6. FLUID DYNAMICS & FLOW MEASUREMENTS

DIFFERENT KIND OF FORCE ACTING ON FLUID PARTICLE

- Pressure force
- Gravity force
- Viscous force

> Remember: If all the three force are taken into account then equation obtained is known as Navier stokes equation.

EULER'S EQUATION

It represents momentum equation in a 2-D, ***inviscid*** steady flow.

$$\frac{dP}{\rho} + g.dz + v.dv = 0$$

- No viscous effects are considered.

BERNOULLI'S EQUATION

- **Assumptions in Bernoulli's equation:**
  - fluid is ideal
  - flow is steady
  - flow is continuous
  - fluid is incompressible
  - flow is non-viscous
  - flow is irrotational
  - applicable along a stream line

This equation is obtained by integrating Euler's equation.

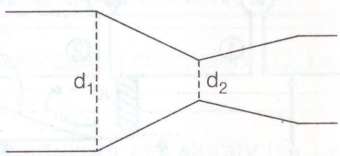
$$\frac{P}{w} + z + \frac{V^2}{2g} = C$$

Here, $\frac{P}{w} + z$ = Pressure head + gravitational head

= Piezometric head

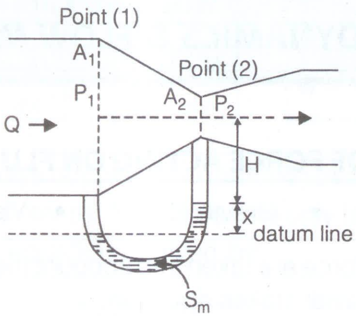
VENTURIMETER

- **General proportion of venturimeter**



$$d_2 = \left(\frac{1}{3} \text{ to } \frac{1}{2}\right) d_1$$

Angle of convergence = 20 – 30°
Angle of divergence = 6 – 7° and it should be not greater than 7° to avoid ***flow separation***.



- It is used for measuring discharge
- $$Q_{ideal} = \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

h = Piezometric head difference
= Pressure head difference

$$= \frac{P_1 - P_2}{\omega} = \frac{V_2^2 - V_1^2}{2g}$$

($\because$ gravitational head difference = 0)

$$h = x\left(\frac{S_m}{S} - 1\right)$$

Here, x = manometric deflection
s_m = Relative density of manometric fluid
s = Relative density of flowing fluid

- $Q_{actual} = C_{dv} \cdot Q_{ideal}$
  For venturimeter $C_{dv} = 0.94 - 0.98$
  Here, C_{dv} = coefficient of discharge

$$C_{dv} = \sqrt{\frac{h - h_l}{h}}$$

h_l = Head loss in convergent divergent section

ORIFICE METER

- It is cheaper arrangement but has more energy loss.

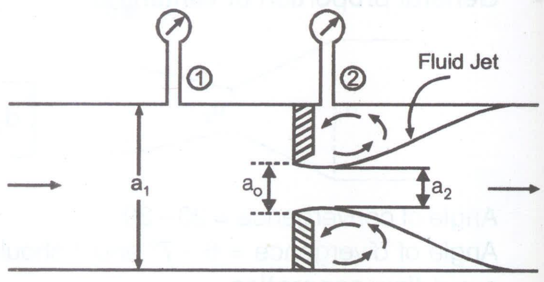
$$Q = \frac{C_d a_1 a_o}{\sqrt{a_1^2 - a_o^2}} \sqrt{2gh}$$

$$a_1 = \frac{\pi}{4} D^2$$

$$a_o = \frac{\pi}{4} d_o^2$$

d_o = dia of orifice

- It is used to measure discharge



ORIFICE METER

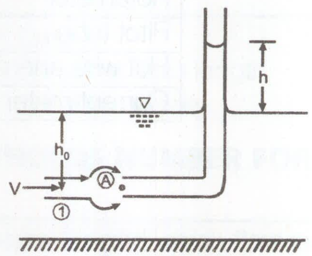
- $C_d = 0.64 - 0.76$
- For orifice

$$C_c = \frac{C_d}{C_v}$$

Here, C_c = Coefficient of contraction
C_d = Coefficient of discharge
C_v = Coefficient of velocity

PITOT TUBE

It is based on principle of conversion of kinetic head into pressure head. The point at which velocity reduces to zero is called stagnation point.



Simple Pitot Tube

$$V_{th} = \sqrt{2gh}$$

$$= \sqrt{2g\left(\frac{p_s - p_o}{\rho g}\right)}$$

$V_{ac} = C_V V_{th}$
C_V = Coefficient of velocity (0.98)
$p_s/\rho g$ = stagnation head &
$p_o/\rho g$ = static head.

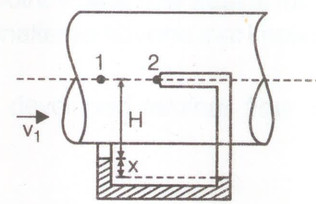
Velocity head is indicated by the difference in liquid level between the Pitot tube and the piezometer. The Pitot tube measures the total head and therefore known as total head tube.

- **Application of Pitot Tube in Pipes**

$$v_1 = \sqrt{2gh}$$

$$h = x\left(\frac{s_m}{s} - 1\right)$$

Here, s_m = Relative density of manometric fluid
s = Relative density of flowing fluid



HYDRAULIC COEFFICIENTS

- $$\text{Contraction coefficient } (C_c) = \frac{\text{Area of jet at vena contraction}}{\text{Area of orifice}}$$
- $$\text{Coefficient of velocity } (C_v) = \frac{\text{Actual velocity } (V_{ac})}{\text{Theoretical velocity } (V_{th})}$$
- $$\text{Coefficient of discharge } (C_d) = \frac{\text{Actual discharge } (Q_{ac})}{\text{Theoretical discharge } (Q_{th})}$$

DEVICES AND THEIR USES

Device	Measurement
Venturimeter	rate of flow (discharge)
Flow nozzle	rate of flow
Orifice meter	rate of flow
Bend meter	rate of flow
Rotameter	rate of flow
Pitot tube	velocity (Local vel.)
Hot wire anemometer	air & gas velocity
Current meter	velocity in open channels

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