LAB 5 – ORIFICE AND FREE JET FLOW

LEARNING OUTCOMES

1. Describe the Bernoulli's principle
2. Describe the energy losses in orifice flow
3. Compute the coefficients of velocity, contraction and discharge

In this experiment, we will use the Orifice and Jet Apparatus (shown in Figure 1) connected to the Armfield Hydraulic Bench to study the orifice flow and measure the energy losses using the coefficients of velocity, contraction and discharge.

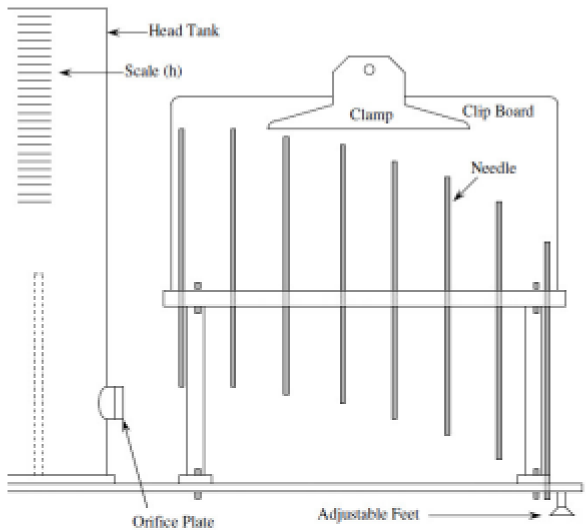

Figure 1. Schematic diagram of the orifice and jet apparatus

EXPERIMENTAL PROCEDURE

1. A **3mm** orifice will be used to conduct this experiment. Ensure that the apparatus is level and clamp a paper to the board. Make sure all the needles are raised to their highest position
2. Turn on the water supply. Once the water has reached the level where it is spilling into the overflow pipe, adjust the flow so that the height remains constant. Record the water level or head (h). At this point the jet should have formed.
3. Measure the flow rate Q using graduated cylinder and stopwatch. Adjust the height of each needle such that the tip of the needle is just above the water jet as it passes underneath.
4. Once all the needles are set mark the position of the needle thus tracing out a curve of the jet on the paper by marking the locations of the needles. Measure the horizontal distance to each needle, this is x. The first mark would be positioned just where visually the 'vena contracta' appears to be (this is closer to the jet and may be located before the first needle). The top end of the first needle is where y = 0. The remaining needles will be lower as the jet curves down. Measure the vertical displacement, y for the jet at each needle location relative to the first needle.
5. Repeat the above steps for four different heads.

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

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g z_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g z_2 \quad (1)$$

Where P is the 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.

Based on Eq. 1, the total energy between two points is conserved. Therefore, when the velocity increases, the pressure is decreased to compensate for the increase in velocity. This equation can be simplified for orifice flow as follows

$$v = \sqrt{2gh} \quad (2)$$

Where h is the change in head or the height of fluid above the orifice

This equation does not account for frictional losses at the entrance and exit of the nozzle. Therefore, the corrected equation that measures the actual velocity can be written as

$$v = C_v\sqrt{2gh} \quad (3)$$

Where C_v is the coefficient of velocity, which allows for effects of viscosity. This can be determined by the trajectory of jet. The discharge (Q) can also be corrected as follows

$$Q = A_c v \quad (4)$$

Where A_c is the area at the vena contracta (Shown in Figure 2) and not the true area of the orifice (A_o). The area of the orifice (A_o) and the area at the vena contracta are related by the coefficient of contract (C_c) as follows

$$A_c = C_c A_o \quad (5)$$

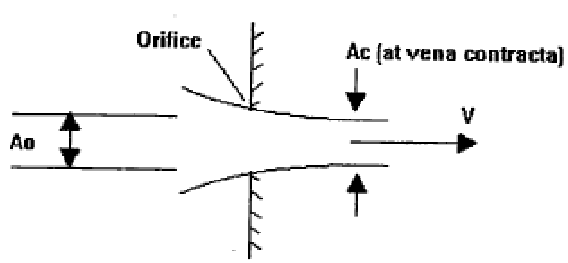

Figure 2. Illustration showing the difference between area of the orifice (A_o) and area at the vena contracta (A_c)

Combining Eq (3), (4) and (5), the equation for discharge can be written as follows

$$Q = C_d A_o\sqrt{2gh} \quad (6)$$

Where C_d is the coefficient of discharge which is the product of C_v and C_c. A plot between Q and $\sqrt{h}$ will be linear and the slope (S), given in Eq. 7 below, can be used to find C_d

$$S = C_d A_o\sqrt{2g} \quad (7)$$

The coefficient of velocity (C_v) from Eq. 3 can be obtained by the equation for the trajectory as follows

$$x = 2C_v\sqrt{yh} \qquad (8)$$

Where x and y are the co-ordinates of the trajectory of the jet in horizontal and vertical direction. Therefore, a plot between x and $\sqrt{yh}$ should give a slope of $2C_v$.

TLDR;

	Parameter	**Equation**
1	Experimental Flowrate	$\frac{Volume}{Time}$
2	Coefficient of discharge (C_d)	Plot Q vs $\sqrt{h}$, Use Eq. 7
3	Coefficient of velocity (C_v)	Plot x vs $\sqrt{yh}$, Slope = $2C_v$
4	Coefficient of contraction (C_c)	$C_d = C_c C_v$
5	Theoretical discharge	Eq. 6

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. Present the figure for Q and $\sqrt{h}$ with trendline. Figure must show the trendline equation [Note: Figures must be referred to in-text]
    b. Present the figure for x and $\sqrt{yh}$ with trendline. Figure must show the trendline equation [Note: Figures must be referred to in-text]
    c. Present neatly formatted Table(s) for collected data. [Note: Tables must be referred in text]
    d. Report and discuss the C_d, C_c, and C_v values.
    e. Compute the theoretical discharge and compare with the experimental discharge
    f. All calculations must be included in appendix and should not be presented here
    g. Discuss your results. How do they compare? What is the reason for discrepancies?
4. Conclusions
    a. Briefly summarize your results and explain what you learned.
5. Appendix
    a. Show one sample calculation here