APL103 Experimental Methods
Experiment 9 Lab Report
Obstruction Type Flow Meters

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Objective:

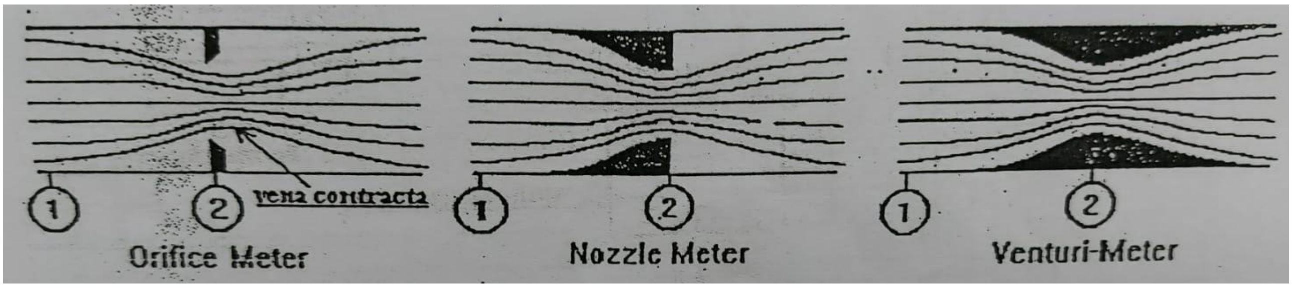
To understand the behavior of various obstruction-type flow meters, namely the venturi meter, the nozzle, and the orifice plate, and to calibrate them over a range of flow rates.

Practical Relevance:

Quick and reliable flow rate measurement is of the utmost importance in any industry handling fluids. Almost always, one needs to measure the flow rate within ducts or confined flows thus, the volumetric or gravimetric method is out of the question. Obstruction meters of the type listed above are the most commonly used devices. The actual meter used depends on the fluid being handled, the accuracy required, and the energy loss that can be tolerated.

Theoretical Background:

For any incompressible fluid, if the flow is forced to go through a contraction, the velocity has to increase for mass balance. This increase in velocity causes the pressure to drop locally (Bernoulli's equation).



For well-designed nozzles and venturis, the minimum flow area occurs at the minimum area of the device, as shown. However, due to the abrupt contraction in the case of the orifice meter, the streamlines continue to converge after the device; the minimum area thus formed is called the vena contracta. If we ignore this extra contraction and apply Bernoulli's equation between points 1 and 2 for each of the devices shown, we have,

$$Q_{th} = A_1 A_2 \sqrt{(2g(\rho_m - \rho_f)h)}/\sqrt{((A_1^2 - A_2^2)\rho_f)} \quad (1)$$

Here, Q_{th} is the volume flow rate, A_1 and A_2 are the areas at sections 1 and 2, respectively, ρ_f, is the density of the working fluid (water), ρ_m, is the density of the manometric fluid (air), and h is the difference in the levels of the two limbs of the manometer, connected between sections 1 and 2.

In actual practice, there are energy losses in the region between sections I and 2, thus the actual flow rate, Q_{act}, is less than Q_{th}. The expression for Q_{act} may then be written in terms of a discharge coefficient, C_d, as follows:

$$Q_{act} = C_d A_1 A_2 \sqrt{(2g(\rho_m - \rho_f)h)}/\sqrt{((A_1^2 - A_2^2)\rho_f)} \quad (2)$$

The value of C_d, depends on the type of device and also on the exact location of the pressure taps.

Experimental set-up:

The rig consists of a constant-head supply tank connected to three supply lines (one for each device to be tested) by means of a common manifold, a volumetric tank at the common outlet, a sump, and a pump. A schematic diagram is shown in figure 1.

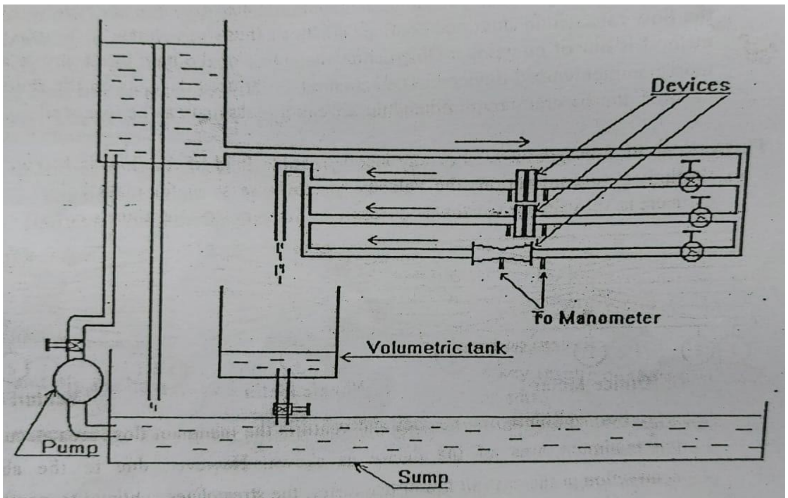


Figure 1: Schematic diagram of the set-up

Procedure:

1) Measure (note down) the pipe diameters and A_1, and A_2 for the three devices.
2) Start the pump and then adjust the constant head pipe to achieve the desired head.
3) Choose one of the three devices and completely open the valve on the input line to this device while keeping the other two valves closed.
4) Measure the pressure differential across the device using the inverted U- tube air manometer provided.
5) Determine the flow rate using either the volumetric or gravimetric method.
6) Repeat steps 5 and 6 for five more flow rates, progressively reducing the flow rate such that the pressure differential is approximately 1 cm of water for the lowest flow rate.
7) Repeat steps 4 through 7 for the other two devices.

Observations:

a) Cross-sectional area of the volumetric tank, a = (44.4 x 46.3) cm^2 = 2055.72 cm^2

Venturimeter:

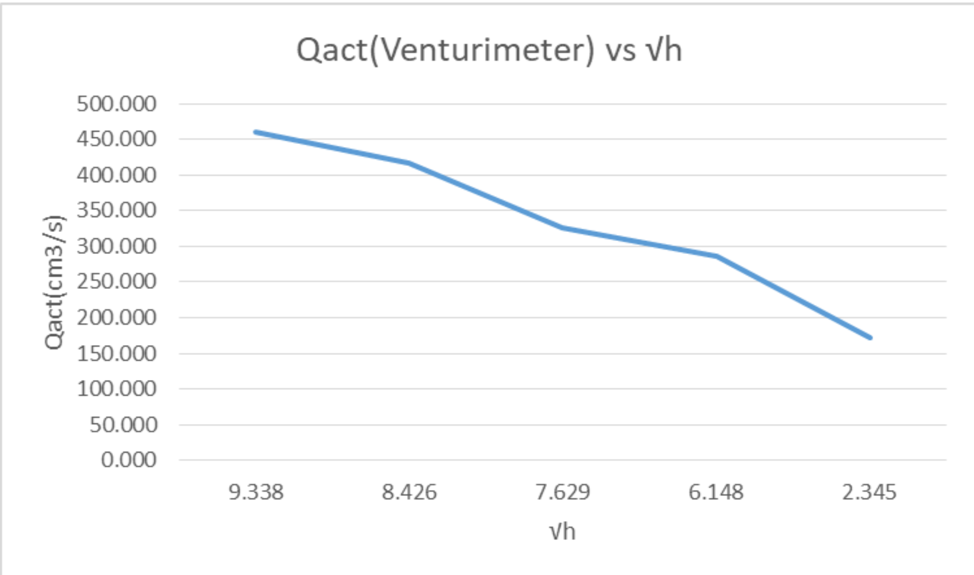
b) Pipe Diameter, D_1 = 32mm
c) Throat Diameter, D_2 = 15mm
d) A_1 = 804.25 mm^2, A_2 = 176.71 mm^2
e) Observation Table:

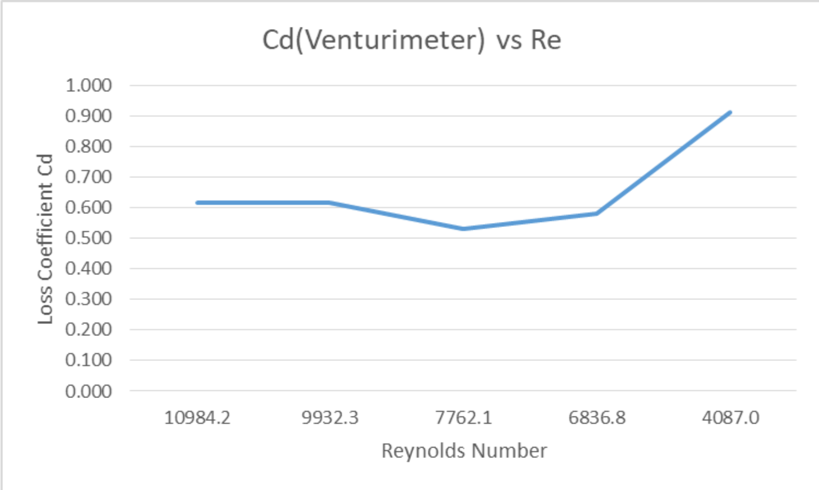
Sr. No.	**Manometer Reading h(cm)**	**Height filled in Volumetric Tank, h'(cm)**	**Time taken for filling, t(s)**
1	87.2	10	44.59
2	71	8	39.45
3	58.2	6	37.86
4	37.8	5	35.82
5	5.5	5	59.92

f) Analysis Table:

Sr. No.	**Actual Flow Rate $Q_{act}(cm^3/s)$**	**Theoretical Flow Rate $Q_{th}(cm^3/s)$**	**Discharge Coefficient C_d**	**Reynolds Number Re**
1	461.027	748.364	0.616	10984.2
2	416.876	675.280	0.617	9932.3
3	325.788	611.387	0.533	7762.1
4	286.951	492.721	0.582	6836.8
5	171.539	187.947	0.913	4087.0

g) Plots:





Orifice meter:

b) Pipe Diameter, D_1 = 32mm

c) Throat Diameter, D_2 = 13mm

d) A_1 = 804.25 mm^2, A_2 = 132.73mm^2

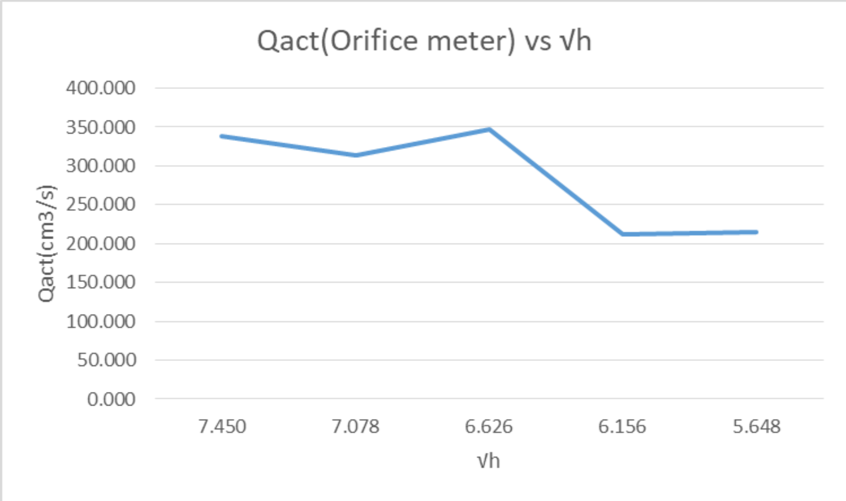
e) Observation Table:

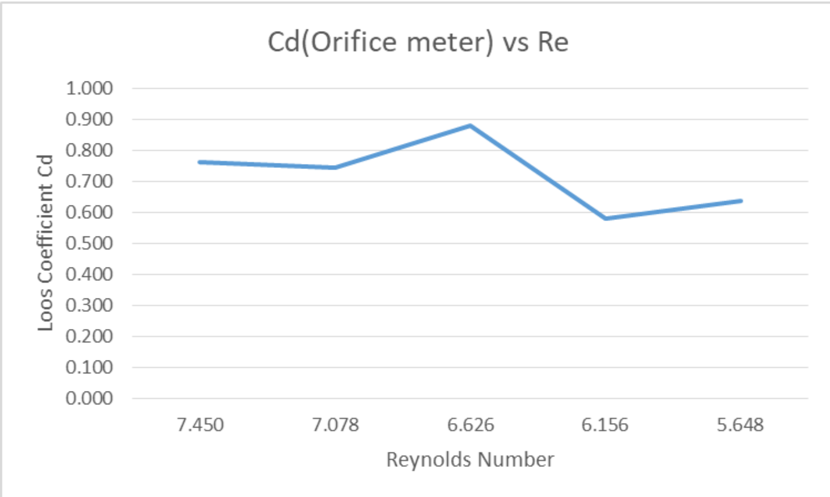
Sr. No.	Manometer Reading h(cm)	Height filled in Volumetric Tank, h'(cm)	Time taken for filling, t(s)
1	55.5	10	60.85
2	50.1	8	52.55
3	43.9	6	35.56
4	37.9	5	48.34
5	31.9	5	47.9

f) Analysis Table:

Sr. No.	Actual Flow Rate $Q_{act}(cm^3/s)$	Theoretical Flow Rate $Q_{th}(cm^3/s)$	Discharge Coefficient C_d	Reynolds Number Re
1	337.834	443.563	0.762	8049.1
2	312.955	421.432	0.743	7456.3
3	346.859	394.495	0.879	8264.1
4	212.631	366.546	0.580	5066.1
5	214.585	336.282	0.638	5112.6

g) Plots:





Nozzle:

b) Pipe Diameter, D_1 = 32mm

c) Throat Diameter, D_2 = 13mm

d) A_1 = 804.25 mm^2, A_2 = 132.73mm^2

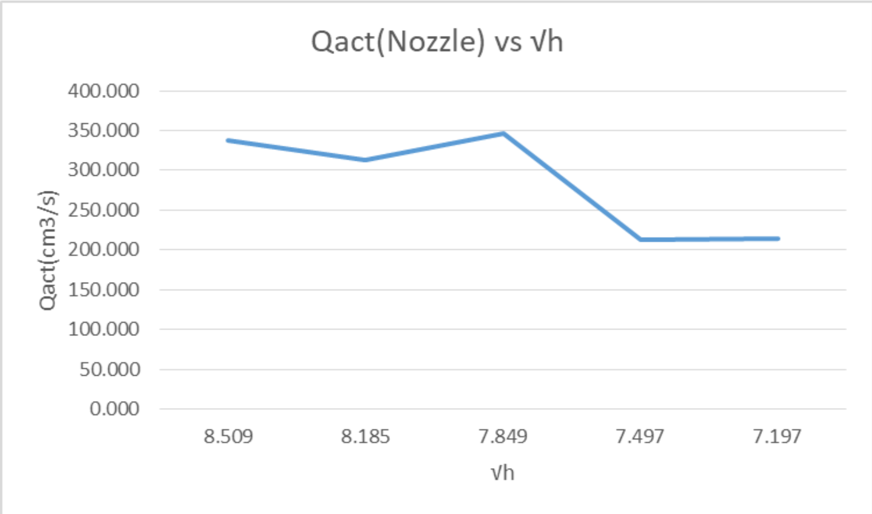
e) Observation Table:

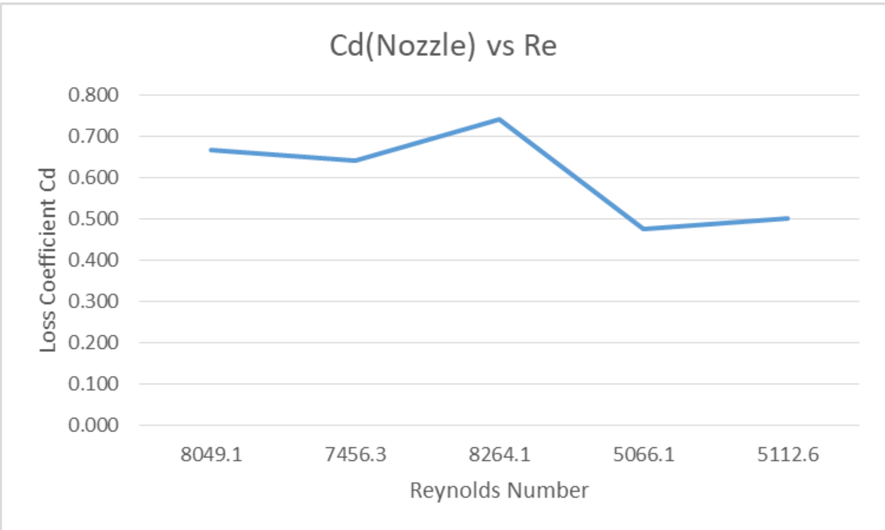
Sr. No.	Manometer Reading h(cm)	Height filled in Volumetric Tank, h'(cm)	Time taken for filling, t(s)
1	72.4	10	60.85
2	67	8	52.55
3	61.6	6	35.56
4	56.2	5	48.34
5	51.8	5	47.9

f) Analysis Table:

Sr. No.	Actual Flow Rate $Q_{act}(cm^3/s)$	Theoretical Flow Rate $Q_{th}(cm^3/s)$	Discharge Coefficient C_d	Reynolds Number Re
1	337.834	506.615	0.667	8049.1
2	312.955	487.356	0.642	7456.3
3	346.859	467.304	0.742	8264.1
4	212.631	446.351	0.476	5066.1
5	214.585	428.523	0.501	5112.6

g) Plots:





Discussion:

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2. A few sources of error are:
   I. Parallax error while taking note of the readings.
   II. There might be changes in the temperature of the fluid due to the conduction of heat from the pipes and the surroundings, causing the density to change.
   III. We are taking the average value of flow velocity, this may cause a deviation from the actual values.

   Methods for improving the experiment:
   I. We should ensure that the pipes are as smooth and frictionless as possible.
   II. The flow pipes should be made of insulating material in order to prevent temperature fluctuations.
   III. The use of clean water will prevent inhomogeneity in the density of the fluid.