RYERSON UNIVERSITY

Faculty of Engineering, Architecture and Science

Course Number	**MEC511**
Course Title	**Thermodynamics and Fluids**
Semester/Year	**Fall 2023**
Instructor	**Dr. J. Cao**

Lab/Tutorial Report NO.	12

Report Title	Lab 2, Venturi Flow

Section No.	01
Group No.	2b
Submission Date	Oct 20, 2023
Due Date	Oct 20, 2023

Name	Student ID	Signature*
Krish Patel	****91722	Krish
Nini Yang	****37659	Nini Yang
Mina Villella	****21521	Mina Villella
Matthew Trieu	****01365	Matt
Krisham Minhas	****31195	Krisham Minhas
Justin Zandstra	****37919	[illegible]

(Note: remove the first 4 digits from your student ID)

**By signing above you attest that you have contributed to this submission and confirm that all work you have contributed to this submission is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at:*

http://www.ryerson.ca/senate/policies/pol60.pdf.

Table of Contents:

Abstract:

The lab experiment aimed to use a Venturi meter to analyze water flow and determine the flow rate of an incompressible fluid. By applying Bernoulli's equation and pressure measurements from piezometers, calculate the theoretical velocity, flow rate, and Reynolds number. The Venturi meter's narrowing throat reduced flow area and increased velocity.

1.0 Introduction:

The lab focuses on exploring the Venturi flow meter's function through the application of Bernoulli's equation to determine the theoretical flow rate of a fluid using piezometer pressure measurements. This involves comparing theoretical calculations with actual flow rate measurements to derive the discharge coefficient, representing the ratio of actual to theoretical flow rates. To accomplish this, following equations will be utilized:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 \qquad (1)$$

Equation 1 pertains to Bernoulli's equation, which is a fundamental principle in fluid dynamics. Bernoulli's equation expresses the conservation of mechanical energy along a streamline for an ideal fluid flow. Here's a summary of the key variables and their meanings within the equation:

- P_1 and P_2: These represent the pressure at two different sections along a streamline
- Bernoulli's equation assumes that pressure changes along the streamline
- γ (gamma): It is the specific weight of the fluid
- V_1 and V_2: These stand for the velocity of the fluid at two different sections.
- g: Represents the gravitational acceleration
- z_1 and z_2: These denote the elevation heads at sections 1 and 2

$$V_1 A_1 = V_2 A_2 \qquad (2)$$

Equation 2 is the continuity equation, a fundamental principle in fluid dynamics. It states that the flow rate at one section must be equal to the flow rate at another section along a fluid streamline. Here's a summary of the key variables and their meanings within the equation:
- P_1 and P_2: These represent the pressure at two different sections along a streamline
- V_1 and V_2: These stand for the velocity of the fluid at two different sections.

$$V_2 = \sqrt{\frac{2g[(p_1 - p_2)/\gamma + (z_1 - z_2)]}{1 - (A_1/A_2)^2}} \tag{3}$$

Equation 3 represents an application of Bernoulli's equation with the continuity equation substituted in, and it's then isolated to solve for the velocity at section 2. It appears to be related to a specific scenario or problem involving fluid flow, likely using a Venturi meter.

$$V_{2a} = C_v V_2 = C_v \sqrt{\frac{2g[(p_1 - p_2)/\gamma + (z_1 - z_2)]}{1 - (A_1/A_2)^2}} \tag{4}$$

To obtain the overall formula for the actual velocity (V2a) in a Venturi flow meter, substitute the expression for V2 from Equation 3 into CvV2. This substitution allows to express V2a in terms of the various parameters involved.

$$D_H = \frac{4A_1}{P_{wet}} \tag{5}$$

The definition of hydraulic diameter is provided as "4 times the cross-sectional area (A) divided by the wetted perimeter (P).

$$R_e = \rho V_1 \frac{D_H}{\mu} \tag{6}$$

Equation 6 provides a way to calculate the Reynolds number (Re) for a fluid flow, specifically for water. The Reynolds number is a dimensionless quantity that characterizes the flow regime of a fluid and is essential in fluid dynamics. Here's a summary of the variables and their descriptions:

- ρ (rho): Represents the density of water
- V_1: Stands for the velocity of water at a specific point in the flow
- D_H: Given by Equation 5, D_H is a specific parameter
- μ: Represents the dynamic viscosity of the fluid

2.0 Apparatus:

The following equipment was used to perform the experiment:

- Water Tank
- Water
- Venturi
- Seven Piezometers
- Outlet Valve
- Blue Dye

3.0 Procedure:

1. Adjust the flow through the Venturi to give the maximum difference between the manometer readings at the upstream location and at the Venturi throat.
2. Record all the manometer readings.
3. Measure the actual volume flow rate (Q) of the water. Make at least two measurements and average the results.
4. Adjust the flow until the difference between upstream manometer reading and the throat manometer reading is one half of the full flow value.
5. Repeat steps 2 and 3 for this lower flow rate.

4.0 Results and Calculations:

MEC511 Lab 2 Venturi Flow Meter

Water temperature: **10°C**

Table 1: Sample experimental data at a flow rate of 0.259 litres per second.

Piezometer	A	B	C	D (throat)	E	F	G
Water column height (m)	0.496	0.482	0.448	0.344	0.407	0.429	0.438

Table 2: Sample experimental data at a flow rate of 0.157 litres per second.

Piezometer	A	B	C	D (throat)	E	F	G
Water column height (m)	0.516	0.513	0.498	0.456	0.481	0.490	0.494

Sample Calculations and Formulas:

Formulas:

Pressure:

$P = \gamma h = pgh\,[\frac{N}{m^2}]$

$g = 9.81\frac{m}{s^2},\ h\ is\ in\ meters\ and\ p_{H20} is\ 1000\frac{kg}{m^3}$

Differential pressure:

$P(A) - P(D)$

Volume Flow Rate(Q):

$Q = V\,A\,(\frac{m^3}{s})$

- V velocity
- A = πr^2 (m^2)

Theoretical velocity:

$$V_{theory} = \sqrt{\frac{2g[\frac{(P_1-P_2)}{\gamma+(Z_1-Z_2)}\}}{(1-(\frac{A_2}{A_1})^2)}}$$

Where both Z's are on the same lvl so 0

$$V_{2a} = C_v V_2 = C_v\sqrt{\frac{2g[(p_1-p_2)/\gamma+(z_1-z_2)]}{1-(A_1/A_2)^2}}$$

$$D_H = \frac{4A_1}{P_{wet}}$$

$$R_e = \rho V_1\frac{D_H}{\mu}$$

Q=0.259

Piezometer	P(A)	P(B)	P(C)	P(D)(Throat)	P(E)	P(F)	P(G)
Gauge Pressure (N/m^2)	4866	4728	4395	3375	3993	4209	4297

Q=0.157

Piezometer	P(A)	P(B)	P(C)	P(D)(Throat)	P(E)	P(F)	P(G)
Gauge Pressure (N/m^2)	5062	5033	4885	4473	4719	4807	4846

2. Theoretical velocity and Theoretical flow rate calculations for table 1.

$$V_{theory} = \sqrt{\frac{2g[\frac{(P_1-P_2)}{\gamma+(Z_1-Z_2)}}{(1-(\frac{A_2}{A_1})^2)}}$$

$A_1 = d \times l = 12.7\,x\,10^{-3} \times 31.75 \times 10^{-3} = 4.03 \times 10^{-4}\ m$

$A_2 = d \times l = 12.7 \times 10^{-3} \times 12.7 \times 10^{-3} = 1.61 \times 10^{-4}\ m$

$Z_1 = 0.496m$

$Z_2 = 0.344m$

$P_1 = P_A = \gamma_{water} Z_1 = 9807(0.496) = 4864.27Pa$

$P_2 = P_D = \gamma_{water} Z_2 = 9807(0.33) = 3373.608Pa$

$$\sqrt{\frac{2(9.81)[(\frac{4864.272-3373.608}{9807}) + (0.496-0.344)]}{(1-(\frac{1.61\times10^{-4}}{4.03\times10^{-4}})^2)}}$$

$V_2 = 1.883$ m/s

$$T = \frac{T_1+T_2}{2} = 9.82\ s$$

$$v1 = \frac{L}{time} = \frac{0.496m}{9.82\ s} = 0.0505\ m/s$$

Q = $V_2 A_2 = (1.8837 m/s)(1.61 \times 10^{-4} m)$
Q = 3.03 x 10^{-4} m^3/s

3. Reynolds Number for table 1.

$R_e = \rho V_1 \frac{D_H}{\mu}$ $\qquad D_H = \frac{4A_1}{Pwet}$

$\mu = 1.12 \times 10^{-3}\ Ns/m^2$

$R_e = (1000)(0.0505 m/s)\frac{D_H}{1.12x10^{-3}}$ $\qquad D_H = \frac{4(4.03 \times 10^{-4})}{[(2\times(12.7\times10^{-3}))+(2\times(31.75\times10^{-3}))]}$

R_e = 817.59

4. Venturi Discharge coefficient (C_V) for table 1.

$C_V = Q_A/Q$ = 0.259/0.303
C_V = 0.852

5. Actual fluid velocity for

V = Q_A / A

Manometer	Height (m)	Area (m^2)	Actual Velocity Q = 0.259	Actual Velocity Q = 0.157
A	0.0317	0.000403	0.644	0.388
B	0.0254	0.000323	0.807	0.481
C	0.0190	0.000241	1.069	0.649
D	0.0127	0.000161	1.602	0.977
E	0.0190	0.000241	1.069	0.649
F	0.0254	0.000323	0.807	0.481
G	0.0317	0.000403	0.644	0.388

6. Theoretical height of manometers

$$V_{2a} = C_v V_2 = C_v \sqrt{\frac{2g[(P_1 - P_2)/\gamma + (z_1 - z_2)]}{(1 - (A_2/A_1)^2)}}$$

$Z_1 = Z_2$

$Z_1 - Z_2 = 0$

$$P_2 = P_1 - \frac{1}{2g}\gamma(\frac{V_{2a}}{C_V})^2(1 - (\frac{A_2}{A_2})^2)$$

$$pgh_2 = pgh_1 - \frac{1}{2g}\gamma(\frac{V_{2a}}{C_V})^2(1 - (\frac{A_2}{A_2})^2)$$

$$h_2 = h_1 - \frac{1}{2g^2p}\gamma(\frac{V_{2a}}{C_V})^2(1 - (\frac{A_2}{A_2})^2)$$

$$h_2 = h_1 - \frac{1}{2g}(\frac{V_{2a}}{C_V})^2(1 - (\frac{A_2}{A_2})^2)$$

Manometer	Theoretical Height(m) Q=0.259	Theoretical Height(m) Q=0.157
A	0.480	0.502
B	0.461	0.492
C	0.408	0.453
D	0.303	0.343
E	0.365	0.453
F	0.404	0.492
G	0.425	0.502

5.0 Discussion:

1. Why is the actual fluid velocity different from the theoretical velocity predicted by Bernoulli's equation?

The actual fluid velocity is lower than the theoretical velocity due to the existence of viscosity. Bernoulli's equation assumes that the fluid used in the experiment is inviscid, which is impossible for fluids in reality. Although the viscosity of water is small, its presence still effects the final velocity.

2. Is the discharge coefficient within the expected range? If not, discuss possible reasons for the discrepancy.

Ideally, the discharge coefficient would be 1 as it would imply that theoretical and experimental flowrate are nearly identical. However, the calculated discharge coefficient is 0.852, which yields a 14.8% error. With a Reynolds number value of 817.59, a discharge coefficient of 0.852 is well within the acceptable range, as shown in the diagram below.

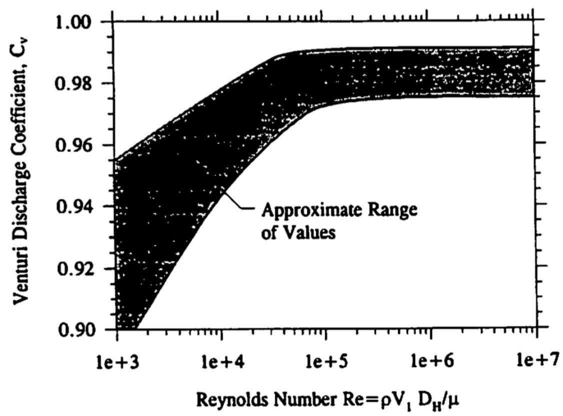

Figure 3: Approximate Range of Discharge Coefficients (C_v) for Venturi Flow Meters.

3. According to your results, where are the head losses the greatest in the Venturi flow meter?

According to the equation for total head loss, a larger velocity or a larger length will result in a larger total head value. On a Venturi meter, the highest velocity is experienced at the throat of the meter, which has the largest length value as well. Therefore, the greatest head losses will be located at the head of the Venturi meter. This theory was confirmed in the experiment, where the dyed liquid was lowest in the tube connected to the throat of the meter.

6.0 Conclusions:

To conclude, the goal of this lab was to study the incompressible flow through a Venturi flow meter and to use Bernoulli's equation to calculate the theoretical volume flow rate and estimate the Venturi discharge coefficient. To obtain the actual flow rate observed in the experiment, calculations were made by using piezometer pressure measurements corresponding to varying cross sectional areas at different points along the pipe. Differences between our calculated value and the theoretical value has been credited to the small effects of the viscosity of the water used in the experiment. The main conclusion that can be drawn from this experiment is that the Venturi meter is an excellent device used to analyze and determine several key characteristics of an incompressible fluid through the use of Bernoulli's equation.

7.0 References:

[1]Naylor, D., & Friedman, J. (n.d.). MEC511 Thermodynamics and Fluid Mechanics Laboratory Manual (R. Buddy, Ed.). Toronto, ON: Toronto Metropolitan University.