# Fundamentals of Control Valve Engineering

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# Table of Contents

## Section 1: Control valve

## Section 2: Actuators

* Types of actuator
* Actuator sizing

## Section 3: Positioners

* Positioners
* Accessories

## Section 4: Server Service

* Noise
* Cavitation
* Flashing
* Choked Flow

## Section 5: Server Service Treatments

- Source and path treatments
- Special cages
- Proper material selection

## Section 6: Standards

## Section 7: Sample Specification

## Section 8: Sample Datasheet

Section 1

# Control valve

# Table of Contents

# Definitions

- **What Is A Control Valve?**

The most common final control element in the process control industries is the control valve. The control valve manipulates a flowing fluid, such as gas, steam, water, or chemical compounds, to compensate for the load disturbance and keep the regulated process variable as close as possible to the desired set point.

The control valve assembly typically consists of the valve body, the internal trim parts, an actuator to provide the motive power to operate the valve, and a variety of additional valve accessories, which can include positioners, transducers, supply pressure regulators, manual operators, snubbers, or limit switches.

- **Actuator:**

A pneumatic, hydraulic, or electrically powered device that supplies force and motion to open or close a valve.

- **Accessory:**

A device that is mounted on the actuator to complement the actuator’s function and make it a complete operating unit. Examples include positioners, supply pressure regulators, solenoids, and limit switches.

- **Capacity (Valve):**

The rate of flow through a valve under stated conditions.

- **I/P:**

Shorthand for current-to-pres-sure (I-to-P). Typically applied to input transducer modules.

- **Positioner:**

A position controller (servomechanism) that is mechanically connected to a moving part of a final control element or its actuator and that automatically adjusts its output to the actuator to maintain a desired position in proportion to the input signal.

- **Travel:**

The movement of the closure member from the closed position to an intermediate or rated full open position.

- **Trim:**

The internal components of a valve that modulate the flow of the controlled fluid.

- **Bonnet:**

The portion of the valve that contains the packing box and stem seal and can guide the stem. It provides the principal opening to the body cavity for assembly of internal parts or it can be an integral part of the valve body. It can also provide for the attachment of the actuator to the valve body. Typical bonnets are bolted, threaded, welded, pressure-seals, or integral with the body. (This term is often used in referring to the bonnet and its included packing parts. More properly, this group of component parts should be called the bonnet assembly.)

- **Seat:**

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

- **Cage:**

A part of a valve trim that surrounds the closure member and can provide flow characterization and/or a seating surface. It also provides stability, guiding, balance, and alignment, and facilitates assembly of other parts of the valve trim. The walls of the cage contain openings that usually determine the flow characteristic of the control valve.

- **Port:**

The flow control orifice of a control valve.

- **Packing:**

A part of the valve assembly used to seal against leakage around the valve disk or stem.

- **Seat Ring:**

A part of the valve body assembly that provides a seating surface for the closure member and can provide part of the flow control orifice.

- **Valve Stem:**

In a linear motion valve, the part that connects the actuator stem with the closure member.

- **Yoke:**

The structure that rigidly connects the actuator power unit to the valve.

- **Fail-Closed:**

A condition wherein the valve closure member moves to a closed position when the actuating energy source fails.

- **Fail-Open:**

A condition wherein the valve closure member moves to an open position when the actuating energy source fails.

- **Fail-Safe:**

A characteristic of a valve and its actuator, which upon loss of actuating energy supply, will cause a valve closure member to be fully closed, fully open, or remain in the last position, whichever position is de-fined as necessary to protect the process. Fail-safe action can involve the use of auxiliary controls connected to the actuator.

- **Flow Coefficient (Cv):**

A constant (Cv) related to the geometry of a valve, for a given travel, that can be used to establish flow capacity. It is the number of U.S. gallons per minute of 60°F water that will flow through a valve with a one pound per square inch pressure drop.

- **Seat Leakage:**

The quantity of fluid passing through a valve when the valve is in the fully closed position with pressure differential and temperature as specified.

- **Vena Contracta:**

The portion of a flow stream where fluid velocity is at its maximum and fluid static pressure and the cross-sectional area are at their minimum. In a control valve, the vena contracta normally occurs just downstream of the actual physical restriction.

- **Feedback Signal:**

The return signal that results from a measurement of the directly controlled variable. For a control valve with a positioner, the re-turn signal is usually a mechanical indication of closure member stem position that is fed back into the positioner.

- **Supply Pressure:**

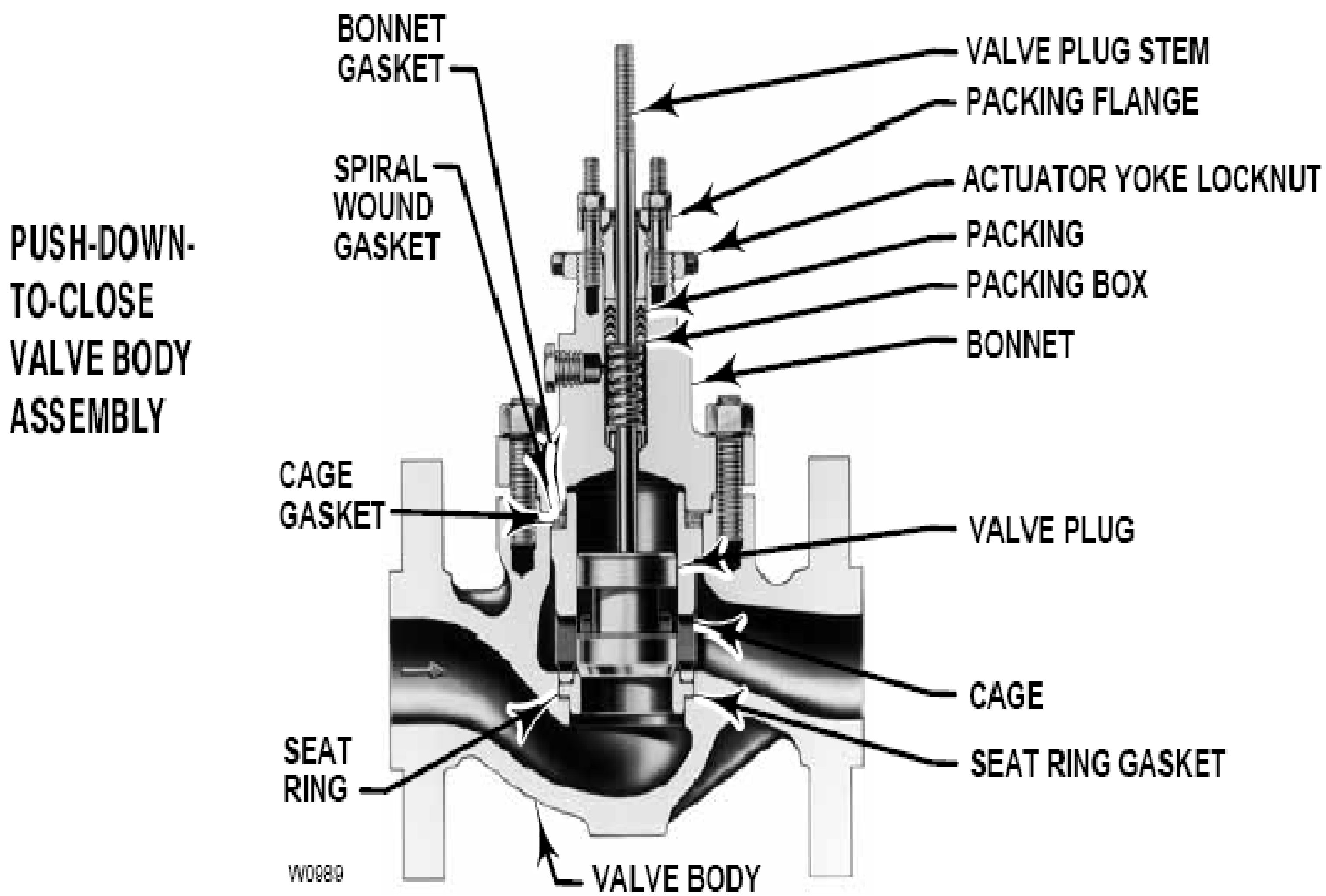
The pressure at the supply port of a device. Common values of control valve supply pres-sure are 20 psig for a 3 to 15 psig range and 35 psig for a 6 to 30 psig range.

# Types of control valves

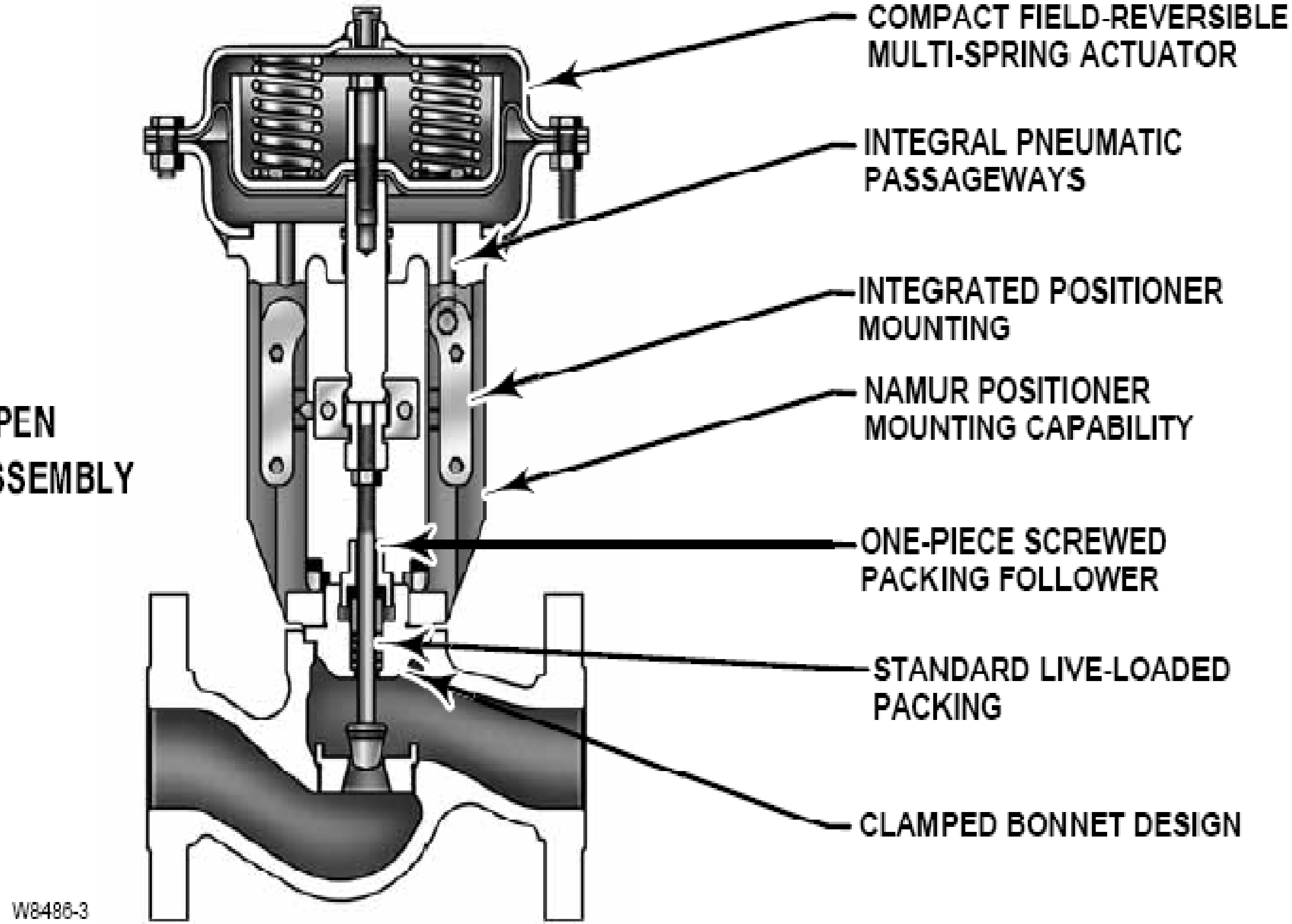
- Globe Valves
- Ball Valves
- Butterfly Valves
- Eccentric Disk

# Globe valves

- Size Limitation
- Lower Capacity than Ball or Butterfly
- Overall expensive specially in large sizes
- Tight shutoff in small sizes


PUSH-DOWN-TO-CLOSE VALVE BODY ASSEMBLY
BONNET GASKET
SPIRAL WOUND GASKET
CAGE GASKET
SEAT RING
W0989
VALVE BODY
VALVE PLUG STEM
PACKING FLANGE
ACTUATOR YOKE LOCKNUT
PACKING
PACKING BOX
BONNET
VALVE PLUG
CAGE
SEAT RING GASKET

AIR-TO-OPEN
VALVE ASSEMBLY

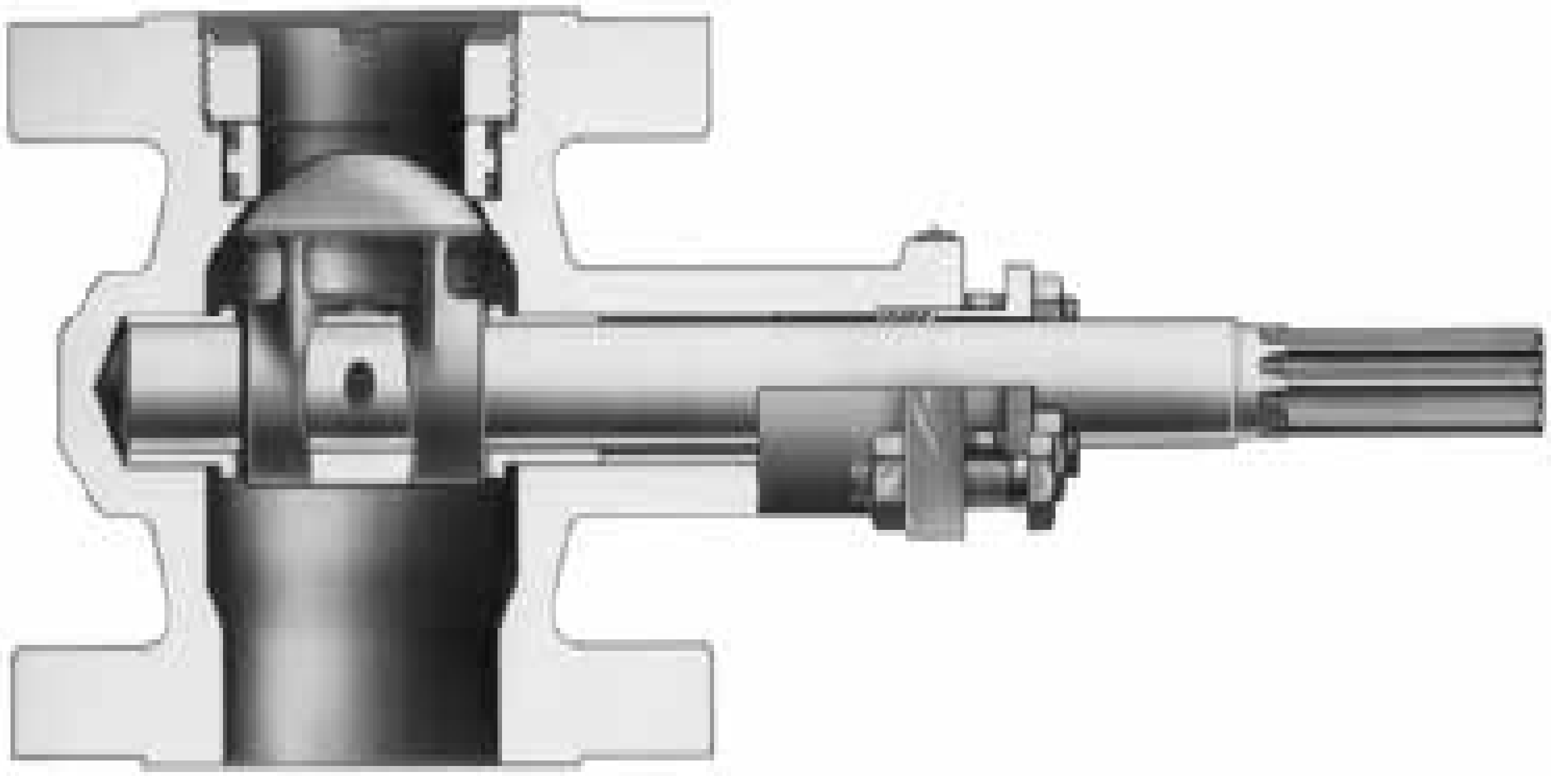


# Ball Valves

- Classified as High-Recovery Valves
- Limited in allowable pressure drop and temperature than globe valves
- Good shutoff capabilities
- Almost ½ price of globe valves

W4920/IL

SEGMENTED BALL VALVE



V/4170/IL

# Butterfly Valves

- Most Economical valve on a cost per flow capacity basis
- Fully lined valves bore can provide tight shutoff
- Low cost body material for corrosive fluid due to lined body bore
- Handling of high inlet pressure and pressure drop


CONTOURED DISK BUTTERFLY VALVE

# Eccentric Disk Valves

- Almost similar to butterfly valves, except size limitation

# Balance plug Style Valve Bodies

- Single ported that only one seat ring is used
- High capacity
- High capacity
- Large sizes
- Smaller actuator sizes
- Cage style allows ease of reducing trim, characteristic change
- Unbalance is double ported

# Data needed for Control Valve Selection

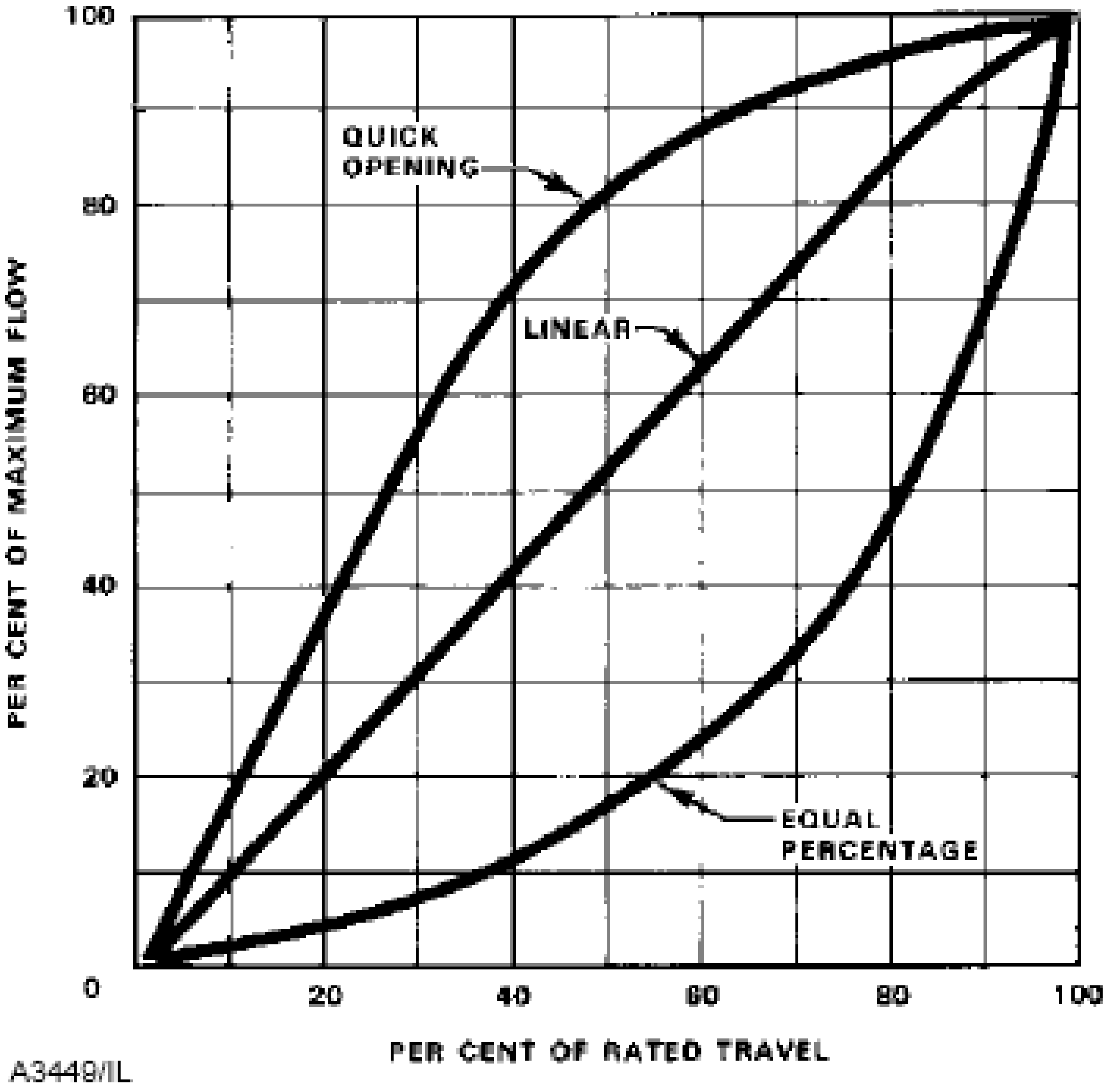
- Type of fluid
- Temperature of fluid
- Flow rate of fluid
- Viscosity of fluid
- Specific Gravity of fluid
- Inlet pressure (Upstream)
- Outlet pressure (Downstream)
- Delta P shutoff for actuator sizing
- Pipe size/Schedule

# Data needed for Control Valve Selection

- Valve type
- Body material
- End connection type (Flanged or Screwed)
- Valve Action (F.C. or F.O)
- Type of Actuator
- Instrument Air Supply Pressure
- Accessories/Positioners/Etc.

# Valve Characteristics

- The flow characteristic of a control valve is the relationship between flow rate through the valve and valve travel as the travel is varied from 0-100%
- Typical valve characteristics conducted in this manner are named Linear, Equal-Percentage, and Quick Opening


QUICK OPENING
LINEAR
EQUAL PERCENTAGE
PER CENT OF MAXIMUM FLOW
PER CENT OF RATED TRAVEL
0
20
40
60
80
100
A3449/IL

# Characterized Cages for Globe-Style Valve Bodies

W0958/IL

QUICK OPENING

W0959/IL

LINEAR

W0067/IL

EQUAL PERCENTAGE

# Valve Body Material

- Valve body material selection is usually based on the Pressure, Temperature, Corrosive properties and Erosive Properties of the flow media.
- Cast carbon steel (ASTM A216-Grade WCB) is the most popular steel for valve bodies in moderate service such as Air, superheat or saturated steam, non corrosive fluids.
- Cast Chrome-Moly Steel (ASTM A217-Grade WCB-C9) has addition of chromium/Molybdenum that provide corrosion resistance and also is suitable for temperature up to 1050 Deg.F.

- Cast type 304 SST (ASTM A351-Grade CF8) is for oxidizing and very corrosive fluids.
- Cast type 316 SST (ASTM A351-Grade CF8M) is same as 304 SST but since it has addition of Molybdenum then better resistance to corrosion.
- Cast Iron (ASTM A126) is used for steam. Water. Gas and non corrosive fluids and is inexpensive.
- Cast Bronze (ASTM B61& ASTM B62) is used for steam, Air, Water, Oil and non corrosive fluids.

# Type of Bonnet

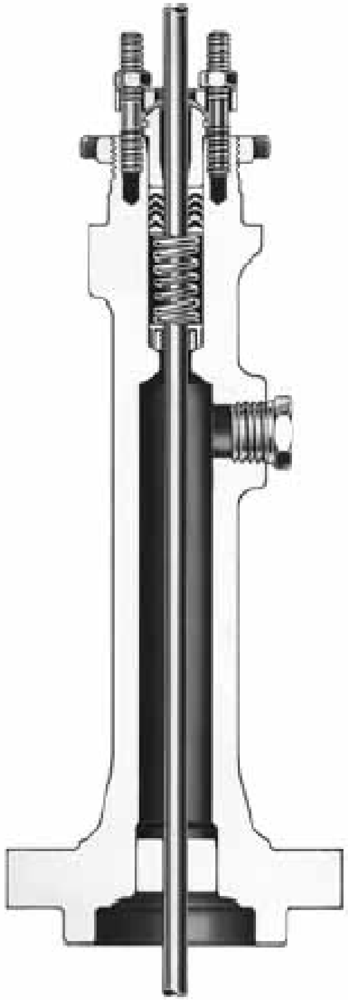
- **Standard Bonnet**

- **Extension Bonnet**

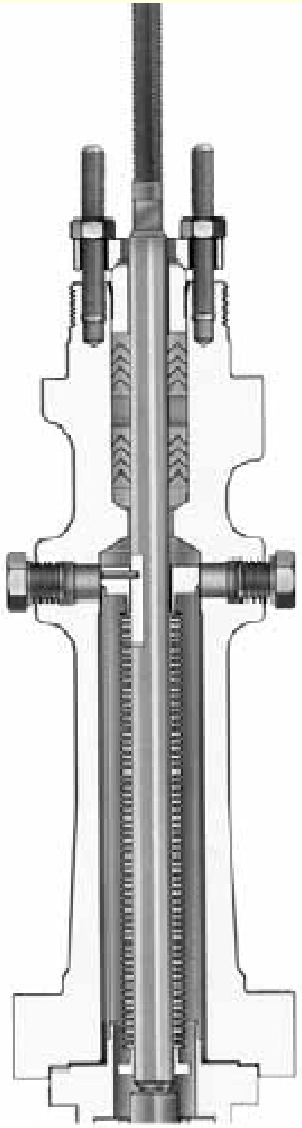
  Are used for high and low temperature service to protect packing from extreme temperature.

- **Bellows Seal Bonnets**

  Are used when no leakage are allowed, Toxic fluids, Volatile, Radioactive or highly expensive fluids.



Extension Bonnet



Bellows Seal Bonnet

# Type of Packing

## PTFE Type

- Standard TFE up to 232 Deg. C.
- Supercedes old TFE/ASB. Which is obsoleted for health reason
- Minimizes friction, so may require smaller Actuator
- Good resistivity to most known chemicals
- No lubrication required

## Graphite Type

- High temperature service up to 1200 Deg.F.
- Leak free
- No lubrication required

Section 2

# Actuators

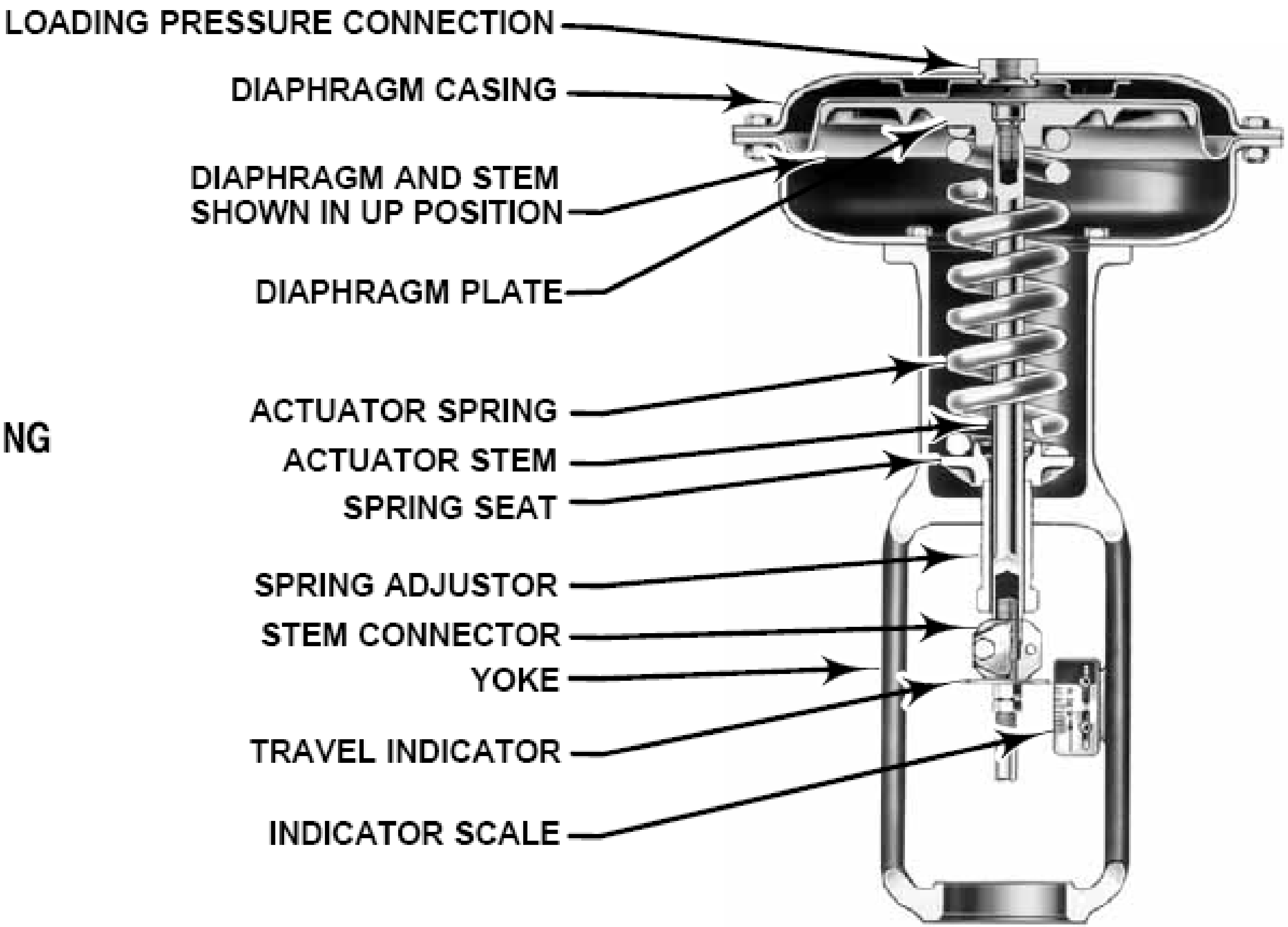
# Table of Contents

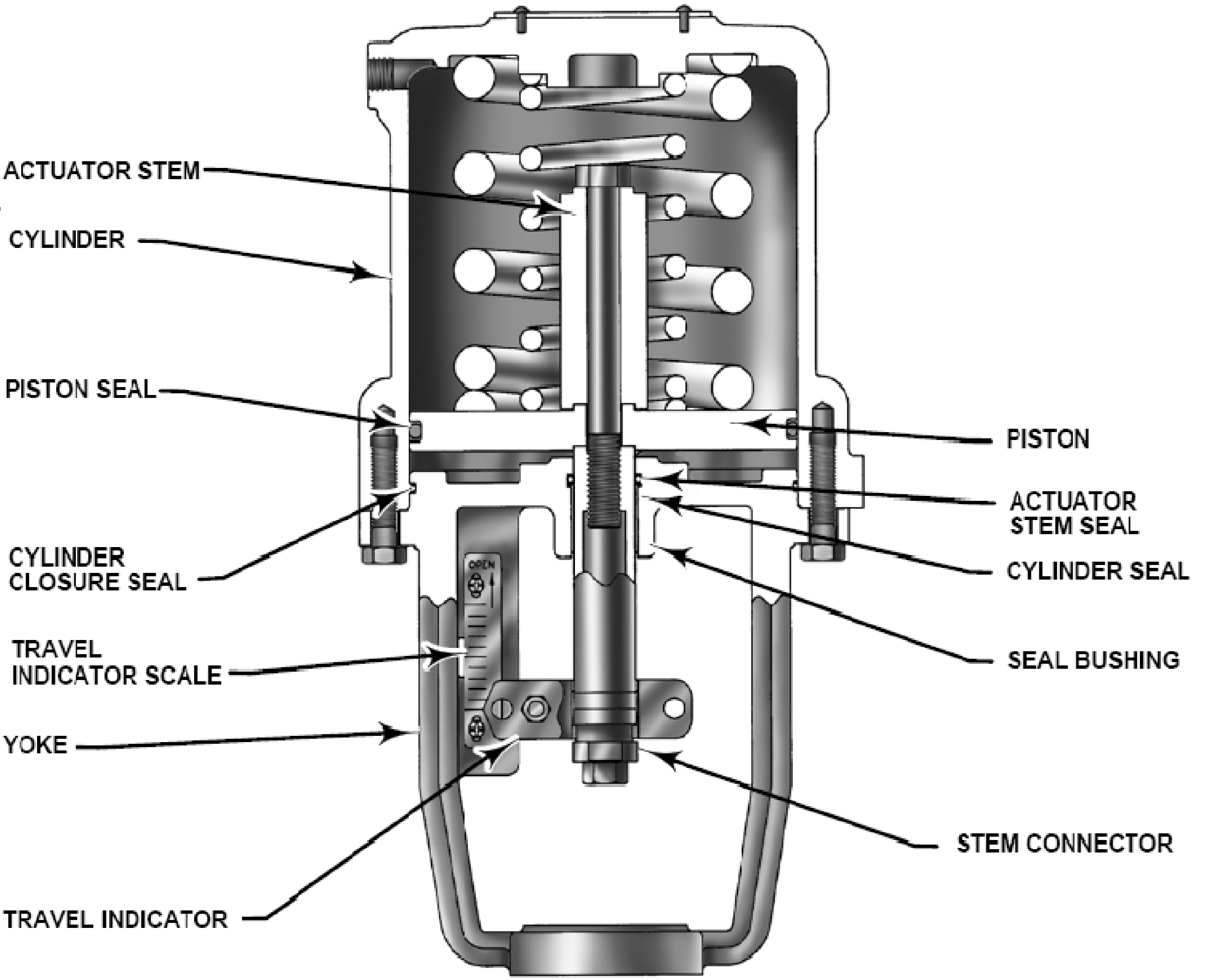
# <u>Types of actuator</u>

- ***<u>Pneumatically</u>*** operated control valve actuators are the most popular type in use, but ***<u>electric</u>***, ***<u>hydraulic</u>***, and ***<u>manual</u>*** actuators are also widely used. The ***<u>spring and diaphragm</u>*** pneumatic actuator is most commonly specified due to its dependability and simplicity of design. Pneumatically operated ***<u>piston</u>*** actuators provide high stem force out-put for demanding service conditions. Adaptations of both spring-and-diaphragm and pneumatic piston actuators are available for direct installation on rotary-shaft control valves.

- Electric and electro-hydraulic actuators are more complex and more ex-pensive than pneumatic actuators. They offer advantages where no air supply source is available, where low ambient temperatures could freeze condensed water in pneumatic supply lines, or where unusually large stem forces are needed. A summary follows, discussing the design and characteristics of popular actuator styles.

# DIRECT-ACTING ACTUATOR






*Typical Double-Acting Piston Actuator with Bias Spring*

# Diaphragm Actuators

- Pneumatically operated diaphragm actuators use air supply from controller, positioner, or other source.
- Various styles include: direct-acting (increasing air pressure pushes down diaphragm and extends actuator stem); reverse-acting (in-creasing air pressure pushes up diaphragm and retracts actuator stem); reversible (actuators that can be assembled for either direct or reverse action); direct-acting unit for rotary valves (increasing air pressure pushes down on diaphragm, which may either open or close the valve, depending on orientation of the actuator lever on the valve shaft).

- Net output thrust is the difference between diaphragm force and opposing spring force.
- Molded diaphragms provide linear performance and increased travels.
- Output thrust required and supply air pressure available dictate size.
- Diaphragm actuators are simple, dependable, and economical.

## Piston Actuators

- Piston actuators are pneumatically operated using high-pressure plant air to 150 psig, often eliminating the need for supply pressure regulator.
- Piston actuators furnish maximum thrust output and fast stroking speeds.
- Piston actuators are double acting to give maximum force in both directions, or spring return to provide fail-open or fail-closed operation.
- Various accessories can be incorporated to position a double-acting piston in the event of supply pressure failure. These include pneumatic trip valves and lock-up systems.

- Also available are hydraulic snubbers, hand wheels and units without yokes, which can be used to operate butterfly valves, louvers, and similar industrial equipment.
- Other versions for service on rotary-shaft control valves include a sliding seal in the lower end of the cylinder. This permits the actuator stem to move laterally as well as up and down without leakage of cylinder pres-sure. This feature permits direct connection of the actuator stem to the actuator lever mounted on the rotary valve shaft, thereby eliminating one joint or source of lost motion.

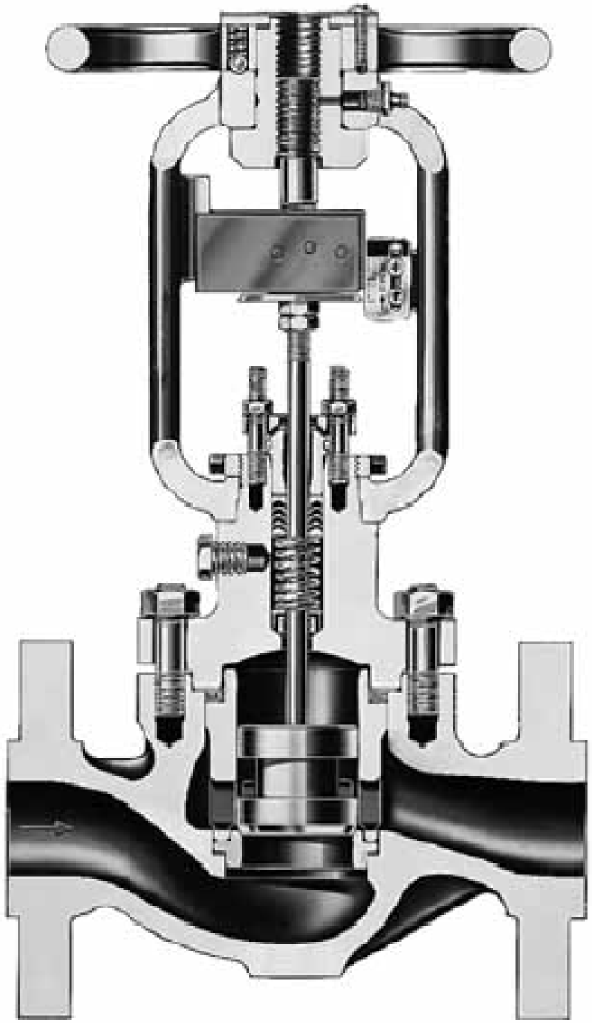
# Electro-hydraulic Actuators

- Electro-hydraulic actuators require only electrical power to the motor and an electrical input signal from the controller.
- Electro-hydraulic actuators are ideal for isolated locations where pneumatic supply pressure is not available but where precise control of valve plug position is needed.
- Units are normally reversible by making minor adjustments and might be self-contained, including motor, pump, and double-acting hydraulically operated piston within a weather proofor explosion-proof casing.

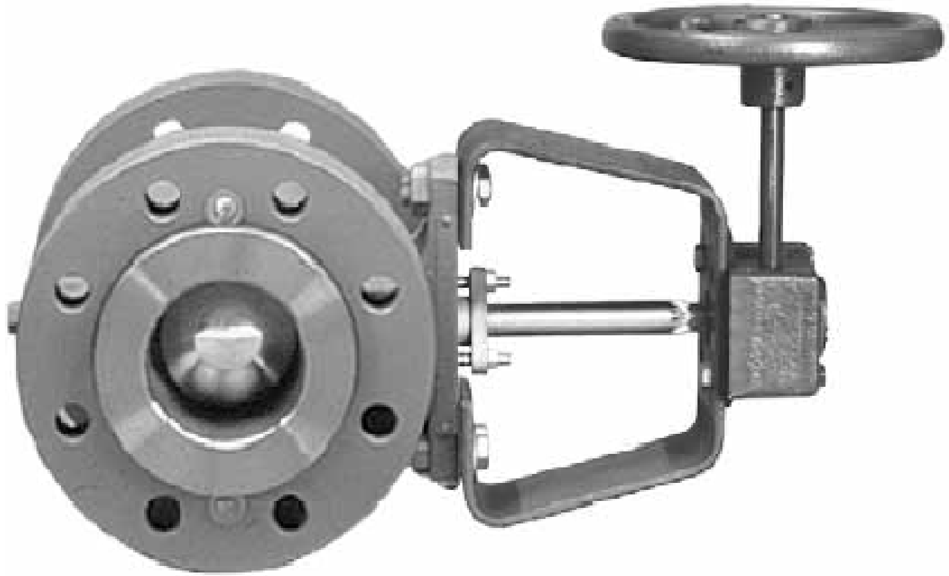
Control Valve with
Double-Acting Electrohydraulic
Actuator and Handwheel

# Manual Actuators

- Manual actuators are useful where automatic control is not required, but where ease of operation and good manual control is still necessary . They are often used to actuate the bypass valve in a three-valve bypass loop around control valves for manual control of the process during maintenance or shut down of the automatic system.
- Manual actuators are available in various sizes for both globe style valves and rotary-shaft valves.
- Dial-indicating devices are available for some models to permit accurate repositioning of the valve plug or disk.
- Manual actuators are much less expensive than automatic actuators.



FOR SLIDING-STEM VALVES



FOR ROTARY-SHAFT VALVES

*Typical Manual Actuators*

# Electric Actuators

- Traditional electric actuator designs use an electric motor and some form of gear reduction to move the valve. Through adaptation, these mechanisms have been used for continuous control with varying degrees of success. To date, electric actuators have been much more expensive than pneumatic for the same performance levels. This is an area of rapid technological change, and future designs may cause a shift towards greater use of electric actuators.

# Actuator sizing

- Actuators are selected by matching the force required to stroke the valve with an actuator that can supply that force. For rotary valves a similar process matches the torque required to stroke the valve with an actuator that will supply that torque. The same fundamental process is used for pneumatic, electric, and electro-hydraulic actuators.

## The force required to operate a globe valve includes:

- Force to overcome static unbalance of the valve plug
- Force to provide a seat load
- Force to overcome packing friction
- Additional forces required for certain specific applications or constructions

Section 3

# Positioners

# Table of Contents

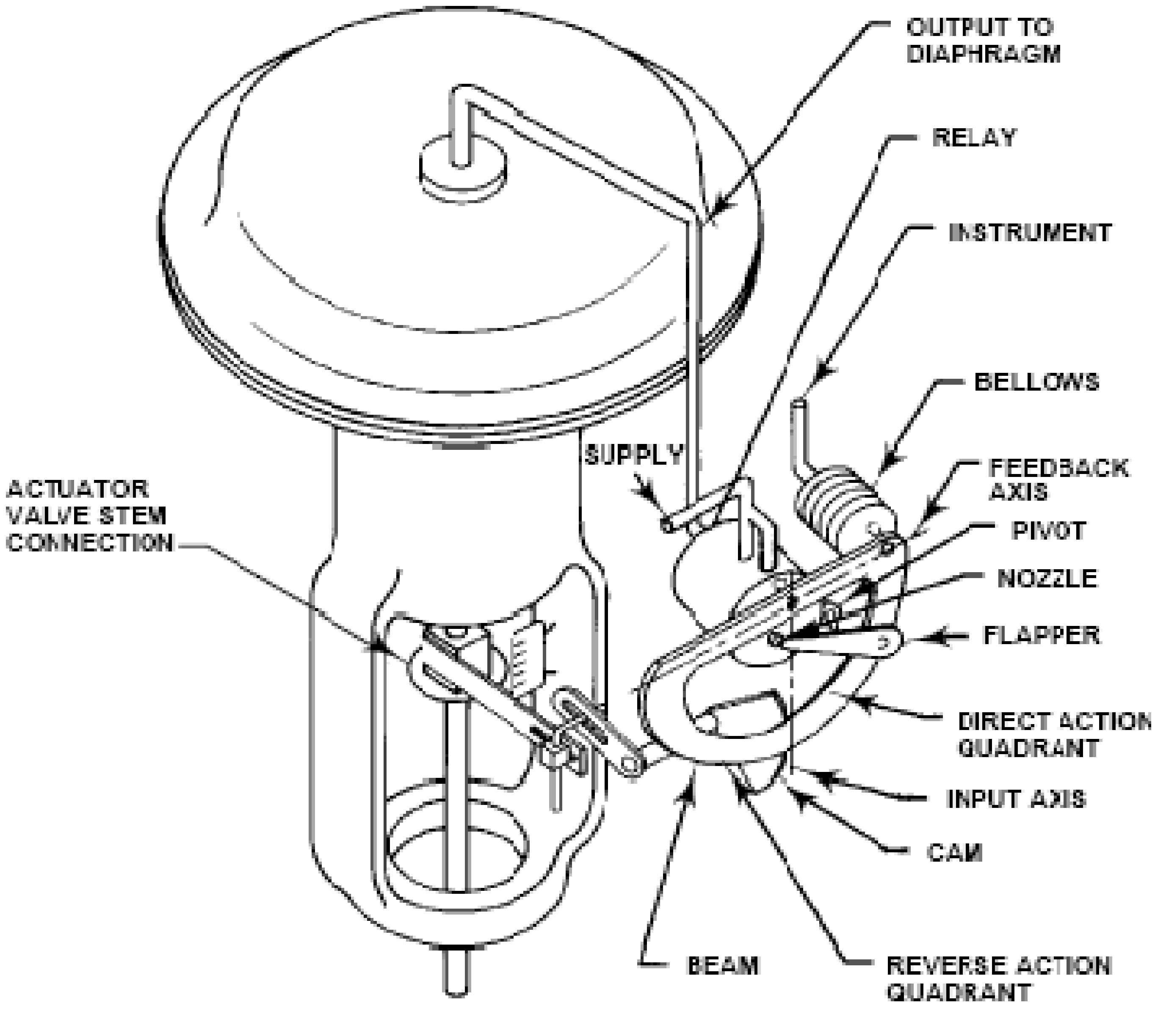
# Positioners

Pneumatically operated valves depend on a positioner to take an input signal from a process controller and convert it to valve travel. These instruments are available in three configurations:

1. ***Pneumatic Positioners***—A pneumatic signal (usually 3-15 psig) is supplied to the positioner. The positioner translates this to a required valve position and supplies the valve actuator with the required air pressure to move the valve to the correct position.
2. ***Analog I/P Positioner***—This positioner performs the same function as the one above, but uses electrical current (usually 4-20 mA) instead of air as the input signal.

***3. Digital Controller***—Although this instrument functions very much as the Analog I/P described above, it differs in that the electronic signal conversion is digital rather than analog. The digital products cover three categories.

- Digital Non-Communicating—A current signal (4-20 mA) is supplied to the positioner, which both powers the electronics and controls the output.
- HART—This is the same as the digital non-communicating but is also capable of two-way digital communication over the same wires used for the analog signal.
- Fieldbus—This type receives digitally based signals and positions the valve using digital electronic circuitry coupled to mechanical components.




*Positioner Schematic for Diaphragm Actuator*

# Why We install Positioner?

- For Fast operation
- Due to packing friction
- Long Travel valves
- Big Actuators
- Better Accuracy
- Split Range Applications

# Accessories

- Limit Switches
- Solenoid Valve Manifold
- Supply Pressure Regulator
- Pneumatic Lock-Up Systems
- Electro-Pneumatic Transducers

Section 4

# Sever Service

## Table of Contents

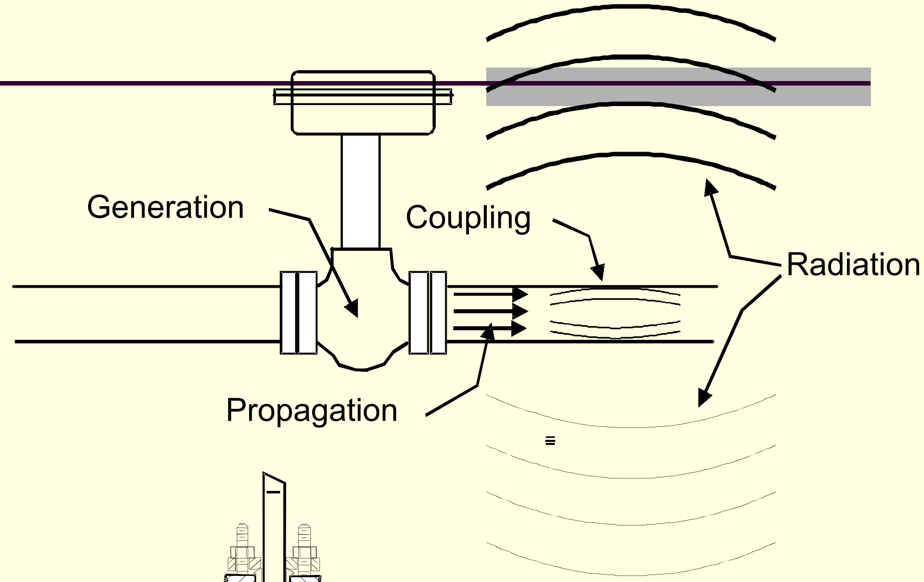
# Noise

## Source of Valve Noise

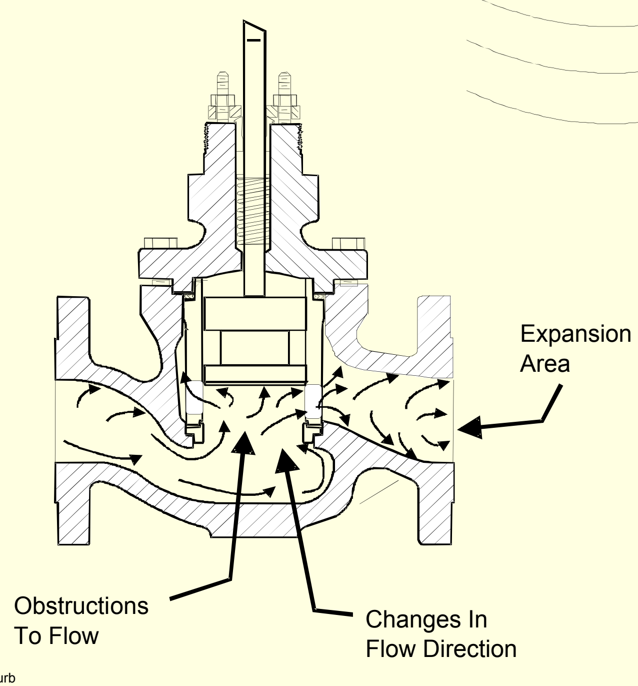
- Mechanical Vibration of valve component
- Hydrodynamic Noise
- Aerodynamic Noise

# Types of Control Valve Noise

- **Mechanical Vibration Noise**
  - Plug Instability Noise
  - Resonant Noise
  - Lateral movement of plug
  - Frequencies less than 1500Hz




- **Aerodynamic Noise**
  - Highest energy components are in audible range
  - Turbulence of flow
  - Flow path, obstructions, rapid expansion, deceleration, and direction changes
  - Frequencies typical 500 to 8000 Hz



# Mechanical Damage

- High noise levels can cause pipe vibration
  - Damage to downstream equipment

- Noise above 110 dBA can destroy a valve very quickly

# Cavitation and Flashing

- The IEC liquid sizing standard calculates an allowable sizing pressure drop, DPmax. If the actual pressure drop across the valve, as defined by the system conditions of P1 and P2, is greater than DPmax then either flash-ing or cavitation may occur. Structural damage to the valve and adjacent piping may also result.
- If pressure at the vena contracta should drop below the vapor pressure of the fluid (due to increased fluid velocity at this point) bubbles will form in the flow stream. Formation of bubbles will increase greatly as vena contracta pressure drops further be-low the vapor pressure of the liquid. At this stage, there is no difference be-tween flashing and cavitation, but the potential for structural damage to the valve definitely exists.

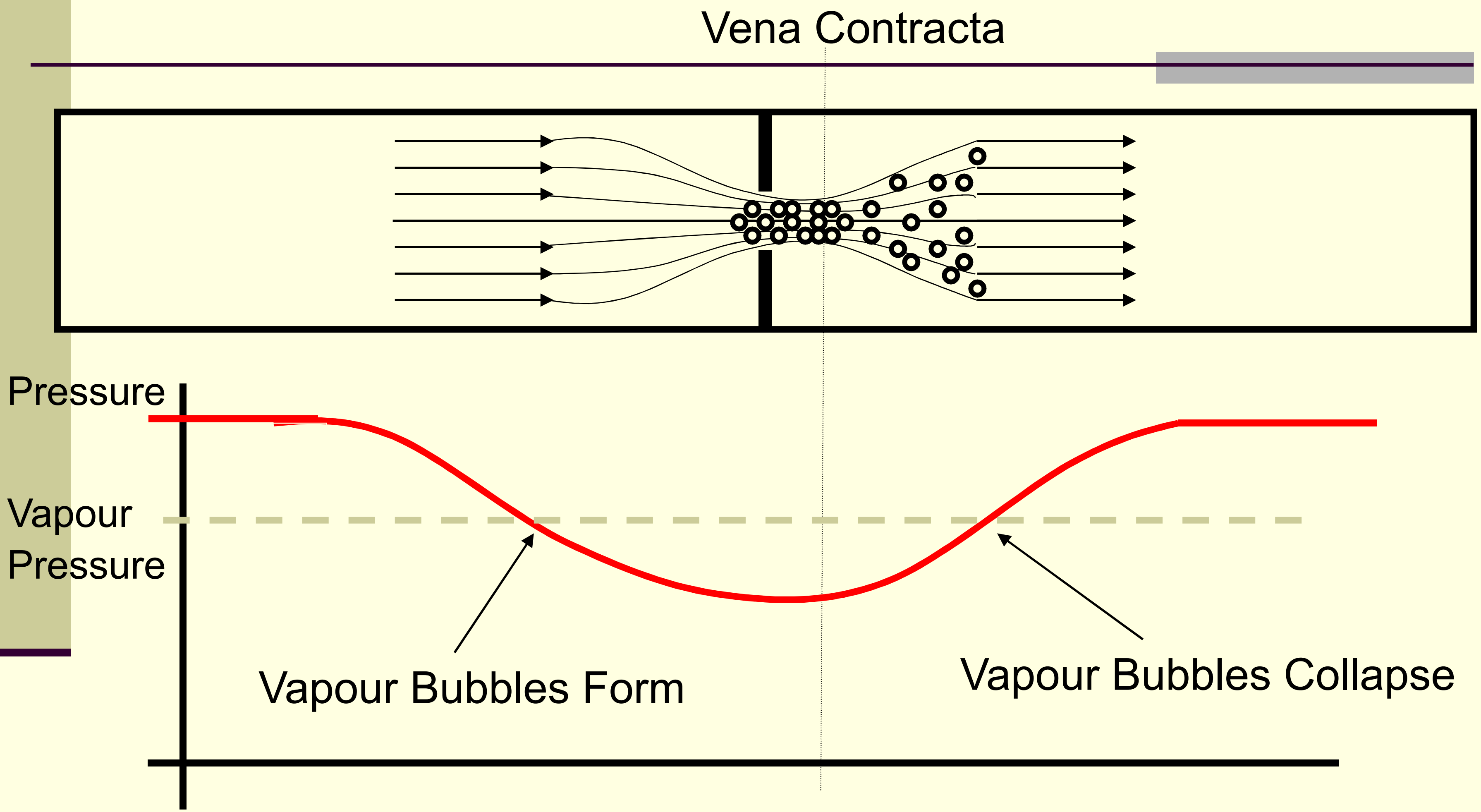
# Cavitation and Flashing

- If pressure at the valve outlet remains below the vapor pressure of the liquid, the bubbles will remain in the down stream system and the process is said to have flashed. Flashing can produce serious erosion damage to the valve trim parts and is characterized by a smooth, polished appearance of the eroded surface. Flashing damage is normally greatest at the point of highest velocity, which is usually at or near the seat line of the valve plug and seat ring.
- On the other hand, if down stream pressure recovery is sufficient to raise the outlet pressure above the vapor pressure of the liquid, the bubbles will collapse, or implode, producing cavitation.

# Cavitation and Flashing

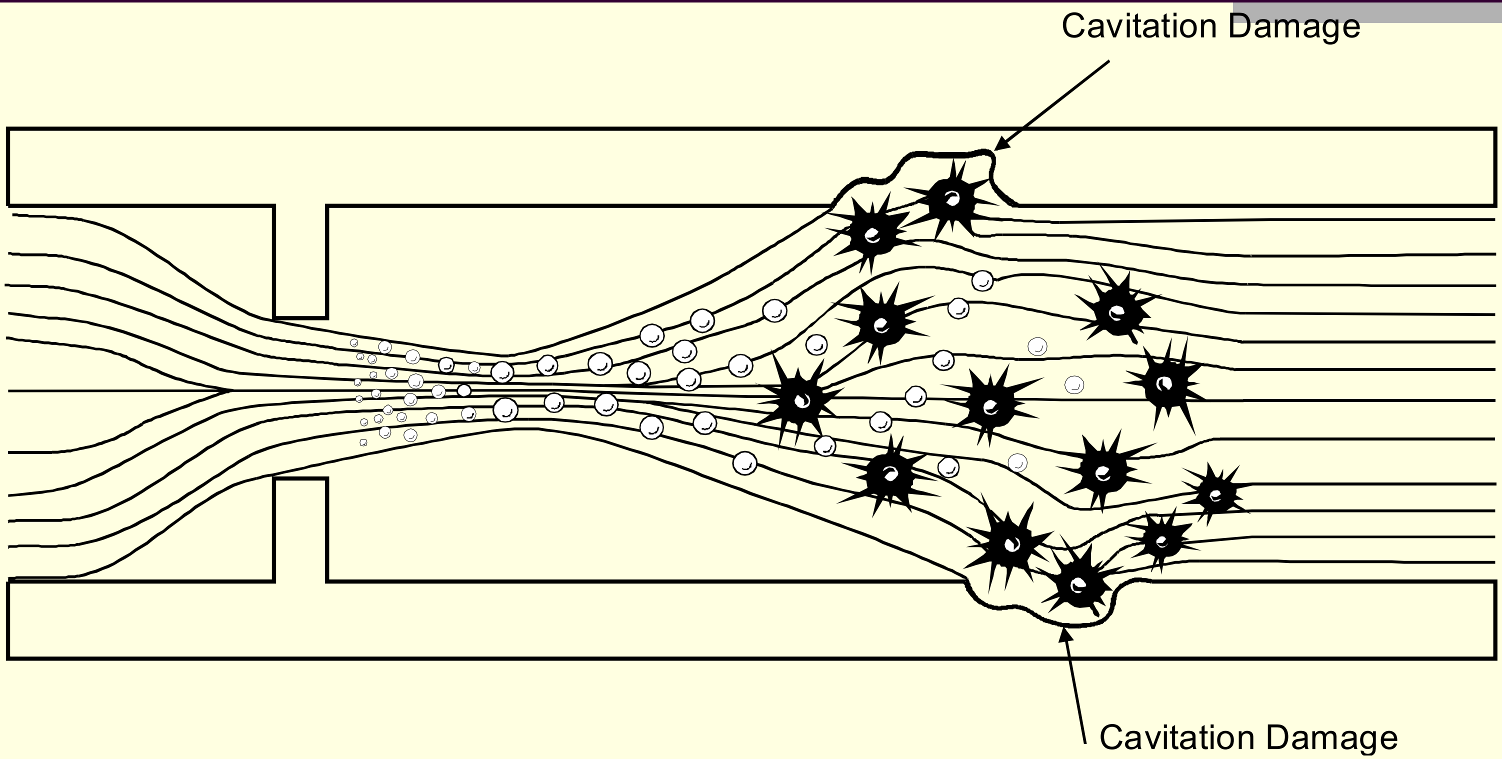
- Collapsing of the vapor bubbles releases energy and produces a noise similar to what one would expect if gravel were flowing through the valve. If the bubbles collapse in close proximity to solid surfaces in the valve, the energy released will gradually tear away the material leaving a rough, cinder like surface. Cavitation damage may extend to the adjacent downstream pipe line, if that is where pressure recovery occurs and the bubbles collapse. Obviously, high recovery valves tend to be more subject to cavitation, since the downstream pressure is more likely to rise above the liquid's vapor pressure.

# Cavitation



Vena Contracta
Pressure
Vapour
Pressure
Vapour Bubbles Form
Vapour Bubbles Collapse

# Cavitation Damage

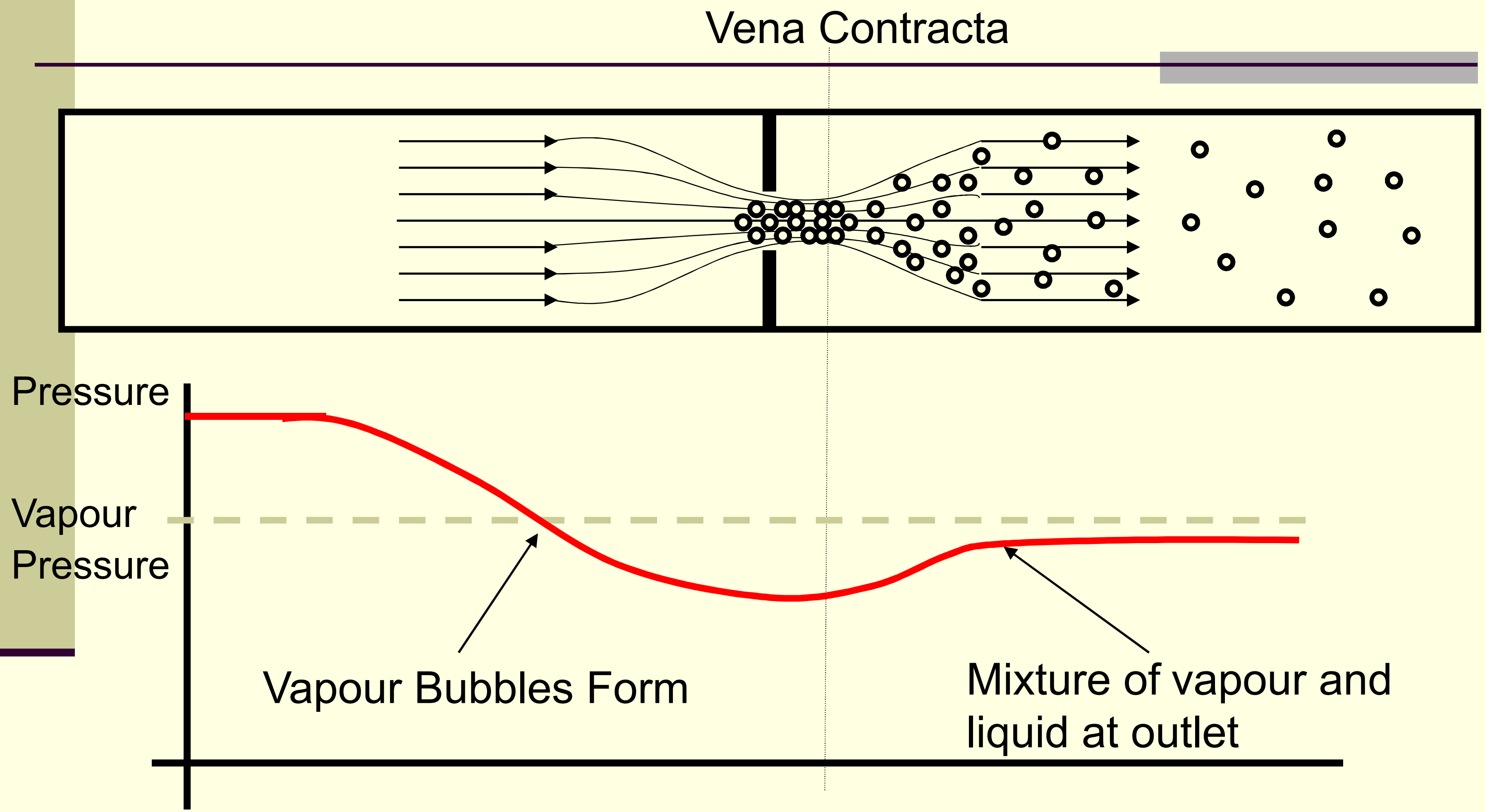


# Valve style comparison

- Rotary Valves
  - High Recovery
  - Low Km ($Fl^2$)
  - $P_{\text{vena Contracta}}$ Very low
  - Not suited to high pressure drops
    - Bearings/shaft/Seals
  - Attenuators give low level protection against cavitation
- Globe Valves
  - Low recovery
  - High Km ($Fl^2$)
  - $P_{\text{vena Contracta}}$ close to P2
  - Suited to very high pressure drops
    - Cage guided
  - High technology multi stage anti-cavitation trims

# Cavitation Damage

# Flashing


Vena Contracta
Pressure
Vapour
Pressure
Vapour Bubbles Form
Mixture of vapour and
liquid at outlet

# Flashing Damage

# choked flow

- The maximum or limiting flow rate ($q_{max}$), commonly called choked flow, is manifested by no additional in-crease in flow rate with increasing pressure differential with fixed up-stream conditions. In liquids, choking occurs as a result of vaporization of the liquid when the static pressure within the valve drops below the vapor pressure of the liquid.
- Choked Flow Causes Flashing and Cavitation.

Section 5

# Server Service Treatments

## Table of Contents

*	Source and path treatments

*	Special cages

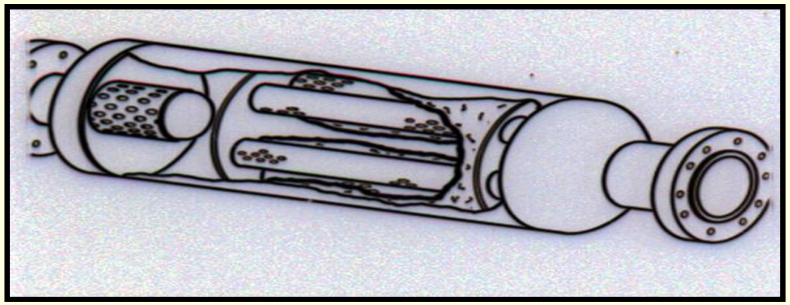
*	Proper material selection

# Noise Solutions

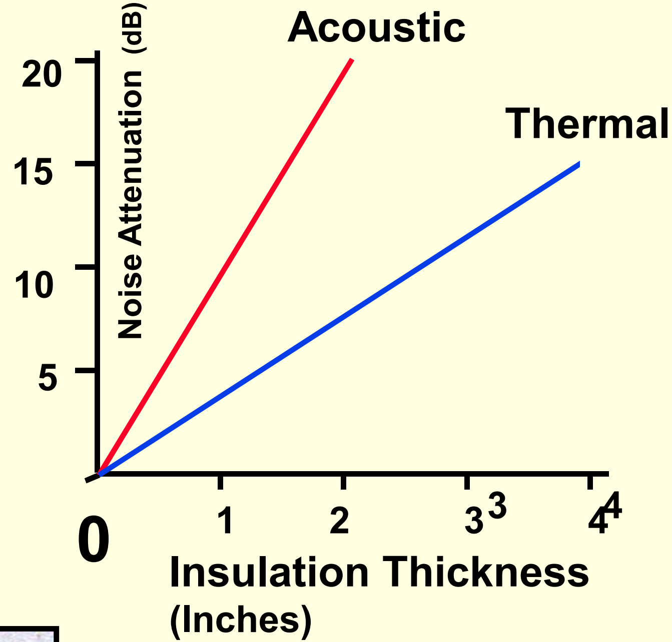
- Noise reduction can be very expensive
  - Special trim
  - Larger valve size
- Examine specified noise levels
  - are they really required
    - location of valve
    - valve operation
      - When / duration / what else will be happening
      - Typically Emergency Vent valves only operate over short periods and a higher noise level is accepted

# Noise Solutions

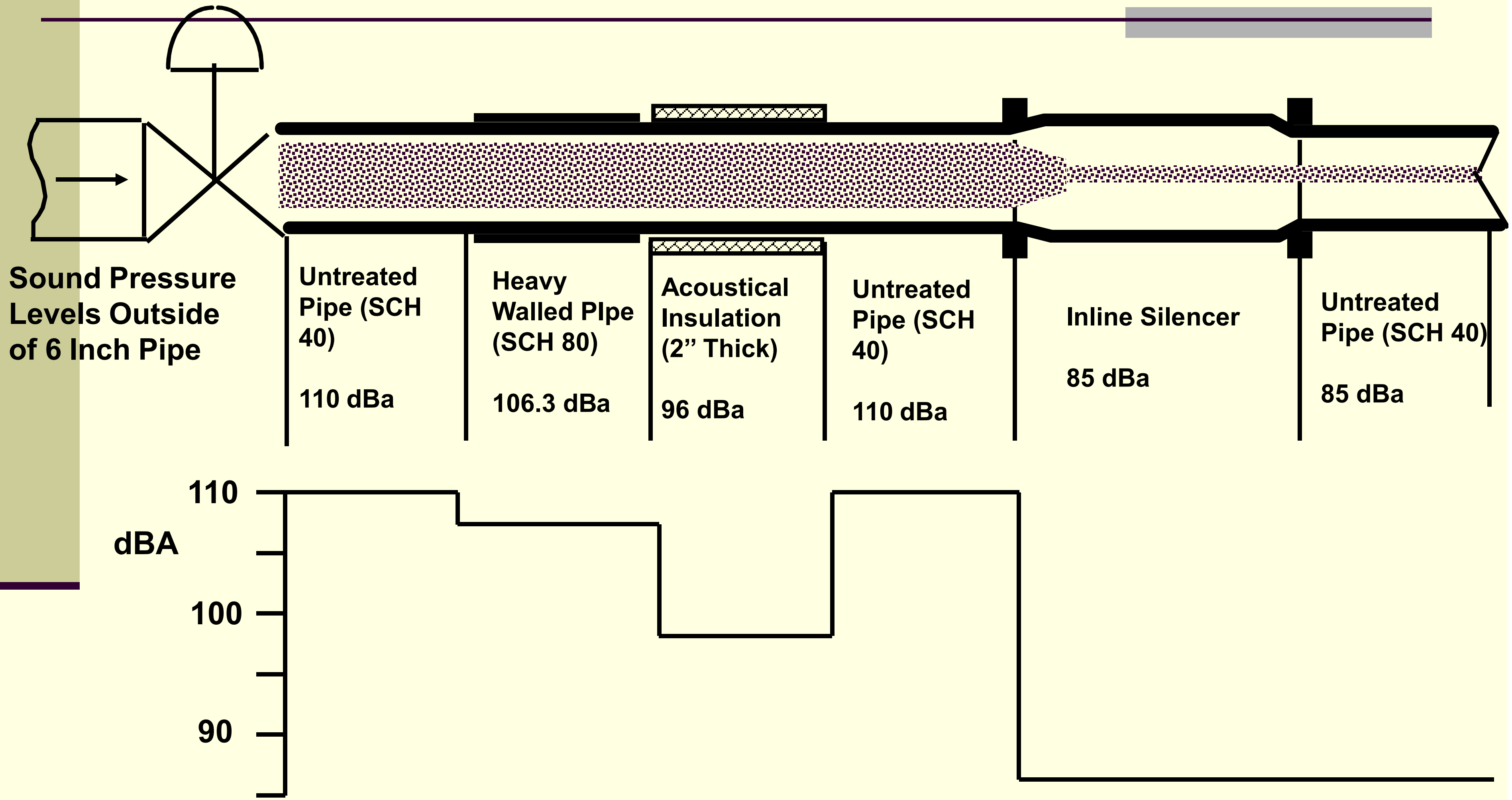
- Path treatment
  - Treatment of the noise after it is generated in the valve
  - Heavy Walled Pipe
    - Ensure correct diameter and schedule are used
    - Does schedule align with pressure rating?
  - thermal or acoustic insulation
  - Silencers



**Most steam valves are insulated so use it to reduce price**



# Path Treatment



# Noise Solutions

- Source Treatment
  - Treatment of the noise at source
    - Reduce the noise generated
    - Change the properties of the noise generated
  - Special valve trim

# IEC 534-8-3
## 5 step procedure for calculating valve noise

1. Determine stream power at the vena contracta

2. Convert to noise power at the valve outlet

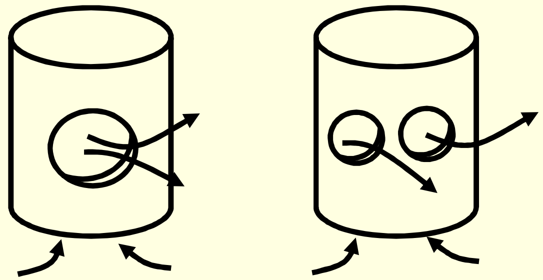
3. Determine sound pressure level in the flow stream

4. Determine A-Weighted sound pressure level outside pipe wall

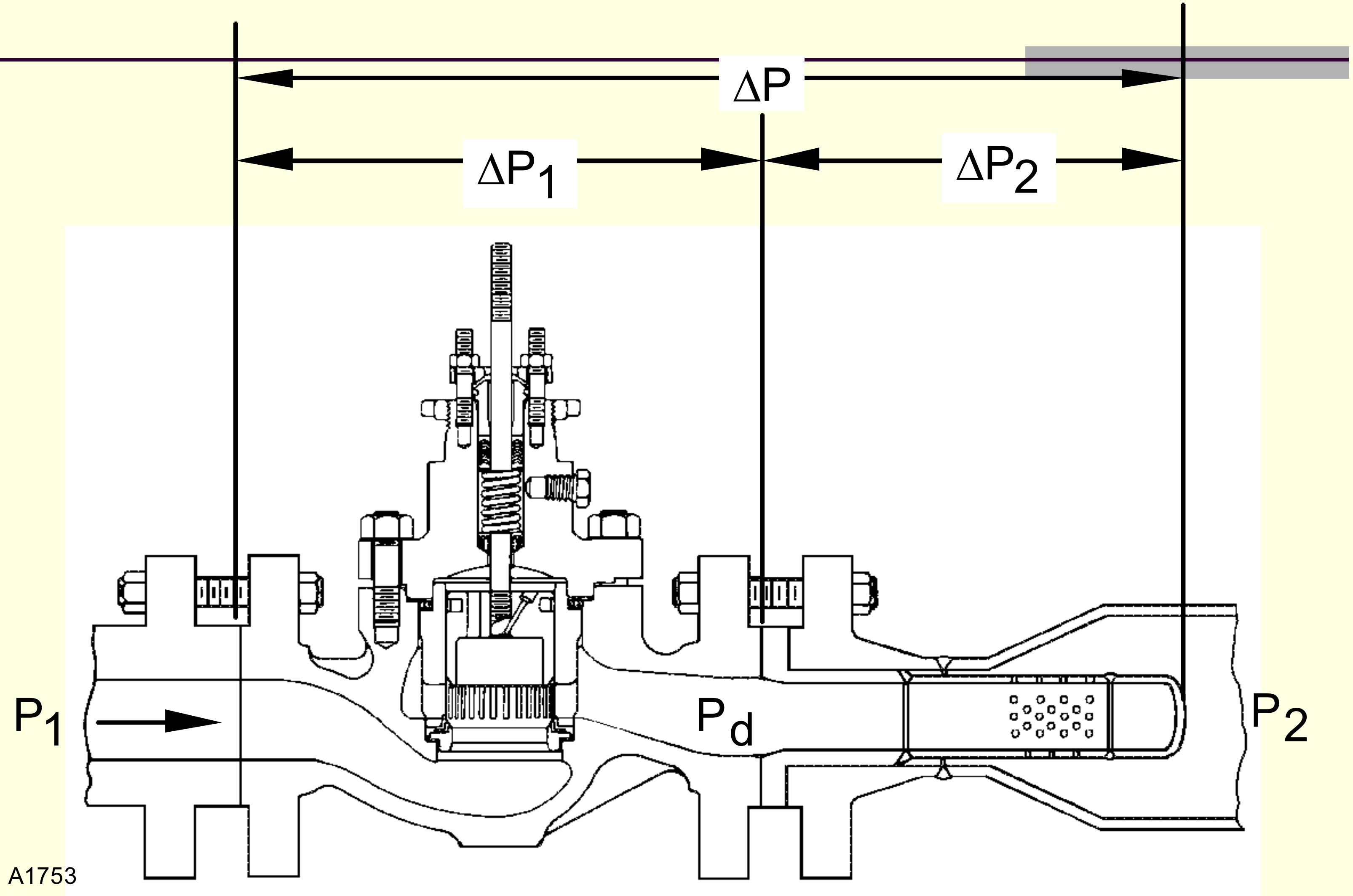
5. Translate sound pressure level to standard observer location

# Noise Attenuating Cages

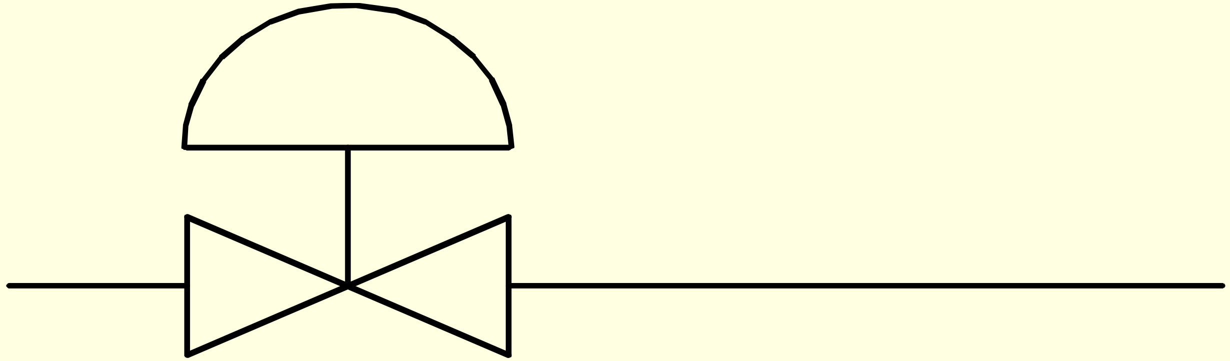
- **Slotted or Drilled Hole Cages**
  - Divide flow into smaller jets
  - Prevent jets from combining
  - Shift the noise frequency outside audible range
- **Examples**
  - WhisperFlo, Whisper III, and Whisper I

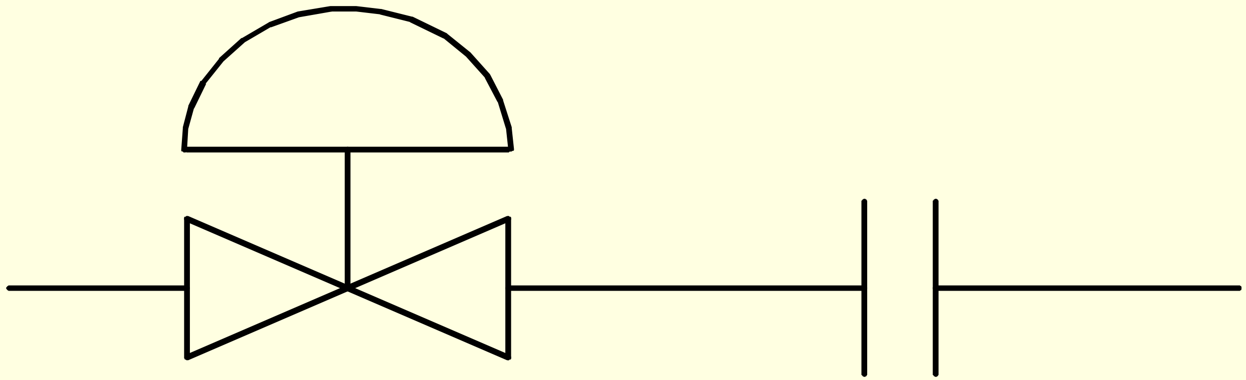


# Inline Diffuser



# Diffuser Sizing Objective

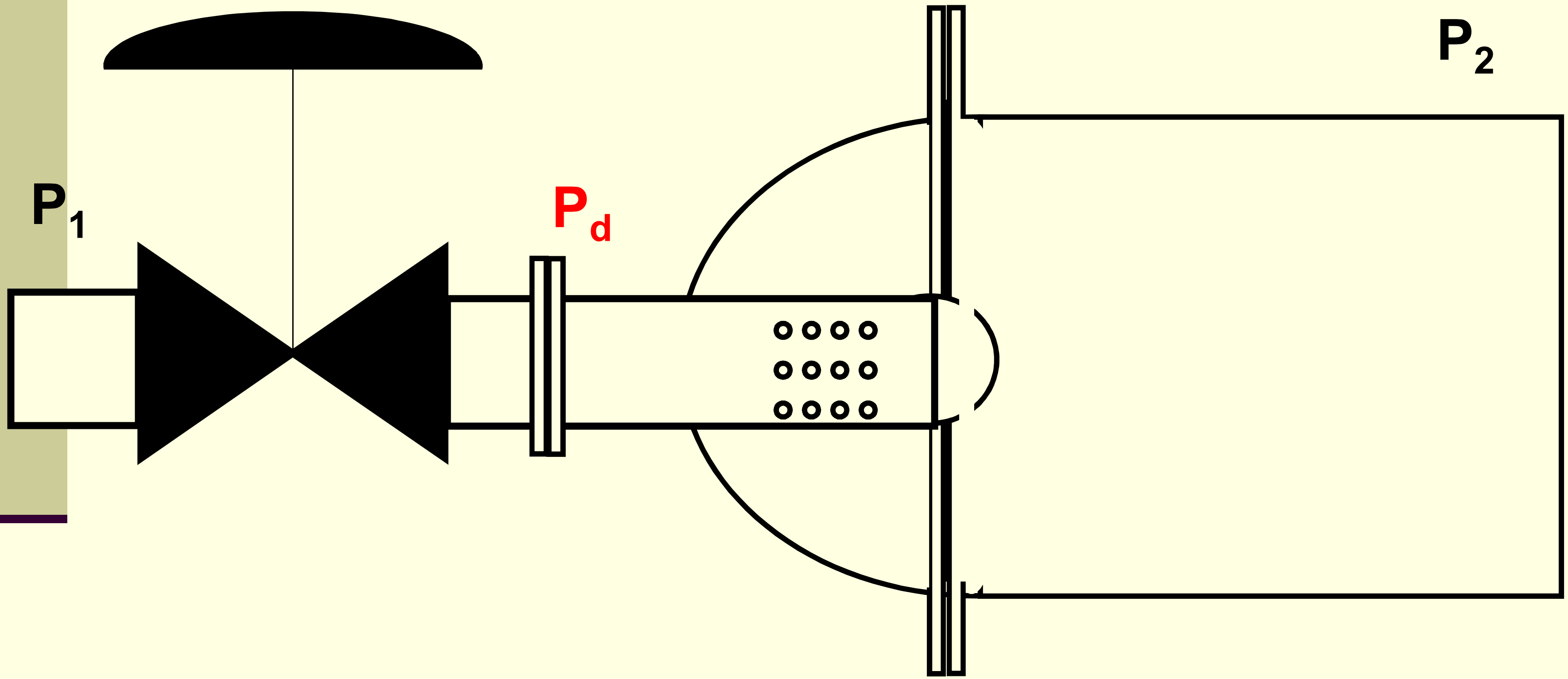



A6347

# Diffusers

**Optimisation in program adjusts the $P_d$ until the noise from the valve and diffuser are equal**

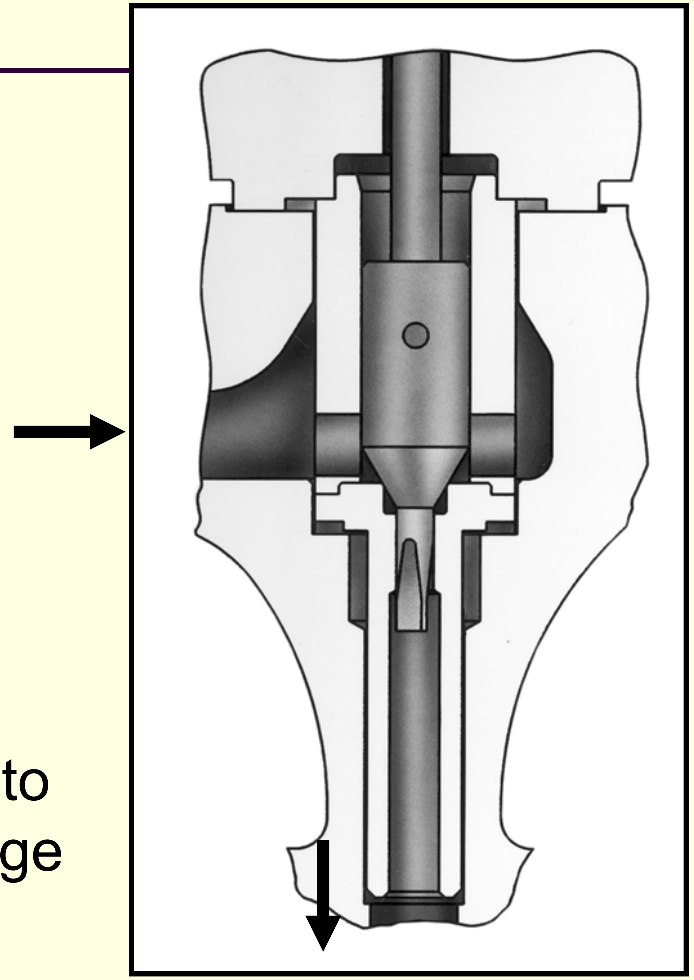


# Cavitation Solutions

- Path Treatment
  - Treating the effects of cavitation
    - Protecting exposed areas with hardened materials
    - Selecting valve to direct the cavitation away from surfaces
- Source Treatment
  - Treating the cause of cavitation

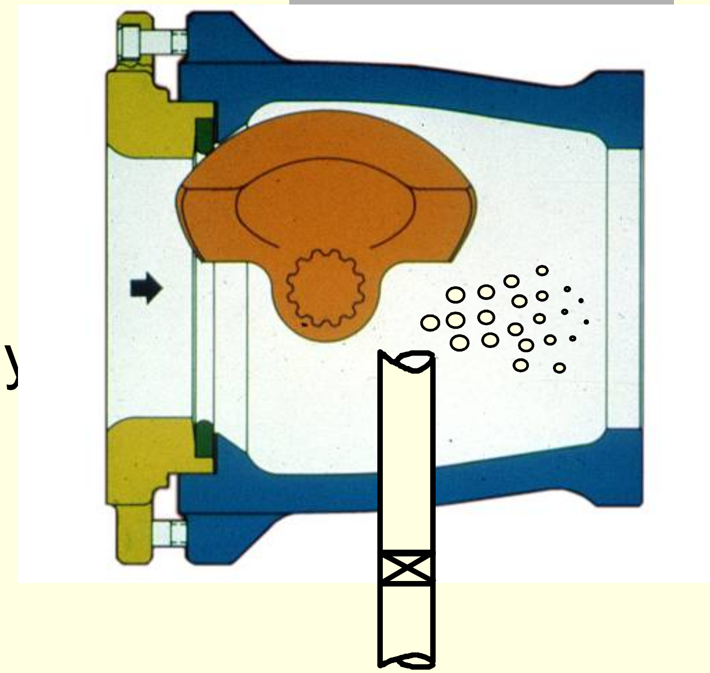
# Cavitation - Path Treatment

- Select body style that directs the cavitation away from surfaces
  - Angle body
    - Flow down
    - Liner
    - Hardened trim
    - Micro-Flat Trim for low Cv requirements
  - Cavitation is mainly confined to the centre of the outlet passage



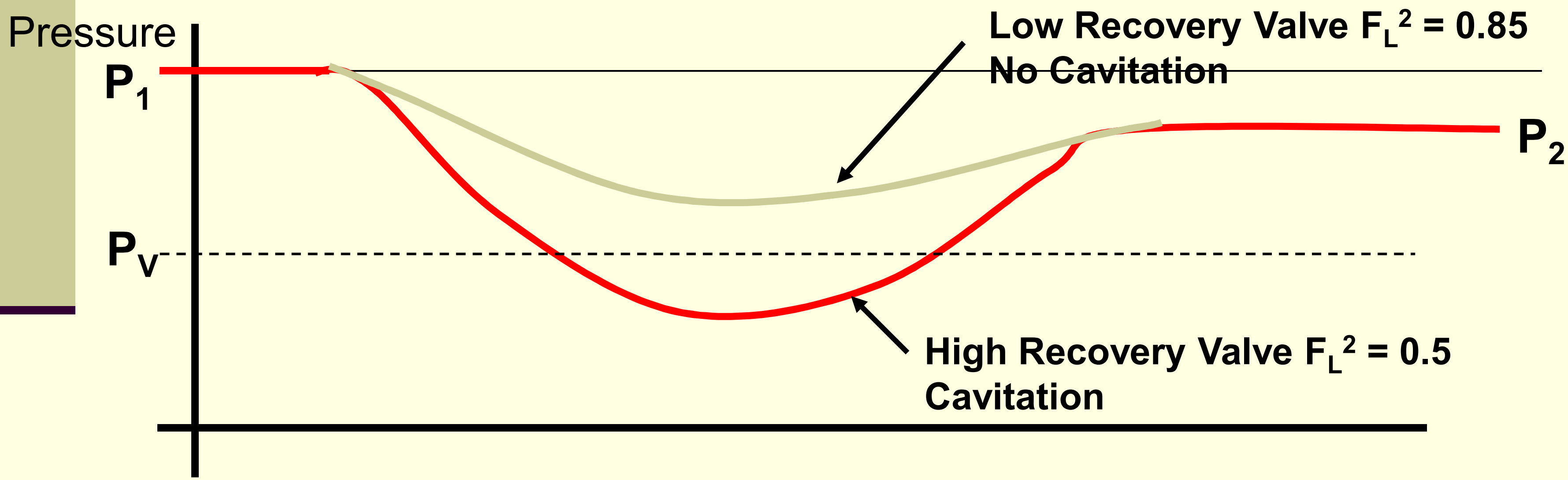
# Cavitation - Path Treatment

- Aspiration
  - Inject air into cavitating flow stream
    - Air bubbles absorb energy released in bubble collapse

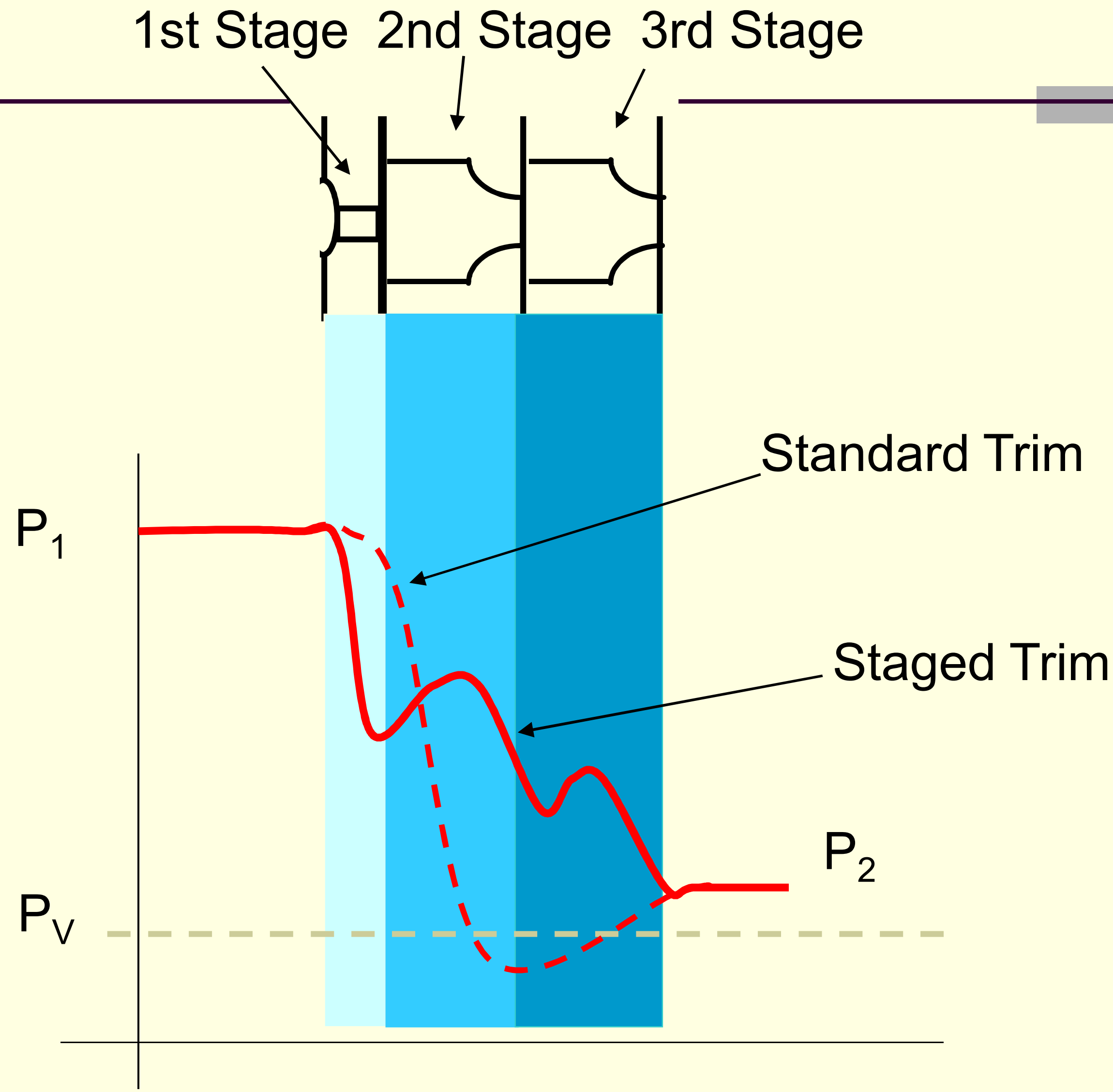


# Cavitation - Source Treatment

- Treating the cause of cavitation
  - Use valve trim that avoids cavitation
    - Low recovery valve
      - High $F_L^2$( $K_M$)
      - Change from rotary valve to globe



# Staged Pressure Drop



Section 6

# Standards

# REFERENCE CODES AND 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.

**American Petroleum Institute (API)**

- Spec 6D, Specification for Pipeline
- Valves (Gate, Plug, Ball, and Check Valves)
- 598, Valve Inspection and Testing
- 607, Fire Test for Soft-Seated Quarter-Turn Valves
- 609, Lug- and Wafer-Type Butterfly Valves

## Iranian Petroleum Standard (IPS)& National Petrochemical Co. Standard (NPCS)

- IPS-E-IN-160,Engineering standard for Control Valves
- IPS-M-IN-160,Material standard for control valves
- IPS-C-IN-160,Construction and installation standard for Control Valves
- NPCS-MS-IN-23,M.S. for Control Valves
- NPCS-SD-IN-18,Air Connection for Control Valves

## American Society of Mechanical Engineers (ASME)

- B16.1, Cast Iron Pipe Flanges and Flanged Fittings
- B16.4, Gray Iron Threaded Fittings
- B16.5, Pipe Flanges and Flanged Fittings (for steel, nickel-based alloys, and other alloys)
- B16.10, Face-to-Face and End-to-End Dimensions of Valves (see ISA standards for dimensions for most control valves)
- B16.24, Cast Copper Alloy Pipe
- B16.25, Butt welding Ends
- Flanges and Flanged Fittings
- B16.34, Valves - Flanged, Threaded and Welding End
- B16.42, Ductile Iron Pipe Flanges and Flanged Fittings
- B16.47, Large Diameter Steel Flanges (NPS 26 through NPS 60)

## 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 Range ability of Control Valves

- S75.12, Face-to-Face Dimensions for Socket Weld-End and crewed-End Globe-Style Control Valves (Classes 150, 300, 600, 900, 1500, and 2500)
- S75.13, Method of Evaluating the Performance of Positioners with Analog Input Signals
- S75.14, Face-to-Face Dimensions for Butt-weld-End Globe-Style Control Valves (Class 4500)
- S75.15, Face-to-Face Dimensions for Butt-weld-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

## International Standards Organization (ISO)

- 5752, Metal valves for use in flanged pipe systems - Face-to-face and centre-to-face dimensions
- 7005-1, Metallic flanges - Part 1: Steel flanges
- 7005-2, Metallic flanges - Part 2: Cast iron flanges
- 7005-3, Metallic flanges - Part 3: Copper alloy and composite flanges

## NACE International

- **NACE MR0175/ISO 15156**, Petroleum and Natural Gas Industries Materials for Use in H2S-Containing Environments in Oil and Gas Production
- **NACE MR0175-2002**, Sulfide Stress Corrosion Cracking Resistant Metallic Materials for Oil Field Equipment
- **NACE MR0103**, Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments

Section 7

# Sample Specification

# Technical specification

**Body Construction**

The minimum size for control valves shall be 1” as per the pipe specification. If a smaller CV is required, reduced trim shall be used. Valve bodies with flanged ends shall be 300 lbs RF minimum or in accordance with the piping specifications. Welding and other repairs to valve body castings are not permitted. Body material shall be carbon steel minimum or in accordance with the piping specification, cast iron is not allowed.

Unless otherwise stated in the valve data sheets or dictated by its application, the selection of valve type shall be in the following order of preference:

- Eccentric rotary plug valve
- Globe valve
- Ball valve
- Butterfly valve
- Other types such as angle, split body, “Y” shall be considered when the process fluid may be erosive, viscous or carrying suspended solids

Control valve bodies shall not be fitted with bottom drain plugs.  A bottom flange shall be provided for valves that require bottom access for trim removal.

Valve-bonnets shall be of bolted construction with fully retained gaskets.

Flow direction shall be permanently and clearly marked on the valve body.

**2.1.1** Eccentric Rotary Plug Valves

When these are used for general purpose control and shutoff, valve selection is limited to the obtainable valve size, the required pressure/temperature rating and allowable leakage rate.

**2.1.2** Globe Valves

The preferred style of control valves is flanged single seat globe type, with the body being of single cast construction.
Where low pressure drop or high recovery can not be achieved by globe valves, butterfly or characterized ball valves may be considered.
Split-body globe valves may only be applied with the approval of the COMPANY.
Double seated globe valves shall have top and bottom guided construction.
Three way globe valves are prohibited.

**2.1.3** Ball Valves

Ball valves may be considered for on/off duty or for large sizes on throttling service.
Ball valves shall be considered as throttling valve for hydrocarbon services with coking tendencies, erosive services, or suspended solids where settlement in globe valve body may occur. The use of reduced ball trim is allowed.

Ball valves shall be considered for on/off duty in line sizes up to 6” when the leakage rate can not be met with a globe valve, or in fuel gas lines for shut off purposes. Valves must have full line size trim.

**2.1.4** Butterfly Valves

These shall not be used for shut off purposes.
60˚ opening butterfly valves shall be considered when the required size is larger than 6” with a low pressure drop which would make it economically attractive, or on corrosive services where body lining of standard globe valves becomes economically unfeasible.
Butterfly valves shall be flangeless (wafer) type with drilling to suit the pipeline flange drilling.
They shall normally be furnished with long stroke diaphragm actuators.

**2.1.5** Angle Body Valves

These may be applied to:
High noise applications, where a globe valve is not suitable
Liquid flows where cavitations may occur in the valve
Hydrocarbon services with tendency towards coking
Erosive services
Angle valves shall have full venture throat.

**2.1.6** Self Acting Regulators

Self acting regulators or pressure regulators (PCV's), shall have the same general requirements as control valves.
Reducing regulators, back pressure regulators and differential pressure regulators shall be specified as required on the individual data sheets.
The diaphragm for these shall be designed to meet the design pressure requirements of the process line as stated on the valve data sheet.
If the process fluid governs the use of a seal pot, the VENDOR shall supply a suitable seal pot fully assembled on the regulator body.
When a regulator is used in a gas blanketing system complete with pilot regulators or other devices, the VENDOR shall assemble them on a suitable gauge board as a complete unit. The VENDOR shall submit his proposal to the COMPANY for approval.

## 2.2 Body Size

Reduced Trims in oversized bodies shall be used for:
Situations where the calculated flow coefficient would result in a standard valve two or more sizes smaller than the line.
Fluids or cavitating conditions
Fluids containing solids
When calculated valve size is below one inch
The normal sizes of control bodies should be selected from the following series 1", 1½", 2", 3", 4", 6", 8", 10", 12", and so on.
Globe type valves up to 8" size may be used for Emergency Blow down services.

## 2.3 End Connection

The Flange ANSI rating class shall be in accordance with the piping class unless otherwise specified. The minimum flange rating shall be 300# lbs for valve sizes up to 8”. The flange finish shall be in accordance with ANSI B46.1.

Screwed end connections may be used on small valves, not larger than 2”, in accordance with the pipe specification. The thread shall be NPT where required. Consideration shall be given to valve design for maintenance or replacement of internals.

Wafer type valves may be considered only for butterfly valves.

Welded end connections shall be butt weld or socket weld as per the pipe specification.

## 2.4 Face to Face Dimensions

The face-to-face dimensions of flanged globe-body control valves shall be in accordance with ISA-S75-03 for pipe classes up to 600 lbs, and to ISA-S75-16 for pipe classes 900 lbs and above.

The face-to-face dimensions for wafer type control valves shall be in accordance with ISA-S75-04.

The face-to-face dimensions of socket weld end, all pipe classes, and screwed end, pipe classes up to 600 lbs, globe style control valves shall be in accordance with ISA-S75-12.

The face-to-face dimensions for Butt weld end globe style control valves shall be in accordance with ISA-S75-015.

## 2.5 Guide Bushings

Guide Bushings for moving parts such as the valve stem shall be of corrosion resistant material.

## 2.6 Packing Glands

Packing Glands shall be equipped with flange style gland followers with bolted construction to seal against leakage around the valve disk or stem. Packing materials shall be suitable for the stated service conditions and compliance with environmental regulations.

A lubricator with steel isolating valve shall be provided where packing lubrication is required.

## 2.7 Packing and Stuffing Box

Packing materials shall be:

- PTFE-based for packing temperatures below 200˚C.
- Graphite-based, metal-reinforced, for packing temperatures over 200˚C. Lubrication is not required, but for applications above 427˚C an extension or steel yoke should be used.

Packing shall not contain asbestos.

External lubricators or grease nipples shall not be applied. Depending upon the design of the valve, an extended bonnet may be required to keep the temperature at the stuffing box at an acceptable value for the applied packing.

An extended bonnet shall be required if the operating differential pressure across the valve could otherwise cause freezing of the stuffing box/packing and/or ice formation on the trim. For example, this may be the case for compressor recycle (anti-surge) valves.

For valves in cryogenic service that are intended for installation inside a “cold box” an extended bonnet shall be applied for bringing the stuffing box outside the cold box. The stuffing box shall be on top of the extended bonnet.

The stuffing box shall be provided with an adjustable, bolted gland flange and gland follower. If, for technical reasons, the valves are to be delivered with a loose gland, this shall be clearly indicated on the appropriate valve with a warning sign.

For valves in vacuum service, special attention should be paid to the type of stem packing/sealing facilities as well as to the stem surface finish. The packing box shall be suitable for vacuum service.

## 2.8 Gaskets

Body-to-bonnet and, if required, body-to-bottom flange gaskets shall be of the spiral would type. Unless otherwise dictated by the process conditions, the gasket material shall be AISI 316 stainless steel, graphite filled, as a minimum.

## 2.9 Body Material

The material selection of the body (including bonnet and/or bottom flange), shall be as specified in individual data sheets.

Cast iron bodies shall not be used.

For applications in sour gas service, not only body materials but also all metals exposed to line fluid shall meet the requirements of NACE MR-01-75, latest edition.

Exceptions: Alloy 20, monel, 17-4PH, when specified.

All flanged globe and ball valves with ring joint facing shall also have ring joint bonnet.

Castings shall be free from injurious blowholes, porosity shrinkage faults, cracks or other defects. Castings with defects that were plugged, welded, burned or impregnated are unacceptable. Wall thickness shall meet or exceed minimum requirements of applicable codes.

Bonnets and blind heads shall be of the same material as the valve body and of integral or bolted type construction with fully retained gaskets. Threaded connections are not acceptable.

## 2.10 <u>Valve Trim Seat Rings</u>

<u>Trim Characteristics</u>

The flow characteristics shall be specified in order to obtain a linear characteristic over the operating range. The characteristic shall normally be:

- linear, when the major part of the energy loss in the system is across the control valve over its range of operation
- equal percentage, ported or contoured

This usually results in using:

i) equal percentage characteristics on flow, temperature, and gas pressure loops

ii) linear characteristics on level services

iii) linear characteristics on liquid pressure control applications, taking into consideration the energy loss stated above

Linear characteristics shall be applied when specifically required by the process or control applications, such as, compressor anti-surge control, split range control, manually controlled valves via the PCS, and minimum flow protection for pumps.

Quick opening characteristics shall only be used when the quick opening feature is considered to be necessary for process control reasons.

Trim Material

Vendor shall quote the trim material in accordance with control valves data sheets. The vendor shall take in due consideration the overall material selection philosophy and the specified data of corrosion, suspended solids, cavitations flashing and fluid velocity. The trim material on control valves data sheets shall be considered as a minimum requirement. Suitable material shall be furnished as trim where sever service require greater hardness, special alloys or coatings to prevent excessive erosion or corrosion.

If the valve is specified to have reduced trim, the seat ring and plug or cage post area shall be reduced, but the body shall remain as specified. Reduced trim shall be replaced with full sized trim.

Cage trim shall be considered standard. Special trim may be used for noise and cavitation or flashing, and the VENDOR recommendation shall be followed.

- Erosive services
- Wet gas or steam service with a pressure drop greater than 5 bar.
- Other services in which the pressure drop is greater than 10 bar at design conditions.

Plug stems shall have adequate strength to withstand maximum developed thrust of the actuators. Separable plugs and stems shall be pinned.

Rotary stem valves (Butterfly, ball, etc) shall have suitable guiding to prevent excessive shaft deflection due to maximum differential pressure or actuator thrust.

For 6” and larger valves, the post and guide bushing shall be designed to prevent rotation of the valve plug and stem.

**2.11 Bonnets**

The bonnet of a control valve is that part of the body assembly through which the valve plug stem or rotary shaft moves. On globe or angle bodies, it is the pressure retaining component for one end of the valve body. The bonnet normally provides a means of mounting the actuator to the body and houses the packing box. Generally, rotary valves do not have bonnets.

On globe style control valves, the bonnet shall be made the same as the valve body material or it is an equivalent forged material, as it is a pressure containing part subject to the line conditions.

Bolted flange bonnets shall have a drilled and tapped hole on the side of the packing box, for applications such as purging of the valve body and bonnet, or to detect leakage from the first set of packing or from a failed bellows. The VENDOR shall plug the opening with a suitable plug.

Extension bonnets shall be used for either high or low temperature services to protect valve stem packing from extreme process temperatures.

Bellows seal bonnets shall be used when no leakage along the stem can be tolerated. These are often used when the process fluid is toxic, volatile, radioactive or highly expensive.

**2.12 <u>Seat Leakage</u>**

Control valve seat leakage shall be designed and constructed in accordance with the requirements specified on the individual data sheet and classified according to ANSI B 16-104.

Class II 0.5% of maximum valve capacity

Class III 0.1% of maximum valve capacity

Class IV 0.01% of maximum valve capacity

Class V 5 x 10-4 ml/min/psid/port diameter

Class VI Tabulated by valve size and bubbles per minute

| Size (inches) | Bubbles/min |
|---|---|
| 1 | 1 |
| 1.5 | 2 |
| 2 | 3 |
| 3 | 6 |
| 4 | 11 |
| 6 | 27 |
| 8 | 45 |

Also refer to paragraph 6.3 for seat leakage tests.

**2.13 <u>Yoke and Stem</u>**

Yokes shall be of suitable rigid material for open type construction and heavy duty.

Actuator stems shall have adequate strength to withstand maximum developed thrust of actuator.

All valves shall be equipped with a valve stem travel indicator.

## 2.14 Types of Actuators

### 2.14.1 General

Valve Actuators shall normally be spring return and diaphragm type. All actuators shall be adequate to stroke the valve under the maximum differential pressure to which the valve may be exposed.

The actuators shall have a position indicator.

Air operated diaphragms and springs shall be selected to optimise on a bench setting range of 0.2-1 barg for the specified maximum upstream pressure with the downstream pressure of zero bar. The “Bench Setting Range” and the “In Service Stroking Range” shall be specified on the control valve data plates.

The valve actuator shall be sized so the valve will operate with 10% more than the maximum indicated upstream pressure. The spring barrel shall accommodate interchangeable springs.

The Actuator spring shall be fully enclosed in a metal housing and permanently treated to resist atmospheric corrosion.

### 2.14.2 Stroking Speed

The VENDOR shall design the actuators of the control valves for the following services, to meet the stroking speed requirements specified on the individual data sheet:

Anti-surge control valves

On/off service control valves

Where the stroking time requirements in any one direction can not be met, a volume booster (for a modulating control valve) or a quick exhaust valve (for an On-Off valve) shall be considered.

Pneumatic Spring Diaphragm Actuators

Pneumatic spring diaphragm actuators are the most frequently used device for positioning control valves and should be used whenever possible.

The diaphragm and spring combination shall be properly sized by the VENDOR using the Vendor's formula to overcome the unbalance of forces at the valve seat, and to provide stable operation throughout the stroke.

Operating differential pressures during different operation and shut-off will be specified on the individual data sheet for the VENDOR's design.

If operating conditions permit, ball valves should be equipped with long stroke diaphragm actuators instead of piston actuators.

Diaphragm cases shall be of steel construction with suitable corrosion protection for a Gas refinery atmosphere. Diaphragm cases shall be bolted.

Diaphragm shall be of moulded age resistant material suitable for withstanding the pressure and chemical characteristics of the operating medium over a wide range of ambient temperatures.

Diaphragm effective area shall remain essentially constant throughout the full stroke. The required thrust to stroke the valve shall be accompanied by applying a 0.2-1 barg air signal to this effective area.

When double diaphragm pressure balanced type valves are specified, the area of the air diaphragm shall be twice the area of the gas diaphragm unless otherwise noted on the individual data sheet.

**2.14.4** Pneumatic Piston Actuators

Pneumatic piston actuators shall be used where requirement of high thrust long stroke, or higher speed of response, or great unbalanced forces can not be achieved by diaphragm actuators.

Actuators should be sized using formula furnished by the VENDOR, taking into account the pressure of the available instrument air.

To obtain a fail-safe action, piston actuators shall be equipped with a trip system in accordance with the VENDOR's standard practice. Should it be desirable to maintain the last position of the control valve in the event of air failure, the actuator should be furnished complete with lock-in trip valves.

Springless pneumatic piston actuators shall be equipped with a volume tank, which shall be self standing, equipped with a ¼" drain valve, a pressure gauge, and a nameplates made of stainless steel, and supplied by the VENDOR.

The capacity of the volume tank shall be designed by the VENDOR with the following conditions:

Minimum instrument air pressure: 4.0 barg

Minimum holding air: For three full strokes

Piston operators shall be the spring-return type for throttling service.

Pneumatic piston type actuators shall have integral mounted force balance positioners and shall fail safe as noted on the individual data sheet on air failure. All piston operators for throttling service shall have a positioner.

Pistons and Cylinders shall be of material suitable for withstanding the pressure and chemical characteristics of the operating medium over a wide range of ambient temperatures.

All necessary pneumatic equipment for operation of these actuators shall be provided by the VENDOR. The normal air supply for piston operators shall be 7 Barg. For on/off service with a fail safe detection, a volume tank and a three way valve shall be used instead of a spring return.

**2.14.5** Electrohydraulic Actuators

Where applicable, hydraulic actuators shall be double acting cylinders mounted on the valves. The cylinders shall be constructed with stainless steel rod, screws and nuts as a minimum. Seals shall be viton as a minimum.

Hydraulic actuators shall be provided with suitable steel brackets, between the valves and the cylinders. Re-adjustment of the valve stem position in relation to the piston position shall be possible.

Actuator shall be totally enclosed and sealed to give protection to all internal moving parts.

The valve VENDOR shall supply the opening and closing torques, including the maximum allowance valve shear torque, and travel distances to enable the actuator VENDOR to select a suitable hydraulic cylinder.

The maximum torque needed for a valve stroke shall be multiplied by 1.3 safety coefficient at the minimum hydraulic pressure.

Unless otherwise specified, the maximum valve stroking time to achieve the safety position shall be 1 second per inch of the valve body size.

The CONTRACTOR shall provide all interconnecting piping between the hydraulic unit and the valve actuator. The interconnecting piping shall include all pipes and fittings, isolating valves, couplings, etc.

Electrical connections shall be as per the data sheets.

## 2.15 Control Valve Accessories

### 2.15.1 Enclosures of Accessories

All enclosures of accessories shall be suitable to meet the specified climatic conditions, instrument enclosure shall be dust proof and waterproof, mechanical protection degree IP65 as per IEC- 529.

### 2.15.2 Electro-Pneumatic Positioners (E/P)

Positioners are not normally specified for fast loops such as flow control, but usually are specified under the following conditions:

- When process temperature is above 230 ˚C or below 0 ˚C.
- When the normal differential pressure across the valve is above 14 Barg
- For balanced valves (double ported), 6” or larger
- For single valves 3” or larger or when the pressure drop exceeds 5 Barg
- For butterfly, ball, or plug and three way valves
- When the process fluid is viscous, a slurry or sludge
- For split range services
- For flashing services
- For high pressure services when tight packing may cause sticking
- For piston operators
- For special valve characteristics
- When specified, the valve positioners shall be mounted and piped to the valve yoke. Pneumatic positioners shall have a filter regulator, gauges and a bypass valve.

All throttling control valves shall be provided with Smart E/P Positioners capable of handling HART signals unless otherwise specified in the data sheet.

E/P Positioners shall be reversible.

The valve Positioners shall be sufficient capacity in both directions for pressuring and venting the actuator to prevent response time limitations.

E/P converters shall convert 4-20 mA signals to 0.2-1.0 barg signals and shall meet the requirement of Intrinsically Safe where required. The type of protection will be specified in the individual data sheets.

Valve positioners with selectable characterizing cam shall be properly adjusted by the VENDOR. An identification plate marked with air supply pressure, air signal and air consumption shall also be provided.

**2.15.3** Handwheels

Control valves shall be provided without a handwheel, unless otherwise indicated on the individual data sheets. Handwheels shall be used in diaphragm actuated valves when there is no block and bypass around the control valve. Handwheels shall not be used on emergency or shut-off valves.

If a handwheel is required, the following are the minimum requirements:

- The handwheel shall be of fire safe design
- The handwheel shall be provided with position indicators
- The operating force shall not exceed 350 N on the rim of the handwheel
- The transfer from actuator operation to handwheel operation shall be possible in all stem positions.
- The handwheel should be of the non-declutchable type.

All side mounted handwheels shall be suitable for use as an adjustable travel limit stop in both directions and shall incorporate a neutral position.

Gears and screw threads of the side mounted type shall be enclosed and have a minimum of backlash.

**2.15.4** Lock-up Valves

Air lock-up valves shall be provided for the following applications if indicated on individual data sheets:

- All services requiring the control valve to remain in the position immediately prior to a complete failure of the instrument air supply.
- All shut-off control valves requiring an air supply pressure higher than the guaranteed minimum instrument air pressure.

The lock-up valves shall be provided to indicate the range and the set values.

The lock-up valves shall be set at 0.5 bar above the required control valve air supply pressure unless some other set value is required for a particular actuator.

The lock-up valves shall be adjusted by the valve VENDOR.

The lock-up valves shall have a bolt adjustment provided with a locking facility to prevent tampering.

For control valves with a valve positioner, the lock-up shall be installed between the positioner output and the actuator. Where lock-up valves are applied on solenoid operated valves, the solenoid valve shall be installed between the lock-up valve and the actuator.

**2.15.5** Volume Boosters

Volume boosters shall be provided if needed to achieve the stroking times specified in the requisition. Volume boosters for pneumatic actuators shall be of the high capacity type with fast throttling facilities to control the required capacity.

**2.15.6** Solenoid Valves

Solenoid valves shall be fitted in airlines to the control valve only if specified in the individual data sheets.

Solenoids shall be used to move the valve to the fail safe position. For diaphragm actuated valves, the solenoid shall be three way, ¼" NPT and explosion proof. For piston operated valves, it shall be four way, ¼" NPT and explosion proof. Where specified, the solenoid shall be piped and mounted on the control valve.

The solenoid valves shall be provided with a disc and/or seat of resilient material to give a TSO feature. They should be suitable for installing on a mounting plate.

The air passages in the solenoid valves shall be large enough to achieve the opening or closing time of the valve as stated in the requisition. If this would lead to unrealistically large passages and consequently high power consumption of the solenoid valve, consideration should be given to the use of quick exhaust valves .

The capacity of the solenoid valve (e.g. capacity, pressure rating) shall be checked against the instrument air requirement of the particular actuator.

The minimum port size in the solenoid valve shall be stated by the solenoid valve manufacture and this shall be taken into account for the stroking time.

Solenoid valves shall be without exhaust port protectors but, to prevent plugging, shall be provided with a piece of tubing bent downwards with the end cut off an angle of 45 degree.

For long-stroke large-volume pneumatic cylinder actuators, e.g. actuators on rotary valves, considerations shall be given to the use of pneumatically operated solenoid valves which can handle the required air capacity of the particular actuator. Pneumatically operated primary solenoid valves shall be activated via a secondary solenoid valve, which shall be electrically operated.

Solenoid valves with flying leads shall be provided with a junction box for termination of the leads..

For control valves with a valve positioner, the solenoid valve shall be installed between the positioner output and the actuator.

Solenoid valves should be direct-operated, the application of pilot-operated solenoid valves requires the approval of the COMPANY.

Pneumatic connections shall be ½" NPT female and electrical connections shall be ISO M20 x 1.5.

## Limit Switches

Where specified on the individual data sheet, limit switches shall be installed on the control valves, and shall be used to indicate valve position (open, closed, or in transit). The construction of limit switches shall be as follows:

- Limit switches shall be hermetically sealed switches suitable for mounting on the valve. They shall not be affected mechanically or functionally by any vibration.
- Limit switch shall be magnetically operated type, electrical construction and the type of protection will be specified on the individual data sheets.

- They shall have ISO M20 x 1.5 electrical connections.
- Contact shall be SPDT type with rating capacity of 24V DC 1A.
- The limit switches shall be provided with terminal box suitable for external wiring by others.
- Limit switches shall be mounted and tested at the factory.

### **2.15.8** Limit Stops

Limit stops shall be fitted only if indicated on the P&ID or the individual data sheets.

Limit stops shall be mechanical devices mounted on the actuator, but they shall not form part of the handwheel mechanism (if provided). Bolts screwed in the body shall not be used as a limit stop.

Screwed bolt-type limit stops, e.g. on the control valve stem, adjustable over the full length of the stroke shall be applied.

To prevent tampering, the limit stops shall be fitted with a locking facility, e.g. a locking nut.

The limit stops shall be adequately protected against unintentional adjustments.

The Manufacturer/Supplier shall set the limit/travel stops at the required minimum or maximum valve opening.

### **2.15.9** Filter Regulators

Air filter regulators shall be installed in the instrument air supply lines to the actuator and/or positioner or individual instruments, in order to regulate the instrument air supply pressure. The make of filter regulator shall be as specified in the requisition.

The air filter regulators shall be of the reducing-relief valve type, with drainage facility and bolt adjustment provided with a locking facility, e.g. a locking nut, to prevent tampering.

The air filter cartridges shall be of the rigid structure type to channelling, rupturing shrinkage or distortion and shall have maximum mesh size of 40m.

The capability, e.g. output capacity and required spring range, of the filter-requirement shall be checked against the instrument air requirement of the particular positioner and/or actuator or pneumatic instrument.

Glass (bowl-type) filter regulators shall not be used.

**2.15.10** Instrument Air Tubings

All instrument air supply and signal tubings and fittings shall be 316 stainless steel as a minimum. Air tubing shall be sized correctly by the VENDOR in order not to starve the valve.

## 2.16 Control Valve Sizing

General Considerations

Control valves sizing shall be according to ISA S75.1, or VENDOR's standard method of valve sizing using a proven system.

The VENDOR shall submit the valve calculation sheet when necessary for evaluation work.

The valve calculation sheet shall show the capacities, noise levels, and all the other information. For valves having different operation conditions calculation sheets shall be provided for all operation condition.

The sizes given on the individual data sheet should be considered as preliminary and the VENDOR shall confirm valve sizes.

Valves Sizing

Valves shall generally be selected to control with maximum limit operating conditions between 10% and 90% of its opening stroke. Control valves shall be sized such that the valve opening at normal flow condition to be around 60%-75% depending on trim characteristic.

Butterfly valves shall normally be sized for a maximum travel of 60o, unless the valve characteristics allow control over a wider range of opening.

Valves sizing shall be based on the sizing CV in accordance with the following criteria:

a) If normal flow is specified:

Calculated Cv – Based on normal flow

Selected Cv – Based on 1.4 x normal flow

b) If maximum flow is specified but is equal to or less than 1.4x normal flow.

Calculated Cv – Based on normal flow

Selected Cv – Based on 1.5 x normal flow

c) When maximum flow is specified, but is greater than 1.4x normal flow

Calculated Cv – Based on normal flow

Selected Cv – Based on 1.1 x maximum flow

The selected manufacturer "CV's" shall be used to determine valve size.

**2.17** **Noise Level**

The maximum noise level for each control valve shall be limited to:

a) 85 dBA for normal operation

Measured as one meter away from the downstream pipe work of the valve.

The VENDOR shall calculate the control valves' noise emission, as follows:

b) Throttling control valves

- Calculation shall be made with the sizing data
- When there are several flowing conditions, the normal and maximum flow conditions shall be utilized
- For the cavitation valves, the minimum flow conditions shall also be considered for the calculation.

c) On/off valves

At fully opened condition, the noise level shall be calculated.

Where necessary, the VENDOR may use diffusers in conjunction with low noise valves.

Where final noise calculation indicates more than 85 dB(A), higher scheduled pipes shall be considered for the downstream pipings.

In those applications where the use of low noise valves and increased line schedule still do not provide a low enough noise level, use of suitable acoustical insulation downstream and upstream of the valve will be required, to meet the noise requirements.

**2.18 Limitation in Outlet Velocity**

The velocity in the valve outlet should not reach sonic velocity. Acoustic fatigue associated with large-flow gas piping systems shall be taken into consideration.

**2.19 Instrument Air Supply**

The conditions of the instrument air supplies will be as follows:

- Clean and dry (Dew point – 20˚C, at 8 barg)
- Pressure:

Minimum: 5.0 barg

Operating: 8.5 barg

Design: 9.5 barg

**2.20 Nameplate**

Control Valves

Each control valve shall be furnished with a corrosion resistant nameplate, permanently fastened with drive-screws and stamped as follows:

a) Manufacturer’s name, model number, and serial number (valve and actuator)

b) Valve action on air failure

c) Operating range

d) Body and trim size (in inches)

e) Body and trim materials

f) Trim type, and characteristic

g) Body and flange rating

h) Instrument tag number in accordance with the individual data sheet

i) Stem travel length

j) Installed CV value

k) Bench setting/spring range

l) Limit stop setting in % travel and between brackets the related Cv valve (if any)

m) Stroking time

n) Signal range

**Performance Guarantees**

The VENDOR shall guarantee the following minimum performances for the throttling control valves.

Hysteresis 5% of maximum valve stroke without positioner

1% of maximum valve stroke with connected positioner

Dead band 6% of the signal range without positioner

1% of the signal range with connected positioner

Linearity (understood as a deviation from linear relation between percent rated travel and diaphragm pressure):

±5% of maximum valve stroke without positioner

±5% of maximum valve stroke without positioner

Note: From the selected plug model and/or positioner type, when the above mentioned values can not be achieved the VENDOR shall inform the COMPANY of their deviation.

## 2.22 Electrical Certification

All electrical apparatus shall be certified to CENELEC for European countries and other recognized authorities in the manufacturer country i.e.

- PTB For Germany
- BASEEFA For England
- LCIE For France
- CSA For Canada
- INIEX For Belgium
- F.M. For USA
- U.L. For USA
- J.I.S For Japan

- JIS shall only be accepted subject to COMPANY approval.

## 3. Fat

### 3.1 General

Prior to shipment of valves a factory acceptance test shall be carried out by VENDOR and witnessed by COMPANY or 3rd party inspectors to demonstrate the compliance with the requirement of project document. FAT procedure shall be submitted for COMPANY approval at least 6 weeks prior to inspection and testing.

The following tests shall be executed on the number of control valves as specified in the requisition:

Seat leakage test:

The test results shall be made available as part of the package of final certified document and drawings.

### 3.2 Dimensional and Flange Face Finish Check

- The face-to-face dimensions of flanged globe-body control valves shall be as stated in the relevant standard.

All dimensions (including overall height) shall be as shown on the Manufacturer/Supplier's drawings.

The flange face finish shall be checked in accordance with ANSI 46.1.

**3.3** **Seat Leakage Test**

The seat leakage test shall be in accordance with ANSI-B16-104.

The seat leakage test procedures shall be executed for all control valves of class V or VI. For a double-seated control valve the leakage rate shall not exceed the limits of class II.

For each control valve, in the shut-off position, the Manufacturer/Supplier shall perform a leakage calculation at the test conditions (as defined in the test procedure) and at operating conditions with the specified fluid.

The control valve shall be tested under the thrust or torque applied by the actuator, with the signal pressure that will be available to close the valve, e.g. 0.2 to 1.0 bar bench setting as required.

For each valve tested, the Manufacturer/Supplier will state the following data:

- Flow direction
- Test medium
- Test differential pressure
- Duration of test
- Seat leakage flow rate measured
- Allowable seat leakage flow rate
- Seat leakage class (if applicable).

**3.4** **Performance and Mechanical Operation Test**

The control valve shall be completely assembled and fitted with all accessories such as positioner, solenoid valve(s), etc. The packing box shall be correctly packed to the tightness as needed for the hydrostatic test (if necessary, packing shall be renewed after testing).

The performance and mechanical test, which shall be executed randomly shall include a Hysteresis test, a dead band test and a stroking time test.

The actuating medium for the tests shall be clean, dry air or nitrogen.

The Hysteresis test shall consist of measuring the valve stem position for the following sequence of input signals: 50%, 75%, 100%, 75%, 50%, 25%, 0%, 25%, and 50%.

Hysteresis shall not exceed 5% of maximum valve stroke (without positioner), and shall not exceed 1% of maximum valve stroke (with connected positioner).

The dead band test is expressed in percentage of the input span and shall be measured at 5%, 50% and 95% of the input span. The maximum dead band found shall not exceed 6% of rated input signal (without positioner), and shall not exceed 1% of rated input signal (with connected positioner).

Testing shall be performed under atmospheric conditions (at zero differential pressure and ambient temperature) and with the minimum specified air supply pressure.

The above test results should be recorded on a X-Y recorder.

If the control valve is equipped with a handwheel, the fully open and closed position of the valve shall be achieved with handwheel operation, taking over from actuator starting at mid-position.

If the control valve is equipped with limit switches, they shall be checked for functional operation with a proximity tester.

## 3.5 Materials Inspection and Certification

Material inspection and certification requirements shall be as per the VENDOR standards.

The COMPANY reserves the right to send his inspectors or 3rd party inspectors to the VENDOR's works and his SUBVENDOR's to check, whether their design and manufacturing schedule is being maintained.

The inspectors shall have the right to access to the areas involved for the construction of the equipment and instruments ordered under this specification and the VENDOR shall give them the necessary co-operation.

For the special tests, if any, refer to the requirements specified on the individual data sheet.

**4. Inspection & testing**

**4.1** Inspection and testing procedure of those instruments covered by this technical specification shall be submitted by the VENDOR at least 6 weeks prior to inspection and testing for review and approval.

**4.2** Without imposing any limitation on the above requirements, as minimum, the following tests and inspections shall be made by the VENDOR.

a) Calibration check

b) Hydrostatic

c) Specification/dimension check

**4.3** The COMPANY reserves the right to send his inspectors or 3rd party inspectors to the VENDORS shop and his SUB-VENDORS schedule is being maintained. to check, whether their design and manufacturing.

**4.4** The inspectors shall have the right access to the areas involved for the construction of the equipment's ordered under this specification, and the VENDOR shall give them the necessary co-operation.

**4.5** For the special test, if any refer to the requirements specified on the individual data sheet.

**5. SPARE PARTS AND SPECIAL TOOLS**

**5.1 Spare Parts**

The VENDOR shall provide lists of recommended spare parts, which shall include the original part numbers with prices for commissioning, start-up and two years operation. All spare parts shall be identified individually.

The VENDOR shall be able to provide spares back up and support for the plant life of at least 25 years.

**5.2 Special Tools**

The VENDOR shall provide any special tools required for the satisfactory operation and maintenance of his equipment. A complete list of special tools shall be provided by the VENDOR at enquiry stag .

## 6. DOCUMENTATION

The VENDOR shall provide the following documentation as a minimum:

- Detailed drawing of the control valve assembly including overall dimensions, face to face dimensions, rating, actuator type and size, accessories, materials, and weights.
- Control valve calculations including noise calculations
- Wiring and pneumatic connection details

Section 8

# Sample Datasheet

| Section | No. | Item | | | | Units | @ Max. Flow | @ Norm. Flow | @ Min. Flow |
|---|---|---|---|---|---|---|---|---|---|
| GENERAL | 1 | Tag Number | Equipment Number | | | | | | |
| | 2 | Service | | | | | | | |
| | 3 | Line Number | P&ID Number | | | | | | |
| | 4 | Area Classification | | | | | | | |
| | 5 | Ambient Temperature: | | Min. | Max. | | | | |
| | 6 | Allowable Sound Pressure Level dBA | | | | | | | |
| | 7 | Tightness Requirements | | | | | | | |
| | 8 | Available Air Supply Pressure: | | Min. | Max. | | | | |
| | 9 | Power Failure Position | | | | | | | |
| | 10 | | | | | | | | |
| PIPE LINE | 11 | Line Size and Schedule | | Inlet | Outlet | | | | |
| | 12 | Pipe Material | | | | | | | |
| | 13 | Pipe Insulation | | | | | | | |
| PROCESS CONDITIONS | 14 | Process Fluid | | | | | | | |
| | 15 | Upstream Condition | | | | | | | |
| | 16 | Differential Pressure | | | | | | | |
| | 17 | | | | | Units | @ Max. Flow | @ Norm. Flow | @ Min. Flow |
| | 18 | Flow Rate | | | | | | | |
| | 19 | Inlet Pressure | | | | | | | |
| | 20 | Pressure Drop | | | | | | | |
| | 21 | Inlet Temperature | | | | | | | |
| | 22 | Molecular Mass | | | | | | | |
| | 23 | Inlet Compressibility Factor | | | | — | | | |
| | 24 | Inlet Viscosity | | | | | | | |
| | 25 | Inlet Specific Heats Ratio | | | | — | | | |
| | 26 | Inlet Vapor Pressure | | | | | | | |
| | 27 | | | | | | | | |
| CALCULATED RESULTS | 28 | Flow Coefficient Cv | | | | — | | | |
| | 29 | Travel | | | | % | | | |
| | 30 | SPL @ | | | | dBA | | | |

| Section | No. | Item | | | | Section | No. | Item | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BODY AND TRIM | 31 | MFR | Model | | | POSITIONER | 56 | MFR | Model | | |
| | 32 | Body Type | | | | | 57 | Signal: Inlet | Outlet | | |
| | 33 | Body Size | Trim Size | | | | 58 | Increase Signal Valve: | | | |
| | 34 | Rated Cv | Characteris. | | | | 59 | Cam Characteristic | | | |
| | 35 | End Connec. & Rating | | | | | 60 | Bypass | Gauges | | |
| | 36 | Body Material | | | | | 61 | | | | |
| | 37 | Bonnet Type | Material | | | SOLENOID VALVE | 62 | MFR | Model | | |
| | 38 | Flow Direction | | | | | 63 | Type | | | |
| | 39 | Flow Action To | | | | | 64 | When De-Energ.Valve: | | | |
| | 40 | Lubricator | Isolat. Valve | | | | 65 | | | | |
| | 41 | Guiding | No. of Ports | | | SWITCHES | 66 | MFR | Model | | |
| | 42 | Trim Type | | | | | 67 | Type | Quantity | | |
| | 43 | Rated Travel | | | | | 68 | Contacts / Rating | | | |
| | 44 | Plug/ Ball/ Disk Material | | | | | 69 | Switching Position | | | |
| | 45 | Seat Material | | | | | 70 | | | | |
| | 46 | Cage | Stem Material | | | AIR SET | 71 | MFR | Model | | |
| | 47 | Gasket Material | | | | | 72 | Set Pressure | | | |
| | 48 | Packing Material | | | | | 73 | Filter | Gauge | | |
| ACTUATOR | 49 | MFR | Model | | | | 74 | | | | |
| | 50 | Type | | | | TESTS | 75 | Hydro. Pressure | | | |
| | 51 | Size | Area | | | | 76 | Leakage | | | |
| | 52 | Air Failure Valve: | | | | | 77 | | | | |
| | 53 | Handwheel Location | | | | PURCHASE | 78 | Vendor | | | |
| | 54 | Bench Range | | | | | 79 | Manufacturer | | | |
| | 55 | | | | | | 80 | Model | | | |
| Notes: | | | | | | | 81 | Purchase Order Num | | | |
| | | | | | | | 82 | Test Catagory | | | |
| REV 202-07 | | | | | | | 83 | Serial Number | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | INSTRUMENT SPECIFICATION | |
| | | | | | | Control Valve | |
| | | | | | | | |
| | | | | | | | Sheet of |
| No. | By | Chkd | Appr | Date | Revision | Code: 202 | Dwg. No.: Rev.: |

| Section | No. | Item | Item | Value | Value |
|---|---|---|---|---|---|
| GENERAL | 1 | Tag Number | | | |
| | 2 | Service | | | |
| | 3 | P&ID Number | Equipment Number | | |
| | 4 | Area Classification | | | |
| BODY | 5 | Body Size | Trim Size | | |
| | 6 | Valve Type | Body Material | | |
| | 7 | Connections & Rating | Bolting | | |
| | 8 | Bonnet | Finish (µINS) | | |
| | 9 | Packing | Lubrication & Isolation | | |
| | 10 | | | | |
| TRIM | 11 | Plug Material | Seat Material | | |
| | 12 | Shaft Material | Trim Form | | |
| | 13 | Number of Seats | Guiding | | |
| | 14 | Characteristic | Flow tends to | | |
| | 15 | Leakage Class | Trim Number | | |
| | 16 | | | | |
| ACTUATOR | 17 | Actuator Type | Model Number | | |
| | 18 | Mounting Position | Size | | |
| | 19 | Spring Range | Air Failure | | |
| | 20 | Operating Signal | | | |
| | 21 | Manual Reset | Reset Location | | |
| | 22 | | | | |
| ACCESSORIES | 23 | Positioner | I/P Transducer | | |
| | 24 | Signal Input | Signal Output | | |
| | 25 | Gauges | Bypass | | |
| | 26 | Air Supply | Air Set | | |
| | 27 | Lockup | Handwheel | | |
| | 28 | Trim Character | Split Range | | |
| | 29 | Solenoid Valve | | | |
| | 30 | Limit Switch Close | Limit Switch Open | | |

| Section | No. | Item | Units | @ Max. Flow | @ Norm. Flow | @ Min. Flow |
|---|---|---|---|---|---|---|
| PROCESS DATA | 31 | Fluid / State | | | | |
| | 32 | Corrosive / Erosive / Fouling Material | | | | |
| | 33 | | Units | @ Max. Flow | @ Norm. Flow | @ Min. Flow |
| | 34 | Flow Rate @ Norm. T | | | | |
| | 35 | Pressure Drop @ | | | | |
| | 36 | Inlet Pressure @ | | | | |
| | 37 | Temperature | | | | |
| | 38 | Cv Calc. @ | —— | | | |
| | 39 | Valve Opening | % | | | |
| | 40 | SPL @ | dBA | | | |

| Section | No. | Item | Item | Value | Value |
|---|---|---|---|---|---|
| PROCESS DATA | 41 | △ P @ Shut-Off | Selected Valve Cv | | |
| | 42 | Design Pressure | Design Temperature | | |
| | 43 | Vapor Pressure | Critical Pressure | | |
| | 44 | S. G. @ Base | S. G. @ Conditions | | |
| | 45 | Viscosity @ Oper. | M.W. Gas | | |
| | 46 | Sp Heat Ratio Cp/Cv | Z | | |
| | 47 | Line Size and Sch. | Line Number | sch. | |
| | 48 | Cavitating Service | Valve Cm, Ct, Fl, Cl | | |

| Section | No. | Item | Valve | Positioner | Transducer |
|---|---|---|---|---|---|
| | 49 | | Valve | Positioner | Transducer |
| PURCHASE | 50 | Vendor | | | |
| | 51 | Manufacturer | | | |
| | 52 | Model | | | |
| | 53 | Purchase Order Number | | | |
| | 54 | Serial Number | | | |
| | 55 | Price | | | |
| | 56 | | | | |

Notes:

REV 203-07

| No. | By | Chkd | Appr | Date | Revision | INSTRUMENT SPECIFICATION<br>Control Valve Style 2 | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Sheet 1 of 1 |
| | | | | | | Code: 203 | Dwg. No.: Rev.: |

# ***FLOW MEASUREMENT***

## Contents



**1.Defini on**

Flow measurement account for high percentage of the process variables measured in the chemical processing industries.

The most common method of measuring flow is the differential pressure or “Head” device which Utilizes restriction element(orifice, venture,etc…)in line. For this method ,flow rate is proportional to the square root of the differential pressure generated by flow through the restriction.

**Nature of Fluids**

Acknowledge of some basic characteristics of fluids is necessary for choosing the best method of fluid measurement.

**Viscosity**

Is defined as a fluid to resist the forces of shear or deformation.a good example of highly viscous material is cold sorghum molasses ,which does not flow easily in comparison to water.the unit of viscosity is centipoises.(cP)in metric system unit

**Density**

Is define as mass per unit volume

**Specific Gravity**

Is its weight  ratio to a standard. For liq.the standard is water, and for gas and vapor is Air.

**Temperature**

The effect of temp.changeshas already been notedon viscosity, density and compressibility

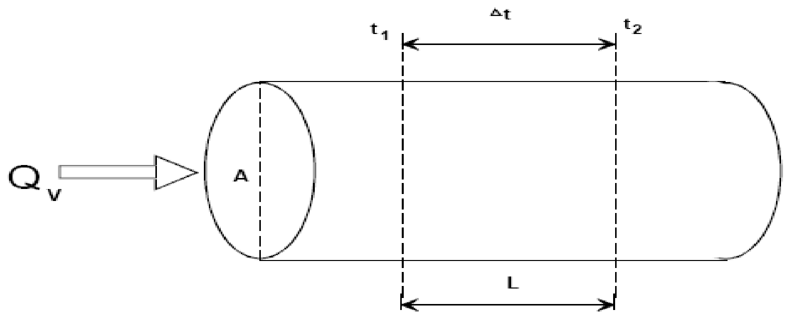
**Pressure**

The Effect of pressure variation has been well definein its relation to density,Specific gravityand compressibility.

**Flow**

Flow is defined as a quantity of fluid moved in a given interval of time.

- A quantity of fluid can be expressed as a volume or as a mass. Therefore, totaled flow and instantaneous flow, defined below, will be expressed in terms of volume flow and mass flow.
- **Totalised Flow** is the total quantity of fluid moved. In this case, time is ignored as a factor or dimension, for the quantity of the fluid is more
- important than the speed with which it is transported or used. Units of flow used for totalised flow is metre3, litre, gallon, barrel, kg, ton
- **Instantaneous flow**
- Instantaneous flow is the rate of flow: the quantity fluid moved per unit of time.
- QV = Volume / Δt



INSTANTANEOUS FLOW

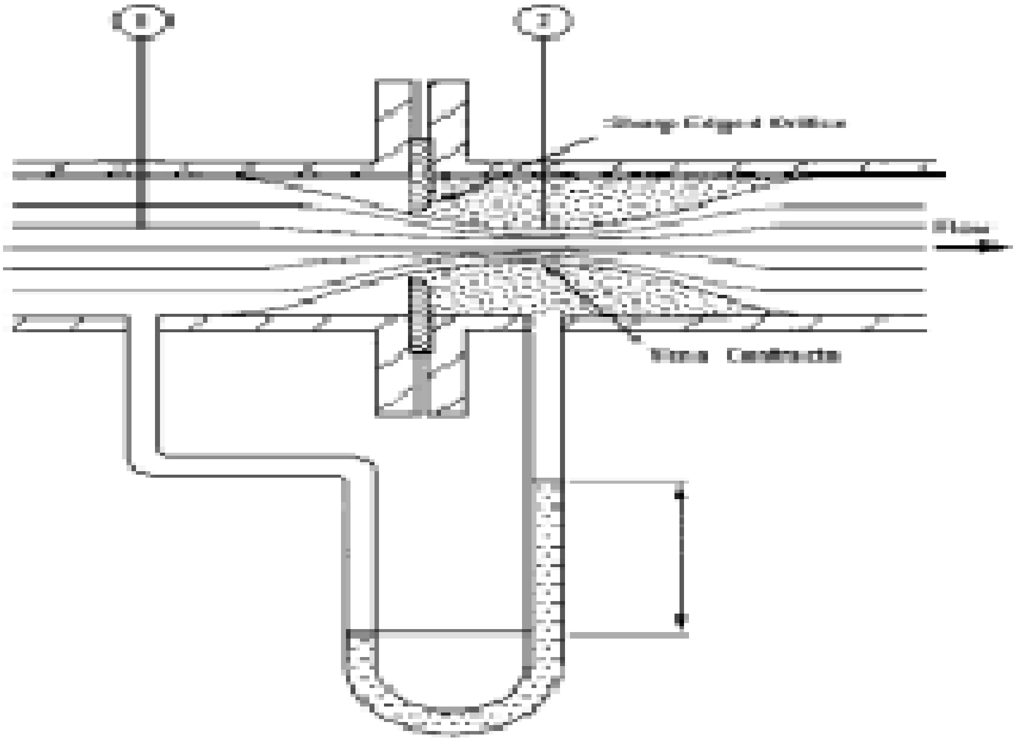
- Since volume moved between me t1 and t2 (.t) equates:
- A (cross section area) x L (length)
- We can write: QV = A x L / .t
- Also: L / .t = v (velocity)
- **Volume Flow formula is expressed as follows**:
- **QV = A x v**

- QV is expressed in m3 / s, in SI Units
- when A in m2
- and v in m / s
- **Mass flow can be expressed as follows**:
- Since: mass = volume x density:
- **QM =QV x** .
- QM is expressed in kg / s in SI units.
- when QV is in m3 / s
- and . is in kg **/** m3
- Mass flow is expressed in kg / h when QV is in m3 / h
- <u>**REYNOLDS' NUMBER**</u>
- REYNOLDS derived a means of quan fying fluid flow into 2 ranges of numerical values that
- indicate either laminar or turbulent flow by use of the **following relationship:**
- Re = Dv /v1
- Where;
- ***Re: Reynolds number (dimensionless unit)***
- D : pipe diameter ( m )
- v : average fluid velocity ( m/s )
- v1 : fluid kinema cs viscosity ( m2/s )
- In filled pipes, Reynolds number depends on fluid velocity, viscosity, and on pipe diameter. The Reynolds number gives an indication of the flow

conditions, and Reynolds found by increasing the velocity, that the flow patterns change from laminar flow to turbulent flow at a number of approximately 2000.Reynolds numbers greater than 4000 are generally accepted as being in the turbulent region.

- Transi on flow occurs in the range of 2000 to 4000
- **<u>Bernoulli's equation</u>**
- Considering a short section of pipe and a non-compressible fluid, it is assumed:
- - no temperature change in the flowing fluid
- - the fluid is flowing in a horizontal pipe
- - no work is added to the fluid by a pump
- Bernoulli.s principle and theorem:
- -For an incompressible, under ideal flow conditions - For a stream of ideal fluid in steady
- state, with no frictional forces acting under gravitational forces, Bernoulli theorem state that sum of pressure energy, kinetic energy and potential energy is constant:
- For a mass of 1 kg:
- P1 /. + V2 /2 + Z = constant
- Since the total energy of the fluid at the start, must be the same as at the end, it is possible
- to equate the applicable energy terms that apply to the case selected, namely, the pressure
- energy and the kinetic energy terms:
- P1/. + V1

- 2 /2 = P2/. + V2
- 2/2 = constant
- Or, stated as total fluid energy, remembering the assumptions above:
- **E1 = E2 = constant**
- Consequently, whenever its pressure increases, the velocity decreases and when its pressure decreases, the velocity increases.
- **DIFFERENTIAL PRESSURE MEASUREMENT**
- Differential pressure metering is one of the oldest methods of measuring flow rate in industry. for permanent flow in a continuous pipe,the mass flow is constant all along the pipe. As per Bernoulli.s equation
- A restriction in the pipe will produce a differential pressure (.P) across this restriction, due to the change in fluid velocity.
- Thus .P can be measured from which the flow can be calculated.



A TYPICAL ORIFICE METER

- **2.Orifice Flowmeter**
- The flow element such as Orifice Plate and Venturi effect is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase through the constriction to satisfy the equation of continuity, while its pressure must decrease due to conservation of energy: the gain in kinetic energy is balanced by a drop in pressure or a pressure gradient force. An equation for the drop in pressure due to Orifice or venturi effect may be derived from a combination of Bernoulli's principle and the equation of continuity.

- **Orifice Plate**

- Orifice plate technology represents one of the most accepted and versatile methods for measuring flow. Its simplicity is attractive from both maintenance and application perspectives. However, to achieve the full performance of orifice plate technology, a considerable amount of detail must be attended to.
- This device is a thin sharp edged plate with a concentric bore, installed in the pipe.

An orifice plate (restriction) inserted in a pipe will produce a differential pressure (ΔP) across this restriction, due to the change in fluid velocity.

Applying Bernoulli.s equa on to the upstream (P1) and downstream (P2) locations of an orifice plate a relationship between ΔP (which can be measured) and flow can be worked out . refer next paragraph- and it is found that the (ΔP) generated across an orifice is proportional to the square of the flow through the orifice plate.

**Orifice Plate construction**

**Description**

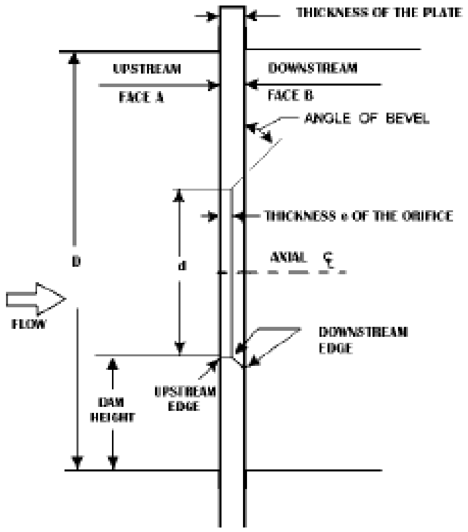
The orifice plate is usually constructed of metal, with a bore of a predetermined size and

machined to tight tolerances. It is installed between two flanges in the pipe and forms a

restriction in the flow through the pipe.

ORIFICE FLOWMETER

CONCENTRIC SQUARE - EDGED ORIFICE PLATE




Orifice plates generally are unidirectional. As the direction of the orifice plate cannot be

determined once it is installed in the pipe, standard industry practice is to stamp or affix key

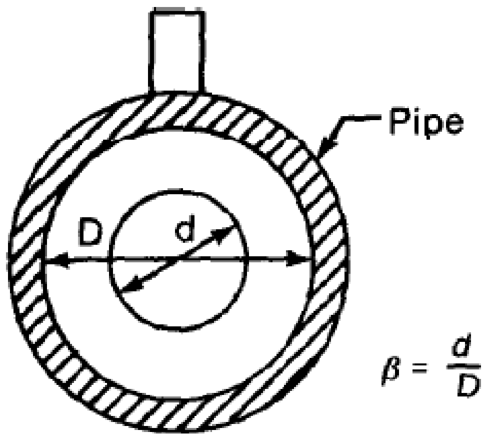
dimensional information on the upstream side of the orifice plate handle.

*The thin, concentric, square-edged orifice plate* is the most commonly applied type of orificeplate.

The bore is circular and is in a position such that upon installation the circle will be

positioned in the center of the pipe. As the plate is thick compared to the diameter of the pipe, the back of the orifice is usually beveled or counter-bored to make the orifice plate effectively thinner and performance more predictable.

The diameter ratio of the orifice to the pipe ID (termed the β ratio) is commonly used to characterize the orifice plate.




*Eccentric orifice plates*, have a circular opening machined in the same manner as a

concentric orifice plate, but located nearly tangent to the bottom of the pipe for liquids and tangent to the top of the pipe for gases.

This type of orifice plate can be used to allow entrained gases or liquid in two-phase flows to

*An integral orifice plate* is a machined concentric orifice assembly that is mounted inside or directly attached to the transmitter. Integral orifice flowmeters are applied to small flows,

typically in the l/ 2 to 1- 1 / 2 inch pipe size.

**Vent and Weep Holes**

Orifice plates may be specified with either a vent or a weep hole for liquid or gas service,

respectively.

*Vent holes* allow gas that may accumulate upstream of the orifice plate

*Weep holes* are commonly used at the bottom of the pipe to allow condensation to pass through the flowmeter

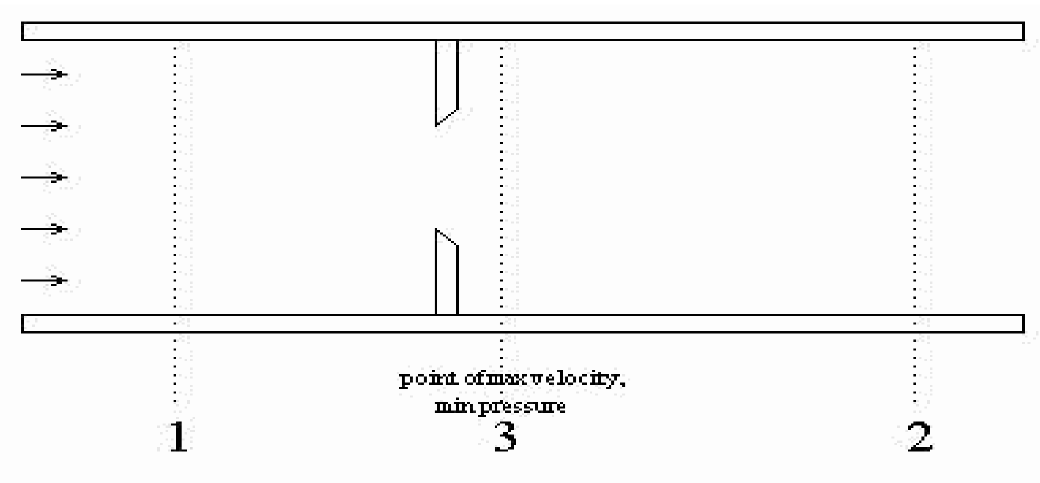
When the fluid being measured is not clean, the weep or vent hole can plug

**Pressure Taps locations**

Pressure taps are located upstream and downstream of the orifice plate to allow

measurement of the differential pressure. The points upstream will be the high-pressure tap,

and the point downstream will be the low-pressure tap.




Several sensors rely on the **pressure drop or head** occurring as a fluid flows by a resistance. The relationship between flow rate and pressure difference is determined by the Bernoulli equation.

- An orifice plate is a restriction with an opening smaller than the pipe diameter which is inserted in the pipe; the typical orifice plate has a concentric, sharp edged opening.

- Because of the smaller area the fluid velocity increases, causing a corresponding decrease in pressure.
- The flow rate can be calculated from the measured pressure drop across the orifice plate, $P_1$-$P_3$.
- The orifice plate is the most commonly used flow sensor, but it creates a rather large non-recoverable pressure due to the turbulence around the plate, leading to high energy consumption.
- **Bernoulli's equation**

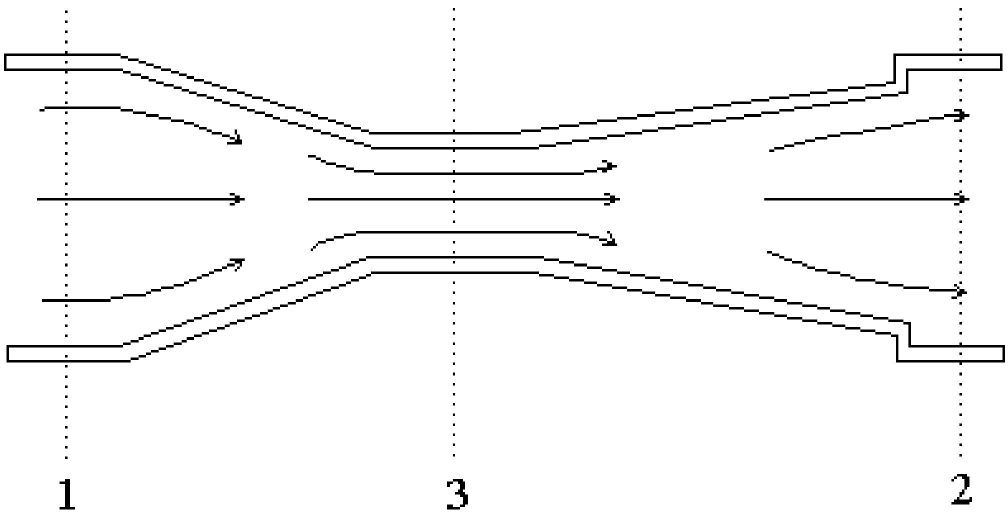
$$\frac{P_1}{\rho g} + \frac{1}{2g} v_1^2 = \frac{P_3}{\rho g} + \frac{1}{2g} v_3^2 + \Sigma f$$

where f represents the total friction loss

that is usually assumed negligible.

**3.Venturi Tube**

Venturi tubes are more expensive to construct than a simple orifice plate which uses the same principle as a tubular scheme, but the orifice plate causes significantly more permanent energy loss.




The change in cross-sectional area in the venturi tube causes a pressure change between the convergent section and the throat, and the flow rate can be determined from this pressure drop. Although more expensive that an orifice plate; the venturi tube introduces substantially lower non-recoverable pressure drops .

The Venturi tube is used where little pressure drop is available or required.

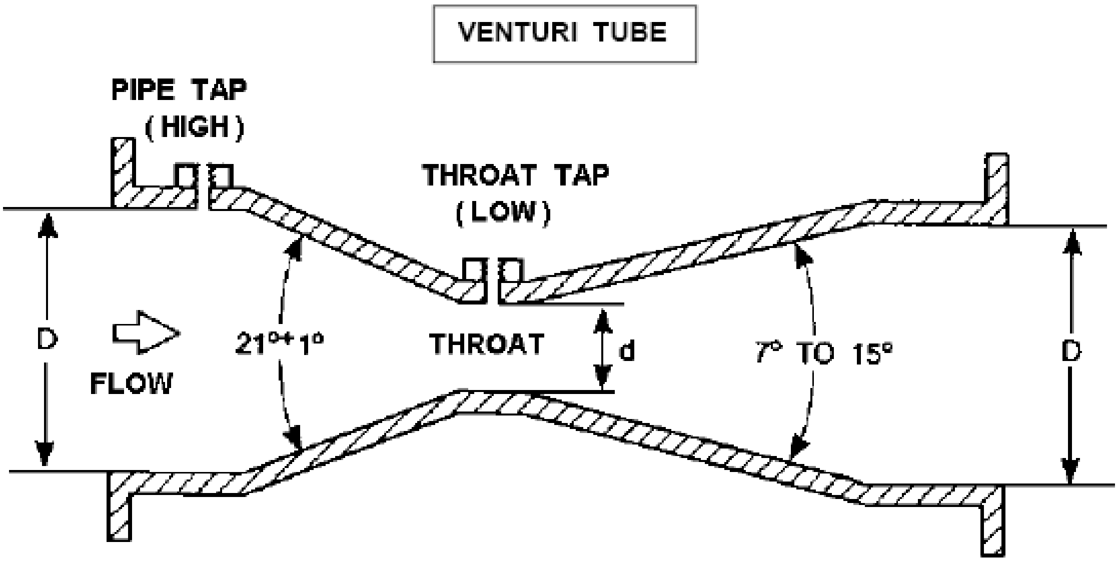
The classical Venturi tube consists of a converging conical inlet section, a cylindrical throat and a diverging recovery cone.

Fluid velocity increases in the converging inlet section, increasing the velocity head and decreasing the pressure head.

The flow rate remains static in the throat section where there is no cross-sectional

dimensional change, but it decreases in the recovery section, and the decreased velocity head is recovered as pressure.

The relatively large recovery at this point results in a permanent pressure loss of only 10 to 25 % of the differen    al pressure across the tube. When very high flow rates are involved, substantial savings in power requirements can be obtained.




Pressure taps for Venturi sections are usually located in the uniform section upstream ahead of the cone for the high-pressure measurement, and at the throat for the low pressure measurement.

## 4.Pitot Tubes

A Pitot tube is a pressure measuring instrument used to measure fluid flow velocity by determining the stagnation pressure. Bernoulli's equation is used to calculate the dynamic pressure and hence fluid velocity.

- Pitot tubes were invented by Henri Pitot in 1732 to measure the flowing velocity of fluids. Basically a differential pressure (d/p) flowmeter, a pitot tube measures two pressures: the static and the total impact pressure.
- Pitot tubes are used to measure air flow in pipes, ducts, and stacks, and liquid flow in pipes, weirs, and open channels.

- While accuracy and rangeability are relatively low, pitot tubes are simple, reliable, inexpensive, and suited for a variety of environmental conditions, including extremely high temperatures and a wide range of pressures.
- The point velocity of approach (VP) can be calculated by taking the square root of the difference between the total pressure (PT) and the static pressure (P) and multiplying that by the C/D ratio, where C is a dimensional constant and D is density:

$$V_P = C(P_T - P)^{1/2} / D$$

- A single-port pitot tube can measure the flow velocity at only a single point in the cross-section of a flowing stream.
- The probe must be inserted to a point in the flowing stream where the flow velocity is the average of the velocities across the cross-section, and its <u>impact port must face directly into the fluid flow</u>.

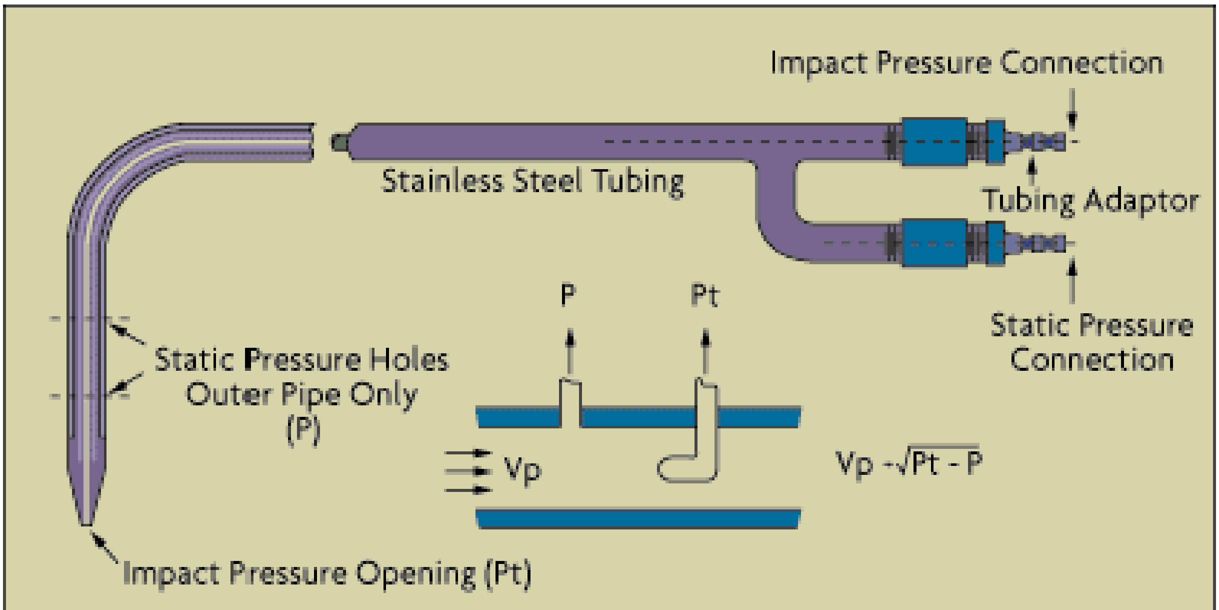


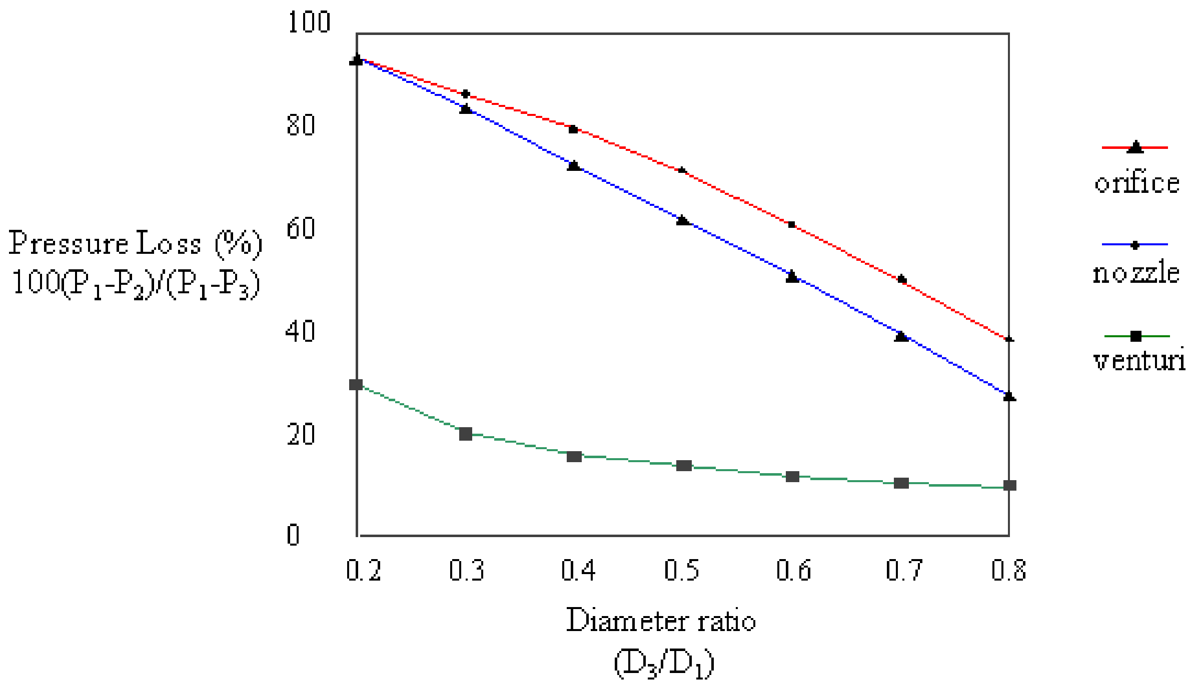

Figure 2-9: Pitot Tubes Measure Two Pressures

(Figure 2-9).

- The pitot tube measures the static and dynamic (or impact) pressures of the fluid at **one point** in the pipe.
- The flow rate can be determined from the difference between the static and dynamic pressures which is the velocity head of the fluid flow.
- Both the pitot tube and annubar contribute very small pressure drops, but they are not physically strong and should be used only with clean fluids.

**4.Flow Nozzle**

- A flow nozzle consists of a restriction with an elliptical contour approach section that terminates in a cylindrical throat section.
- Pressure drop between the locations one pipe diameter upstream and one-half pipe diameter downstream is measured.
- Flow nozzles provide an intermediate pressure drop between orifice plates and venturi tubes; also, they are applicable to some slurry systems.



## Comparison between flow-meters

| Sensor | Rangeability[1] | Accuracy[2] | Dynamics (s) | Advantages | Disadvantages |
|---|---|---|---|---|---|
| **orifice** | 3.5:1 | 2-4% of full span | - | -low cost<br>-extensive industrial practice | -high pressure loss<br>-plugging with slurries |
| **venturi** | 3.5:1 | 1% of full span | - | -lower pressure loss than orifice<br>-slurries do not plug | -high cost<br>-line under 15 cm |
| **flow nozzle** | 3.5:1 | 2% full span | - | -good for slurry service<br>-intermediate pressure loss | -higher cost than orifice plate<br>-limited pipe sizes |
| **turbine** | 20:1 | 0.25% of measurement | - | -wide rangeability<br>-good accuracy | -high cost<br>-strainer needed, especially for slurries |
| **vortex shedding** | 10:1 | 1% of measurement | - | -wide rangeability<br>-insensitive to variations in density, temperature, pressure, and viscosity | -expensive |
| **positive displacement** | 10:1 or greater | 0.5% of measurement | - | -high reangeability<br>-good accuracy | -high pressure drop<br>-damaged by flow surge or solids |

## 5.Vortex Flow-meters

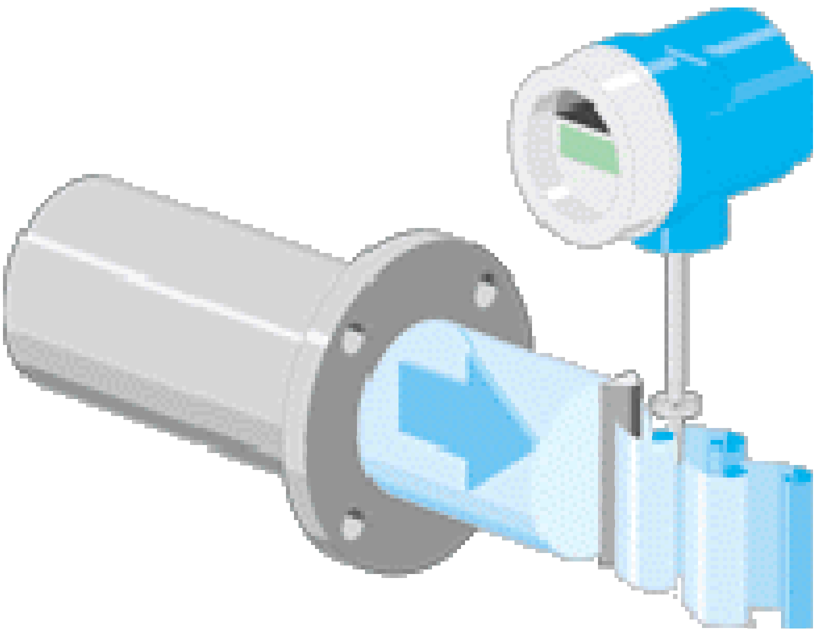
Another method of flow measurement involves placing a bluff body (called a shedder bar) in the path of the fluid. As the fluid passes this bar, disturbances in the flow called vortices are created. The vortices trail behind the cylinder, alternatively from each side of the bluff body. This vortex trail is called the Von Kármán vortex street a er von Karman's 1912 mathema cal descrip on of the phenomenon. The frequency at which these vortices alternate sides is essentially proportional to the flow rate of the fluid. Inside, atop, or downstream of the shedder bar is a sensor for measuring the frequency of the vortex shedding. This sensor is often a piezoelectric crystal, which produces a small, but measurable, voltage pulse every time a vortex is created. Since the frequency of such a voltage pulse is also proportional to the fluid velocity, a volumetric flow rate is calculated using the cross sectional area of the flow meter. The frequency is measured and the flow rate is calculated by the flowmeter electronics.

With f= SV/L where,

- f = the frequency of the vortices
- L = the characteristic length of the bluff body
- V = the velocity of the flow over the bluff body
- S = Strouhal number, which is essentially a constant for a given body shape within its operating limits

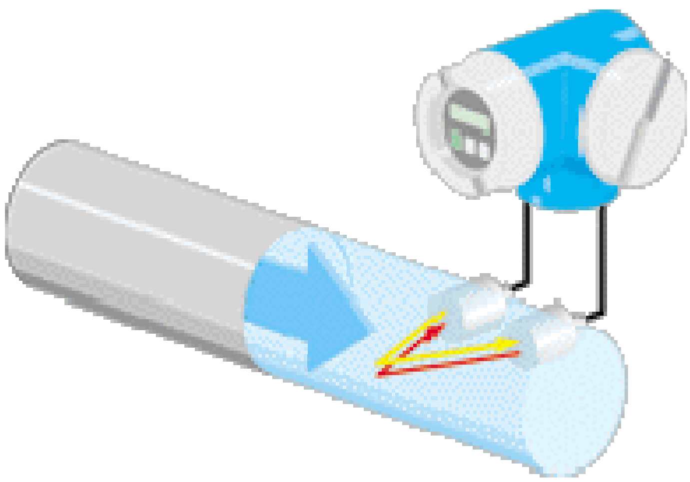
This measuring principle is based on the fact that vortices are formed downstream of an obstacle in a fluid flow, e.g. behind a bridge pillar.

This phenomenon is commonly known as the Kármán vortex street.



1. When the fluid flows past a bluff body in the measuring tube, vortices are alternately formed on each side of this body.
2. The frequency of vortex shedding down each side of the bluff body is directly proportional to mean flow velocity and to volume flow.
3. As they shed in the downstream flow, each of the alternating vortices creates a local low pressure area in the measuring tube.
4. This is detected by a sensor, such as capacitive sensor and fed to the electronic processor as a primary, digitized, linear signal.
5. Capacitive sensors with integrated temperature measurement can directly register the mass flow of saturated steam as well, for example.
6. Universally suitable for measuring liquids, gases and steam
7. Largely unaffected by changes in pressure, temperature and viscosity
8. High long-term stability (lifetime K factor), no zero-point drift
9. No moving parts
10. Marginal pressure loss

**6.Ultrasonic flow-meters**



Swimming against the flow requires more power and more time than swimming with the flow. Ultrasonic flow measurement is based on this elementary transit time difference effect.

- Two sensors mounted on the pipe simultaneously send and receive ultrasonic pulses.
- At zero flow, both sensors receive the transmitted ultrasonic wave at the same time, i.e. without transit time delay.
- When the fluid is in motion, the waves of ultrasonic sound do not reach the two sensors at the same time.
- This measured "transit time difference" is directly proportional to the flow velocity and therefore to flow volume.
- By using the absolute transit times both the averaged fluid velocity and the speed of sound can be calculated.
- **Ultrasonic flow meters** measure the difference of the propagation time (transit time) of ultrasonic pulses propagating in (normally an inclination angle around 30 to 45° is used) flow direc on and against the flow direction.
- This time difference is a measure for the averaged velocity of the fluid along the path of the ultrasonic beam.

Using the two transit times $t_{up}$ and $t_{down}$ and the distance between receiving and transmitting transducers $L$ and the inclination angle α, one can write the equations

$$v = \frac{L}{2\sin(\alpha)} \frac{t_{up} - t_{down}}{t_{up}\, t_{down}}$$

$$c = \frac{L}{2} \frac{t_{up} + t_{down}}{t_{up}\, t_{down}}$$

where *v* is the average velocity of the fluid along the sound path and *c* is the speed of sound.

Measurement of the **doppler shift** resulting in reflecting an **ultrasonic** beam off the flowing fluid is another recent, accurate innovation made possible by electronics.

Non-contact measurement from outside. Ideal for measuring highly aggressive liquids or fluids under high pressure

advantage

- With homogeneous fluids, the principle is independent of pressure, temperature, conductivity and viscosity
- Usable for a wide range of nominal diameters Direct meter installation on existing pipes.
- Non-invasive measurement
- No pipe constrictions, no pressure losses
- No moving parts. Minimum outlay for maintenance and upkeep

## 7.Major issues for selecting flowmeters

**Accuracy** - Accuracy is the degree of conformity of the measured value with the accepted standard or ideal value, which we can take as the true physical variable.

**Accuracy** is usually reported as a range of maximum inaccuracy. These ranges should have a significance level, such as 95% of the measurements will be within the inaccuracy range.

**Repeatability** – The closeness of agreement among a number of consecutive measurements of the same variable (value) under the same operating conditions, approaching in the same direction.

rifice flow meters with accuracy of ±3% of maximum flow range.

**Reproducibility** – The closeness of agreement among a number of consecutive measurements of the same variable (value) under the same operating conditions over a period of time, approaching from both directions. This is usually expressed as non-reproducibility as a percentage of range (span).

- Often, an important balance is between accuracy and reproducibility, with the proper choice depending on each process application.
- **Linearity -** This is the closeness to a straight line of the relationship between the true process variable and the measurement.
- Lack of linearity does not necessarily degrade sensor performance. If the nonlinearity can be modeled and an appropriate correction applied to the measurement before it is used for monitoring and control, the effect of the non-linearity can be eliminated.
- Linearity is usually reported as **non-linearity**, which is the maximum of the deviation between the calibration curve and a straight line positioned so that the maximum deviation is minimized.

**Reliability** – Reliability is the probability that a device will adequately perform (as specified) for a period of time under specified operating conditions. Some sensors are required for safety or product quality, and therefore, they should be very reliable. Reliability is affected by maintenance and consistency with process environment

**Range/Span** - Most sensors have a limited range over which a process variable can be measured, defined by the lower and upper range values. Usually, the larger the range, the poorer the accuracy, and reproducibility. Therefore, engineers select the smallest range that satisfies the process requirements.

Rangeability is the ratio of full span to smallest flow that can be measured with sufficient accuracy.

If a chemical reactor typically operates at 300 °C, the engineer might select a range of 250-350 °C.

Since the reactor will be started up from ambient temperature occasionally, an additional sensor should be provided with a range of -50 to 400 °C.

**Dynamics** - The use of the sensor dictates the allowable delay in the sensor response. When the measured value is used for control, sensor delays should be minimized, while sensors used for monitoring longer-term trends can have some delay.

**Safety -** The sensor and transmitter often require electrical power. Since the sensor is located at the process equipment, the environment could contain flammable gases, which could explode when a spark occurs.

**Maintenance** – Sensors require occasional testing and replacement of selected components that can wear. Engineers must know the maintenance requirements so that they can provide adequate spare parts and personnel time. Naturally, the maintenance costs must be included in the economic analysis of a design.

**Cost** - Engineers must always consider cost when making design and operations decisions. Sensors involve costs and when selected properly, provide benefits. These must be quantified and a profitability analysis performed.

Remember that the total cost includes costs of transmission (wiring around the plant), installation, documentation, plant operations, and maintenance over the life of the sensor.

## 8.FLOW ORIFICE SIZING

### 8.1 Introduction

• Many factors are considered in the sizing of differential pressure elements.

• Precise calculations are performed on a computer due to interaction of flowmeter parameters and the numerical tedium of precise calculations. Refer flow orifice sizing prac ce using INSTRUCALC so ware (ISO 5167), next paragraph.

### 8.2 Methodology

*The methodology for sizing orifice plates and other differential producing devices explained*

*here after is for the understanding of the calculation, to know .what the computer is doing.*

*when using any sizing software.* Chronology here after is based upon ASME/ISO discharge coefficients and uses equations presented in Flow Measurement Engineering Handbook by

R. W. Miller.

- Plant calculations are performed by *calculating a sizing factor and estimating the*

*approximate β ratio of the flowmeter.*

- Precise calculations are performed by iteration.

- Calculations below are presented in terms of mass flow.

***Step 1: knowing maximum flow, design flow, select a maximum differen al pressure***

***for the ΔP flowmeter.***

In gas applications, the differential pressure should be selected such that the expansion factor varia on is kept to less than 1 percent, i.e.ΔP / P less than or equal to 0.04

In commonly used of inches WC and psia, the relationship is approximated by:

ΔP (in.WC) / P (psia) < or = 1.0

*When the design flow is not known, assume that the design flow is 80 percent of the full*

*scale flow. A differen al pressure of 100 inches of water column* ***(25 kPa)*** *is assumed when*

*this parameter is not otherwise specified.*

The design flow and the differential pressure at design flow are used in all subsequent

calculations to evaluate the flowmeter coefficient at design conditions, thereby minimizing

the averaged flow error.

***Step 2: Calculate Reynolds number*** at design flow and operating conditions to ensure that

it is greater than the minimum values below:

Liquid Gas (vapor)

*Reynolds Number*

Orifice

Venturi nozzle

LO-Loss

RD > or = 10 000

RD > or = 100 000

RD > or = 100 000

RD > or = 10 000

RD > or = 10 000

RD > or = 10 000

*Expansion factor* Y1 = 1.0

Y2 = 1.0

ΔP (in.WC) / P1 (psia) < or = 0.50

ΔP (in.WC) / P2 (psia) < or = 1.0

***Step 3: Calculate the sizing factor at design flow and opera ng condi ons***

***Note:*** this sizing factor depends upon the Standard used, but the calculation methodology

will be similar (ref. Introduction above). For practice purpose we shall use the following from

American Standard, **computer prac ce will be on ISO 5167**

*SM = Q(lb/hr) / [358.9268 Fa . D² . Fp 1/2 . ρ(upstream)*

*1/2 . Δp (in. WC) ½]*

where ρ is in pounds per cubic feet and D is in inches.

Fa is the thermal expansion factor, which is defined as follows: when the coefficients of

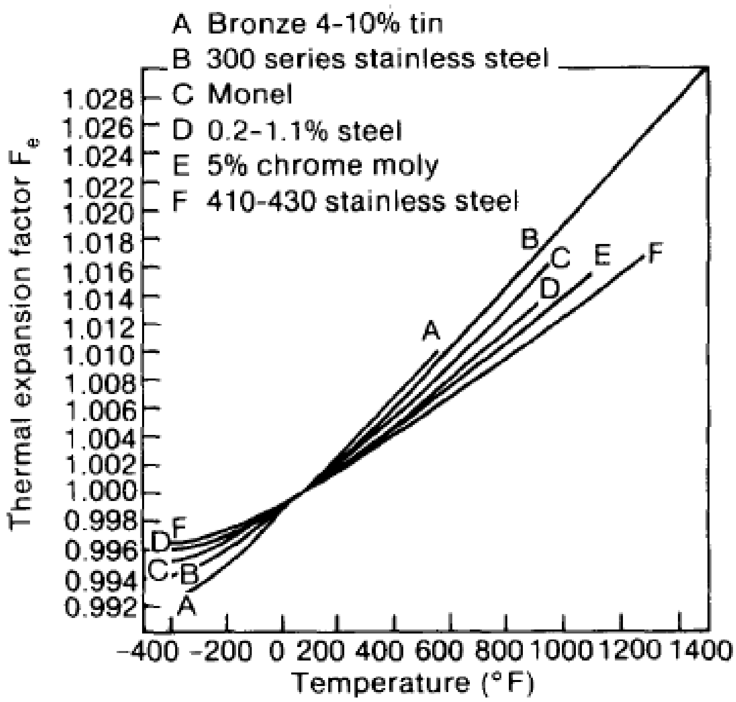
linear expansion often called the thermal expansion coefficients, of the primary element and

pipe are approximately the same.

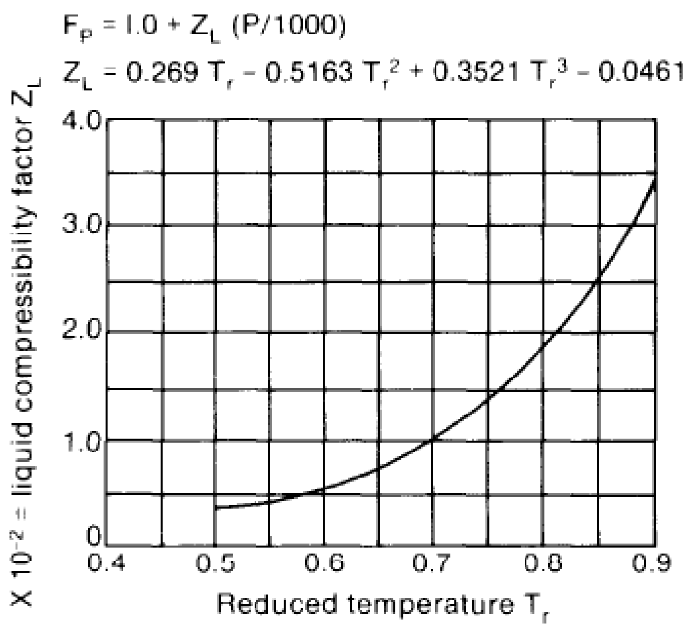
Fa = 1 + 2 α (T°F - 68)

Graph below shows the relationship between the expansion factor and temperature for most

commonly used orifice plate materials.




Fp is the compressibility factor correc    on, which is 1.0 for gases and most liquid




***Step 4: Calculate the approximate β ra   oǵr the appropriate primary device*** using SM

calculated above and the following approximate sizing equations.

The extracts given here below are examples of β0 approximate Sizing Equa   ons for some

flow orifices.

Orifice Type Equation

Corner, flange, D-D/2 taps

RD < 200 000

RD > 200 000

2.5 D - 8D taps

Eccentric, all taps

Segmental, all taps

Quadrant ($\beta$ < or = 0.6)

Conic, corner ($\beta$ < or = 0.3)

$\beta 0 = [1 + (0.6/ SM + 0.06)^2 ] - ¼$

$\beta 0 = [1 + (0.6/ SM )^2] - ¼$

$\beta 0 = [1 + (0.61/ SM + 0.55)^2 ] - ¼$

$\beta 0 = [1 + (0.607/ SM + 0.088)^2 ] - ¼$

$\beta 0 = [1 + (0.634/ SM - 0.062)^2 ] - ¼$

$\beta 0 = [1 + (0.76/ SM + 0.26)^2 ] - ¼$

$\beta 0 = [1 + (0.734/ SM )^2 ] - ¼$

$\beta$ is typically limited between 0.12 and 0.75 ($0.2 < \beta < 0.75$).

**Remark: When $\beta$ is outside these limits,** or is desired to be different from the calculated

$\beta$, one has to start again from step 1 with a higher or lower $\Delta P$ value to decrease

$\beta$, or a

lower $\Delta P$ value to increase $\beta$.

For an iterative solution, one must continue with the next step.

However when approximate bore giving an accuracy of approximately 2% is desired, one can proceed to step 9.

***Step 5: calculate the discharge coefficient C, which has the form:***

C = Cinfinity + (b / RD

n)

Using β and following Table,

| Equations & Values for $C_\infty$, b and n | | $R_E$ number term | |
|---|---|---|---|
| Orifice | **Discharge coefficient $C_\infty$ at infinite $R_D$ number** | Coefficient b | Exponent n |
| Corner taps | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8$ | $91.71\beta^{2.5}$ | 0.75 |
| Flange taps (*D* in inches) | | | |
| $D \geq 2.3$ | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.09\dfrac{\beta^4}{D(1-\beta^4)} - 0.0337\dfrac{\beta^3}{D}$ | $91.71\beta^{2.5}$ | 0.75 |
| $2 \leq D \leq 2.3^d$ | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4} - 0.0337\dfrac{\beta^3}{D}$ | $91.71\beta^{2.5}$ | 0.75 |
| Flange taps ($D^*$ in millimeters) | | | |
| $D^* \geq 58.4$ | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 2.286\dfrac{\beta^4}{D^*(1-\beta^4)} - 0.856\dfrac{\beta^3}{D^*}$ | $91.71\beta^{2.5}$ | 0.75 |
| $50.8 \leq D^* \leq 58.4^d$ | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4} - 0.856\dfrac{\beta^3}{D^*}$ | $91.71\beta^{2.5}$ | 0.75 |
| D and *D*/2 taps | $0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4} - 0.0158\beta^3$ | $91.71\beta^{2.5}$ | 0.75 |

***Step 6***

**For liquids, set $Y_1$ equal to 1.0.**

**For gases and vapors, calculate the gas expansion factor upstream of the flowmeter, $Y_1$,** using equations in next Table. Subscripts 1 and 2 represent conditions upstream and downstream of the flowmeter, respectively, and k is the isentropic exponent for an ideal gas: $k = C_p / C_v$ where $C_p$ and $C_v$ are the specific heats at constant pressure and volume, respectively.

*Summary of gas (vapor) Expansion factor equations for concentric orifice*

| Primary device | Equation | |
|---|---|---|
| Corner, flange, *D* and *D*/2 taps | | |
| Upstream measurements | $Y_1 = 1 - (0.41 + 0.35\beta^4)\dfrac{x_1}{k}$ | |
| Downstream measurements | $Y_2 = \sqrt{1 + x_2} - (0.41) + 0.35\beta^4)\dfrac{x_2}{k\sqrt{1 + x_2}}$ | $x_1 = \dfrac{\Delta p_{\text{in. WC}}}{27.73 P_{1\ \text{psia}}}$ |
| 2½*D* and 8*D* | | |
| Upstream measurements | $Y_1 = 1 - [0.333 + 1.145(\beta^2 + 0.7\beta^5 + 12\beta^{13})]\dfrac{x_1}{k}$ | |
| Downstream measurements | $Y_2 = \sqrt{1 + x_2} = [0.333 + 1.145(\beta^2 + 0.7\beta^5 + 12\beta^{13})]\dfrac{x_2}{k\sqrt{1 + x_2}}$ | $x_2 = \dfrac{\Delta p_{\text{in. WC}}}{27.73 P_{1\ \text{psia}}}$ |

***Step 7***

Calculate the next estimate for β asβ = [1+ (C x Y1 / SM)² ] .1/4

***Step 8***

Repeat steps 5,6, and 7 un l two consecu ve itera onsβ of differ by less than 0.0001

***Step 9***

**Calculate the bore of the flowmeter using d = β X D**

Several additional factors exist that can be introduced into the denominator of the

expression for SM to compensate for special measuring situations, such as to correct for

steam quality (gas-liquid flows), drain or vent holes, water vapor in a gas.

## 9.Sample of data sheet and related calculation and specification

# DATA SHEET FOR FE 5900 (OILY WATER)

*ORIFICE PLATES*

1. Concentric [X] Others ______
2. ISA Standard [ ] Others ISO 5167
3. Bore : Maximum Rate [ ] Nearest 0.1 mm [X]
4. Material : 304 SS [ ] 316 SS [X] Others ______
5. Ring Material & Type : N/A ( NOTE-8 ) △3
6. MFR & Model No. TROUVAY & CAUVIN

*ORIFICE FLANGE*

7. Tap : Flange [X] Vena Contracta [ ] Pipe [ ]
8. Tap Size:1/2" NPTF [X] Other TWO TAPPINGS PER FLANGE △3
9. Type Weld Neck [X] Slip On [ ] Threaded [ ]
10. Material : Steel [ ] CARBON STEEL A-105
11. Flange included: [X] By Other [ ]
12. Option : Jack Screws [X] Other : ______
13. MFR. & Models No. TROUVAY & CAUVIN

| | | | | | | |
|---|---|---|---|---|---|---|
| *GENERAL* | 14 | Tag Number | FE-5900 | | | |
| | 15 | Service | To Water Degasing Boot | | | |
| | 16 | P & I D No. | PPA-12-E3-090-C, Rev. 5 | | | |
| | 17 | Line Number | 12"-OW-B03-59040 | | | |
| | 18 | Line Size / Schedule | 12" SCH 30 | | | |
| | 19 | Engineering Units | Flowrate : M3/Hr , | Pressure : Barg, | Temperature : °C , | Viscosity : cP |
| *PROCESS DATA* | 20 | Fluid | OILY WATER | | | |
| | 21 | Fluid State | Liquid | | | |
| | 22 | Maximum Flow | 375 | | | |
| | 23 | Normal Flow | 90 | | | |
| | 24 | Pressure | 4 | | | |
| | 25 | Temperature | 25 - 75 | | | |
| | 26 | Specific Gravity at Base | 1 | | | |
| | 27 | Specific Gravity @ operating | 0.97 | | | |
| | 28 | Supercomp. Factor | | | | |
| | 29 | Mol Weight / Cp/Cv | | | | |
| | 30 | Operating Viscocity | 0.6 | | | |
| | 31 | Quality % or Superheat | | | | |
| | 32 | Base Pres. / Base Temp | | | | |
| | 33 | Design Press. / Temp. | 18 / -29 / 95 | | | |
| | 34 | Identification Of Fuild | 1 1 1 1 | | | |
| | 35 | Meter maximum | 375 | | | |
| *METER* | 36 | Type of Meter (Note 2) | D/P CELL | | | |
| | 37 | Diff. Range - Dry (mBar) | 0 - 250 | | | |
| | 38 | Seal Sp. Gr. at 15.6 °C | | | | |
| | 39 | Static Press. Range | | | | |
| | 40 | Chart or Scale Range | | | | |
| | 41 | Chart Multiplier | | | | |
| | 42 | | | | | |
| *PLATE & FLANGE* | 43 | Beta = d / D | 0.561602 | △3 | | |
| | 44 | Orifice Bore Diameter mm | 172.461 | | | |
| | 45 | Line I.D. mm | 307.086 | | | |
| | 46 | Flange Rating | 300 # ANSI RF | | | |
| | 47 | Vent Hole mm | 6.35 | | | |
| | 48 | Min Plate Thickness mm | 4.775 | | | |
| | 49 | Selected Orifice Bore Dia . ( mm ). | 172.5 | | | |
| | 50 | Maximum Calculated Flow | 374.245 | | | |

| *Identification Of Fluid* | | | 1 | 0 |
|---|---|---|---|---|
| | 1st Number | Gas | WET | DRY |
| | | Liquid | H2O > 500ppm | H2O < 500ppm |
| | 2nd Number | | CORROSIVE | NON CORROSIVE |
| | 3rd Number | | IBP > 40 °C | IBP < 40 °C |
| | 4th Number | | FOULING / SOLID SETTING | NO FOULING / NO PARTICLES |

Notes :

1. Each orifice plate shall be engraved on its upstream side the following information
   -The word : UPSTREAM -Tag number -D and d dimension in mm -Flange Rating -Material -The word : SQUARE
2. Refer to Flow Transmitter data sheet
3. Vendor to confirm and provide orifice bore calculation.
4. Vendor to refer to and comply with TOTAL Spec. GPK-70-0-06-B, Instrument Design and Installation, Rev. 1 Status C.
5. For flange material vendor shall follow Piping Class Specification GPK-22-2-03-P, Rev.3.
6. Painting shall be to Spec. SP-COR-181 Painting of Offshore and Onshore Structures and Equipment.
7. Flange finish : For 300 # RF - Stock , For 600 # RF - Smooth , For 900# & 1500# - RTJ
8. Orifice plate is of paddle type △3

# DATA SHEET FOR FE 4503 (FUEL GAS)

| | | NO | BY | DATE | REVISION | | | |
|---|---|---|---|---|---|---|---|---|
| | DATA SHEET | 3 | EDDY | 12/03/98 | C | SHEET 7 OF 16 | | |
| | ORIFICE PLATE AND | 4 | EDDY | 24/04/98 | D | SPEC. NO. PPA-70-E3-216-D | | REV. 3 |
| | FLANGE | 5 | EDDY | 01/06/98 | 0 | CONTRACT EPSC3 | | DATE 17-02-99 |
| | | 6 | EDDY | 17/07/98 | 1 | REQ. | P.O. | |
| | | 7 | FMAP | 30/11/98 | 2 | | | |
| | | 8 | FMAP | 17/02/99 | 3 | | | |
| | | CLIENT : TOTAL INDONESIE | | | | PREP'D | CHK'D | APPR'D |
| | | PROJECT : PCK/EPSC3 | | | | FMAP | BABU | JO |

*ORIFICE PLATES*

1. Concentric [X] Others ______
2. ISA Standard [ ] Others ISO 5167
3. Bore : Maximum Rate [ ] Nearest 0.1 mm [X]
4. Material : 304 SS [ ] 316 SS [X] Others ______
5. Ring Material & Type : N/A ( NOTE-8 ) △3
6. MFR & Model No. TROUVAY & CAUVIN

*ORIFICE FLANGE*

7. Tap : Flange [X] Vena Contracta [ ] Pipe [ ]
8. Tap Size:1/2" NPTF [X] Other TWO TAPPINGS PER FLANGE △3
9. Type Weld Neck [X] Slip On [ ] Threaded [ ]
10. Material : Steel [ ] CARBON STEEL A-105
11. Flange included: [X] By Other [ ]
12. Option : Jack Screws [X] Other : ______
13. MFR. & Models No. TROUVAY & CAUVIN

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| GENERAL | 14 | Tag Number | FE-4503 | | FE-4504 | | FE-4505 | | FE-4507 | |
| | 15 | Service | FG Purge from MP FG Distr. | | FG Purge from MP FG Distr. | | FG Purge from MP FG Distr. | | FG Purge from MP FG Distr. | |
| | 16 | P & I D No. | PPA-12-E3-070-C, Rev. 5 | | PPA-12-E3-070-C, Rev. 5 | | PPA-12-E3-070-C, Rev. 5 | | PPA-12-E3-070-C, Rev. 5 | |
| | 17 | Line Number | 2"-FG-B03-56206 | | 2"-FG-B03-40068 | | 2"-FG-B03-56290 | | 2"-FG-B03-56291 | |
| | 18 | Line Size / Schedule | 2" SCH 80 | | 2" SCH 80 | | 2" SCH 80 | | 2" SCH 80 | |
| | 19 | Engineering Units | Flowrate : MMSCFD , | | Pressure : Barg, | | Temperature : °C , | | Viscosity : cP | |
| PROCESS DATA | 20 | Fluid | FUEL GAS | | FUEL GAS | | FUEL GAS | | FUEL GAS | |
| | 21 | Fluid State | Gas | | Gas | | Gas | | Gas | |
| | 22 | Maximum Flow | 0.354 | | 0.354 | | 0.354 | | 0.354 | |
| | 23 | Normal Flow | 0.354 | | 0.354 | | 0.354 | | 0.354 | |
| | 24 | Pressure | 4 | | 4 | | 4 | | 4 | |
| | 25 | Temperature | 36 | | 36 | | 36 | | 36 | |
| | 26 | Specific Gravity at Base | | | | | | | | |
| | 27 | Upstream density ( kg/m3 ) | 4.6 | | 4.6 | | 4.6 | | 4.6 | |
| | 28 | Supercomp. Factor | | | | | | | | |
| | 29 | Mol Weight / Cp/Cv | 22.6 | 1.2 | 22.6 | 1.2 | 22.6 | 1.2 | 22.6 | 1.2 |
| | 30 | Operating Viscocity | 0.01 | | 0.01 | | 0.01 | | 0.01 | |
| | 31 | Quality % or Superheat | | | | | | | | |
| | 32 | Base Pres. / Base Temp | | | | | | | | |
| | 33 | Design Press. / Temp. | 40 | | 40 | | 40 | | 40 | |
| | 34 | Identification Of Fuild | 1 1 0 0 | | 1 1 0 0 | | 1 1 0 0 | | 1 1 0 0 | |
| | 35 | Meter Maximum | 0.5 | | 0.5 | | 0.5 | | 0.5 | |
| METER | 36 | Type of Meter (Note 2) | D/P CELL | | D/P CELL | | D/P CELL | | D/P CELL | |
| | 37 | Diff. Range - Dry (mBar) | 0 - 125 | | 0 - 125 | | 0 - 125 | | 0 - 125 | |
| | 38 | Seal Sp. Gr. at 15.6 °C | | | | | | | | |
| | 39 | Static Press. Range | | | | | | | | |
| | 40 | Chart or Scale Range | | | | | | | | |
| | 41 | Chart Multiplier | | | | | | | | |
| | 42 | | | | | | | | | |
| PLATE & FLANGE | 43 | Beta = d / D | 0.609849 | | 0.609849 | | 0.609849 | | 0.609849 | |
| | 44 | Orifice Bore Diameter mm | 30.0351 | | 30.0351 | | 30.0351 | | 30.0351 | |
| | 45 | Line I.D. mm | 49.25 | | 49.25 | | 49.25 | | 49.25 | |
| | 46 | Flange Rating | 300 # ANSI RF | | 300 # ANSI RF | | 300 # ANSI RF | | 300 # ANSI RF | △3 |
| | 47 | Drain Hole mm | 2.381 | | 2.381 | | 2.381 | | 2.381 | |
| | 48 | Min Plate Thickness mm | 3.175 | | 3.175 | | 3.175 | | 3.175 | |
| | 49 | Selected Orifice Bore Dia . ( mm ). | 30 | | 30 | | 30 | | 30 | |
| | 50 | Maximum Calculated Flow | 0.497796 | | 0.497796 | | 0.497796 | | 0.497796 | |

| | | | | |
|---|---|---|---|---|
| Identification Of Fluid | | | 1 | 0 |
| | 1st Number | Gas | WET | DRY |
| | | Liquid | H2O > 500ppm | H2O < 500ppm |
| | 2nd Number | | CORROSIVE | NON CORROSIVE |
| | 3rd Number | | IBP > 40 °C | IBP < 40 °C |
| | 4th Number | | FOULING / SOLID SETTING | NO FOULING / NO PARTICLES |

Notes :

1. Each orifice plate shall be engraved on its upstream side the following information
   -The word : UPSTREAM -Tag number -D and d dimension in mm -Flange Rating -Material -The word : SQUARE
2. Refer to Flow Transmitter data sheet
3. Vendor to confirm and provide orifice bore calculation.
4. Vendor to refer to and comply with TOTAL Spec. GPK-70-0-06-B, Instrument Design and Installation, Rev. 1 Status C.
5. For flange material vendor shall follow Piping Class Specification GPK-22-2-03-P, Rev.3.
6. Painting shall be to Spec. SP-COR-181 Painting of Offshore and Onshore Structures and Equipment.
7. Flange finish : For 300 # RF - Stock , For 600 # RF - Smooth , For 900# & 1500# - RTJ
8. Orifice plate is of paddle type △3

## DATA SHEET FOR FE 4500 (HC GAS)

| | | | | |
|---|---|---|---|---|
| DATA SHEET ORIFICE PLATE AND FLANGE | NO / BY / DATE / REVISION | | | SHEET 8 OF 16 |
| | 3 EDDY 12/03/98 C | | | SPEC. NO. PPA-70-E3-216-D — REV. 3 |
| | 4 EDDY 24/04/98 D | | | |
| | 5 EDDY 01/06/98 0 | | | CONTRACT EPSC3 — DATE 17-02-99 |
| | 6 EDDY 17/07/98 1 | | | |
| | 7 FMAP 30/11/98 2 | | | REQ. — P.O. |
| | 8 FMAP 17/02/99 3 | | | |
| | CLIENT : TOTAL INDONESIE | | | PREP'D FMAP — CHK'D BABU — APPR'D JO |
| | PROJECT : PCK/EPSC3 | | | |

*ORIFICE PLATES*

1. Concentric [X] Others
2. ISA Standard [ ] Others ISO 5167
3. Bore : Maximum Rate [ ] Nearest 0.1 mm [X]
4. Material : 304 SS [ ] 316 SS [X] Others
5. Ring Material & Type : N/A ( NOTE-8 ) /3\
6. MFR & Model No. TROUVAY & CAUVIN

*ORIFICE FLANGE*

7. Tap : Flange [X] Vena Contracta [ ] Pipe [ ]
8. Tap Size:1/2" NPTF [X] Other TWO TAPPINGS PER FLANGE /3\
9. Type Weld Neck [X] Slip On [ ] Threaded [ ]
10. Material : Steel [ ] A 182 F321 /3\
11. Flange included: [X] By Other [ ]
12. Option : Jack Screws [X] Other :
13. MFR. & Models No. TROUVAY & CAUVIN

| | No | Item | FE-4500 | | FE-4510 | |
|---|---|---|---|---|---|---|
| GENERAL | 14 | Tag Number | FE-4500 | | FE-4510 | |
| | 15 | Service | 1-V 4500 Outlet to flare | | 1-V 4510 Outlet to flare | |
| | 16 | P & I D No. | PPA-12-E3-030-C, Rev. 5 /3\ | | PPA-12-E3-031-C, Rev. 5 /3\ | |
| | 17 | Line Number | 10"-G-D48-45033 | | 10"-G-D48-45130 | |
| | 18 | Line Size / Schedule | 10" SCH 40S | | 10" SCH 40S | |
| | 19 | Engineering Units | Flowrate : MMSCFD , | Pressure : Barg, | Temperature : °C , | Viscosity : cP |
| PROCESS DATA | 20 | Fluid | HC GAS | | HC GAS | |
| | 21 | Fluid State | Gas | | Gas | |
| | 22 | Maximum Flow | 75.9 | | 21.55 | |
| | 23 | Normal Flow | 17.5 | | 19.5 | |
| | 24 | Pressure | 32 - 36 | | 7 | |
| | 25 | Temperature | 23 - 58 | | 15 / 48 / 52 | |
| | 26 | Specific Gravity at Base | | | | |
| | 27 | Upstream Density ( kg/m3 ) | 29.4 | | 8.8 | |
| | 28 | Supercomp. Factor | | | | |
| | 29 | Mol Weight / Cp/Cv | 24.8 | 1.2 | 24.4 | 1.2 |
| | 30 | Operating Viscocity | 0.01 | | 0.01 | |
| | 31 | Quality % or Superheat | | | | |
| | 32 | Base Pres. / Base Temp | | | | |
| | 33 | Design Press. / Temp. | 40 | -29 / 75 | 18 | -29 / 75 |
| | 34 | Identification Of Fuild | 1 1 0 0 | | 1 1 0 0 | |
| | 35 | Meter maximum | 80 | | 25 /3\ | |
| METER | 36 | Type of Meter (Note 2) | D/P CELL | | D/P CELL | |
| | 37 | Diff. Range - Dry (mBar) | 0 - 500 | | 0 - 250 | |
| | 38 | Seal Sp. Gr. at 15.6 °C | | | | |
| | 39 | Static Press. Range | | | | |
| | 40 | Chart or Scale Range | | | | |
| | 41 | Chart Multiplier | | | | |
| | 42 | | | | | |
| PLATE & FLANGE | 43 | Beta = d / D | 0.680269 | | 0.620405 | |
| | 44 | Orifice Bore Diameter mm | 173.128 | | 157.893 | |
| | 45 | Line I.D. mm | 254.5 | | 254.5 | |
| | 46 | Flange Rating | 300 # ANSI RF | | 300 # ANSI RF /3\ | |
| | 47 | Drain Hole mm | 6.35 | | 5.556 | |
| | 48 | Min Plate Thickness mm | 4.775 | | 4.775 | |
| | 49 | Selected Orifice Bore Dia. ( mm ). | 173.1 | | 157.9 | |
| | 50 | Maximum Calculated Flow | 79.6582 | | 24.99 | |

| Identification Of Fluid | | | 1 | 0 |
|---|---|---|---|---|
| | 1st Number | Gas | WET | DRY |
| | | Liquid | H2O > 500ppm | H2O < 500ppm |
| | 2nd Number | | CORROSIVE | NON CORROSIVE |
| | 3rd Number | | IBP > 40 °C | IBP < 40 °C |
| | 4th Number | | FOULING / SOLID SETTING | NO FOULING / NO PARTICLES |

Notes :

1. Each orifice plate shall be engraved on its upstream side the following information
   -The word : UPSTREAM -Tag number -D and d dimension in mm -Flange Rating -Material -The word : SQUARE
2. Refer to Flow Transmitter data sheet
3. Vendor to confirm and provide orifice bore calculation.
4. Vendor to refer to and comply with TOTAL Spec. GPK-70-0-06-B, Instrument Design and Installation, Rev. 1 Status C.
5. For flange material vendor shall follow Piping Class Specification GPK-22-2-03-P, Rev.3.
6. Painting shall be to Spec. SP-COR-181 Painting of Offshore and Onshore Structures and Equipment.
7. Flange finish : For 300 # RF - Stock , For 600 # RF - Smooth , For 900# & 1500# - RTJ
8. Orifice plate is of paddle type /3\

## ISO Orifice Plate - Concentric - Flange Taps - Liq

Tag number FE-5900

### Input data

| | |
|---|---|
| Fluid | OILY WATER |
| Maximum liquid flow | 375 m3/h |
| Normal liquid flow | 90 m3/h |
| Flow temperature | 50 degC |
| Inlet pressure | 4 barg |
| Differential range | 250 mbar |
| SG @ flow conditions | .97 |
| SG @ base conditions | 1 |
| Viscosity @ FTP | .6 cp |
| Pipe inside diameter | 307.086 mm |
| Orifice diameter | 172.461 mm |
| Base pressure | 14.696 psia |
| Base temperature | 59 degF |
| Barometric pressure | 14.7 psia |
| Element material | 316 stainless steel |
| Pipe material | Carbon steel |
| Vent hole diameter | 6.35 mm |

### Output data

| | |
|---|---|
| Beta ratio | .561602 |
| Normal flow differential | 14.4 mbar |
| Accuracy percent | .6013 percent |
| Reynolds number | 172602 |
| Max pressure loss | 168.2 mbar |
| Max power loss | 1812 watts |
| | |
| Thermal expansion factor | 1.00107 |
| Discharge coefficient | .606256 |
| Vent hole factor | 1.00129 |

## ISO Orifice Plate - Concentric - Flange

Tag number FE-4512/4/5

### Input data

| | |
|---|---|
| Fluid | HC LIQUID |
| Maximum liquid flow | 25000 bbl/d |
| Normal liquid flow | 16604 bbl/d |
| Flow temperature | 34 degC |
| Inlet pressure | 17.5 barg |
| Differential range | 250 mbar |
| SG @ flow conditions | .722 |
| SG @ base conditions | .73 |
| Viscosity @ FTP | .35 cp |
| Pipe inside diameter | 154.051 mm |
| Orifice diameter | 102.552 mm |
| Base pressure | 14.696 psia |
| Base temperature | 59 degF |
| Barometric pressure | 14.7 psia |
| Element material | 316 stainless steel |
| Pipe material | Carbon steel |
| Vent hole diameter | 3.175 mm |

### Output data

| | |
|---|---|
| Beta ratio | .6657 |
| Normal flow differential | 110.3 mbar |
| Accuracy percent | .6147 percent |
| Reynolds number | 526165 |
| Max pressure loss | 140.6 mbar |
| Max power loss | 656.2 watts |
| Thermal expansion factor | 1.00052 |
| Discharge coefficient | .605763 |
| Vent hole factor | 1.00086 |

## ISO Orifice Plate - Concentric - Flange T

Tag number FE-4503/4/5/7

### Input data

| | |
|---|---|
| Fluid | FUEL GAS |
| Maximum gas flow | .5 Msft3/d |
| Normal gas flow | .354 Msft3/d |
| Inlet pressure | 4 barg |
| Differential range | 125 mbar |
| Flow temperature | 36 degC |
| Molecular weight | 22.6 |
| Cp/Cv specific heat ratio | 1.2 |
| Viscosity @ FTP | .01 cp |
| Pipe inside diameter | 49.25 mm |
| Density @ FTP | 4.6 kg/m3 |
| Orifice diameter | 30.0351 mm |
| Base pressure | 14.696 psia |
| Base temperature | 15 degC |
| Barometric pressure | 14.7 psia |
| Drain hole diameter | 2.381 mm |
| Element material | 316 stainless steel |
| Pipe material | Carbon steel |

### Output data

| | |
|---|---|
| Beta ratio | .609849 |
| Normal flow differential | 62.66 mbar |
| Accuracy percent | .5452 percent |
| Reynolds number | 286663 |
| Max pressure loss | 77.99 mbar |
| Max power loss | .357 hp |
| Thermal expansion factor | 1.00058 |
| Discharge coefficient | .604409 |
| Gas expansion factor | .99523 |
| Base pressure factor | .999997 |
| Base temperature factor | 1 |
| Drain hole factor | 1.00583 |

**SPECIFICATION FOR ORIFICE PLATES, RESTRICATION**

**ORIFICES AND FLANGES**

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| REV. | PURPOSE OF ISSUE | PREPARED BY | REVIEWED BY | APPROVED BY | DATE |

## CONTENTS

A. **SCOPE**

The purpose of this specification together with the data sheets and other documents included in the Material Requisition (MR) is to define the minimum requirements for design, manufacture, supply, test & delivery of the orifice plates and flanges
according to related standards, codes & best engineering practices.

B. **CONFLICTING REQUIREMENTS**

In the event of any conflict between this specification, related standards, codes, purchase requisition, etc.

The order of precedence shall be as follows:

- Data sheets included in the Material Requisition
- This specification
- Codes and standards
-

C. **CODES AND STANEDARDS**

IPS-E-IN-130 Engineering standard for Flow instruments .

IPS-M-IN-130 Material and equipment standard for Flow instruments.

IPS-C-IN-130 Construc on standard for Flow instruments.

API RP 551 Process measurement instrumentation

API RP 554 Process instrumentation

NACE MR 01 75 Standard Material Requirement : Sulfide stress cracking resistant metallic materials oilfield equipment.

ASME B1.20.1 Pipe thread, general purpose (Inch) revision and redesigna on of ASME/ANSI B2.11968 R (2001)

ASME B16.5 Pipe flange and flanged fittings

BS 1042 Measurement of fluid flow by means of pressure differential devices

ISO 5167/5168 Measurement of fluid flow by means of pressure differential / Measurement of fluid flow

**D.**

**E. <u>DEFINITIONS AND TERMINOLOGIES</u>**

Owner:

Manufacturer: Shall mean the party who manufacturers the item of work.

Purchaser / Contractor: Shall mean the parties which have contractual responsibility for the design, engineering, procurement and construction of the plant.

Vendor / supplier : Shall mean company mentioned in the contract as supplying any equipment in the project.

Shall : Refer to a requirement

Should: Refer to a recommendation

Will : Refer to an action by the purchaser other than by the vendor / supplier

May: Refer to one acceptable course of action.

Must: Refer to a statutory requirement.

## F. UNITS OF MEASURMENT

International system of units (SI) shall be used for the whole project, engineering calculation results, instrument ranges and control settings. All dimension and ratings shall be metric, except for pipes and fittings threads, which shall be in inches.

## G. TECHNICAL REQUIREMENTS

In general, flow measurement shall be based on sharp, thin, square-edged, concentric orifice plates mounted between a pair of weld neck flanges, unless otherwise specified.

Square edge orifices with corner taps are not recommended for general applications.

In general 316 stainless steel orifice plates shall be provided as minimum. Where the nature of the fluid is such as to require a higher alloy, or other material, it shall be consistent with the line specification. When the temperature exceed 450 oC the thickness shall be adjusted to suit the application.

The drain/vent hole shall be drilled in rough after finish of fluid inlet side surface. On completion of work, it shall be free of burrs and / or scores.

All material supplied under this specification shall be adequate for the proposed services. Proper consideration shall be given to their function with regard to the environmental conditions, corrosion, chemical attack, electrical and process hazard.

Vendor shall comply in totality with data sheets included in the Material Requisition. The vendor is requested to fill in the relevant sections / lines in the data sheets and submit the completed data sheets with his quotation for review and evaluation.

The ratio of the orifice diameter to the pipeline internal diameter (ID) (d/D, Beta) shall be from 0.25 to 0.7 (both inclusive).

Orifice plate thickness, bore diameter and other parameters shall be machined to tolerance level allowed as per ISO-5167 (Latest Edi on).

Wetted parts exposed to the sour service shall be consistent with the NACE MR-01-75 (Latest Edi on).

The minimum orifice flange ra ng shall be 300# ANSI.

45° taps on the orifice flanges are not acceptable.

Each plate shall be provided with a tab projected beyond the flanges with the following required data engraved on it. The tab shall be in line with the drain / vent hole:

Tag number

Type of element

Pipe ID/ Nominal diameter in mm

Flange rating

Bore diameter in mm

Plate material

Beta Ratio

Vendor is responsible for sizing of all plates and shall provide calculation details for purchaser’s approval.

Orifice plates shall be designed, manufactured and sized according to the BS-1042/part 1 or ISO-5167and 5168.

The surface of the orifice plate shall have a finishing equal or equivalent to finishing No. 4 of ASTM A-480.

The compete assembly including orifice plate, orifice flanges, gasket, bolts and nuts shall be supplied by vendor.

All orifice flanges shall be weld neck, raised face, smooth finish 100-150 AARH.

Flow rate to be measured shall be kept between 30% and 90% of the design flow.

Orifice plates shall be calculated at 110% of the design process maximum flow rate.

The primary elements shall be sized for use with differential pressure transmitters having one of the following ranges in mbar:

0-12.5, 0-25, 0-50, 0-125, 0-250, 0-500, 0-1000.

The preferred rang is 0-250 mbar; the range 0-1000 mbar should be avoided where possible. In case of compressible fluids, the selected differen al pressure shall preferably not exceed 3.6% of the upstream static absolute pressure.

Restriction Orifice Plates

Restriction orifice plates shall be designed / supplied to the same specification as flow orifice plates.

Restriction orifice plates are devices for creating a pressure drop or for limiting a flow rate

The construction of restriction orifice plates shall be in stainless steel.

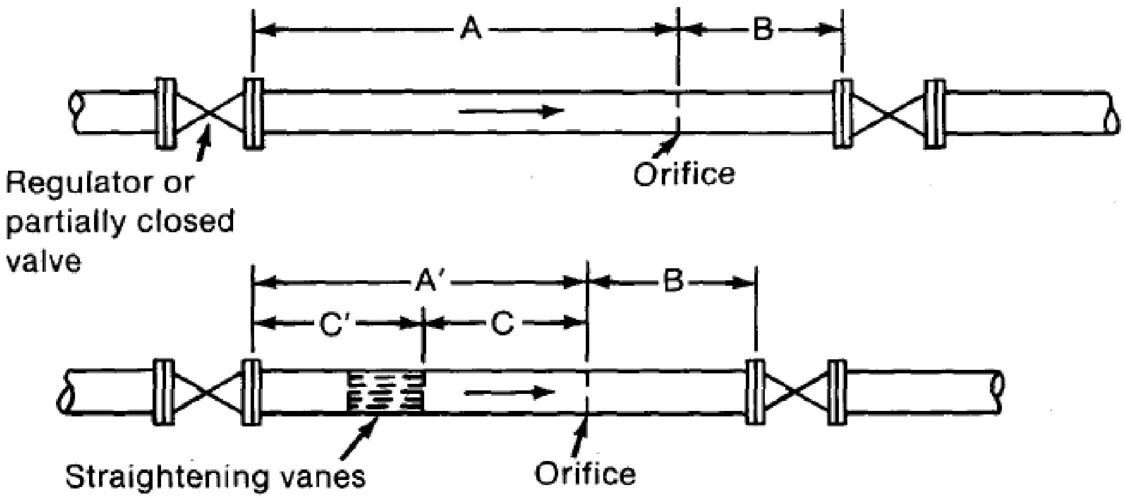
The relevant dimension (thickness, …) shall be adjusted to suit the application.

## 10.Requirements from AGA for orifice metering of natural gas

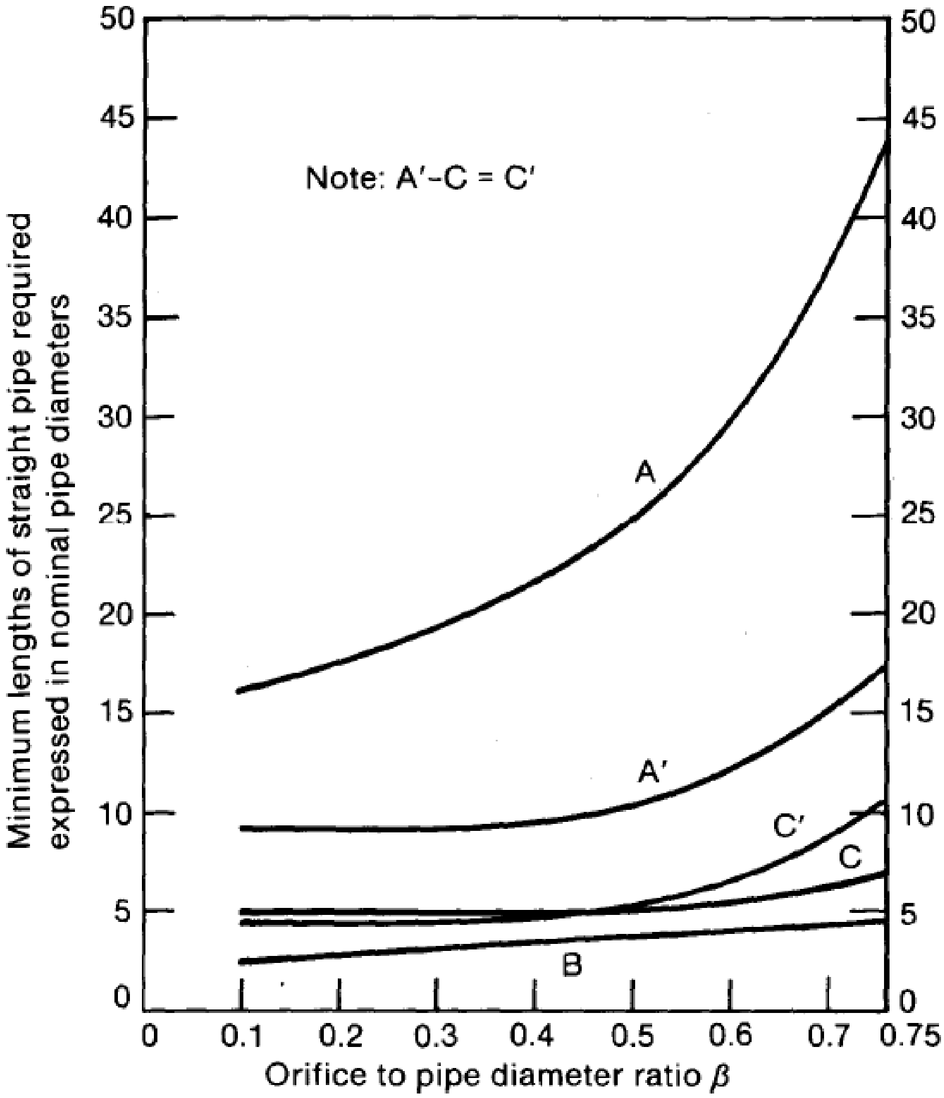
**Notes 1:**

When "pipe taps" are used, lengths A, A’, and C shall be increased by 2 pipe diameters, and B by 8 pipe diameters.

When the diameter of the orifice may require changing to meet different conditions, the lengths of straight pipe should be those required for the maximum β ratio that may be used.



A
B
Regulator or partially closed valve
Orifice
A′
B
C′
C
Straightening vanes
Orifice

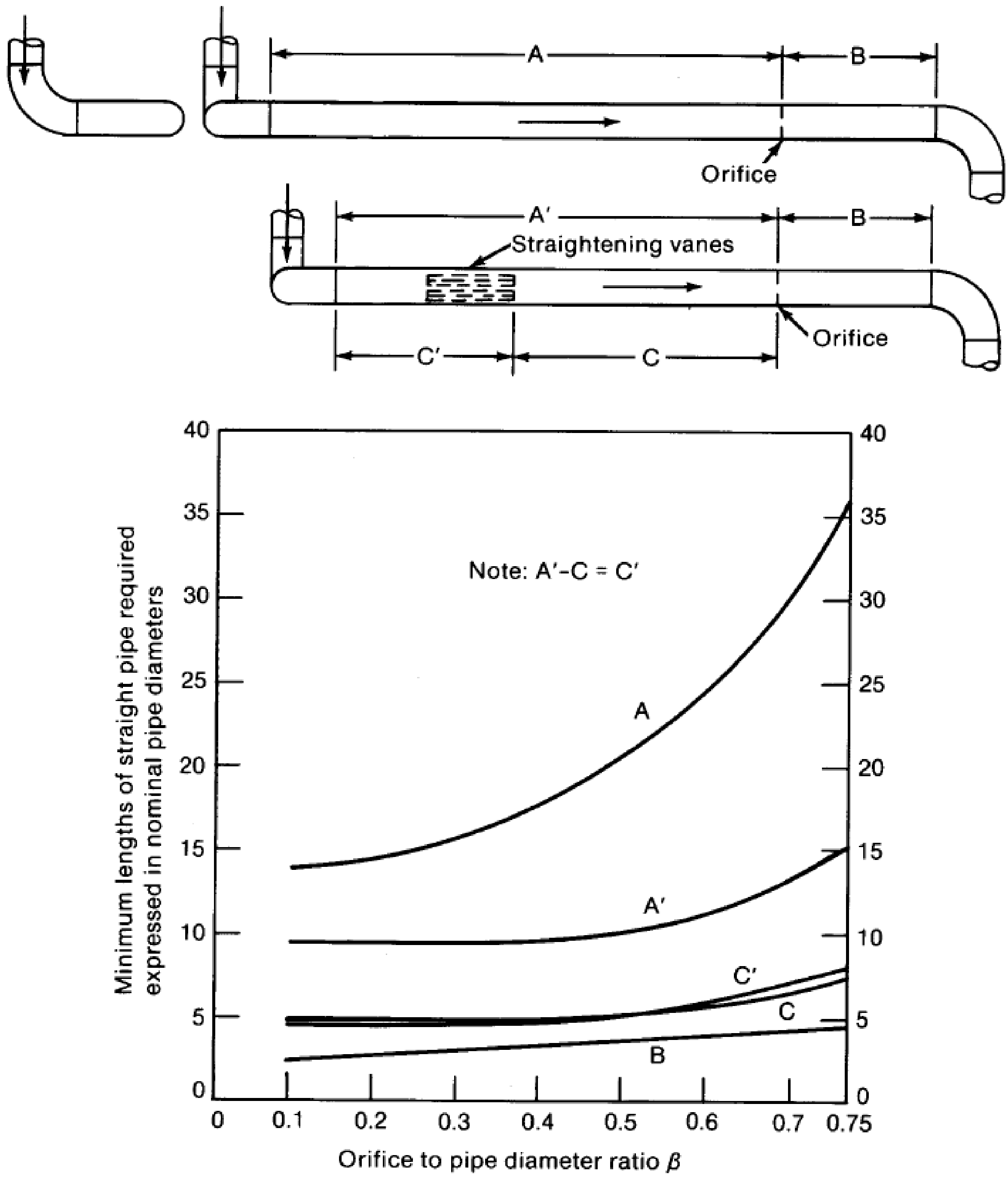
Note: A′-C = C′
A
A′
C′
C
B
Minimum lengths of straight pipe required expressed in nominal pipe diameters
Orifice to pipe diameter ratio β
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.75
5
10
15
20
25
30
35
40
45
50

**Notes 2:**

When "pipe taps" are used, lengths A, A’, and C shall be increased by 2 pipe diameters, and B by 8 pipe diameters.

When the diameter of the orifice may require changing to meet different conditions, the lengths of straight pipe should be those required for the maximum β ratio that may be used.

When the 2 L.s shown in the above sketches are closely (less than [31D1) preceded by a third which is not in the same plane as the middle or second ell, the piping requirements shown by A should be doubled.



A
B
Orifice
A′
B
Straightening vanes
Orifice
C′
C
Note: A′-C = C′
A
A′
C′
C
B
Minimum lengths of straight pipe required expressed in nominal pipe diameters
Orifice to pipe diameter ratio β
0
5
10
15
20
25
30
35
40
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.75

**Notes 3:**

When "pipe taps" are used, lengths A, A’, and C shall be increased by 2 pipe diameters, and B by 8 pipe diameters.

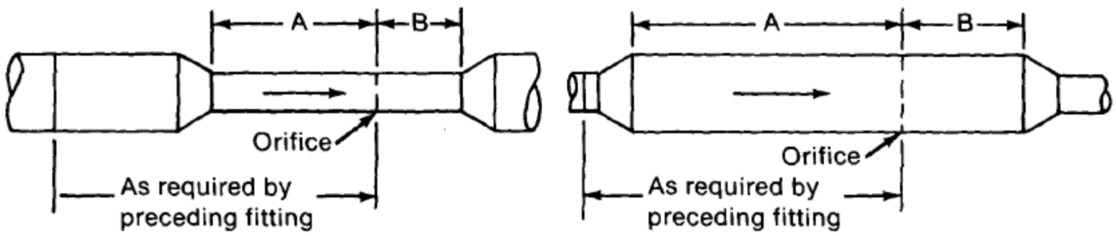
When the diameter of the orifice may require changing to meet different conditions, the lengths of straight pipe should be those required for the maximum β ratio that may be used.

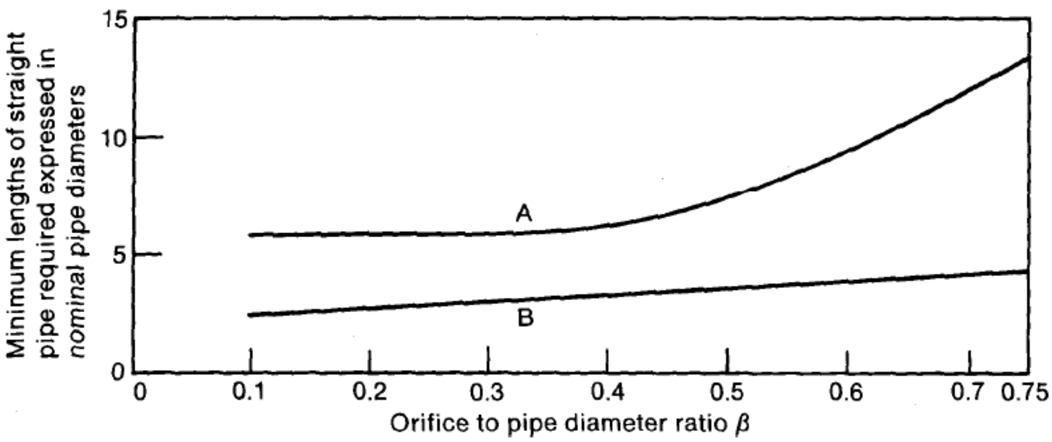
**Notes 5:**

When "pipe taps" are used, length A shall be increased by 2 pipe diameters, and B by 8 pipe diameters.

When the diameter of the orifice may require changing to meet different conditions, the lengths of straight pipe should be those required for the maximum β ratio that may be used.

Straightening vanes will not reduce required lengths of straight pipe A. Straightening vanes are not required because of the reducers. They may be required because of other fittings which precede the reducer. Length A is to be increased by an amount equal to the length of the straightening vanes whenever they are used.




11.Standards

**ISO 5167**

Measurement of fluid flow by means of pressure differential devices

- **ISO 5168**

Measurement of fluid flow - Estimation of uncertainty of a flow-rate measurement

- **AGA Report N° 3 / API 14.3**

Orifice metering of natural gas

- **AGA Report N° 8**

Compressibility factors of natural gas and other related hydrocarbon gases.

-IPS-E-IN-130 Engineering standard for Flow instruments .

-IPS-M-IN-130 Material and equipment standard for Flow instruments.

-IPS-C-IN-130 Construc on standard for Flow instruments.

-API RP 551 Process measurement instrumentation

-API RP 554 Process instrumentation

-NACE MR 01 75 Standard Material Requirement : Sulfide stress cracking resistant metallic materials oilfield equipment.

-ASME B1.20.1 Pipe thread, general purpose (Inch) revision and redesignation of -ASME/ANSI B2.1-1968 R (2001)

-ASME B16.5 Pipe flange and flanged fittings

-BS 1042 Measurement of fluid flow by means of pressure differential devices

# Pressure Relief

*"Grace under pressure"*

*– Ernest Hemingway*

J.GHOTBI

# What is the Hazard?

- Despite safety precautions …
  - Equipment failures
  - Human error, and
  - External events, can sometimes lead to …
- Increases in process pressures beyond safe levels, potentially resulting in …
- *OVERPRESSURE due to a RELIEF EVENT*

# What are Relief Events?

- External fire
- Flow from high pressure source
- Heat input from associated equipment
- Pumps and compressors
- Ambient heat transfer
- Liquid expansion in pipes and surge

# Potential Lines of Defense

- Inherently Safe Design
  - Low pressure processes
- Passive Control
  - Overdesign of process equipment
- Active Control
  - *Install Relief Systems*

# What is a Relief System?

- A relief device, and
- Associated lines and process equipment to safely handle the material ejected

# Why Use a Relief System?

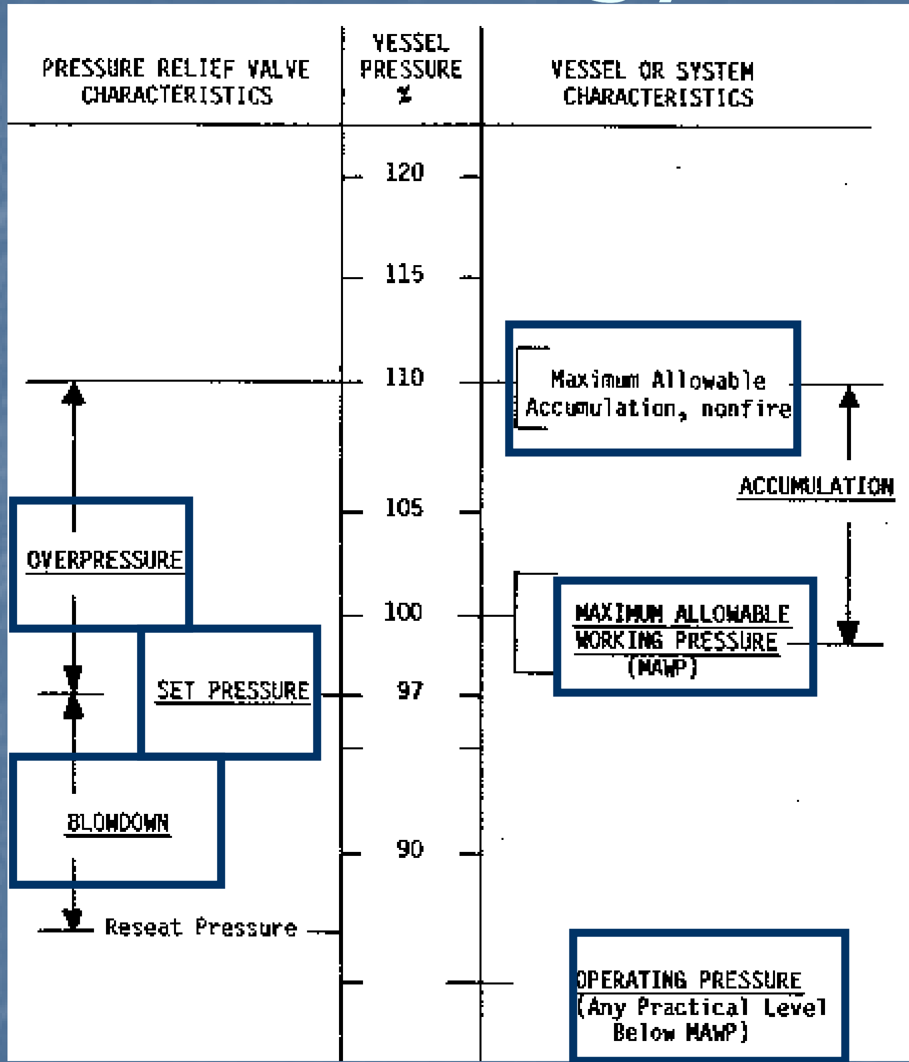
- *Inherently Safe Design* simply can't eliminate every pressure hazard

- *Passive designs* can be exceedingly expensive and cumbersome

- *Relief systems* work!

# Pressure Terminology

MAWP
Design pressure
Operating pressure
Set pressure
Overpressure
Accumulation
Blowdown



# Code Requirements

General Code requirements include:

- ASME Boiler & Pressure Vessel Codes
- ASME B31.3 / Petroleum Refinery Piping
- ASME B16.5 / Flanges & Flanged Fittings

# Code Requirements

Relieving pressure shall not exceed MAWP (accumulation) by more than:

- 3% for fired and unfired steam boilers
- 10% for vessels equipped with a single pressure relief device
- 16% for vessels equipped with multiple pressure relief devices
- 21% for fire contingency

# Relief Design Methodology

1. LOCATE RELIEFS
2. CHOOSE TYPE
3. DEVELOP SCENARIOS
4. SIZE RELIEFS (1 or 2 Phase)
5. CHOOSE WORST CASE
6. DESIGN RELIEF SYSTEM

# Locating Reliefs – Where?

- All vessels
- Blocked in sections of cool liquid lines that are exposed to heat
- Discharge sides of positive displacement pumps, compressors, and turbines
- Vessel steam jackets
- Where PHA indicates the need

**LOCATE RELIEFS**

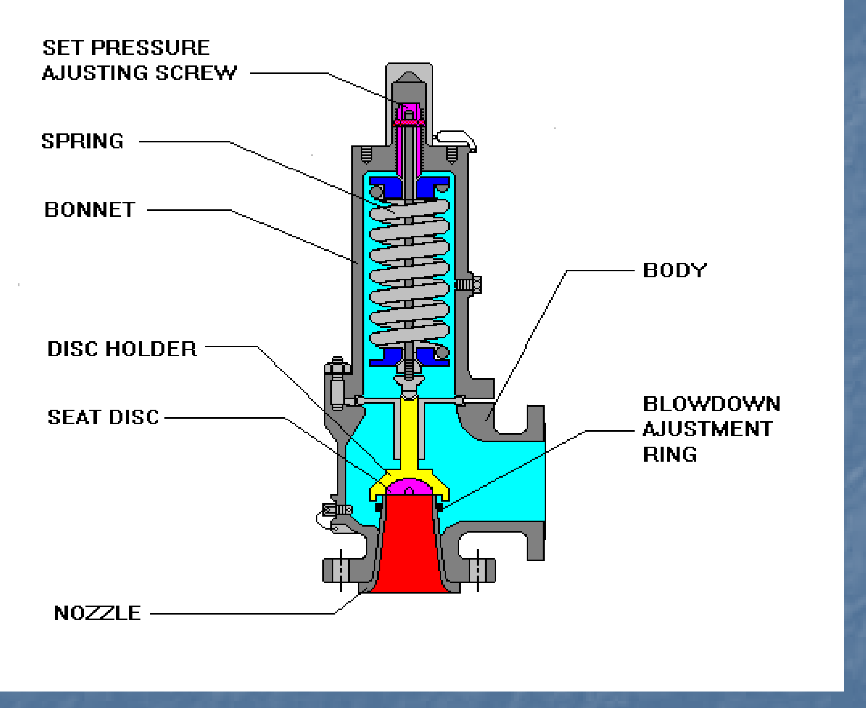
# Choosing Relief Types

- Spring-Operated Valves
- Rupture Devices

**CHOOSE TYPE**

# Spring-Operated Valves

- Conventional Type




CHOOSE TYPE

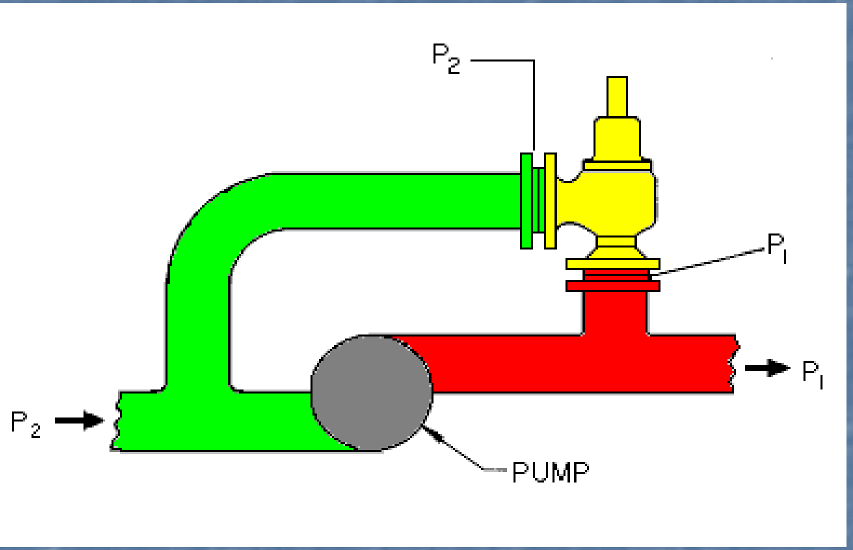
# P lief

Conventional Relief Valve

**CHOOSE TYPE**

# Superimposed Back Pressure

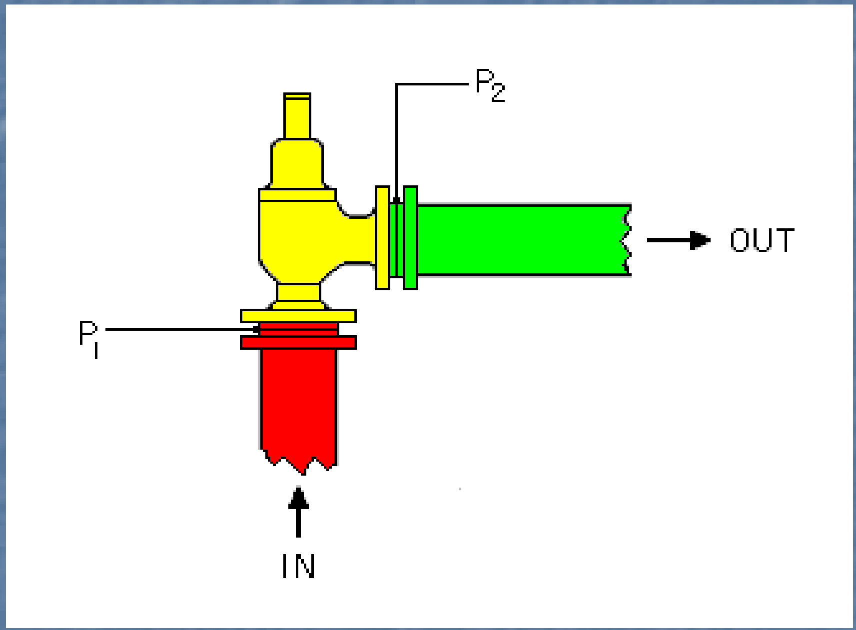
- Pressure in discharge header before valve opens
- Can be constant or variable




CHOOSE TYPE

# Built-up Back Pressure

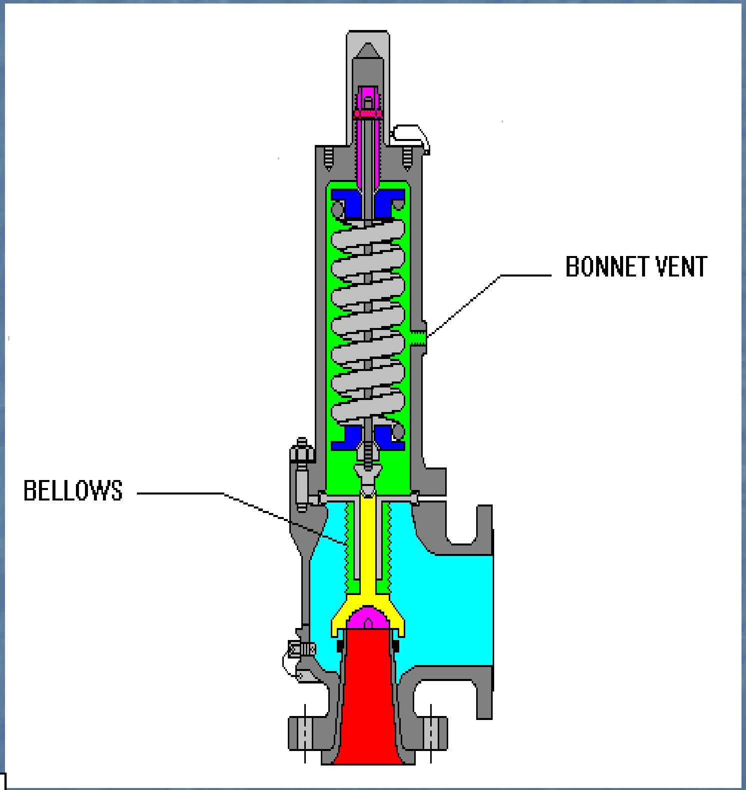
- Pressure in discharge header due to frictional losses after valve opens
- Total = Superimposed + Built-up




CHOOSE TYPE

# Spring-Operated Valves

- Balanced Bellows Type




CHOOSE TYPE

Bellows
Relief Valve

**CHOOSE TYPE**

# Pros & Cons: Conventional Valve

- Advantages
  - Most reliable type if properly sized and operated
  - Versatile -- can be used in many services
- Disadvantages
  - Relieving pressure affected by back pressure
  - Susceptible to chatter if built-up back pressure is too high

**CHOOSE TYPE**

# Pros & Cons: Balanced Bellows Valve

- Advantages
  - Relieving pressure not affected by back pressure
  - Can handle higher built-up back pressure
  - Protects spring from corrosion

- Disadvantages
  - Bellows susceptible to fatigue/rupture
  - May release flammables/toxics to atmosphere
  - Requires separate venting system

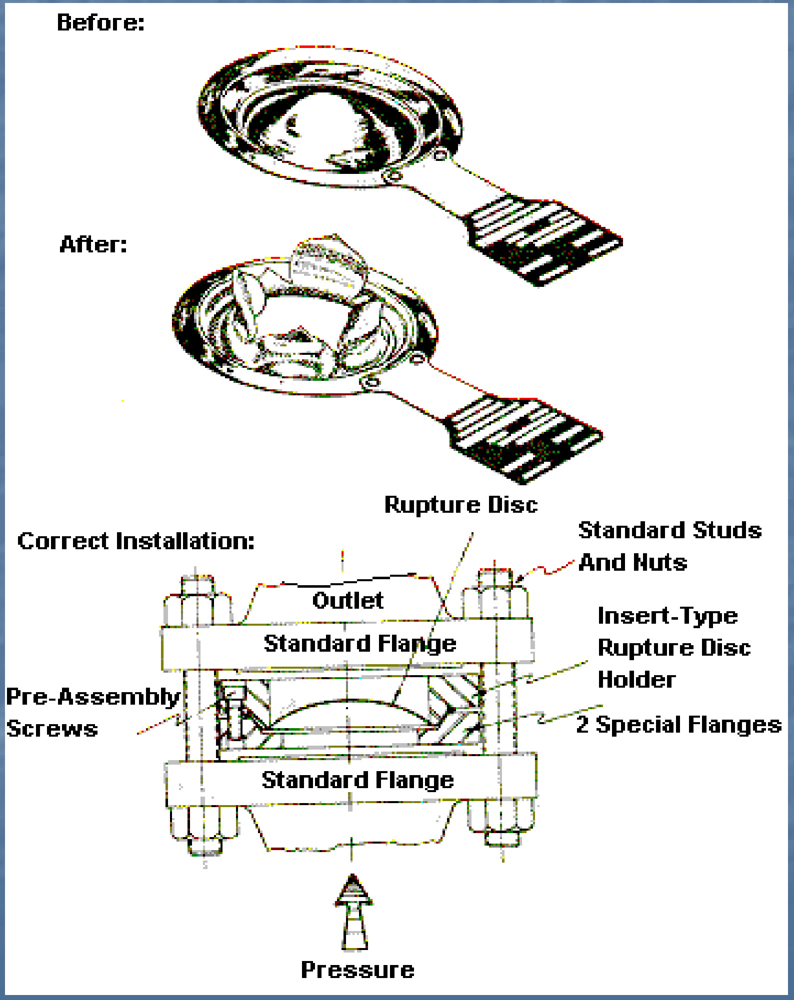
**CHOOSE TYPE**

# Rupture Devices

- Rupture Disc
- Rupture Pin

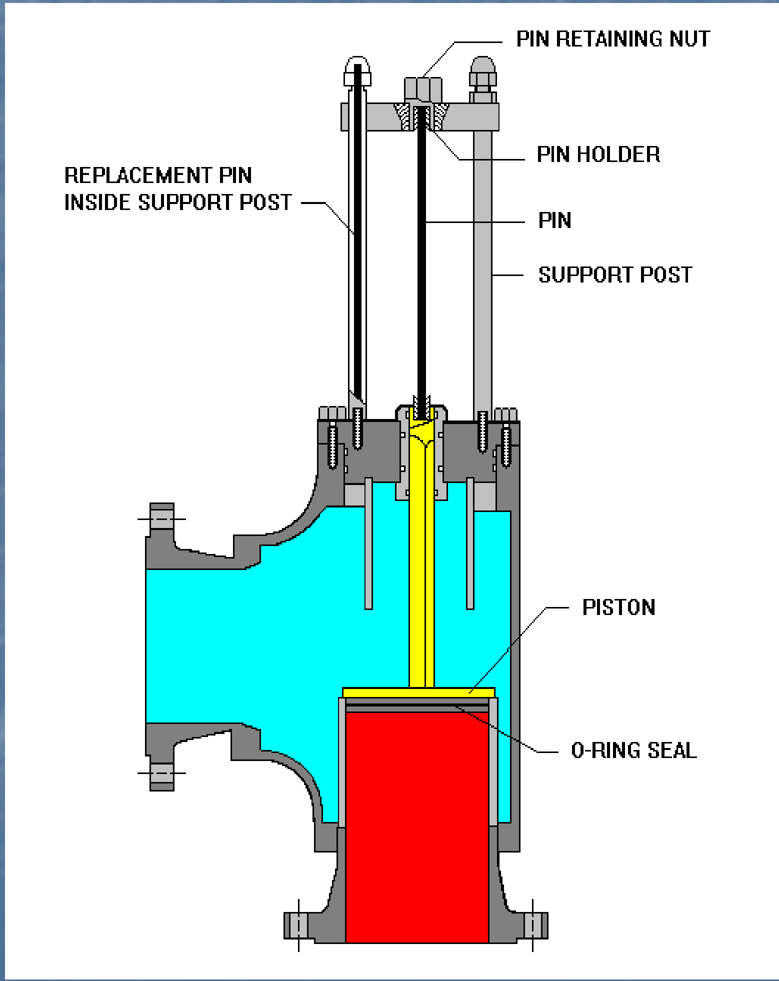
**CHOOSE TYPE**

# Conventional Metal Rupture Disc




CHOOSE TYPE

# Conventional Rupture Pin Device




**CHOOSE TYPE**

# When to Use a Spring-Operated Valve

- Losing entire contents is unacceptable
  - Fluids above normal boiling point
  - Toxic fluids
- Need to avoid failing low
- Return to normal operations quickly
- Withstand process pressure changes, including vacuum

**CHOOSE TYPE**

# When to Use a Rupture Disc/Pin

- Capital and maintenance savings
- Losing the contents is not an issue
- Benign service (nontoxic, non-hazardous)
- Need for fast-acting device
- Potential for relief valve plugging
- High viscosity liquids

**CHOOSE TYPE**

# When to Use Both Types

- Need a positive seal (toxic material, material balance requirements)
- Protect safety valve from corrosion
- System contains solids

**CHOOSE TYPE**

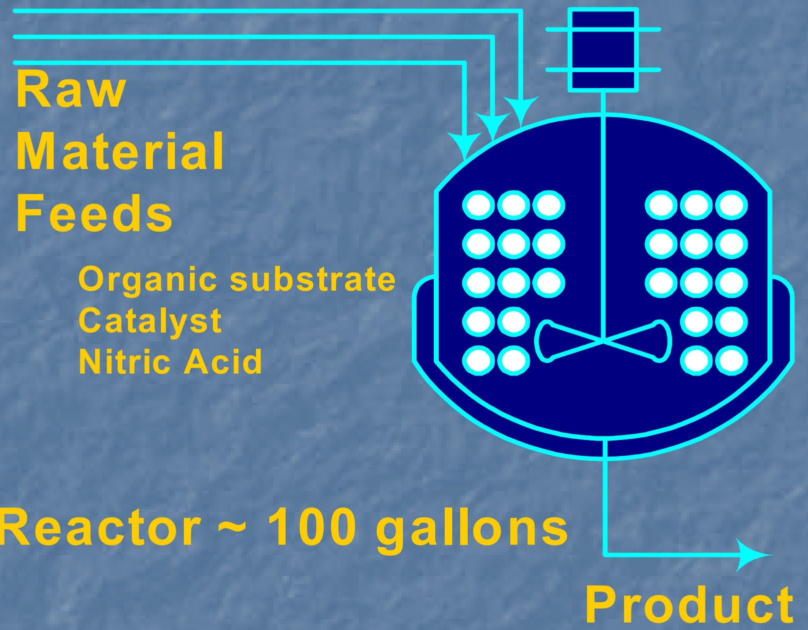
# Relief Event Scenarios

- A description of one specific relief event
- Usually each relief has more than one relief event, more than one scenario
- Examples include:
  - Overfilling/overpressuring
  - Fire
  - Runaway reaction
  - Blocked lines with subsequent expansion
- Developed through Process Hazard Analysis (PHA)

**DEVELOP SCENARIOS**

# An Example: Batch Reactor

- Control valve on nitric acid feed line stuck open, vessel overfills
- Steam regulator to jacket fails, vessel overpressures
- Coolant system fails, runaway reaction




**DEVELOP SCENARIOS**

# Sizing Reliefs

- Determining relief rates
- Determine relief vent area

**SIZE RELIEFS**
**(Single Phase)**

# Scenarios Drive Relief Rates

- Overfill (e.g., control valve failure)
  - Maximum flow rate thru valve into vessel
- Fire
  - Vaporization rate due to heat-up
- Blocked discharge
  - Design pump flow rate

**SIZE RELIEFS (Single Phase)**

# Overfill Scenario Calcs

- Determined maximum flow thru valve (i.e., blowthrough)
- Liquids: $$Q_m = C_v A \sqrt{2 \rho g_c \Delta P}$$
- Gases: $$\left(Q_m\right)_{choked} = C_v A P_o \sqrt{\frac{\gamma g_c M}{R_g T_o}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$$

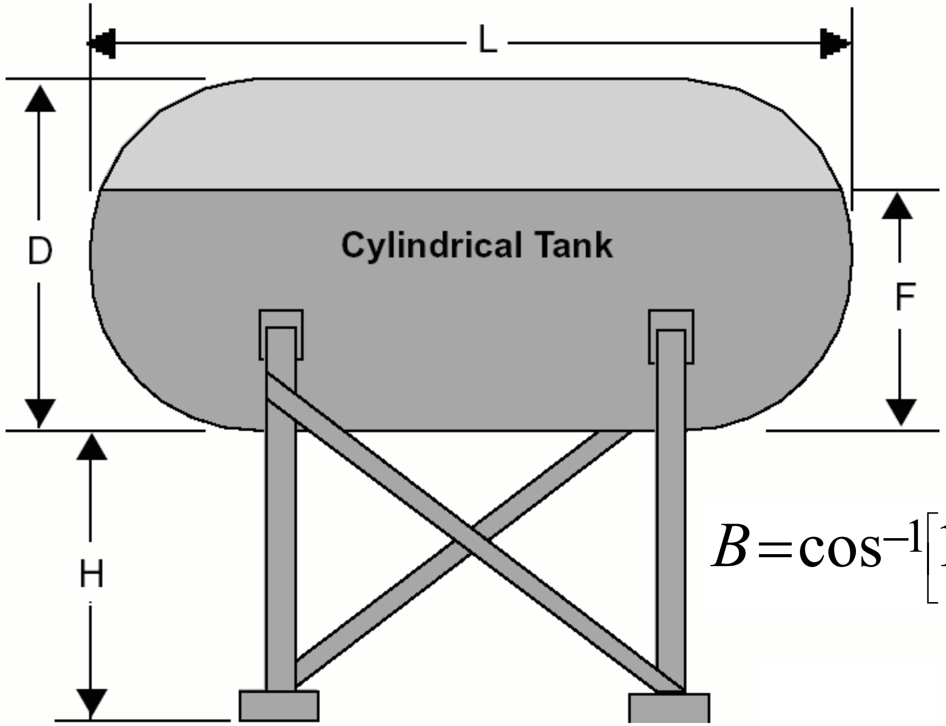
**SIZE RELIEFS (Single Phase)**

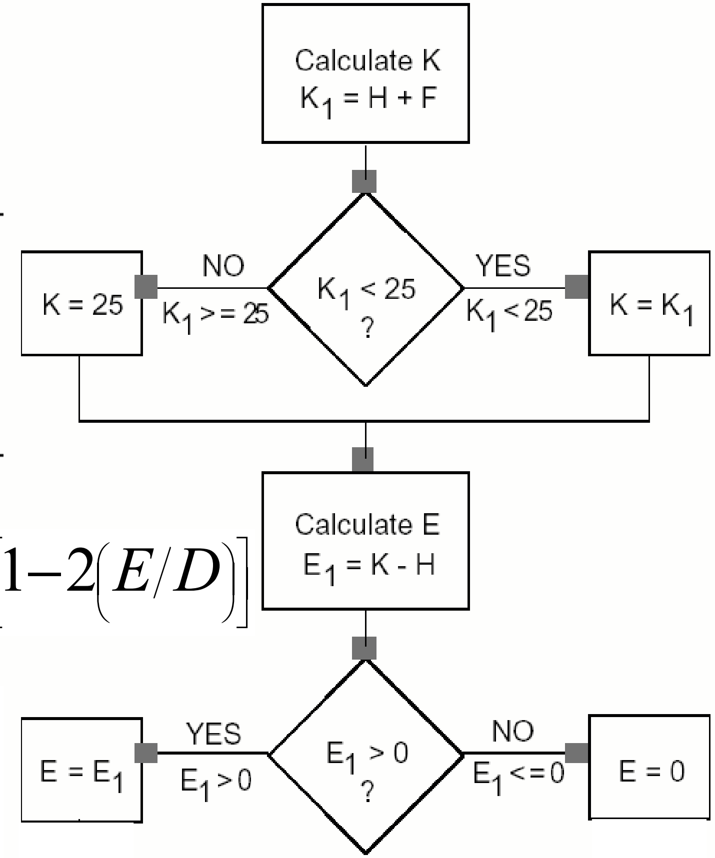
# Fire Scenario Calcs

- API 520 gives all equations for calculating fire relief rate, step-by-step
  1. Determine the total wetted surface area
  2. Determine the total heat absorption
  3. Determine the rate of vapor or gas vaporized from the liquid

**SIZE RELIEFS (Single Phase)**

# Determine Wetted Area




$$B = \cos^{-1}\left[1-2\left(E/D\right)\right]$$

$$A_{\text{wet}} = \pi\left(D\right)\left\{E+\left[\left(L-D\right)\left(B\right)\right]/180\right\}$$

**SIZE RELIEFS (Single Phase)**

# Determine Heat Absorption

- Prompt fire-fighting & adequate drainage:

$$Q_{\mathrm{Btu/hr}} = 21{,}000 \cdot F \cdot \left(A_{\mathrm{wet}}\right)^{0.82}$$

- Otherwise:

$$Q_{\mathrm{Btu/hr}} = 34{,}500 \cdot F \cdot \left(A_{\mathrm{wet}}\right)^{0.82}$$

where

Q is the heat absorption (Btu/hr)

F is the environmental factor

- 1.0 for a bare vessel
- Smaller values for insulated vessels

$A_{wet}$ is the wetted surface area ($ft^2$)

**SIZE RELIEFS (Single Phase)**

# Determine Vaporization Rate

$$W = Q / H_{vap}$$

where

W = Mass flow, lbs/hr

Q = Total heat absorption to the wetted surface, Btu/hr

$H_{vap}$ = Latent heat of vaporization, Btu/lb

**SIZE RELIEFS (Single Phase)**

# Determine Relief Vent Area

- Liquid Service

$$A=\left[\frac{\text{in}^2(\text{psi})^{1/2}}{38.0\ \text{gpm}}\right]\frac{Q_v}{C_o K_v K_p K_b}\sqrt{\frac{(\rho/\rho_{ref})}{1.25P_s-P_b}}$$

where

- A is the computed relief area (in$^2$)
- $Q_v$ is the volumetric flow thru the relief (gpm)
- $C_o$ is the discharge coefficient
- $K_v$ is the viscosity correction
- $K_p$ is the overpressure correction
- $K_b$ is the backpressure correction
- $(\rho/\rho_{ref})$ is the specific gravity of liquid
- $P_s$ is the gauge set pressure ($lb_f/in^2$)
- $P_b$ is the gauge backpressure ($lb_f/in^2$)

**SIZE RELIEFS (Single Phase)**

# Determine Relief Vent Area

$$A = \frac{Q_m}{C_o \chi K_b P}\sqrt{\frac{Tz}{M}}$$

$$P = P_{max} + 14.7$$

$P_{max} = 1.1P_s$ for unfired pressure vessels

$P_{max} = 1.2P_s$ for vessels exposed to fire

$P_{max} = 1.33P_s$ for piping

$P_s$ is the set pressure for the relief valve

- M is average molecular weight of gas ($lb_m$/lb-mol)
- P is maximum absolute discharge pressure ($lb_f/in^2$)
- $\chi$ is an isentropic expansion function

**SIZE RELIEFS (Single Phase)**

# Determine Relief Vent Area

- Gas Service

$$\chi = 519.5\sqrt{\gamma\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$$

where

- $\chi$ is an isentropic expansion function
- $\gamma$ is heat capacity ratio for the gas
- Units are as described in previous slide

**SIZE RELIEFS (Single Phase)**

# A Special Issue: Chatter

- Spring relief devices require 25-30% of maximum flow capacity to maintain the valve seat in the open position
- Lower flows result in *chattering*, caused by rapid opening and closing of the valve disc
- This can lead to destruction of the device and a dangerous situation

**SIZE RELIEFS (Single Phase)**

# Chatter - Principal Causes

- Valve Issues
  - Oversized valve
  - Valve handling widely differing rates

- Relief System Issues
  - Excessive inlet pressure drop
  - Excessive built-up back pressure

**SIZE RELIEFS**
**(Single Phase)**

# Worst Case Event Scenario

- Worst case for each relief is the event requiring the largest relief vent area
- Worst cases are a subset of the overall set of scenarios for each relief
- The identification of the worst-case scenario frequently affects relief size more than the accuracy of sizing calcs

**CHOOSE WORST CASE**

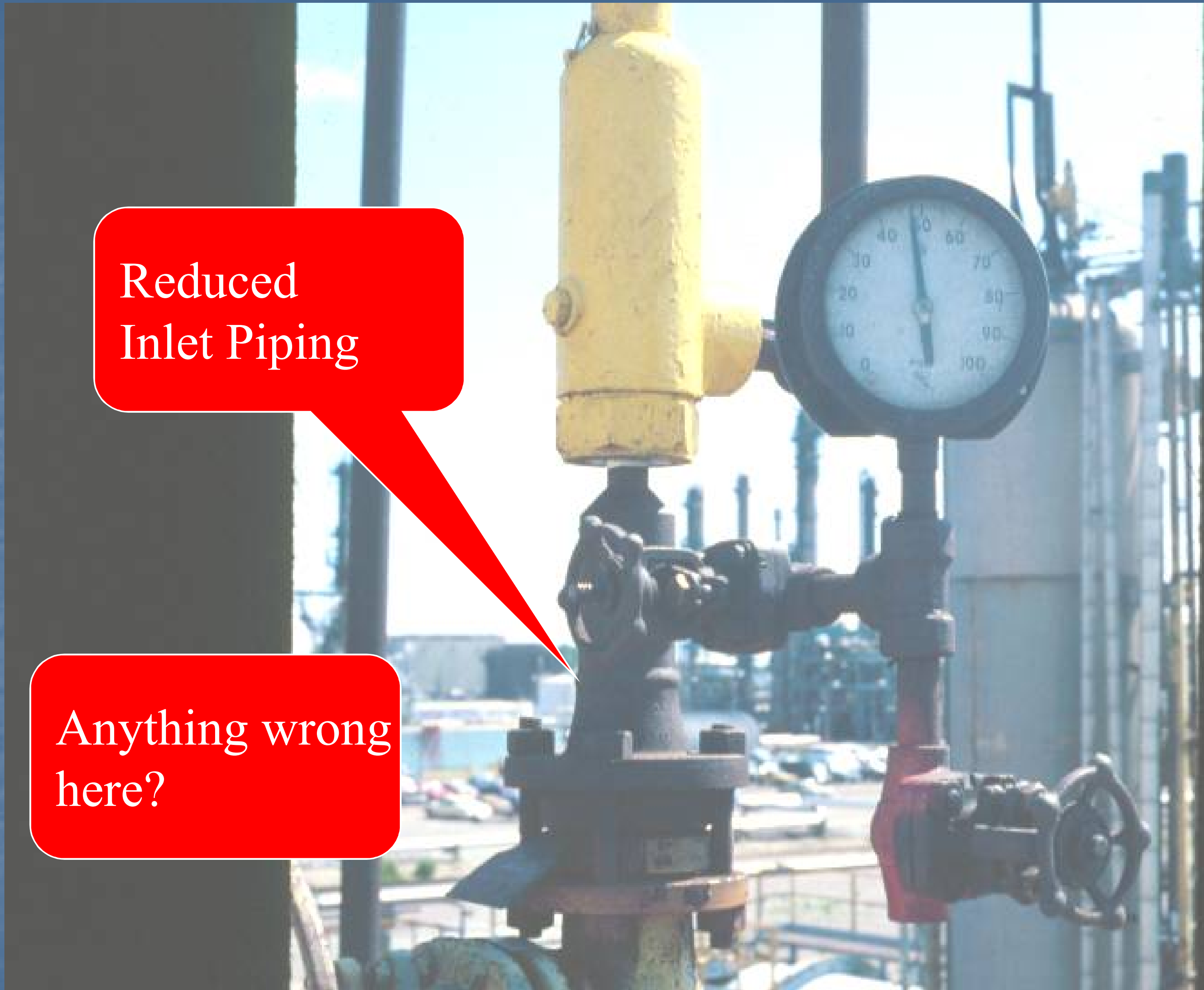
# Design Relief System

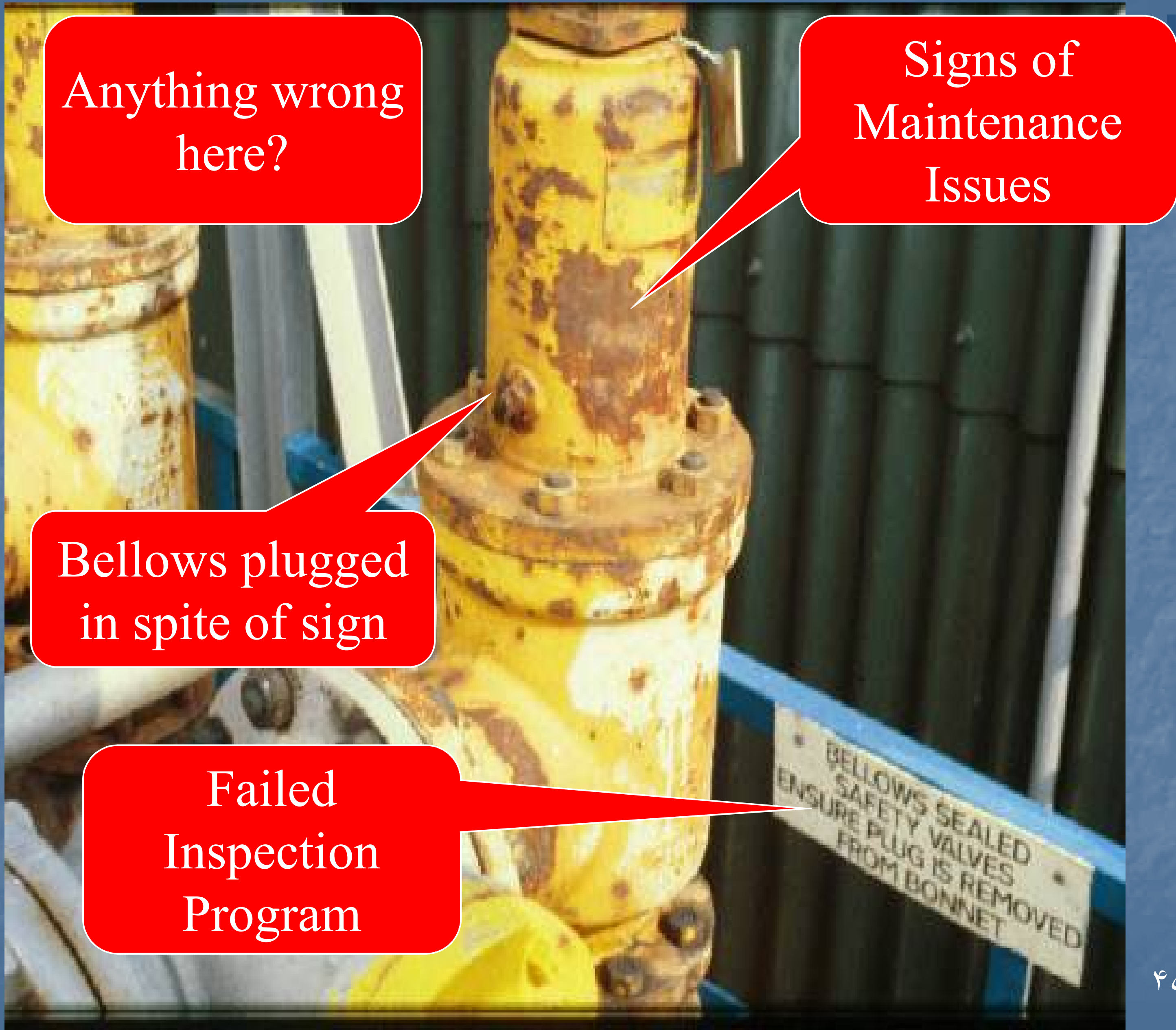
- Relief System is more than a safety relief valve or rupture disc, it includes:
  - Backup relief device(s)
  - Line leading to relief device(s)
  - Environmental conditioning of relief device
  - Discharge piping/headers
  - Blowdown drum
  - Condenser, flare stack, or scrubber

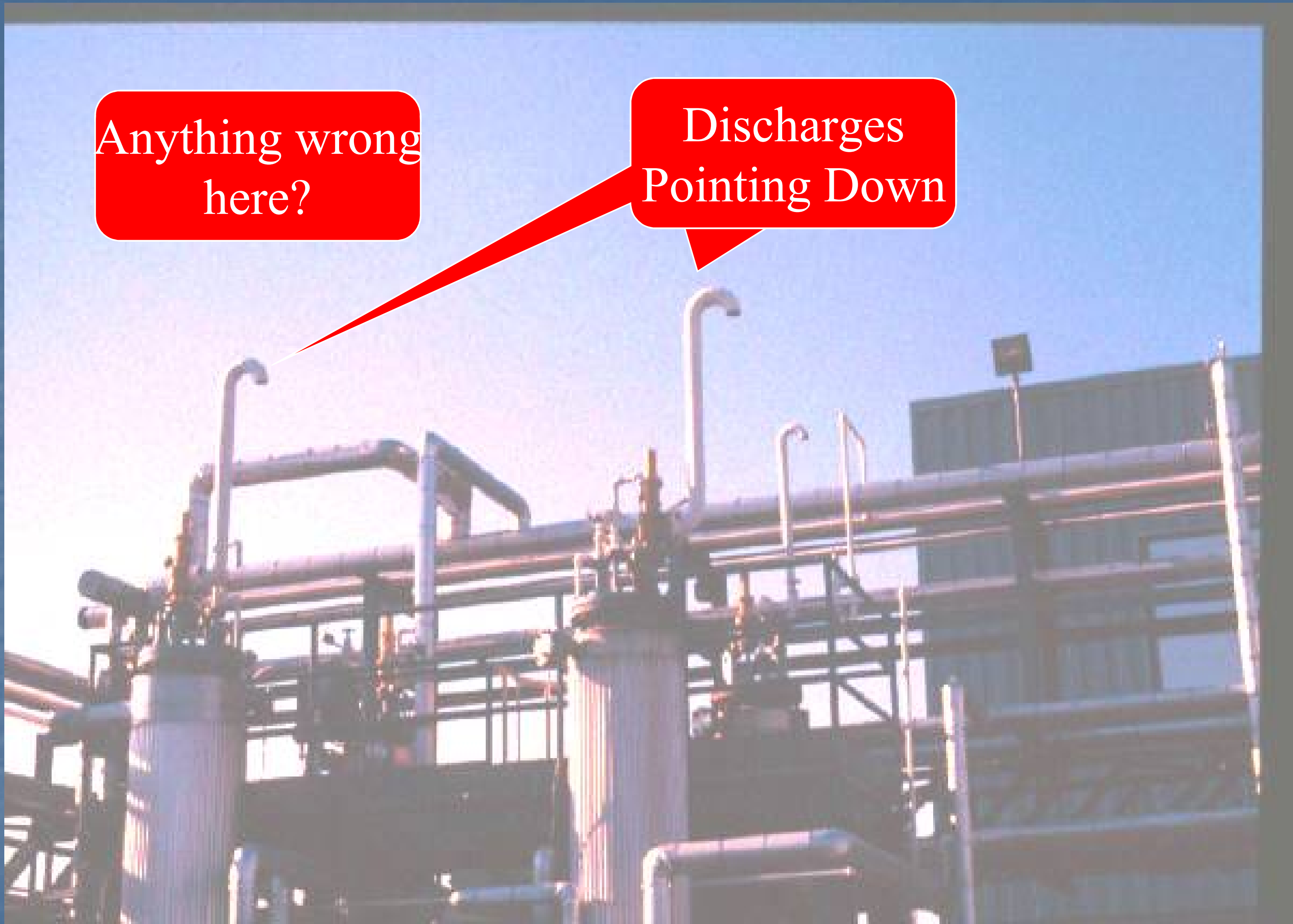
# Installation, Inspection, and Maintenance

- To undermine all the good efforts of a design crew, simply …

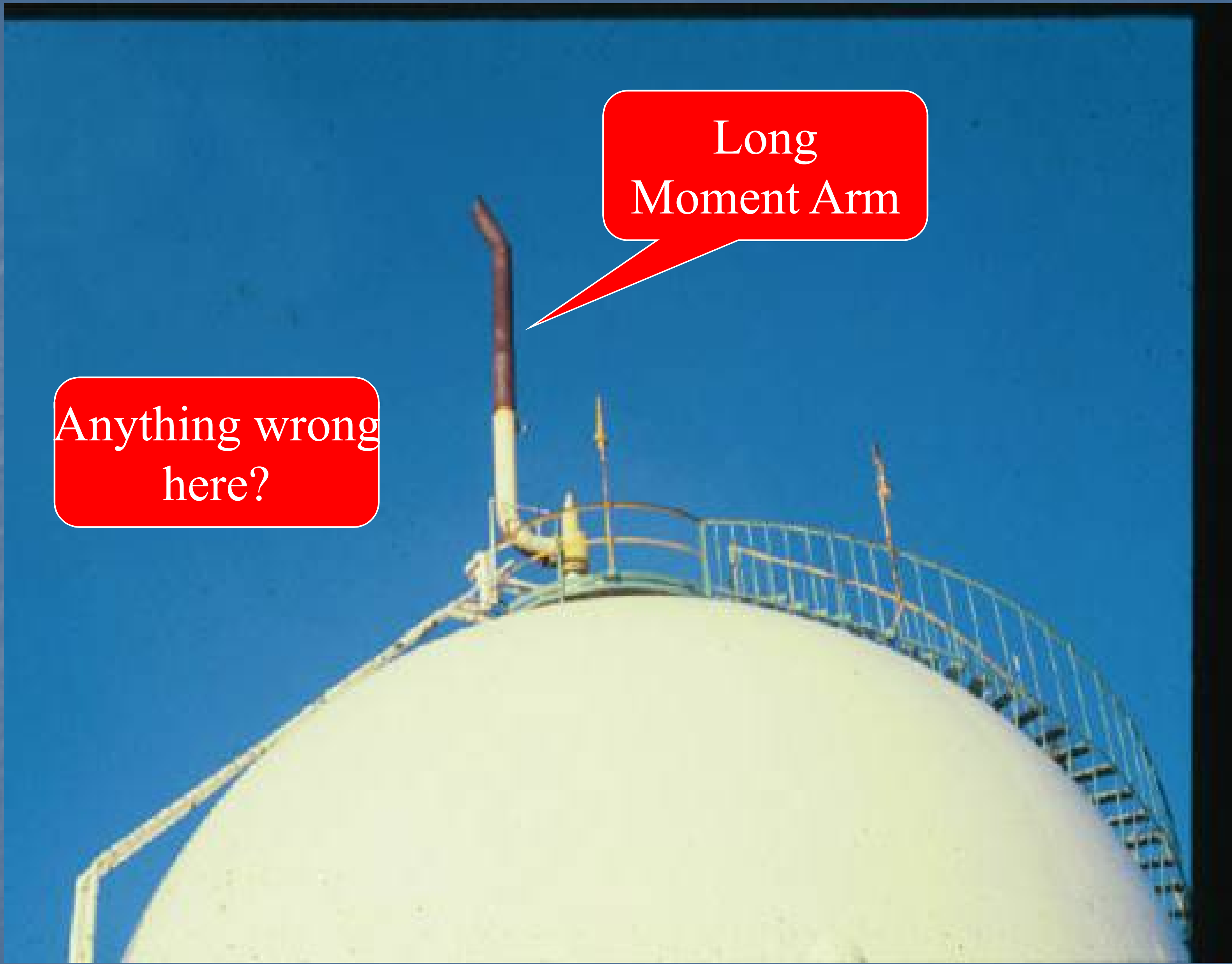
1. Improperly install relief devices
2. Fail to regularly inspect relief devices, or
3. Fail to perform needed/required maintenance on relief devices

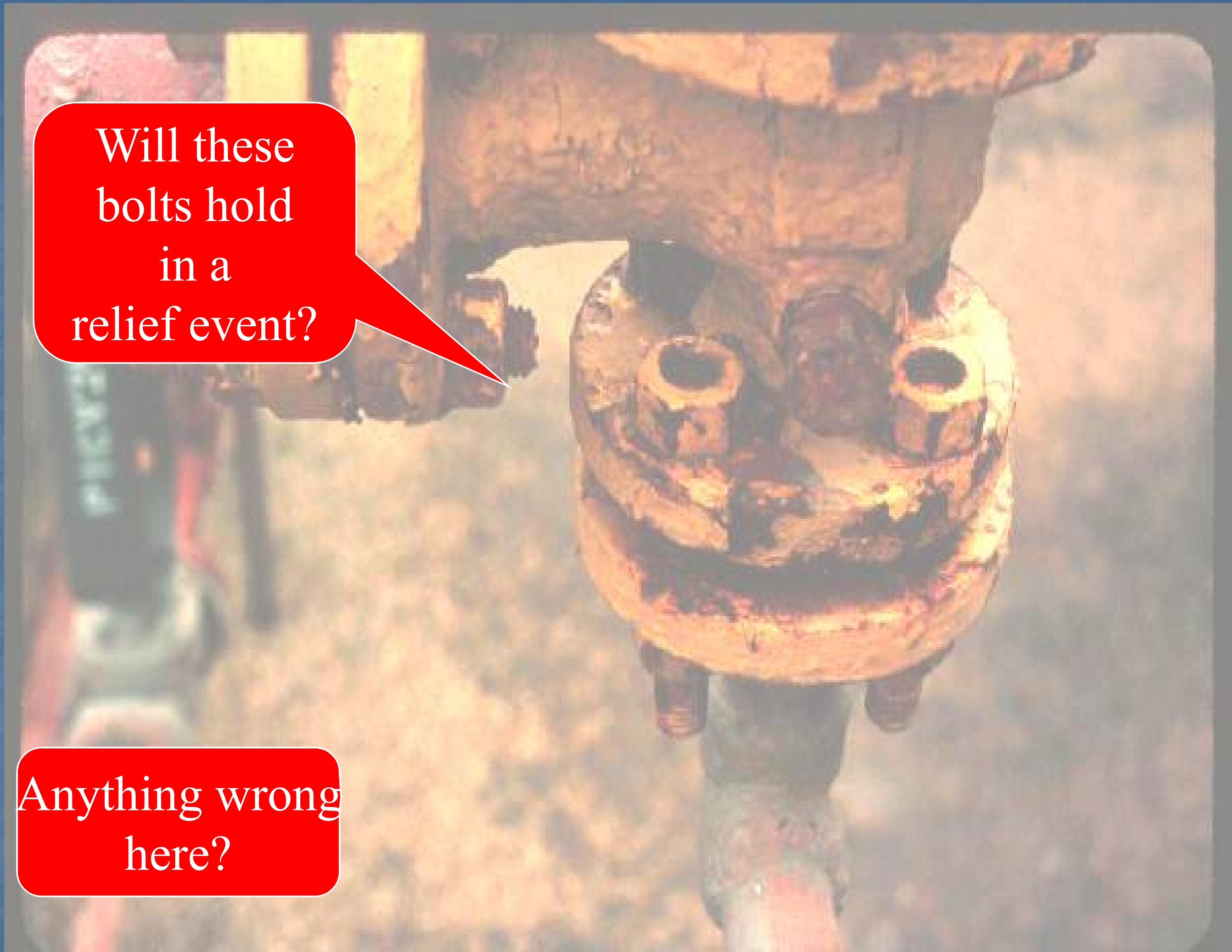

Reduced
Inlet Piping
Anything wrong
here?


Anything wrong here?
Signs of Maintenance Issues
Bellows plugged in spite of sign
Failed Inspection Program
BELLOWS SEALED
SAFETY VALVES
ENSURE PLUG IS REMOVED
FROM BONNET



Anything wrong here?
Discharges Pointing Down


Long
Moment Arm
Anything wrong
here?


Will these bolts hold in a relief event?
Anything wrong here?

# Mexico City Disaster

**Major Contributing Cause: Missing Safety Valve**

# Summary

- Pressure Relief
  - Very Important ACTIVE safety element
  - Connected intimately with Process Hazard Analysis
  - Requires diligence in design, equipment selection, installation, inspection and maintenance
- Look forward to …
  - Two-phase flow methodology/exercise

# References

- *Crowl and Louvar* – Chemical Process Safety, Chapters 8 and 9
- *Ostrowski* – Fundamentals of Pressure Relief Devices
- *Sterling* – Safety Valves: Practical Design, Practices for Relief, and Valve Sizing

END OF PRESENTATION