MET 335W

Pitometers and Velocity Profiles

March 28, 2019

William McClenney

wmccl001@odu.edu

Experiment Title: Pitometers and Velocity Profiles

Purpose:
In this lab, an understanding of the operation of a pitometer and how to use the results to determine the velocity profile in a circular duct and the flow rate.

Theoretical Considerations:
Average velocity of flow can be converted to volume flow rate by using the equation $Q = Av$ Pitometers are used to measure flow. Basically, our pitometer is measuring pressure, using two tubes. One tube faces the fluid stream directly and the other tube is at a right angle to it. The difference between the total and static pressure is the dynamic pressure. Applying Bernoulli's, we are able to calculate the fluid velocity. The pitometer is moved across the duct to find the velocity at different points and get a velocity profile. Fifteen readings are taken and a plot of velocity versus duct diameter is made.

Description of Apparatus:
1. Circular duct (140 mm in diameter)
2. Centrifugal Fan
3. Digital Manometer
4. Pitometer: The pitometer is actually a tube within a tube; one is at a right angle to the other. Stagnation, or total pressure (p_s) and static pressure (p_1), use the same manometer device for measurement of pressure because the only requirement is to determine the *difference* in pressure.

Step-by-Step Procedures:
1. Before starting the experiment, the ambient temperature and barometric pressure for the room were measured and recorded on the data sheet.
2. Hearing protection was utilized for the involved parties, due to the loud noise exerted by the fan.
3. The toggle switch controlling the fan (located on the side of the fan) was switched to the "on" position.
4. The power switch controlling the digital manometer was switched to the "on" position.
5. The small pitometer tube (located on top of the duct) was lifted up approximately 1.5 mm from the bottom of the duct, and the reading on the digital manometer (in inches of water) was recorded on the data sheet.
6. The pitometer tube was lifted 8.5 mm upwards, and the digital manometer reading was recorded on the data sheet.
7. The pitometer tube was lifted 10 mm upwards, and the digital manometer reading was recorded on the data sheet.
8. Again, the process was repeated, with the pitometer tube being lifted upwards in increments of 10 mm until reaching the top of the duct, and the digital manometer reading was recorded on the data sheet for each 10 mm point the pitometer stopped.
9. Once all 15 readings were recorded on the data sheet, the power switch controlling the digital manometer was switched to the "off" position.
10. The toggle switch controlling the fan was switched to the "off" position.
11. This completed the Pitometer and Velocity Profile experiment.

Table 1: Recorded Data Table:

Probe Position (mm)	Manometer Reading, h_m (inches of H_2O)
Bottom most	
-70.0	0.00
-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
+70.0	0.00
Top most	

Sample Calculations:

1. Velocity = $v = \frac{\sqrt{(2\ g)\ (h_m)\ (\Upsilon_m)}}{\Upsilon}$ * ** $= \sqrt{\frac{2\ (9.81\ m/s^2)\ (h_m)\ (9810\ N/m^3)}{11.856\ N/m^3}}$

→at the wall, the manometer reads zero, thus, $v = \sqrt{\frac{2\ (9.81\ m/s^2)\ (0\ m)\ (9810\ N/m^3)}{11.856\ N/m^3}}$

$= 0$

For Probe position, -68.5 mm,

→ manometer reading was 0.0152 m, $v = \sqrt{\frac{2\ (9.81\ m/s^2)\ (0.015215\ m)\ (9810\ N/m^3)}{11.856\ N/m^3}}$

$= 15.7$ m/s

(Υ_m)* = Specific weight of manometer fluid (water) = 9810 N/m^3

Υ ** = Specific weight of air = 11.856 N/m^3

Graph Calculations

1. Flow Rate: $Q = \frac{\pi D^2 (v_1 + v_2 + \ldots + v_{10})}{40}$

$Q = \frac{\pi\ (0.140\ m)^2}{40} \cdot (\ 175.7\ ) = 0.270\ m^3/s$

2. Average (Bulk) Velocity: $V_{avg} = \frac{4Q}{\pi D^2} = \frac{4\ (0.270\ m3/s)}{\pi\ (0.140)^2} = 17.6$ m/s

3. Pitometer points which corresponded to the average (bulk) velocity of 17.6 m/s (from the graph):

   - At or near the following points
   - R = +47.0, +19.5
   - R = - 36, -14.5

Table 2: Calculated Data Table:

Probe Position (mm)	Manometer Reading, h_m (inches of H_2O)	Manometer Reading, h_m (feet of H_2O)	Manometer Reading, h_m (m)	Velocity (m/s)
Bottom most				
-70.0	0.00	0.0000	0.0000	0.0
-68.5	0.60	0.0500	0.0152	15.7
-60.0	0.70	0.0583	0.0178	17.0
-50.0	0.73	0.0608	0.0185	17.3
-40.0	0.75	0.0625	0.0190	17.5
-30.0	0.80	0.0667	0.0203	18.1
-20.0	0.82	0.0683	0.0208	18.3
-10.0	0.72	0.0600	0.0183	17.2
0.0	0.70	0.0583	0.0152	15.7
+10.0	0.73	0.0608	0.0185	17.3
+20.0	0.78	0.0650	0.0198	17.9
+30.0	0.82	0.0683	0.0208	18.3
+40.0	0.77	0.0642	0.0196	17.8
+50.0	0.76	0.0633	0.0193	17.7
+60.0	0.75	0.0625	0.0190	17.5
+68.5	0.70	0.0583	0.0178	17.0
+70.0	0.00	0.0000	0.0000	0.0
Top most				

Graph:

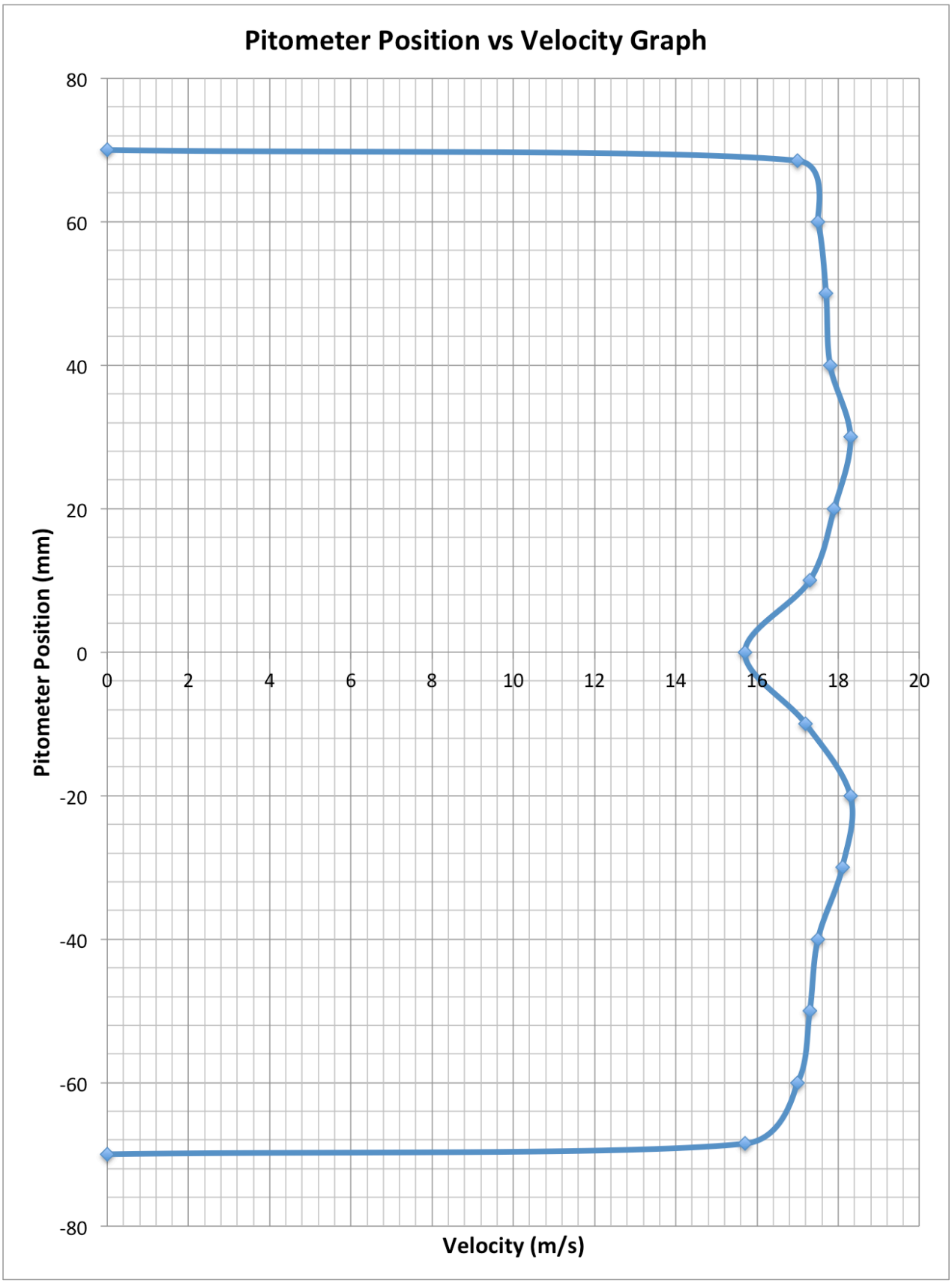
Pitometer Position vs Velocity Graph
80
60
40
20
0
-20
-40
-60
-80
Pitometer Position (mm)
0
2
4
6
8
10
12
14
16
18
20
Velocity (m/s)

Table 3: Graph Values of Velocity at Specified Values of Radius

Radius	Radius	Velocity (m/s)
(0.948R)	-66.36	16.5
(0.836R)	-58.52	17.1
(0.708R)	-49.56	17.4
(0.543R)	-38.01	17.6
(0.316R)	-22.12	18.4
0.316R	22.12	18.0
0.543R	38.01	17.9
0.708R	49.56	17.7
0.836R	58.52	17.6
0.948R	66.36	17.5
	Sum	**175.7**

Discussion of Results and Conclusions:

In this lab, we were able to use data to determine the flowrate and the average (or bulk) velocity in a 0.140-meter duct. Utilizing a pitometer, the velocity was determined across different points in the duct, to give a velocity profile. Each of the different points had its own flow rate. When we plotted the measured velocities versus the pitometer probe position, we were able to determine corresponding velocity at a specific location.

Our graph could be considered to have a widened parabola shape with a dip in the middle. There was a fan in our duct, so instead of getting a maximum flow in the middle, it is more at the ends. In addition, the velocity of fluid at the wall of the duct is zero. Also, from our graph, specific pitometer placement points reveal our average velocity of 17.6 meters/second. This average (bulk velocity corresponds to near the following regions +47.0, +19.5, -36.0, and -14.5.

Overall, theoretical considerations were met. A possible source of error could be attributed to our pitometer: seeded placement in the duct was not assured with full integrity. This would most certainly lead to error in our manometer readings and also in the velocity profile. In addition, much time was spent in getting a best fit line for our graph. Error in the drawing of this line would also cause error in average flow and velocity.

Of all the labs from MET 335w, the Pitometer and Velocity Profiles was my favorite and that was because of the charm of the pitometer. The pitometer is small, efficient, of reasonable cost and does not appear to difficult to work with. It is a basic kind of instrument that does its job- which is prediction of flow, based on Bernoulli's equation.