MET 335

Module 8 – Orifice Plate Coefficents

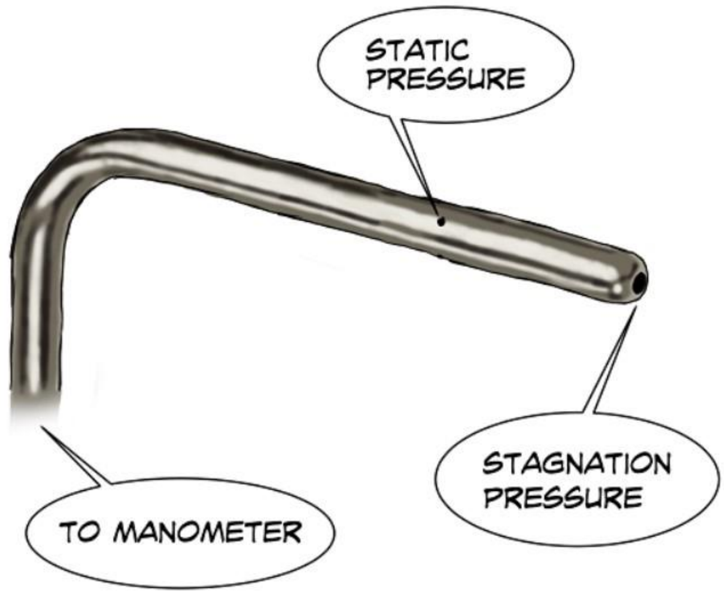
July 10th, 2023

Dylan J Arnold

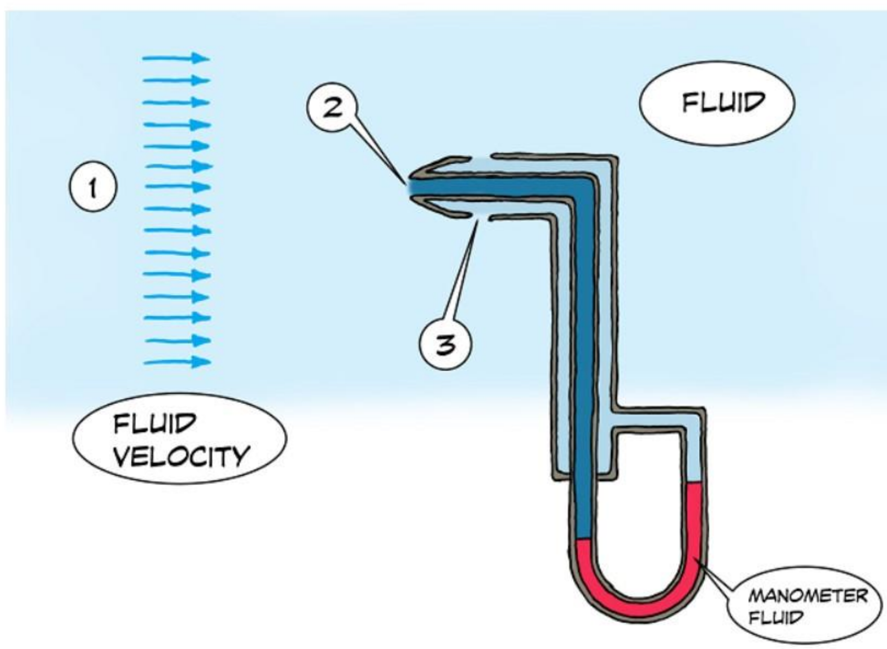
darno005@odu.edu

Purpose, Theory, and Procedure

1. **Experiment Title**
   a. Pitometers and Velocity Profiles
2. **Purpose**
   a. To develop an understanding of the operation of a pitometer and how to use recorded results to determine the velocity profile in a circular duct and the flow rate using formulas derived from the Bernoulli's equation.
3. **Theoretical Considerations**
   a. $Energy\ possessed\ by\ the\ fluid = \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1$
   b. $P_2 = P_1 + \frac{\gamma V_1^2}{2g}$
   c. $P_2 - P_3 = (P_1 + \frac{\gamma V_1^2}{2g}) - P_1 = \gamma(x) + \gamma_m(h_m) - \gamma_m(x + h_m)$
   d. $\frac{(V_1)^2}{2g} = h_m(\gamma_m - \gamma)$
   e. $V_1 = \sqrt{2gh_m(\frac{\gamma_m}{\gamma_{air}} - 1)}$
   f. $\gamma_m >>> \Rightarrow \frac{\gamma_m}{\gamma} >>> 1$
   g. $V = \sqrt{\frac{2gh_m\gamma_m}{\gamma_{air}}}$
   h. $A_n = \frac{1}{10}(\frac{\pi D^2}{4}) = \frac{\pi D^2}{40}$
   i. $Q_n = A_n V_n = \frac{\pi D^2}{40} V_n$
   j. $Q_{Total} = \sum Q_n = Q_1 + Q_2 + Q_3 + ... + Q_{10}$
   k. $V_{Average} = \frac{Q_{Total}}{A_{Duct}} = \frac{Q_{Total}}{\left(\frac{\pi D_{Duct}{}^2}{4}\right)}$
4. **Drawing or Sketch**



a. *Figure 1 - Pitometer*



b. *Figure 2 - Pitometer Cross-section*

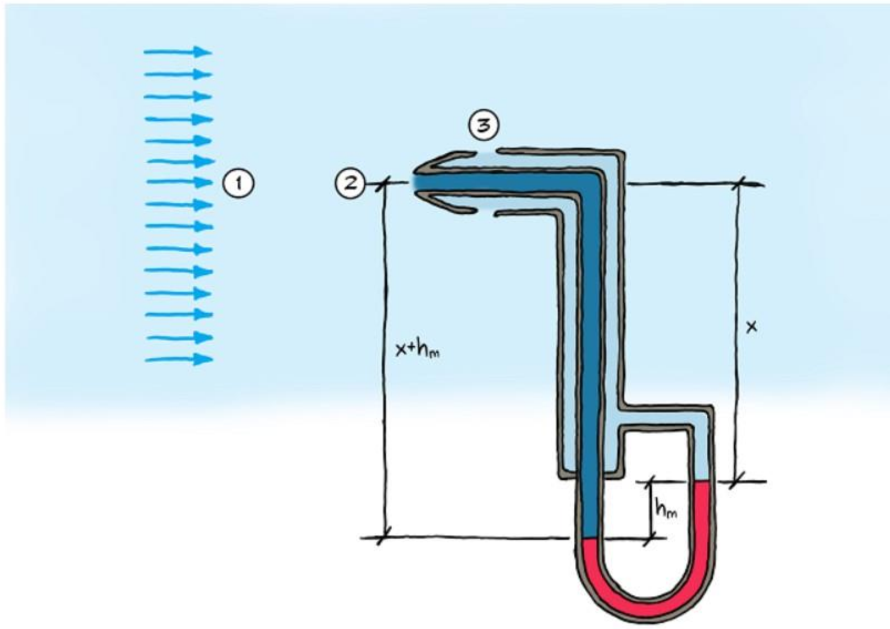


Figure 3 - Pitometer Derivation

c.

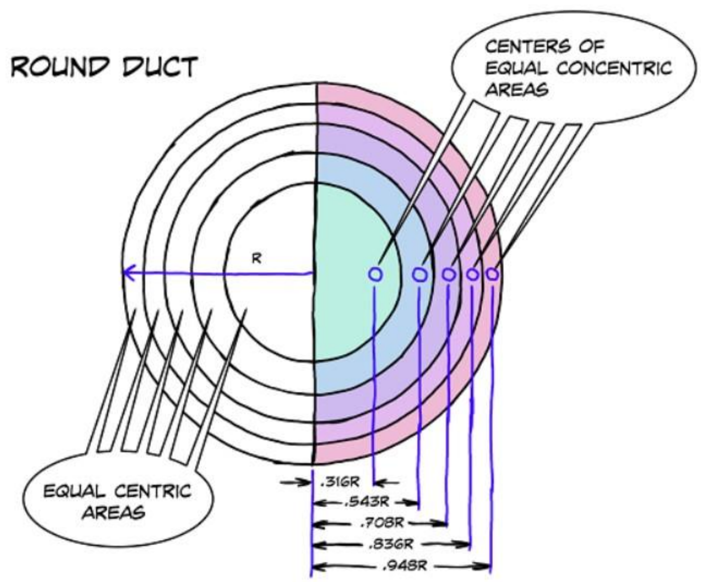


Figure 4 - Concentric Area Locations

d.

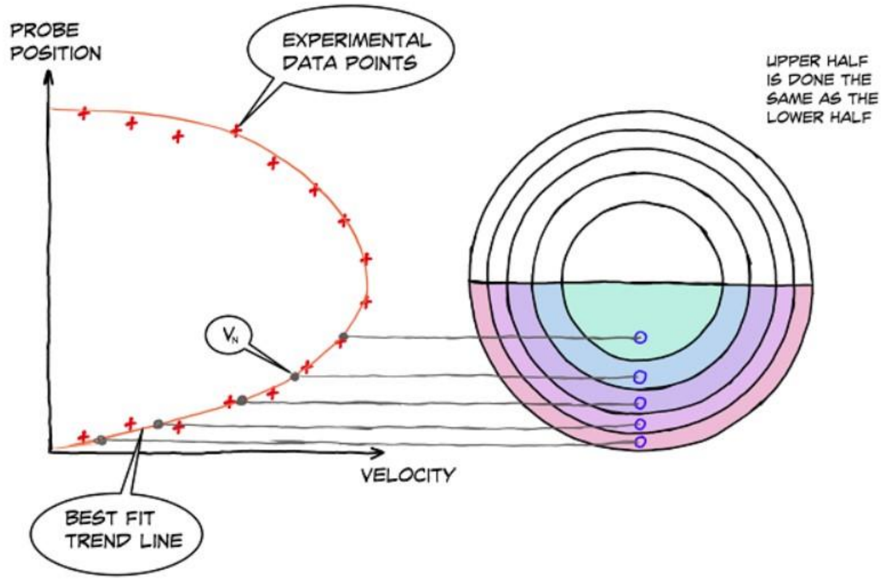


Figure 5 - Determining Velocities

e.

5. **Verbal Description**
    a. The above graphics show that this experiment makes use of a circular duct that is 140mm in diameter. That 140mm diameter has a pitometer installed upstream of the suction from a centrifugal fan that produces air flow in the duct. The installed pitometer should be placed so that the opening is facing and parallel to the air flow to the get the most accurate readings possible. A digital manometer is attached to the installed pitometer and is calibrated to read in units of inches of water.
6. **Step-by-Step Procedure**
    a. Started the lab by walking into the lab room.
    b. Identified the three components we will be working with for this lab:
        i. Duct
        ii. Digital Manometer
        iii. Pitometer
    c. Recorded ambient air temperature.
        i. 75°F
    d. Recorded barometric pressure of room.
        i. 29.95
    e. Turned fan switch on.
    f. Turned digital manometer switch on.
    g. Looked at guide on how to read pitometer and digital manometer.
    h. Selected pitometer to move it to -68.5mm position.
    i. Recorded digital manometer reading.
        i. 0.60”

j. Selected pitometer to move it to -60.0mm position.
k. Recorded digital manometer reading.
    i. 0.70”
l. Selected pitometer to move it to -50.0mm position.
m. Recorded digital manometer reading.
    i. 0.73”
n. Selected pitometer to move it to -40.0mm position.
o. Recorded digital manometer reading.
    i. 0.75”
p. Selected pitometer to move it to -30.0mm position.
q. Recorded digital manometer reading.
    i. 0.80”
r. Selected pitometer to move it to -20.0mm position.
s. Recorded digital manometer reading.
    i. 0.82”
t. Selected pitometer to move it to -10.0mm position.
u. Recorded digital manometer reading.
    i. 0.72”
v. Selected pitometer to move it to 0.0mm position.
w. Recorded digital manometer reading.
    i. 0.70”
x. Selected pitometer to move it to 10.0mm position.
y. Recorded digital manometer reading.
    i. 0.73”
z. Selected pitometer to move it to 20.0mm position.
aa. Recorded digital manometer reading.
    i. 0.78”
bb. Selected pitometer to move it to 30.0mm position.
cc. Recorded digital manometer reading.
    i. 0.82”
dd. Selected pitometer to move it to 40.0mm position.
ee. Recorded digital manometer reading.
    i. 0.77”
ff. Selected pitometer to move it to 50.0mm position.
gg. Recorded digital manometer reading.
    i. 0.76”
hh. Selected pitometer to move it to 60.0mm position.
ii. Recorded digital manometer reading.
    i. 0.75”
jj. Selected pitometer to move it to 68.5mm position.
kk. Recorded digital manometer reading.

i. 0.70”

ll. Turned digital manometer switch off.

mm. Turned fan switch off.

nn. Lab successfully completed.

Recorded Data Table(s)

Ambient Temperature: (°F)	75
Barometric Pressure:	29.95

Probe Position (mm)	Manometer Reading, h_m (inches of water)
-68.5	0.60
-60.0	0.70
-50.0	0.73
-40.0	0.75
-30.0	0.80
-20.0	0.82
-10.0	0.72
0.0	0.70
10.0	0.73
20.0	0.78
30.0	0.82
40.0	0.77
50.0	0.76
60.0	0.75
68.5	0.70

Sample Calculations

$$V = \sqrt{\frac{2gh_m\gamma_m}{\gamma_{air}}} = \sqrt{\frac{2*32.17405\frac{ft}{s^2}*0.60in*\frac{1\,ft}{12in}*62.43\frac{lb}{ft^3}}{0.764\frac{lb}{ft^3}}} = \boxed{16.21\frac{ft}{s}}$$

$$A = \frac{\pi D^2}{40} = \frac{\pi*(70mm*2*\frac{1in}{25.4mm})^2*\frac{1\,ft^2}{144in^2}}{40} = \boxed{0.01657\,ft^2}$$

$$Q = A_nV_n = 17.51\frac{ft}{s}*0.01217\,ft^2 = \boxed{0.21321\frac{ft^3}{s}}$$

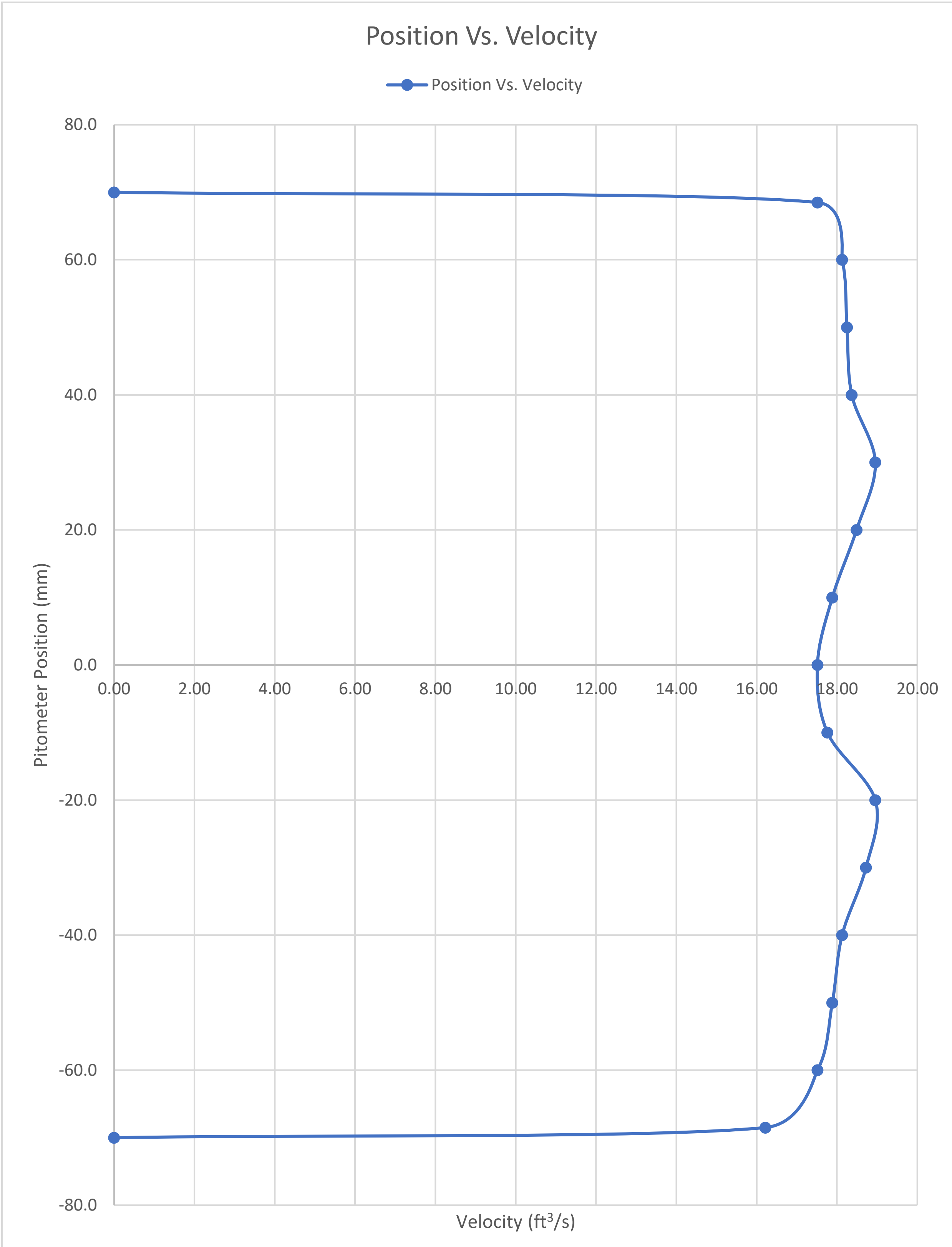
$$Q_{total} = SUM\,(ALL\,Q_n) = \boxed{1.64938\frac{ft^3}{s}}$$

$$V_{average} = \frac{Q_{Total}}{A_{Duct}} = \frac{Q_{Total}}{\left(\frac{\pi D_{Duct}{}^2}{4}\right)} = \frac{1.64938}{\left(\frac{\pi*\frac{(140*\frac{1}{25.4})^2}{144}}{4}\right)} = \boxed{9.954\frac{ft}{s}}$$

Calculated Data Table(s)

Probe Position (mm)	Manometer Reading, h_m (inches of water)	Velocity (ft/s)	A_n (ft^2)	Q_n (ft^3/s)	Q_{total} (ft3/s)	$V_{average}$ (ft/s)
-70.0	0.00	0.00	0.01657	0.00000	1.64938	9.954151
-68.5	0.60	16.21	0.01587	0.25728		
-60.0	0.70	17.51	0.01217	0.21321		
-50.0	0.73	17.88	0.00845	0.15120		
-40.0	0.75	18.13	0.00541	0.09808		
-30.0	0.80	18.72	0.00304	0.05698		
-20.0	0.82	18.96	0.00135	0.02564		
-10.0	0.72	17.76	0.00034	0.00601		
0.0	0.70	17.51	0.00000	0.00000		
10.0	0.73	17.88	0.00034	0.00605		
20.0	0.78	18.49	0.00135	0.02501		
30.0	0.82	18.96	0.00304	0.05769		
40.0	0.77	18.37	0.00541	0.09938		
50.0	0.76	18.25	0.00845	0.15427		
60.0	0.75	18.13	0.01217	0.22069		
68.5	0.70	17.51	0.01587	0.27789		
70.0	0.00	0.00	0.01657	0.00000		

Graph(s)


Position Vs. Velocity
Position Vs. Velocity
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
Pitometer Position (mm)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Velocity (ft³/s)

Discussion of Results and Conclusions

From the graph above, it looks as if none of our pitometer positions meet our average velocity calculation of 9.95 ft/s. This may bring up a red flag in some of our calculations, but I am going to remain confident in my findings because we had to include the two zeroes (at -70mm position and 70mm position).

The curve developed looks a little funky but is in the realm of what the hand drawn curve is in the figure screenshotted above. We also see a symmetrical shape with the "bump" to 19 ft/s for pitometer positions -30mm and 30mm. What could be the cause of this? I'm not entirely sure because the curve seems to come back to the normal curvature after that -30/30mm reading.

Some sources of error that could potentially happen during this lab are some significant figure errors. If you choose to round to tenths versus hundredths or thousandths, you could alter your findings the more you use values in equations. Another source of error is the constants for gravitational acceleration and specific weights. Lastly, the main source of error I can see happening during this lab is not converting everything to the same units. I ran into this for the diameter value in the A formula. Instead of multiplying the pitometer position by 2, I left it as is which was causing my other equations to use the wrong value. After double-checking and verifying the correct diameter value, my values are more in line with what I am aiming for.