HYDROPLEX

High Pressure Pump, Valve, and System Specialists

Throttling Valve Sizing

Serving the Oil and Gas Industry since 1980
with products and solutions

NOT JUST A SOURCE BUT A RESOURCE

Topics of Discussion

Terminology and Definitions

Data for Sizing a Throttling Valve

Sizing Equations

Terminology and Definitions

Trim – Those parts of a valve body assembly, excluding the valve body and bonnet which are exposed and in contact with the line fluid

Terminology and Definitions

Control Valve – A valve with a power positioning actuator used to move the valve trim to any position relative to valve port or ports in response and in proportion to an external signal.

Terminology and Definitions

Linear Flow Characteristics – An inherent flow characteristic which can be represented ideally by a straight line on a rectangular plot of flow versus percent rated travel

Terminology and Definitions

Capacity – Rate of flow through a valve under stated conditions

Dead Band – The degrees or precent the discs can be rotated without passing fluid through the orifices

Flow Characteristic – Relationship between flow through the valve and percent rated travel of the trim as the latter is varied from 0 to 100%

Terminology and Definitions

Fluid – Type of fluid and fluid state

Specific Gravity – Specific Gravity of flow at normal operating temperature

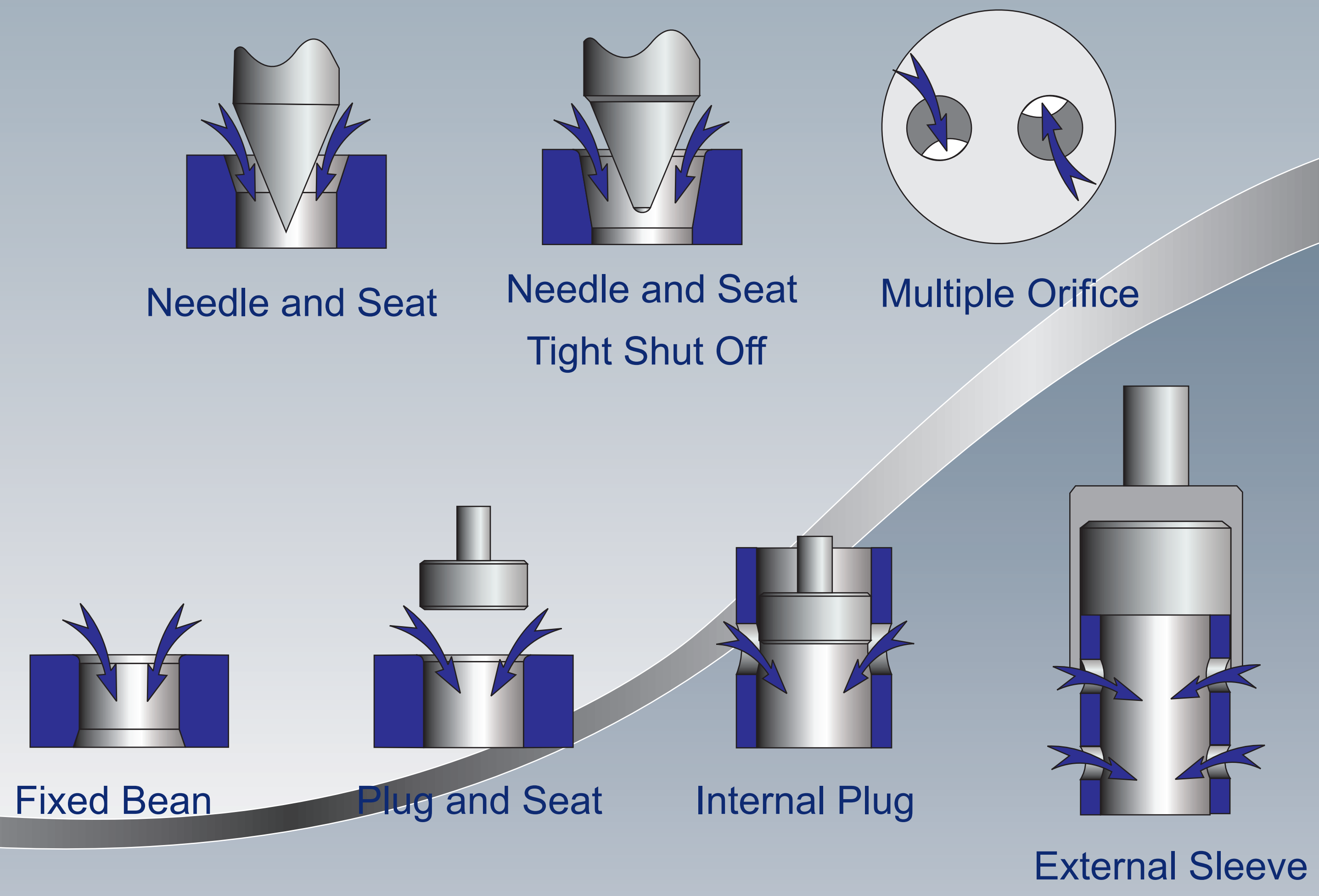
Molecular Weight – Molecular Weight of fluid

Viscosity – Viscosity at flowing temperature

Terminology and Definitions

Throttling – Providing a pressure drop by changing the turbulence in the process fluid in order to vary the fluid flow to change a process variable to the desired value

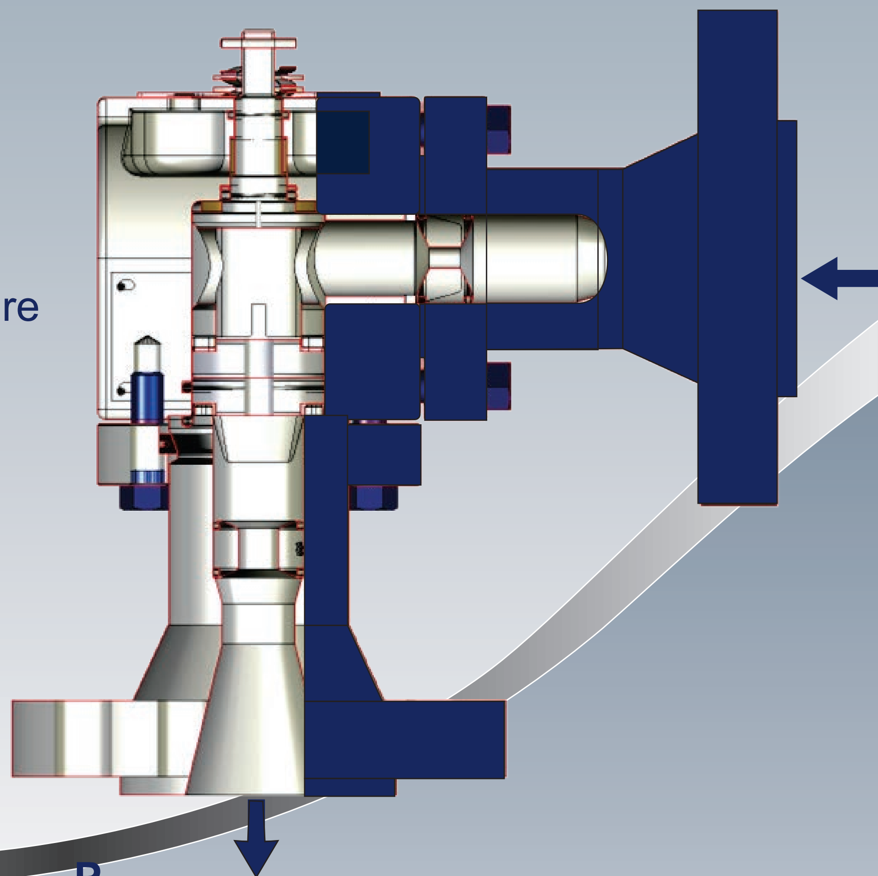
Throttling Methods



Terminology and Definitions

Vena Contracta – a point downstream of the orifice where the fluid stream reaches its minimum cross section and thus its maximum velocity and minimum pressure

Symbol Explanation



ΔP

Pressure Drop:
Differential Pressure
Head Loss

Q - Flow Rate
T - Fluid Temperature

P_1
Inlet Pressure
Upstream Pressure

P_2
Outlet Pressure
Downstream Pressure

Symbol Definitions

Cv

Valve Flow Coefficient

Dimensionless

Valve Flow Coefficient (Cv) is a valve's capacity for a liquid or gas to flow through it. It is technically defined as "the volume of pure water at 60°F (in US gallons) that will flow through a valve per minute with a pressure drop of 1 psi across the orifice."

Symbol Definitions

ΔP

Inlet Pressure (P_1) – Outlet Pressure (P_2)

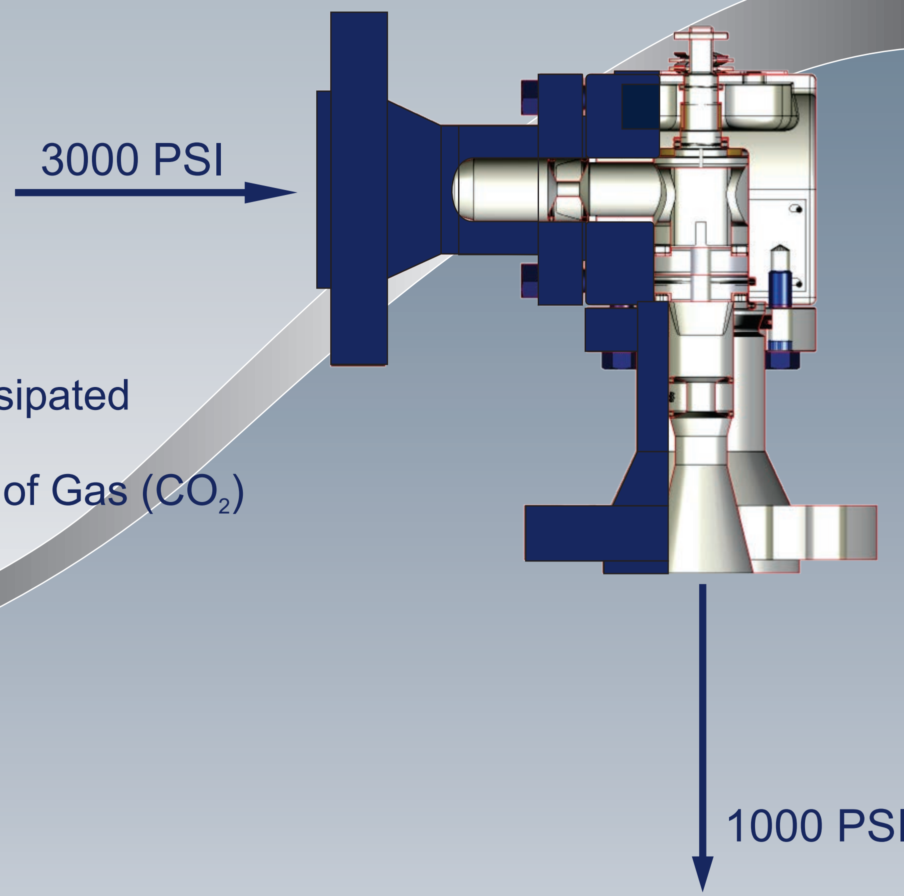
Pounds per Square Inch (PSI)

The Pressure Drop

P_1 - 3000 PSI
P_2 - 1000 PSI
Q - 15 MMSCFD
T - 25 °F
SG- 0.70
MW- 4.57
Inlet Velocity 33 FPS
Outlet Velocity 116 FPS

Pressure Drop (P_1-P_2) is Energy being Dissipated in the form of:

(1) Increased Velocity
(2) Fluid Friction
(3) Vaporization of Water
(4) Liquefying of Gas (CO_2)
(5) Other(s)



Additional Loss Results in:

(1) Erosion
(2) Cavitation
(3) Flashing
(4) Freezing
(5) Noise
(6) Vibration

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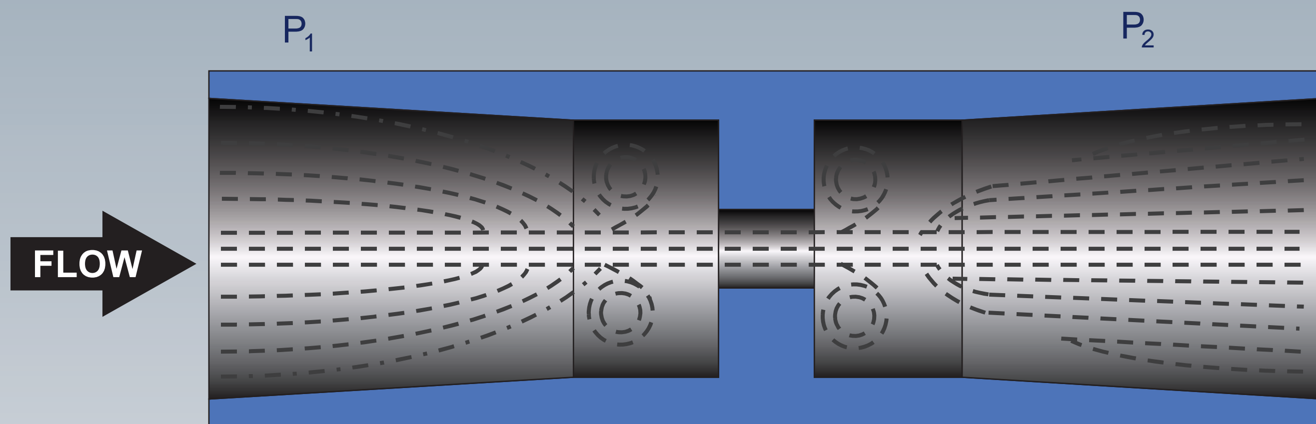
Choked Flow/Critical Flow (Gases)

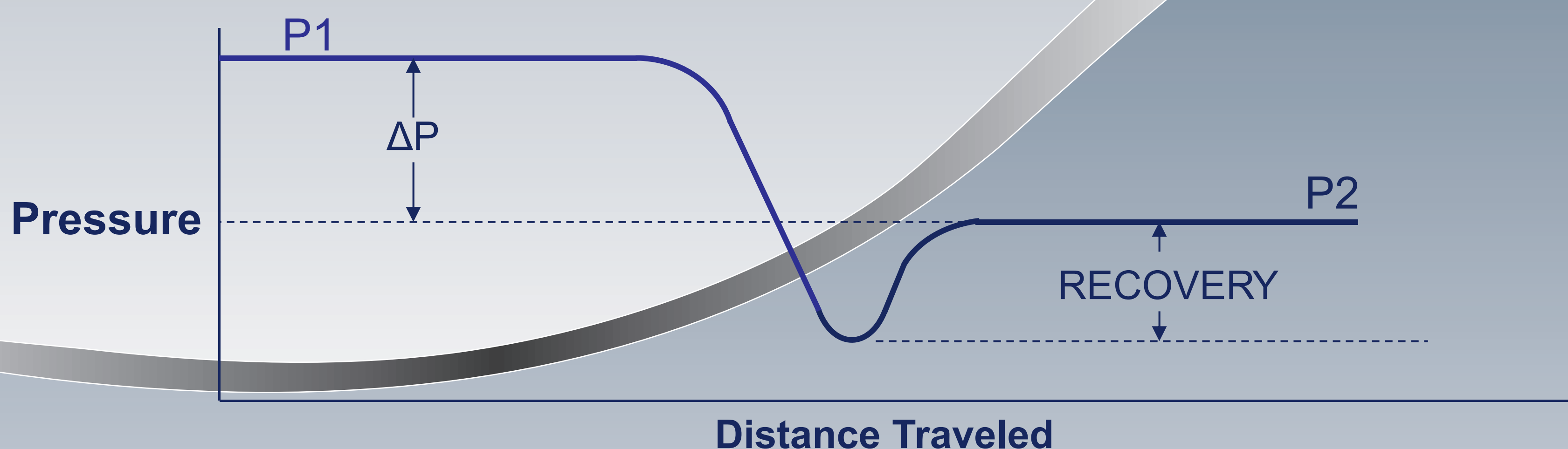
In Gas flow, when the Pressure Drop across the Throttling Area reaches Sonic Velocity, the Flow Rate will not increase even if the Outlet Pressure (Downstream of the Choke) is further reduced. Aside from intense noise, no damage is incurred unless the flow stream carries particulates. However, vibration may cause metal fatigue or bolting failure.

VALVE SIZING

ΔP Ratio

$$\Delta PR = \frac{\Delta P}{P_1}$$

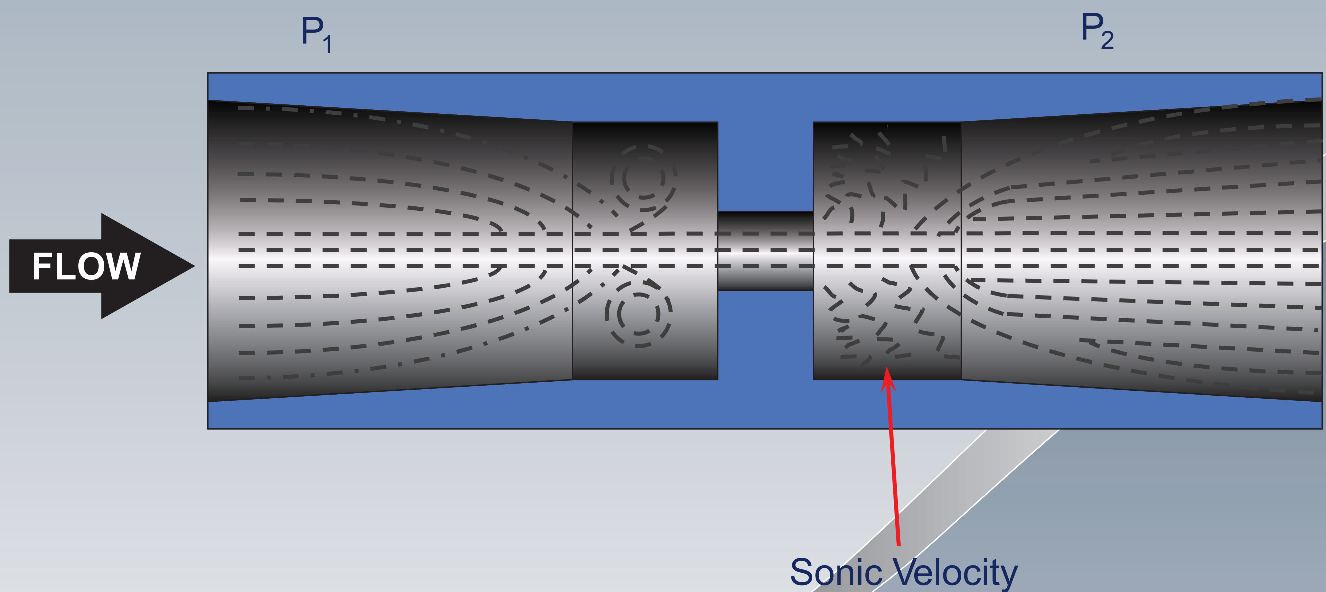




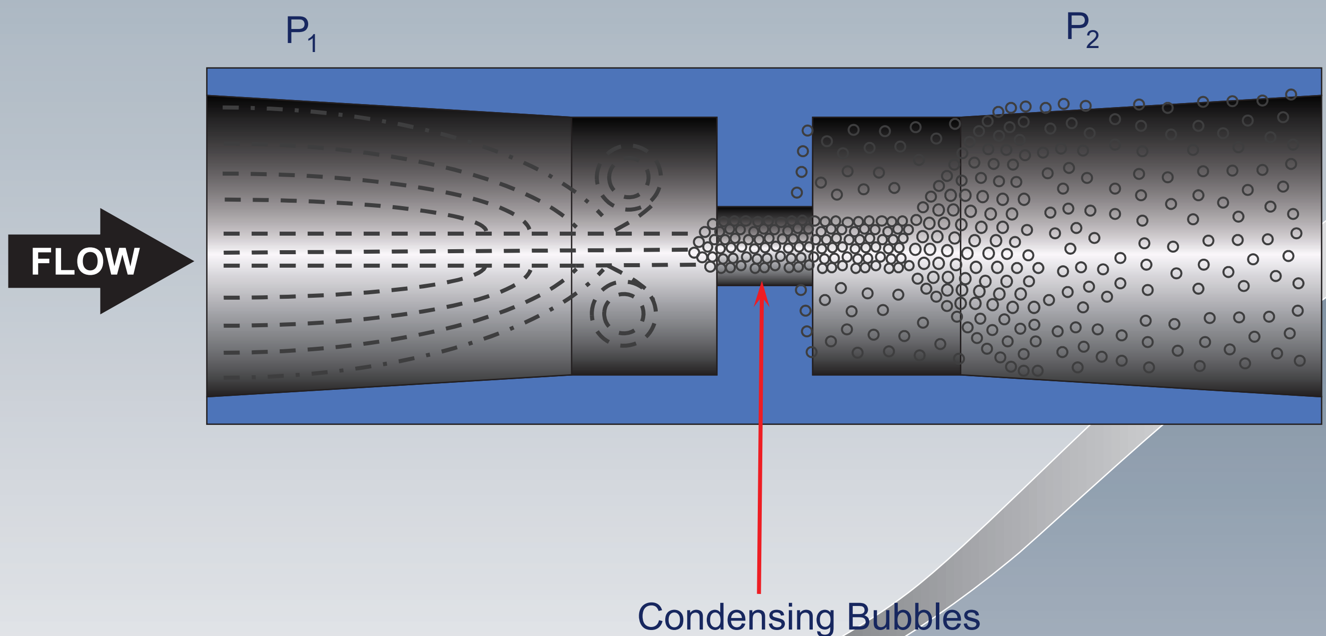
Choked Flow (Liquids)

When Liquid flows through a choke at a condition where the pressure in the throttling area drops to the Vapor Pressure, the liquid will “Boil” and form Vapor Bubbles. Fully choked flow is the condition where so much vapor is formed that further reduction in the outlet pressure (downstream of choke) will not increase flow rate.

Choked Critical Flow (Gas)



Choked Flow (Liquids)



Cavitation (Liquids)

Pressure Drop (ΔP/Differential Pressure) through the Orifice, if great enough, will cause the pressure to drop to the Liquid Vapor Pressure causing bubbles to form or boil. As the liquid moves farther away from the orifice there is an increase in pressure (Pressure Recovery) causing condensation of bubbles into the liquid. This collapsing of bubbles causes shock waves to occur in the choke body which may cause damage to valve and downstream piping.

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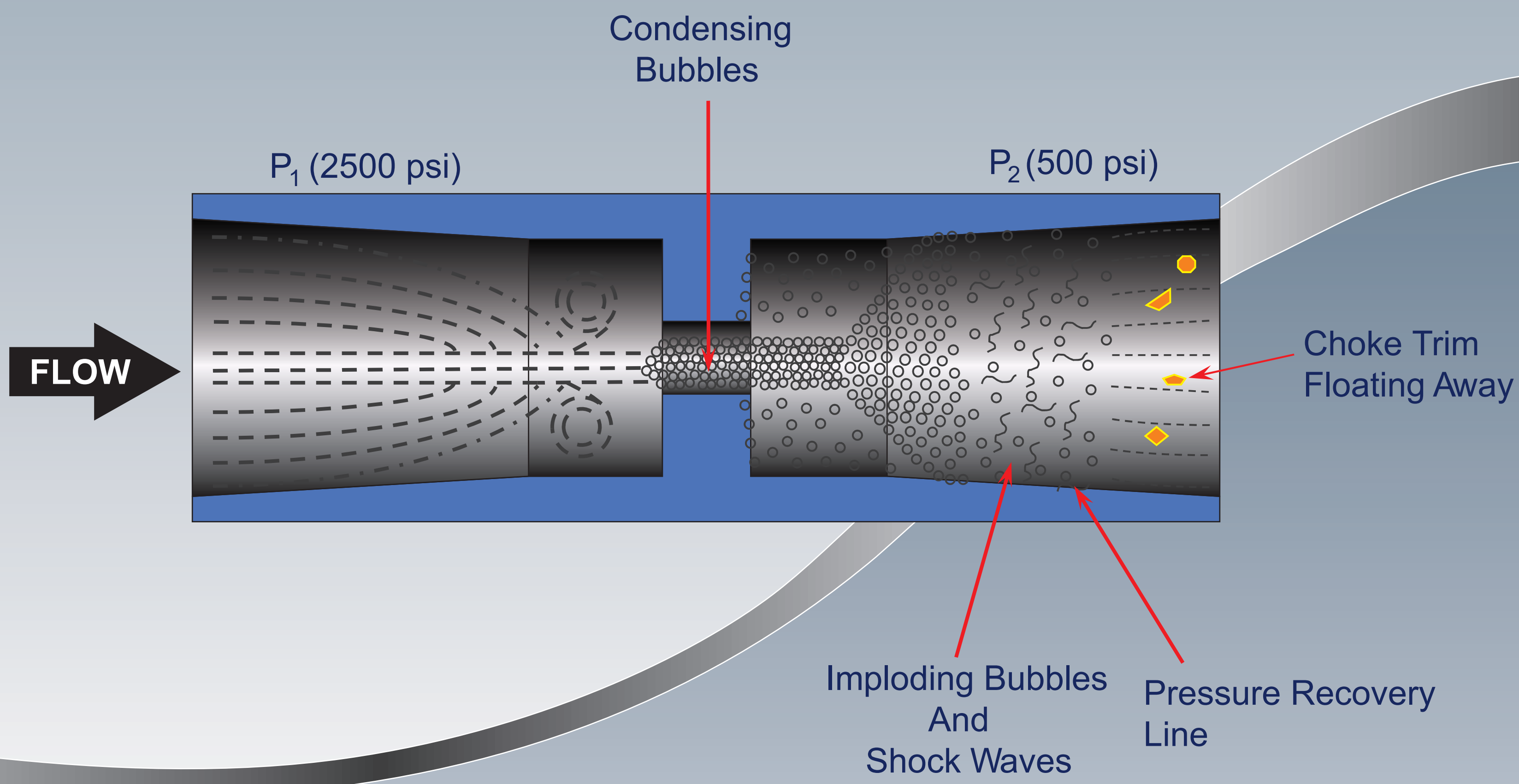
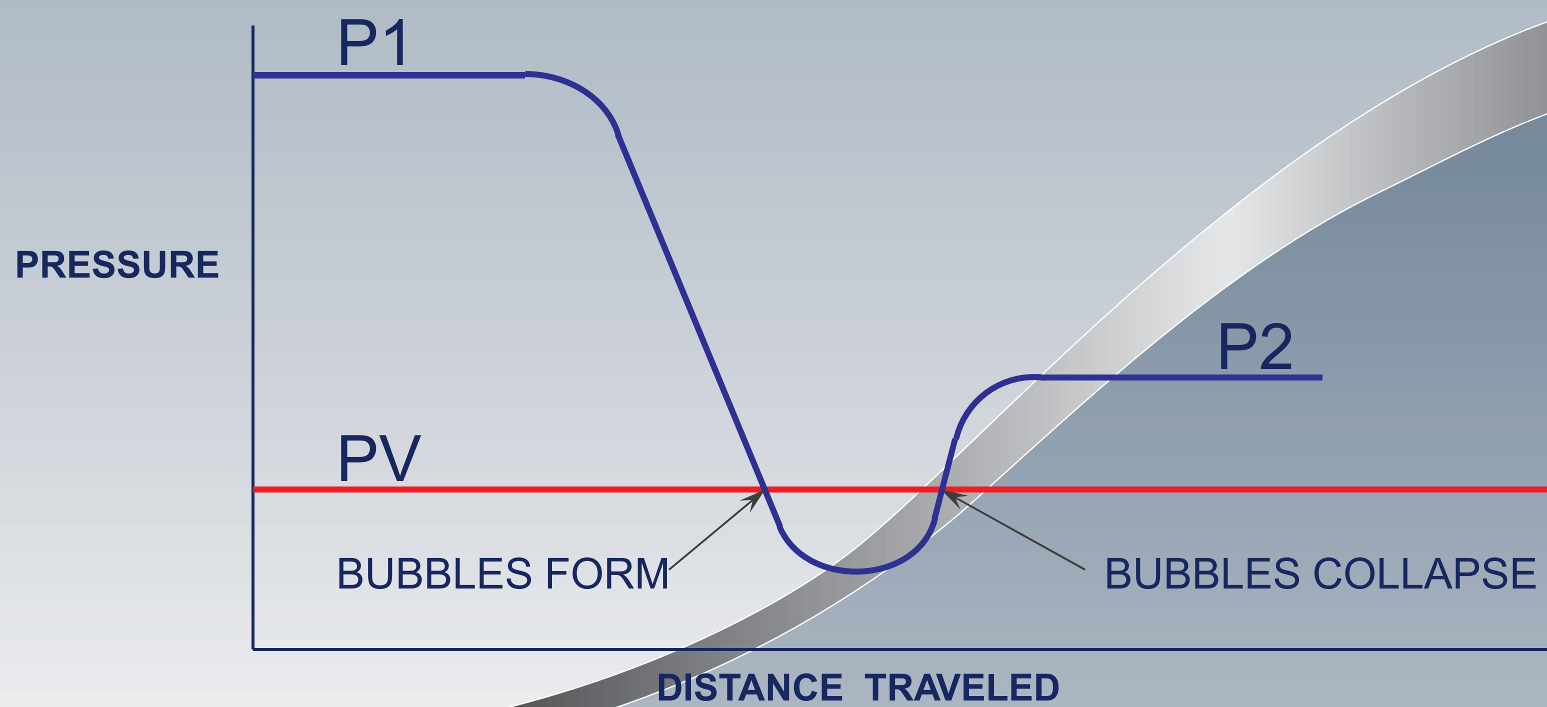
Cavitation (Liquids)



Cavitation

Occurs When Pressure Drops Below PV

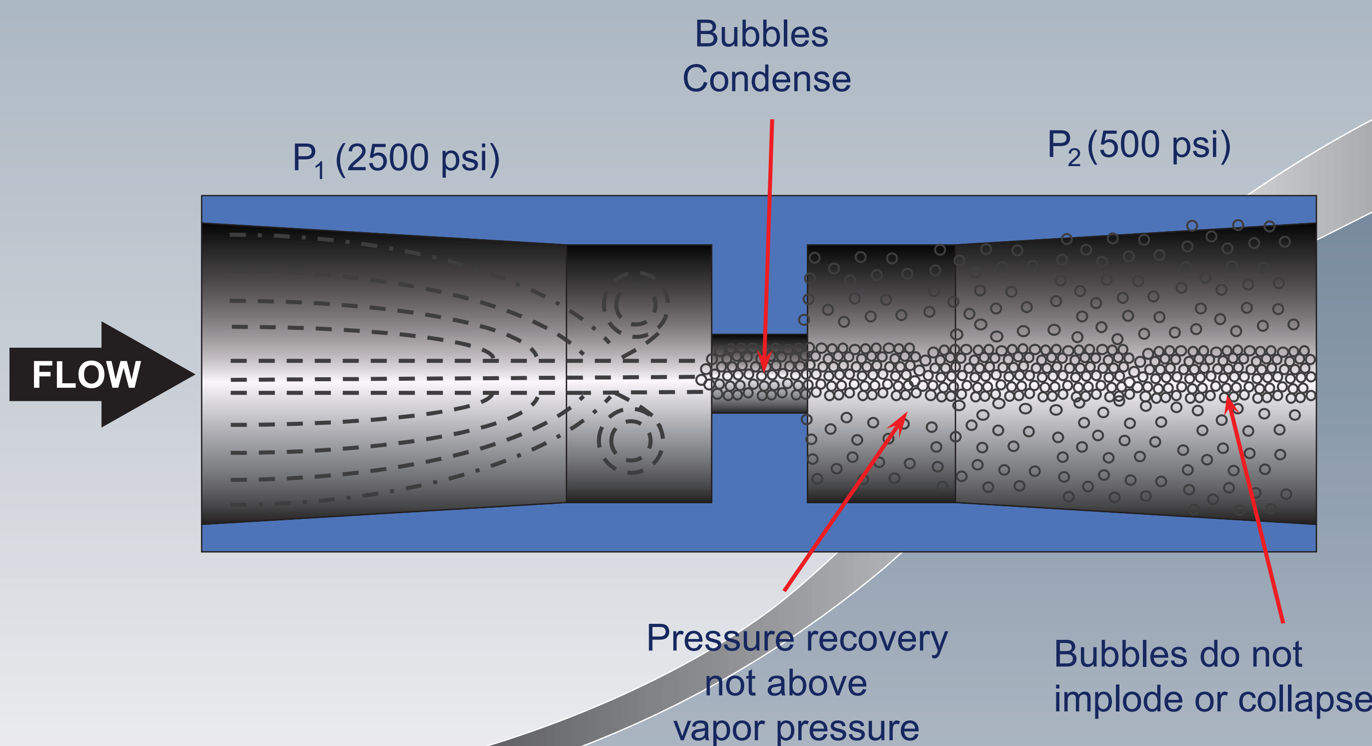


$$\Delta PR = \frac{\Delta P}{P1 - PV}$$

Flashing (Liquids)

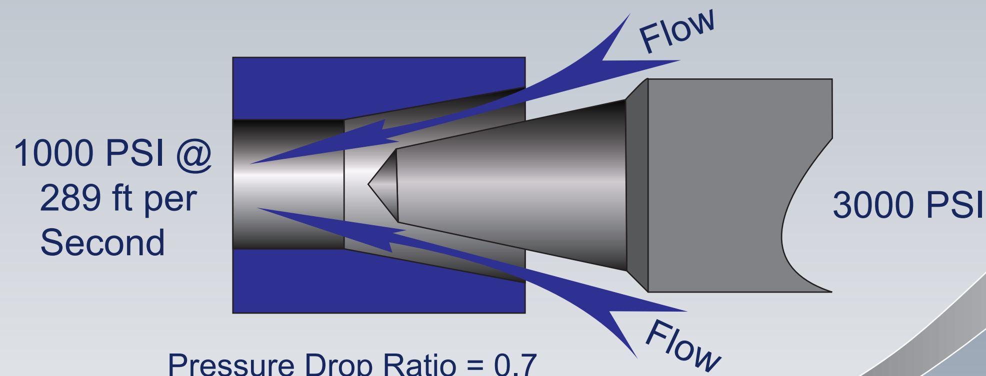
If pressure recovery does not return to higher than the vapor pressure as the Vapor/Liquid stream moves farther away from the orifice (the pressure remains at liquid Vapor Pressure). This process is called “Flashing”. Flashing occurs at High Velocities, is noisy, and causes Erosion if the flow stream carries sand particles.

Flashing (Liquids)



Erosion

Erosion is the damage caused by the impingement of high velocity particles on the material surface



Pressure Drop Ratio = 0.7

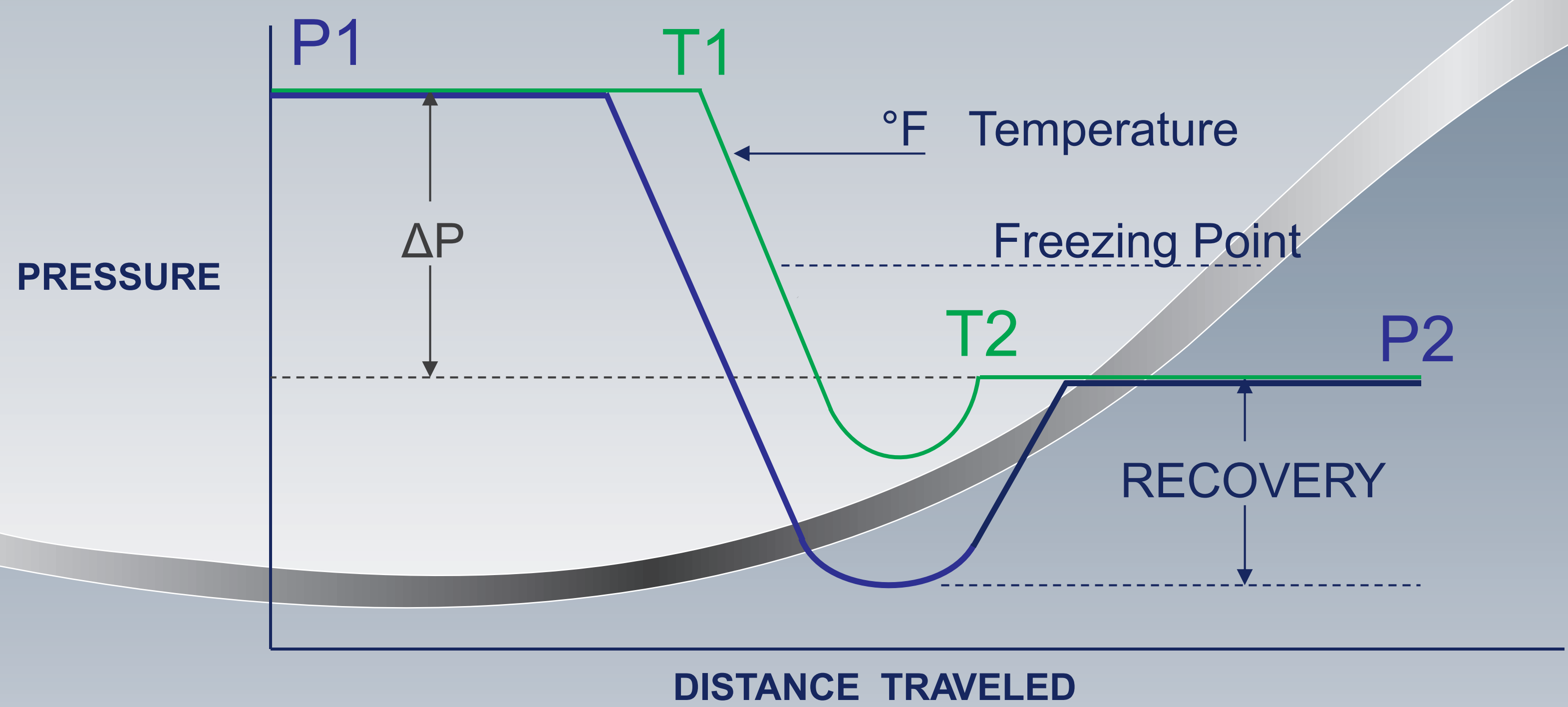
Flow Characteristics: Gas

P_1 = 3000 psi
P_2 = 1000 psi
Q = 10 MMSCFD
SG = .65
T = 105° F
½% Solids (Sand)
2” Carbon Steel Pipe XXS = 1.503” ID

Freezing

The Expansion Cooling (JT effect) in Gas throttling often Freezes water or Hydrates in the valve body

Rule of Thumb foe every 100 psi drop in pressure with gas a 6-8 degree F drop in temperature can be expected.



Freezing

Typical Methods of handling:

1) Preheating the Gas Expansion (Line heaters or GPU)
2) Injecting Compounds which lower the Hydrate Formation Temperature
3) Jacketing & Heating the valve body

Sizing Situations

Typical Applications which require specific sizing Requirements include:

Natural Gas
Oil
Water
Oil and Water (two phase flow)
Oil and Gas (two phase flow)
Oil, Gas and Water (three phase flow)
Liquid CO_2
Gaseous CO_2
Water and Steam (two phase flow)
Saturated Steam

Sizing Data for Gas

P_1 - Inlet Pressure (psia, psig, bar a, kpa a)

P_2 - Outlet Pressure (psia, psig, bar a, kpa a)

Q_G - Flow (scf/d, m^3/hr, kg/hr)

G - Specific Gravity

T - Temperature (F, °C, °R, °K) °

Sizing Data for 2 Phase Flow

P_1 - Inlet Pressure (psia, psig, bar a, kpa a)

P_2 - Outlet Pressure (psia, psig, bar a, kpa a)

Q_G - Flow (scf/d, m^3 /hr, kg/hr)

Q_L - Flow (bbl/d, gal/min, lbs/hr, kg/hr, m/d)

SG_g - Specific Gravity of Gas

SG_L - Specific Gravity of Liquid or API Gravity

T - Temperature (°F, °C, °R, °K)

Sizing Data for CO_2 (Gaseous)

- P_1 - Inlet Pressure (psia, psig, bar a, kpa a)
- P_2 - Outlet Pressure (psia, psig, bar a, kpa a)
- Q_G - Flow (scf/d, m^3/hr, kg/hr)
- P_v - Vapor Pressure (Function of Temperature)
- $\underline{V}$ - Specific Volume (Function of Temperature and (P_1) Pressure)
- G_g - Specific Gravity of Gas
- T - Temperature (°F, °C, °R, ° K)

Flow Equations for Compressible Fluids (Gas, Vapors, Steam, CO_2 etc.)

Non-Choked Turbulent Flow

$$Cv = \frac{W}{63.3Y}\sqrt{\frac{V}{X\,P_1}}$$ [Mass Flow Rate]

or

$$Cv = \frac{Q}{1360\,P_1 Y}\sqrt{\frac{SG\,T_1\,Z}{X}}$$ [Volumetric Flow Rate]

Choked Turbulent Flow

Substitute X_t for X in the above Equations

Where:

W = Flow Rate (lb/hr)
Y = Expansion Factor – Limits (1.0 to 0.67)
X = DP/P_1 (Pressure Drop Ratio)
Q = Flow Rate (SCF/D)
T_1 = Temperature (°R)
V = Specific Volume (ft^3/lb)
$_1$ = Inlet Pressure (PSIA)
X_t = Critical Pressure Drop Ratio
SG = Specific Gravity
Z = Compressibility Factor

Sizing Data for Liquids

P_1 - Inlet Pressure (psia, psig, bar a, kpa a)

P_2 - Outlet Pressure (psia, psig, bar a, kpa a)

Q_L - Flow (scf/d, m^3/hr, kg/hr)

SG - Specific Gravity

T - Temperature (°F, °C, ° R, °K)

VALVE SIZING

Application Information

Flow Equations for Liquids (Water, Oil etc.)

Non-Choked Turbulent Flow

$$Cv = Q \sqrt{\frac{SG}{P_1 - P_2}}$$

Choked Turbulent Flow

$$Cv = \frac{Q}{F_1} \sqrt{\frac{SG}{P_1 - P_{vc}}}$$

$$P_{vc} = F_f P_V$$

Where:

P_1 = Inlet Pressure (PSIA)

Q = Flow Rate (SCF/D)

F_1 = Liquid Pressure Recovery Factor

F_f = Liquid Critical Pressure Ratio Factor

$$0.96 - 0.28 \left[\frac{P_v}{P_c}\right]^{1/2}$$

P_2 = Outlet Pressure (PSIA)

SG = Specific Gravity

P_{vc} = Pressure at Vena Contracta

P_v = Liquid Vapor Pressure

P_c = Liquid Critical Pressure