17

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Experiment 4

Flow Through an Orifice

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Objective:

1. Determining the contraction (C_c) and velocity coefficients (C_v)
2. Calculating the discharge coefficient (C_d)

Equipments and apparatus:

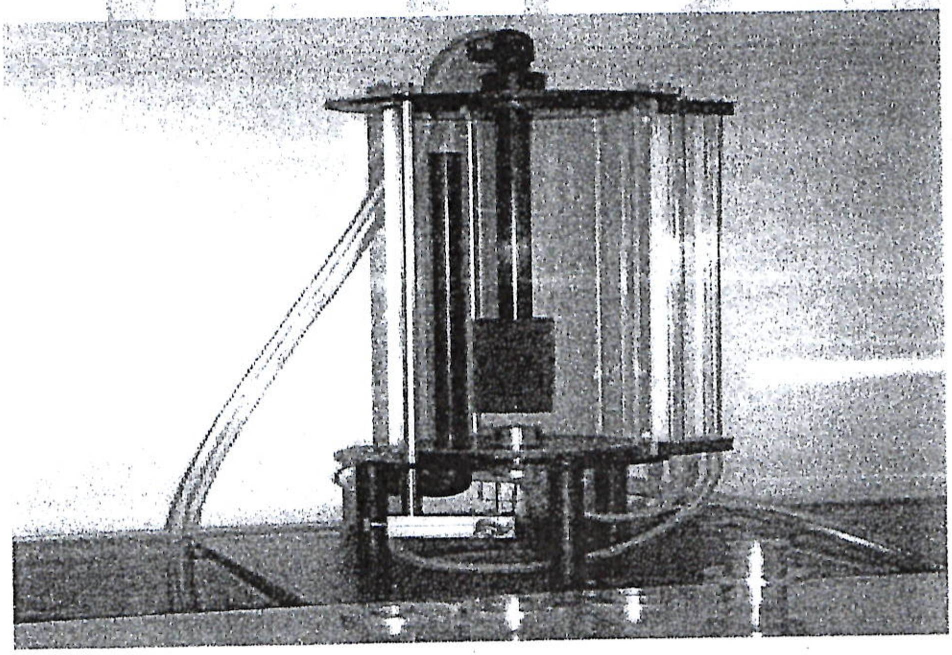
1. The Orifice Discharge accessory consists of a cylindrical glass tank which has an orifice fitted in the base. A traverse assembly is provided which enables a pitot tube to be positioned anywhere in the jet.

Attached to this pitot tube is a sharp blade which can be traversed across the jet to accurately measure the jet diameter and the vena contracta diameter and so determine the contraction coefficient.

The pitot head and the total head across the orifice are shown on manometer tubes adjacent to the tank. In addition to the standard orifice, supply includes four additional orifices. These are supplied in an attractive storage case. A label inside the lid gives dimensional details of each orifice.

2. Measuring Tank.

3. Stopwatch.



Procedure:

1. Open the inlet valve and maintain the head constant (at supply tank) over the orifice.

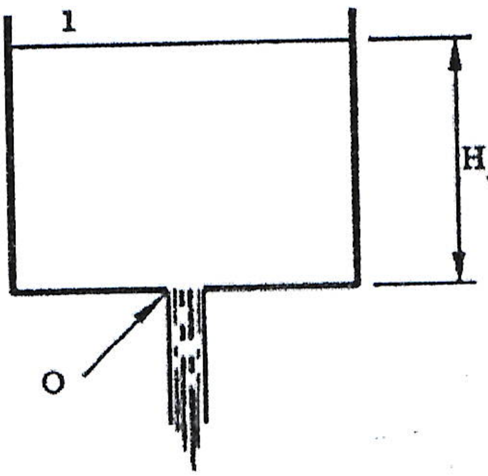
2. Allow water to flow through the orifice and note the maximum head over the orifice that permits the water jet to flow into the measuring tank. Divide this head to approximately 7 steps of readings.

3. Regulate the inlet valve to obtain a constant head H_w over the orifice and note the time taken for collecting water to a height 'h' in the measuring tank.

3. Note X_1 and Y_1 co-ordinates using the pointer gauge at the center of vena contracta (taken as 0.5 time the diameter outside the orifice opening).

4. Adjust the head over the orifice and repeat the experiment.

Theoretical background and Calculation:



Applying Bernoulli's theorem between the surface of the water 1 and the orifice 0 yields

$$Z_1 + \frac{P_1}{\rho g} + \frac{V_1^2}{2g} = Z_o + \frac{P_o}{\rho g} + \frac{V_o^2}{2g}$$

However $P_l = P_o$ = atmospheric pressure

$$V_1 = 0 \quad and \quad Z_1 - Z_o = H_o$$

hence substituting these into Bernoulli's equation gives

$$H_o = \frac{V_o^2}{2g}$$

In other words, the theoretical velocity of the water passing through the orifice is given by

$$V_o = \sqrt{2g H_o}$$

and hence the quantity of water being discharged through the orifice is given by

$$\dot{Q} = a V_o$$

$$= a \sqrt{2g H_o}$$

However in practice the discharge is always less than this theoretical amount due to the viscosity of the fluid, to surface tension and due to resistance of the air. The disparity between the theoretical discharge velocity and the actual discharge velocity is allowed for by introducing a factor C_v known as the **Coefficient of Velocity** so that

$$V_{actual} = C_v \sqrt{2g H_o}$$

If the discharge from a sharp edged orifice is examined closely it will be observed that the minimum diameter of the jet of water discharging from the orifice is smaller than the orifice diameter. The plane at which this occurs is known as the **Vena Contracta**, which is the plane where stream lines first become parallel. Applying the discharge equation at the vena contracta,

$$\dot{Q} = a_c C_v \sqrt{2g H_o}$$

which can be written as

$$\dot{Q} = a C_c C_v \sqrt{2g H_o}$$

where $C_c = a_c / a = \textit{Coefficient of Contraction}$

or more simply as

$$\dot{Q} = a C_d \sqrt{2g H_o}$$

where $C_d = C_c C_v = \textit{Coefficient of Discharge}$

Typical values of C_d range from 0·6 to 0·65, i.e. the actual flow through a sharp edged orifice is approximately 60% of the theoretical value. The value of the Coefficient of Discharge may be determined by measuring the quantity of water discharged over a period of time whilst the head is maintained at a constant level.