Abstract:

Calibration

This experiment investigates characteristics and features regarding three different flow measuring devices used to measure the internal flow rate of a fluid (inside a pipe or a duct).
Two of these devices are flow obstruction devices; namely, venture tube and orifice plate meters.
The third is a variable head flow meter device named rotameter.
Fluid is made to flow passing a venture tube, then an orifice plate following to a rotameter.

Pressure drop across each device is noted using manometer fixed at entry and exit of each flow meter where readings are read off as heights in mm H2O. Actual flow rate is calculated using a measuring tank and a stopwatch.
Flow rate is also calculated from pressure data obtained from the flow meter devices and their coefficients of discharge were calculated and compared (detailed calculations and analysis are shown in subsequent sessions).

Venture tube meter resulted in a higher discharge coefficient than the orifice plate meter and hence causes less flow losses; this is a result of smooth change in the area of the venture tube rather than a sudden area drop seen in the orifice plate.
Rotameter had the advantage of ability of usage without the need of an external power supply.

give values

Nomenclature/Symbols:

Objectives:

1- Feature the different characteristics of flow measuring devices; namely, Venturi tube and the orifice plate.
2- Measure the pressure drop across the venturi and the orifice and calculate the volumetric flow rate both theoretical and actual for these devices and compare.
3- Inspection of rotameter operation and measures

only one objective

i.e. Calibration

Procedure:

???

1- Let the operator set your apparatus ready
2- Fully open flow valve for the first data group,
3- Empty the weighing tank, then set the tank lever arm down, start a stop watch as soon as you see the lever arm rising and add the 2.5 kg mass to it
4- When the arm rises again stop your stopwatch and record the time read
5- Read manometer levels (mm $H2O$) at the venture's entry, throat and exit, and at tapped Perspex flanges and right angle pressure tapped denoted by A,B,C,E,F , & G respectively, also record float height of the rotameter.
6- Decrease the flow valve opening and repeat step 3-6 recording set of data each time.

Do not Copy

Use your own language

Apparatus used:

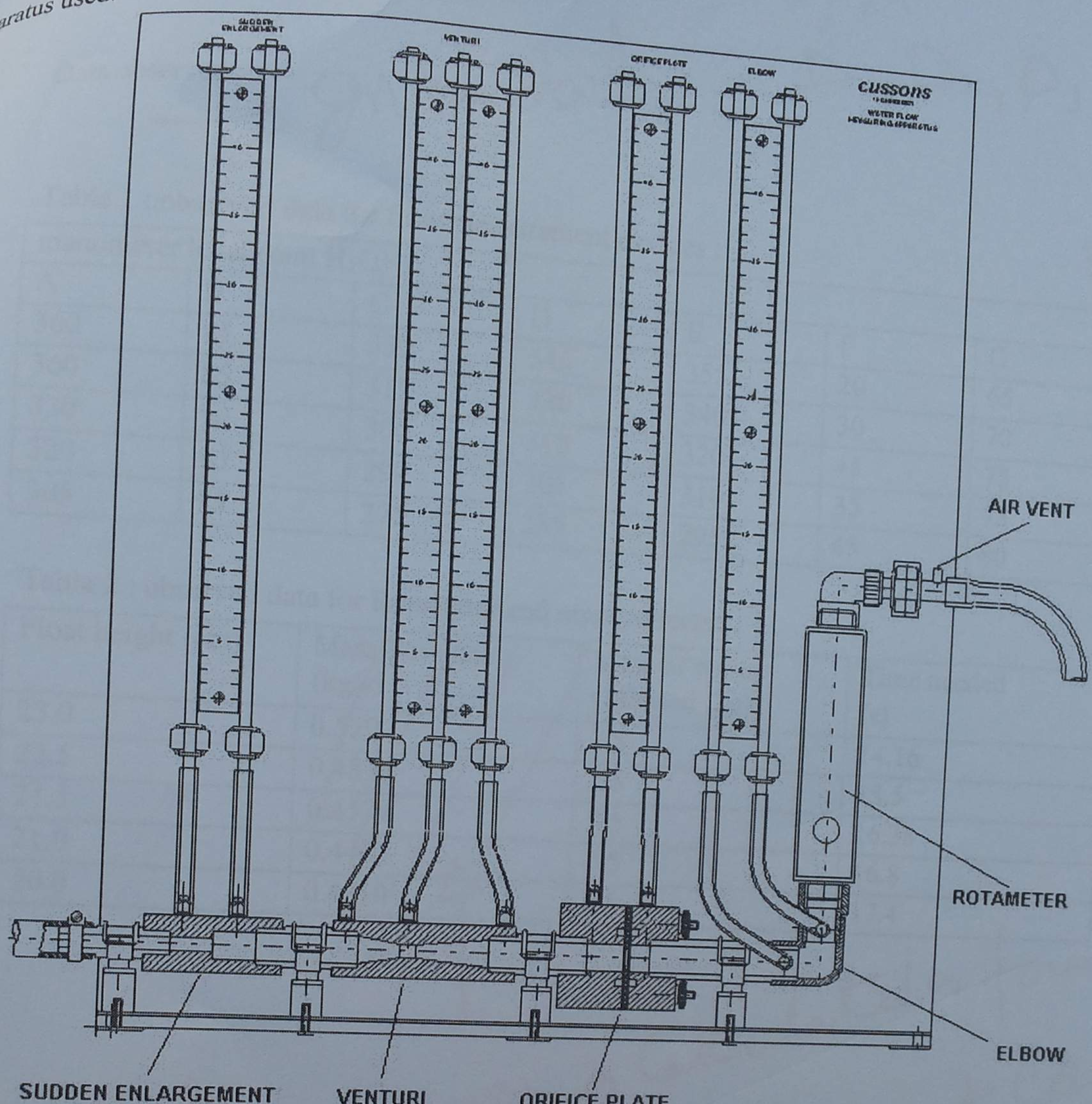

Figure (1): Water Flow Measuring Apparatus

How it works:

7.5 Kg

Connect the flow prover device to the hydraulic bench, adjusting the water valve will yield a different flow rates, then different pressures of water is to be measured from piezometers located at various points. The hydraulic bench contains a weigh tank which is to be filled by 7.2 kg of water and this mass is to trapped by virtue of the hanger and an auxiliary mass then time to fill the weigh tank is to be measured by a stop watch to find the mass flow rate. Finding the mass flow rate and pressures will yield us to calculate the discharge coefficient in order to calibrate venture, orifice and rotameter.

Data observed :

→ given data   ρ, μ   D1, D2, D3, ...

Table 1 : observed data for flow measurement devices :

manometer level (mm H_2O)						
A	B	C	D	E	F	G
360	85	330	345	355	20	65
360	85	315	330	340	30	70
330	90	300	310	320	45	75
320	90	290	305	310	35	75
305	95	275	285	295	45	80

Where???

Table 2 : observed data for Rotameter and mass collected :

Float height (cm)	Mass flow rate (kg/s)	Mass of water collected (kg)	Time needed (s)
23.0	0.5297	7.5	14.16
22.5	0.4839	7.5	15.5
21.5	0.4579	7.5	16.38
21.0	0.4464	7.5	16.8
20.0	0.4310	7.5	17.4

this is calculated or found from curve, not exp.

Sample Calculation

Results and discussion:

Table 3: final results:

Volume flow rate (m³/s)*10⁻³	Reynolds' number for venturi	Reynolds' number for orifice	Discharge coefficient for venture (C_v)	Discharge coefficient for orifice (C_o)
0.5297	39026.67	31220.37	1.04966	0.6498
0.4839	35652.61	28522.59	0.95890	0.6171
0.4579	33741.39	26990.67	0.97140	0.6200
0.4464	32891.07	26315.90	0.96730	0.6045
0.4310	31757.54	25406.68	0.97740	0.6121

Table (4) Comparison between venture meter and orifice

	Venture	Orifice
Accuracy	More accurate	Lees accurate
Pressure loss	low	large
Pressure recovery	better	worse
Cost	expensive	cheap
Space	larger	less

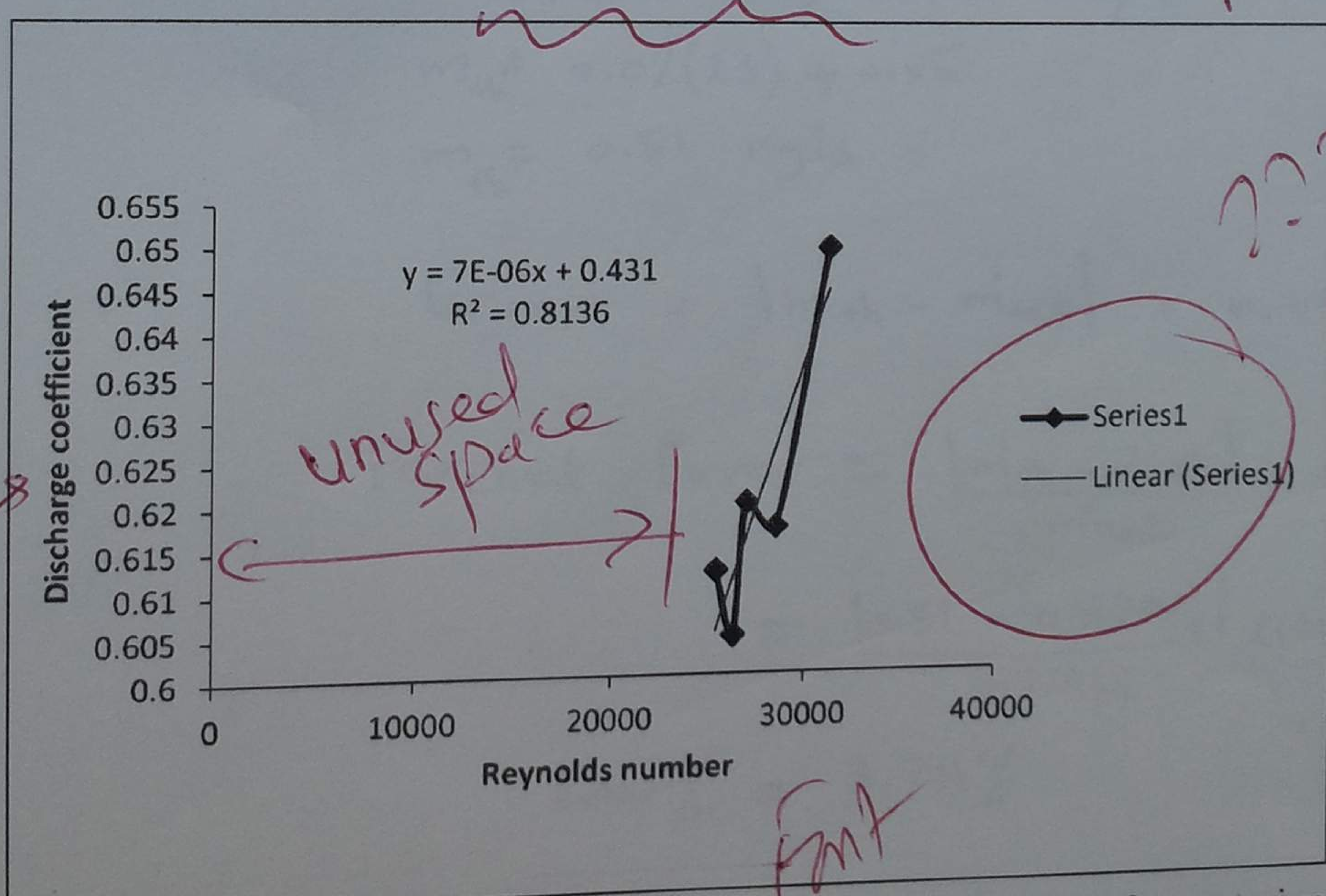

Figure 2: variation of discharge coefficient with Reynolds number for venturi meter.

Sample calculation

Water:

Density = 1000 Kg/m^3.
Dynamic viscosity = 1.08×10^{-3} N.s/m^2.
Mass collected = 7.5 Kg.
Time for collection = 14.16 sec.

1. Actual mass flow rate:

$$\dot{m}_{act} = \frac{\text{mass collected}}{\text{time needed}} = \frac{7.5}{14.16} = 0.52966 \text{ Kg/s}.$$

2. Rotameter: Height = 23 cm

using equation from curve:

$$\dot{m}_{th} = 0.02h + 0.05 \text{ [Kg/s]}$$

where h is water height in (cm)

$$\dot{m}_{th} = 0.02(23) + 0.05$$

$$\dot{m}_{th} = 0.51 \text{ Kg/s}$$

$$\text{Error} = |\dot{m}_{th} - \dot{m}_{act}| = 0.01966 \text{ Kg/s}$$

$$\text{Percent Error} = \frac{|\dot{m}_{th} - \dot{m}_{act}|}{\dot{m}_{act}} \times 100\%$$

$$= \frac{|0.51 - 0.52966|}{0.52966} \times 100\%$$

$$\text{Error\%} = 3.711\%$$

[3] Venturi meter:

Inlet pipe diameter [1] = 26 mm.
Throat diameter [2] = 16 mm.
Inlet piezometer height (A) = 360 mm.
Throat piezometer height (B) = 85 mm.

Theoretical velocity at throat:

$$V_{2th} = \sqrt{\frac{2g\,\Delta h}{1-\left(\frac{d_2}{d_1}\right)^4}}$$

$$V_{2th} = \sqrt{\frac{2 \times 9.81 \times (0.36-0.085)}{1-\left(\frac{0.016}{0.026}\right)^4}} = 2.5097 \text{ m/s}.$$

Theoretical mass flow rate:

$$\dot{m}_{th} = \rho_{water} V_{2th} A_2$$

$$= 1000 \times 2.5097 \times \frac{\pi}{4}(0.016)^2$$

$$\dot{m}_{th} = 0.5046 \text{ Kg/s}.$$

Discharge Coefficient for Venturi (C_v):

$$C_v = \frac{\dot{m}_{act}}{\dot{m}_{th}} = \frac{0.52966}{0.5046} = 1.04966.$$

$C_v > 1$; there are some errors in time measurement.

Reynolds' Number:

$$Re = \frac{\rho V_{2act} d_2}{\mu}$$

, Where $V_{act} = C_v V_{th}$, μ is dynamic Viscosity.

$$= \frac{1000 \times 1.04966 \times 2.5097 \times 0.016}{1.08 \times 10^{-3}}$$

$$Re = 39026.6667$$

$$\text{Error in } (\dot{m}) = |\dot{m}_{th} - \dot{m}_{act}| = |0.5046 - 0.52966|$$

$$= 0.02506 \text{ Kg/s}$$

$$\text{Percent Error} = \left|\frac{\dot{m}_{th} - \dot{m}_{act}}{\dot{m}_{act}}\right| \times 100\%$$

$$= \left|\frac{0.5046 - 0.52966}{0.52966}\right| \times 100\% = 4.731\%$$

4 Orifice plate meter:

Inlet pipe diameter [1] = 51 mm.
Throat diameter [2] = 20 mm.
Inlet piezometer height (E) = 355 mm.
Throat piezometer height (F) = 20 mm.

theoretical throat velocity:

$$V_{th_2} = \sqrt{\frac{2g\,\Delta h}{1-\left(\frac{d_2}{d_1}\right)^4}}$$

$$V_{th_2} = \sqrt{\frac{2\times 9.81\times(0.355-0.02)}{1-\left(\frac{0.02}{0.051}\right)^4}} = 2.59459\ m/s$$

theoretical mass flow rate:

$$\dot{m}_{th} = \rho_{water}\, V_{2th}\, A_2$$
$$= 1000\times 2.59459\times \frac{\pi}{4}(0.02)^2$$
$$\dot{m}_{th} = 0.8151\ kg/s.$$

Discharge Coefficient for orifice (C_o):

$$C_o = \frac{\dot{m}_{act}}{\dot{m}_{th}} = \frac{0.52966}{0.8151} = 0.6498.$$

Reynolds' number:

$$Re = \frac{\rho\, U_{2act}\, d_2}{\mu}$$
$$= \frac{1000\times 0.6498\times 2.59459\times 0.02}{1.08\times 10^{-3}}$$
$$Re = 31220.37$$

$$\text{Error in } (\dot{m}) = |\dot{m}_{th}-\dot{m}_{act}| = |0.8151-0.52966|$$
$$= 0.28544\ kg/s$$

$$\text{Percent Error} = \left|\frac{\dot{m}_{th}-\dot{m}_{act}}{\dot{m}_{act}}\right|\times 100\%$$
$$= \left|\frac{0.8151-0.52966}{0.52966}\right|\times 100\%$$
$$E\% = 53.8911\ \%$$

5 Uncertainties analysis :

In the theoretical velocity of the venturimeter:

$$V_{th} = \sqrt{\frac{2g\,\Delta h}{1-\beta^4}}$$

, where β is the diameter ratio

there is a change only in (Δh), so

$$\frac{\partial V}{\partial \Delta h} = \frac{1}{2}\sqrt{\frac{2g}{1-\beta^4}}\ \Delta h^{-1/2}$$

and

the uncertainty of (Δh) $[W_{\Delta h}]$:

$$W_{\Delta h} = \frac{\text{smallest devision}}{2}$$

$$W_{\Delta h} = \frac{1.0 \times 10^{-3}\ m}{2} = 0.5 \times 10^{-3}\ m$$

$$W_V = \pm\sqrt{\left(\frac{\partial V}{\partial \Delta h} W_{\Delta h}\right)^2}$$

$$= \pm\sqrt{\left(\frac{1}{2}\sqrt{\frac{2g}{1-\beta^4}}\ \Delta h^{-1/2}\ W_{\Delta h}\right)^2}$$

$$W_V = \pm\left(\sqrt{\left(\left(\sqrt{\frac{2 \times 9.81}{1-\left(\frac{16}{26}\right)^4}}\ (0.36-0.085)^{-1/2}\right) \times 0.5 \times 10^{-3}\right)^2}\right) \times 0.5$$

$$W_V = \pm\ 2.2815 \times 10^{-3}\ m/s$$

In the theoretical velocity of the orifice plate:

and since all variables are multiplied this form of the equation can be used:

$$\frac{W_V}{V} = \pm\sqrt{\left(a\frac{W_{\Delta h}}{\Delta h}\right)^2}$$

where a is Δh power at the velocity equation which is (0.5)

from the observed data

$$\Delta h = 0.355 - 0.02 = 0.335\ m$$

also the theoretical velocity is to be

$$V_{th} = 2.59459\ m/s.$$

$$\frac{W_V}{2.59459} = \pm\sqrt{\left(\frac{0.5 \times 0.5\times10^{-3}}{0.335}\right)^2}$$

$$W_V = \pm\ 1.936 \times 10^{-3}\ m/s.$$

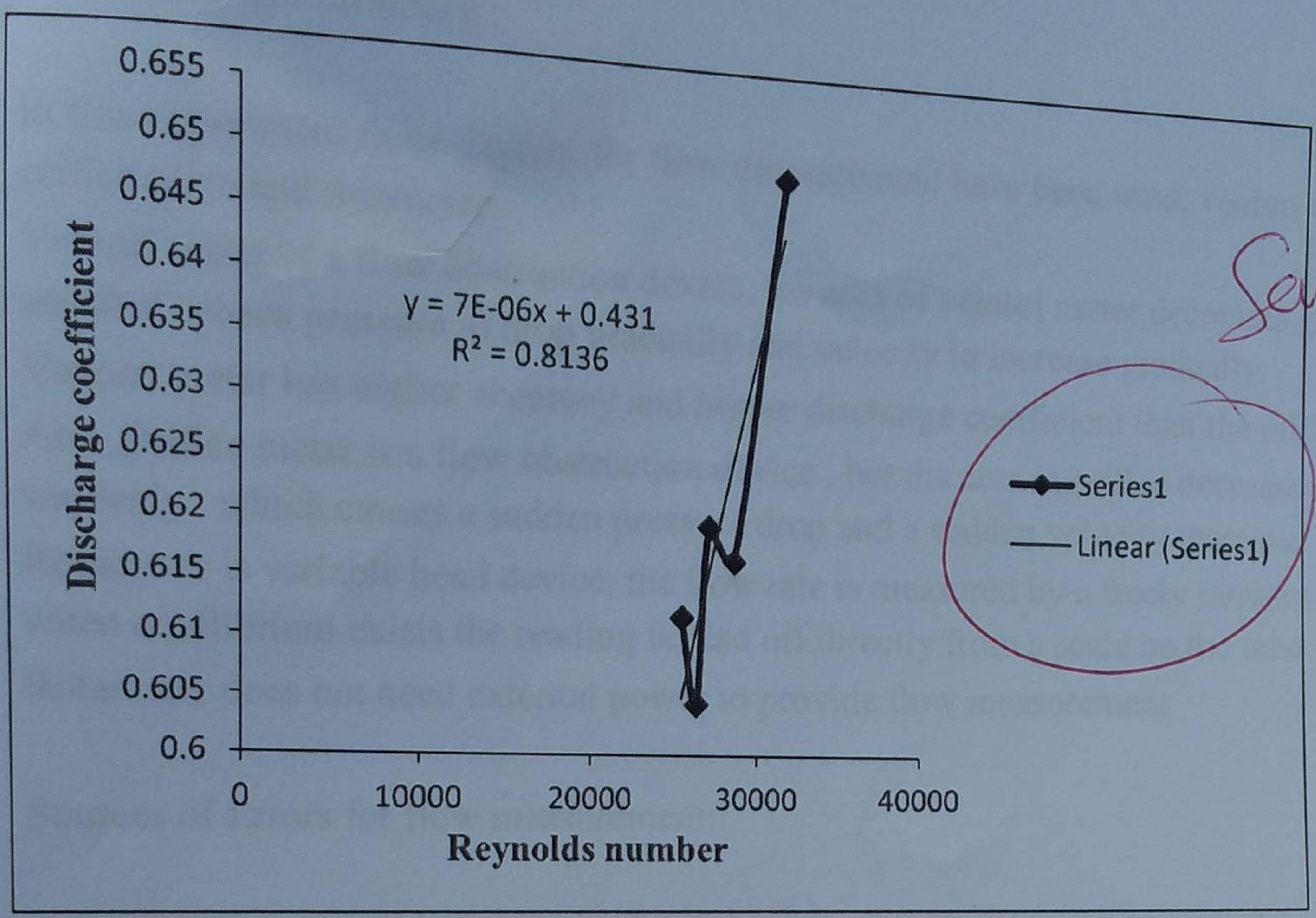

Figure 3: variation of discharge coefficient with Reynolds number for orifice meter

Some Comments

Discussion

The differential pressure flow meter mechanical devise , like the orifice, and venturi meter, is used for pipe flow measurement. For each type, a constriction (like an orifice plate) in the flow path causes a pressure drop across the meter. The pressure drop can be measured and correlated with flow rate.

Conclusion and summary :

In this experiment three devices for flow measurement have been used; venturi tube, orifice plate and rotameter.

Venturi meter is a flow obstruction device, the area of venturi meter decreases gradually and that causes pressure to drop gradually and velocity to increase gradually.

Venturi meter has higher accuracy and higher discharge coefficient than the orifice meter.

Also Orifice meter is a flow obstruction device , but the area in orifice decreases suddenly which causes a sudden pressure drop and a sudden velocity increase.

Rotameter is variable head device, the flow rate is measured by a freely moving float and when equilibrium exists the reading is read off directly from a scale on the tube.

Rotameter does not need external power to provide flow measurement.

Sources of Errors for flow measurement:

1. Parallax error during data taken.

How??

2. Leakage in system.
3. Dirtiness of the reading access tube.
4. Water bubbles inside the access data reading tube is not escape correctly .

where did you use it??

References:

Books:

Engineering fluid mechanics 9th edition

Websites:

http://www.brighthubengineering.com/hydraulics-civil-engineering/52906-orifice-flow-nozzle-and-venturi-meter-for-pipe-flow-measurement/