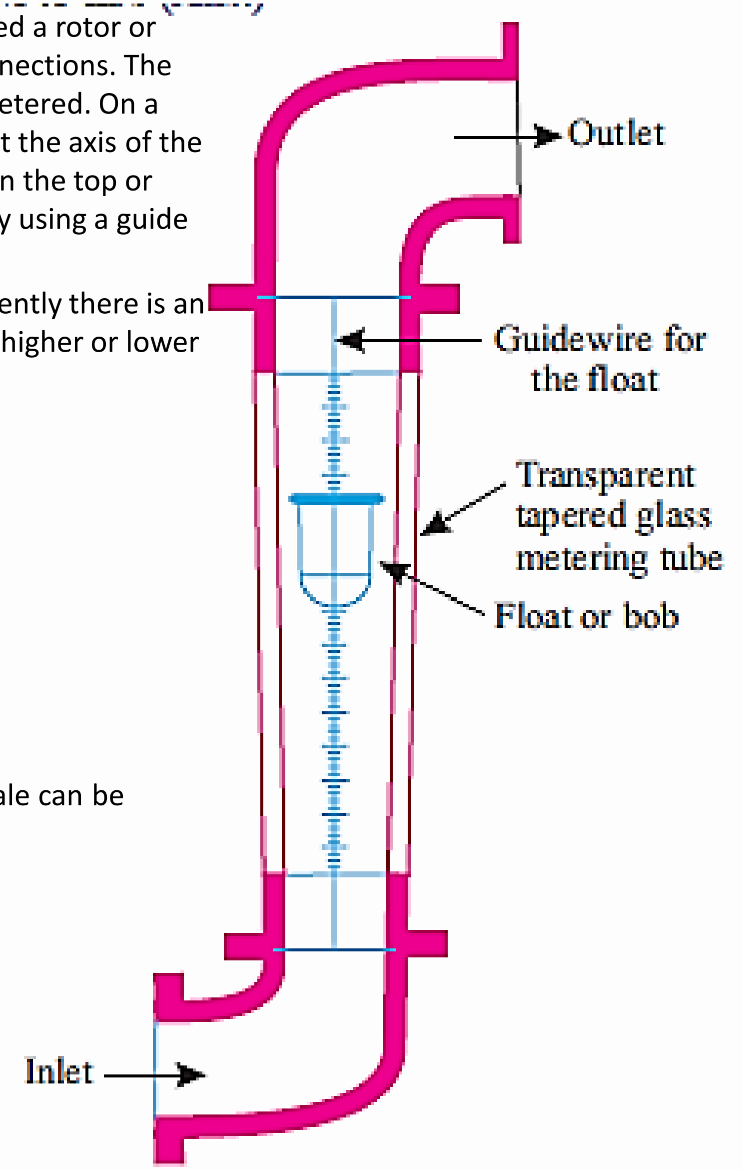
Rotameter and Elbow meter

- Construction: It consists of a tapered metering glass tube, inside of which is located a rotor or active element (float) of the meter. The tube is provided with inlet and outlet connections. The specific gravity of the float or bob material is higher than that of the fluid to be metered. On a part of the float spherical slots are cut which cause it (float) to rotate slowly about the axis of the tube and keep it centred. Owing to this spinning, accumulation of any sediment on the top or sides of float is checked. However, the stability of the bob may also be ensured by using a guide along which the float would slide.
- Working : When the rate of flow increases the float rises in the tube and consequently there is an increase in the annular area between the float and the tube. Thus, the float rides higher or lower depending on the rate of flow. The discharge through a rotameter is given by:
- Q = Cd Aann. [2gVfl (rfl – rf)/Afrf]1/2 ...
- where, Q = Volume flow rate,
- Cd = Co-efficient of discharge,
- Aann. = Annular area between float and tube,
- Vfl = Volume of float,
- ρfl = Density of float material,
- ρf = Density of fluid, and
- Af = Maximum cross-sectional area of the fluid.
- As the flow area Aann. is a function of height of float in the tube, the flow rate scale can be engraved on the tube corresponding to a particular float.
- Advantages :
- 1. Simpler in operation.
- 2. Handling and installation easy.
- 3. Wide variety of corrosive fluids can be handled.
- 4. Low cost, relatively. Limitations :
- 1. Mounted vertically, limited to small pipe sizes and capacities.
- 2. Less accurate, compared to venturimeter and orificemeter.



- Elbow meter
- When liquid flows around a pipe bend, there is an increase in pressure with radius, i.e. the pressure at the outer wall of the bend is more than that at the inner wall. This difference of pressure which exists between the outside and inside of the bend is used for the easurement of discharge in a pipeline. As shown in Fig. 6.37. the pipe bend is provided with two pressure tappings, one each at the inner and outer walls of the bend. These tappings are connected to the limbs of U-tube manometer.

As per literature, the following relation between velocity and pressure difference is available:

$$K\frac{V^2}{2g} = \left(\frac{p_0}{w}+z_0\right)-\left(\frac{p_i}{w}+z_i\right) \quad ...(6.11)$$

where, K = Constant (depends upon the shape and size of the bend), *ranges from* 1.3 *to* 3.2, and

V = Velocity of flow.

Suffices 0 and i represent the conditions at the outer and inner walls of the pipe bend.

or,
$$V = \frac{1}{\sqrt{K}}\sqrt{2g}\sqrt{\left(\frac{p_0}{w}+z_0\right)-\left(\frac{p_i}{w}+z_i\right)} \quad ...[6.11\ (a)]$$

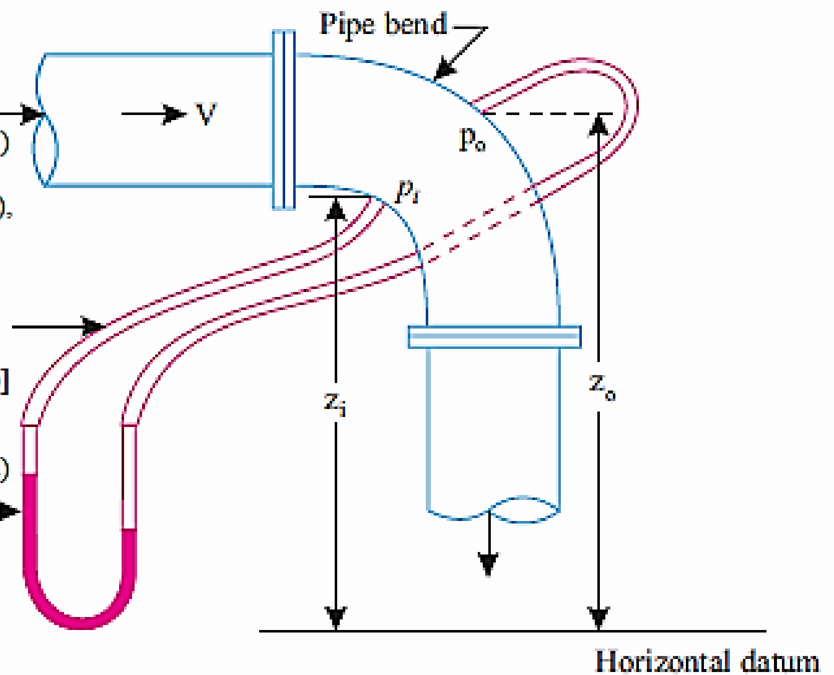
$\therefore$
$$\text{Discharge, } Q = AV = C_d A\sqrt{2g}\sqrt{\left(\frac{p_0}{w}+z_0\right)-\left(\frac{p_i}{w}+z_i\right)} \quad ...(6.12)$$

where, $C_d = \frac{1}{\sqrt{k}}$ = Co-efficent of discharge, and

A = Cross-sectional area of the pipe.

(C_d varies between 0.56 and 0.88)

The following empirical relation has been suggested: $C_d = \sqrt{\frac{R_b}{D}}$,



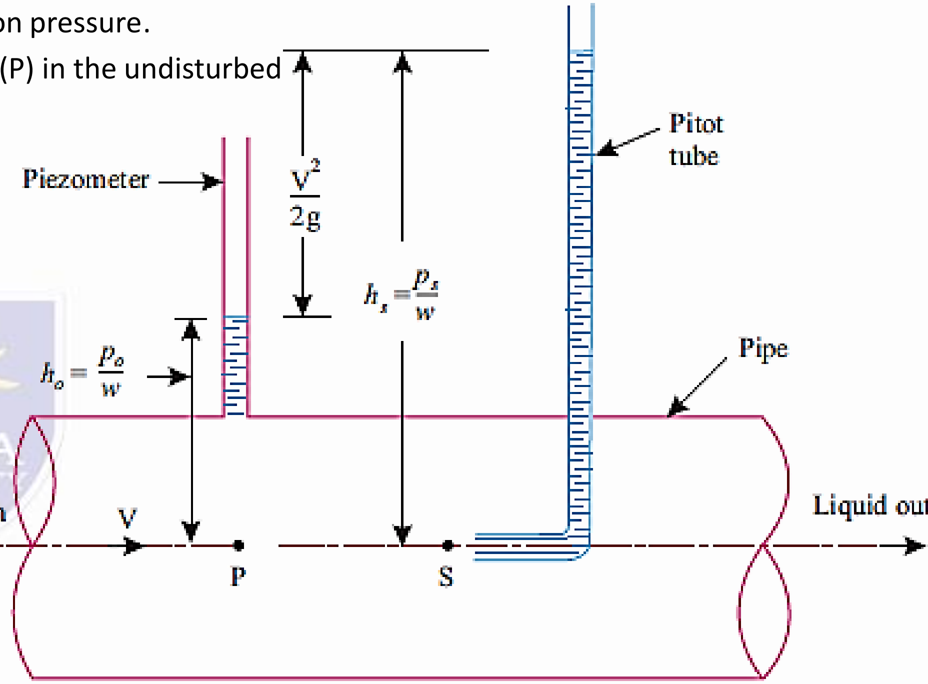
- where, Rb = Radius of pipe bend, and D = Diameter of the pipe.
- An elbowmeter can be conveniently used for the measurement of discharge in pipes which are fitted with elbows and bends.
- Its accuracy, with proper calibration, approaches that of a venturimeter or nozzle.

Fluid Properties

- Pitot Tube : Pitot tube is one of the most accurate devices for velocity measurement. It works on the principle that if the velocity of flow at a point becomes zero, the pressure there is increased due to conversion of kinetic energy into pressure. It consists of a glass tube in the form of a 90° bend of short length open at both its ends. It is placed in the flow with its bent leg directed upstream so that a stagnation point is created immediately in front of the opening (Fig. 6.38). The kinetic energy at this point gets converted into pressure energy causing the liquid to rise in the vertical limb, to a height equal to the stagnation pressure.
- Applying Bernoulli's equation between stagnation point (S) and point (P) in the undisturbed
- flow at the same horizontal plane, we get:

$$\frac{p_0}{w} + \frac{V^2}{2g} = \frac{p_s}{w} \quad \text{or} \quad h_0 + \frac{V^2}{2g} = h_s$$

$$V = \sqrt{2g\,(h_s - h_0)} \quad \text{or} \quad \sqrt{2g\,\Delta h}$$

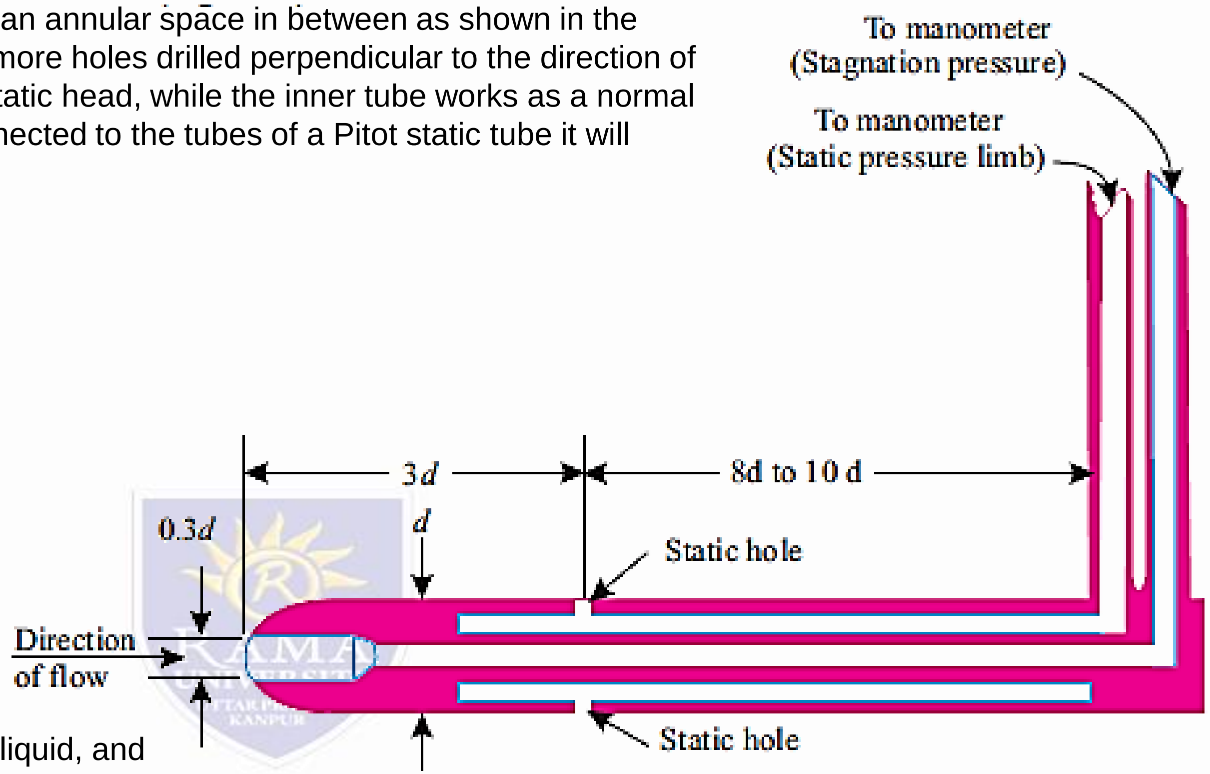


- where, p0 = Pressure at point 'P', i.e. static pressure,
- V = Velocity at point 'P', i.e. free flow velocity,
- ps = Stagnation pressure at point 'S', and
- Δh = Dynamic pressure
- = Difference between stagnation pressure head (hs) and static
- pressure head (h0).
- The height of liquid rise in the Pitot tube indicates the
- stagnation head. The static pressure head
- may be measured separately with a piezometer (Fig. 6.38). Both the static pressure as well as stagnation pressure can be measured in a device known as Pitot static tube.

It consists of two concentric Pitot tubes with an annular space in between as shown in the figure. The outer tube has additional two or more holes drilled perpendicular to the direction of flow and thus the liquid level in it gives the static head, while the inner tube works as a normal Pitot tube. If a differential manometer is connected to the tubes of a Pitot static tube it will measure the dynamic pressure head.

If y is the manometric difference, then

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



where, Sm = Specific gravity of manometric liquid, and
S = Specific gravity of the liquid flowing through the pipe.
When a Pitot tube is placed in the fluid-stream the flow along its outer surface gets accelerated and causes the static pressure to decrease. Also the stem, which is perpendicular to the flow direction,
tends to produce an excess pressure head. In order to take these effects into account eqn. (1) is
modified to give the actual velocities as:
V = C 2gΔh ...(2)
where, C = A connective coefficient which takes into account the effect of stem and bent leg.
The most commonly used form of Pitot static tube known as the Prandle-Pitot-tube is so designed that the effect of stem and bent leg cancel each other, i.e., C = 1.

- A submarine fitted with a Pitot tube moves horizontally in sea. Its axis is 12 m below the surface of water. The Pitot tube fixed in front of the submarine and along its axis is connected to the two limbs of a U-tube containing mercury, the reading of which is found to be
- 200 mm. Find the speed of the submarine. Take the specific gravity of sea water = 1.025 times fresh water.

Solution. Reading of the manometer, $y = 200 \text{ mm} = 0.2 \text{ m of mercury}$

Sp. gravity of mercury, $S_{hl} = 13.6$

Sp. gravity of sea water, $S_l = 1.025$

To find the head, (h), using the relation: $h = y\left(\frac{S_{hl}}{S_l} - 1\right)$, we have:

$$h = 0.2\left(\frac{13.6}{1.025} - 1\right) = 2.45$$

$\therefore$ Velocity of the submarine

$$V = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.45} = \mathbf{6.93 \text{ m/s or } 24.9 \text{ km/h (Ans.)}}$$

- Petroleum oil (sp. gr. = 0.9 and viscosity = 13 cP) flows isothermally through a horizontal 5 cm pipe. A Pitot tube is inserted at the centre of a pipe and its leads are filled with the same oil and attached to a U-tube containing water. The reading on the manometer is 10 cm. alculate the volumetric flow of oil in m3/s. The co-efficient of Pitot tube is 0.98. (Delhi

Solution. *Given*: Sp gr. of oil = 0.9; $\mu = 13 \text{ cP} = \frac{13}{100} \times 0.1 \text{ Ns/m}^2 = 0.013 \text{ Ns/m}^2$

$$y = 10 \text{ cm of Hg} = 0.1 \text{ m of Hg.}, D = 5 \text{ cm} = 0.05 \text{ m}$$

Co-efficient of Pitot tube, $C_v = 0.98$

Volumetric flow of oil:

$$\text{Differential head, } h = y\left(\frac{S_{Hg}}{S_{Oil}} - 1\right) = 0.1\left(\frac{13.6}{0.9} - 1\right) = 1.411$$

$$\therefore \text{ Actual velocity of flow, } V = C_v\sqrt{2gh} = 0.98\sqrt{2 \times 9.81 \times 1.411} = \mathbf{5.156 \text{ m/s}}$$

$$\text{Volumetric flow of oil} = A \times V = \frac{\pi}{4} \times 0.05^2 \times 5.156 = \mathbf{0.01 \text{ m}^3\text{/s (Ans.)}}$$

Fluid Properties

- It is required to place an orifice in the side of a tank at such an elevation that the jet will attain a maximum horizontal distance from the tank at the level of its base. What is the proper distance from the orifice to the free surface when the depth of liquid in the tank is maintained at 1.2 m?
- Solution. Depth of liquid in the tank = 1.2 m
- x = 2gh × t ...(i)

and, $y = -\frac{1}{2} gt^2$ ...(ii)

Eliminating t, we get:

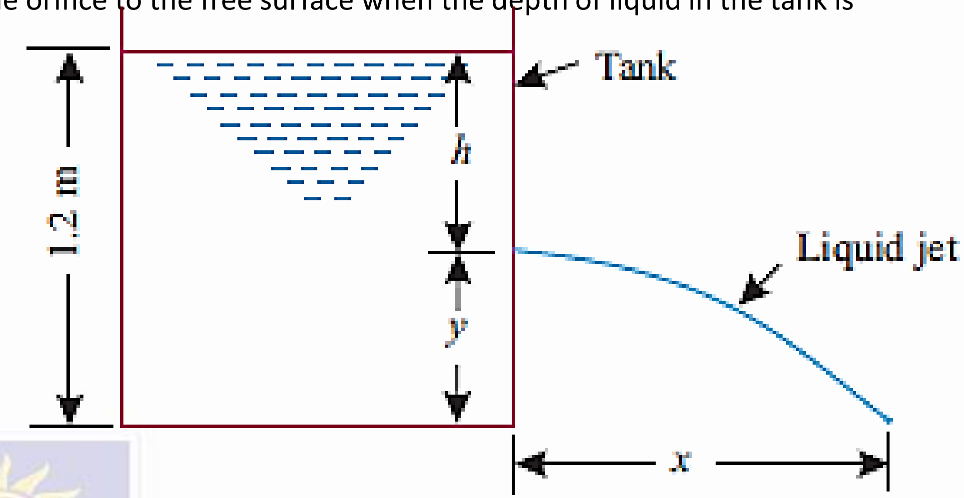
$$y = -\frac{1}{2} g \times \left(\frac{x}{\sqrt{2gh}}\right)^2$$

$$= -\frac{1}{2} \times g \times \frac{x^2}{2gh}$$

or, $y = -\frac{x^2}{4h}$

Also, $1.2 = h + y$ or $y = 1.2 - h$

$\therefore$ $(1.2 - h) = -\frac{x^2}{4h}$



Also, $1.2 = h + y$ or $y = 1.2 - h$

$\therefore$ $(1.2 - h) = -\frac{x^2}{4h}$

or, $x^2 = -4h\,(1.2 - h) = -4.8\,h + 4h^2$

For horizontal distance x to be maximum $\frac{dx}{dh} = 0$

$\therefore$ $2x\frac{dx}{dh} = -4.8 + 8h = 0$ or $h = 0.6$ m

Thus, the orifice should be located at a distance of **0.6 m below the free surface. (Ans.)**