

**Faculty of Engineering and Technology**

**Mechanical Engineering Department**

**Fluid Mechanics laboratory**

**ENME312**

**Experiment #3**

**Venturi-Meter apparatus**

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**Abstract**

 The Venturi-Meter is a differential pressure flow meter, used to find out the flow rate of water. A Hydraulic Bench was used to supply water and find the experimental Mass Flow Rate.

 It contains 11 vertical manometers that measures the head at different cross-sectional areas. Those readings are recorded in millimeter in a table per each run. Multiple runs can be done by changing the flow rate by a side valve, each time the readings differ and the mass flow rate too. The Hydraulic Bench measures the flow rate through recording the time it takes water to equalize the level of a certain weight as shown in Figure 1.

 The **Aim** of the experiment is to measure the Flow Rate of a liquid using the Venturi-Meter instrument, and a hydraulic bench through preforming multiple runs.

 The experiment revolves about recording readings of manometers at different areas, which can be worked out to find the Theoretical Flow Rate. Also, the Experimental Flow Rate can be found by recording mass and time for a certain flow. In order to conduct this experiment two main **Principles** are taken into consideration which are *Bernoulli Equation* and *Continuity Equation*.

 As a **Result**, the values of Qtheoretical and Qexperimental were found. So, the discharge coefficient for all runs was found and multiple relations and graphs were drawn.

**Objectives**

To Measure:

* Mass of the pieces put to hold up the water tank and the arm length.
* The time for water to equalize the mass \* arm length.
* The manometer readings in each run.
* Cross-Sectional areas at key points.

To Analyze:

* How the readings change with the change of flow rate.
* How the time needed to fill the tank changes as flow rate changes.
* Different arm length gives different time reading.
* The behavior of Discharge Coefficient against Flow Rate.

To Determine:

* Experimental and Theoretical Flow Rates for each run using two readings.
* The Slope of Qexp vs Qth graph (Discharge Coefficient).
* The Flow Pressure and Velocity as functions of Venturi length.

**Sample Calculation:**

 As previously mentioned, Bernoulli and Continuity equations should be used. So:

$\frac{V1^{2}}{2g}+h1= \frac{V2^{2}}{2g}+h2= \frac{Vn^{2}}{2g}+h$ (1)

* h: Water head at a certain point [m].
* u: Velocity of the fluid at a certain point [m/s].
* g: Acceleration due to gravity which equals 9.81 [m/s2].

$Q=A1V1=A2V2=AnVn$ (2)

* *a1*: Cross-section area of a certain point [m2].

 By combining (1) and (2) we get the following formula for Theoretical Value of Q and v:

$V2= \sqrt{\frac{2g\left(h1-h2\right)}{1-\left(\frac{a2}{a1}\right)^{2}}}$ (3)

$Q=Cd×a2 \sqrt{\frac{2g\left(h1-h2\right)}{1-\left(\frac{a2}{a1}\right)^{2}}}$ (4)

 Experimental value of Q can be found by:

$Q=\dot{\frac{m}{ρ}}$ (5)

Also, the discharge coefficient is:

$Cd=\frac{Qexp}{Qth}$ (6)

A sample calculation of run 5 in our data is as follows:

 T = 32.53 s, h1 = 0.169 m, h2 = 0.036 m, a1 = 530.9 mm2, a2 = 201.1 mm2, Mass = 4 kg, arm = 3 m.

 So experimentally by (5):

$\dot{m}=\frac{4 ×3}{32.53}$ = 0.37 🡪 $Q=\frac{\dot{m}}{ρ}=0.000369 m^{3}/s$

And theoretically by (3) and (4):

$$V2 =\sqrt{\frac{2g\left(0.169-0.036\right)}{1-\left(\frac{201.1}{530.9}\right)^{2}}}= 1.74 m/s$$

$$Q=V\_{2}a\_{2}= 1.74×201.1×10^{-6}=0.000351 m^{3}/s$$

Finally, the Discharge Coefficient by (6):

$$Cd=\frac{0.000369}{0.000351}=1.0515$$

**Results:**

Table (1): Main Data Readings

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Run** | **time (sec)** | **ha (m)** | **hb (m)** | **hc (m)** | **hd (m)** | **he (m)** | **hf (m)** | **hg** **(m)** | **hh (m)** | **hj (m)** | **hk m)** | **hl (mm)** |
| **1** | 25.32 | 0.24 | 0.222 | 0.13 | 0.002 | 0.25 | 0.99 | 0.14 | 0.165 | 0.184 | 0.196 | 0.204 |
| **2** | 26.66 | 0.211 | 0.196 | 0.117 | 0.005 | 0.23 | 0.88 | 0.123 | 0.146 | 0.163 | 0.174 | 0.18 |
| **3** | 27.82 | 0.194 |  |  | 0.014 |  |  |  |  |  |  |  |
| **4** | 28.38 | 0.186 |  |  | 0.026 |  |  |  |  |  |  |  |
| **5** | 32.53 | 0.169 |  |  | 0.036 |  |  |  |  |  |  |  |
| **6** | 34.53 | 0.163 |  |  | 0.052 |  |  |  |  |  |  |  |
| **7** | 40.1 | 0.155 |  |  | 0.065 |  |  |  |  |  |  |  |
| **8** | 44.87 | 0.144 |  |  | 0.074 |  |  |  |  |  |  |  |
| **9** | 52.91 | 0.135 |  |  | 0.084 |  |  |  |  |  |  |  |
| **10** | 63.35 | 0.129 |  |  | 0.094 |  |  |  |  |  |  |  |

Table (2): Q Calculations and variables.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Exper. |  |  |  | Theo |  |  |
| **M(exp) (kg/s)** | **Q (m3/s)** |  | **ΔH (m)** | **v2 (m/s)** | **Q (m3/s** |  | **Cd (unitless)** |
| 0.47 | 0.000474 |  | 0.24 | 2.33 | 0.000469 |  | 1.01 |
| 0.45 | 0.00045 |  | 0.21 | 2.17 | 0.000437 |  | 1.03 |
| 0.43 | 0.000431 |  | 0.18 | 2.03 | 0.000408 |  | 1.06 |
| 0.42 | 0.000423 |  | 0.16 | 1.91 | 0.000385 |  | 1.10 |
| 0.37 | 0.000369 |  | 0.13 | 1.74 | 0.000351 |  | 1.05 |
| 0.35 | 0.000348 |  | 0.11 | 1.59 | 0.000321 |  | 1.08 |
| 0.30 | 0.000299 |  | 0.09 | 1.44 | 0.000289 |  | 1.04 |
| 0.27 | 0.000267 |  | 0.07 | 1.27 | 0.000255 |  | 1.05 |
| 0.23 | 0.000227 |  | 0.05 | 1.08 | 0.000217 |  | 1.04 |
| 0.19 | 0.000189 |  | 0.04 | 0.89 | 0.00018 |  | 1.05 |

Figure (1): Q experimental (m3/s) vs Q theoretical (m3/s) graph and slope.

Figure (2): Discharge Coefficient (unitless) vs Q theoretical graph (m3/s).

Figure (3): Fluid Pressure (m) as a function of Venture pipe longitudinal distance(mm).

**Discussion of Results:**

 The main purpose from the Venturi-Meter experiment was to find out Flow Rate (Q) Experimentally and Theoretically, so monometer measurements and areas had to be recorded to work out the Theoretical Value. Meanwhile, Mass and Time were recorded to find the Experimental value. For accuracy, multiple runs were conducted at different water flow rates.

 Our sample calculation was about Run No. 5, where we started by recording the *Mass* (4 kg \* 3) and the *Time* water had taken to left the mass (32.53 s). Thus, Qexp was calculated to be (0.000369 m3/s). Alongside*, Manometer Measurements* (0.169 m & 0.036 m) and *Areas* (530.9 mm2 & 201.1 mm2) were recorded for two points. Therefore, Qtheo was worked out to be (0.000351 m^3/s). The rest of data is recorded in Table (1), and Flow Rates are calculated in Table (2).

 Head Difference between the points was reduced each run to observe the behavior of the flow, And the **Relationship** was that less head difference is made due to smaller water flow rate. Also, longer time needed to left the mass is noticed at smaller water flow rate.

 The most **observable trend** is that Qth and Qexp readings increases in a linear way with a slope close to 1 as observed in Figure (1). Meanwhile, the discharge coefficient value constant behavior against Qth is demonstrated in Figure (2). Finally, Pressure Head values along the venturi behaves in a concave up curve as show in Figure (3), with a final reading less than the first one due to losses.

The Final Results that have been calculated are pretty logical and close both Theoretically and Experimentally. Also, the value of Cd remained constant in all runs which eliminates any possible Blunders. However, our experimental values turned to be larger than theoretical ones, which also yields a value of Cd > 1.

 Normally Cd should be < 1 by a bit, so sources of errors should be stated to be taken into consideration next times. And here are some possible error sources:

1. Instrumental Errors: errors because of inaccuracies in the machine.
2. Operator Errors: errors produced by misreading or mismeasuring values (e.g. Manometer and stopwatch values).
3. Systematic Errors: Loss of digits when dealing with significant figures.
4. Calculation Errors: Error in equations inserted into the software to find values and/or incorrectly copying numbers.

**Conclusion:**

 As a result, we have gotten our flow rate values for each run which can be applied to help us with our purpose from finding it. Getting greater than 1 Discharge Coeff. is **not** considered acceptable, which means that the experiment can be reconducted again with trying to eliminate possible sources of errors. The error here is thought to be systematic since all the values have a wrong values and all of these values are shifted similarly.

**Applications:**

 Flow Rate can sometimes be important to measure for certain fluids, that is why Venturi-Meter is used in different fields like:

* Industrial: Measuring Oil and Gas flows to conduct certain calculations.
* Aerospace: Many airplanes use Venture and similar instruments to measure the outside air flow hitting the outer body surface.
* The flow of chemicals in pipelines.
* Water treatment plants, venturi-meter is used to measure the pressure difference and the discharge of water.