LAB 6 – BERNOULL'S PRINCIPLE DEMONSTRATION

LEARNING OUTCOMES

1. Demonstrate the Bernoulli's principle
2. Compute the total head, pressure head and velocity head for varying flowrates

In this experiment, we will use the Bernoulli's Theorem Demonstration Apparatus (shown in Figure 1) connected to the Armfield Hydraulic Bench to measure the total head, pressure head and velocity head at different points in a clear acrylic duct of varying circular cross section.

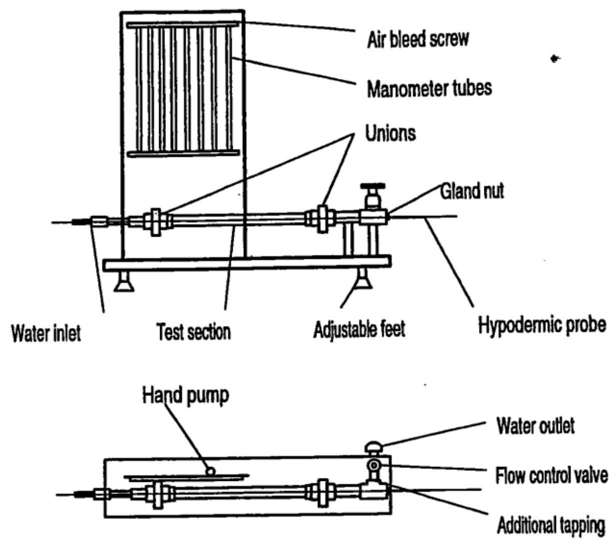

Figure 1. Schematic diagram of the orifice and jet apparatus

The duct is connected to manometers that allow the measurement of static pressure head simultaneously at each of 6 sections. The section potions are shown in Figure 2 and their diameters are shown in Table 2.

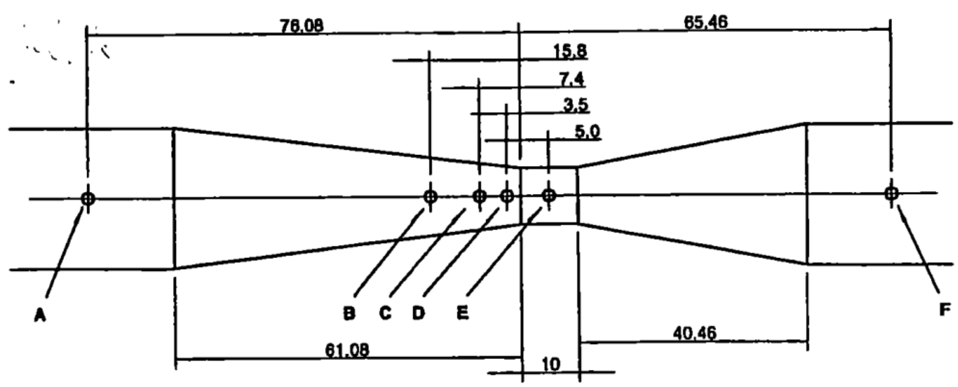

Figure 2. Schematic diagram of the duct with the manometer sections and their diameters

Table 1. Diameters of duct at different tapping positions

Tapping Position	Manometer Legend	Diameter (mm)
A	h_1	25.0
B	h_2	13.9
C	h_3	11.8
D	h_4	10.7
E	h_5	10.0
F	h_6	25.0

EXPERIMENTAL PROCEDURE

1. Ensure that the equipment is horizontal and start the pump
2. Adjust the pump flow until there is a widest possible difference between the inlet and throat (where the duct constricts) of the channel, with the water level visible every piezometer tube
3. Measure the flow rate using a stopwatch
4. Measure the height of the water level in the piezometer tube together with the corresponding distance from the channel entrance
5. Take four repeat measurements for four different flowrates
6. Switch off the pump and close the main valve.

THEORY AND DATA ANALYSIS

In fluid mechanics, Bernoulli's principle is used to relate the velocity and pressure of a fluid for a steady, incompressible, frictionless flow along a streamline. This can be written mathematically as follows

$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+z_2 \quad (1)$$

Where P is the static pressure, v is the velocity, ρ is the density, g is the gravitational constant, z is the elevation. The subscripts 1 and 2 refer to the two different points along the streamline.

The velocity (V) can be calculated for any flow rate (Q) as follows

$$v=\frac{Q}{A} \quad (2)$$

Where A is the normal cross-sectional area. The flow rate (Q) can be measured as follows

$$Q=\frac{Volume\ collected}{time} \quad (3)$$

Equation (1) can be further simplified for the Bernoulli's theorem apparatus because the set up is horizontal (z_1=z_2). In addition, the static pressure head (p) is measured using the manometer directly (h). Therefore, it can be rewritten as follows

$$h_1+\frac{v_1^2}{2g}=h_2+\frac{v_2^2}{2g} \quad (4)$$

Where the terms on the left side and right side are the total heads at location 1 and 2 respectively. The total head remains constant according to Bernoulli's principle. Furthermore, for an incompressible fluid, conservation of mass requires that volume is also conserved. Therefore, flowrate across the tube remains constant. This is called the continuity equation and can be written as follows

$$Q = A_1 v_1 = A_2 v_2 \quad (5)$$

Where A_1 and v_1 are the area and the velocity at the tapping position 1.

Substituting Eq. 5 in Eq 4, we can write a generalized form of Bernoulli's equation in terms of flow rate (Q), the manometer readings (h) and area of the tapping sections as follows

$$h_1 + \frac{Q^2}{2A_1^2 g} = h_2 + \frac{Q^2}{2A_2^2 g} \quad (6)$$

TL;DR

	Parameter	**Equation**
1	Experimental Flowrate (Q)	$\frac{Volume}{Time}$
2	Static pressure head (h)	Manometer reading
3	Areas (A)	Table 1
4	Velocity head	$\frac{v^2}{2g}$
5	Total head	static head (h) + velocity head

DELIVERABLES

One team lab report containing the following

1. Letter of Transmittal (example: http://users.rowan.edu/~jagadish/resources/LoT_Example.pdf)
2. Materials and Methods
   a. In paragraph format explain what materials you used
   b. Explain the procedure for collecting data in your own words in paragraph format
   c. Explain the method for analyzing the data collected in lab. Retype all the equations, screenshotting is not permitted. Use subscripts and superscript where necessary
3. Results and Discussion
   a. For each flow rate present the static head (h), velocity (v), velocity head and total head
   b. What is the difference in total head (head loss) between tapping positions 1 and 6?
   c. Present a figure showing the variation of total head with distance.
   d. Discuss your results
      i. Explain the change in velocity at different sections? Does it change as expected?
      ii. How does head loss vary with flow rate?
      iii. What is the reason for losses?
   e. All calculations must be included in appendix and should not be presented here
4. Conclusions
   a. Briefly summarize your results and explain what you learned.
5. Appendix
   a. Show one sample calculation here

Fluid Mechanics
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Trial _____

Volume collected (V)________________ (ml)

Time (t) _____________________ seconds

Flow rate (Q = V/t) ____________ m^3/s

Tapping position	Manometer reading (h)	Distance (m)	Diameter (mm)	Velocity (v=Q/A)	Velocity Head $(\frac{v^2}{2g})$	Total head
A		0	25.0			
B		0.0603	13.9			
C		0.0687	11.8			
D		0.0732	10.7			
E		0.0811	10.0			
F		0.1415	25.0			