Experiment B

Flow meters

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1 Introduction

The main purpose of this experiment is to investigate the operation and characteristics of three different types of flowmeter: venture meter, orifice plate meter and variable area meter. By researching the experimental data of these three flow meters at different water pressures, the energy loss of the water flowing through the meters was determined.

2 Theory

There are three different types of flow meters, each with a pressure tube in front of and behind the meter to visualise the water pressure, as shown in figure 1,2 and 3.

The water enters from the venturi flow meter and flows through variable area, the orifice, then out of pipe. It should be noticed that there is an elbow between the venturi and variable area.

The definitions of the symbols are shown in table 1.

In Bernoulli's and continuity equations, for the venture meter,

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} \tag{1}$$

$$Q_1 = Q_2 = A_1 v_1 = A_2 v_2 \tag{2}$$

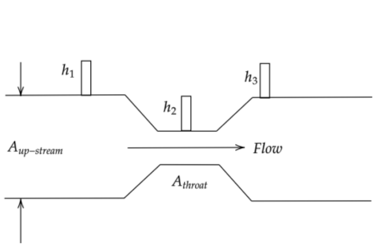

Figure 1: Venture meter

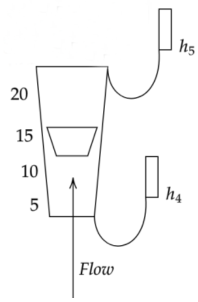

Figure 2: Variable area meter

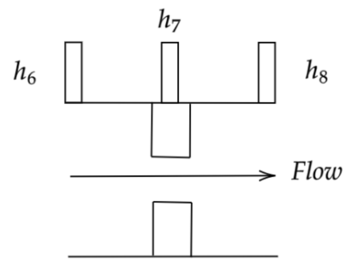

Figure 3: Orifice plate meter

Symbols	Definition	Expression
H_{Qv}	Head difference in venture	$h_1 - h_2$
H_{Qo}	Head difference in orifice	$h_6 - h_7$
H_v	Head loss in venture	$h_1 - h_3$
H_o	Head loss in orifice	$h_6 - h_8$
H_a	Head loss in variable area	$h_4 - h_5$
H_e	Head loss in elbow	$h_3 - h_4$

Table 1: Symbol definitions

Define ΔH as $h_1 - h_2$, Hence,

$$\Delta H = \left[z_1 + \frac{P_1}{\gamma} \right] - \left[z_2 + \frac{P_2}{\gamma} \right] \tag{3}$$

From equation (1),(2) and (3),

$$v_2 = \sqrt{2g\Delta H} * \frac{A_1}{\sqrt{A_1^2 - A_2^2}} \tag{4}$$

Due to the existence of discharge coefficients for the venturi and orifice, it is assumed that $C_d = 0.98$ for venture and $C_d = 0.63$ for orifice.

$$Q_{actual} = C_d Q_{theoretical} = C_d A_2 V_2 = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\Delta H} \tag{5}$$

Finally, the Q_o and Q_v could be write as

$$Q_o = \frac{0.63 A_2 \sqrt{2g\Delta H_{Qo}}}{\sqrt{1 - (\frac{A_2}{A_1})^2}} \qquad Q_v = \frac{0.98 A_2 \sqrt{2g\Delta H_{Qv}}}{\sqrt{1 - (\frac{A_2}{A_1})^2}} \tag{6}$$

For the variable area, there is a visual scale display. This gives a very visibly readable indication of the flow of water.

For the elbow, head loss can be represented as

$$H_e = h_3 - h_4 = k\frac{v^2}{2g} \tag{7}$$

Which k is the coefficient of the elbow loss.

3 Method

In this experiment, a pressure tube was installed at each of the flowmeter. Starting the pump, adjusting the flow rate so that the scale on the variable area was 5, and recording the water pressure data for the 8 different pressure tubes. Finally, the actual flow rate was measured by using a stopwatch and a measuring cylinder.

Repeat the experiment, controlling the scale on the variable area to 10,15,20. Record the data.

4 Results

The experiment data is shown in the following table.

No.	Flowrate	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	V_1(l)	T_1(s)	V_2(l)	T_1(s)	$Q_{average}=\frac{V}{T}$ (L/s)
1	5(L/min)	220	203	211	209	155	155	145	149	6	63	7	70.06	0.097576
2	10 (L/min)	248	199	228	220	164	165	132	143	11	63	11	64.47	0.172613
3	15 (L/min)	294	187	255	240	175	180	106	130	15	60.25	16	63.03	0.251405
4	20(L/min)	355	160	300	270	197	205	68	117	22	65	22	64	0.341106

(Unit of h: mm)

Table 2: Recording of pressure tubes

5 Analysis

5.1 Regression analysis

Using the data in Table 2 and equations (6) to calculate the Q_o and Q_v.

The regression analysis figure is in figure 5 and data in 4.

H_{Qv}	H_{Qo}	H_{Qa}	Q_v	Q_o	Q_a	Q_{actual}
17	10	54	0.000102725	0.0000953964	0.000083333	0.0000976
49	33	56	0.000174402	0.000173296	0.000166667	0.000173
107	74	65	0.000257718	0.000259506	0.00025	0.000251
195	137	73	0.000347913	0.000353096	0.000333333	0.000341

(Unit of H: mm and Q: m^3/s)

Table 3: Flow rates measured by different methods

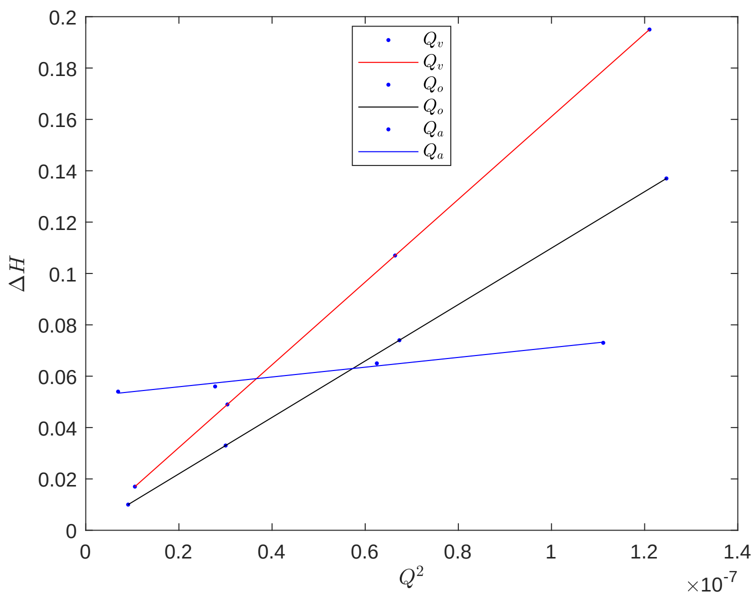

Figure 4: Regression analysis

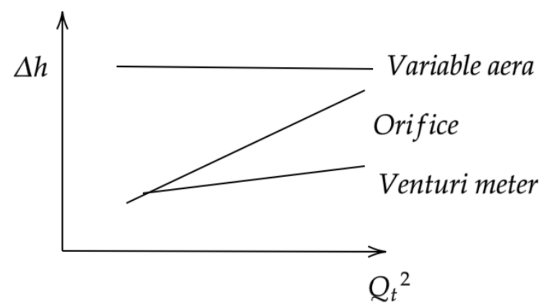

Figure 5: Theoretical figure

	Slope ($*10^6$)	R-square
Q_v	1.611	1
Q_o	1.099	1
Q_a	1.909	0.9855

Table 4: result of regression analysis

Flowrate(L/min)	Q_v	Q_o	Q_a
5	2.233992	5.277012	14.59668
10	0.396002	1.036594	3.444661
15	3.22237	2.51114	0.558865
20	3.514961	1.99558	2.2786

Table 5: Error percentage

5.2 Error analysis

$$Error = \frac{|Q_v - Q_t|}{Q_t} * 100\% \tag{8}$$

The results is shown in the table 5. The error for each flowmeter is calculated by using the final outflow flow rate (Q_{actual}) as the criterion.

The experimental data figure and the theoretical ones show large errors, which can be caused by a number of reasons:

- Errors caused by different initial velocities of water which flowing into the different flowmeters due to head loss in pipe.
- Inaccurate calculation of the flow rate due to residual water in the measuring cylinder.
- Data errors due to looking down or up at the pressure tube while reading.

6 Conclusion

From the results of the regression analysis, the R-square value of Q_v Q_o is equal to 1, and the Q_a is very close to 1, which demonstrates a strong linear correlation between the x and y axes. Therefore, the data from the regression analysis is valid.

However, there is a large error between the actual measured data and the theoretical data. Theoretically, the slope is $Q_o > Q_v > Q_a$. For the height of the line, $Q_a > Q_o > Q_v$. For the actual measured slope, $Q_v > Q_o > Q_a$, and there are lines intersecting and Q_v and Q_o exceed Q_a in the later data.

In conclusion, the measured experimental data had a very strong linear correlation, demonstrating that the experiments were performed correctly. Comparison with the theoretical figure, It can speculate that the experimental error is not human-caused, but more likely to be an error in the experimental apparatus itself.