

# 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 re-searching 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,

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

$$Q_1 = Q_2 = A_1 v_1 = A_2 v_2 \quad (2)$$

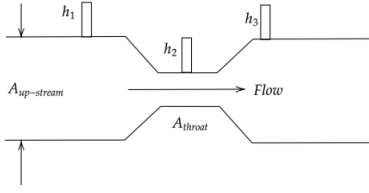


Figure 1: Venturi meter

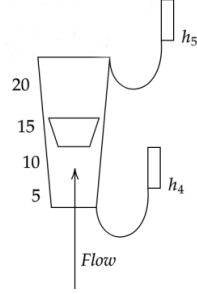


Figure 2: Variable area meter

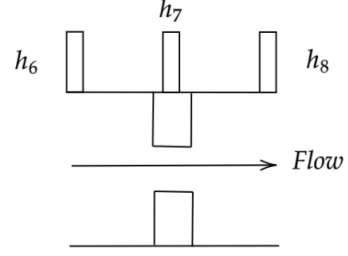


Figure 3: Orifice plate meter

Symbols	Definition	Expression
$H_{Qv}$	Head difference in venturi	$h_1 - h_2$
$H_{Qo}$	Head difference in orifice	$h_6 - h_7$
$H_v$	Head loss in venturi	$h_1 - h_3$
$H_o$	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  $\Delta H$  as  $h_1 - h_2$ , Hence,

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

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

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

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

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

Finally, the  $Q_o$  and  $Q_v$  could be write as

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

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

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

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.

$H_{Q_v}$	$H_{Q_o}$	$H_{Q_a}$	$Q_v$	$Q_o$	$Q_a$	$Q_{actual}$
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

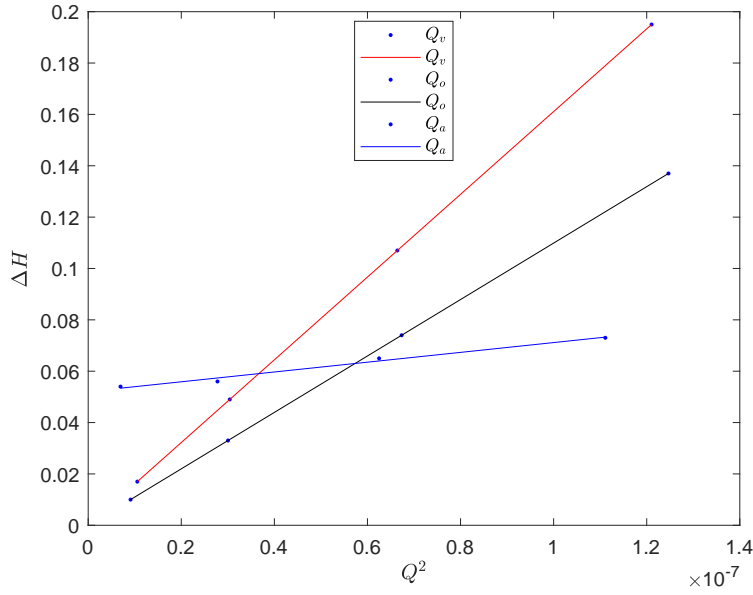


Figure 4: Regression analysis

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

Table 4: result of regression analysis

No.	$Q_v$	$Q_o$	$Q_a$
1	2.233992	5.277012	14.59668
2	0.396002	1.036594	3.444661
3	3.22237	2.51114	0.558865
4	3.514961	1.99558	2.2786
Average	2.34	2.718	5.22

Table 5: Error percentage

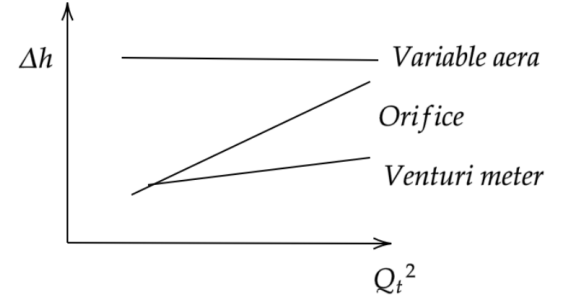


Figure 5: Theoretical figure

## 5.2 Error analysis

$$Error = \frac{|Q_v - Q_t|}{Q_t} * 100\% \quad (8)$$

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 error analysis, The average error for all three different flowmeters is less than 10%. But, it is noticed that the error is a little large at the variable area in the first set of data. A new experiment could be considered to obtain more accurate results.

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 be obtained that the experimental error is not caused by human beings. Rather, it is an error in the experimental apparatus itself.