Objectives:

1. To find the coefficient of discharge for venturi meter.
2. To find the coefficient of discharge for orifice meter.

Theory:

Venturi meter and orifice meter are the commonly used flow meters for measuring mass/volumetric flow rate or velocity of the flowing fluid. These flow meters are also known as variable head meters. They are categorized as full-bore meter as measurement of the fluid takes place when it flows through a conduit or channel.

Venturi meter:

The venturi meter has a converging conical inlet, a cylindrical throat and a diverging recovery cone. It has no projections into the fluid, no sharp corners and no sudden changes in contour. The following figure shows the venturi meter with uniform cylindrical section before converging entrance, a throat and divergent outlet.

Figure 1. Venturi meter

The converging inlet section decreases the area of the fluid stream, causing the velocity to increase and the pressure to decrease. The low pressure is measured in the center of the cylindrical throat as the pressure will be at its lowest value, where neither the pressure nor the velocity will be changing. As the fluid enters the diverging section the pressure is largely
recovered lowering the velocity of the fluid. The major disadvantages of this type of flow detection are the high initial costs for installation and difficulty in installation and inspection.

The *Venturi effect* is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase through the constriction to satisfy the equation of continuity, while its pressure must decrease due to conservation of energy: the gain in kinetic energy is balanced by a drop in pressure or a pressure gradient force. An equation for the drop in pressure due to Venturi effect may be derived from a combination of Bernoulli’s principle and the equation of continuity.

The equation for venturi meter is obtained by applying Bernoulli equation and equation of continuity assuming an incompressible flow of fluids through manometer tubes. If $V_1$ and $V_2$ are the average upstream and downstream velocities and $\rho$ is the density of the fluid, then using Bernoulli’s equation we get,

$$\alpha_2 V_2^2 - \alpha_1 V_1^2 = \frac{2g \Delta P_2}{\rho} \quad \text{.................................. (1)}$$

where $\alpha_1$ and $\alpha_2$ are kinetic energy correction factors at two pressure tap positions.

Assuming density of fluid to be constant, the equation of continuity can be written as:

$$V_1 = \left(\frac{D_1}{D_2}\right)^2 V_2 \quad \text{................................. (2)}$$

where $D_1$ and $D_2$ are diameter of pipe and throat in meters respectively.

Eliminating $V_1$ from equation (1) and equation (2) we get,

$$V_2 = \frac{1}{\sqrt{\alpha_2 - \alpha_1 \beta^2}} \sqrt{\frac{2g \Delta P_2}{\rho}} \quad \text{................................. (3)}$$

where $\beta$ is the ratio of the diameter of throat to that of diameter of pipe.

If we assume a small friction lose between two pressure taps, the above equation (3) can be corrected by introducing empirical factor $C_v$ and written as,

$$V_2 = \frac{C_v}{\sqrt{1-\beta^2}} \sqrt{\frac{2g \Delta P_2}{\rho}} \quad \text{................................. (4)}$$
The small effect of the kinetic energy factors \( \alpha_1 \) and \( \alpha_2 \) are also taken into account in the definition of \( C_v \).

Volumetric flow rate \( Q_a \) can be calculated as:

\[
Q_a = V_2S_2 = \frac{C_vS_2}{\sqrt{1-\beta^4}} \sqrt{\frac{2(P_1-P_2)}{\rho}} \quad \text{……….. (5)}
\]

where, \( S_2 \) is the cross sectional area of throat in m\(^2\).

Substituting \( (P_1-P_2) = \rho gH \) in above equation (5) we get,

\[
Q_a = V_2S_2 = \frac{C_vS_2}{\sqrt{1-\beta^4}} \sqrt{2g\Delta H} \quad \text{……….. (6)}
\]

where \( \Delta H \) is the manometric height difference * (specific gravity of manometric fluid – specific gravity of manometric fluid of water).

**Orifice meter:**

An orifice meter is essentially a cylindrical tube that contains a plate with a thin hole in the middle of it. The thin hole essentially forces the fluid to flow faster through the hole in order to maintain flow rate. The point of maximum convergence usually occurs slightly downstream from the actual physical orifice this is the reason orifice meters are less accurate than venturi meters, as we cannot use the exact location and diameter of the point of maximum convergence in calculations. Beyond the vena contracta point, the fluid expands again and velocity decreases as pressure increases.

![Figure 2. Orifice meter](image-url)
The above figure 2 shows the orifice meter with the variable position of vena contracta with respect to plate. Orifice meter uses the same principle of continuity equation and Bernoulli principle to calculate the volumetric flow rate, as shown above for venturi meter.

So,

\[ Q_a = V_2S_2 = \frac{C_aS_2}{\sqrt{1-eta^4}} \sqrt{2g\Delta H} \]  

(7)

Here \( C_a \) is the orifice discharge coefficient.

**Procedure:**

1. Check all the clamps for tightness.
2. Check whether the water level in the tank is sufficient such that the suction pipe of pump is completely immersed.
3. For measurement through venturi, open the outlet valve of the venturi meter and close the valve of orifice meter.
4. For a good amount of variation in discharge also close the by-pass valve of pump.
5. Now switch on the pump.
6. Open the gate valve and start the flow.
7. If any air bubbles exist in U-tube manometer remove them through air cock valve.
   Operate the air cock valve slowly and cautiously to avoid mercury run away through water.
8. Wait for a while for stabilization of flow.
9. Close the gate valve of measuring tank and measure the time for discharge of five liters of water and the manometer difference. Before taking any measurements, make sure the flow is stable.
10. Repeat the procedure by changing the discharge by slowly opening the by-pass valve and take the six readings.
11. Repeat the same for orifice meter.
Given data:

For venturi meter:

Cross sectional area of throat in venturi meter \( (S_2) = 1.76 \times 10^{-4} \text{ m}^2 \)

Ratio of diameter of throat to pipe \( (\beta) = 0.4848 \)

For orifice meter:

Cross sectional area of throat in venturi meter \( (S_2) = 1.54 \times 10^{-4} \text{ m}^2 \)

Ratio of diameter of throat to pipe \( (\beta) = 0.4904 \)

Observations and calculations:

A) Venturi meter

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<thead>
<tr>
<th>Reading no.</th>
<th>( h_1 ) (cm)</th>
<th>( h_2 ) (cm)</th>
<th>time (seconds)</th>
<th>( Q_m ) (m(^3)/sec)</th>
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B) Orifice meter

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References:


3. Website: www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/chap14_03.html (visited: 22 July 2011)