EXPERIMENT VENTURIMETER

Objectives, Venturimeter:
  a) Understand Bernoulli’s Law as it applies to flow measurement devices
  b) Understand how you can use a pressure difference (water column) between 2 different cross sectional areas of flow to calculate a flowrate and compare it to a known flowrate obtained by filling a tank over a recorded known time interval
  c) Appreciate how this device may be used in industry to measure incompressible fluid flow
  d) Be able to use a measuring tank to calibrate device and therefore find a coefficient of discharge “C” for meter (correction factor)
  e) Place the data for 5 different flow-rates on an Excel spreadsheet and graph flowrate Q (y-axis) vs. Δh (x-axis). Include correction factor “C” in your plot.
  f) Explain how frictional losses effect readings

Read the following BEFORE starting:

1. Objective:
To calibrate the given Venturimeter.

2. APPARATUS:
Venturimeter, Measuring Tank, Manometer, Steady supply of water.

3. THEORY:
The Venturimeter is used to measure the discharge along a pipe. The fluid flowing in the pipe is led through a contraction section to a throat, which has a smaller cross-sectional area than the pipe, so that the velocity of the fluid through the throat is higher than that in the pipe. This increase of velocity is accompanied by a fall in pressure, the magnitude of which depends on the rate of flow, so that by measuring the pressure drop, the discharge may be calculated. Beyond the throat the fluid is decelerated in a pipe of slowly diverging
section shows the arrangement of the VenturiMeter, which is manufactured in aluminum. Water enters via the bench supply valve and passes through a flexible hose into the meter. Beyond the control valve, which is just downstream of the meter, a further flexible hose leads to the measuring tank. At various points along the length of the convergent-divergent passage of the Venturi, piezometer tubes are drilled into the wall and connected to vertical manometer tubes mounted in front of a scale marked in millimeters. The manometer tubes connect at their top ends to a common manifold in which the amount of air may be controlled by a small air valve at one end.

The whole assembly of Venturi meter, manometer tubes, scale and manifold is supported on a base mounted on adjustable screwed feet. It may be noted that in the usual form of Venturi meter intended for flow measurement, pressure tappings are made only at the entrance and at the throat, as these two readings suffice to measure the discharge. The larger number of tappings on this experimental Venturi tube is intended to show the distribution of pressure along the length of the convergent-divergent passage. The apparatus consist of a flow bench that allows water flow to the venture meter. Inside the flow bench is weighing tank connected to one end of a lever arm. The end of the lever arm protrudes from the side of the flow bench so that the amount of weight on this end of the lever arm may be adjusted (as shown in Figure 12.2). The purpose of the lever arm is to measure the actual mass flow rate of water flowing through the measuring devices. When using the hydraulic bench, placing weight on the lever arm closes the trip valve of the inner tank. When water entering the tank is sufficiently heavy enough to counterbalance the weight on the arm, the arm will rise and the trip valve will open.
Dividing the mass of water contained in the tank by the amount of time it takes for the internal tank to fill will yield the actual mass flow rate. Since the adjustable weight end of the lever arm has a three-to-one advantage over the water tank end, the mass of the water in the tank will equal three times the mass added to the lever arm. The weight of the hanger is accounted for in the design of the equipment; therefore, do not add the weight of the hanger to weights placed on the hanger.

Consider the flow of an incompressible fluid through the convergent-divergent pipe shown in Figure 2. The cross-sectional area at the upstream section 1 is $a_1$ and at throat section 2 is $a_2$. 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](image)

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:

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

(1)
in which $u_1$, $u_2$ and $u_n$ are the velocities of flow through sections 1, 2 and $n$. The equation of continuity is:
\[ u_1 a_1 = u_2 a_2 = u_n a_n = Q \] (2)

in which $Q$ 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 (2) becomes:
\[ Q = a_2 \times \frac{2g(h_1 - h_2)}{\sqrt{1 - \left( \frac{a_2}{a_1} \right)^2}} \] (3)

In practice, there is some loss of energy between sections 1 and 2, and the velocity is not absolutely constant across either of these sections. As a result, the measured values of $Q$ usually fall a little short of those calculated from Equation (3) and it are customary to allow for this discrepancy by writing:
\[ Q = C a_2 \times \frac{2g(h_1 - h_2)}{\sqrt{1 - \left( \frac{a_2}{a_1} \right)^2}} \] (4)

in which $C$ 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 given meter it may vary slightly with the discharge, but usually lies within the range 0.92 to 0.99.

The ideal pressure distribution along the convergent divergent pipe may be seen from Bernoulli’s Equation 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, i.e.

\[
\frac{h_n - h_1}{(u_2^2 / 2g)} = \frac{u_1^2 - u_n^2}{u_2^2}
\]

Substituting on the right hand side area ratios in place of velocity ratios from the equation of continuity 2, the ideal pressure distribution becomes:

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

Where, \(a_1\) = area of the inlet
\(a_2\) = area of the throat.
\(g\) = acceleration due to gravity.
\(h\) = \(h_1 - h_2\) = differential manometer reading
\(C\) = co-efficient of discharge.

4. PROCEDURE:
1- Make sure the air purge valve on the upper manifold is tightly closed.

2- Set both apparatus flow control and bench supply valve to approximately 1/3 their fully open positions.

3- Switch on bench supply valve and allow water to flow. (Tap manometer tubes in order to remove air bubbles from apparatus.)

4- Close apparatus flow control valve.

5- Release air purge valve to allow water to rise approximately 2/3 the way up the manometer tubes.

6- Open apparatus flow control valve to obtain full flow. (At this condition the pressure difference between the Venturi inlet [A] and throat [D] is approximately 240mm.

7- Make 5 runs, increasing flowrate from minimum to maximum. Also measure \(h_1\) and \(h_2\). This is your raw data. At each flow rate fill tank over timed interval. This is your known standard which you will use to calibrate device and find "C", the correction factor coefficient, that is used to in flow equation above, to make meter read correctly.

\(h_1\) is the height of water in manometer tube \(A\) (inlet) and \(h_2\) is the height of water in manometer tube \(D\) (throat). Vary the flow rates so that \((h_1 - h_2)\) goes from approximately 240mm to 0mm. Use 2-2 kg weights on
balance arm (tank). When tank balances with arm, there will be 12 kg water in tank, due to a 3:1 ratio on the arm. Recall that water has a density of 1000 kg/m$^3$. By timing the time to fill tank, you can get mass flowrate (known value) to find “C” correction factor. Use Equation (3) above to derive calculated flowrates. Put all data on spreadsheet (see below) and plot calculated and known flowrates for the 5 tests. Calculate “C” at each of the 5 flowrates.

5. OBSERVATIONS:-

Diameter of inlet=internal diameter of the pipe=d$_1$= m.

Area at the inlet a$_1$=$\pi d_1^2$ / 4= m$^2$.

Diameter at the throat d$_2$ = meter.

Area at a$_2$ = $\pi d_2^2$ / 4 = m$^2$.

<table>
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<th>Venturi Specifications</th>
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<td>Piezometer Tube No.</td>
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<td>A(1)</td>
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<td>B</td>
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<td>C</td>
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Discussion of Results:
Use spreadsheet similar to one shown to enter data and do calculations (equations 3 and 4). Also do plots showing flowrates at each of the 5 trials. Make sure you use consistent units!!
<table>
<thead>
<tr>
<th>Name</th>
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<th>D</th>
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<th>F</th>
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