counter weight is placed at the other end of the lever which balances the brake when unloaded. Two stops S, S are provided to limit the motion of the lever.

When the brake is to be put in operation, the long end of the lever is loaded with suitable weights W and the nuts are tightened until the engine shaft runs at a constant speed and the lever is in horizontal position. Under these conditions, the moment due to the weight W must balance the moment of the frictional resistance between the blocks and the pulley.

Frictional resistance between the blocks and the pulley (Anticlockwise) = T

Balancing moment provided by the externally hanging weight W about pulley centre (Clockwise) = W.L = Mg.L

In equilibrium, frictional resistance (anticlockwise) = Balancing moment (clockwise), or

$$T = Mg.L$$

Power of the machine under test = $T.\omega = Mg.L(2\pi N/60) = MNk$ where, k = a constant for a particular brake.

Advantages:

1. Simple construction
2. Less cost
3. Suitable for measuring small torque

Disadvantages:

1. Not suitable for large torque/power.
2. Cooling system required because large heat is generated.
3. Friction is not uniform; dynamometer is subjected to severe oscillations.

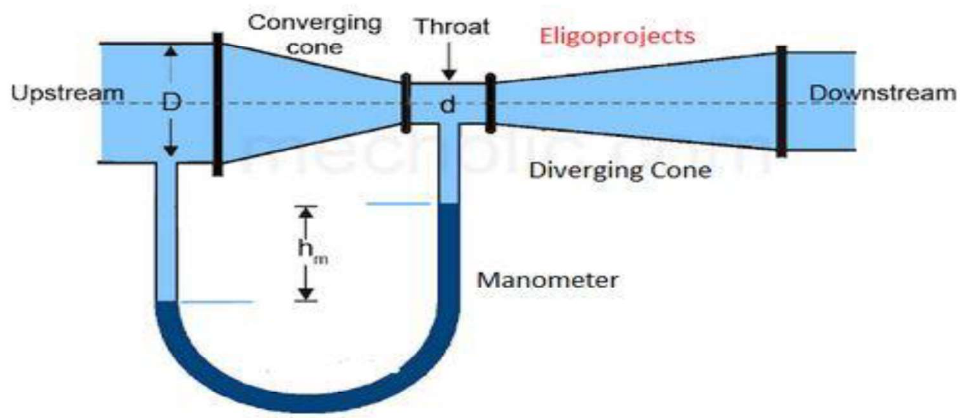
Flow Measurement

There are various types of liquid flow measurement devices, as listed below:

- Venturi meter,
- Orifice meter,
- Rotameter,
- Pitot Tube, etc.

Venturimeter

A venturi meter is a device that is used to measure the speed flow of incompressible fluid through a pipe. The device converts pressure energy into kinetic energy and measures the rate of flow of liquid through pipes. It has a tube of broad diameter and a small constriction towards the middle. Venturi meter works on the principle of the Bernoulli equation such that the velocity of the fluid increases as the pressure decreases. The theory states that when the cross-sectional area of the flow decreases, a pressure difference is created between the different regions of the flow. his helps measure the difference under pressure which further helps to measure the discharge inflow.



Components of a Venturi Meter

A Venturi meter is made up of the following components:

- **Converging Part**: The area of the cone decreases when water flows through it. Therefore, there is an increase in the speed of flowing water and a decrease in the pressure.
- **Throat Diameter**: The area remains constant in a throat diameter when water flows through it therefore the speed and pressure also remain constant.
- **Diverging Part**: The area increases when water flows through the cone and therefore the speed decreases and the pressure decreases.

Working of a Venturi Meter

The venturi meter works on the principle of Bernoulli's equation which states that the pressure decreases as the velocity increases.

- The cross section of the throat is less than that of the inlet pipe.
- As the cross section from the inlet pipe to the throat of venturimeter decreases, the fluid velocity increases, and therefore the pressure decreases.
- Due to a decrease in the pressure, a pressure difference is created between the throat of the venturi meter and the inlet pipe.
- This is further measured by applying a differential manometer between the throat section and the inlet section. It can also be measured by using two gauges on the inlet section and throat.
- The pressure difference through the pipe is then calculated after obtaining the rate of flow.

Expression for the rate of flow through a Venturimeter

Let d1, p1, v1 & a1, are the diameter at the inlet, pressure at the inlet, velocity at the inlet and area at the cross section 1.

And d2, p2, v2 and a2 are the corresponding values at section 2.

Applying bernoulli's equation at sections 1 and 2

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

As the pipe is horizontal, so z1 = z2

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g}$$

$$\frac{p_1 - p_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g} \qquad \ldots\ldots\ldots..(1)$$

Therefore

(P1 – P2)/ρg is the difference of pressure heads at section 1 and 2 and it is equal to h. so

$$h = \frac{p_1 - p_2}{\rho g}$$

Substituting this value of h in equation (1), we get

$$h = \frac{v_2^2 - v_1^2}{2g} \qquad \ldots\ldots\ldots\ldots\ldots..(2)$$

Now applying continuity equation at section 1 and 2

$$a_1 v_1 = a_2 v_2$$

$$v_1 = \frac{a_2 v_2}{a_1}$$

Substituting this value of v1 in equation (2) and solving, we get

$$v_2 = \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

Discharge

$$Q = a_2 v_2$$

Substituting value of v2 in above equation

$$Q = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

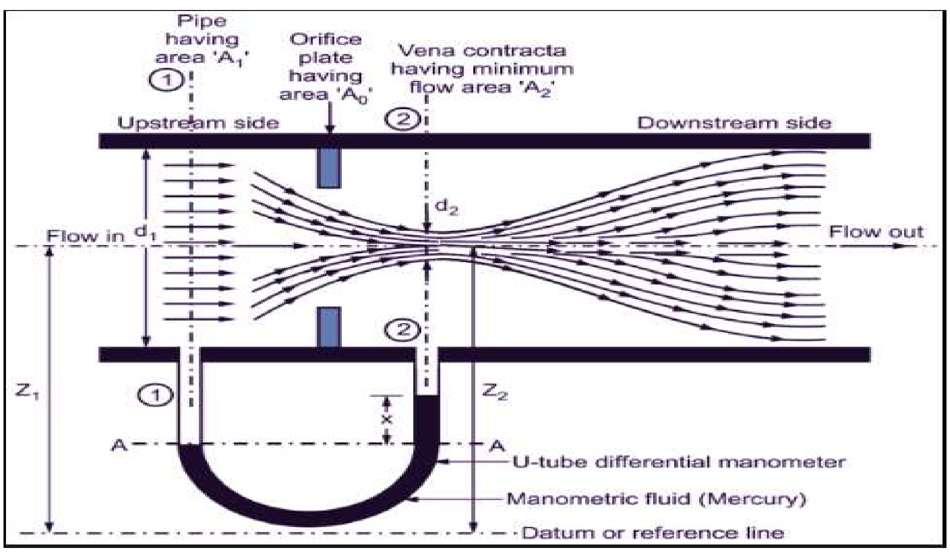
Q is the theoretical discharge under ideal conditions. Actual discharge will be less than the theoretical discharge. The actual discharge is given by the formula

$$Q_{act} = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

Where Cd is the coefficient of venturimeter and its value is less than 1.

Orificemeter

Orifice : It is an abrupt or sudden hole or opening in a flowing fluid passage (pipeline).

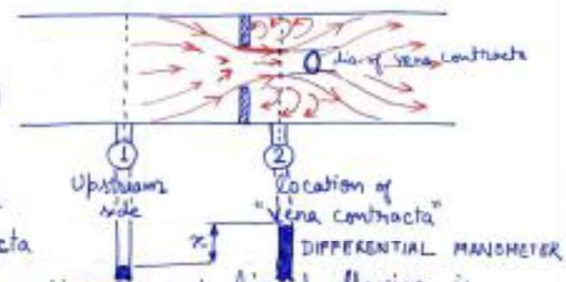


Vena Contracta: When a fluid passes through an orifice in a pipeline, the diameter of this passing stream keeps on decreasing up to a little distance. *Vena contracta* is the point in the fluid stream where the diameter of the stream is the least, and the fluid velocity is at its maximum.

Working: By the application of Bernoulli's equation between the location of the orifice and vena contracta, we can find the rate of discharge theoretically. An additional factor for *vena contracta* is also considered. Also, there are just converging and diverging streams, in place of converging and diverging nozzles. Rest all principle of working is same as Venturimeter.

Orifice Meter

It is a device to measure the rate of flow of liquid through a pipeline. An orifice is basically a hole through which liquid is passed. The dia. of orifice is between 0.4 to 0.8 times the dia. of pipeline.



Vena contracta appears a few distance away from the orifice. (Vena Contracta is a location where the downstream diameter of liquid flowing is minimum. This diameter is less than that of the orifice diameter.

A differential manometer is connected between the upstream side and vena contracta the get the differential pressure head.

Let, d_1 = diameter at section ① ; d_2 at section ②

p_1 = pressure at section ① ; p_2 at section ②

v_1 = velocity at section ① ; v_2 at section ②

A_1 = Area at section ① ; A_2 at section ②

Applying Bernoulli's eq^n between ① and ② —

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

elevation of both ~~th~~ the sides is same, i.e. $z_1 = z_2$

$$\Rightarrow \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g}$$

$$\Rightarrow \frac{p_1 - p_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g}$$

Let $\frac{p_1 - p_2}{\rho g}$ = difference in pressure head = h (in meters)

$$\Rightarrow h = \frac{v_2^2 - v_1^2}{2g}$$

$$\Rightarrow v_2^2 = v_1^2 + 2gh \quad \text{—— (I)}$$

from continuity equation,

$$A_1 v_1 = A_2 v_2 \Rightarrow v_1 = \frac{A_2 v_2}{A_1} \quad \text{—— (II)}$$

Let A_0 = Area of the orifice,

$$\boxed{\text{Coefficient of contraction } C_c = \frac{A_2}{A_0} = \frac{(\text{Area at vena Contracta})}{(\text{Area at orifice})}}$$

$$\Rightarrow \boxed{A_2 = A_0 \cdot C_c} \quad \text{—— (X)}$$

$$\Rightarrow v_1 = \frac{A_0 \cdot C_c}{A_1} \cdot v_2 \quad (\text{from (II)})$$

putting this value in eq^n (I) →

$$v_2^2 = \left(\frac{A_0 C_c}{A_1}\right)^2 \cdot v_2^2 + 2gh$$

$$\Rightarrow v_2 = \frac{\sqrt{2gh}}{\sqrt{\left(1 - \frac{A_0^2}{A_1^2} \cdot C_c^2\right)}}$$

$$\Rightarrow \text{Discharge } Q = A_2 \cdot v_2 = A_0 \cdot C_c \cdot v_2 \quad (\text{from (X)})$$

$$\boxed{Q = \frac{A_0 \cdot C_c \cdot \sqrt{2gh}}{\sqrt{\left(1 - \frac{A_0^2}{A_1^2} \cdot C_c^2\right)}}} \quad \text{—— (III)}$$

Now, C_d = coefficient of discharge of orificemeter is defined as —

$$\boxed{C_d = \frac{C_c \cdot \sqrt{1 - (A_0/A_1)^2}}{\sqrt{1 - (A_2/A_1)^2}}} = \frac{C_c \cdot \sqrt{1 - (A_0/A_1)^2}}{\sqrt{1 - \left(\frac{A_0 C_c}{A_1}\right)^2}}$$

$$\Rightarrow C_c = C_d \cdot \frac{\sqrt{1 - (A_0 C_c / A_1)^2}}{\sqrt{(1 - A_0/A_1)^2}}$$

putting the value of C_c in eq^n (III), we get —

$$\boxed{Q = C_d \cdot \frac{A_0 A_1 \sqrt{2gh}}{\sqrt{A_1^2 - A_0^2}}}$$

(The desired Relation)

Note: The coeff. of discharge of orificemeter (C_d) is much smaller than that of a Venturimeter.