Wentworth Institute of Technology

Department of Civil Engineering

CIVE 3000L - 01 Fluid Mechanics

Technical Memorandum #4

Lab Title: Venturi Meters

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Objective:

The objective of the Venturi Meter lab is to understand how Bernoulli's Equation can be applied to the flow of water through a tube. By understanding the validity of this equation and relating it to tapered circular pipes, students can record measurements and complete calculations to understand concepts such as total energy, head space, velocity heads, volumetric flow, and gradient levels.

Results:

To view the lab results measurements from this laboratory experiment, view the following tables. The information from Trial 1 is displayed in Tables 1.0, 1.1 and 1.2, while information from Trial 2 is displayed in Tables 1.3, 1.4, 1.5, and information from Trial 3 is displayed in Tables 1.6, 1.7, and 1.8.

Table 1.0 Venturi Meter Measurements Trial 1

Tube Number	Diameter Cross Section(mm)	Diameter Cross Section(mm)	Manometer Levels (mm)	Manometer Levels (m)	Area of Tube (m^2)
1	25	0.025	225	0.225	0.000490874
2	13.9	0.0139	218	0.218	0.000151747
3	11.8	0.0118	211	0.211	0.000109359
4	10.7	0.0107	205	0.205	8.99202E-05
5	10	0.01	195	0.195	7.85398E-05
6	25	0.025	196	0.196	0.000490874

Table 1.1 Volumetric Flow Rate Calculations Trial 1

Volume Filled (L)	1
Time (s)	18.62
Volumetric Flow, Q (L/s)	0.053705693
Volumetric Flow, Q (m^3 /s)	5.37057E-05

Table 1.2 Venturi Meter Calculations Trial 1

Velocity (m/s)	Total Energy Tapping Port (m)	Pressure Head (m)	Elevation Head (PE)	Velocity Head (KE) (m)
0.109408339	0.225610101	0.225	-	0.000610101
0.353916525	0.224384144	0.218	-	0.006384144
0.491096035	0.22329232	0.211	-	0.01229232
0.597259253	0.223181377	0.205	-	0.018181377
0.683802119	0.218832076	0.195	-	0.023832076
0.109408339	0.196610101	0.196	-	0.000610101

Table 1.3 Venturi Meter Measurements Trial 2

Tube Number	Diameter Cross Section(mm)	Diameter Cross Section(mm)	Manometer Levels (mm)	Manometer Levels (m)	Area of Tube (m^2)
1	25	0.025	160	0.16	0.000490874
2	13.9	0.0139	150	0.15	0.000151747
3	11.8	0.0118	143	0.143	0.000109359
4	10.7	0.0107	134	0.134	8.99202E-05
5	10	0.01	115	0.115	7.85398E-05
6	25	0.025	120	0.12	0.000490874

Table 1.4 Volumetric Flow Rate Calculations Trial 2

Volume Filled (L)	1
Time (s)	15.2
Volumetric Flow, Q (L/s)	0.065789474
Volumetric Flow, Q (m^3 /s)	6.57895E-05

Table 1.5 Venturi Meter Calculations Trial 2

Velocity (m/s)	Total Energy Tapping Port (m)	Pressure Head (m)	Elevation Head (PE)	Velocity Head (KE)
0.134025215	0.160915533	0.16	-	0.000915533
0.433547744	0.159580206	0.15	-	0.009580206
0.601592642	0.161446162	0.143	-	0.018446162
0.731642585	0.161283429	0.134	-	0.027283429
0.837657595	0.15076301	0.115	-	0.03576301
0.134025215	0.120915533	0.12	-	0.000915533

Table 1.6 Venturi Meter Measurements Trial 3

Tube Number	Diameter Cross Section(mm)	Diameter Cross Section(mm)	Manometer Levels (mm)	Manometer Levels (m)	Area of Tube (m^2)
1	25	0.025	287	0.287	0.000490874
2	13.9	0.0139	274	0.274	0.000151747
3	11.8	0.0118	260	0.26	0.000109359
4	10.7	0.0107	246	0.246	8.99202E-05
5	10	0.01	225	0.225	7.85398E-05
6	25	0.025	232	0.232	0.000490874

Table 1.7 Volumetric Flow Rate Calculations Trial 3

Volume Filled (L)	1
Time (s)	13.18
Volumetric Flow, Q (L/s)	0.075872534
Volumetric Flow, Q (m^3 /s)	7.58725E-05

Table 1.8 Venturi Meter Calculations Trial 3

Velocity (m/s)	Total Energy Tapping Port (m)	Pressure Head (m)	Elevation Head (PE)	Velocity Head (KE)
0.154566257	0.288217672	0.287	-	0.001217672
0.499994363	0.286741813	0.274	-	0.012741813
0.693794246	0.284533662	0.26	-	0.024533662
0.84377597	0.282287354	0.246	-	0.036287354
0.966039108	0.272565319	0.225	-	0.047565319
0.154566257	0.233217672	0.232	-	0.001217672

Sample Calculations:

P = γh; P = pressure (kg / ms^2), h = height (m), γ = specific weight (kN/ m^3)

H = $\frac{P}{\gamma}$, where γ = 9.81 kN/ m^3

$\frac{P_1}{\gamma_1} + Z_1 + \frac{V^2{}_1}{2g} = \frac{P_2}{\gamma_2} + Z_2 + \frac{V^2{}_2}{2g}$; Z = elevation (m), V = velocity (m/s), g = gravity

$Z_1 = Z_2;\ E_1 = \frac{P_1}{\gamma_1} + Z_1 + \frac{V^2{}_1}{2g}; E_2 = \frac{P_2}{\gamma_2} + Z_2 + \frac{V^2{}_2}{2g}$

$\frac{P_1}{\gamma_1} + \frac{V^2{}_1}{2g} = \frac{P_2}{\gamma_2} + \frac{V^2{}_2}{2g}$

$E_1 = E_2$; E = energy

Q = $\frac{Volume}{Time}$; Q = volumetric flow (L/s or m^3 / s) where 1,000 L = 1 m^3

Q = $\frac{Velcoity}{Area}$

Velocity = $\frac{Q}{Area}$

Discussion:

When analyzing the total energy at the different tapping ports, it becomes apparent that these measurements are similar in value. For Trial 1, the energies range from 0.226 m to 0.197 m, while Trial 2 ranges from 0.161 m to 0.151 m, while Trial 3 ranges from 0.288 m to 0.233 m. These values can be reviewed in Tables 1.2, 1.5, and 1.8

View the sample calculations portion of this lab to understand how to calculate the 1 mm difference in the manometer.

When analyzing the velocity heads, pressure heads and elevation heads, it is important to consider the value of each. The velocity head represents the bulk motion of the fluid or the kinetic energy, while the pressure head represents the height of liquid in each tube, while the elevation head represents the potential energy. The pressure head values represent the manometer levels, which range from 0.287 m to 0.115 m. Elevation head is able to be disregarded due to its equality on both sides of the sample calculation. Lastly, the velocity head ranges from 0.048 m to 0.0006 m.

Between trials, the flow rate, or Q, has an effect on both the upstream and downstream manometer total head values. As the Q value increases, the total head both upstream and downstream also increases from the venturi meter, creating a direct relationship.

Diagram 1.9 Venturi Meter Diagram

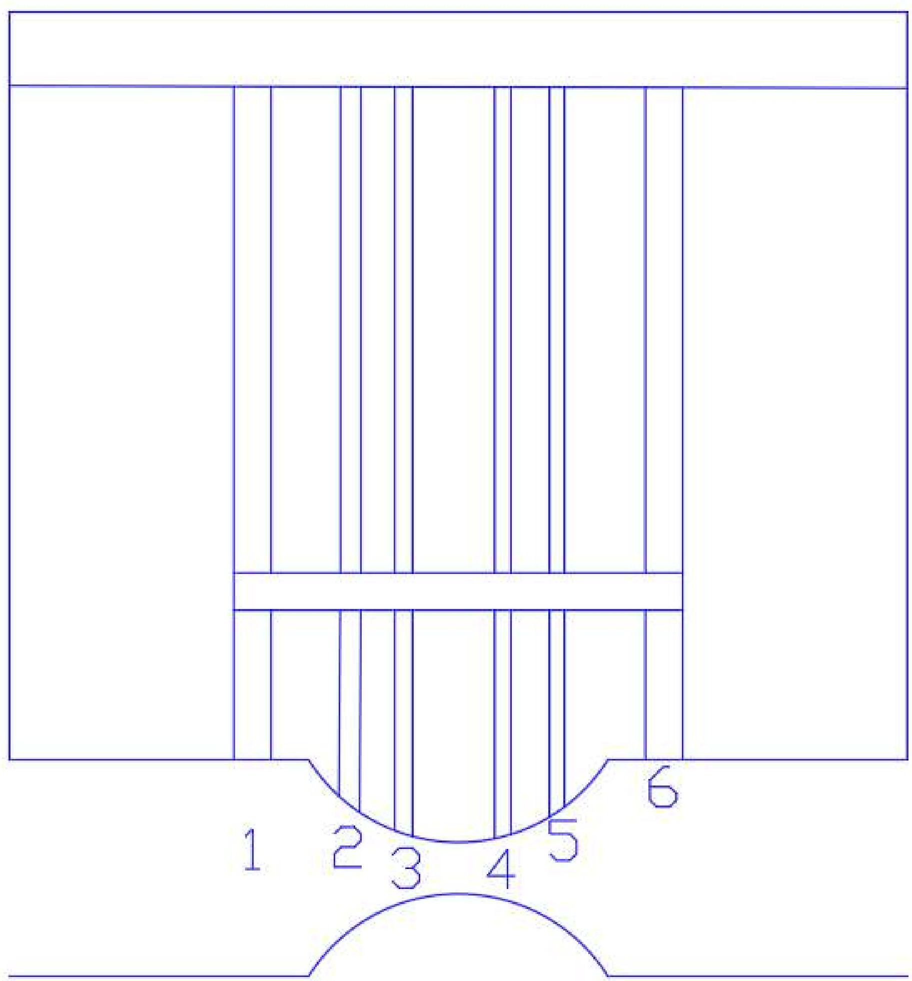


Diagram 1.10 Hydraulic Gradient Level & Energy Gradient Level

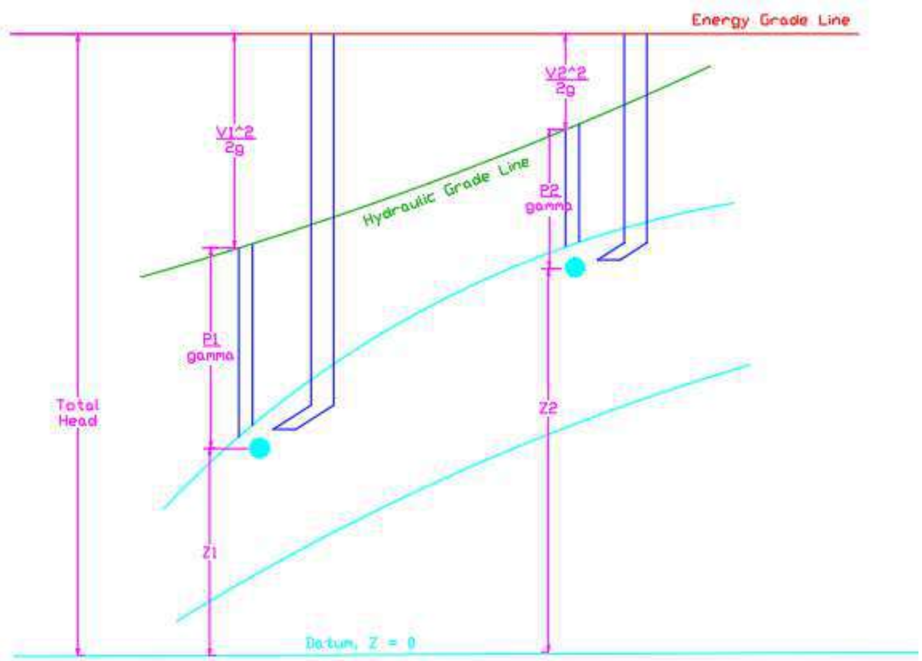
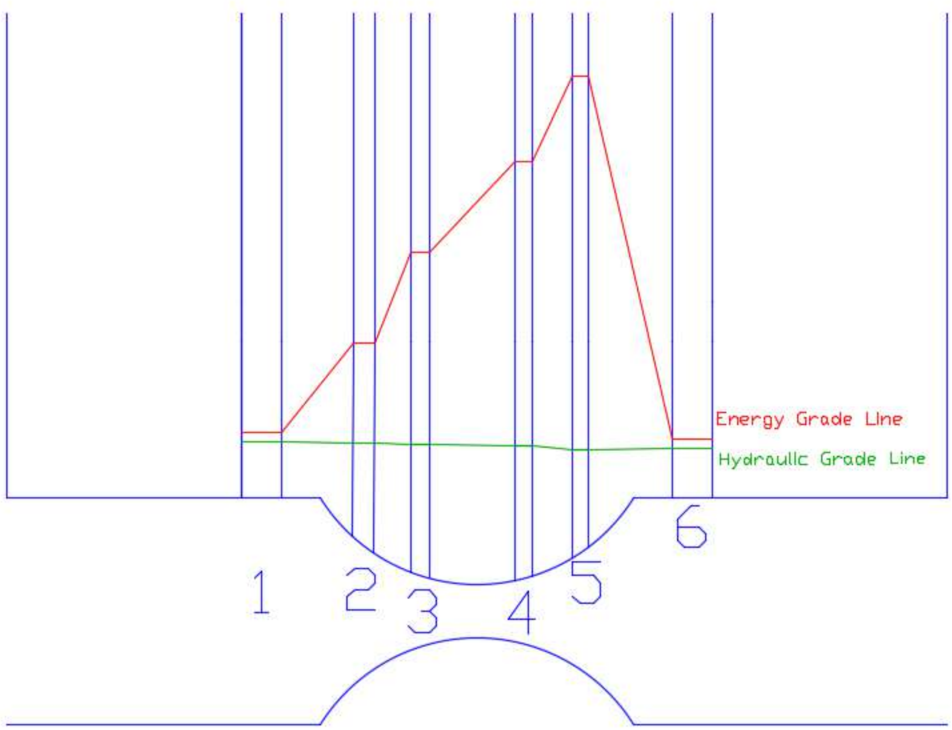


Diagram 1.11 Hydraulic Gradient Level & Energy Gradient Level with Actual Values



Conclusion:

This experiment satisfies the objective of understanding how Bernoulli's Equation can be used to help understand water flow through tubes. This experiment can be deemed successful, as the results indicate that a rise in the differential head values can be explained by an increase in the volumetric flow, proving the Venturi effect. The data also indicates that rubes with a larger diameter cross section experienced slower velocities, as anticipated.