Fluid Mechanics Laboratory Manual

Experiment No. 6

Calibration of Orifice Meter

Name of the Student: ______________________

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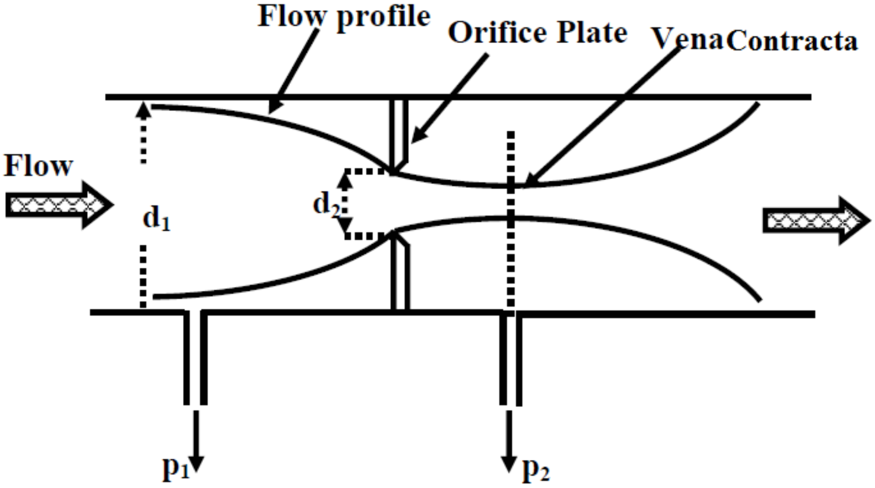

Figure 1: Orifice Meter

Title of the Experiment: Calibration of Orifice Meter

Aim: To calibrate the given orifice meter and to determine the variation of coefficient of discharge over Reynolds number.

Introduction

Flow meters are used in the industry to measure the volumetric flow rate of fluids. Differential pressure type flow meters (Head flow meters) measure flow rate by introducing a constriction in the flow. The pressure difference caused by the constriction is correlated to the flow rate using Bernoullis theorem.

An orifice meter is a differential pressure flow meter which reduces the flow area using an orifice plate.An orifice is a flat plate with a centrally drilled hole machined to a sharp edge. The orifice plate is inserted between two flanges perpendicularly to the flow, so that the flow passes through the hole with the sharp edge of the orifice pointing to the upstream. The relationship between flow rate and pressure drop can be determined using Bernoullis equation as in eq:2

$$Q = \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{{A_1}^2 - {A_2}^2}}$$

Where

- Q = Actual discharge m^3/s
- A_1 = Area of the pipe m^2
- A_2 = Area of the throat m^2
- H = Differential pressure head of liquid m

The fluid contracts and then expands as it moves through the orifice and this results in a pressure drop across the orifice, which can be measured. The magnitude of the pressure drop can be related to the volumetric flow rate. An orifice in a pipeline is shown in figure 1 with a manometer for measuring the drop in pressure (differential) as the fluid passes through the orifice. The minimum cross sectional area of the jet is known as the *vena contracta*.

As the fluid flows through the orifice plate the velocity increases, at the expense of pressure head. The pressure drops suddenly as the orifice is passed. It continues to drop until the *vena contracta* is reached and then gradually increases until at approximately 5 to 8 diameters downstream a maximum pressure point is reached that will be lower than the pressure upstream of the orifice. The decrease in pressure as the fluid passes thru the orifice is a result of the increased velocity of the fluid passing through the reduced area of the orifice. When the velocity decreases as the fluid leaves the orifice the pressure increases and tends to return to its original level. All of the pressure loss is not recovered because of friction and turbulence losses in the stream. The pressure drop across the orifice increases when the rate of flow increases. When there is no flow there is no differential. The differential pressure is proportional to the square of the velocity, it therefore follows that if all other factors remain constant, then the differential pressure is proportional to the square of the rate of flow.

Bernoullis equation is applied to a streamline down the centre of the pipe from a point 1 well upstream of the restriction to point 2 in the vena contracta of the jet immediately downstream of the restriction where the streamlines are parallel and the pressure across the duct may therefore be taken to be uniform. For a real flow through a restriction, the assumptions above do not hold completely.

We cannot easily measure the cross-sectional area of the jet at the vena contracta at cross-section 2 where the streamlines are parallel. These errors in the idealized analysis are accounted for by introducing a single, cover all correction factor, the discharge coefficient, **Cd**.

So he flow rate through orifice meter can be given by the eq:2

$$Q = C_d \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{{A_1}^2 - {A_2}^2}}$$

Coefficient of discharge for a given orifice type is a function of the Reynolds number ($NReo$)based on orifice diameter and velocity, and diameter ratio . At Reynolds number greater than about 30000,the coefficients are substantially constant and independent of diameter ratio and Reynolds number.

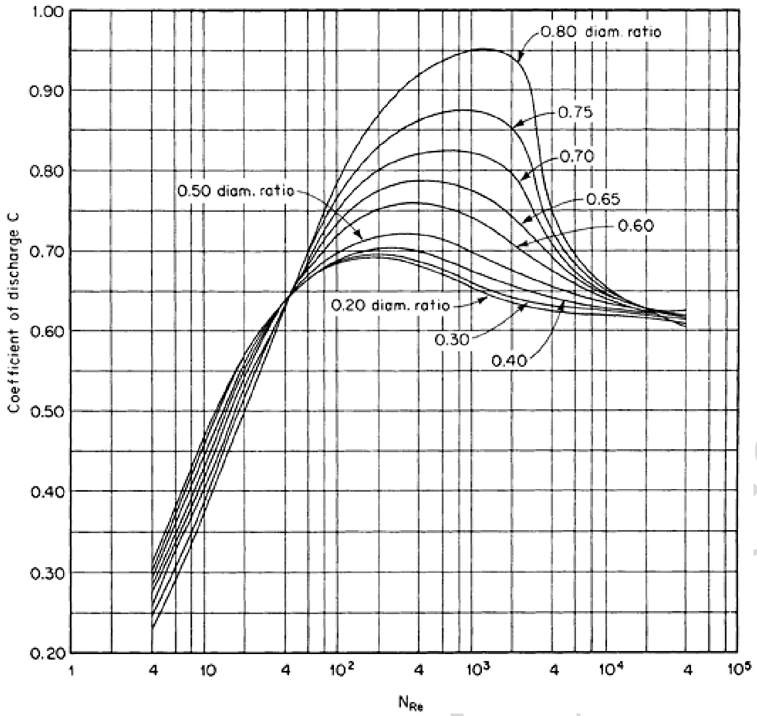

Figure 2: Variation of C_d with Reynolds number for different diameter ratio

Credit: *Perry's Chemical Engineers' Handbook, Robert Perry, Eighth Edition*

Experimental Setup

Experimental setup consist of a main tank, a pump, bypass valve, a collecting tank and the venturimeter. Venturimeter is installed in the pipe connecting to pump and the collecting tank. A manometer is installed between the pipe and throat of the venturimeter. Mercury is used as manometric fluid.

Specifications

- Area of the collecting tank = 0.41 × 0.33 m^2
- Diameter of the pipe = 28 mm
- Diameter of the throat = 14 mm

Experimental Procedure

1. Open the bypass valve fully
2. Start the pump.
3. Adjust the inlet gate valve and bypass valve to get the steady flow across the venturi meter
4. Close the discharge valve of the collection tank and measure the time for rise of 10 cm of water column.
5. Record the pressure difference in the manometer connected between the upstream side and the throat of the venturi meter.
6. Increase the flow rate by adjusting the gate valve and bypass valve.
7. Repeat the procedure for 5 times.

Observations

Table 1: **Observation Table**

Sr. No.	Differential Head (Hg)	Time for rise in water level of 10 cm
1		
2		
3		
4		
5		

Calculations

Actual Discharge $$Q_a = \frac{A_t \times R}{t} \tag{1}$$

$$\text{Differential head in water column} = \text{H} \ = H_{Hg}\left(\frac{S_{Hg}}{S_w} - 1\right) \tag{2}$$

$$\text{Theoretical Discharge} \qquad Q_t = \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{{A_1}^2 - {A_2}^2}} \tag{3}$$

$$\text{Discharge Coefficient} \qquad C_d = \frac{Q_t}{Q_a} \tag{4}$$

Results

Table 2: **Results**

Sr. No.	Theoretical Discharge	Actual Discharge	Reynolds number	C_d
1				
⋮				
6				

Conclusion

Plot

1. The variation of C_d with Reynolds number