

Experiment 6

ORIFICE AND FREE JET FLOW DETERMINATION OF COEFFICIENT OF VELOCITY FROM JET

INTRODUCTION:

The orifice consists of a flat plate with a hole drilled in it. When a fluid passes through an orifice, the discharge is often considerably less than the amount calculated on the assumption that the energy is conserved and that the flow through the orifice is uniform and parallel. This reduction in flow is normally due to a contraction of the stream which takes place through the restriction and continues for some distance downstream of it, rather than to any considerable energy loss.

With the flow through apparatus, arrangements are made to measure the extent of the reduction in flow, contraction of the stream and energy loss, as water discharges into the atmosphere from a sharp-edged orifice in the base of a tank.

OBJECTIVE:

- Determine Velocity coefficient for small orifice
- Comparing the measured jet trajectory with the theoretically predicted jet trajectory

APPARATUS:

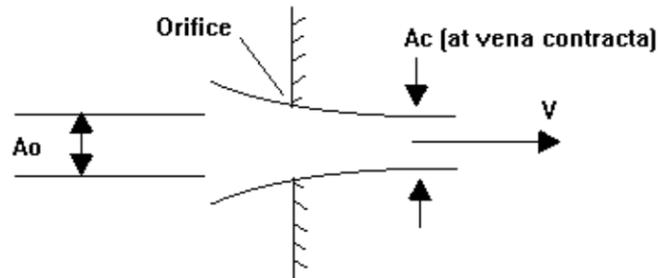
- the F1-17 Orifice and free jet flow apparatus
- The F1-10 Hydraulic Bench
- Graph paper

THEORY:

From the application of Bernoulli's Equation (conservation of mechanical energy for a steady, incompressible, frictionless flow): the ideal orifice outflow velocity at the jet vena contracta (narrowest diameter) is where h is the height of fluid above the orifice.

$$v_i = \sqrt{2gh}$$

Where h is the height of fluid above the orifice.



The actual

velocity is

$$v = C_v \sqrt{2gh} < 1 \dots \dots \dots (1)$$

C_v is the coefficient of velocity, which allows for the effects of viscosity a

C_v can be determined from the trajectory of the jet using the following argument:

Neglecting the effect of air resistance, the horizontal component of the jet velocity can be assumed to remain constant so that in time, t , the horizontal distance travelled,

$$X = vt \dots \dots \dots (2)$$

Because of the action of gravity, the fluid also acquires a downward vertical (y -direction) component of velocity. Hence, after the same time, t , (i.e. after travelling a distance x) the jet will have a y displacement given by

$$y = g \frac{t^2}{2}$$

This can be rearranged to give:

$$t = \sqrt{2 \frac{y}{g}} \dots \dots \dots (3)$$

Substitution for t from (3) into (2) and for v from (1) into (2) yields the result:

$$C_v = \frac{x}{2} \sqrt{yh}$$

Hence, for steady flow conditions, i.e. Constant h , C_v can be determined from the x , y co-ordinates of the jet. A graph of x plotted against \sqrt{yh} will have a slope of $2C_v$

PROCEDURE:

For this experiment, you will need the Orifice and Free Jet Flow module and graph paper.

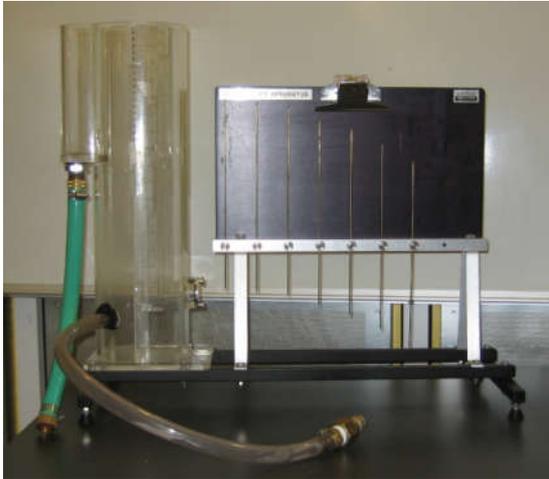


Figure 1: Orifice and Free Jet Flow Module

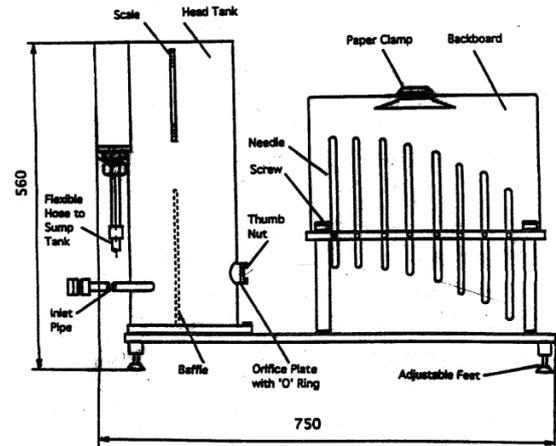


Figure 2: Orifice and Jet Apparatus

1. Position the overflow tube to give a high head. Note the value of the head.
2. The jet trajectory is obtained by using the needles mounted on the vertical backboard to follow the profile of the jet.
3. Release the securing screw for each needle in turn and move the needle until its point is just immediately above the jet and re-tighten the screw.
4. Attach a sheet of paper to the back-board between the needle and board and secure it in place with the clamp provided so that its upper edge is horizontal.
5. Mark the location of the top of each needle on the paper. Note the horizontal distance from the plane of the orifice (taken as $x = 0$) to the co-ordinate point marking the position of the first needle.
6. This first co-ordinate point should be close enough to the orifice to treat it as having the value $y = 0$.
7. Thus y displacements are measured relative to this position.
8. Estimate the likely experimental errors in each of the quantities measured.
9. Repeat this test for a low reservoir head.
10. Repeat this test for a low reservoir head.
11. Then repeat the above procedure for the second orifice.

TABLE OF OBSERVATIONS AND CALCULATIONS:

- Small Orifice: Diameter=3mm=0.003m

	Orifice Diameter d(m)	Head h(m)	Horizontal Distance X(m)	Vertical Distance y(m)	\sqrt{yh} (m)
1	0.003		0.0135		
2	0.003		0.0635		
3	0.003		0.1135		
4	0.003		0.1635		
5	0.003		0.2135		
6	0.003		0.2635		
7	0.003		0.3135		
8	0.003		0.3635		

- Large Orifice: Diameter=6mm=0.006m

	Orifice Diameter d(m)	Head h(m)	Horizontal Distance X(m)	Vertical Distance y(m)	\sqrt{yh} (m)
1	0.006		0.0135		
2	0.006		0.0635		
3	0.006		0.1135		
4	0.006		0.1635		
5	0.006		0.2135		
6	0.006		0.2635		
7	0.006		0.3135		
8	0.006		0.3635		

GRAPHICAL RELATIONSHIP:

Plot x against \sqrt{yh} and determine the slope of the graph.

The velocity coefficient C_v is equal to the average slope/2.

CONCLUSION AND RECOMMENDATIONS:

Compare the values of C_v with values reported in the textbook for an Orifice Meter and discuss any difference (or look for web resources).