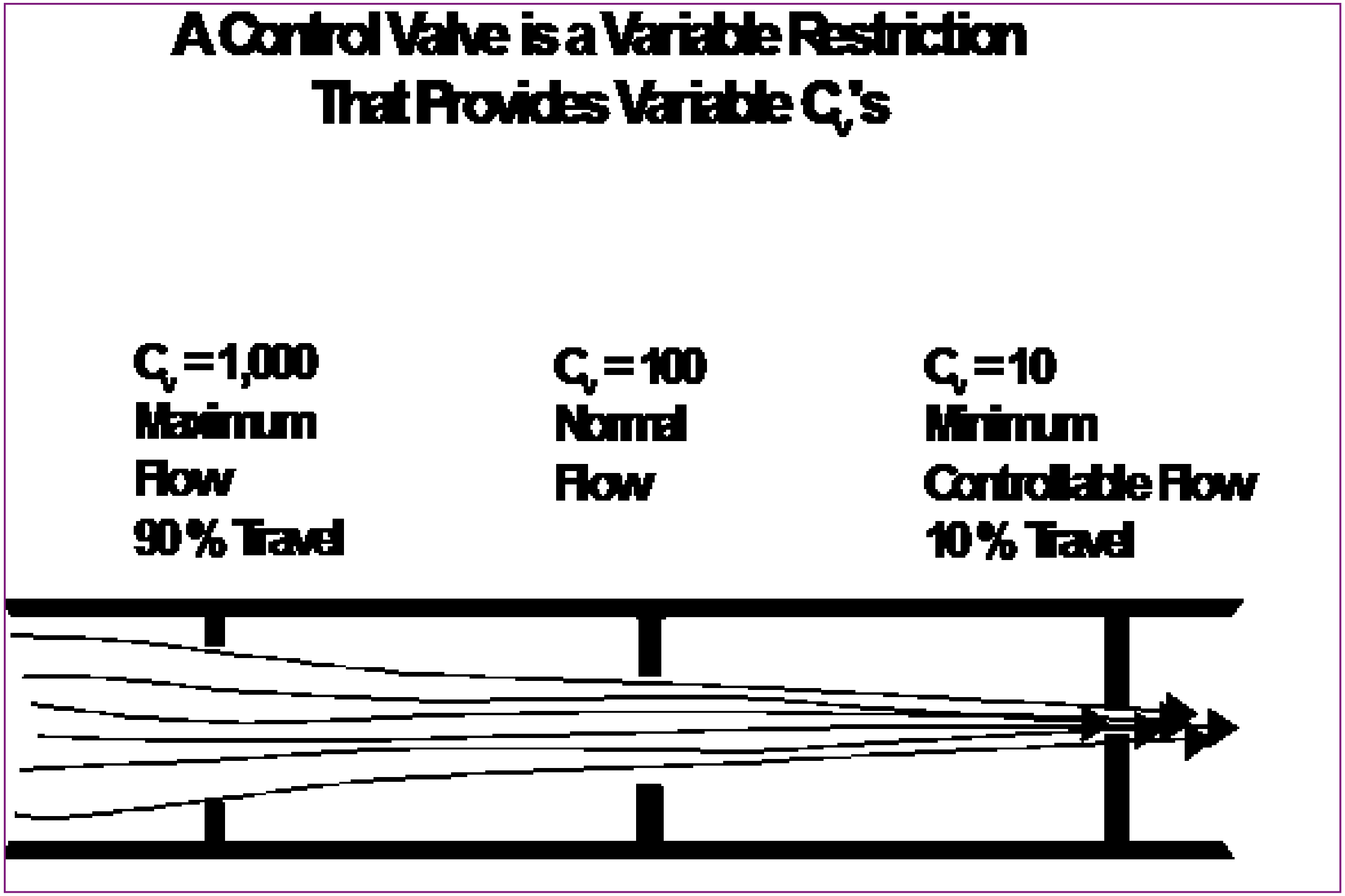
Flow Coefficient (CV)

The valve flow coefficient, CV is the number of U.S. gallons per minute of water at 60 degrees F which will pass through a given flow restriction with a pressure drop of 1 psi.

For example, a control valve which has a flow coefficient, or CV, of 12 has an effective port area that it passes 12 gallons per minute of water with 1 psi pressure drop.

CONTROL VALVE SIZING

Valve as a Variable Restriction

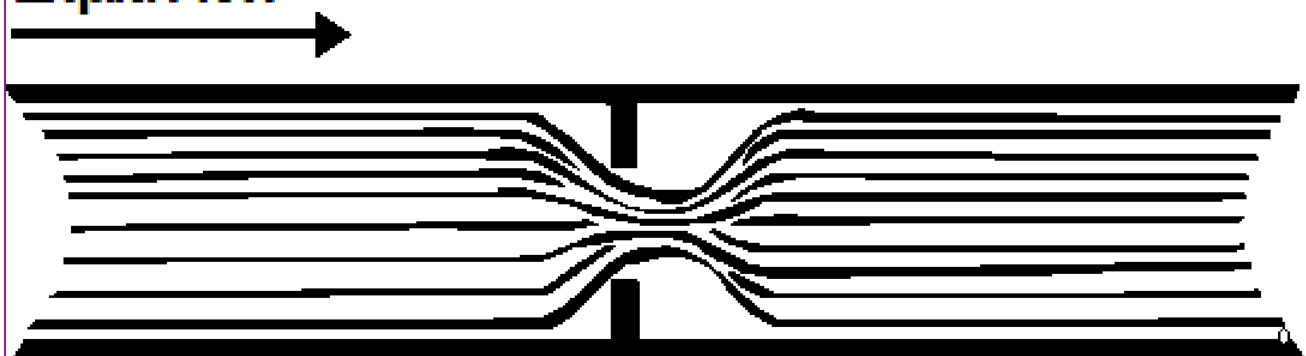


Pressure Drop

Available Energy to Produce Flow is the Pressure Drop

$$\Delta P = P_1 - P_2$$

Liquid Flow



P_1 = 100 psig

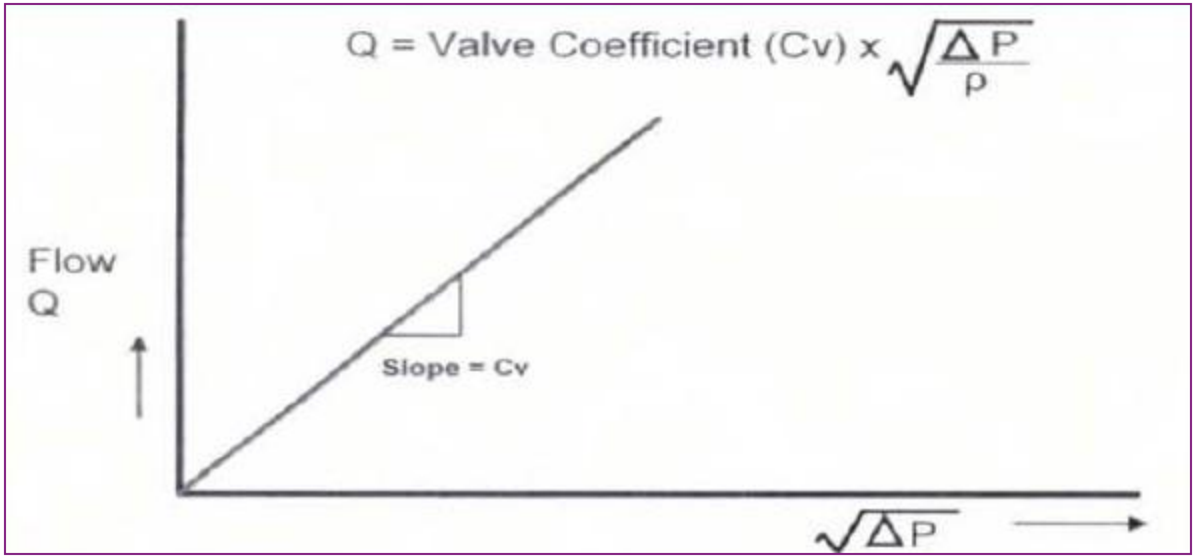
P_2 = 75 psid

ΔP = 100 psig - 75 psig = 25 psig

CONTROL VALVE SIZING

Flow Capacity Coefficient Cv

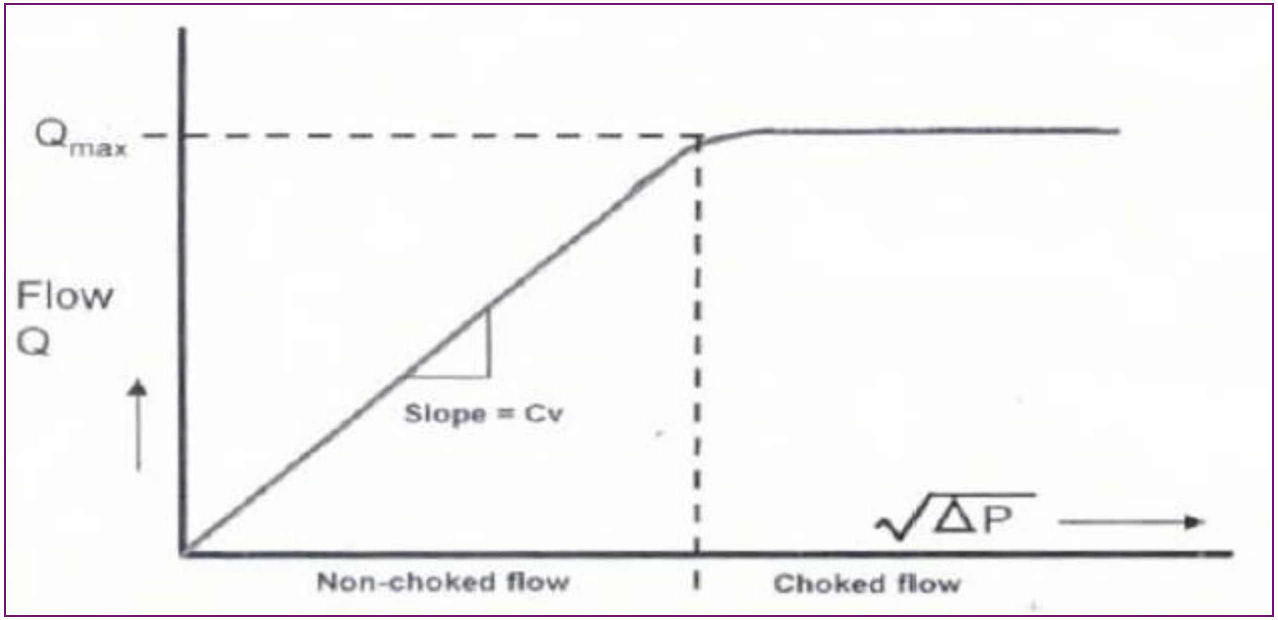
Hence we can show that the flow versus square root or pressure drop relationship for any valve is given in the form shown as a straight line with slope Cv .



CONTROL VALVE SIZING

Choked flow conditions (critical flow)

Choked flow is also known as critical flow and It occurs when an increase in pressure drop across the valve no longer creates an increase in flow.



CONTROL VALVE SIZING

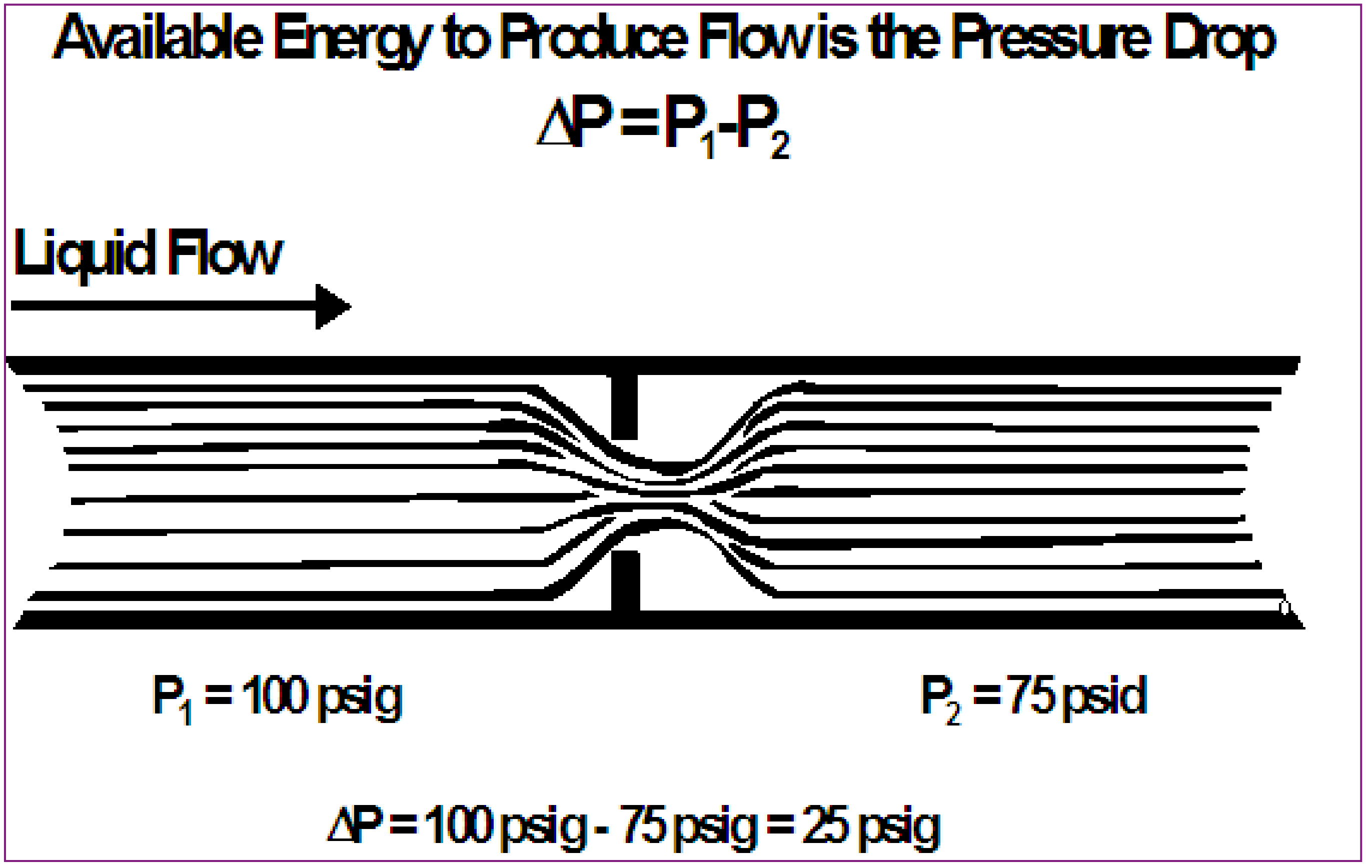
Choked flow conditions (critical flow)

In liquid applications the capacity of the valve is severely limited if the pressure conditions for a liquid are low enough to cause flashing and Cavitation.

For gases and vapors the capacity is limited if the velocity reaches the sonic velocity.

CONTROL VALVE SIZING

Pressure Drop



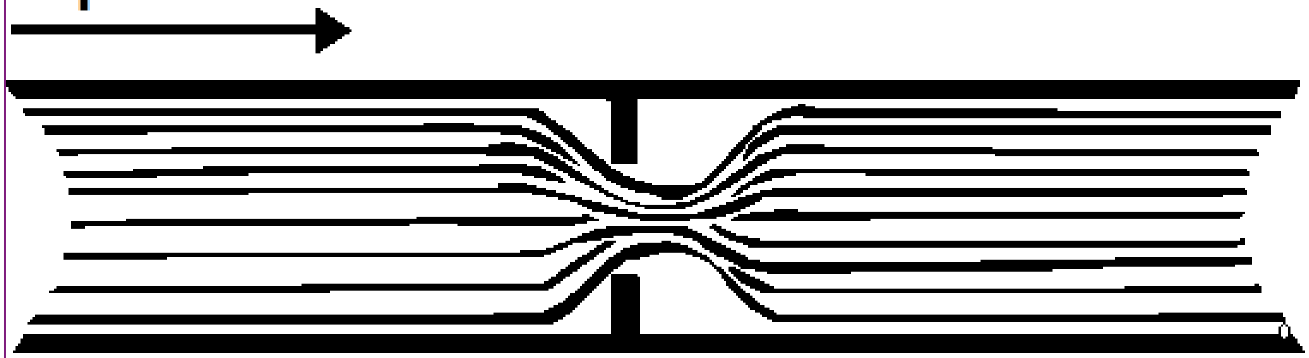
CONTROL VALVE SIZING

Pressure Drop

Available Energy to Produce Flow is the Pressure Drop

$\Delta P = P_1 - P_2$

Liquid Flow



$P_1 = 100$ psig

$P_2 = 75$ psid

$\Delta P = 100$ psig - 75 psig $= 25$ psig

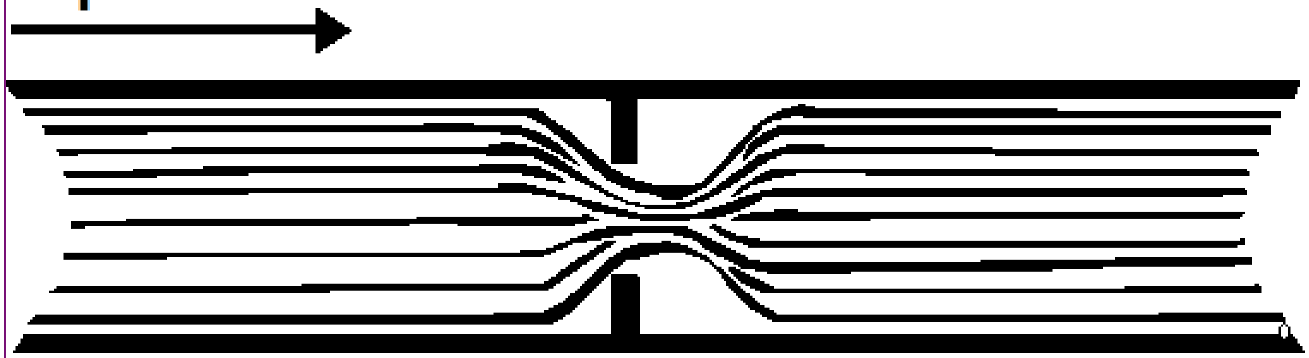
CONTROL VALVE SIZING

Pressure Drop

Available Energy to Produce Flow is the Pressure Drop

$$\Delta P = P_1 - P_2$$

Liquid Flow



P_1 = 100 psig P_2 = 75 psid

ΔP = 100 psig - 75 psig = 25 psig

CONTROL VALVE SIZING

Liquid sizing equation

$$Q = C_v \sqrt{\frac{P_1 - P_2}{G_f}}$$

$$C_v = \frac{q}{N_1 F_P \sqrt{\frac{P_1 - P_2}{G_f}}}$$

Q = Volumetric flow rate of liquid (gallons per minute, GPM)
Cv = Flow coefficient of valve
P1 = Upstream pressure of liquid (PSI)
P2 = Downstream pressure of liquid (PSI)
Gf = Specific gravity of liquid (ratio of liquid density to standard water density)

CONTROL VALVE SIZING

Liquid Design Equations

$$q = F_p C_v \sqrt{\Delta P / G}$$

$$w = 63.3\, F_p C_v \sqrt{\Delta P \gamma}$$

$$F_p = [\,(\Sigma K C_d^2 / 890) + 1\,]^{-1/2}$$

$$\Sigma K = K_1 + K_2 + K_{B1} - K_{B2}$$

$$K_{B1} = K_{B2} = 1 - \beta^4$$

$$K_1 \cong 0.5(1 - \beta^2)^2$$

$$K_2 \cong 1.0(1 - \beta^2)^2$$

$$C_d = C_v / d^2$$

$$\beta = d/D$$

$$\Delta P_{max} = F_L^2 (P_1 - F_F P_v)$$

$$F_F = 0.96 - 0.28 \sqrt{\frac{P_v}{P_c}}$$

P_1 = pressure upstream of valve
P_2 = pressure downstream of valve
ΔP_{max} = maximum effective pressure drop across valve
F_L = valve liquid pressure recovery factor
F_F = liquid critical pressure ratio factor
P_v = liquid vapour pressure at flowing temperature
P_c = liquid critical pressure

$$P_1 - P_2 < \Delta P_{max}$$

$$\Delta P_{eff} = P_1 - P_2$$

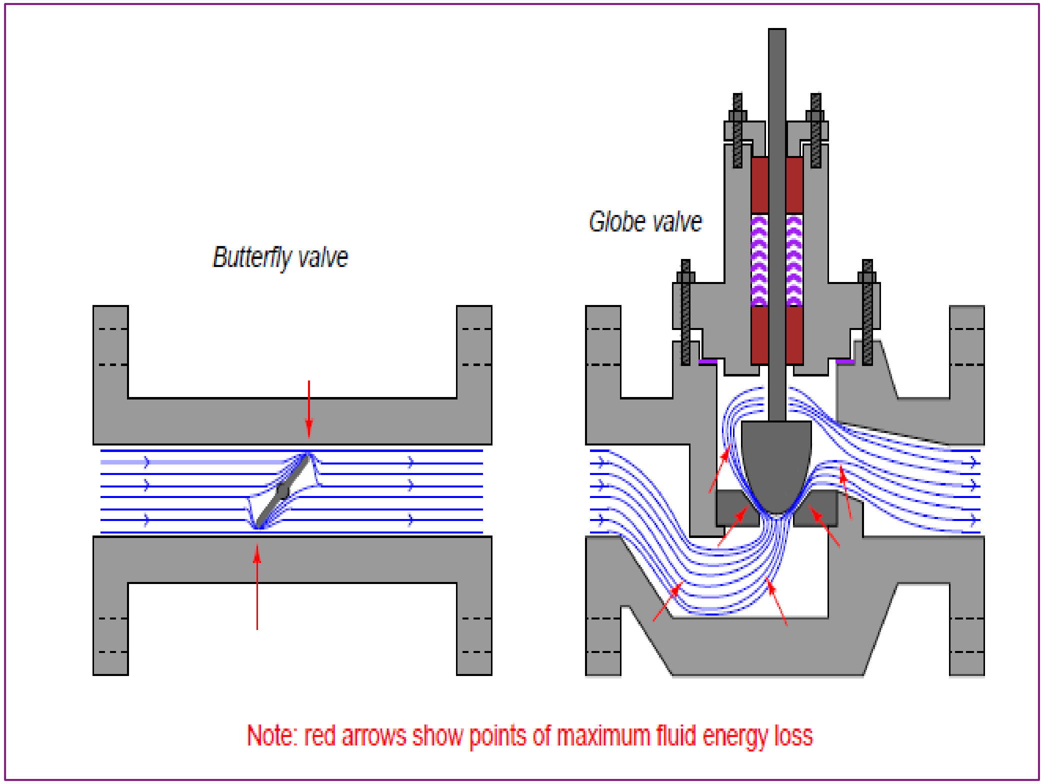
$$\Delta P_{eff} = \Delta P_{max}$$

CONTROL VALVE SIZING

Relative flow capacity

Not all control valve types exhibit the same Cv coefficients, however, for the same pipe size. A 4 inch butterfly valve, for example, has a much greater full-open Cv rating than a 4 inch globe valve, due to the much more direct path it offers to a moving fluid.

$$C_d = \frac{C_v}{d^2}$$



CONTROL VALVE SIZING

Typical values for relative flow coefficient

Valve design type	C_d
Single-port globe valve, ported plug	9.5
Single-port globe valve, contoured plug	11
Single-port globe valve, characterized cage	15
Double-port globe valve, ported plug	12.5
Double-port globe valve, contoured plug	13
Rotary ball valve, segmented	25
Rotary ball valve, standard port (diameter $\approx 0.8d$)	30
Rotary butterfly valve, 60^o, no offset seat	17.5
Rotary butterfly valve, 90^o, offset seat	29
Rotary butterfly valve, 90^o, no offset seat	40

CONTROL VALVE SIZING

Steps To Accurately Size A Liquid Control Valve

1. Specify the required design flow rate
2. Specify the allowable pressure drop across the valve
3. Choose a valve type and body size from the manufacturers' tables
4. Calculate the first estimate of the piping geometry factor
5. Determine if the flow through the valve will be sub-critical or critical. That is, will some of the liquid vaporise causing flashing or cavitation?
6. Calculate the effective pressure drop across the valve
7. Calculate the first estimate of the required valve Cv
8. Check that the calculated Cv is less than the actual Cv of the selected valve (re-select suitable valve from manufacturers' tables if required)
9. Check that valve control range is OK
10. If the Cv and control range are suitable the valve is correctly sized. If not re-select another valve and repeat the sizing procedure from Step 3

CONTROL VALVE SIZING

Control Valve Sizing Rules Of Thumb

1- Set the design flow as the greater of:
   1.3 x normal flow rate
   1.1 x maximum required flow rate

2- Set the control pressure drop to equal 50% – 60% of the frictional pressure loss of the piping system

3- Limit the maximum flow rate : minimum flow rate turndown to 5:1 for linear trim valves and 10:1 for equal percentage trim valves

4- The valve should be able to control the required range of flow rates between 10% and 80% of valve opening

5- Ideally select a valve that has a body size 1 pipe size smaller than the pipe in which it is to be installed (e.g. select a 3" valve for a 4" pipe)

6- Never select a valve larger than the pipe in which it is to be installed

CONTROL VALVE SIZING

What are the Control Valves sizing procedure?

STEP #1: Define the system

STEP #2: Define a maximum available (allowable) pressure drop for the valve

STEP #3: Calculate the valve flow coefficient

STEP #4: Preliminary valve selection

STEP #5: Check the Cv and stroke percentage at the minimum flow

STEP #6: Check the gain across applicable flow rates

Liquid Sizing Examples

Example 1

The following example has been adapted from the Emerson Control Valve Handbook.

We need to size a valve in liquid propane duty. The required information is given below:

Step 1 : Define the System

Design flow rate = 800 US gpm

Upstream pressure = 314.7 psia

Downstream pressure = 289.7 psia

Pressure drop across valve = 25 psi

Liquid temperature = 70F

Propane specific gravity = 0.5

Propane vapour pressure = 124.3 psia

Propane critical pressure = 616.3 psia

Pipe size = 4 inch

CONTROL VALVE SIZING

Liquid Sizing Examples

STEP #2 Define a maximum available (allowable) pressure drop for the valve

Pressure Drop = Upstream Pressure – Downstream Pressure
= 25 psi

CONTROL VALVE SIZING

Liquid Sizing Examples

STEP #3: Calculate the valve flow coefficient

$$C_v = Q\sqrt{\frac{G}{\Delta P}}$$

Note Fp & Fr =1

where:

Q = design flowrate (gpm)

G = specific gravity relative to water

ΔP = allowable pressure drop across wide open valve

$Cv = (800 / 1)(0.5 / 25)^{0.5} = 117.9$

CONTROL VALVE SIZING

Liquid Sizing Examples

STEP #4; Preliminary valve selection

We will choose an Emerson 3" ES globe valve with linear trim as the preliminary selection. From the valve table we can see that the actual Cv is 135 and FL is 0.89

CONTROL VALVE SIZING

Liquid Sizing Examples

Linear - Flow Up

Linear Characteristic

Valve Size, Inches	Port Diameter		Maximum Travel		Flow Coefficient	Valve Opening—Percent of Total Travel										F_L (1)
	Inches	mm	Inches	mm		10	20	30	40	50	60	70	80	90	100	
1 & 1-1/4	1-5/16	33.3	3/4	19	C_v	2.27	4.12	6.23	8.54	11.0	13.4	15.8	17.8	19.3	20.1	0.89
					K_v	*1.96*	*3.56*	*5.39*	*7.39*	*9.52*	*11.6*	*13.7*	*15.4*	*16.7*	*17.4*	- - -
					X_T	0.691	0.691	0.690	0.696	0.696	0.708	0.709	0.705	0.702	0.690	- - -
1-1/2	1-7/8	47.6	3/4	19	C_v	3.56	7.01	11.1	15.1	19.0	22.9	26.7	30.0	33.1	34.9	0.92
					K_v	*3.08*	*6.06*	*9.60*	*13.1*	*16.4*	*19.8*	*23.1*	*25.9*	*28.6*	*30.2*	- - -
					X_T	0.628	0.582	0.604	0.647	0.683	0.699	0.715	0.737	0.741	0.764	- - -
	1-5/16	33.3	3/4	19	C_v	2.42	4.30	6.40	8.77	11.5	14.6	17.8	21.1	24.3	26.9	0.95
					K_v	*2.09*	*3.72*	*5.54*	*7.59*	*9.95*	*12.6*	*15.4*	*18.3*	*21.0*	*23.3*	- - -
					X_T	0.648	0.682	0.712	0.693	0.664	0.678	0.701	0.732	0.756	0.799	- - -
2	2-5/16	58.7	1-1/8	29	C_v	8.49	17.1	25.9	35.3	44.4	52.9	59.2	62.0	63.9	65.3	0.91
					K_v	*7.34*	*14.8*	*22.4*	*30.5*	*38.4*	*45.8*	*51.2*	*53.6*	*55.3*	*56.5*	- - -
					X_T	0.618	0.635	0.689	0.710	0.723	0.732	0.742	0.759	0.761	0.762	- - -
	1-5/16	33.3	3/4	19	C_v	2.22	4.11	6.06	8.25	11.0	14.3	18.0	21.8	26.0	30.9	0.91
					K_v	*1.92*	*3.56*	*5.24*	*7.14*	*9.52*	*12.4*	*15.6*	*18.9*	*22.5*	*26.7*	- - -
					X_T	0.725	0.694	0.729	0.746	0.688	0.675	0.667	0.686	0.711	0.722	- - -
2-1/2	2-7/8	73.0	1-1/2	38	C_v	10.4	22.2	34.9	47.1	58.2	66.6	73.7	79.3	84.4	86.5	0.93
					K_v	*9.00*	*19.2*	*30.2*	*40.7*	*50.3*	*57.6*	*63.8*	*68.6*	*73.0*	*74.8*	- - -
					X_T	0.672	0.727	0.739	0.776	0.783	0.832	0.858	0.877	0.854	0.866	- - -
	1-7/8	47.6	3/4	19	C_v	3.50	6.85	10.8	14.8	18.9	23.3	28.2	34.1	41.1	48.6	0.93
					K_v	*3.03*	*5.93*	*9.34*	*12.8*	*16.3*	*20.2*	*24.4*	*29.5*	*35.6*	*42.0*	- - -
					X_T	0.617	0.627	0.679	0.716	0.740	0.752	0.783	0.774	0.778	0.783	- - -
3	3-7/16	87.3	1-1/2	38	C_v	15.3	34.3	52.8	71.4	87.8	101	112	121	129	135	0.89
					K_v	*13.2*	*29.7*	*45.7*	*61.8*	*75.9*	*87.4*	*96.9*	*105*	*112*	*117*	- - -
					X_T	0.607	0.631	0.663	0.694	0.720	0.742	0.762	0.786	0.771	0.751	- - -
	2-5/16	58.7	1-1/8	29	C_v	6.39	13.0	20.7	29.1	38.2	47.9	58.0	68.4	79.3	88.8	0.91
					K_v	*5.53*	*11.2*	*17.9*	*25.2*	*33.0*	*41.4*	*50.2*	*59.2*	*68.6*	*76.8*	- - -
					X_T	0.662	0.677	0.704	0.677	0.648	0.646	0.643	0.658	0.714	0.742	- - -

1. At 100% travel.
2. If coefficients listed above for the 8 inch linear cage with 2 inch (51 mm) travel are not sufficient for your application, consider using the quick opening cage. The 8 inch quick opening cage with 2 inch (51 mm) travel has approximately a linear characteristic.

Restricted trim.

CONTROL VALVE SIZING

Liquid Sizing Examples

Don't make the mistake of trying to match a valve with your calculated Cv value. The Cv value should be used as a guide in the valve selection, not a hard and fast rule. Some other considerations are:

a. Never use a valve that is less than half the pipe size

b. Avoid using the lower 10% and upper 20% of the valve stroke. The valve is much easier to control in the 10-80% stroke range.

For our case, it appears the 3 inch valve will work well for our Cv value at about 70-80% of the stroke range.

Notice that we're not trying to squeeze our Cv into the 3 inch valve which would need to be more than 100% stroke to handle our maximum flow.

The calculated required Cv of 113.1 is less than the actual Cv of the selected valve of 135 so the valve is large enough.

CONTROL VALVE SIZING

Liquid Sizing Examples

Calculating Piping Geometry Factor. Fp

$$F_p = \left[1 + \frac{\sum K}{890}\left(\frac{Cv}{d_{\text{valve}}^2}\right)^2\right]^{-0.5}$$

$\sum K$ = sum of fittings factors

d_{valve} = control valve body nominal size (inches)

Cv = Cv of selected control valve

$$\sum K = 1.5\left(1 - \frac{d_{\text{valve}}^2}{d_{\text{pipe}}^2}\right)^2$$

d_{pipe} = piping nominal diameter (inches)

We will assume that 4” x 3” reducers will be used to install the selected 3” valve in the 4” pipe. In this case the piping geometry factor is:

$\Sigma K = 1.5\ (1 - (3^2 / 4^2))^2 = 0.287$

$F_P = [1 + (0.287 / 890)(135 / 3^2)^2]^{-0.5} = 0.96$

CONTROL VALVE SIZING

Liquid Sizing Examples

Check if flow through the valve is sub-critical or critical:

$F_F = 0.96 – 0.28\ (124.3 / 616.3) = 0.83$

$DP_{max} = (0.89)^2\ (314.7 – 0.83 \times 124.3) = 167.6$ psi

$P_1 – P_2 = 314.7 – 289.7 = 25$ psi

Therefore: $P_1 – P_2 < DP_{max}$ so the flow is sub-critical

The effective pressure drop across the valve is $P_1 – P_2$ because the flow is sub-critical

$DP_{eff} = 25$ psi

CONTROL VALVE SIZING

Liquid Sizing Examples

Calculate the first estimate of Cv:

$Cv = (800 / 0.96)(0.5 / 25)^{0.5} = 117.9$

The calculated required Cv of 117.9 is less than the actual Cv of the selected valve of 135 so the valve is large enough

Check if the control valve range is OK:

From the valve table, the selected valve will be about 75% open to give the required Cv of 117.9. This is within the acceptable control range of 10% to 80% of valve opening.

The selected 3” linear trim valve is correctly sized for the specified duty

Example 2

STEP #1: Define the system

The system is pumping water from one tank to another through a piping system with a total pressure drop of 150 psi. The fluid is water at 70 ^{0}F. Design (maximum) flowrate of 150 gpm, operating flowrate of 110 gpm, and a minimum flowrate of 25 gpm. The pipe diameter is 3 inches. At 70 ^{0}F, water has a specific gravity of 1.0.

Key Variables: Total pressure drop, design flow, operating flow, minimum flow, pipe diameter, specific gravity

CONTROL VALVE SIZING

Example 2

STEP #2: Define a maximum allowable pressure drop for the valve

When defining the allowable pressure drop across the valve, you should first investigate the pump. What is its maximum available head? Remember that the system pressure drop is limited by the pump. Essentially the Net Positive Suction Head Available (NPSHA) minus the Net Positive Suction Head Required (NPSHR) is the maximum available pressure drop for the valve to use and this must not be exceeded or another pump will be needed.

The usual rule of thumb is that a valve should be designed to use 10-15% of the total pressure drop or 10 psi, whichever is greater. For our system, 10% of the total pressure drop is 15 psi which is what we'll use as our allowable pressure drop when the valve is wide open (the pump is our system is easily capable of the additional pressure drop).

CONTROL VALVE SIZING

Example 2

STEP #3: Calculate the valve characteristic

For our system,

$$C_v = Q\sqrt{\frac{G}{\Delta P}}$$

where:

Q = design flowrate (gpm)

G = specific gravity relative to water

ΔP = allowable pressure drop across wide open valve

$$C_v = 150\sqrt{\frac{1}{15}} = 38.7 \cong 39$$

CONTROL VALVE SIZING

Example 2

STEP #4: Preliminary valve selection

FLOW CHARAC-TERISTIC	VALVE SIZE		MAXI-MUM TRAVEL	PORT DIA.	DESIGNS ED AND ET (FLOW DOWN)					DESIGN ES (FLOW UP)				
					Valve Opening, Percent of Total Travel									
					10	30	70	100	100	10	30	70	100	100
	DIN	Inches	mm	mm	C_v				F_L	C_v				F_L
Equal Percentage	DN 25	1, 1-1/4	19	33.3	.783	2.20	7.83	17.2	.88	.783	1.86	9.54	17.4	.95
	DN 40	1-1/2	19	47.6	1.52	3.87	17.4	35.8	.84	1.54	3.57	17.2	33.4	.94
	DN 50	2	29	58.7	1.66	4.66	25.4	59.7	.85	1.74	4.72	25.0	56.2	.92
	DN 65	2-1/2	38	73.0	3.43	10.8	49.2	99.4	.84	4.05	10.6	45.5	82.7	.93
	DN 80	3	38	87.3	4.32	10.9	66.0	136	.82	4.05	10.0	59.0	121	.89
	DN 100	4	51	111.1	5.85	18.3	125	224	.82	6.56	17.3	103	203	.91
	DN 150	6	51	177.8	12.9	43.3	239	394	.85	13.2	41.1	223	357	.86
	DN 200	8	76	203.2	27.0	105	605	818	.96	25.9	97.8	618	808	.85
					X_T				- - -	X_T				- - -
	DN 25	1, 1-1/4	19	33.3	.766	.587	.743	.667	- - -	.754	.763	.630	.721	- - -
	DN 40	1-1/2	19	47.6	.780	.716	.690	.679	- - -	.674	.694	.698	.793	- - -
	DN 50	2	29	58.7	.827	.774	.702	.687	- - -	.863	.849	.792	.848	- - -
	DN 65	2-1/2	38	73.0	.778	.678	.661	.660	- - -	.747	.745	.783	.878	- - -
	DN 80	3	38	87.3	.774	.682	.663	.675	- - -	.768	.761	.754	.757	- - -
	DN 100	4	51	111.1	.731	.643	.672	.716	- - -	.722	.739	.718	.822	- - -
	DN 150	6	51	177.8	.688	.682	.736	.778	- - -	.723	.767	.808	.816	- - -
	DN 200	8	76	203.2	.644	.636	.725	.807	- - -	.825	.681	.735	.827	

CONTROL VALVE SIZING

Design in steps

1. Specify the variables required to size the valve as follows
2. Determine the equation constant, N
3. Determine Fp, the piping geometry factor
4. Determine Qmax or ΔPmax
5. Solve for required Cv, using the appropriate equation:
6. Select the valve size using the appropriate flow coefficient table and the calculated Cv value.

CONTROL VALVE SIZING

Design steps in details

STEP 1

Specify the variables required to size the valve as follows:

Desired design: refer to the appropriate valve flow coefficient table.
Process fluid (water, oil, etc.).

Appropriate service conditions q or w, P1, P2 or ΔP, T1, Gf, Pv, Pc, and υ

CONTROL VALVE SIZING

STEP 2

Determine the equation constant, N. N is a numerical constant contained in each of the flow equations to provide a means for using different systems of units.

		N	w	q	$p^{(2)}$	γ	T	d, D
N_1		0.0865 0.865 1.00	- - - - - - - - -	m^3/h m^3/h gpm	kPa bar psia	- - - - - - - - -	- - - - - - - - -	- - - - - - - - -
N_2		0.00214 890	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	mm inch
N_5		0.00241 1000	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	mm inch
N_6		2.73 27.3 63.3	kg/h kg/h lb/h	- - - - - - - - -	kPa bar psia	kg/m^3 kg/m^3 lb/ft^3	- - - - - - - - -	- - - - - - - - -
$N_7^{(3)}$	Normal Conditions $T_N = 0°C$	3.94 394	- - - - - -	m^3/h m^3/h	kPa bar	- - - - - -	deg K deg K	- - - - - -
	Standard Conditions $T_s = 15.5°C$	4.17 417	- - - - - -	m^3/h m^3/h	kPa bar	- - - - - -	deg K deg K	- - - - - -
	Standard Conditions $T_s = 60°F$	1360	- - -	scfh	psia	- - -	deg R	- - -
N_8		0.948 94.8 19.3	kg/h kg/h lb/h	- - - - - - - - -	kPa bar psia	- - - - - - - - -	deg K deg K deg R	- - - - - - - - -
$N_9^{(3)}$	Normal Conditions $T_N = 0°C$	21.2 2120	- - - - - -	m^3/h m^3/h	kPa bar	- - - - - -	deg K deg K	- - - - - -
	Standard Conditions $Ts = 15.5°C$	22.4 2240	- - - - - -	m^3/h m^3/h	kPa bar	- - - - - -	deg K deg K	- - - - - -
	Standard Conditions $T_S = 60°F$	7320	- - -	scfh	psia	- - -	deg R	- - -

CONTROL VALVE SIZING

STEP 3

Determine Fp, the piping geometry factor

$$Fp = \left[1 + \frac{\Sigma K}{N_2}\left(\frac{C_v}{d^2}\right)^2\right]^{-1/2}$$

$$K_1 + K_2 = 1.5\left(1 - \frac{d^2}{D^2}\right)^2$$

$$\Sigma K = K_1 + K_2 + K_{B1} - K_{B2}$$

where,

K_1 = Resistance coefficient of up-stream fittings

K_2 = Resistance coefficient of downstream fittings

K_{B1} = Inlet Bernoulli coefficient

K_{B2} = Outlet Bernoulli coefficient

$$K_{B1} \text{ or } K_{B2} = 1 - \left(\frac{d}{D}\right)^4$$

CONTROL VALVE SIZING

STEP 4

Determine qmax (the maximum flow rate at given upstream conditions) or ΔPmax (the allowable sizing pressure drop).

STEP 5

Solve for required Cv, using the appropriate equation:

- For volumetric flow rate units—

$$C_v = \frac{q}{N_1 F_p \sqrt{\frac{P_1 - P_2}{G_f}}}$$

STEP 6

Select the valve size using the appropriate flow coefficient table and the calculated Cv value.

CONTROL VALVE SIZING

Gas sizing equations

$$C_v = \frac{q}{N_7 \ F_p \ P_1 \ Y \sqrt{\frac{x}{G_g \ T_1 \ Z}}}$$

q = Gas flow rate, in units of Standard Cubic Feet per Hour (SCFH)
Cv = Valve capacity coefficient
ΔP = Pressure dropped across valve, pounds per square inch differential (PSID)
P1 = Upstream valve pressure, pounds per square inch absolute (PSIA)
P2 = Downstream valve pressure, pounds per square inch absolute (PSIA)
Gg = Specific gravity of gas (ratio of gas density to standard air density)
T1 = Absolute temperature of gas in degrees Rankine (oR), equal to degrees Fahrenheit plus 459.67
Fp = the piping geometry factor.
Y = expanison factor
Z = compressibility factor

CONTROL VALVE SIZING

Y the expansion factor

This coefficient allows to use for compressible fluids the same equation structure valid for incompressible fluids. Used to compensate for volume expansion for compressible fluids after pressure head decreases .

$$Y = 1 - \frac{x}{3F_k\ x_T}$$

Fk = k/1.4, the ratio of specific heats factor

k = Ratio of specific heats

x = ΔP/P1, the pressure drop ratio

xT = The pressure drop ratio factor for valves installed without attached fittings. More definitively, xT is the pressure drop ratio required to produce critical, or maximum, flow through the valve when Fk = 1.0

CONTROL VALVE SIZING

The Ratio of Specific Heats

The Ratio of Specific Heats can be expressed as:

$$k = c_p / c_v$$

Gas	Ratio of Specific Heats
Acetylene	1.30
Air, Standard	1.40
Ammonia	1.32
Argon	1.66
Benzene	1.12
N-butane	1.18
Iso-butane	1.19
Carbon Dioxide	1.28
Carbon Disulphide	1.21
Carbon Monoxide	1.40
Chlorine	1.33
Ethane	1.18
Ethyl alcohol	1.13
Ethyl chloride	1.19
Ethylene	1.24
Helium	1.66
N-heptane	1.05
Hexane	1.06
Hydrochloric acid	1.41
Hydrogen	1.41
Hydrogen chloride	1.41
Hydrogen sulphide	1.32
Methane	1.32
Methyl alcohol	1.20
Methyl butane	1.08
Methyl chloride	1.20
Natural Gas (Methane)	1.32

CONTROL VALVE SIZING

XTP the Pressure Drop Ratio Factor

xTP is the same coefficients xT however determined on valves supplied with reducers or installed not in according to the standard set up.

$$x_{TP} = \frac{x_T}{F_p^{\,2}}\left[1 + \frac{x_T\,K_i}{N_5}\left(\frac{C_v}{d^2}\right)^2\right]^{-1}$$

N5 = Numerical constant found in the Equation Constants table

d = Assumed nominal valve size

Cv = Valve sizing coefficient from flow coefficient table at 100 percent travel for the assumed valve size

Fp = Piping geometry factor

xT = Pressure drop ratio for valves installed without fittings attached.

xT values are included in the flow coefficient tables

CONTROL VALVE SIZING

Pressure drop limit !

pressure drop are realized when the value of x becomes equal to or exceeds the appropriate value of the product of either Fk xT or Fk xTP at which point:

$$y = 1 - \frac{x}{3F_k\ x_T} = 1 - 1/3 = 0.667$$

Although in actual service, pressure drop ratios can, and often will exceed the indicated critical values, this is the point where critical flow conditions develop Thus, for a constant P1, decreasing P2 (i.e., increasing P) will not result in an increase in the flow rate through the valve. Values of x, therefore, greater than the product of either **FkxT or FkxTP** must never be substituted in the expression for Y.

This means that Y can never be less than 0.667. This same limit on values of x also applies to the flow equations that are introduced in the next section.

CONTROL VALVE SIZING

Compressibility factor (Z)

The compressibility factor (Z), also known as the compression factor, is the ratio of the molar volume of a gas to the molar volume of an ideal gas at the same temperature and pressure. It is a useful thermodynamic property for modifying the ideal gas law to account for the real gas behavior.

$$\boxed{Z = \frac{pV}{RT}}$$

CONTROL VALVE SIZING

Sizing for gases in steps

1. Specify the variables required to size the valve
2. Determine the equation constant, N
3. Determine Fp, the piping geometry factor
4. Determine Y, the expansion factor.
5. Solve for required Cv, using the appropriate equation:
6. Select the valve size using the appropriate flow coefficient table and the calculated Cv value.

CONTROL VALVE SIZING

Sizing for gases in steps

Example

We need to size a valve in steam duty. The required information is given below:

Design flow rate = 125000 lb/hr = 56689 kg/hr

Upstream pressure = 500 psig = 35.50 bara

Downstream pressure = 250 psig = 18.26 bara

Pressure drop across valve = 250 psi = 17.24 bar

Upstream steam temperature = 500F

Density of steam at upstream conditions = 1.0434 lb/ft^3 = 16.71 kg/m^3

Steam ratio of specific heat capacities = 1.28

Pipe size = 6 inch

CONTROL VALVE SIZING

Sizing for gases in steps

Example

Calculation

Design flow rate = 56689 kg/hr

Allowable pressure drop across the valve = 17.24 bar

We will choose an Emerson 4" ED globe valve with linear cage as the preliminary selection. From the valve table we can see that the actual Cv is 236 and X_{TP} is 0.688

CONTROL VALVE SIZING

Sizing for gases in steps
Valve specification

Linear — Linear Characteristic

Valve Size, NPS	Port Diameter mm	Port Diameter Inches	Maximum Travel[2] mm	Maximum Travel[2] Inches	Flow Coefficient	10	20	30	40	50	60	70	80	90	100	F_L[1]
1	33.3	1.3125	19	0.75	C_v	3.21	5.50	8.18	10.9	13.2	15.0	16.9	18.6	19.9	20.6	0.84
					K_v	*2.78*	*4.76*	*7.08*	*9.43*	*11.4*	*13.0*	*14.6*	*16.1*	*17.2*	*17.8*	- - -
					X_T	0.340	0.644	0.494	0.509	0.532	0.580	0.610	0.629	0.628	0.636	- - -
1-1/2	47.6	1.875	19	0.75	C_v	4.23	7.84	11.8	15.8	20.4	25.3	30.3	34.7	37.2	39.2	0.82
					K_v	*3.66*	*6.78*	*10.2*	*13.7*	*17.6*	*21.9*	*26.2*	*30.0*	*32.2*	*33.9*	- - -
					X_T	0.656	0.709	0.758	0.799	0.738	0.729	0.708	0.686	0.683	0.656	- - -
					F_d	0.30	0.37	0.41	0.44	0.44	0.41	0.38	0.35	0.34	0.34	- - -
	33.3 (3)	1.3125 (3)	19	0.75	C_v	2.92	5.70	9.05	12.5	15.6	18.5	21.1	23.9	26.8	29.2	0.91
					K_v	*2.53*	*4.93*	*7.83*	*10.8*	*13.5*	*16.0*	*18.3*	*20.7*	*23.2*	*25.3*	- - -
					X_T	0.690	0.651	0.633	0.634	0.650	0.666	0.708	0.718	0.737	0.733	- - -
2	58.7	2.3125	29	1.125	C_v	7.87	16.0	24.9	33.4	42.1	51.8	62.0	68.1	70.6	72.9	0.77
					K_v	*6.81*	*13.8*	*21.5*	*28.9*	*36.4*	*44.8*	*53.6*	*58.9*	*61.1*	*63.1*	- - -
					X_T	0.641	0.720	0.728	0.767	0.793	0.754	0.683	0.658	0.652	0.638	- - -
					F_d	0.30	0.35	0.36	0.37	0.37	0.36	0.35	0.35	0.34	0.33	- - -
	33.3 (3)	1.3125 (3)	19	0.75	C_v	3.53	6.36	9.92	13.3	16.5	19.7	22.7	25.6	29.3	33.3	0.87
					K_v	*3.05*	*5.50*	*8.58*	*11.5*	*14.3*	*17.0*	*19.6*	*22.1*	*25.3*	*28.8*	- - -
					X_T	0.456	0.529	0.549	0.582	0.611	0.633	0.671	0.723	0.727	0.694	- - -
2-1/2	73.0	2.875	38	1.5	C_v	9.34	21.6	35.5	49.5	62.7	74.1	83.6	93.5	102	108	0.81
					K_v	*8.08*	*18.7*	*30.7*	*42.8*	*54.2*	*64.1*	*72.3*	*80.9*	*88.2*	*93.4*	- - -
					X_T	0.680	0.660	0.644	0.669	0.674	0.706	0.716	0.687	0.658	0.641	- - -
					F_d	0.27	0.33	0.35	0.36	0.35	0.34	0.32	0.29	0.27	0.27	- - -
	47.6 (3)	1.875 (3)	19	0.75	C_v	4.10	8.09	12.3	16.7	21.1	26.8	33.7	41.3	49.2	57.0	0.84
					K_v	*3.55*	*7.00*	*10.6*	*14.4*	*18.3*	*23.2*	*29.2*	*35.7*	*42.6*	*49.3*	- - -
					X_T	0.668	0.646	0.684	0.688	0.698	0.694	0.678	0.668	0.669	0.666	- - -
3	87.3	3.4375	38	1.5	C_v	14.5	32.9	52.1	70.4	88.5	105	118	133	142	148	0.82
					K_v	*12.5*	*28.5*	*45.1*	*60.9*	*76.6*	*90.8*	*102*	*115*	*123*	*128*	- - -
					X_T	0.671	0.699	0.697	0.720	0.733	0.718	0.707	0.650	0.630	0.620	- - -
					F_d	0.26	0.32	0.35	0.36	0.36	0.36	0.36	0.28	0.29	0.30	- - -
	58.7 (3)	2.3125 (3)	29	1.125	C_v	8.06	16.9	26.7	37.5	49.0	61.4	73.8	85.3	94.7	102	0.85
					K_v	*6.97*	*14.6*	*23.1*	*32.4*	*42.4*	*53.1*	*63.8*	*73.8*	*81.9*	*88.2*	- - -
					X_T	0.592	0.614	0.662	0.672	0.674	0.676	0.694	0.722	0.736	0.732	- - -
4	111.1	4.375	51	2	C_v	23.3	50.3	78.1	105	127	152	181	203	223	236	0.82
					K_v	*20.2*	*43.5*	*67.6*	*90.8*	*110*	*131*	*157*	*176*	*193*	*204*	- - -
					X_T	0.691	0.714	0.720	0.731	0.764	0.757	0.748	0.762	0.732	0.688	- - -
					F_d	0.31	0.36	0.38	0.38	0.37	0.35	0.32	0.30	0.27	0.28	- - -
	73.0 (3)	2.875 (3)	38	1.5	C_v	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
					K_v	*8.45*	*19.5*	*32.2*	*44.8*	*56.8*	*67.0*	*75.7*	*84.7*	*92.6*	*97.7*	- - -
					X_T	0.926	0.899	0.873	0.904	0.919	0.962	0.972	0.937	0.891	0.872	- - -

CONTROL VALVE SIZING

Sizing for gases in steps

Example

We will assume that 6” x 4” reducers will be used to install the selected 4” valve in the 6” pipe. In this case the piping geometry factor is:

$\Sigma K = 1.5\ (1 - (4^2 / 6^2))^2 = 0.463 F_P = [1 + (0.463 / 890)(236 / 4^2)^2]^{-0.5} = 0.95$

The pressure drop ratio factor, $X_T = 0.688$

The inlet fittings head loss coefficient is:

$K_i = 0.5\ (1 - (4^2 / 6^2))^2 + 1 - (4 / 6)^4 = 0.957$

So the modified pressure drop ratio factor is:

$X_{TP} = 0.688 / 0.95^2[1 + 0.688 \times 0.957 / 1000\ (236 / 4^2)^2]^{-1} = 0.667$

CONTROL VALVE SIZING

Sizing for gases in steps

Check if flow through the valve is sub-critical or critical:

F_k = 1.28 / 1.4 = 0.91F_k X_{TP} = 0.91 x 0.667 = 0.607(P_1 – P_2) / P_1 = (35.50 – 18.26) / 35.50 = 0.486

Therefore: (P_1 – P_2) / P_1 < F_k X_{TP} so the flow is sub-critical

The effective pressure drop ratio across the valve is (P_1 – P_2) / P_1 because the flow is sub-critical:

X_{eff} = 0.486

Calculate the expansion factor:

Y = 1 – 0.486 / (3 x 0.91 x 0.667) = 0.733

CONTROL VALVE SIZING

Sizing for gases in steps

Calculate the first estimate of Cv:

$Cv = 56689 / (27.3 \times 0.95 \times 0.733 (0.486 \times 35.50 \times 16.71)^{0.5}) = 175.6$

The calculated required Cv of 175.6 is less than the actual Cv of the selected valve of 236 so the valve is large enough

Check if the control valve range is OK:

From the valve table, the selected valve will be a just less 70% open to give the required Cv of 175.6. This is within the acceptable control range of 10% to 80% of valve opening.

The selected 4" linear cage valve is correctly sized for the specified duty

Result

The selected valve is an Emerson 4" ED globe valve with linear trim and a maximum Cv of 236.

CONTROL VALVE ENGINEERING PROBLEMS

CONTROL VALVE ENGINEERING PROBLEMS

Stiction

Stiction is the combination of the words "stick" and "friction".

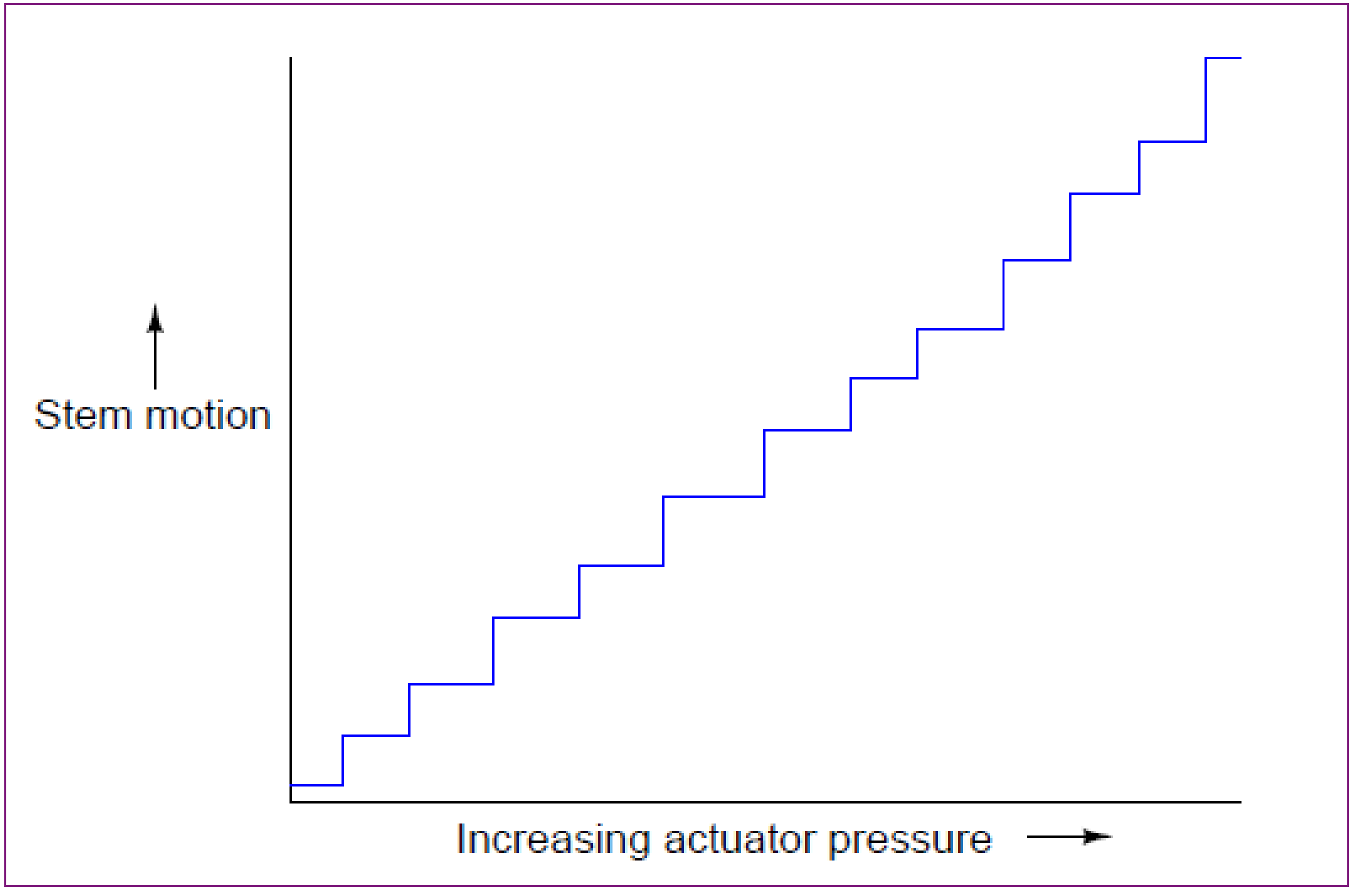
Friction is classified as either static or dynamic.

When stiction is present it will keep a valve from moving for small changes in its position command, and then when enough force is applied the actuator overcomes the initial resistance and the valve jumps to a new position.

Stiction is often the result of an actuator that is undersized or excessive friction in the valve packing.

CONTROL VALVE ENGINEERING PROBLEMS

How stiction affect valve movement

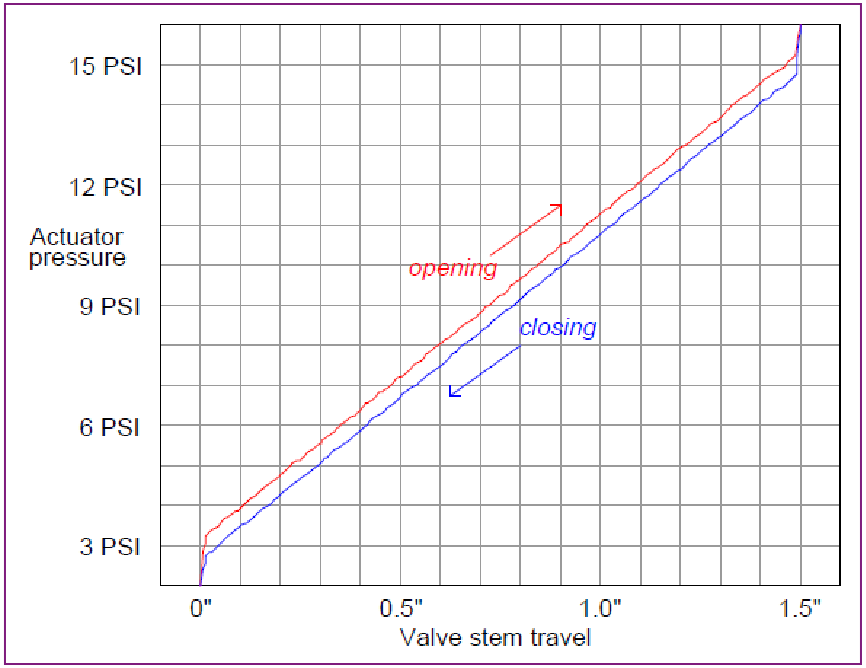


CONTROL VALVE ENGINEERING PROBLEMS

Solutions

Avoid over tighten packing assembly to help in stopping leakage .

Smart positioners can adjust force supplied to actuator stem to help in improving stiction problem



CONTROL VALVE ENGINEERING PROBLEMS

Flashing

When a fluid passes through the constrictive passageways of a control valve, its average velocity increases.

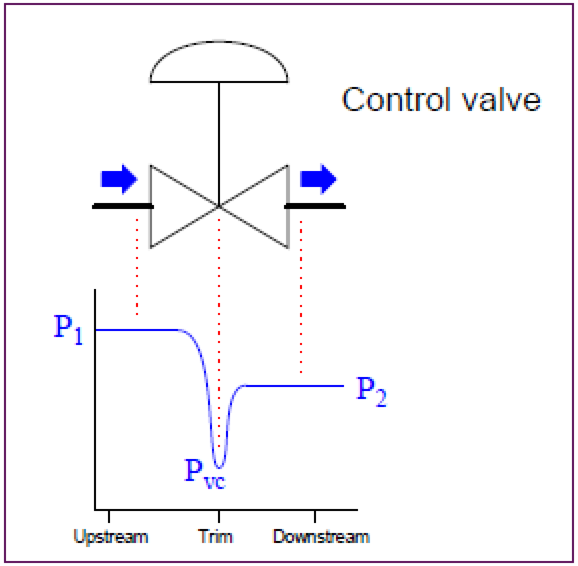
This is predicted by the Law of Continuity, which states that the product of fluid density (ρ), cross-sectional area of flow (A), and velocity (v) must remain constant for any flowstream:

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

As fluid velocity increases through the constrictive passages of a control valve, the fluid molecules' kinetic energy increases. In accordance with the Law of Energy Conservation, potential energy in the form of fluid pressure must decrease correspondingly.

What is flashing ?

If the fluid being throttled by the valve is a liquid (as opposed to a gas or vapor), and its absolute pressure ever falls below the vapor pressure of that substance, the liquid will begin to boil. This phenomenon, when it happens inside a control valve, is called flashing.



Flashing is almost universally undesirable in control valves. The effect of boiling liquid at the point of maximum constriction is that flow through the valve becomes "choked" by the rapid expansion of liquid to vapor as it boils, severely inhibiting the total flow rate allowed through the valve. Flashing is also destructive to the valve trim, as boiling action propels tiny droplets of liquid at extremely high velocities past the plug and seat faces, eroding the metal over time.

CONTROL VALVE ENGINEERING PROBLEMS

Pressure recovery factor

This factor compares the valve's total pressure drop from inlet to outlet versus the pressure drop from inlet to the point of minimum pressure within the valve.

$$F_L = \sqrt{\frac{P_1 - P_2}{P_1 - P_{vc}}}$$

Where,

FL = Pressure recovery factor (unitless)

P1 = Absolute fluid pressure upstream of the valve

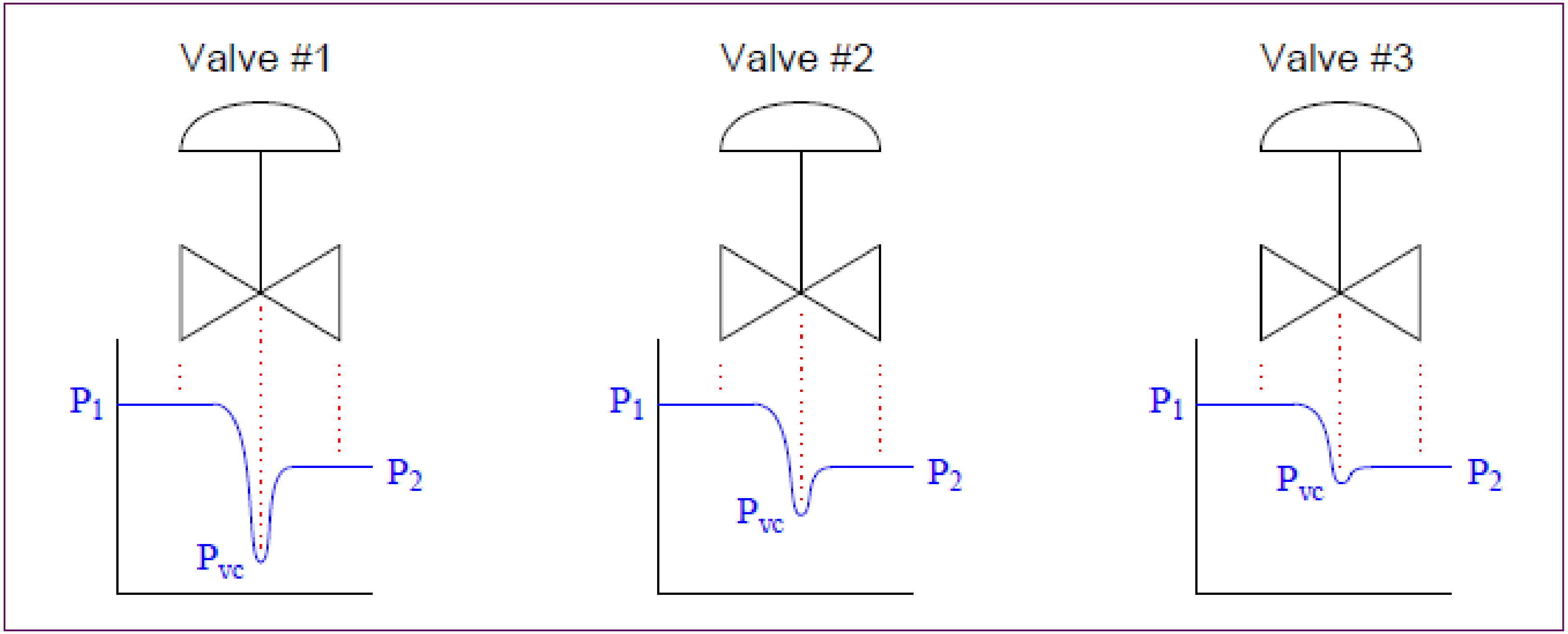
P2 = Absolute fluid pressure downstream of the valve

Pvc = Absolute fluid pressure at the vena contracta

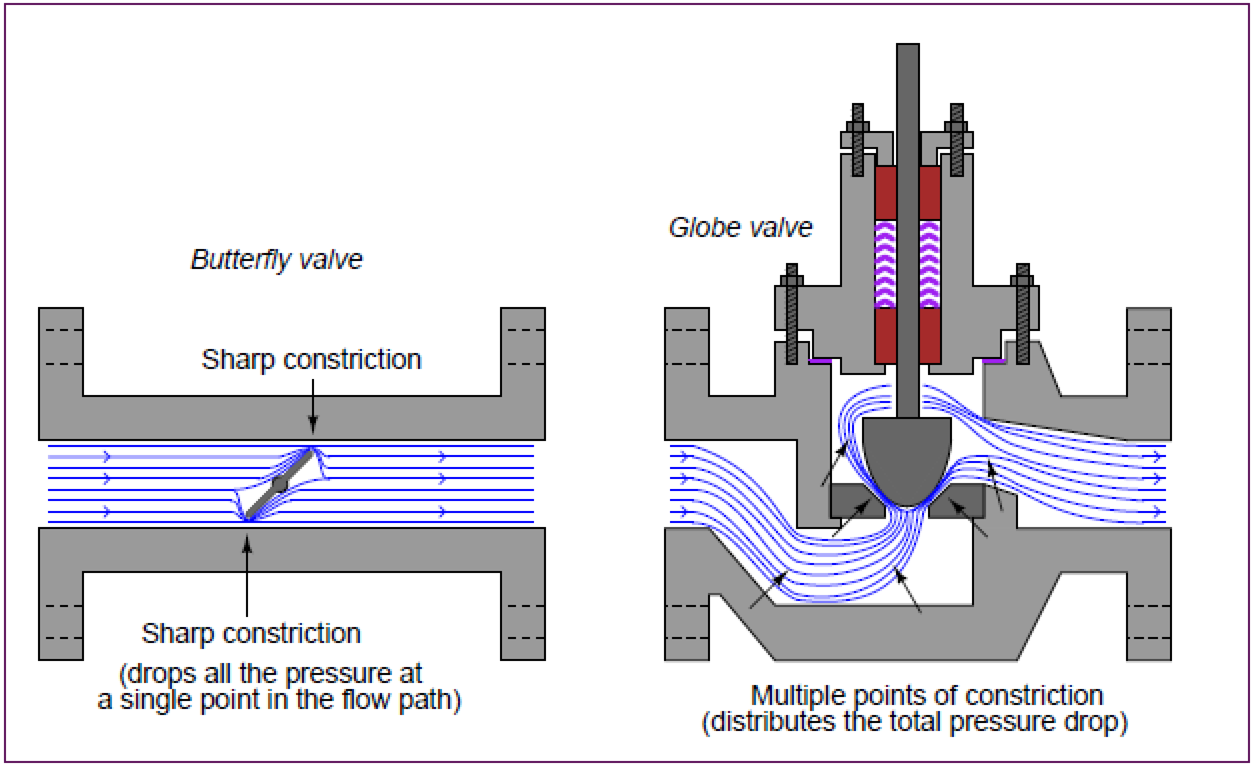
(point of minimum fluid pressure within the valve)

CONTROL VALVE ENGINEERING PROBLEMS

How can Fl affect on flashing



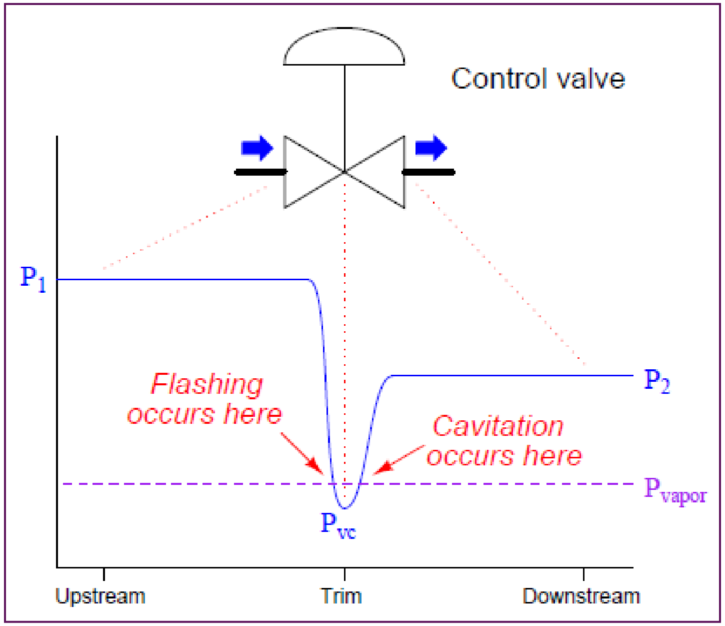
Effect of valve body on flashing



Cavitation

If fluid being throttled is a liquid, and the pressure at the vena contracta is less than the vapor pressure of that liquid at the flowing temperature, the liquid will spontaneously boil.

This is the phenomenon of flashing previously described. If, however, the pressure recovers to a point greater than the vapor pressure of the liquid, the vapor will re-condense back into liquid again. This is called cavitation.



Cavitation explanation

As destructive as flashing is to a control valve, cavitation is worse. When vapor bubbles recondense into liquid they often do so asymmetrically, one side of the bubble collapsing before the rest of the bubble. This has the effect of translating the kinetic energy of the bubble's collapse into a high-speed "jet" of liquid in the direction of the asymmetrical collapse. These liquid "microjets" have been experimentally measured at speeds up to 100 meters per second (over 320 feet per second).

What is more, the pressure applied to the surface of control valve components in the path of these microjets is immense. Each microjet strikes the valve component surface over a very small surface area, resulting in a very high pressure ($P = F/A$) applied to that small area.

Pressure estimates as high as 1500 newtons per square millimeter (1.5 giga-pascals, or about 220000 PSI!) have been calculated for control valve applications involving water.

Effect of cavitation

CONTROL VALVE ENGINEERING PROBLEMS

Several methods exist for abating cavitation in control valves

1. Prevent flashing in the first place
2. Cushion with introduced gas
3. Sustain the flashing action

CONTROL VALVE ENGINEERING PROBLEMS

Preventing flashing

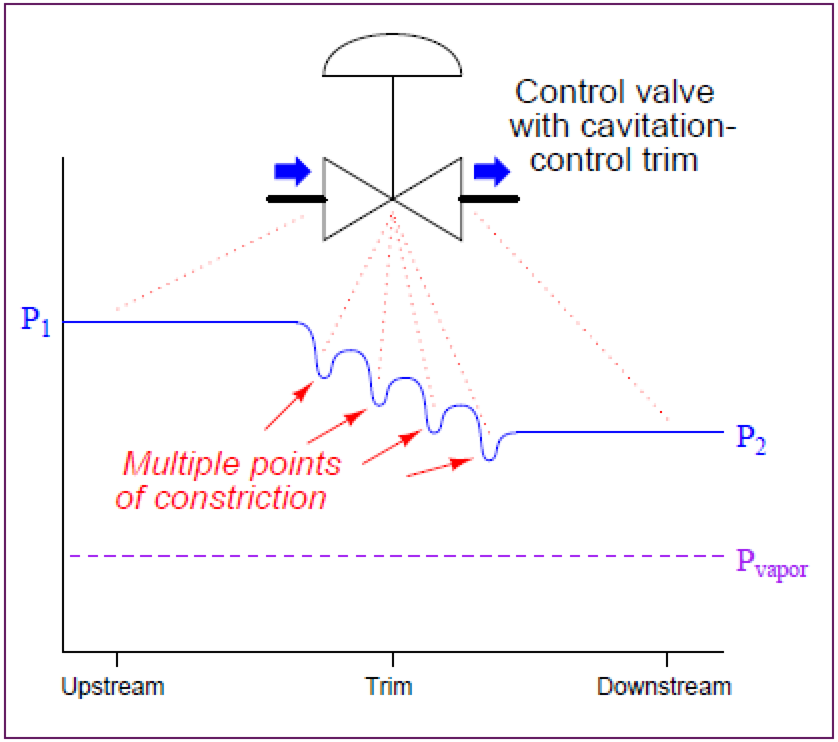
Select a control valve type having less pressure recovery (i.e. greater FL value)

- Increase both upstream and downstream pressures by relocating the valve to a higher pressure location in the process.
- Use multiple control valves in series to reduce the lowest pressure at either one
- Decrease the liquid's temperature (this decreases vapor pressure)

CONTROL VALVE ENGINEERING PROBLEMS

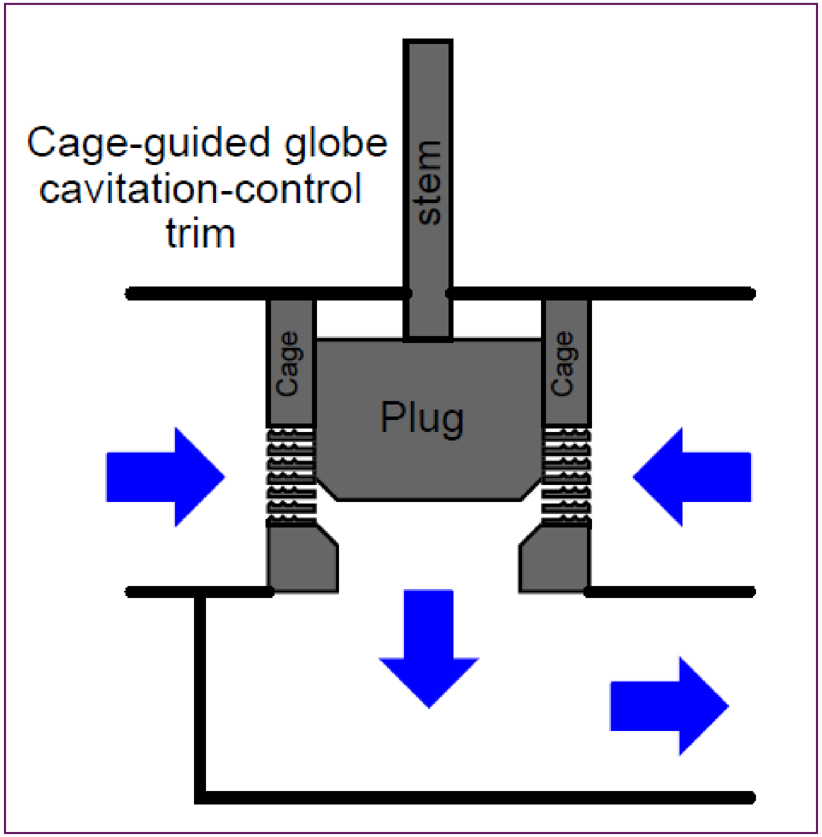
Use cavitation-control valve trim

A valve equipped with cavitation-control trim will have a different pressure profile, with multiple vena contracta points where the fluid passes through a series of constrictions within the trim itself



Special trim design

This way, the same final permanent pressure drop (P1 −P2) may be achieved without the lowest pressure ever falling below the liquid's vapor pressure limit.



CONTROL VALVE ENGINEERING PROBLEMS

Ball valve special trim

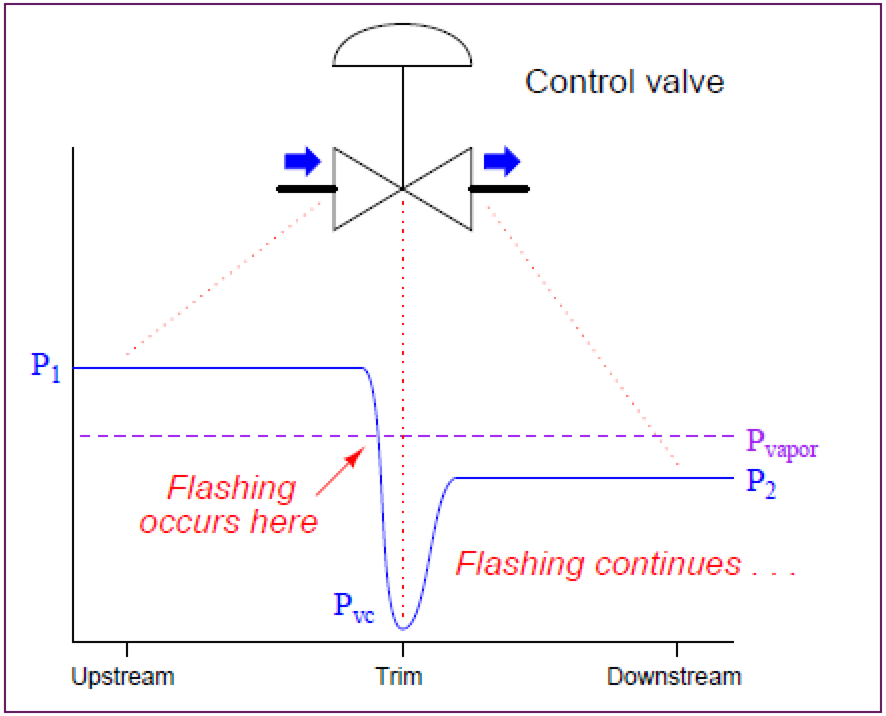
CONTROL VALVE ENGINEERING PROBLEMS

Cushion with introduced gas

This Cavitation abatement method is practical only in some process applications, where a non reacting gas may be injected into the liquid stream to provide some "cushioning" within the cavitating region. The presence of non-condensible gas bubbles in the liquid stream disturbs the microjets' pathways, helping to dissipate their energy before striking the valve body walls.

Sustain the flashing action

This avoids cavitation at the cost of guaranteed flashing within the control valve, which is generally not as destructive as cavitation.



Chocked flow

Both gas and liquid control valves may experience what is generally known as choked flow. Simply put, "choked flow" is a condition where the rate of flow through a valve does not change substantially as downstream pressure is reduced.

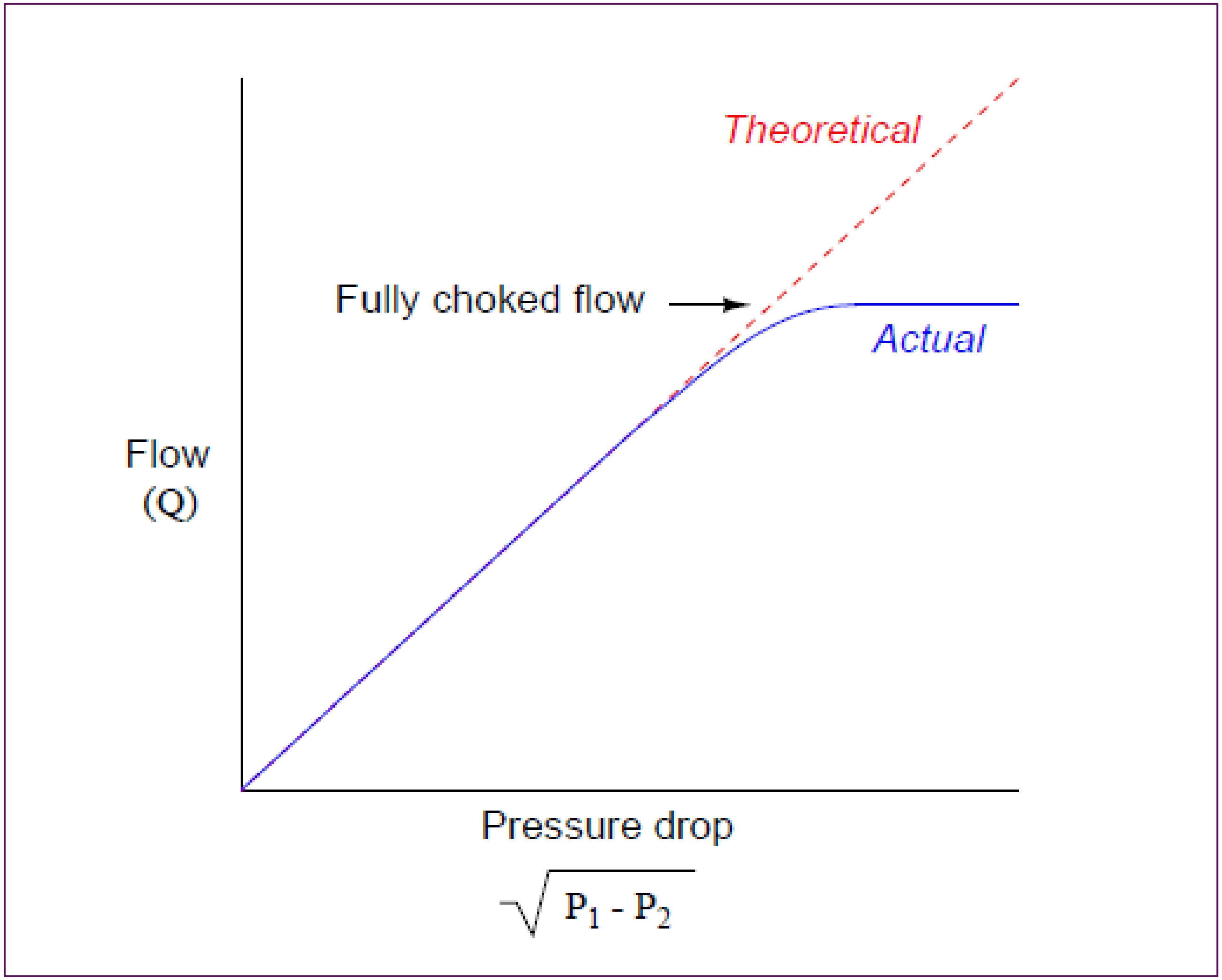
In a gas control valve, choking occurs when the velocity of the gas reaches the speed of sound for that gas. This is often referred to as critical or sonic flow. In a liquid control valve, choking occurs with the onset of flashing.

The reason sonic velocity is relevant to flow capacity for a control valve has to do with the propagation of pressure changes in fluids.

$$Q = C_v \sqrt{\frac{P_1 - P_2}{G_f}}$$

CONTROL VALVE ENGINEERING PROBLEMS

Flow vs ΔP



CONTROL VALVE ENGINEERING PROBLEMS

Notes

We may still increase flow rate through a choked valve by increasing its upstream pressure.

An approximate predictor of choked flow conditions for gas valve service is the upstream-to minimum absolute pressure ratio. When the vena contracta pressure is less than one-half the upstream pressure, both measured in absolute pressure units, choked flow is virtually guaranteed.

Choked flow in liquid services is predicted when the vena contracta pressure equals the liquid's vapor pressure, since choking is a function of flashing for liquid flow streams.

CONTROL VALVE ENGINEERING PROBLEMS

Noise

A troublesome phenomenon in severe services is audible noise produced by control valves. Noise output is worse for gas services experiencing sonic (critical) flow and for liquid services experiencing cavitation, although it is possible for a control valve to produce substantial noise even when avoiding these operating conditions.

CONTROL VALVE ENGINEERING PROBLEMS

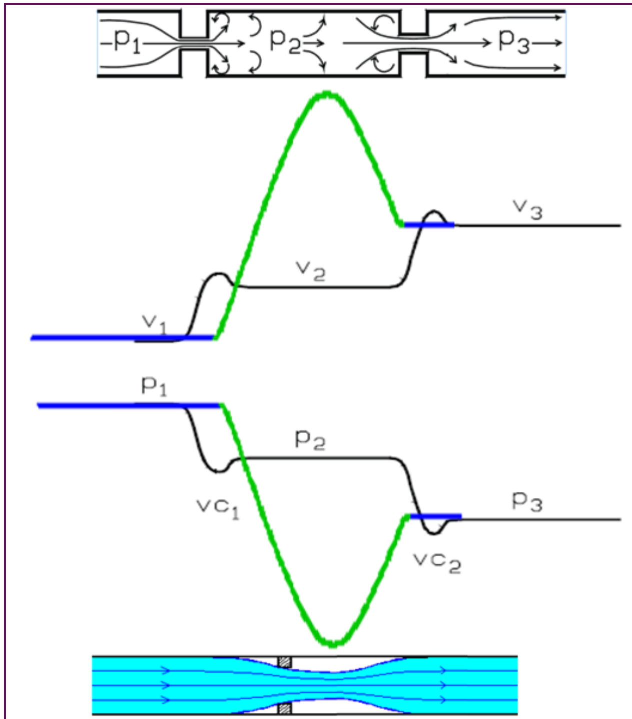
There are two strategies for reducing control valve noise:

1. Source control, that is doing something to the valve to make it less noisy.
    - -pressure drop staging
    - -flow division

2. Path control, that is doing something to prevent the noise from reaching the people who would be bothered by it.

Pressure drop staging

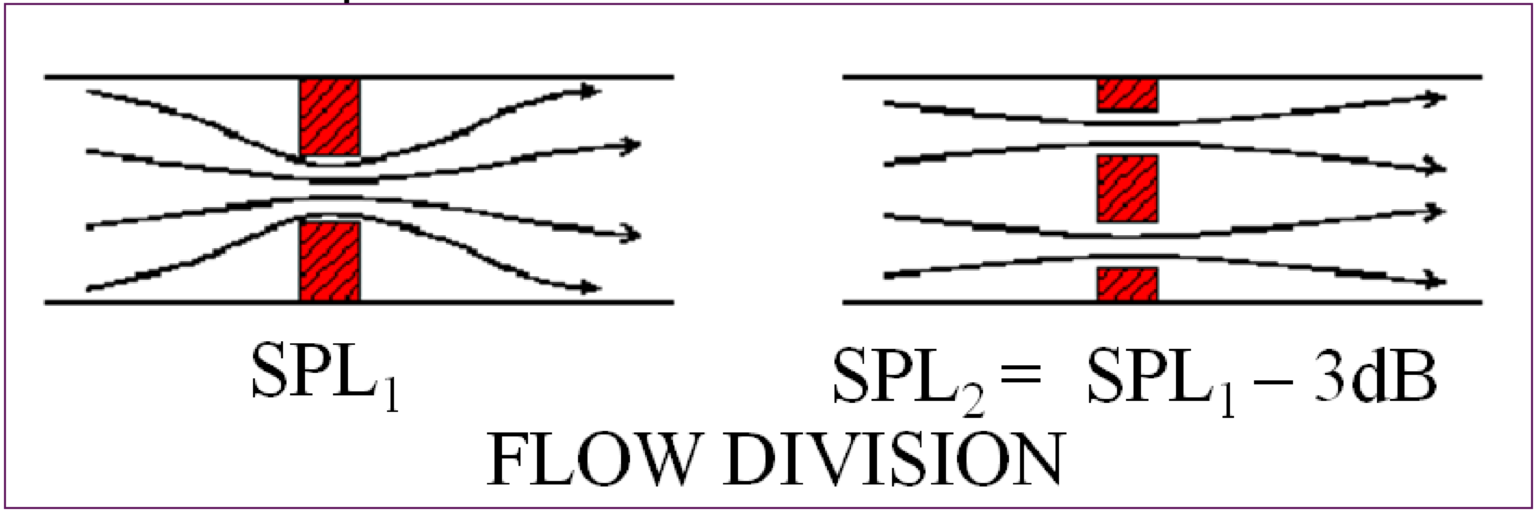
The first method of source control of aerodynamic noise is called "pressure drop staging." Pressure drop staging means that instead of taking the entire pressure drop in one step, the pressure drop is divided up into two or more steps. When the pressure drop is taken in more than one step, the individual velocity peaks are smaller than the velocity peak that would result from a single stage pressure drop. Because of the strong relationship between noise and velocity, small reductions in velocity can have a large effect on reducing the noise.



PRESSURE DROP STAGING

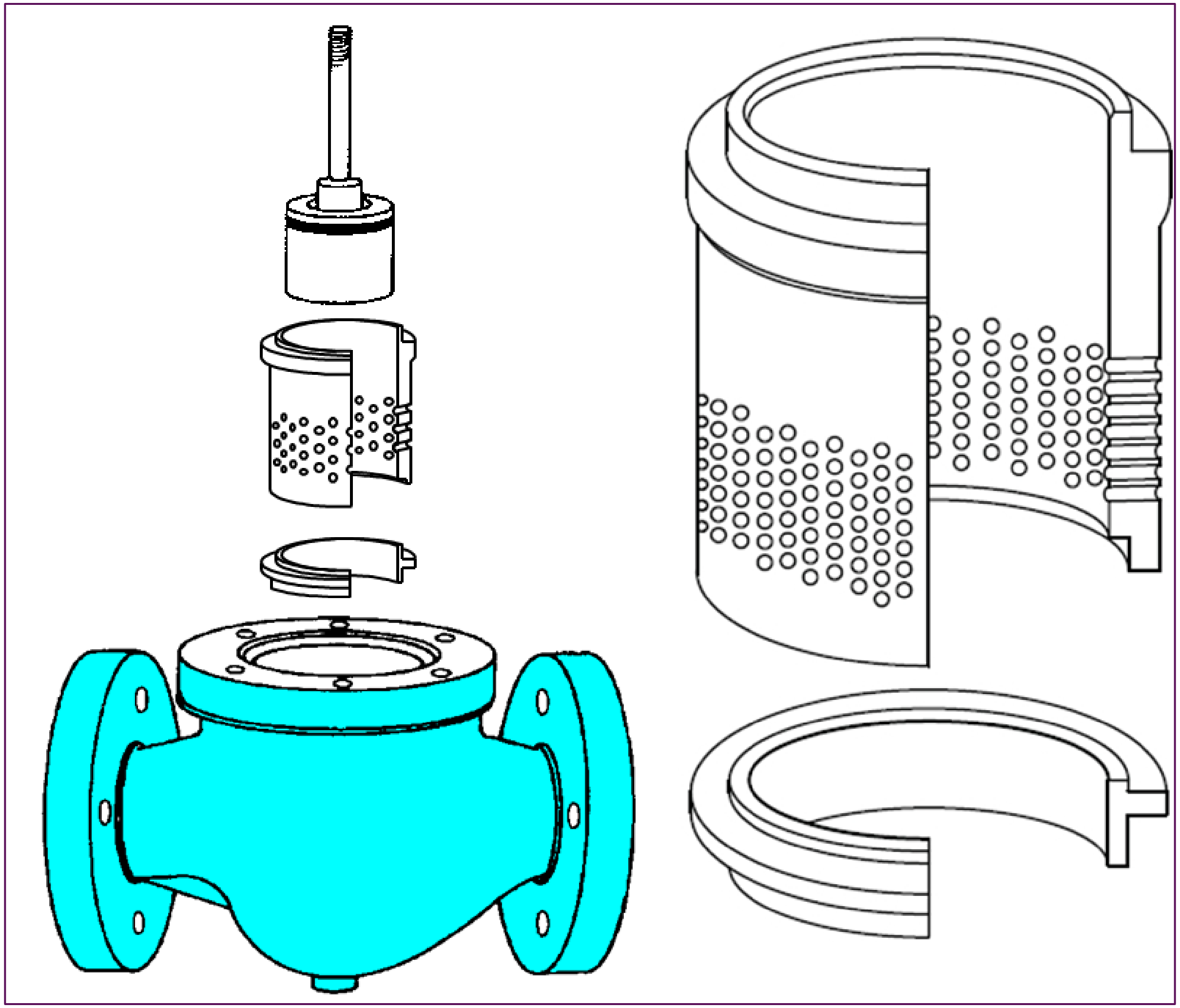
Flow division

The second method of source control of aerodynamic noise is called "flow division." Flow division means that instead of having the flow pass through a single opening, the flow is divided up so that it passes through several openings in parallel. Every time you double the number of openings, you reduce the noise by 3 dBA. The reduction is due mainly to the fact that the smaller openings shift the noise to a higher frequency. The higher frequencies are attenuated more as the sound passes through the pipe wall than are the lower frequencies. Also, because the human ear (and the "A" weighting curve on noise meters) attenuate higher frequencies, both the measured and perceived noise is decreased.



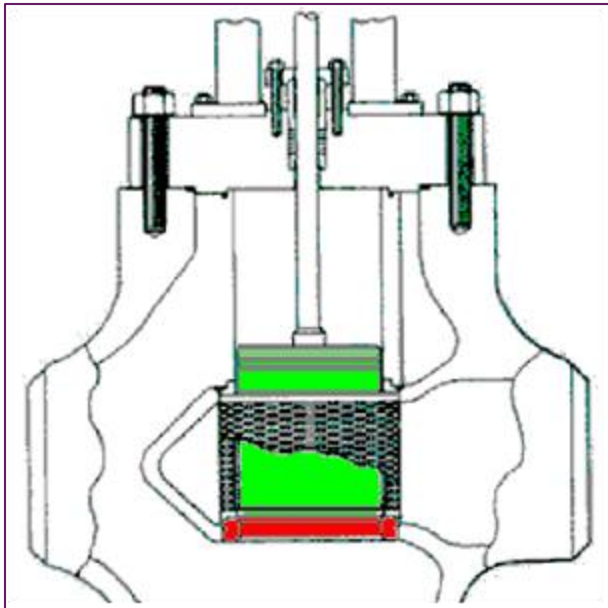
CONTROL VALVE ENGINEERING PROBLEMS

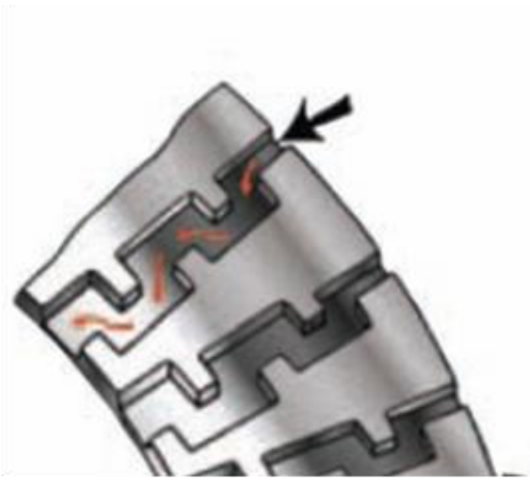
Example of how the principle of flow division can be applied to globe control valves.



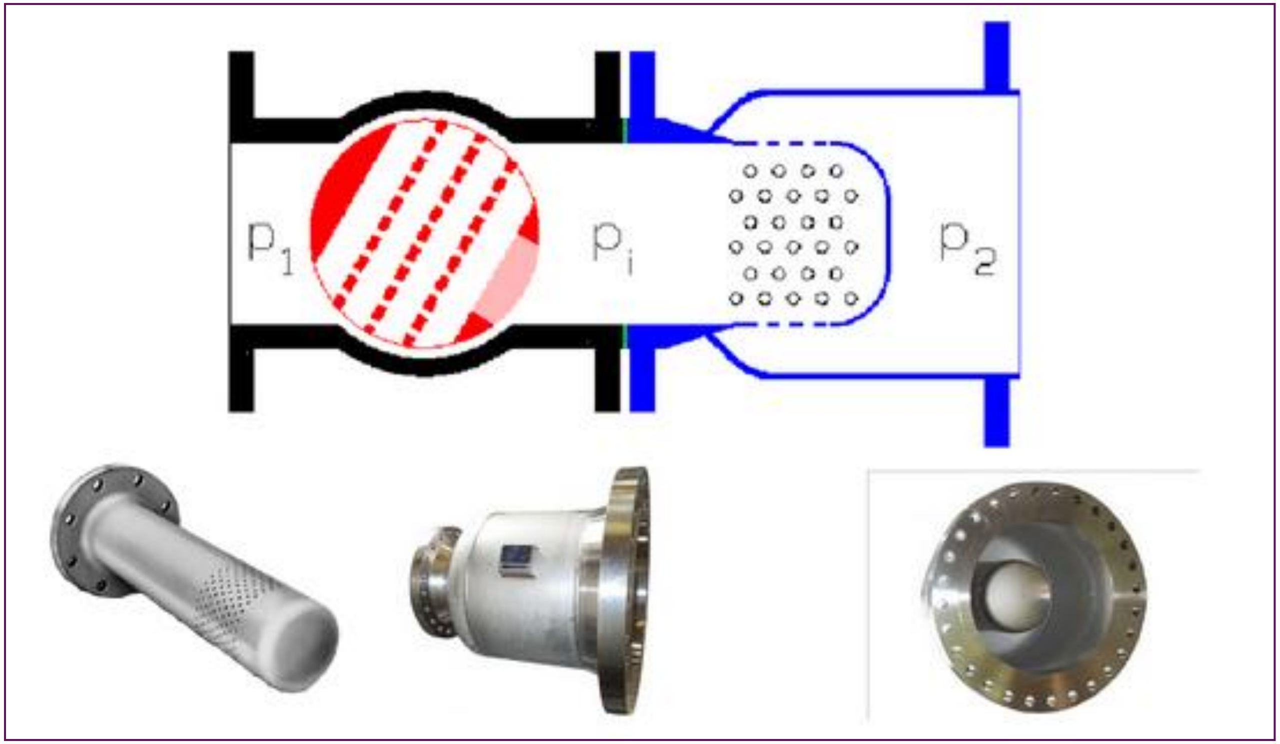
CONTROL VALVE ENGINEERING PROBLEMS

Combining both flow division and pressure drop staging for very noisy applications.





Inline diffuser with ball valve



Special valve trim

A common cage-guided globe valve trim design for noise reduction uses a special cage designed with numerous, small holes for process gas to flow through. These small holes do not in themselves reduce aerodynamic noise, but they do shift the frequency of that noise up. This increase in frequency places the sound outside the range where the human ear is most sensitive to noise, and it also helps to reduce noise coupling to the piping, confining most of the noise "power" to the internal volume of the process fluid rather than radiating outward into the air.

Path control

Distance : Most valve noise behaves as a line source. Most of the noise is radiated from the downstream piping and the intensity of the noise remains constant for long distances downstream.

Heavy wall pipe :The thicker the pipe wall, the more the noise is attenuated as it passes through the pipe wall to where we hear it.

Thermal or acoustic insulation: Using thermal or acoustic insulation on the piping downstream of a valve can reduce the sound pressure level that people are exposed to.

CONTROL VALVE ENGINEERING PROBLEMS

Erosion

A problem common to control valves used in slurry service (where the process fluid is a liquid containing a substantial quantity of hard, solid particles) is erosion, where the valve trim and body are worn by the passage of solid particles.

There really is no good way to reduce the effects of erosion damage from slurry flows, other than to use exceptionally hard valve trim materials.

CONTROL VALVE ENGINEERING PROBLEMS

Another cause of erosion in control valves is wet steam, where steam contains droplets of liquid water propelled at high velocity by the steam flow.

CONTROL VALVE ENGINEERING PROBLEMS

Bonnet damage

CONTROL VALVE ENGINEERING PROBLEMS

Corrosion

Corrosive chemicals may attack the metal components of control valves if those components are not carefully selected for the proper service.

CONTROL VALVE ENGINEERING PROBLEMS

Notes

The effects of corrosion are multiplied when combined with the effects of cavitation. Most metals develop what is known as a passivation layer in response to chemical attack. The outer layer of metal corrodes, but the byproduct of that corrosion is a relatively inert compound acting to shield the rest of the metal from further attack.

Rust on steel, or aluminum oxide on aluminum, are both common examples of passivation layers in response to oxidation of the metal. When cavitation happens inside a valve, however, the extremely high pressures caused by the liquid microjets will blast away any protection afforded by the passivation layer, allowing chemical attack to begin anew. The result is rapid degradation of the valve components.

INSTALLATION AND MAINTENANCE

INSTALLATION AND MAINTENANCE

Introduction

Optimizing valve efficiency depends on:

- Correct valve selection for the application,
- Proper storage and protection,
- Proper installation techniques, and
- An effective maintenance program.

INSTALLATION AND MAINTENANCE

Proper Storage and Protection

- Typically, manufacturers have packaging standards that are dependent upon the destination and intended length of storage before installation.
- The valve must be stored in a clean, dry place away from any traffic or other activity that could damage the valve.

INSTALLATION AND MAINTENANCE

Proper Installation Techniques

Read the Instruction Manual

- Instruction manuals describe the product and review safety issues and precautions to be taken before and during installation.

Be Sure the Pipeline Is Clean

- Foreign material in the pipeline could damage the seating surface of the valve or even obstruct the movement of the valve plug, ball, or disk so that the valve does not shut off properly.
- Inspect pipe flanges to ensure a smooth gasket surface.
- If the valve has screwed end connections, apply sealant compound to the male pipeline only, not to the female valve threads. Excess compound could cause sticking in the valve plug or accumulation of dirt

INSTALLATION AND MAINTENANCE

Proper Installation Techniques

Inspect the Valve

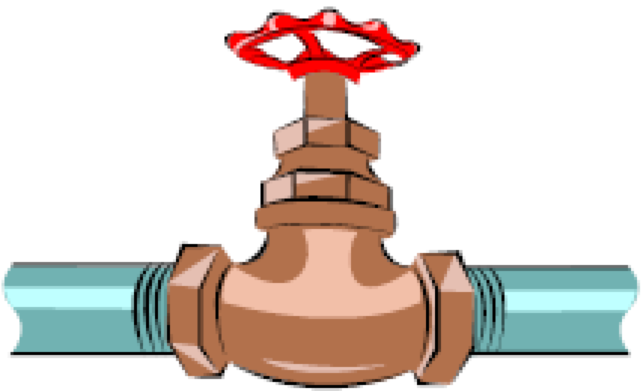
- Do not install a valve known to have been damaged in shipment or while in storage.

- Before installing, check for and remove all shipping stops and protective plugs or gasket surface covers.

- Check inside the valve body to make sure no foreign objects are present.

INSTALLATION AND MAINTENANCE

Use Good Piping Practices



- Most control valves can be installed in any position. However, the most common method is with the actuator vertical and above the valve body. If horizontal actuator mounting is necessary, consider additional vertical support for the actuator.

- Larger valves should be lifted using lifting straps and a mechanical lifting device.

INSTALLATION AND MAINTENANCE

Use Good Piping Practices

- Be sure the body is installed so that fluid flow will be in the direction indicated by the flow arrow.

- Be sure to allow ample space above and below the valve to permit easy removal of the actuator or valve plug for inspection and maintenance.

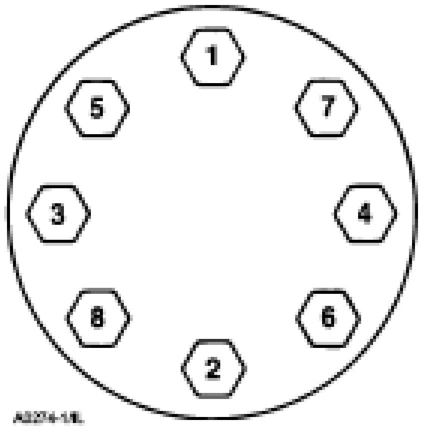
INSTALLATION AND MAINTENANCE

Use Good Piping Practices

- For flanged valve bodies, be sure the flanges are properly aligned to provide uniform contact of the gasket surfaces.

- Snug up the bolts gently after establishing proper flange alignment.

- Finish tightening them in a criss-cross pattern. Proper tightening will avoid uneven gasket loading and will help prevent leaks. It also will avoid the possibility of damaging, or even breaking, the flange.



INSTALLATION AND MAINTENANCE

Check operation

- After installation, the manual operator should be used to fully stroke the valve, observing the motion of the stem.

Check leakage

Check external leakage from the valve:

- Compression packing.
- Bonnet gasket or screw.
- Flanges gasket.