Experiment No. 2

VENTURI METER

Objective

To measure the discharge and to investigate the characteristic of a Venturi Meter.

Apparatus

TecQuipment Venturi Meter, H5
TecQuipment Hydraulic Bench, H1

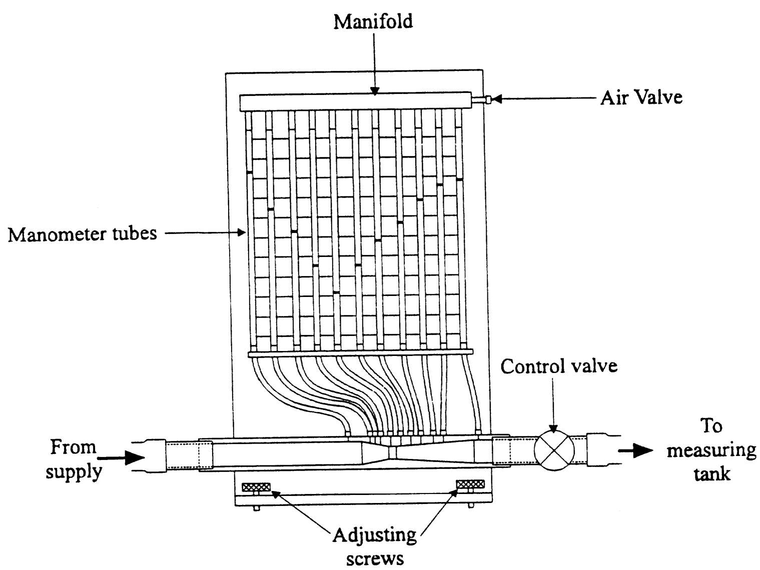


Figure 1: Arrangement of Venturi meter apparatus.

Summary of Theory

Consider the flow of an incompressible fluid through the convergent-divergent pipe shown in Fig.2. The cross-sectional area at the upstream section 1 is a_1, at the throat section 2 is a_2, and at any other arbitrary section n is a_n. Piezometer tubes at these sections register h_1, h_2, and h_n as shown.

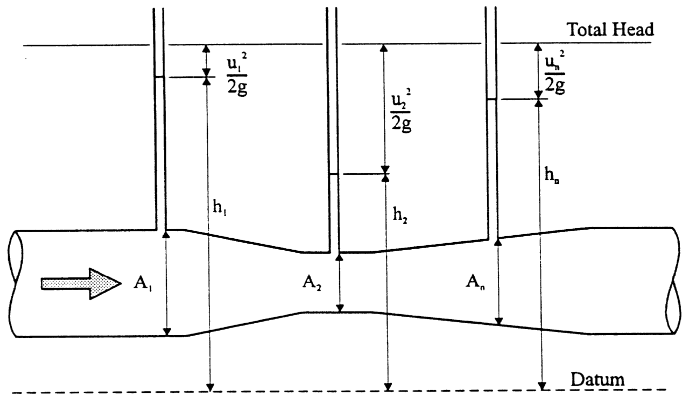


Figure 2: Ideal conditions in a Venturi meter.

Assuming that there is no loss of energy along the pipe, and that the velocity and piezometric heads are constant across each of the sections considered, then Bernoulli's theorem states that

$$\frac{u_1^2}{2g} + h_1 = \frac{u_2^2}{2g} + h_2 = \frac{u_n^2}{2g} + h_n \qquad \dots 1$$

Where u_1, u2 and u_n are the velocities of flow through section 1, 2, and n. The equation of continuity is

$$u_1 a_1 = u_2 a_2 = u_n a_n = Q \qquad \dots 2$$

Q denotes the volume flow or discharge rate.

Substituting in equation (1) for u_1 from equation (2)

$$\frac{u_2^2}{2g}\left(\frac{a_2}{a_1}\right)^2 + h_1 = \frac{u_2^2}{2g} + h_2$$

And solving this equation for u_2 leads to

$$u_2 = \sqrt{\frac{2g(h_1 - h_2)}{1 - \left(\frac{a_2}{a_1}\right)^2}}$$

So that the discharge rate, from equation becomes:

$$Q = a_2 \sqrt{\frac{2g(h_1 - h_2)}{1 - \left(\frac{a_2}{a_1}\right)^2}}$$

…3

In practice, there is some loss of energy between sections 1 and 2, and the velocity is not constant across either of these sections. Consequently, measured values of Q usually fall a little short of those calculated from equation (3) and it is customary to allow for this discrepancy by writing:

$$Q = Ca_2 \sqrt{\frac{2g(h_1 - h_2)}{1 - \left(\frac{a_2}{a_1}\right)^2}}$$

…4

C is known as the coefficient of the meter, which may be established by experiment. Its value varies slightly from one meter to another and even for a give meter it may vary slightly with the discharge, but usually lies within the range of 0.92 to 0.99.

The ideal pressure distribution along the convergent-divergent pipe may be seen from Bernoulli's equation 1 to be given by

$$h_n - h_1 = \frac{u_1^2 - u_n^2}{2g}$$

For the purpose of calculation and of comparison of experimental results with calculation, it is convenient to express $(h_n - h_1)$ as a fraction of the velocity head at the throat of the meter, that is:

$$\frac{h_n - h_1}{\frac{u_2^2}{2g}} = \left(\frac{a_2}{a_1}\right)^2 - \left(\frac{a_2}{a_n}\right)^2$$

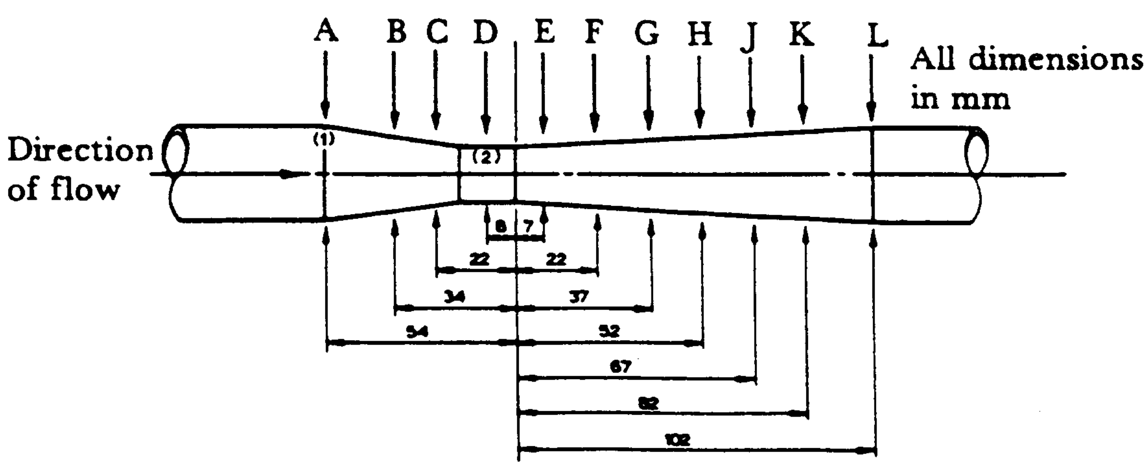
…5

Procedures

1. Set both the apparatus flow control and bench supply valve to approximately one third of the full open position (turn approximately 720°).
2. Check the air purge valve on the upper manifold to ensure that it is tightly closed.
3. Switch on the bench supply by pressing the black button on the right side of the whole Venturi meter setup.
4. Clear the air from the manometer tubes by lightly tapping the tubes with your fingers.
5. Close the apparatus flow control valve. Air will now be trapped in the upper parts of the manometer tubing and the manifold.
6. Record the total head of the system in the result sheet.
7. Adjust the apparatus control valves to obtain full flow (look at the outlet flow).
8. Record the water levels of all the piezometer tubes in the result sheet (Table 2).
9. Place the PVC tubing into the drain hole. Using the stopwatch, measure and record the time it takes for the water to reach 25 litres. The volume of the water could be seen on the left side of the Venturi meter setup. Record the time in Table 2.
10. Close the apparatus control valve slightly to obtain a different flow rate.
11. Record the water level of the piezometer tubes labeled A and D in Table 3.
12. Place the PVC tubing into the drain hole. Using the stopwatch, measure and record the time it takes for the water to reach 25 litres. Record the time in Table 3. Call the instructor.
13. Repeat steps (10) to (12) to obtain an additional 5 sets of water level reading (A and D) with different flow rates.

Data, Observation and Results

- The dimensions of the meter and the position of the piezometer tappings are shown below (also given on the apparatus).



- Complete Table 1 (ideal values).
- Complete Table 2 (experimental values).
- Plot the graph of $(h_n-h_1)/(u_2/2g)$ versus the distance (x_n) for the ideal and experimental pressure distribution on the same graph (Graph 1).
- Calculate experimental and ideal (using equation 3) discharge flow rate in Table 3.
- Calculate the coefficient of Venturi meter using equation 4 in Table 4.
- Plot the graph of C versus ideal flow rate (Graph 2).

Analysis and Discussion

- Describe what happen ideally to the flow as the water flow through the venturi meter.
- Comment on Graph 1.
- Define Coefficient of meter, C and state the theoretical value for venturi meter.
- Comment on Graph 2.
- List the possible sources of errors and safety precaution.

RESULT SHEET

Table 1: Ideal Pressure Distribution

Piezometer tube No. (n)	Dia. of cross section (d_n)	Distance from datum (x_n)	d_2/d_n	$(a_2/a_1)^2$	$(a_2/a_1)^2 - (a_2/a_n)^2$
A (1)	26.00				
B	23.20				
C	18.40				
D (2)	16.00				
E	16.80				
F	18.47				
G	20.16				
H	21.84				
J	23.53				
K	25.24				
L	26.00				

Table 2: Measured Pressure Distribution

Tube No.	Q = m^3/s $(u_2)^2/2g$ = mm		
	h_n	$h_n - h_1$	$\frac{h_n - h_1}{(u_2)^2/2g}$
A (1)			
B			
C			
D (2)			
E			
F			
G			
H			
J			
K			
L			

Table 3: Water level of piezometer tubes A (1) and D (2)

Qty (L)	t (sec)	h_1 (mm)	h_2 (mm)	Q_{exp} (m^3/s)	(h_1-h_2) (m)	$(h_1-h_2)^{1/2}$ ($m^{1/2}$)	Q_{ideal} (m^3/s)
25							
25							
25							
25							
25							
25							

Table 4: Coefficient of Venturi meter

Experimental Q (m^3/s)	Ideal Q (m^3/s)	C