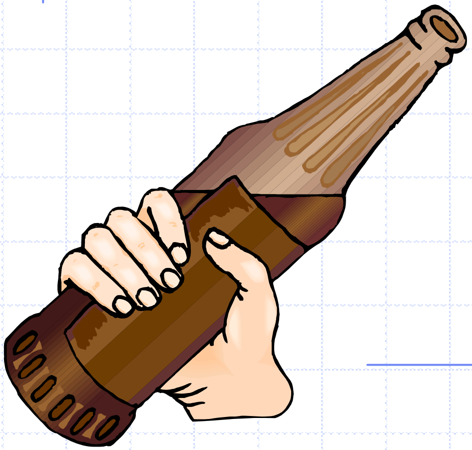
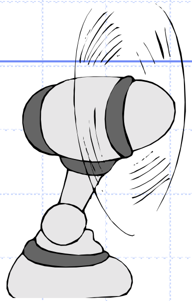
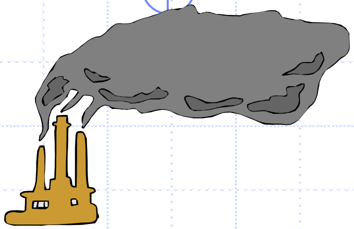
Fluids



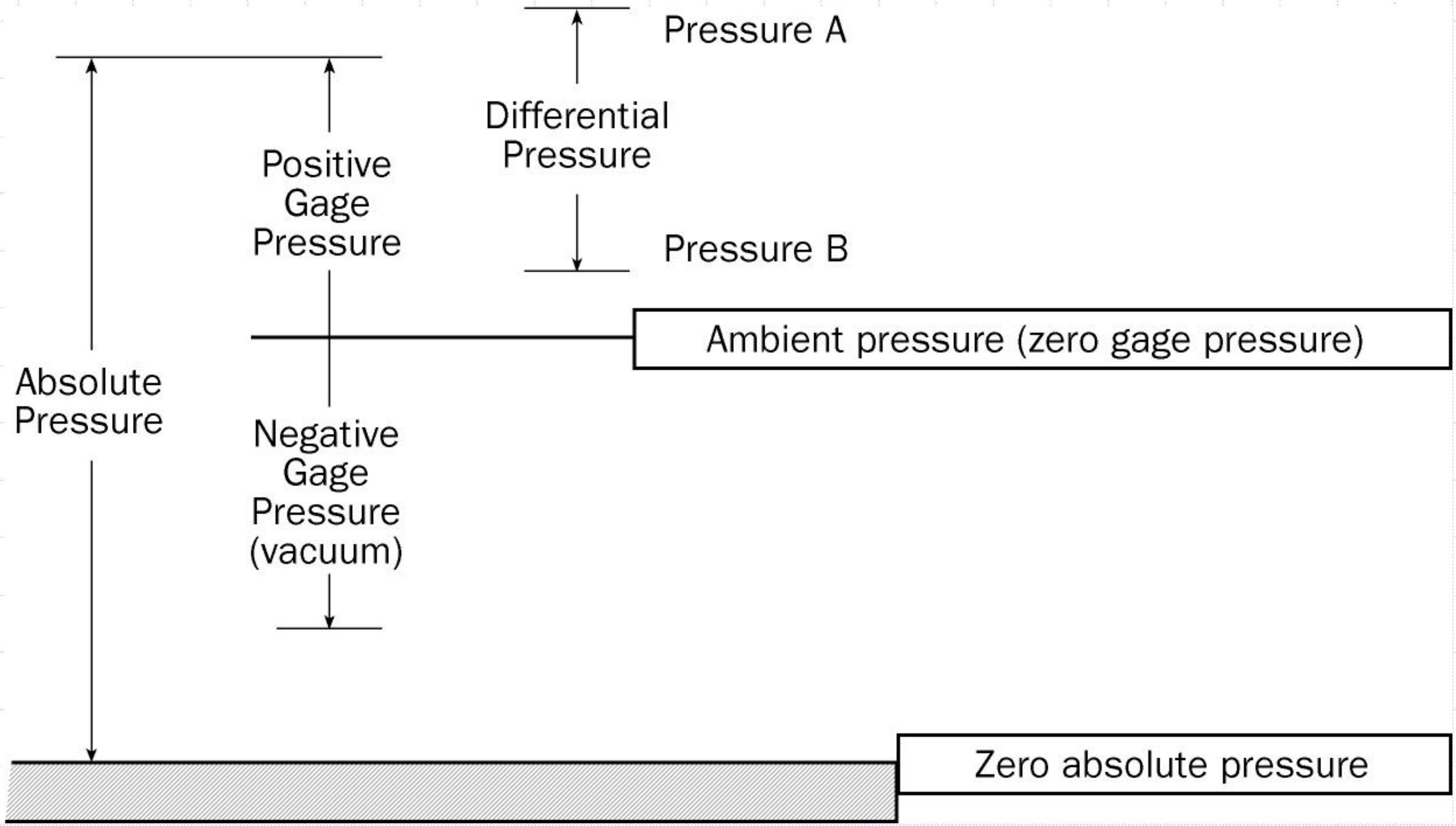




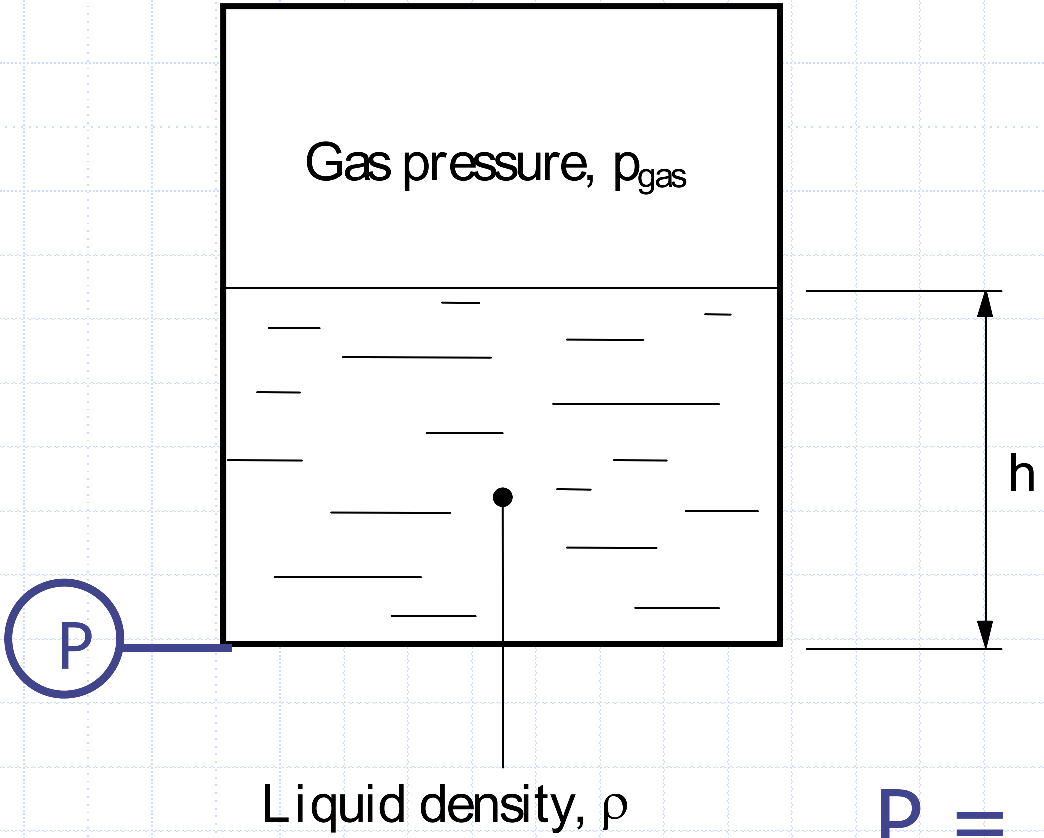
Basic Properties

- Pressure
  - Unit – Pascal (N/m^2)
- Density
  - Unit – kg/m^3
- Viscosity
  - Unit – poise (Pa·s)

Pressure Scales

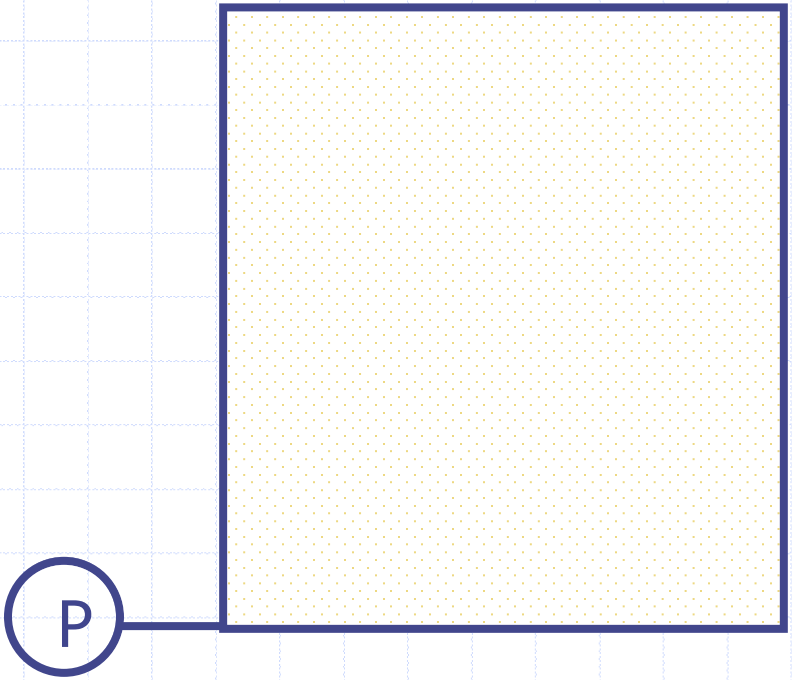


Factors Affecting Pressure (Liquids)



$$P = P_{gas} + \rho g h$$

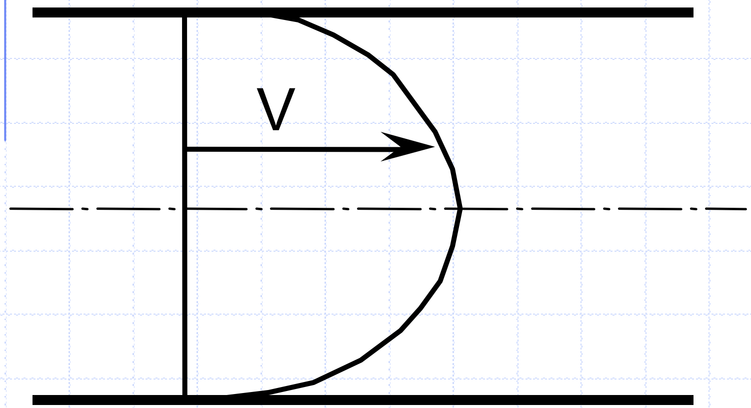
Factors Affecting Pressure (gas)



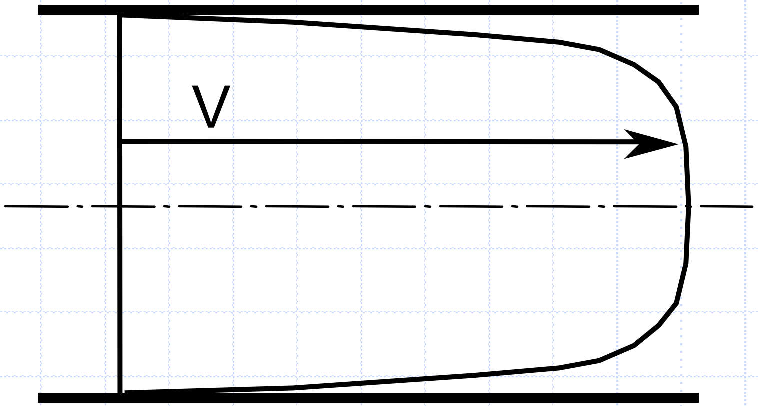
$$P = \frac{m \cdot R \cdot T}{V} = \rho \cdot R \cdot T$$

Laminar and Turbulent Flow

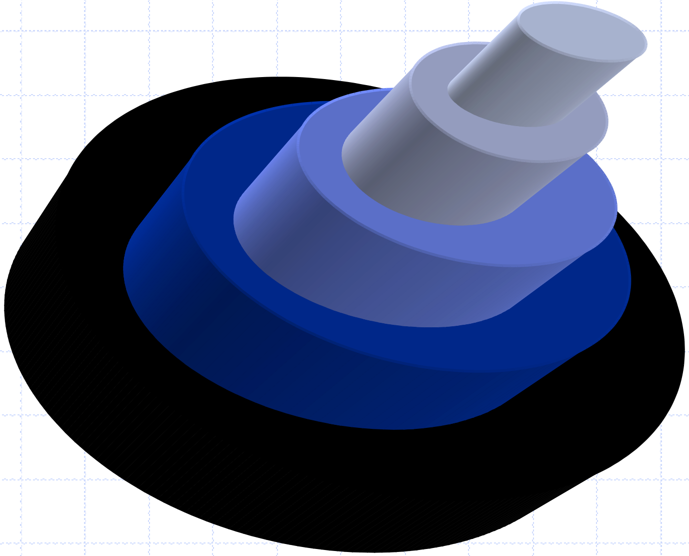
(a) Laminar Flow



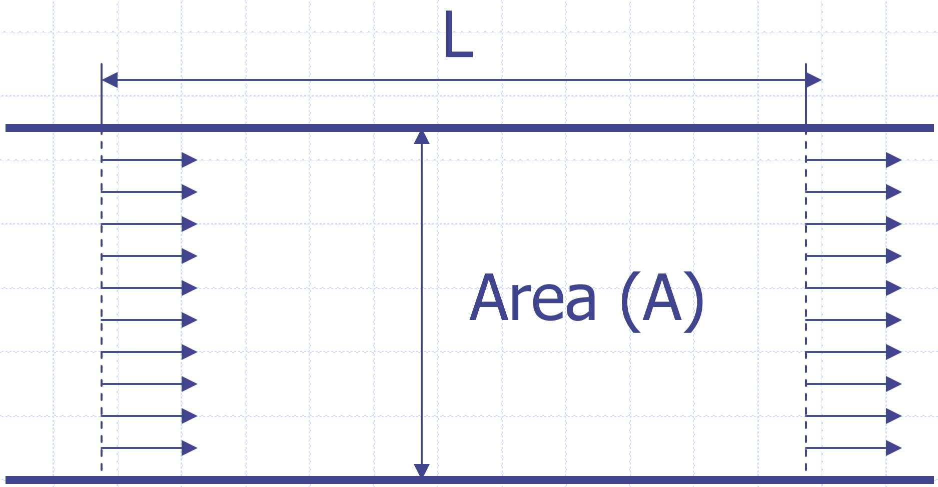
(b) Turbulent Flow



Laminar Flow



Volumetric Flow Rate



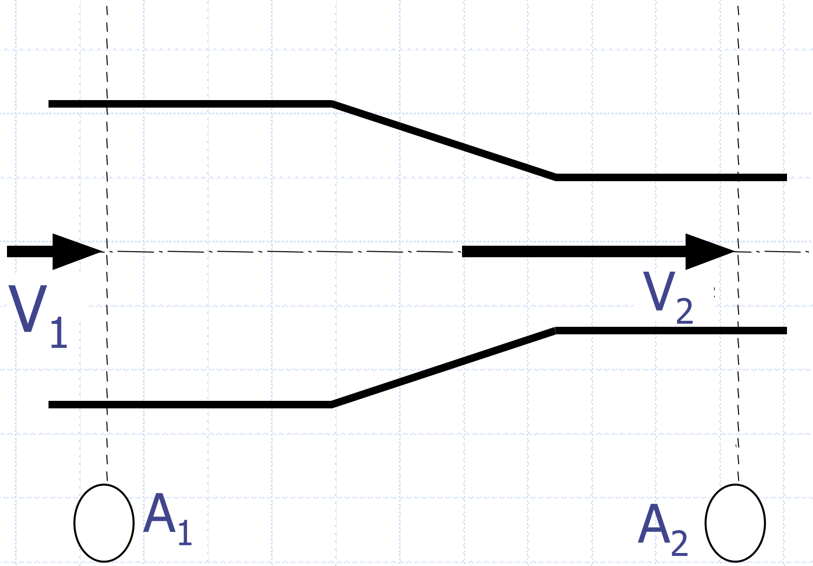
$$\dot{V} = \frac{V}{t} = \frac{A \cdot L}{t} = A \cdot v$$

Mass Flow

$$\rho = \frac{m}{V} \longrightarrow m = V \cdot \rho$$

$$\dot{m} = \dot{V} \cdot \rho = A \cdot v \cdot \rho$$

Continuity Principle



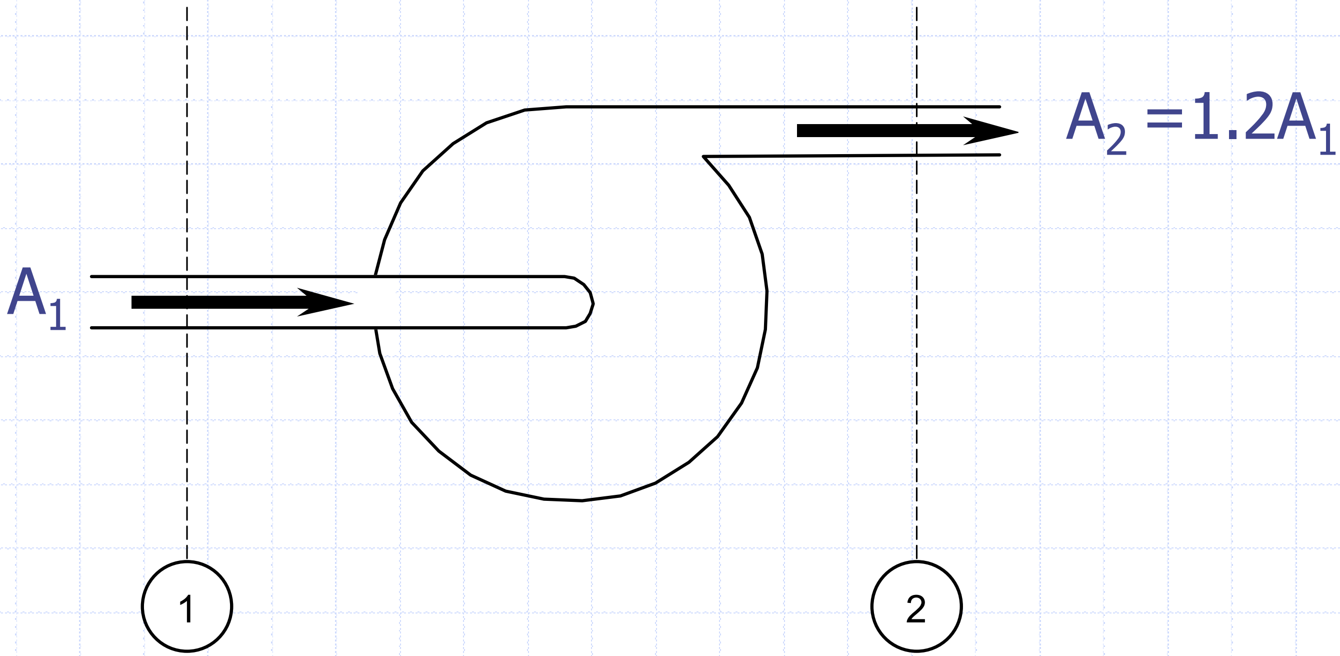
What goes in must come out!

$$\dot{m} = \text{constant} \qquad \dot{m}_1 = \dot{m}_2$$

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

$$A_1 \cdot v_1 = A_2 \cdot v_2 \quad \text{for liquids}$$

What is the relationship between v_1 and v_2?



$$A_1 \cdot v_1 = A_2 \cdot v_2$$

$$v_2 = \frac{A_1}{A_2} \cdot v_1 \quad = \frac{1}{1.2} \cdot v_1 = 0.833 v_1$$

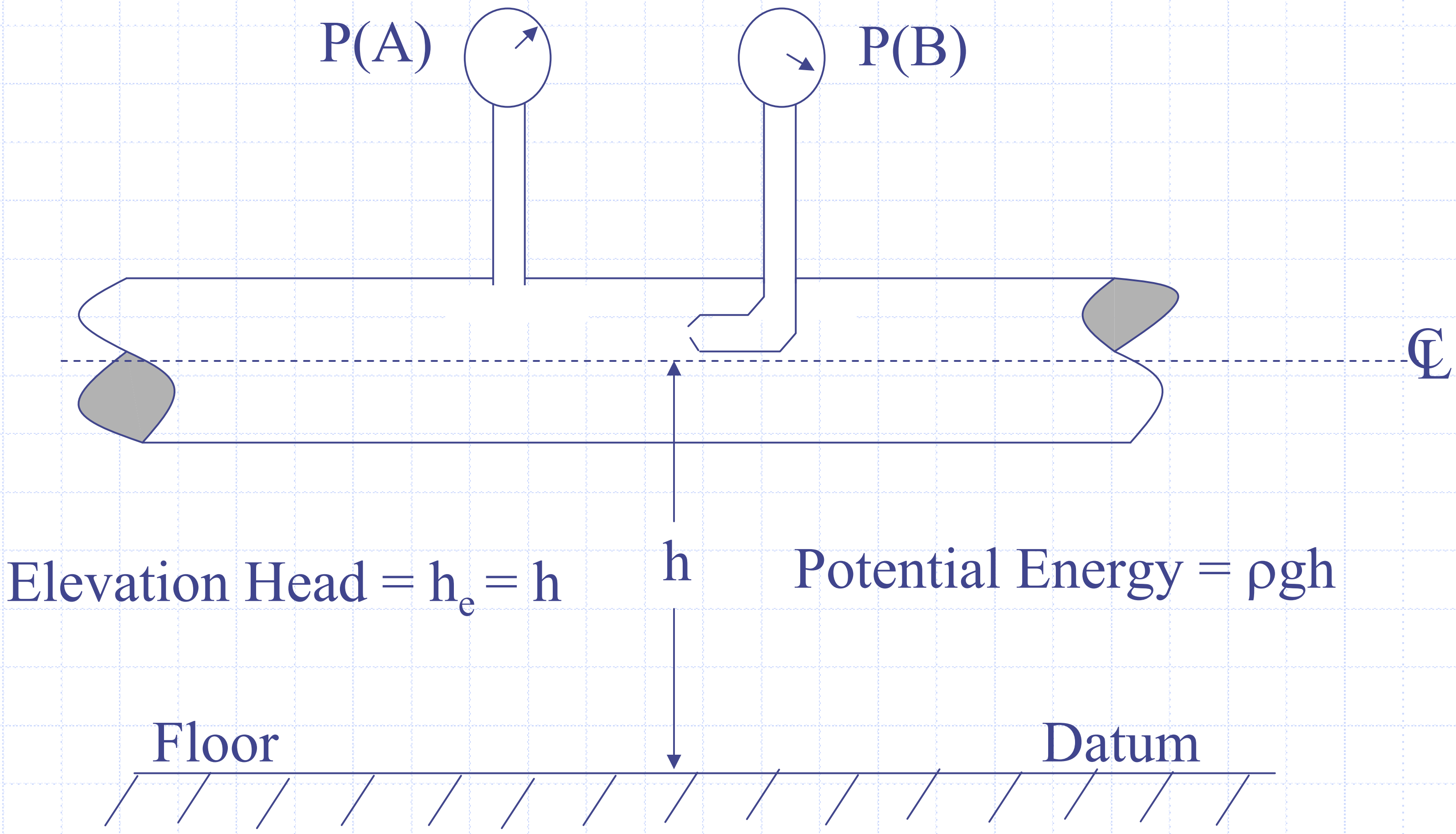
Temperature and Pressure

- What happens to volume flow rates?
  - Temperature increase
    - Liquid
    - Gas
  - Pressure Increase
    - Liquid
    - Gas

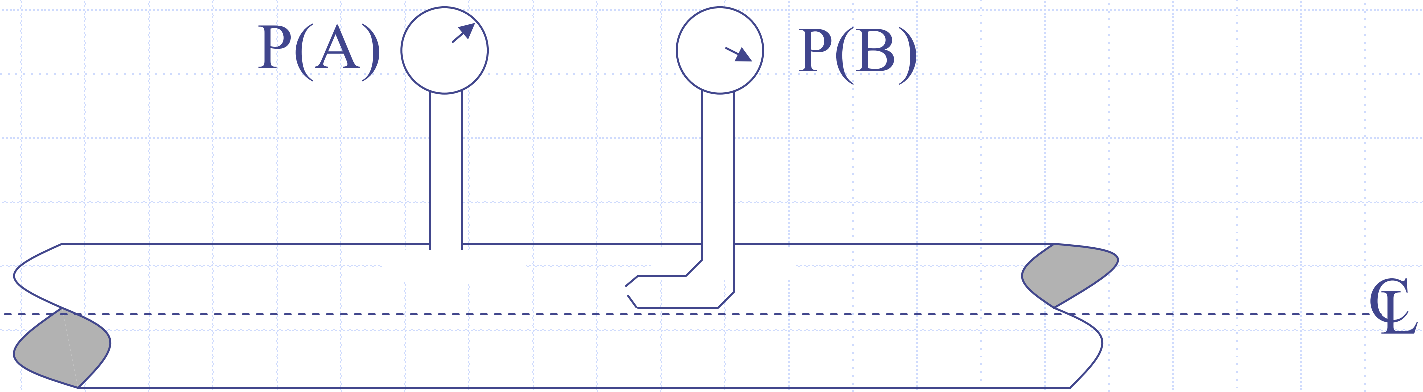
Energy In a Flowing Fluid

- Kinetic energy of moving fluid
- Potential energy due to elevation
- Pressure energy
  - A measure of the work done on the fluid to push it into the pipe
  - Or a measure of work done by the liquid when it comes out of the pipe
- Internal energy
  - Heat, intermolecular forces, intra-molecular forces

Elevation Head



Pressure Head

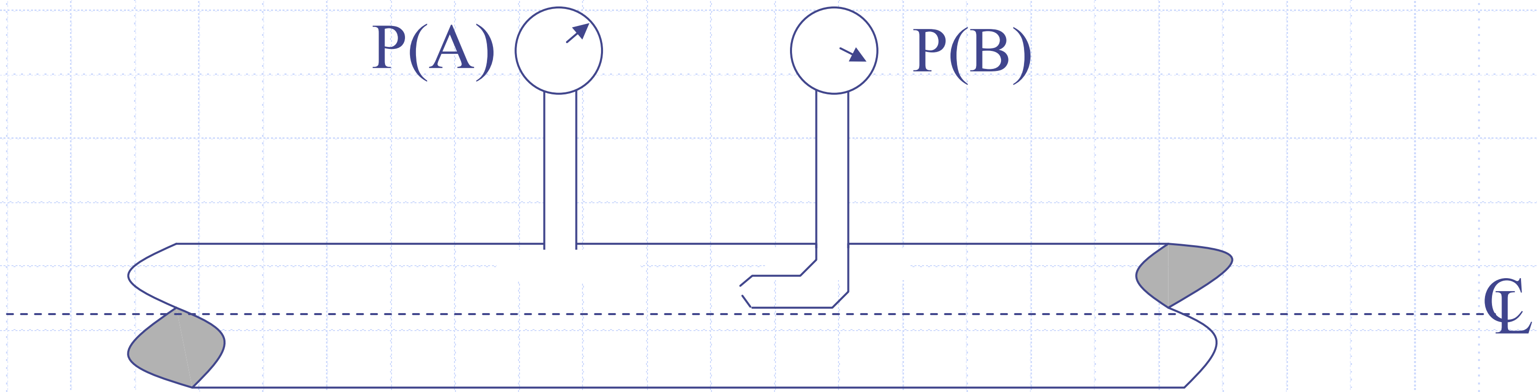


P(A) static pressure of system

Column of water supported by this pressure

Pressure Head $$h_p = \frac{p}{\rho g}$$

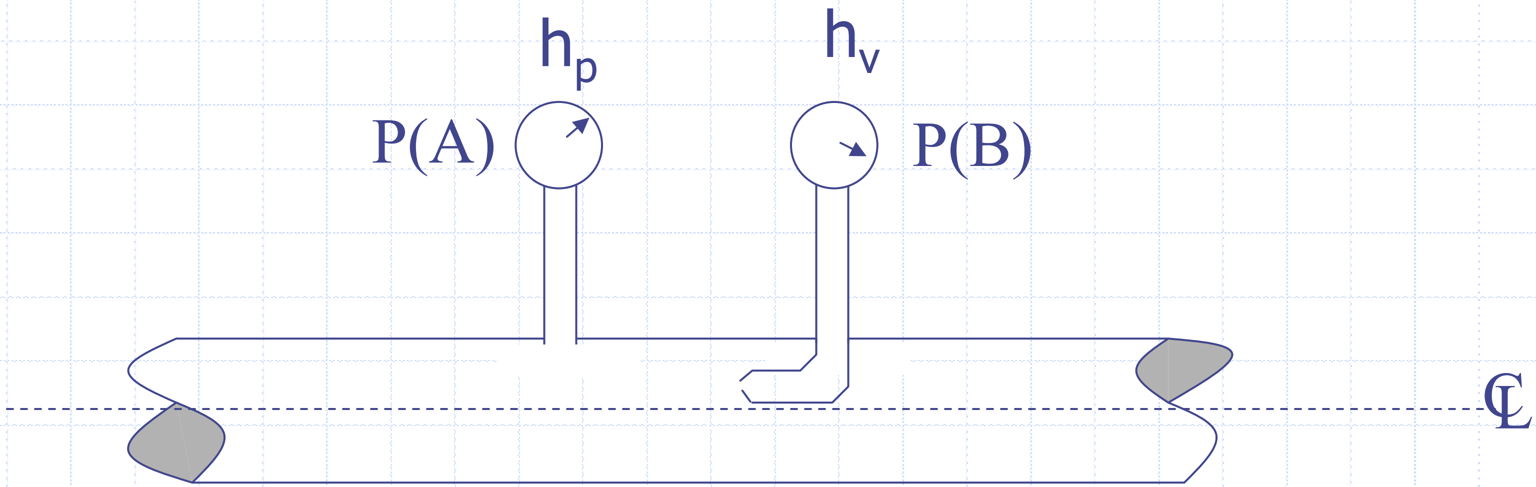
Velocity Head



P(B) is the static pressure plus the pressure of stopping the fluid
Change the kinetic energy of the fluid to potential energy

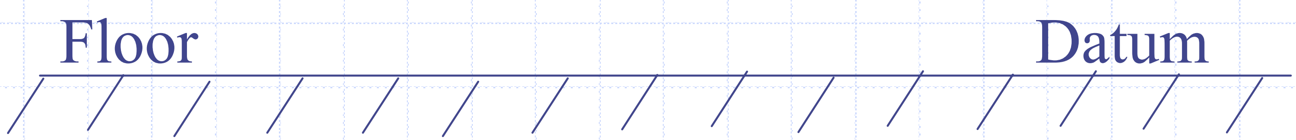
$$h_v = \frac{v^2}{2g}$$

Total Head

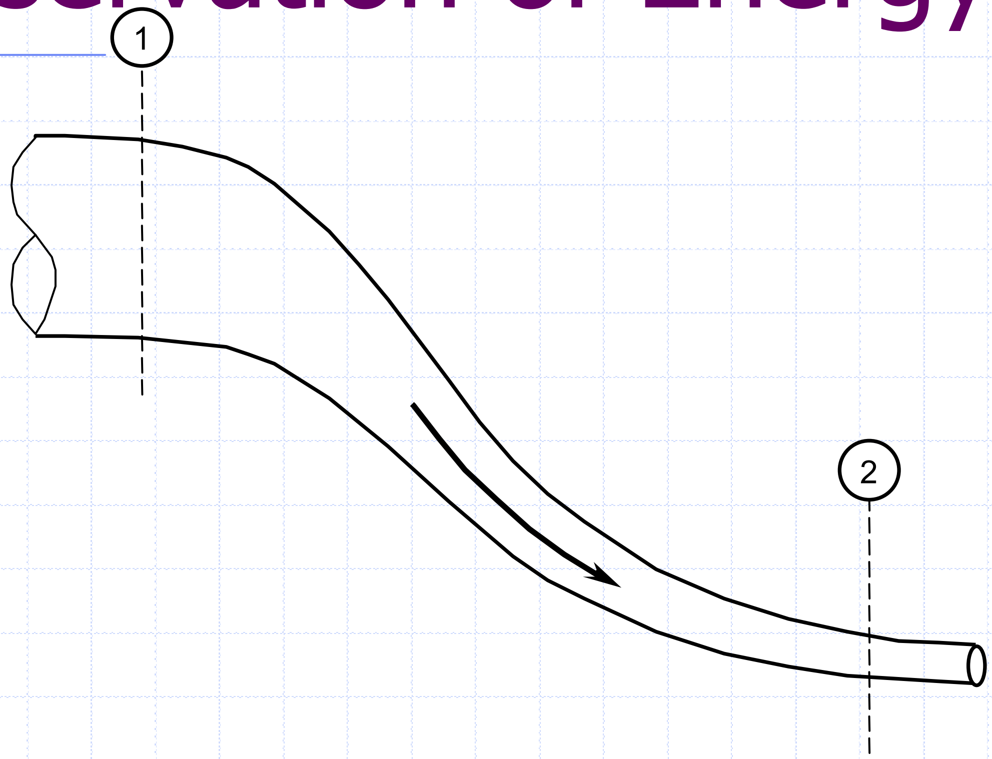


h_e

$$h_t = h_e + h_p + h_v$$



Conservation of Energy



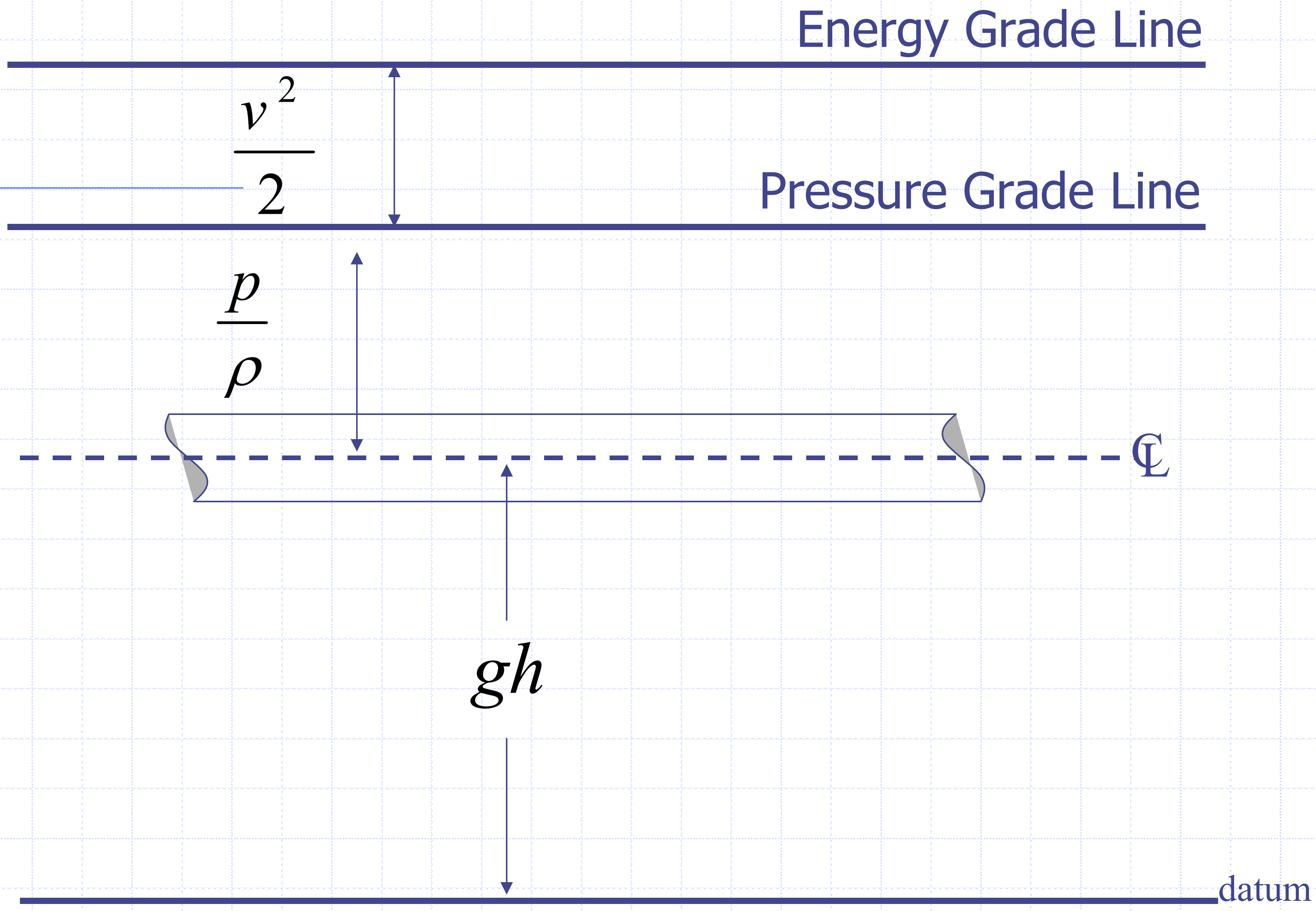
$$h_{e1} + h_{p1} + h_{v1} + h_{added} - h_{\ removed} = h_{e2} + h_{p2} + h_{v2} + h_{loss}$$

Bernoulli's Equation

$$h_{e1} + h_{p1} + h_{v1} + h_{added} - h_{removed} = h_{e2} + h_{p2} + h_{v2} + h_{loss}$$

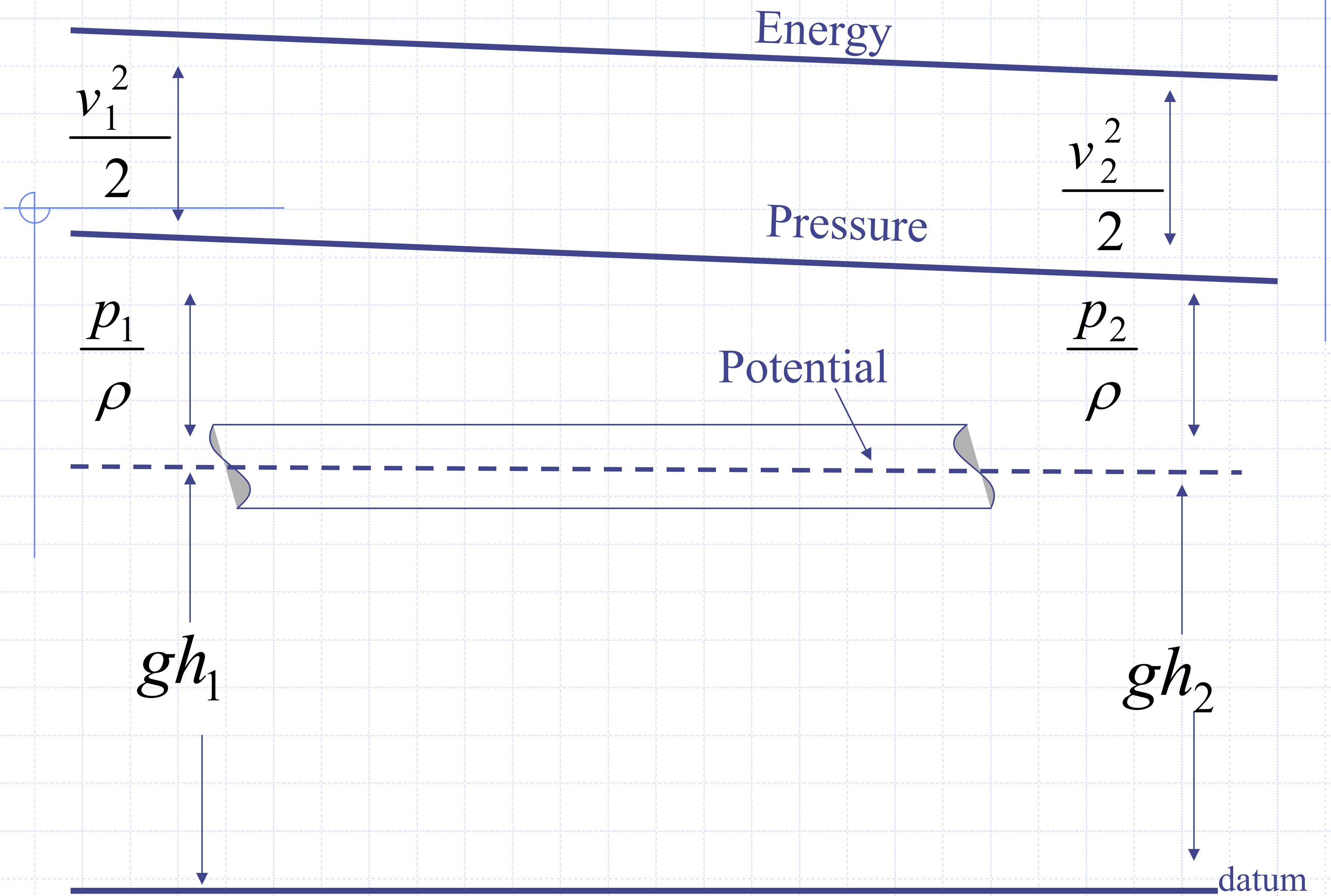
$$h_{e1} + \frac{v_1^2}{2 \cdot g} + \frac{p_1}{\rho \cdot g} + h_{added} - h_{lost} = h_{e2} + \frac{v_2^2}{2 \cdot g} + \frac{p_2}{\rho \cdot g}$$

Energy is conserved in a flowing fluid!



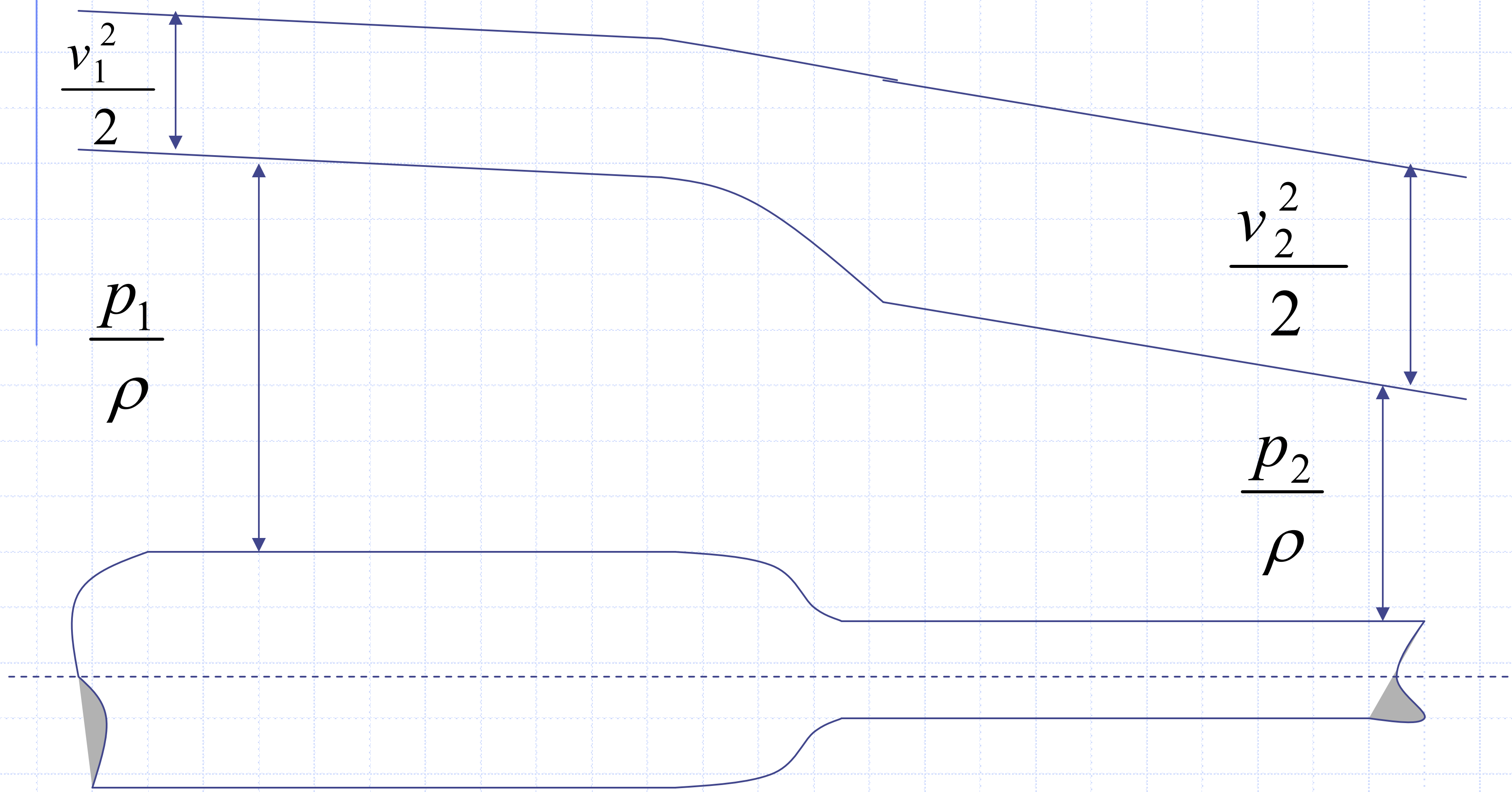
Energy Grade Line
$\frac{v^2}{2}$
Pressure Grade Line
$\frac{p}{\rho}$
℄
gh
datum

Ideal Case

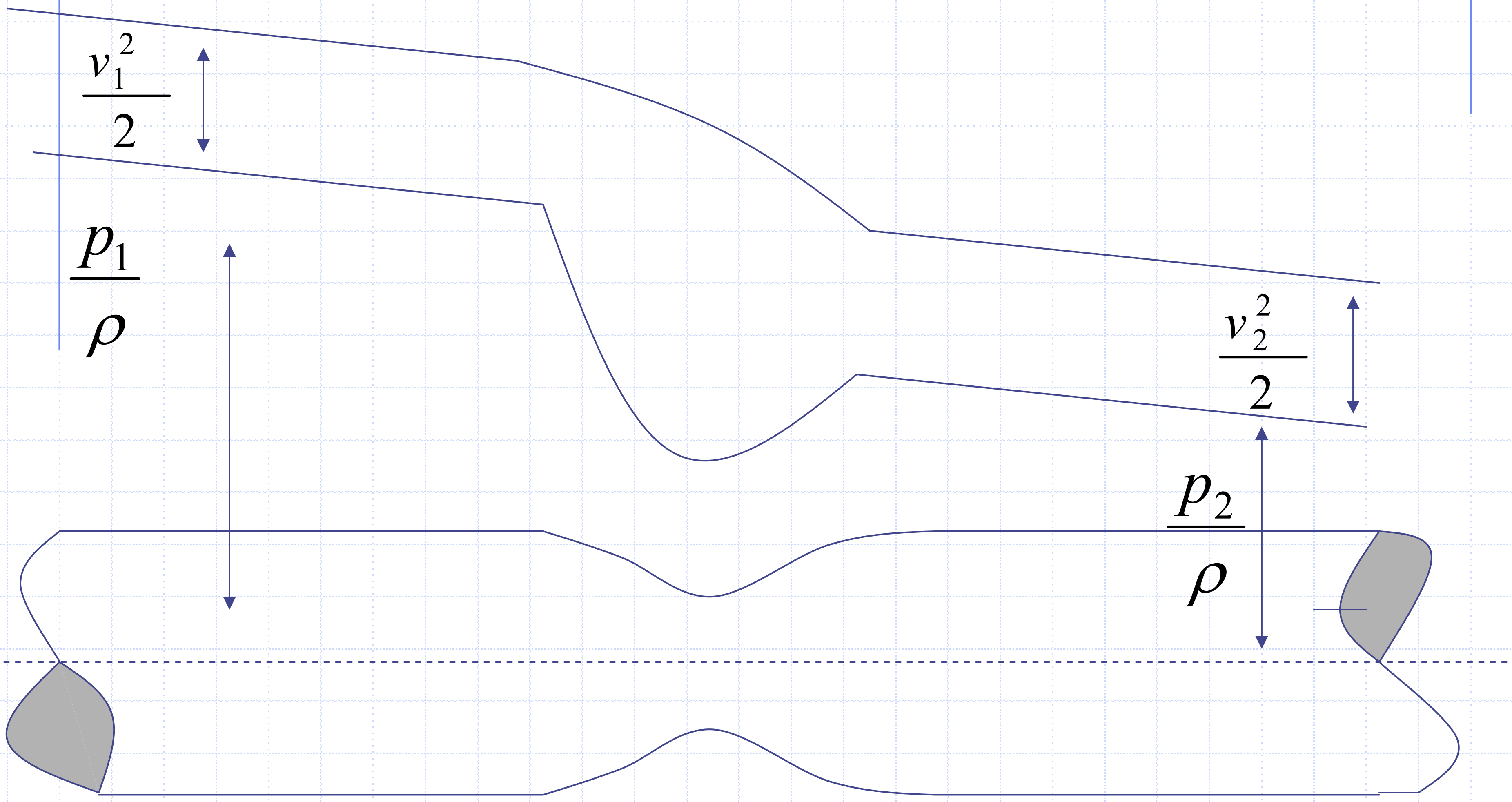


Energy Loss Due to Flow

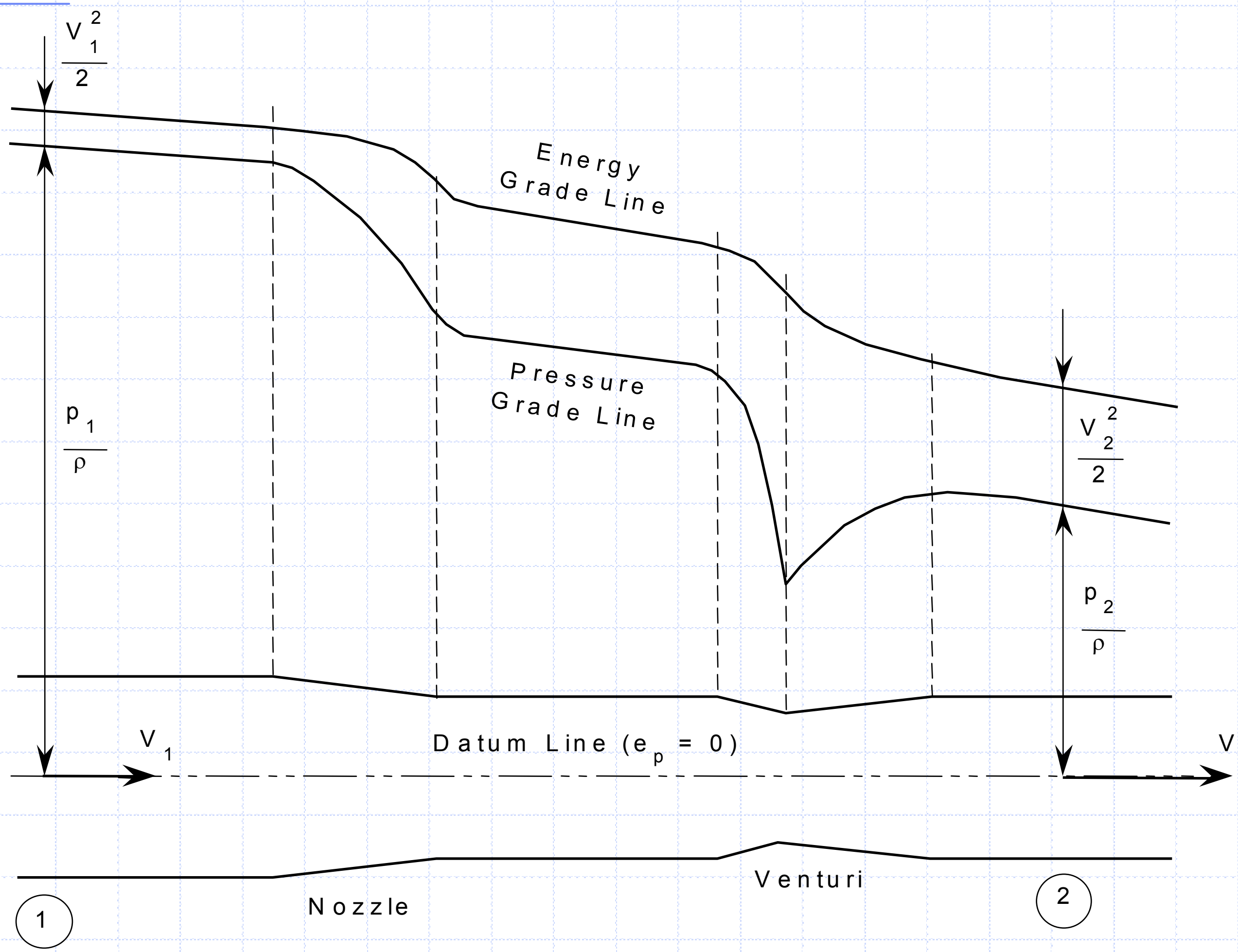
Changes at a reduction



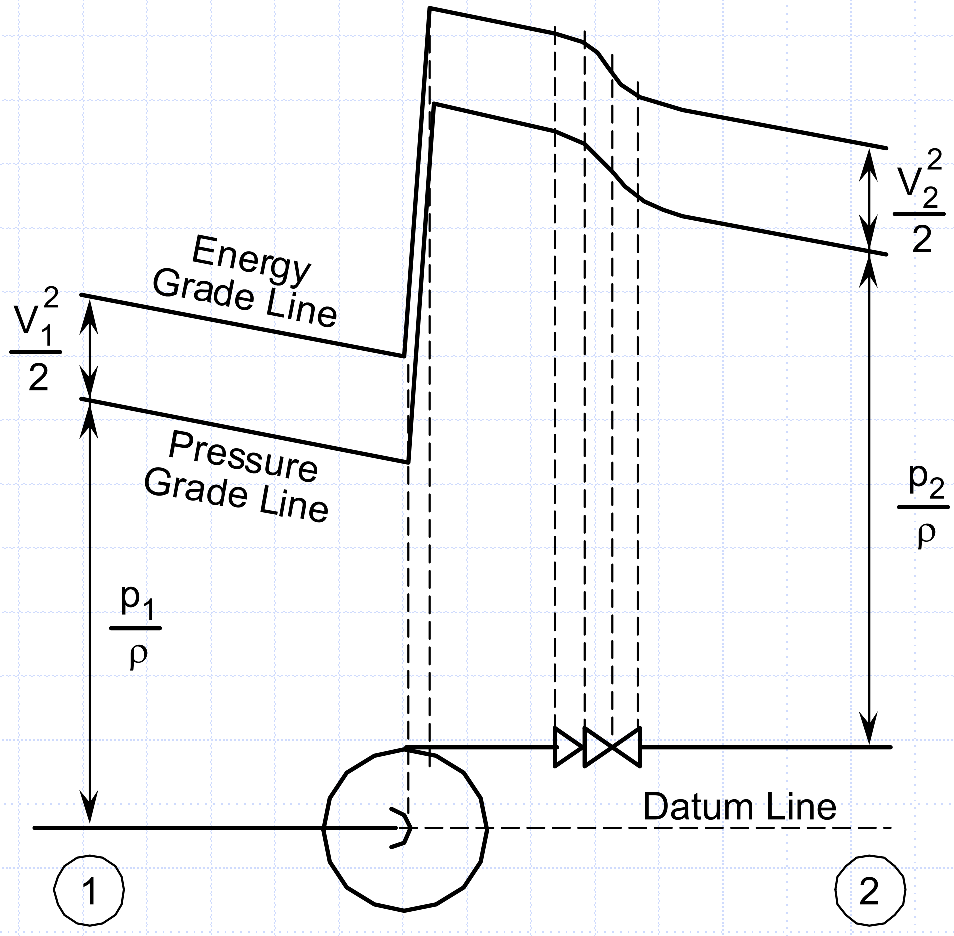
Venturi



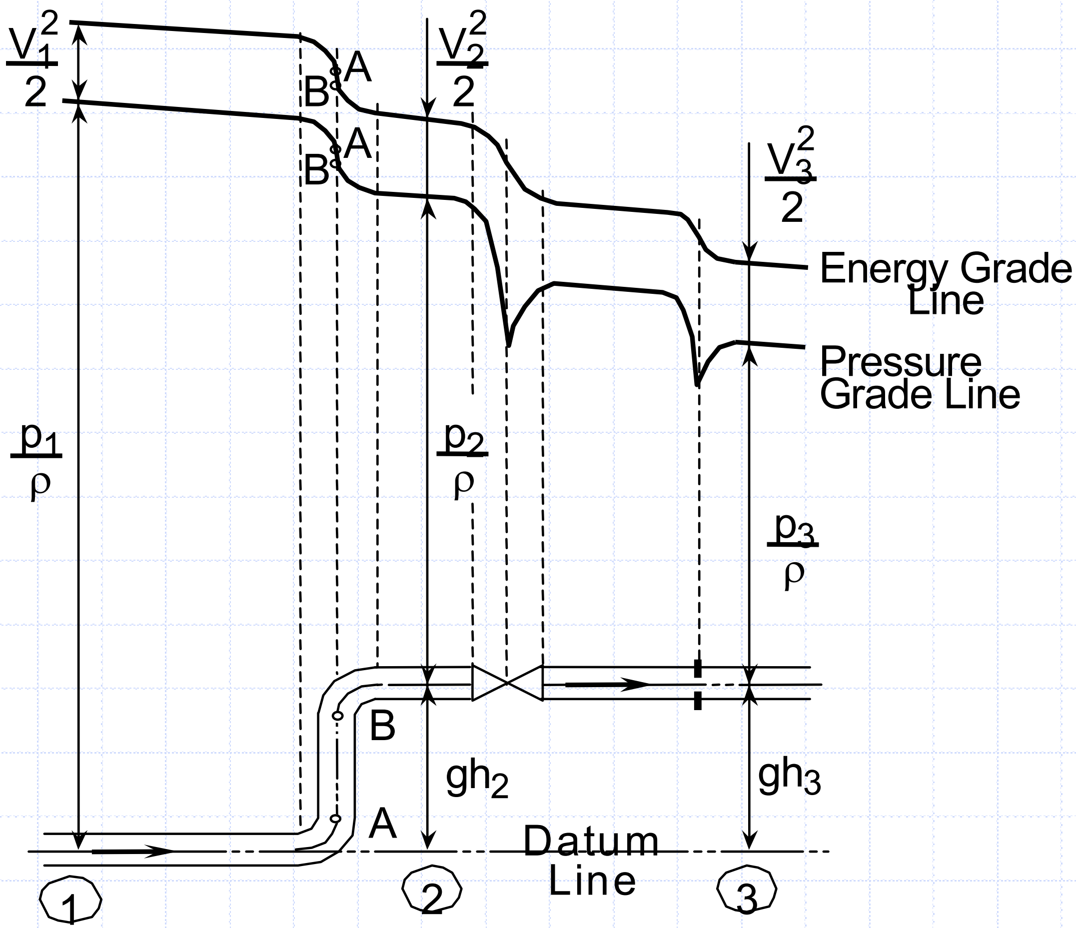
Reduction and Venturi



Pump and Discharge Valves

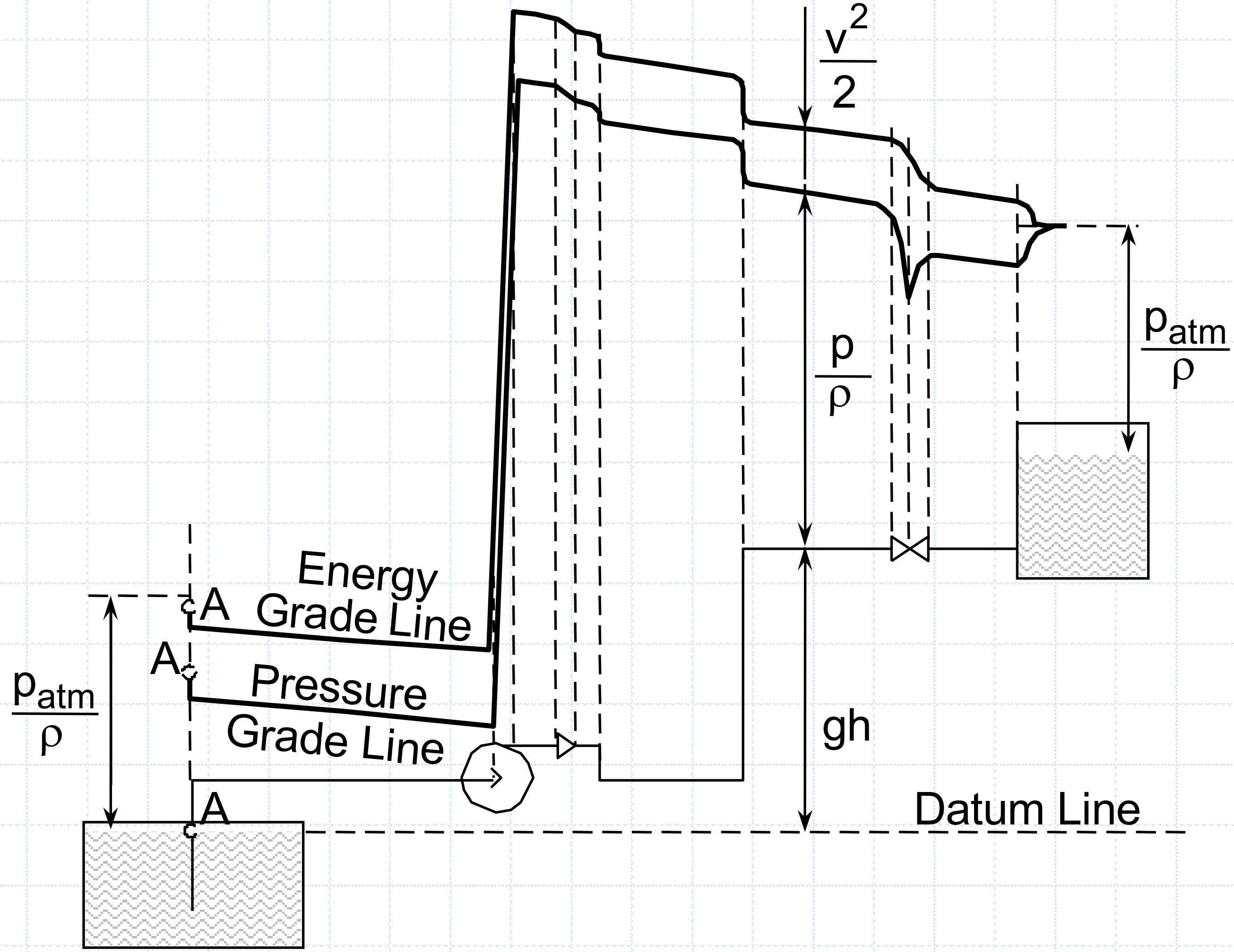


Elevation

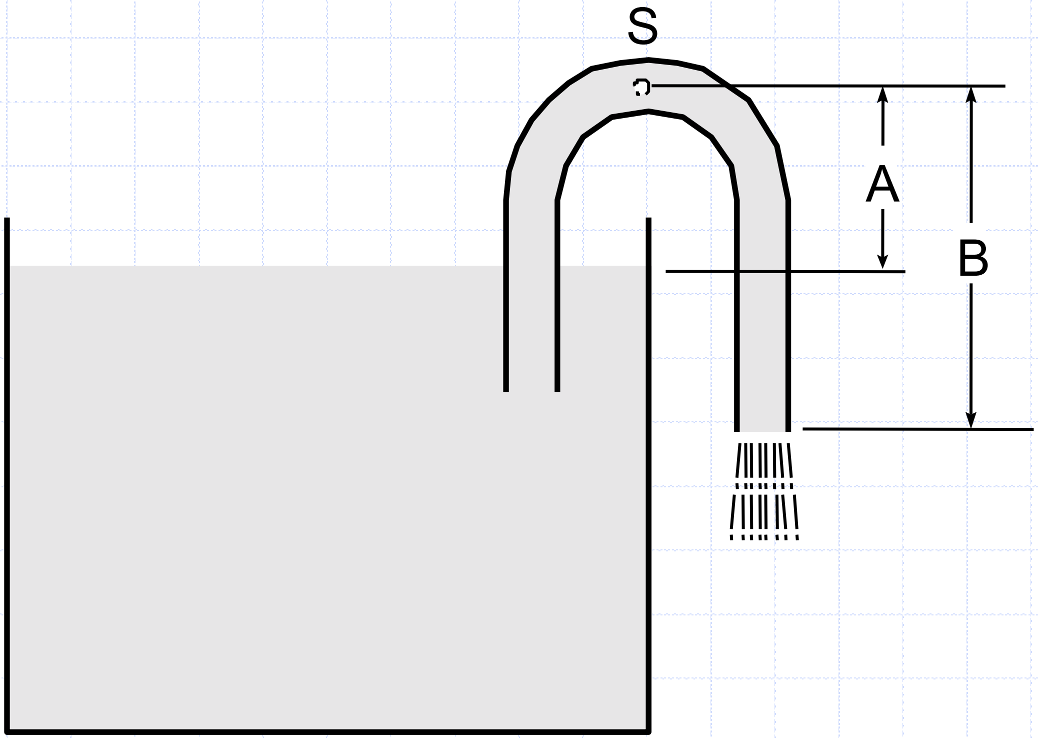


V1 2 / 2
V2 2 / 2
V3 2 / 2
A
B
A
B
Energy Grade Line
Pressure Grade Line
p1 / ρ
p2 / ρ
p3 / ρ
B
A
gh2
gh3
Datum Line
1
2
3

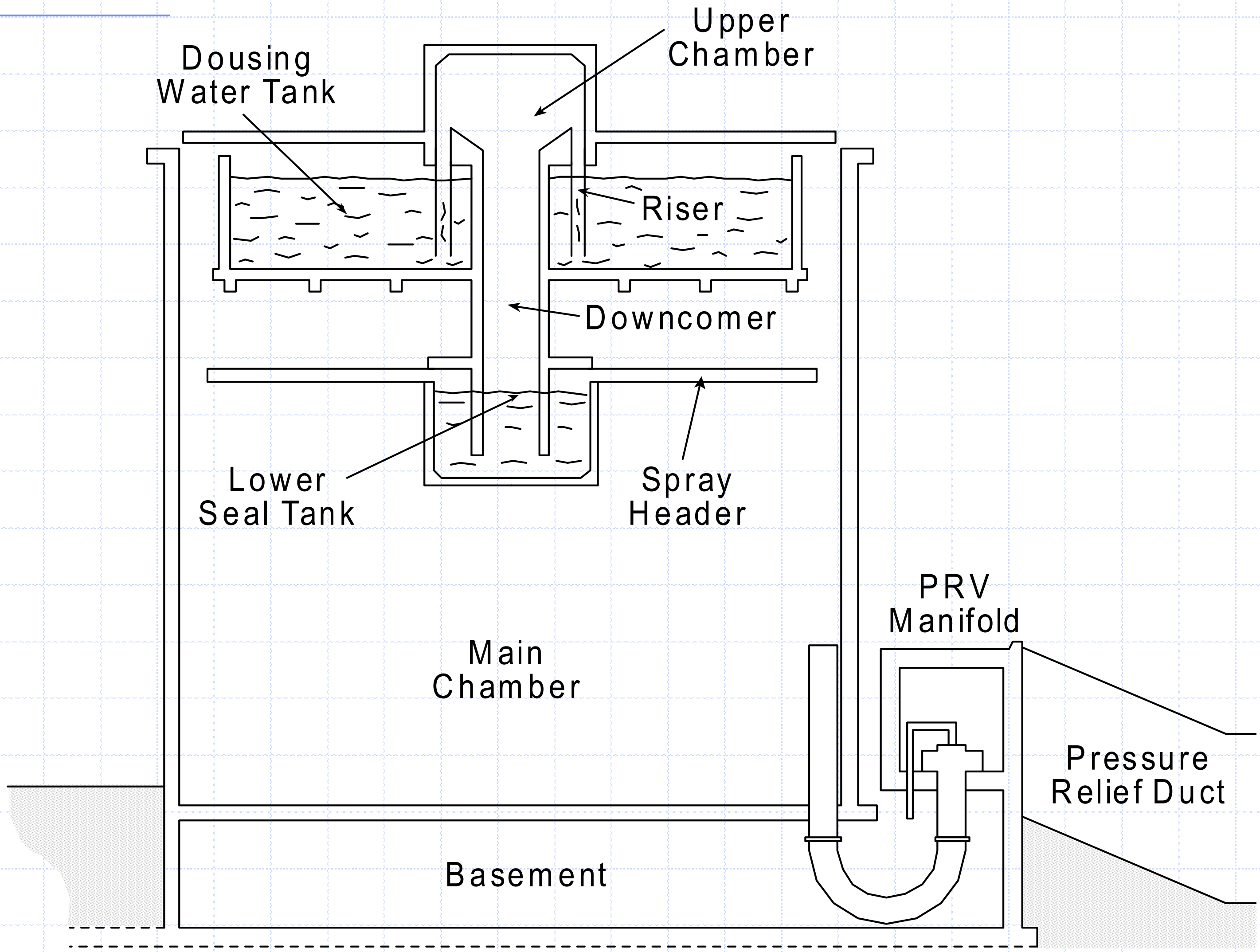
Simple System



Siphon

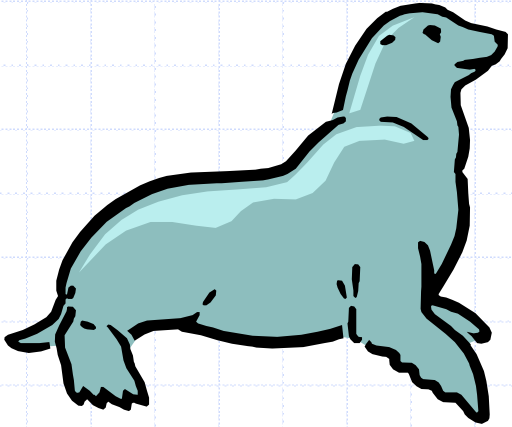


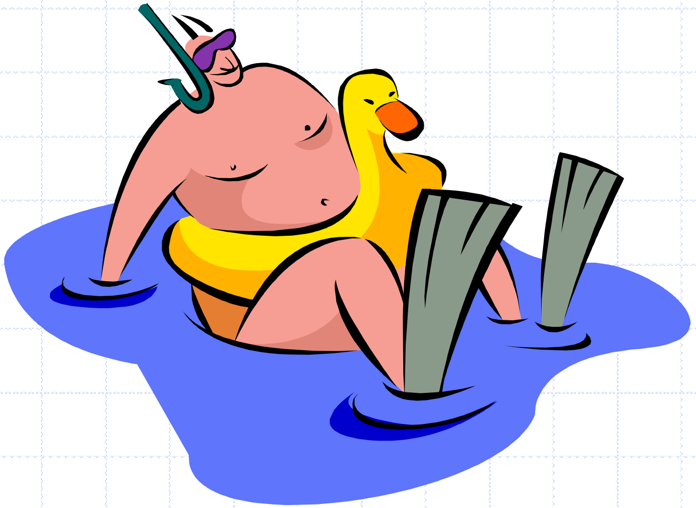
Dousing


Upper
Chamber
Dousing
Water Tank
Riser
Downcomer
Lower
Seal Tank
Spray
Header
PRV
Manifold
Main
Chamber
Pressure
Relief Duct
Basement

Other Topics

- Loop Seals
- Buoyancy





Two Phase Flow

Flow of liquid and gas mixture

How Do We Get 2 Phase Flow?

- Generate vapour
  - Add heat to liquid
  - Drop pressure
- Generate liquid
  - Remove heat from gas
  - Increase pressure
- Allow dissolved gas to come out of solution
- Entrain gas from a leak in

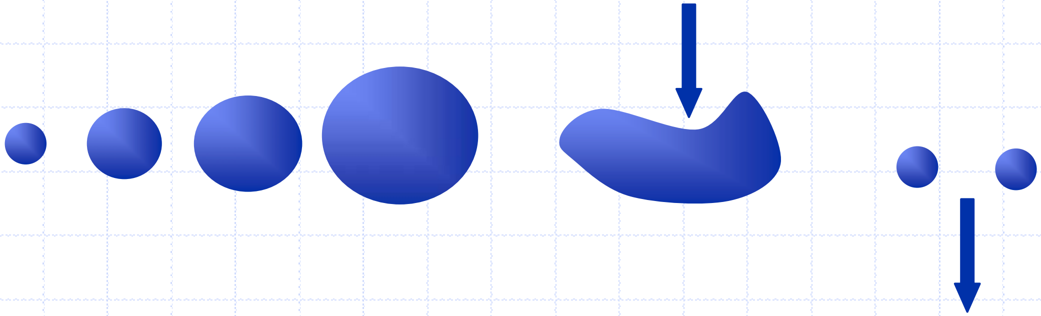
Forms of 2 phase Flow

- Little gas bubbles in a liquid
- Large gas bubbles in a liquid
- A vapour film between a hot surface and cooling liquid
- Small liquid drops in gas flow
- Large liquid slugs in gas flow
- Stratified Flow

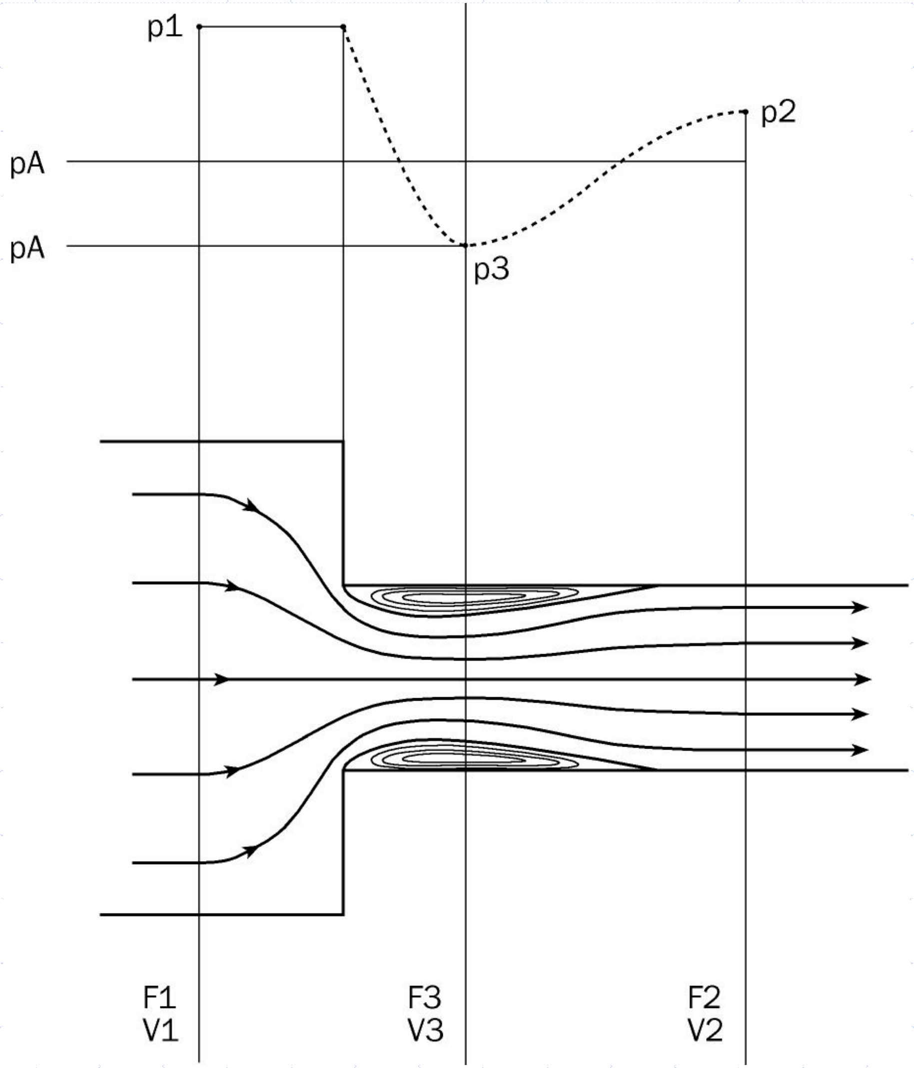
Cavitation

- Pressure in a system drops below the saturation pressure
- Vapour bubbles form
- Bubbles flow to a place when the pressure is higher
- Bubbles collapse
- High speed jets of water appear

Cavitation 2



Cavitation

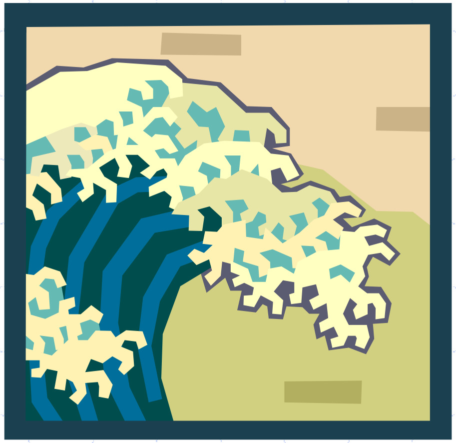


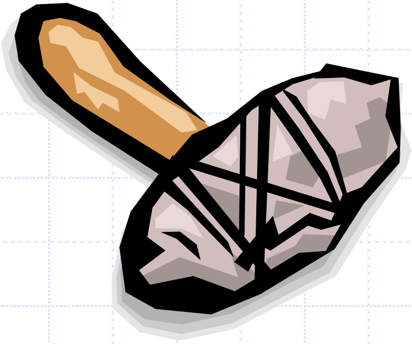
Potential Cavitation Sites

- Suction channels of pumps
- Centrifugal pump impellers
- Sharp elbows and tees
- Down stream of partly open valves
- Sudden changes of flow area

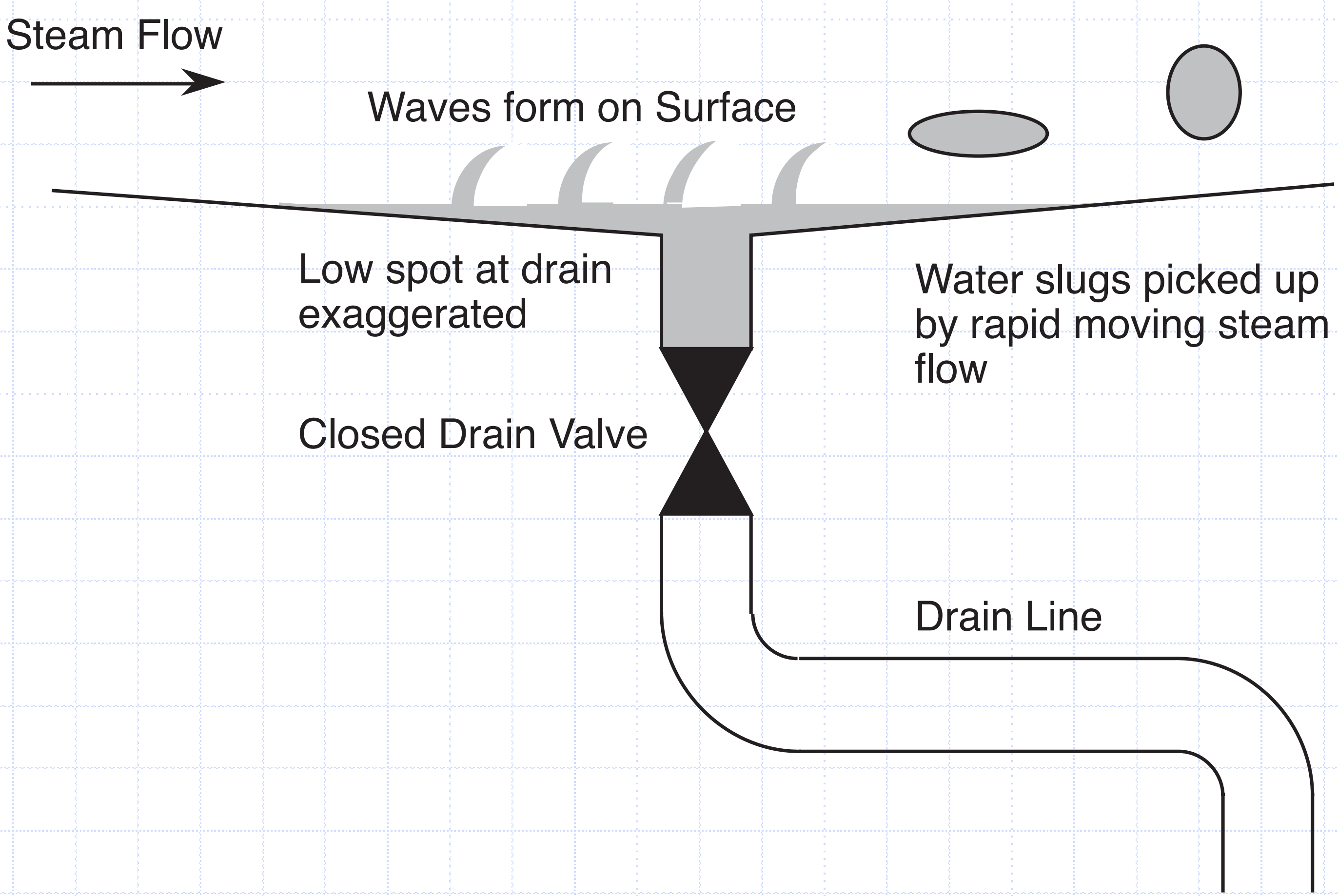
Water Hammer

- Quickly stopping water flowing in a pipe.
- Slugs of water thrown down a pipe by steam flow hitting something solid





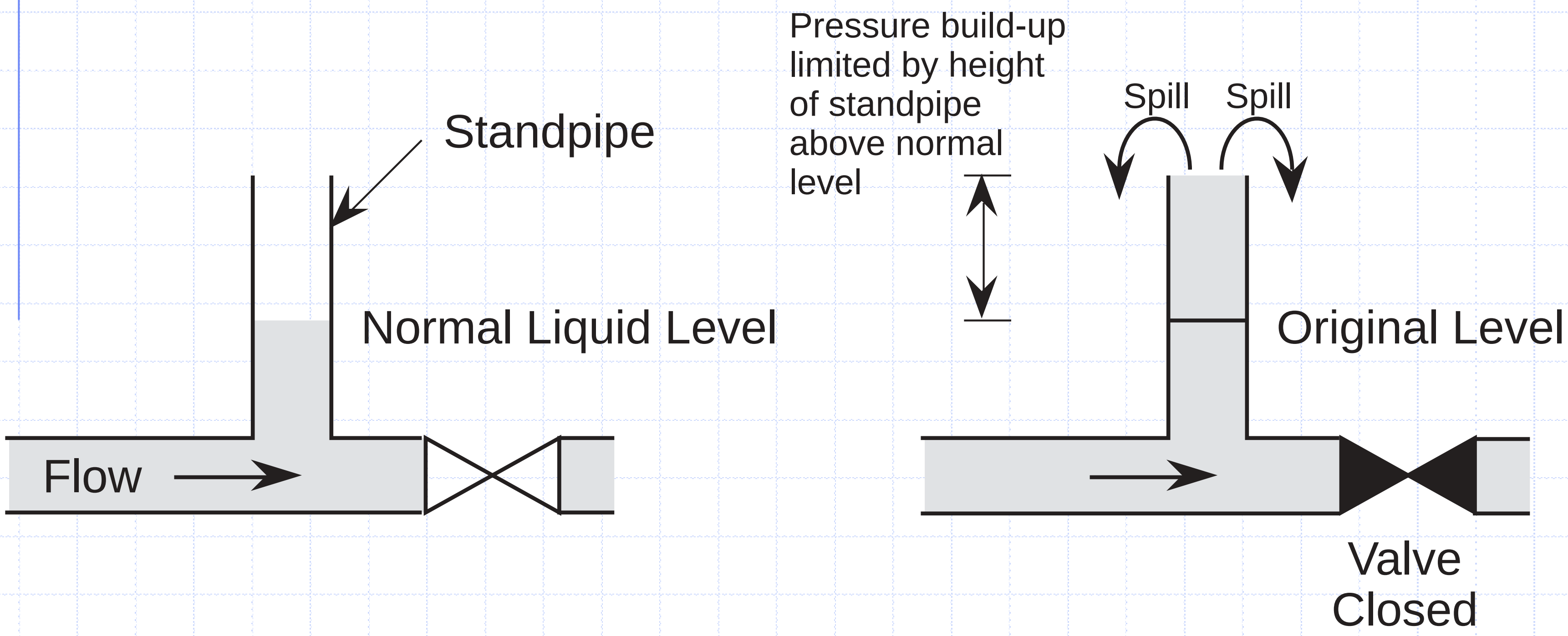
Water Hammer From Water Slugs



Minimizing Water Hammer

- Orifice Plate
- Water hammer arrestors
- Standpipes

Stand Pipe


Standpipe
Normal Liquid Level
Flow
Pressure build-up limited by height of standpipe above normal level
Spill
Spill
Original Level
Valve Closed

Steam Hammer

- Steam bubbles collapse and water at high speed rushes in and then hits something solid

Good Operational Practices

- Draining of a steam or gas system
- Venting and slow priming a liquid system
- Slow valve operation
- Starting centrifugal pumps with discharged valve closed
- Delays between pump starts or stops
- Apply cool water to Hx first

Solid Operation

- Liquid System completely full of water or other liquid
  - Non-compressible
- Susceptible to fast pressure transients
  - Water hammer
  - Velocity Changes

Flow Induced Vibrations

- High turbulence
- Cavitation
- Pressure pulsation
- After effects of steam or water hammer