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INTRODUCTION

A opening made in base or side of vessel, tank or reservoir, which has a closed perimeter (having any shape) through which liquid discharged out is known as Orifice.

→ The top edge of orifice is always below the free surface. If free surface is below the top edge of orifice, the orifice becomes weir.

i.e. essential condition for an opening to function as orifice is that the water or any other liquid stored in tank must be above the topmost point of opening.

→ The orifice is used to measure the discharge of liquid.

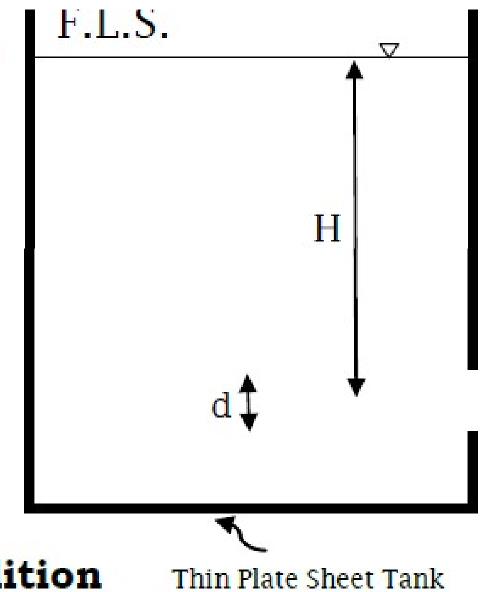
→ The discharge through an orifice depends to upstream edge has beem formed, besides depending on shape & size of orifice.

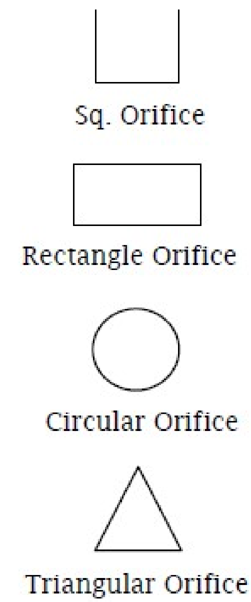
→ An orifice having a sharp upstream edge is known as sharp edged orifice.

Classification of Orifice

(1) According to shape of Orifice :-

(a) Circular orifice
(b) Rectangle Orifice
(c) Square Orifice
(d) Triangle Orifice





(2) According to Size of Orifice :-

(a) Small Orifice, If $H \geq 5d$
(b) Large Orifice, If $H < 5d$

Where, H = Head above the centre of orifice
d = Diameter or Size of Orifice

(3) According to Downstream Condition OR **Nature of Discharge :-**

(a) Free Orifice
(b) Submerged Orifice → (i) Partially Submerged (ii) Fully Submerged

- **Free Discharge Orifice** :-

  When discharge of orifice is free in air, it is called free discharge orifice. (fig a)

- **Submerged Orifice :-**

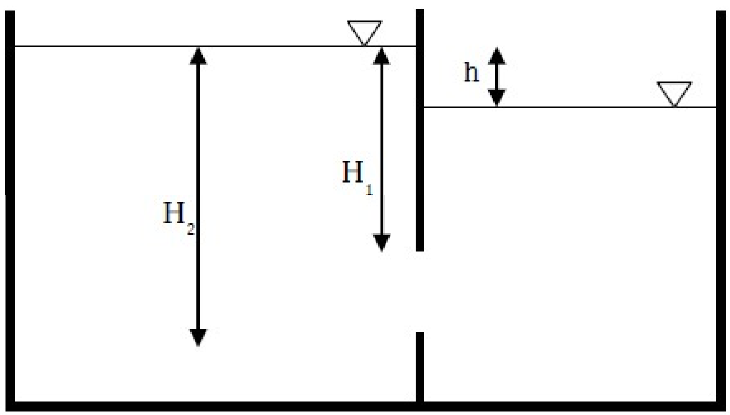
  When orifice discharges the liquid into some other vessel containing the liquid is called Submerged Orifice or Drowned Orifice.

  - **Fully Submerged Orifice** :-

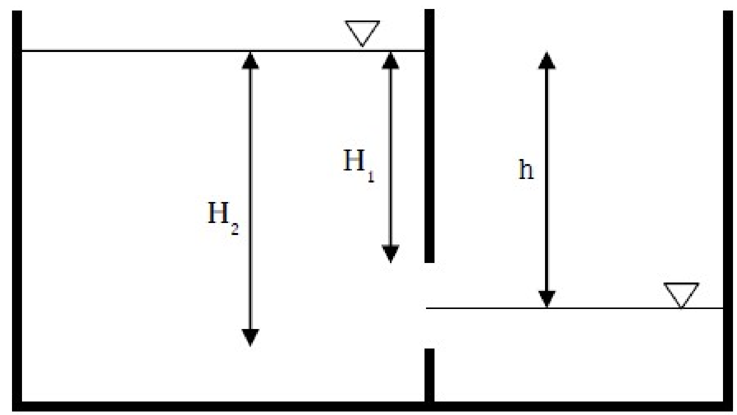
    If whole of downstream (outlet) side of an orifice is under liquid, it is known as Fully Submerged Orifice.

  - **Partially Submerged Orifice :-**

    If whole of downstream side of an orifice is partly under liquid, it is known as Partially Submerged Orifice.



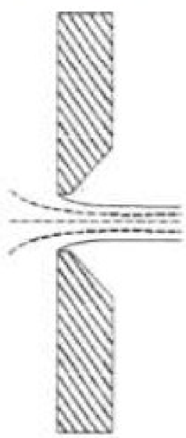
Fully Submerged Orifice



Partially Submerged Orifice

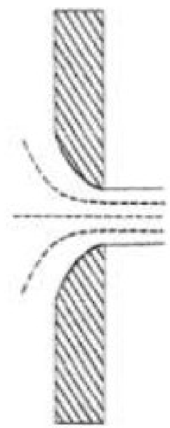
(4) **According to upstream edge condition** OR **Shape of Edge :-**

(a) Sharp Edged Orifice



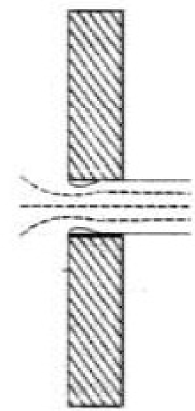
If inner (upstream) edge of rifice is sharp

(b) Bell Mouth Orifice



Its upstream edge is rounded. Due to rounded shape friction is reduced.

(c) Square (Flat) Orifice



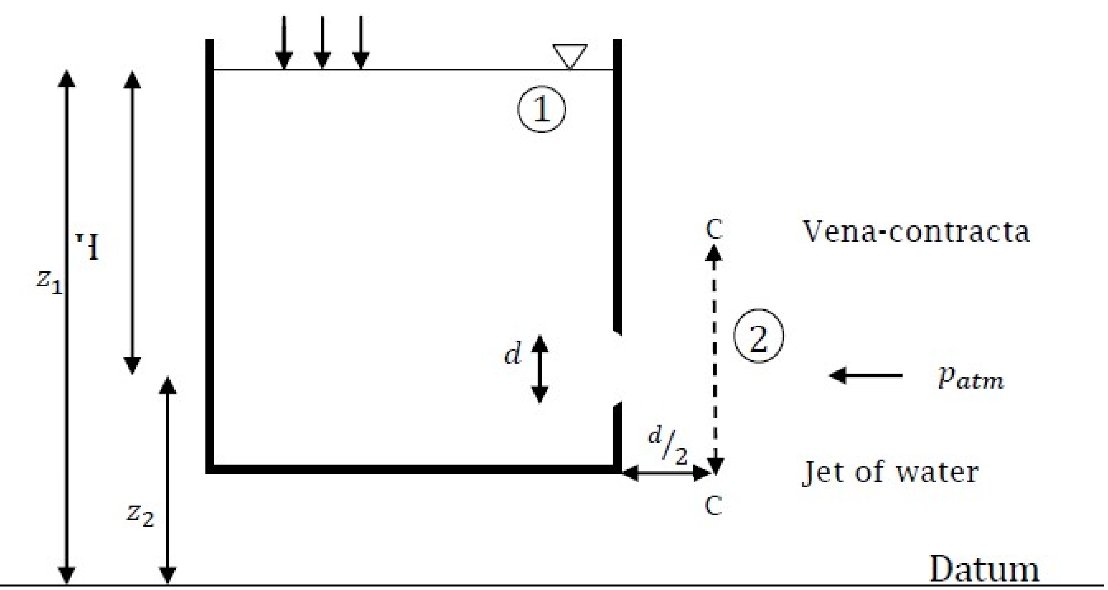
Its upstream edge is square.

Hydraulic Terms Related With Orifice

- **Jet of Water :-**

  The continuous stream of liquid that comes out or flows out of an orifice is known as jet of water.

- **Vena-Contracta :-**



- Consider a tank fitted with an orifice having sharp edged as shown in fig.

The liquid particles in order to flow out through orifice move towards the orifice from all direction. A few of particles first move downward, then take a turn to enter into orifice & then finally flow through it.

It may be noted that liquid particles lose some energy, while taking turn to enter into orifice. It has been observed that the jet after leaving the orifice, gets contracted. The maximum contraction of jet takes place at section C-C at distance $\frac{d}{2}$, where jet is more or less horizontal.

The jet of water after leaving the orifice is contracted. The point where maximum contraction (minimum c/s area) takes place & stream lines becomes first parallel is called as Vena-Contracta.

➢ Torricelli’e Theorem :-

When orifice discharging in atmosphere, the outlet & upper surface of liquid in vessel is exposed to atmosphere.

Consider point 1 & 2 as shown in fig 1.

→ Applying Bernoulli’s equation,

$$\therefore \frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$$

But,

$$p_1 = p_2 = p_{atm} \qquad \therefore z_1 = z_2 + H$$

$$\therefore \frac{V_1^2}{2g} + z_2 + H = \frac{V_2^2}{2g} + z_2$$

$$\therefore \frac{V_1^2}{2g} + H = \frac{V_2^2}{2g}$$

If reservoir is assumed to be sufficiently large & point 1 is considered to be sufficiently far from the orifice then velocity of approach V_1 becomes very small as compared to V_2. Hence neglect V_1

$$\therefore \frac{V_2^2}{2g} = H$$

$$\therefore \boldsymbol{V_2 = \sqrt{2gH}}$$ **>> Torricelli's Equation**

→ If orifice is mall in comparison with head H, the velocity of jet V_2 may be considered to be constant & if V_1 is taken into consideration then.

$$\therefore H = \frac{V_2^2 - V_1^2}{2g}$$

→ Applying Continuity equation

$$\therefore A_1 V_1 = A_c V_2$$

Where, A_1 = c/s area of Reservoir

A_c = c/s area of jet at vena contracta.

$$\therefore \frac{V_1}{V_2} = \frac{A_c}{A_1}$$

$$\therefore H = \frac{V_2^2}{2g}\left(1 - \frac{V_1^2}{V_2^2}\right)$$

$$\therefore H = \frac{V_2^2}{2g}\left(1 - \frac{A_c^2}{A_1^2}\right)$$

$$\therefore V_2 = \sqrt{\frac{2gH}{1 - {A_c^2}/{A_1^2}}}$$

→ The pressure on portion of jet between orifice & vena-contracta is above atmosphere.

As area of c/s of jet is minimum at vena-contracta, the velocity head of particles in portion of jet between the orifice & vena-contracta is lesser than that at vena-contracta, but the elevation head remains same. From Bernoulli's Theorem it, therefore follows that the pressure on this portion of jet is above atmosphere.

➢ Hydraulic Coefficients :-

(1) Coefficient of Contraction (C_c) :-

→ Coefficient of Contraction $(C_c) = \dfrac{\text{c/s area ofjet at vena-contarcta}}{\text{c/s area of jet}} = a_c/a_j$

→ The value of C_c is depends on

- Shape & size of orifice
- Head of Orifice
- Viscosity of liquid i.e. Reynolds Number (R_n)

→ C_c decreases with increase in diameter & head.

→ It varies between **0.613 to 0.690** but average value is taken as 0.64

(2) Coefficient of Velocity(C_v) :-

→ Coefficient of Velocity $(C_v) = \frac{\text{Actual velocity of jet at vena-contracta}}{\text{Theoretical Velocity}} = \frac{V}{V_{theo}} = \frac{V}{\sqrt{2gH}}$

→ C_v increases with increase in diameter or head.

→ Its value varies between **0.95 to 0.99** but average value is taken as 0.98

(3) Coefficient of Discharge (C_d) :-

→ Coefficient of Discharge $(C_d) = \frac{\text{Actual discharge}}{\text{Theo. discharge}} = \frac{Q_{act}}{Q_{theo}} = \frac{\text{Act. Area}}{\text{Theo Area}} \times \frac{\text{Act.Velo}}{\text{Theo.Velo}}$

$$C_d = C_c \times C_V$$

→ Its value varies from **0.62 to 0.65**

(4) Coefficient of Resistance (C_r) :-

→ Coefficient of Resistance $(C_r) = \frac{\text{Loss of kinetic Energy}}{\text{Actual kinetic Energy}} = \frac{\text{Loss of Head}}{\text{Actual Head}}$

→ Loss of kinetic Energy is equal to difference between Theo. kinetic energy & actual kinetic energy.

→ Theo. kinetic energy per unit weight of liquid $= \frac{V_{th}^2}{2g} = \frac{(\sqrt{2gH})^2}{2g} = H$

→ Act. kinetic energy per unit weight of liquid $= \frac{V_{act}^2}{2g} = \frac{(C_v \times \sqrt{2gH})^2}{2g} = \boldsymbol{C_v^2 \times H}$

$$C_r = \frac{\text{Loss of kinetic Energy}}{\text{Actual kinetic Energy}} = \frac{\text{Theo. K.E. - Act. K.E.}}{\text{Act K.E.}}$$

$$= \frac{H - C_v^2 \times H}{C_v^2 \times H}$$

$$\therefore \boldsymbol{C_r = \frac{1 - C_v^2}{C_v^2}}$$

→ **If velocity of approach (V_1) is neglected then, From fig 1.**

Applying modified Bernoulli's equation,

$$\therefore \frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2 + \text{Friction loss of head}$$

But,

$$\frac{p_1}{w} = \frac{p_2}{w} = p_{atm}$$

Here, $V_1 << V_2$. Hence $V_1 = 0$ & $z_1 = z_2 + H$

$$\therefore\ z_2 + H = \frac{V_2^2}{2g} + z_2 + h_f$$

$$\therefore\ \frac{V_2^2}{2g} = H - h_f$$

$$\therefore\ h_f = H - \frac{V_2^2}{2g}$$

Also,

$$C_r = \frac{\text{Loss of Head}}{\text{Actual Head}} = \frac{h_f}{H}$$

$$= \frac{H - \frac{V_2^2}{2g}}{H}$$

$$= 1 - \frac{V_2^2}{2gH}$$

$$= 1 - \frac{V_{act}^2}{V_t^2}$$

$$\boldsymbol{C_r = 1 - C_v^2}$$

Experimental Determination Of Hydraulic Coefficient For Orifice

(1) Determination of Coefficient of velocity (C_v):-

(i) Trajectory Method
(ii) Momentum Method
(iii) Pitot Tube Method

➢ **Trajectory Method :-**

In this method a tank containing water at constant level, maintained by constant supply. An orifice is provided in wall of tank.

Let, P = Particle of water in jet

H = Constant water Head

x = Horizontal distance between C - C & P

y = Vertical distance between C - C & P

V = Act Velocity of jet

t = Time taken by particle to reach from C - C to P in seconds

→ Horizontal distance (x) = Vt

$$\therefore t = \frac{x}{V} \text{ -------- } (1)$$

→ Vertical Distance (y) = $\frac{1}{2}\, g\, t^2$

→ From eqⁿ (1)

$$\therefore\ y = \frac{1}{2}\, g \left(\frac{x}{V}\right)^2$$

$$\therefore\ y = \frac{gx^2}{2V^2}$$

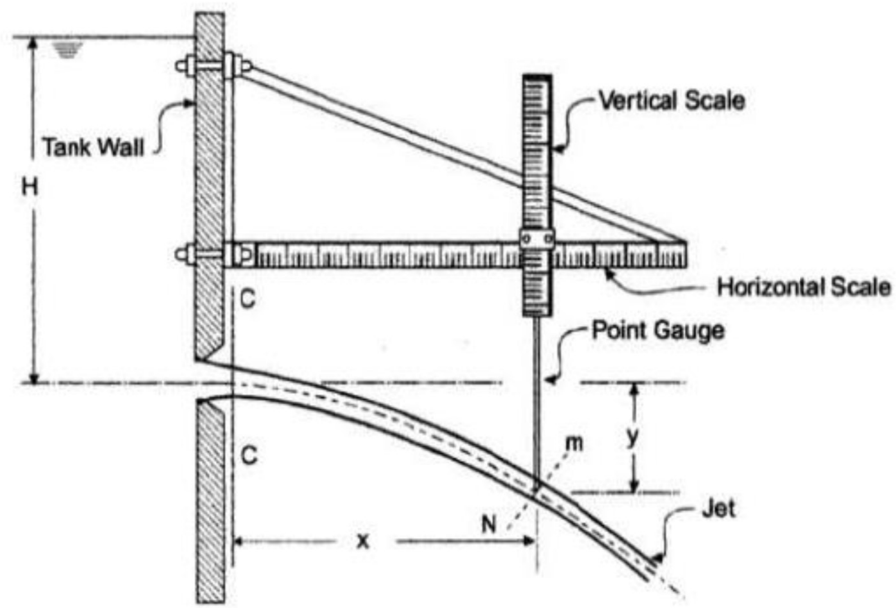
$$\therefore\ V^2 = \frac{gx^2}{2y}$$

$$\therefore\ V_{act} = \sqrt{\frac{gx^2}{2y}}$$

→ Now Theo. velocity (V_{th}) = $\sqrt{2gH}$

→ Now,

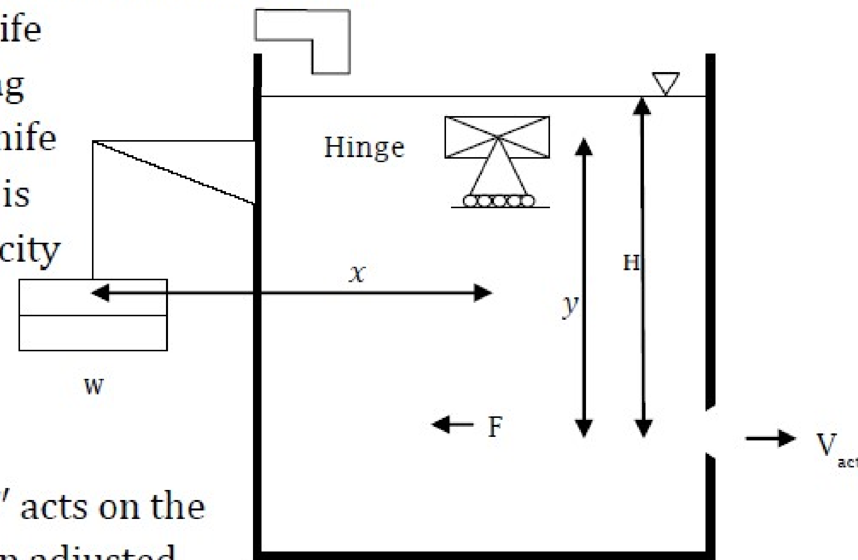
$$\therefore\ C_v = \frac{V_{act}}{V_{theo}} = \frac{\sqrt{\frac{gx^2}{2y}}}{\sqrt{2gH}} = \sqrt{\frac{x^2}{4yH}}$$



- **Momentum Method :-**

This method works on Newton's Third Law of motion i.e. action & reaction are equal in magnitude & opposite in direction.

A tank is suspended on knife edge as shown in fig. First by closing the orifice, the tank is levered on knife edge. By opening the orifice, water is allowed to leave the tank with velocity V_{act} & Force.



Which is given by,

$$\boldsymbol{F} = \frac{w}{g} Q\, V_{act} = \boldsymbol{\rho Q\, V_{act}}$$

An equal & opposite force F' acts on the opposite wall of tank, which is again adjusted by adding known weight ' W ' at a lever erm of x.

→ Taking Moment about knife edge,

$$\therefore\; F \times y = W \times x$$

$$\therefore\; \rho Q\, V_{act} \times y = Wx$$

$$\therefore \quad V_{act} = \frac{Wx}{\rho Q y}$$

→ Now Theo. velocity (V_{th}) = $\sqrt{2gH}$

→ Now,

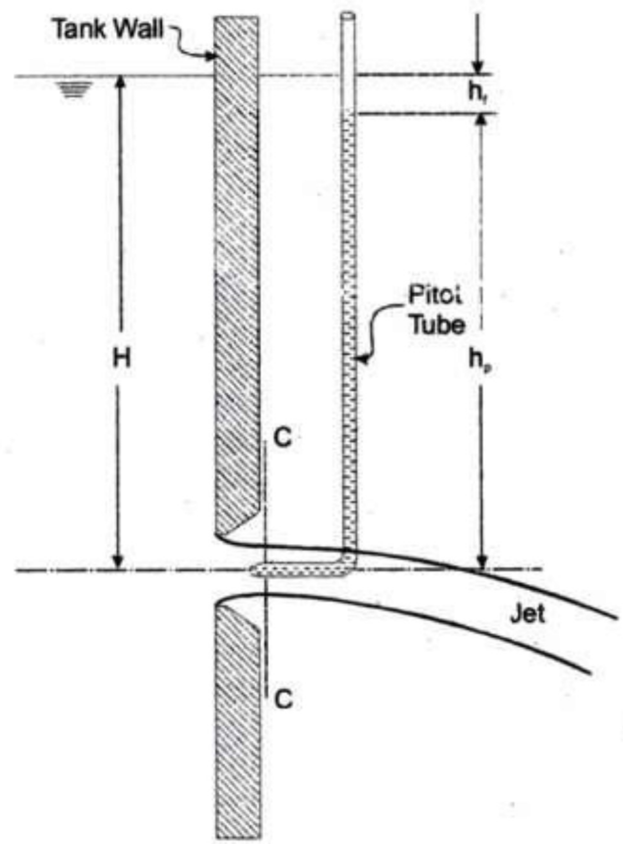
$$\therefore \quad C_v = \frac{V_{act}}{V_{theo}} = \frac{\frac{Wx}{\rho Q y}}{\sqrt{2gH}}$$

$$= \frac{W\,x}{\rho Q y \sqrt{2gH}}$$

→ This method is useful for small tank only.

- **Pitot Tube Method :-**

In this method pitot tube is held at vena-contracta, to measure the velocity head for actual velocity V_{act}.



$\therefore$ Act. Velocity $(V_{act}) = \sqrt{2gH_{act}}$

$\rightarrow$ Theo. velocity $(V_{th}) = \sqrt{2gH}$

$\rightarrow$ Now,

$$\therefore C_v = \frac{V_{act}}{V_{theo}} = \frac{\sqrt{2gH_{act}}}{\sqrt{2gH}}$$

$$= \sqrt{\frac{H_{act}}{H}}$$

(2) Determination of Coefficient of discharge (Cd):-

(i) Volumetric Method

(ii) Gravimetric Method

- **Volumetric Method :-**

In this method, the experimental set up consists of a tank containing the orifice & measuring tank. Water flowing out from the orifice is collected in measuring tank.

In orifice tank, the head over centre of orifice is kept constant by adjusting the inflow, such that inflow & outflow are equal. When the water level in orifice tank stabilises, the head over the orifice is measured by piezometer, the zero of which coincides with the centre line of orifice. Till the time the head over the orifice does not become constant, the discharge from the orifice is collected in idling tank. The water from the idling tank goes directly to waste.

When the head over the orifice becomes constant, the flow is diverted from idling tank to measuring tank. A stopwatch is used to measure the time for which the flow is collected in measuring tank. At the instant when the flow is diverted to measuring tank, the stopwatch is started. Flow is collected for a definite amount of time in measuring tank. The volume of water collected in tank in the time interval is easily calculated.

Let, a = Area of Orifice
A = Area of Measuring Tank
IR = Initial Reading
FR = Final Reading

→ Volume of water collected in tank

$$= \text{c/s area of measuring tank} \times \text{Depth of water collected}$$

$$\therefore \overline{V} = A \times (FR - IR)$$

$$= lb\,(FR - IR)$$

$$\therefore \overline{V} = lbH$$

→ Actual Discharge $(\boldsymbol{Q_{act}}) = \dfrac{\text{Volume collectd in tank}}{\text{Time taken for this volume}} = \dfrac{\overline{\boldsymbol{V}}}{\boldsymbol{t}} = \dfrac{\boldsymbol{lbH}}{\boldsymbol{t}}$

→ Theoretical Discharge $(Q_{th}) = a\sqrt{2gH} = a \times V_{th}$

→ Now,

$$\boldsymbol{C_d} = \frac{Q_{act}}{Q_{theo}} = \frac{lbH}{t\,a\sqrt{2gH}}$$

$$= \frac{\boldsymbol{lb\sqrt{H}}}{\boldsymbol{at\sqrt{2g}}}$$

→ It is universally used method.

→ The only precaution to be taken is to measure the c/s area of measuring tank precisely.

→ The accuracy of this method depends upon accurate determination of c/s area

➤ **Gravimetric Method :-**

This method consists of measurement of weight of water collected instead of the volume. It is easier to measure the weight directly.

W_1 = Weight of tank after collecting water

w = Sliding weight

W_o = Initial weight of tank when tank is empty

W= Net Weight

→ Taking Moment at Fulcrum :-

$\therefore W_1 \times x = w \times y$

OR

Net Weight of Water collected (kg/sec)

= (Final weight of water collected for 30 OR 60 sec) – (Initial weight of empty tank)

→ Actual Discharge (Q_{act}) $= \frac{Weight\ of\ water\ (W)}{\rho_{water} \times g}$

→ Theoretical Discharge (Q_{th}) $= a\sqrt{2gH} = a \times V_{th}$

→ Now,

$$C_d = \frac{Q_{act}}{Q_{theo}}$$

→ The gravimetric method of discharge is not normally preferred because to determine the original position of the beam, by sliding weight, is difficult. A slight change in position of sliding weight will disturb the position of beam. Secondly, with use the knife edge may get worn out. This results are still unreliable.

(3) Determination of Coefficient of Contraction (C_c):-

(i) Using Micrometer Contraction Gauge (Direct Method)

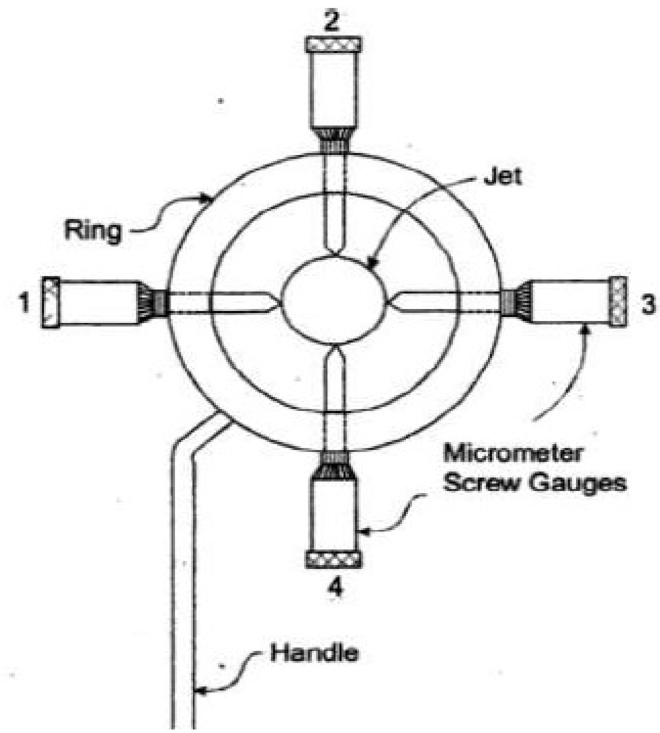
(ii) Using Relationship (Indirect Method)

➤ **Using Micrometer Contraction Gauge (Measuring Ring) :-**

In this method the area of jet at vena-contracta is measured by micrometer contraction gauge.

The screw of gauge are adjusted so that their sharp points just touch the surface of jet & then remove it and measure the distance between two screw as diameter & calculate actual area of jet.

$$\therefore C_C = \frac{a_{act}}{a_{th}} = \frac{d_{jet}}{d_{orifice}}$$



→ The method of direct determination of C_c is not adopted because of,
(1) c/s area of jet is not perfectly circular
(2) The jet is constantly fluctuating and Hence it is very difficult to adjust all Four screw simultaneously touching the jet.

➢ **Using Relationship :-**

→ We know that,
$C_d = C_c \times C_v$ and therefore, $\boldsymbol{C_c = \frac{C_d}{C_v}}$

Examples

(1) A water main gives a pressure reading 490 kPa. Find amount of water in m^3 escaped from it through a circular hole 2.5 cm in diameter in 1 min.

Data :- $p = 490 \times 10^3\ N/m^2$, d= 0.25 m, t = 60 sec

→ We know that Intensity of Pressure

$$p = \rho g H$$

$$\therefore 490 \times 10^3 = 1000 \times 9.81 \times H$$

$$\therefore \mathbf{H = 50\ m\ of\ Water}$$

→ Velocity of water flowing through the orifice $V = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 50}$

$$\therefore \mathbf{V = 31.3\ m/s}$$

→ Amount of water escaped in one minute $= (a_o \times V)\ t$

$$= \frac{\pi}{4} \times 0.25^2 \times 31.3 \times 60$$

$$= \mathbf{0.92\ m^3}$$

A 6 cm diameter orifice is provided in a tank containing water to height of 3 m above orifice. If coefficient of contraction & velocity for the orifice are 0.62 & 0.97 respectively. Determine (i) Actual Discharge (ii) Theoretical Discharge (iii) C_d (iv) Loss of head (v) C_r If air above the water surface is raised to pressure of 0.276 kg/cm^2, determine each of terms, assuming the same value of C_c & C_V.

Data:- $d_o = 6\ cm = 0.06\ m$, $H = 3\ m$, $C_c = 0.62$, $C_v = 0.97$

→ Coefficient of Discharge $\boldsymbol{C_d} = C_c \times C_v = 0.62 \times 0.97 = \mathbf{0.6014}$

→ Theo. Area $(\boldsymbol{A_{th}}) = \frac{\pi}{4} \times d_o^2 = \frac{\pi}{4} \times 0.06^2 = \mathbf{2.827 \times 10^{-3}\ m^2}$

→ Theo. Velocity $(\boldsymbol{V_{th}}) = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 3} = \mathbf{7.672\ m/sec}$

→ We know that, Coefficient of Contraction, $C_c = \frac{A_{act}}{A_{th}}$

$$\therefore 0.62 = \frac{A_{act}}{2.827 \times 10^{-3}}$$

$$\therefore \boldsymbol{A_{act}} = \mathbf{1.753 \times 10^{-3}\ m^2}$$

→ We know that, Coefficient of Velocity, $C_v = \frac{V_{act}}{V_{theo}}$

$fjRεy'z

$\therefore 0.97 = \frac{V_{act}}{7.672}$

$\therefore \boldsymbol{V_{act} = 7.4418\ m/sec}$

→ Act. Discharge $Q_{act} = A_{act} \times V_{act} = 1.753 \times 10^{-3} \times 7.4418 = \mathbf{0.0130\ m^3/sec}$

→ Theo. Discharge $Q_{th} = A_{th} \times V_{th} = 2.827 \times 10^{-3} \times 7.672 = \mathbf{0.0216\ m^3/sec}$

→ Loss of Head $(h_f) = H\ (1 - C_v^2) = 3\ (1 - 0.97^2) =$ **0.1773 m of water.**

→ Coefficient of Resistance $(C_r) = \frac{h_f}{H} = \frac{0.1773}{3} = \mathbf{0.059}$

If air above the water surface is raised to pressure of 0.276 kg/cm^2, then
Intensity of pressure $(p) = \rho g H'$

$\therefore 0.276 \times \frac{9.81}{10^{-4}} = 1000 \times 9.81 \times H'$

$\therefore H' = 2.76$ m of water.

Which means that flow through orifice under total head (H) = 3 + H'

$= 2 + 2.76$

$= \mathbf{5.76}$ **m of water**

→ Act. Discharge $\mathbf{Q_{act}} = A_{act} \times C_v \times V_{th} = 1.753 \times 10^{-3} \times 0.97 \times \sqrt{2 \times 9.81 \times 5.76}$

$= \mathbf{0.0180\ m^3/sec}$

→ Theo. Discharge $\mathbf{Q_{th}} = A_{th} \times V_{th} = 2.827 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 5.76} = \mathbf{0.030\ m^3/sec}$

→ Coefficient of Discharge $(C_d) = \frac{Q_{act}}{Q_{theo}} = \frac{0.0180}{0.030} = \mathbf{0.5989}$

→ Loss of head $(h_f) = H(1 - C_v^2) = 5.76 \times (1 - 0.97^2) = \mathbf{0.3404}$ **m of water**

→ Coefficient of Resistance $(C_r) = \frac{h_f}{H} = \frac{0.34}{5.76} = \mathbf{0.0591}$

Two identical orifices are filed to tank on its vertical side. The upper orifice is 2 m below the water surface & lower are 5 m below the water surface. Find the point where two jet intersects. Take C_v = 0.85 for both orifice.

→ Let, x = P = Where two jet from two orifice meets

h_1 = 2 m = Position of Orifice 1 from FLS

h_2 = 5 m = Position of Orifice 2 from FLS

y_1 = Vertical distance travelled by jet from orifice 1

y_2 = Vertical distance travelled by jet from orifice 2

→ The coefficient of velocity is given by,

$$C_v = \sqrt{\frac{x^2}{4yh}} \text{ ---- (1)}$$

→ As C_v is same for both orifice

$$\therefore C_{v_1} = C_{v_2}$$

$$\therefore \sqrt{\frac{x^2}{4y_1h_1}} = \sqrt{\frac{x^2}{4y_2h_2}}$$

$$\therefore \sqrt{\frac{1}{2\,y_1}} = \sqrt{\frac{1}{5\,y_2}}$$

$\therefore 5\ y_2 = 2\ y_1$

$\therefore \boldsymbol{y_1 = 2.5\ y_2}$

→ From Fig,

$y_1 = y_2 + (5-2)$

$\therefore y_1 = y_2 + 3$

$\therefore 2.5\ y_2 = y_2 + 3$

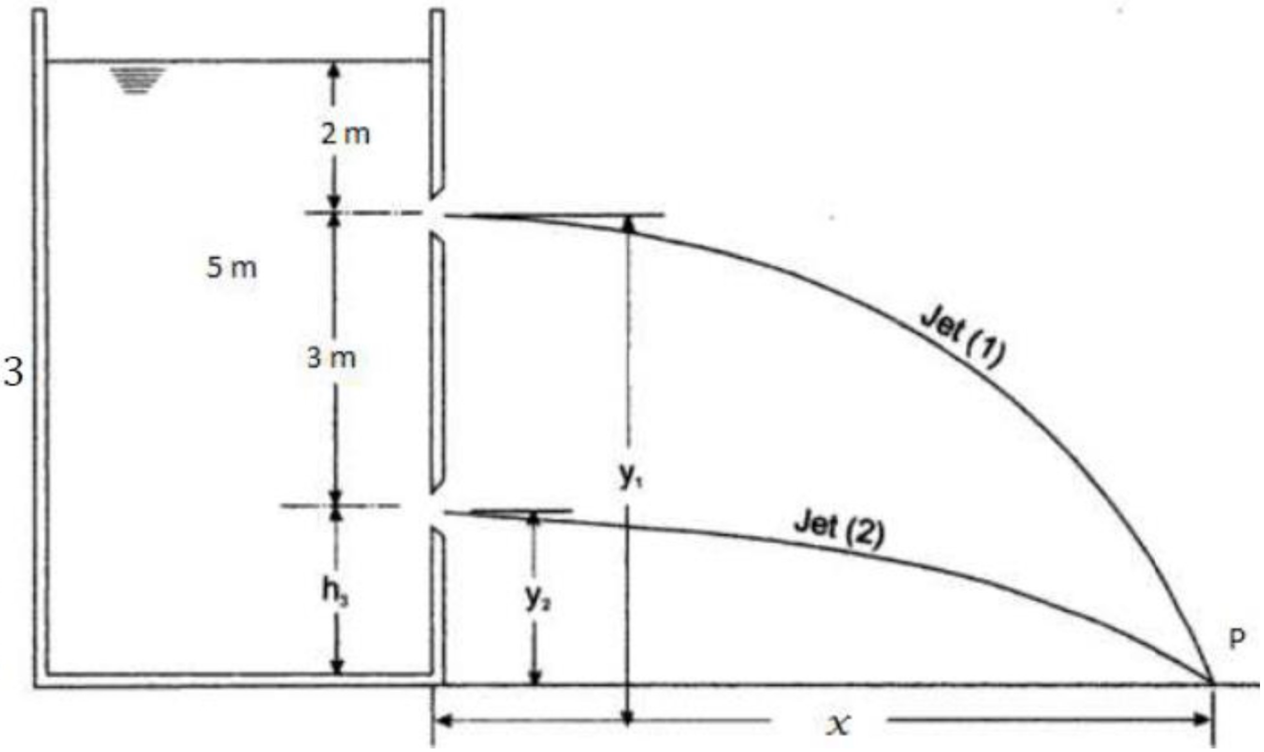
$\therefore \boldsymbol{y_2 = 2\ m}$

$\therefore \boldsymbol{y_1 = 5\ m}$

→ From equation (1)

$\therefore 0.85 = \sqrt{\frac{x^2}{4\times5\times2}}$

$\therefore \boldsymbol{x = 5.38\ m}$



Water Discharged Through Large Orifice

→ When available head of water is less 5 times to height of orifice then it is called Large orifice.

→ In case of small orifice velocity considered as constant & discharge can be calculated by,

$$\therefore Q = C_d \, a \sqrt{2gH}$$

But in case of large orifice, discharge cannot be calculated from above formula.

→ Consider a large rectangular orifice in one side of tank discharging into atmosphere under constant head.

Let,

H_1 = Ht. of liquid above top edge of orifice

H_2 = Ht. of liquid above bottom edge of orifice

H = Ht. of liquid above centre of orifice

b = Width of orifice

d = Depth of orifice = $H_2 - H_1$

→ Now consider an elemental strip of water having thickness 'dH' at distance 'H' from water liquid surface.

→ Area of elemental strip (A) = $b\,dH$

→ Theo. velocity (V_{th}) = $\sqrt{2gH}$

→ Discharge through strip is given by,

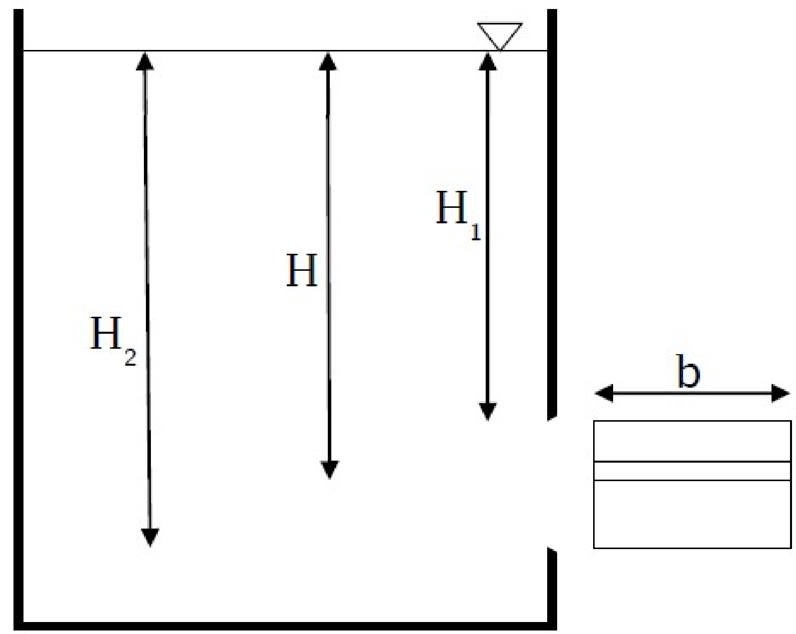
$$dQ = C_d\, a\,\sqrt{2gH}$$

$$\therefore\ dQ = C_d\, b\,\sqrt{2gH}\,dH$$

→ Integrating above equation between the limits H_1 to H_2

$$\therefore\ \int_0^Q dQ = C_d\, b\,\sqrt{2g}\,\int_{H_1}^{H_2}\sqrt{H}\,dH$$

$$\therefore\ Q = \frac{2}{3}\,C_d\, b\,\sqrt{2g}\,\left(H_2^{\frac{3}{2}} - H_1^{\frac{3}{2}}\right)$$



Water Discharged Through Fully Submerged Orifice

→ If an orifice has its outlet fully submerged under liquid so that it discharges a jet of liquid into the liquid of same kind then it is called submerged orifice. (Drowned Orifice). OR If whole of downstream edge of an orifice is under liquid is known as ......

→ Consider a fully submergd orifice as shown in fig.

Point 1 → Upstream side of an orifice

Point 2 → At vena-contracta

Let,

H_1 = Height of water surface above top of orifice

H_2 = Height of water surface above bottom of orifice

H = Difference in water level

b = Width of orifice

C_d = Coefficient of discharge

A = Area of orifice = $b\,(H_2 - H_1)$

→ Height of water above center of orifice on upstream side $\left(\frac{p_1}{w}\right) = H_1 + \frac{H_2 - H_1}{2} = \frac{H_1 + H_2}{2}$

→ Height of water above centre of orifice on downstream side $\left(\frac{p_2}{w}\right) = \frac{H_1 + H_2}{2} - H$

→ Applying Bernoulli's equation at (1) & (2)

$$\therefore \frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$$

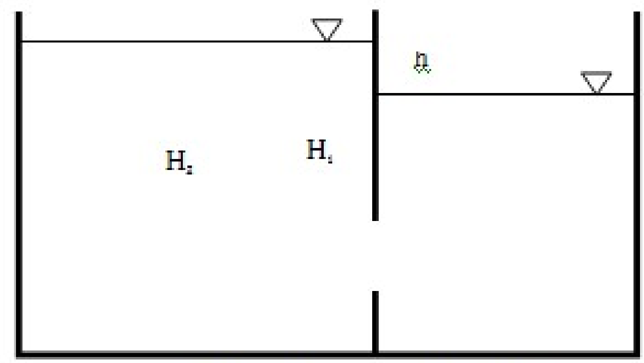
as $z_1 = z_2$ and $V_1 << V_2$, $V_1 = 0$

$$\therefore \frac{p_1}{w} = \frac{p_2}{w} + \frac{V_2^2}{2g}$$

$$\therefore \frac{H_1 + H_2}{2} = \frac{H_1 + H_2}{2} - H + \frac{V_2^2}{2g}$$

$$\therefore V_2^2 = 2gH$$

$$\therefore V_2 = V_{th} = \sqrt{2gH}$$



Fully Submerged Orifice

→ Discharged through orifice,

$$\therefore Q = C_d \times A \times \sqrt{2gH}$$

$$= C_d \times b(H_2 - H_1) \times \sqrt{2gH}$$

Water Discharged Through Fully Submerged Orifice

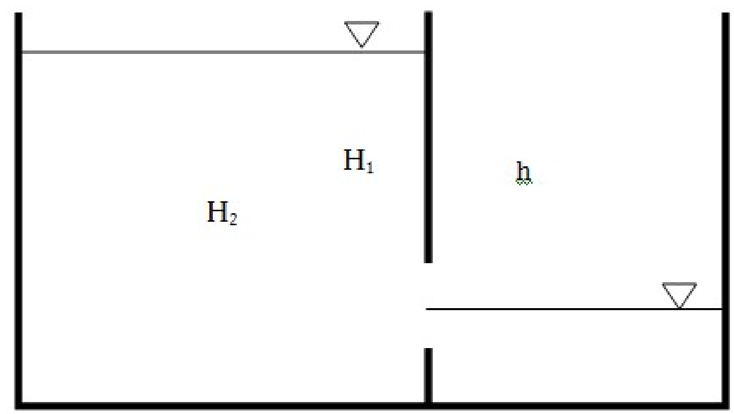
→ If outlet side of an orifice is partially under liquid is known as partially submerged orifice.

→ The partially submerged orifice has two portions one behaves as an orifice discharging freely & second behaves as submerged orifice. Only large orifices behaves like a partially submerged orifice.

→ Total discharged through an partially submerged orifice,

= Discharge through free portion + Discharge through submerged portion

$$= \frac{2}{3} C_d \, b \sqrt{2g} \left(H_2^{\frac{3}{2}} - H_1^{\frac{3}{2}} \right) + C_d \times b(H_2 - H_1) \times \sqrt{2gH}$$



Partially Submerged Orifice

(4) Flow takes place between two tank a & B under pressure through an orifice connecting the tank as shown in fig. Both the tank contains oil having specific gravity 0.82 & level of oil in tank A is 50 cm higher than that in tank B. The load of 12 kN is placed on piston in tank A while tank B is closed & contains entrapped air at pressure 2.90 bar. If tank A is c/s of 0.65 m2 & orifice is 8 cm in diameter. Calculate discharge through orifice. If Cd = 0.75

Data:- Specific Gravity (S_{oil}) = 0.82, h = 50 cm = 0.5 m, Pressure in tank B = p_B = 2.90 bar
Area of tank A (A_A) = 0.65 m², Diameter of orifice (d) = 8 cm

→ Pressure in vessel A,

$$\therefore\ p_A = \frac{Force}{Area} = \frac{12\times10^3}{0.65} = \mathbf{18461.53\ N/m^2}$$

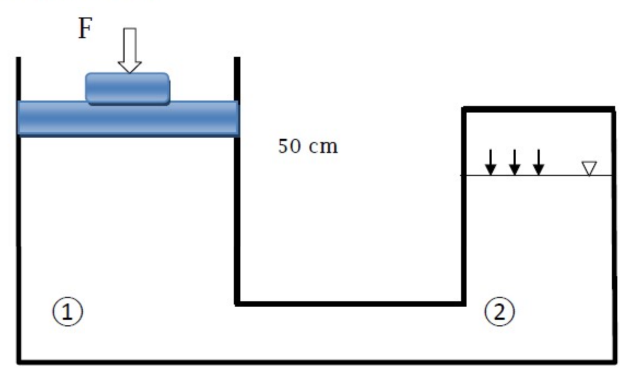
→ According to Bernoulli's equation

Effective head causing flow (H) $= h + \frac{p_1 - p_2}{w} = 0.5 + \frac{(18461.53 - 2.90\times10^5)}{0.82\times9810} = \mathbf{-33.2558\ m}$

→ Discharge (Q) $= C_d\ a\ \sqrt{2gH}$

$$= 0.75 \times \frac{\pi}{4} \times 0.08^2 \times \sqrt{2\times9.81\times33.255}$$

$$= \mathbf{0.096\ m^3/sec}$$




Thank You!