MET 335

Module 5 – Venturi Profiles

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Purpose, Theory, and Procedure

1. **Experiment Title**
    a. Venturi Profiles
2. **Purpose**
    a. To experimentally learn about the operation of a venturi flow meter and the characteristics of such. Students will use a TecQuipment Venturi Meter during this lab.
3. **Theoretical Considerations**
    a. The velocity at any location (N) can be calculated using the measured volumetric flow rate (Q) and the cross-section area at each location.
        i. $V_N = \frac{Q}{A_N}$
    b. Friction can be neglected when the venturi meter is horizontal. This causes the pressure head ($\frac{P}{\gamma}$) at various locations (N) can be calculated throughout the venturi from Bernoulli's equation.
        i. $\frac{P_N}{\gamma} = \frac{P_A}{\gamma} - \frac{(V_N{}^2 - V_A{}^2)}{2g}$
    c. Note that location 1 is the venturi inlet and the location N is any of the 11 pilot static tube locations.
    d. Use the continuity equation if friction is neglected.

$$Q = A_1V_1 = A_4V_4$$

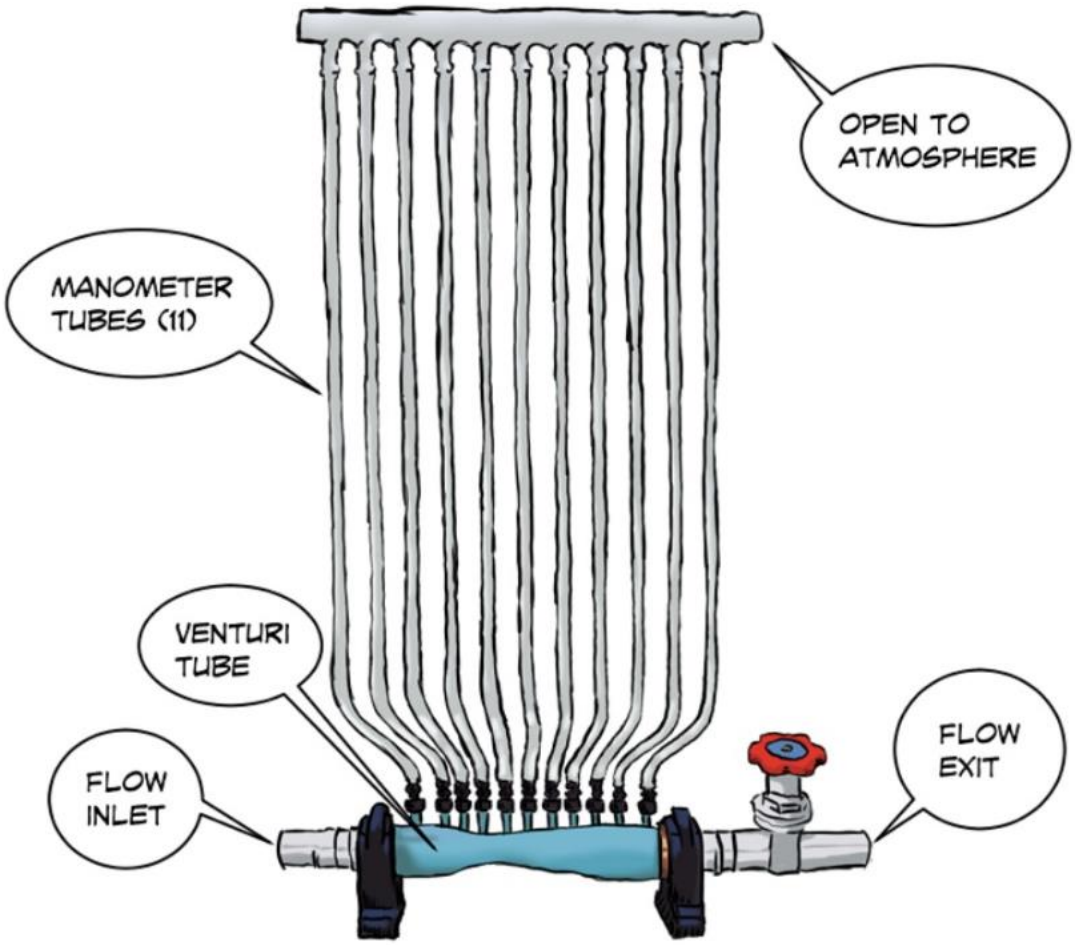
        i. $$Q = A_4\sqrt{\frac{2g(\frac{P_1}{\gamma} - \frac{P_4}{\gamma})}{1-(\frac{D_4}{D_1})^4}}$$
    e. If friction is considered in the venturi, use the venturi coefficient.
        i. $$Q = C_V A_4\sqrt{\frac{2g(\frac{P_1}{\gamma} - \frac{P_4}{\gamma})}{1-(\frac{D_4}{D_1})^4}}$$
            ii. Where C_v is the venturi coefficient and is less than 1.0
    f. C_V can be found experimentally and is dependent upon the inlet Reynolds number $N_{R1.}$
        i. $$C_V = \frac{Q}{A_4}\sqrt{\frac{1-(\frac{D_4}{D_1})^4}{2g(\frac{P_1}{\gamma} - \frac{P_4}{\gamma})}}$$

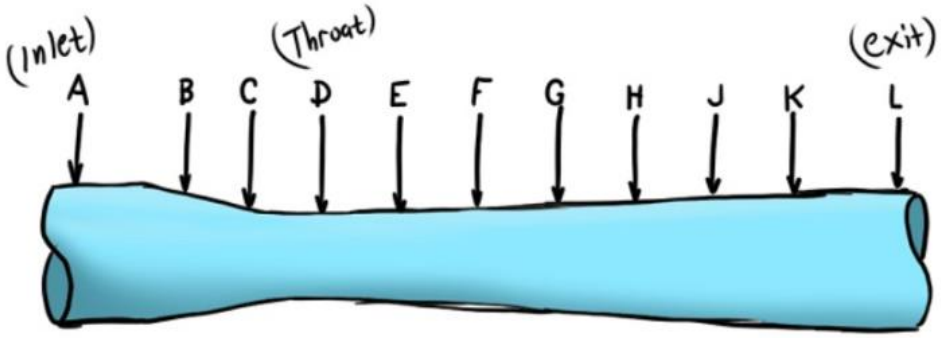
g. The Reynolds number can also be calculated at the venturi inlet.

i. $N_R 1 = \frac{\rho V_1 D_1}{\mu}$

4. Drawing or Sketch

a.

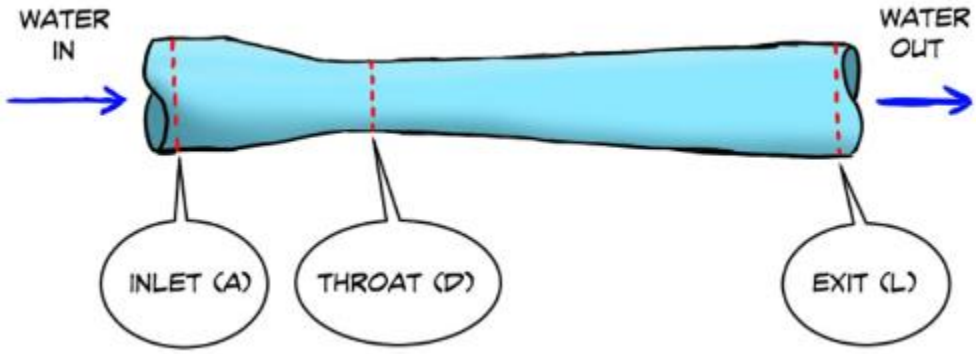




b.

	DIAMETER mm
A	26 00
B	23.20
C	18.90
D	16.00
E	16.80
F	18.97
G	20.16
H	21.84
J	23.53
K	25.24
L	26.00

c.



5. Verbal Description

a. The apparatus above is a TecQuipment Venturi meter. This venturi unit has eleven pitot static tubes attached along its length that measure the actual pressure head profile $\frac{\rho}{\gamma}$. In figure at section 4.c., the pressure heads at the inlet A and throat D may be used in determining the flow coefficient C_v. The entire venturi meter is located on a flow measuring tank assembly. This assembly has a pump that takes the water from a sump pump, which then

pushes it through an upstream control valve, then it goes through the venturi meter, and then finishes off through the downstream control valve into a volume measuring tank. Once it's completed its path, the fluid is then discharged to the sump pump.

6. **Step-by-Step Procedure**
    a. Identified the four components that will be used for the lab:
        i. Upstream Valve
        ii. Venturi meter with tubes and scales
        iii. Tank
        iv. Plunger (Pipe)
    b. Investigated up close screenshot of TQ H5 Venturi Meter
    c. Selected the pump on/off panel
    d. Turned the pump on
    e. Adjusted the upstream control valve
    f. Recorded water levels for each of the 11 tubes:
        i. Tube 1: 278mm
        ii. Tube 2: 270mm
        iii. Tube 3: 170mm
        iv. Tube 4: 7.5mm
        v. Tube 5: 45mm
        vi. Tube 6: 125mm
        vii. Tube 7: 170mm
        viii. Tube 8: 200mm
        ix. Tube 9: 215mm
        x. Tube 10: 238mm
        xi. Tube 11: 245mm
    g. Placed pipe in the tank to measure the volume flow time
    h. Waited for the tank to fill to 15 liters
    i. Recorded the time it took for the tank to fill to 15 liters
        i. 43.21 seconds
    j. Removed the pipe to drain the tank of the 15 liters
    k. Adjusted the upstream control valve
    l. Recorded water levels for Tube 1 and Tube 4:
        i. Tube 1: 288mm
        ii. Tube 4: 18mm
    m. Placed pipe in the tank to measure the volume flow time
    n. Waited for the tank to fill to 15 liters
    o. Recorded the time it took for the tank to fill to 15 liters
        i. 45.6 seconds
    p. Removed the pipe to drain the tank of the 15 liters
    q. Adjusted the upstream control valve

r. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 250mm
    ii. Tube 4: 12mm
s. Placed pipe in the tank to measure the volume flow time
t. Waited for the tank to fill to 15 liters
u. Recorded the time it took for the tank to fill to 15 liters
    i. 46.2 seconds
v. Removed the pipe to drain the tank of the 15 liters
w. Adjusted the upstream control valve
x. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 208mm
    ii. Tube 4: 8mm
y. Placed pipe in the tank to measure the volume flow time
z. Waited for the tank to fill to 15 liters
aa. Recorded the time it took for the tank to fill to 15 liters
    i. 54.3 seconds
bb. Removed the pipe to drain the tank of the 15 liters
cc. Adjusted the upstream control valve
dd. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 176mm
    ii. Tube 4: 14mm
ee. Placed pipe in the tank to measure the volume flow time
ff. Waited for the tank to fill to 15 liters
gg. Recorded the time it took for the tank to fill to 15 liters
    i. 58.2 seconds
hh. Removed the pipe to drain the tank of the 15 liters
ii. Adjusted the upstream control valve
jj. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 148mm
    ii. Tube 4: 10mm
kk. Placed pipe in the tank to measure the volume flow time
ll. Waited for the tank to fill to 15 liters
mm. Recorded the time it took for the tank to fill to 15 liters
    i. 64.0 seconds
nn. Removed the pipe to drain the tank of the 15 liters
oo. Adjusted the upstream control valve
pp. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 124mm
    ii. Tube 4: 14mm
qq. Placed pipe in the tank to measure the volume flow time
rr. Waited for the tank to fill to 15 liters

ss. Recorded the time it took for the tank to fill to 15 liters
    i. 91.2 seconds
tt. Removed the pipe to drain the tank of the 15 liters
uu. Adjusted the upstream control valve
vv. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 100mm
    ii. Tube 4: 8mm
ww. Placed pipe in the tank to measure the volume flow time
xx. Waited for the tank to fill to 15 liters
yy. Recorded the time it took for the tank to fill to 15 liters
    i. 94.9 seconds
zz. Removed the pipe to drain the tank of the 15 liters
aaa. Adjusted the upstream control valve
bbb. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 75mm
    ii. Tube 4: 8mm
ccc. Placed pipe in the tank to measure the volume flow time
ddd. Waited for the tank to fill to 15 liters
eee. Recorded the time it took for the tank to fill to 15 liters
    i. 98.6 seconds
fff. Removed the pipe to drain the tank of the 15 liters
ggg. Adjusted the upstream control valve
hhh. Recorded water levels for Tube 1 and Tube 4:
    i. Tube 1: 55mm
    ii. Tube 4: 14mm
iii. Placed pipe in the tank to measure the volume flow time
jjj. Waited for the tank to fill to 15 liters
kkk. Recorded the time it took for the tank to fill to 15 liters
    i. 150.9 seconds
lll. Removed the pipe to drain the tank of the 15 liters
mmm. Successfully completed lab

Recorded Data Table(s)

Measured volume of water for flow rate:	15	liters

Part 1	
Venturi Profiles	Recorded height of water column in tube (mm)
A(1)	278
B(2)	270
C(3)	170
D(4)	7.5
E(5)	45
F(6)	125
G(7)	170
H(8)	200
J(9)	215
K(10)	238
L(11)	245
Volume Flow Time (seconds)	43.21

Part 2									
Venturi Location	Recorded height of water column in tube (mm)								
A(1) (inlet)	288	250	208	176	148	124	100	75	55
D(4) (throat)	18	12	8	14	10	14	8	8	14
Volume Flow Time (seconds)	45.6	46.2	54.3	58.2	64.0	91.2	94.9	98.6	150.9

Sample Calculations

$$Velocity = \frac{\frac{(\frac{15L}{43.21s})}{1000}}{\pi * .026^2} = \boxed{0.654\frac{m}{s}}$$

$$\mathrm{Re} = \frac{(997 * 0.654 * .026)}{1} = \boxed{16.949 \, or \, 1.7x10^4}$$

$$P_1 - P_4 = 280 - 18 = \boxed{270mm}$$

$$Q = A_4 \sqrt{\frac{2g(\frac{P_1}{\gamma} - \frac{P_4}{\gamma})}{1 - (\frac{D_4}{D_1})^4}} = \boxed{0.0005\frac{m^3}{\min}}$$

$$\frac{P_A}{\gamma} - (\frac{V_N{}^2 - V_A{}^2}{2g}) = 278 - (\frac{0.654^2 - 0.654^2}{2 * 9.81}) = \boxed{0.278m}$$

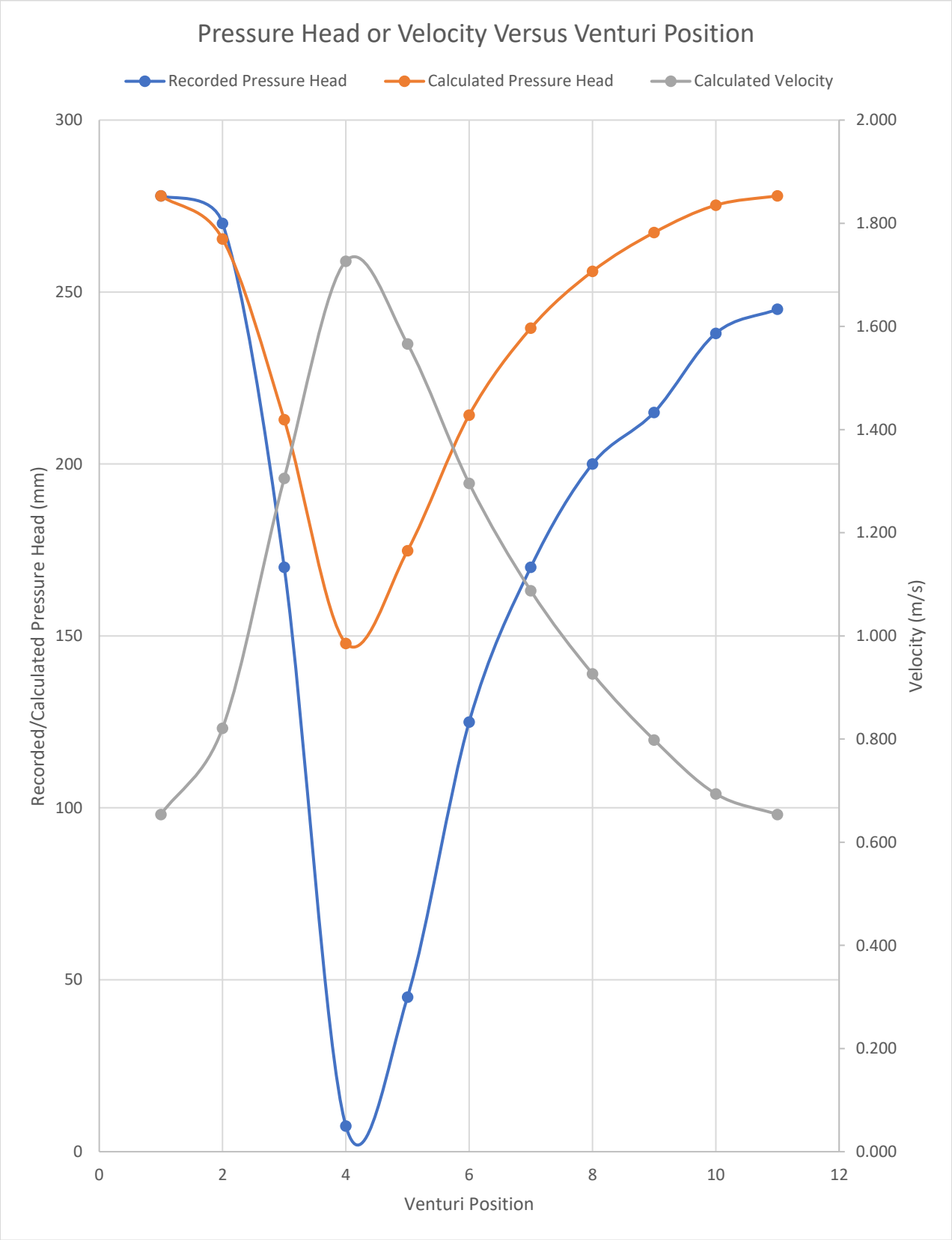
Calculated Data Table(s)

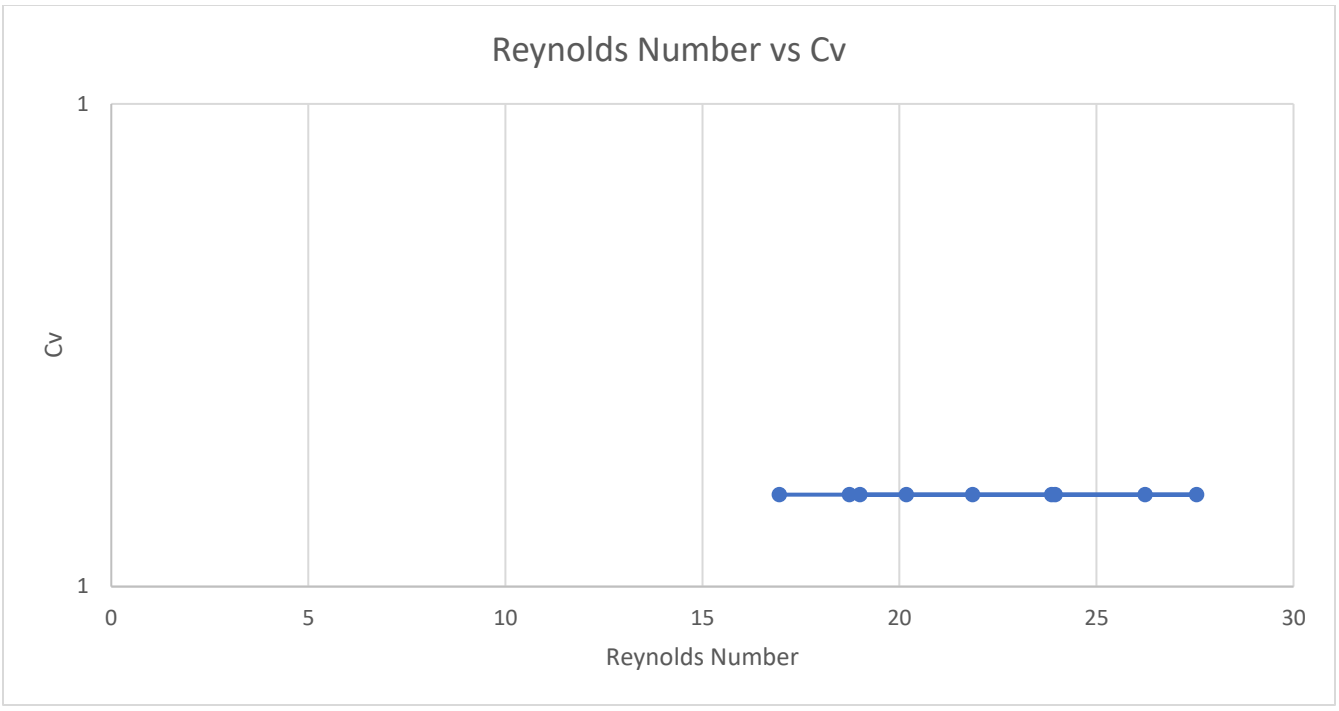
Location	Diameter (mm)	mm to m	Calculated Velocity (m/s)
A(1)	26.00	0.0260	0.654
B(2)	23.20	0.0232	0.821
C(3)	18.40	0.0184	1.306
D(4)	16.00	0.0160	1.727
E(5)	16.80	0.0168	1.566
F(6)	18.47	0.0185	1.296
G(7)	20.16	0.0202	1.088
H(8)	21.84	0.0218	0.927
J(9)	23.53	0.0235	0.798
K(10)	25.24	0.0252	0.694
L(11)	26.00	0.0260	0.654

Venturi Profiles	Calculated Pressure Head (m)
A(1)	0.2780
B(2)	0.2654
C(3)	0.2129
D(4)	0.1479
E(5)	0.1748
F(6)	0.2142
G(7)	0.2395
H(8)	0.2560
J(9)	0.2673
K(10)	0.2753
L(11)	0.2780

Part 2									
Venturi Location	Recorded height of water column in tube (mm)								
A(1) (inlet)	288	250	208	176	148	124	100	75	55
D(4) (throat)	18	12	8	14	10	14	8	8	14
Volume Flow Time (seconds)	45.6	46.2	54.3	58.2	64.0	91.2	94.9	98.6	150.9
Volumetric Flow Rate Q	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002
Reynolds Number (unitless)	16.949								
P_1-P_4 (mm)	270	238	200	162	138	110	92	67	41
C_v	1	1	1	1	1	1	1	1	1
Adjustment	1	2	3	4	5	6	7	8	9

Graph(s)


Pressure Head or Velocity Versus Venturi Position
Recorded Pressure Head
Calculated Pressure Head
Calculated Velocity
Recorded/Calculated Pressure Head (mm)
Velocity (m/s)
Venturi Position
300
250
200
150
100
50
0
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
2
4
6
8
10
12


Reynolds Number vs Cv
Cv
1
1
0
5
10
15
20
25
30
Reynolds Number

Discussion of Results and Conclusions

First off, I'm going to be okay with any point deductions that are given in this specific lab report. It was thrown together at the last minute. I had a business trip that lasted all week last week (minimal internet connection) and then a busy father's day weekend so I didn't have the normal time I do have to put together a proper lab report.

It seems that there is a direct correlation between the Reynolds number and the diameter. The higher the diameter, the lower the Reynolds number. In my calculations, which are probably wrong, I received a value of 1 for all coefficients so the second graph is just practically a straight line.

Another determination after looking at the first graph, there is quite a gap between the recorded values for pressure head and the calculated values for pressure head. The key factor in these calculations is the velocity due to the diameters of the venturi meter.

While I'm not sure when I would ever use a venturi meter in my professional career (mechanical engineer), this was still a neat lab to do and see the venturi meter differentiate with each adjustment of the control valve.

Wrapping this up, I did think it was quite interesting that on the third adjustment the fourth tube's pressure head got down to 8mm but then jumped back up to 14mm before coming back to the value of 8mm. I wonder why this happened instead of a gradual decrease down to 8mm.