Experiment B2: Fluid Flow Measurements

MECHENG 2BA3

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L03 – 2BA3

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Objective

The objective of this lab is to observe and perform the calibration of fluid flow meters and compare various methods of flow measurement.

Theory

As seen in instructions

Procedure

Part A: Comparison of Three Flow Measurement Methodologies

1) Make sure that valves 1 to 8 are closed.
2) Adjust valve 9 such that the flow is directed to the reservoir (110L tank).
3) Open valves 4 and 7.
4) Open valves 1 and 8 slightly and turn on the main pump.
5) Adjust valves 1 and 8 in order to achieve a rotameter flow reading of approximately 6L/min.
6) Record the rotameter reading and the reading from the turbine meter in Table I.
7) Making certain that the small tank (40L) is empty, zero the scale using the "Tare" button. Adjust valve 9 such that the flow is redirected into the tank on the weight scale. Record the filling time using the stop watch provided (fill the tank to approximately half it's total capacity). Adjust valve 9 (while concurrently stopping the stop watch) to redirect the fluid back into the reservoir. Record the weight of the fluid in the tank. Empty the small tank by turning the drain pump on.
8) Repeat steps 5 through 7 for four additional flow rates increased at increments of approximately 6L/min as per the rotameter reading.
9) Turn off the pump

Part B: Calibrating an Orifice meter

1) Make sure that all valves (1 to 8) are closed
2) Adjust valve 9, so that run off is directed to the reservoir.
3) Open valves 2 and 5.
4) Open valves 1 and 8 slightly and turn on the main pump.
5) Adjust valves 1 and 8 in order to achieve as large a $h\Delta$ between manometers (H) and (L) as possible. Be careful to stay within a range that is readable when trying to take measurements. Valve 8 may need to be partially closed for a few seconds in order to force out any air bubbles in the manometers. However, make sure not to fully close valve 8.
6) Record the heights of manometers (H) and (L). Also record TRANS$h\Delta$ from the differential pressure transducer. Record the rotameter reading (Note: Table II has been provided, below, for this purpose).
7) Repeat steps 4 to 6 for four additional flow rates. Adjust the additional flow rates such that they are reasonably evenly spaced.
8) Turn off the pump

Part C: Calibrating a Venturi Meter

1) Make sure valves (1 to 8) are closed.
2) Adjust valve 9, so that run off returns to the reservoir.

3) Open valves 3, and 6.
4) Open valves 1 and 8 slightly and turn on the main pump.
5) Adjust valve 1 and 8 in order to achieve as large a hΔ between manometers (1) and (4) as possible. Be careful to stay within a range that is readable when trying to take measurements. Valve 8 may need to be partially closed for a few seconds in order to force out any air bubbles in the manometers. However, make sure not to fully close valve 8.
6) Record the heights of manometers (1) and (4) using Table III. Also record the Rotameter reading.
7) Record all manometer heights (i.e. 1 to 8) using Table IV. Also record the Rotameter reading.
8) Repeat steps 5 and 6 (not 7) for four additional evenly spaced flow rates.
9) Turn off the pump

Results & Discussion

Part A

	Rotameter	Turbine	Weight Scale		
Flow Setting	Q	Q (L/m)	mass	time (s)	Q
1	6	6.14	20.09	210.9	5.715505
2	12	11.92	20.17	101.9	11.87635
3	18	17.68	20.14	69.1	17.4877
4	24	24.12	20.23	51.13	23.73949
5	30	29.92	20.05	41.13	29.24872

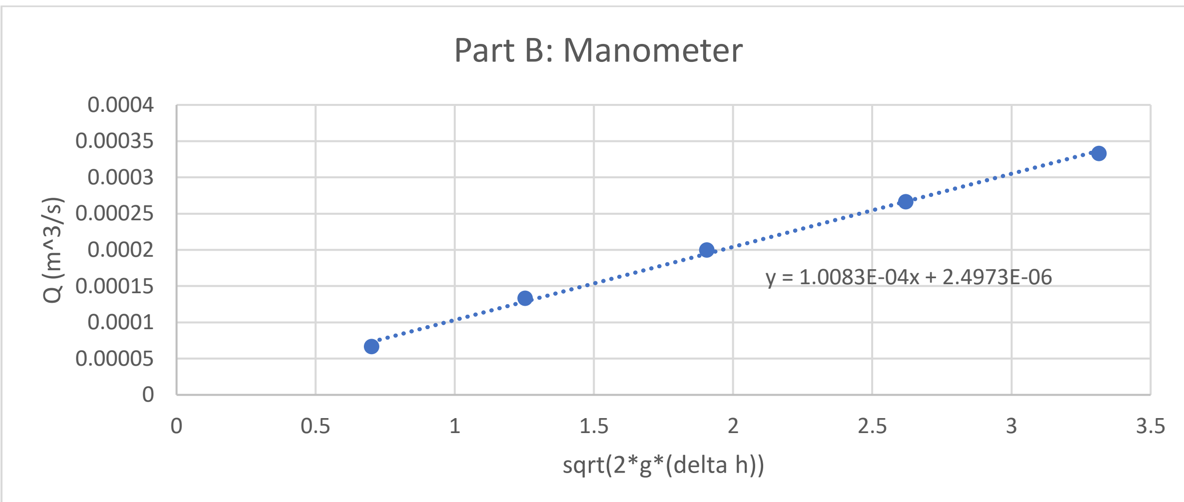
1) From the data collected and assuming the turbine meter takes "true" flow measurement, what is the maximum error introduced by using each of the other two methods of flow measurement (using the Rotameter, and fluid weight with time).

For fluid weight vs time, the main downfall is the introduction of human error. These factors of error are present because of the time needed to close the valve as well as the human reaction time on the press of the timer. In all, error is highly amplified when using this method. Concerning the measurement of the rotameter, the least count of the instrument is 2, which introduces a high degree of uncertainty in the measurement. An uncertainty of $\pm$ 1 is much higher than the uncertainty of the turbine meter, and even the combined uncertainty of the mass/time method (the sum of the relative uncertainties where the absolute uncertainties are ± 0.01 and ± 0.01 respectively).

Part B

Flow Setting	Rotameter Q (m^3/s)	Transducer delta H	Manometer Readings Upstream (H)	Downstream (L)	delta h (m)
1	6.6667E-05	0.01	36.5	34	0.025
2	0.00013333	0.07	70	62	0.08
3	0.0002	0.19	76.5	58	0.185
4	0.00026667	0.36	63	28	0.35
5	0.00033333	0.57	91	35	0.56

1) Plot Q versus sqrt(2g(dh)) . Determine the meter coefficient, given that a plot of Q ∝ sqrt(2g(dh)) should yield a linear relationship.



$$A_o = \pi \left(\frac{D_o}{2}\right)^2$$
$$A_o = \frac{\pi(0.5\ in * 0.0254\ m)^2}{4}$$
$$A_o = 1.267 * 10^{-4}\ m^2$$
$$Q_{orifice} = K * A_o\sqrt{2g\Delta h}$$
$$1.0083 * 10^{-4} = K * A_o$$
$$K = 0.796$$

2) Comment on the appropriateness of using Δh from the manometers to compute the meter coefficient rather than using $h\Delta$_trans from the differential pressure transducer. Given your experience in the lab and the information taught in class which measurement would you suggest using (justify your answer).

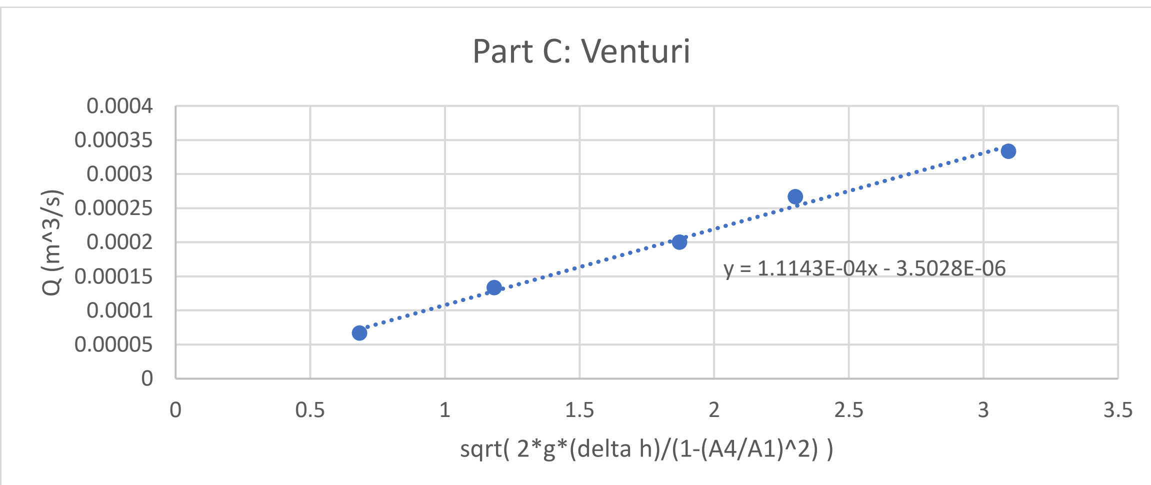
There is more error present in the measurement from the transducer because it has a higher least count than the manometers. By using the manometers to measure difference in height, we can yield a more accurate measurement since the manometer was accurate to the nearest millimeter, making the uncertainty of the difference in height ± 1 mm, even though there are 2 measurements being taken. In contrast, the least count of the transducer is 1 cm, meaning that the uncertainty is $\pm$ 5 mm. Therefore, the manometer is a more precise measurement method, while the transducer might be more accurate.

Part C

Flow Setting	Rotameter	Manometer Readings		
	Volumetric flow rate	Upstream (1)	Throat (4)	delta h
1	6.6667E-05	45	43	0.02
2	0.00013333	47	41	0.06
3	0.0002	75	60	0.15
4	0.00026667	75	48	0.27
5	0.00033333	78	37	0.41

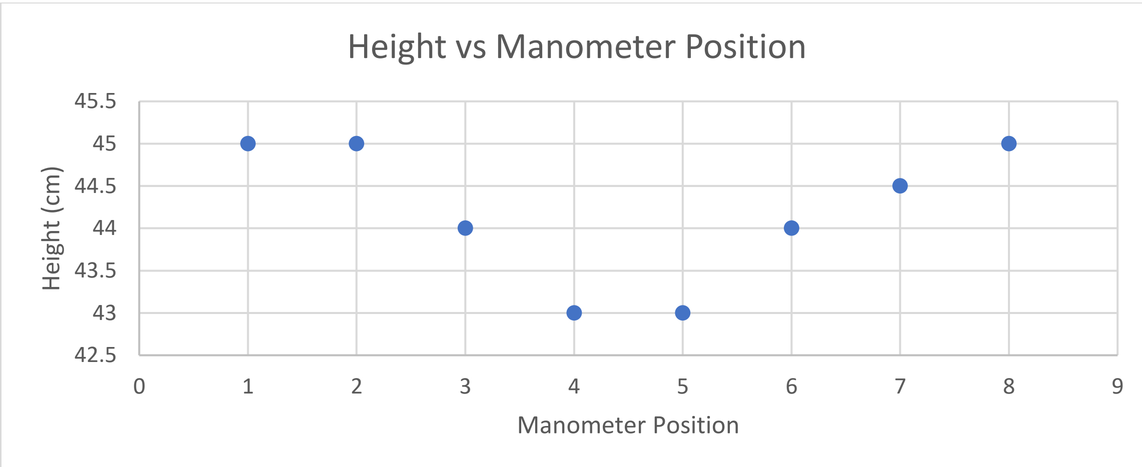
Manometer readings							
1	2	3	4	5	6	7	8
0.45	0.45	0.44	0.43	0.43	0.44	0.445	0.45
45	45	44	43	43	44	44.5	45

1) q vs sqrt(…). Determine meter coefficient in the same way as part B.



$$A_4 = 2.8353 * 10^{-4}\ m^2$$
$$A_1 = 1.1310 * 10^{-4}\ m^2$$
$$Q_{Venturi} = K * A_4 \sqrt{\frac{2g\Delta h}{1-\left(\frac{A_4}{A_1}\right)^2}}$$
$$1.1143 * 10^{-4} = K * A_4$$
$$K = 0.393$$

2) Plot the static pressure distribution (in cm of water) along the length of the meter using the dimensions given in Figure 6. Using the Bernoulli equation, describe what is happening to the fluid velocity for each distinct segment of the curve (recall that the static pressure in a manometer can be expressed as P=ρgh),



By observing the above graph, we can see that there is greater static pressure at the points where there is a smaller cross-sectional area. At the relatively large inlet and outlet points (1, 2, 7, 8), the static pressure is higher, making the velocity lower. At the narrower regions (3, 4, 5, 6), the static pressure is low as measured by the venturi, meaning that the velocity in these regions are higher.

By observing the Bernoulli equation for point 1 (high s.p.) and point 4 (low s.p.),

$$\frac{U_1^2}{2g}+\frac{P_1}{\rho g}=\frac{U_4^2}{2g}+\frac{P_4}{\rho g}$$
$$\frac{U_1^2}{2}+\frac{P_1}{\rho}=\frac{U_4^2}{2}+\frac{P_4}{\rho}$$
$$U_1^2+\frac{2P_1}{\rho}=U_4^2+\frac{2P_4}{\rho}$$

given $P_1 > P_4$, $P_1 - P_4 = C$ (where C > 0)

$$U_1^2 + C = U_4^2$$
$$U_4^2 - U_1^2 = C$$
$$U_4^2 - U_1^2 > 0$$
$$U_4^2 > U_1^2$$
$$\therefore U_4 > U_1$$

Conclusion

In this experiment, the aim was to observe the calibration process of various fluid flow meters and to compare the different methods. After acquiring sample data, relationships were graphed and compared and the error in each method was discussed. Finally, Bernoulli's equation was used to express the relationship between the static pressure and the velocity of the water.