LABORATORY MANUAL FOR **Fluid Mechanics**

Subject Code: **CEP 1302**

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
MIZORAM

LIST OF EXPERIMENTS

EXPERIMENT NO. 01

Determination of C_d for Venturimeter

AIM: To determine the coefficient of discharge C_d for a given venturimeter and to study the variation of this coefficient with discharge.

THEORY: A venturimeter is a device used for measuring the rate of flow of a fluid flowing through a pipe. A schematic diagram of the venturimeter is shown in Fig. 1. As seen from the figure, a venturimeter consists of three parts: (a) An inlet section followed by a short converging part (b) A cylindrical throat and (c) A gradually diverging part. The basic principle of venturimeter is based on Bernoulli's equation. Here, by reducing the cross-sectional area of the flow passage, a pressure difference is created between the inlet and throat & the measurement of the pressure difference enables the determination of the discharge through the pipe.

The inlet section of the venturimeter is of the same diameter as that of the pipe, which is followed by a convergent one. The convergent cone is a short pipe, which tapers from the original size of the pipe to that of the throat of the venturimeter. The throat of the venturimeter is a short parallel side tube having its cross – sectional area smaller than that of the pipe. The divergent cone of the venturimeter is a gradually diverging pipe with its cross–sectional area increasing from that of the throat to the original size of the pipe. In the converging section, acceleration of the flowing fluid is allowed to take place under the favourable pressure gradient in a relatively small length, without appreciable loss of energy. However, in the diverging section, retardation of flow is allowed to take place and to prevent the boundary layer separation and consequently formation of the eddies that result in excessive loss of energy, the divergent section is made longer with a divergence angle of 6^o (approx.). The convergent section of a venturimeter has a convergent angle of 21^o (approx.).

At the inlet and the throat, of the venturimeter, pressure taps are provided through pressure rings. The pressure difference created between the inlet section and throat section can be determined by connecting a differential U-tube manometer between the pressure taps.

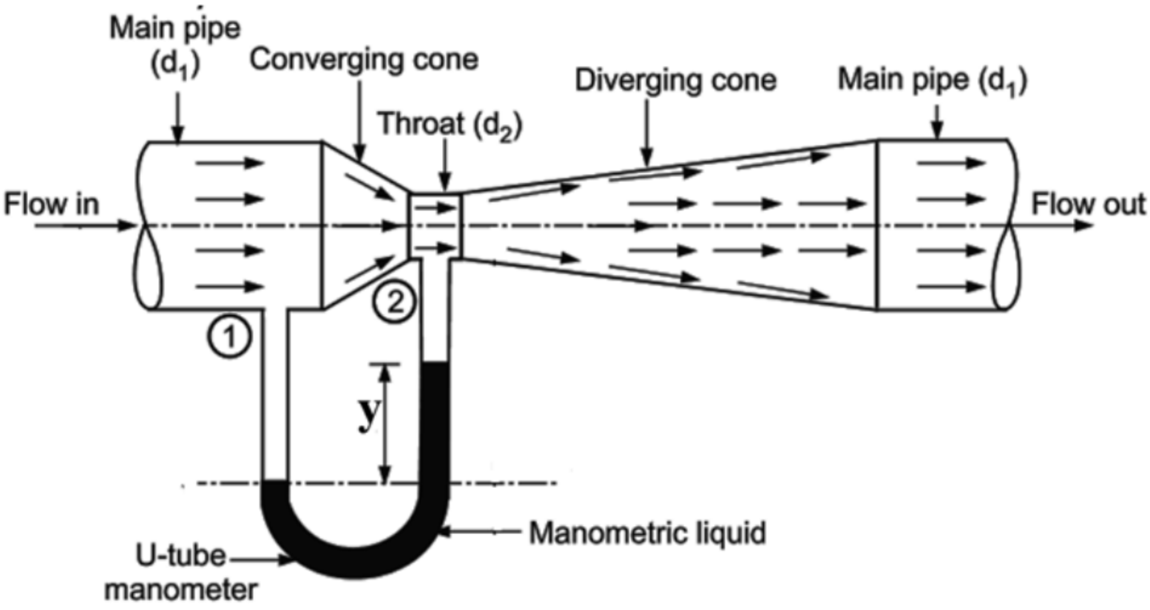


Fig. 1. Venturimeter

Calculation of actual discharge using the below formula:

Let, A = area of the collecting tank in m²

R = rise of water level taken in meters (say 0.1m or 10cm)

t = time taken for rise of water level to rise R metre

The actual discharge can be expressed in m³/sec as:

$$Q_{act} = \frac{A \times R}{t}$$

Calculation of theoretical discharge using the below formula:

Let, H = Difference in reading in the differential manometer

h = Difference of pressure heads at sections 1 and 2 in meter = $H \times \left(\frac{S_m}{S_w} - 1 \right)$

a_1 = Cross sectional area at inlet = $\frac{\pi}{4} d_1^2$

a_2 = Cross sectional area at throat = $\frac{\pi}{4} d_2^2$

d_1 = Diameter of inlet in meter

d_2 = Diameter of throat in meter

S_m = Specific gravity of mercury

S_w = Specific gravity of water

The theoretical discharge in m^3/sec can be expressed as:

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

Calculation of coefficient of discharge using the below formula:

The coefficient of discharge (C_d) can be expressed as:

$$C_d = \frac{Q_{act}}{Q_{th}}$$

APPARATUS:

a) Venturimeter.
b) Piping system.
c) Supply pump set
d) Measuring tank
e) Differential manometer
f) Sump
g) Stopwatch

PROCEDURE:

1. Check whether all the joints are leak proof and water tight. Fill the manometer to about half the height with mercury.
2. Close all the cocks, pressure feed pipes and manometer to prevent damage and overloading of the manometer. Check the gauge glass and meter scale assembly of the measuring tank and see that it is fixed water height and vertically.
3. Check proper electrical connections to the switch, which is internally connected to the motor. First open the inlet gate valve of the apparatus. Adjust the control valve kept at the exit end of the apparatus to a desired flow rate and maintain the flow steadily.
4. The actual discharge is measured with the help of the measuring tank. The differential head produced by the flow meter can be found from the manometer for any flow rate.

5. Start the motor keeping the delivery valve close. The water is allowed to flow through the selected pipe by selecting the appropriate ball valve.
6. By regulating the valve control the flow rate and select the corresponding pressure tapings (i.e. of orifice meter). Make sure while taking readings, that the manometer is properly primed. Priming is the operation of filling the manometers upper part and the connecting pipes with water by venting the air from the pipes.
7. Note down the difference of head "*H*" from the manometer scale, and time required for the rise of 10 cm (i.e. 0.1 m) water in the collecting tank by using stop watch.
8. Repeat the above steps for 3 to 8 times.

Note:

1. Manometer mercury should be handled carefully to prevent spillage.
2. Always use the flow control valve at the pump outlet to control the flow rate.
3. Open only the drain cocks connected to test the Venturimeter (through the manifold) should be opened only after confirming that the correct valves connecting the Venturimeter are open and all others are closed.
4. Do not close the valve at the pipeline outlet as this would build up the pressure in the pipeline which could lead to accidental mercury spillage. This valve is to be used only to stop the flow in that line and allow flow in other line where the Venturimeter is tested.

OBSERVATIONS:

Sl No.	**Manome-ter reading (m)**	**Loss of pressure head (*h*)**	**Rise of the water column in the measuring tank(m)**	**Time for raise of water by *R* meter in sec**	**Actual discharge (m^3/sec)**	**Theoretical discharge (m^3/sec)**	**Coefficient of discharge (C_d)**
	H	$h = H \times \left(\frac{S_m}{S_w} - 1\right)$	R (0.1 m)	T	Q_{act}	Q_{th}	$C_d = \frac{Q_{act}}{Q_{th}}$
1							
2							
3							

CALCULATION:

Area of the collecting tank (A) = …… m²

Acceleration due to gravity (g) = 9.81 m/sec^2

S_m = Specific gravity of mercury = 13.6

S_w = Specific gravity of water = 1

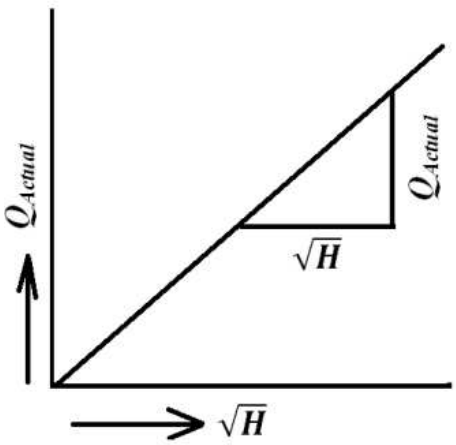
d_1 = Diameter at inlet of the venturimeter = …… m

d_2 = Diameter at throat of the venturimeter = ……. m

a_1 = Cross sectional area at inlet = $\frac{\pi}{4} d_1^2$

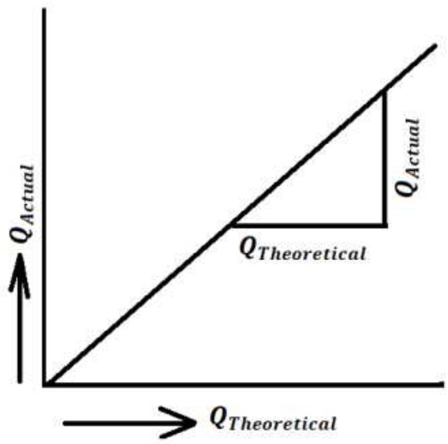
a_2 = Cross sectional area at throat = $\frac{\pi}{4} d_2^2$

NATURE OF GRAPH:

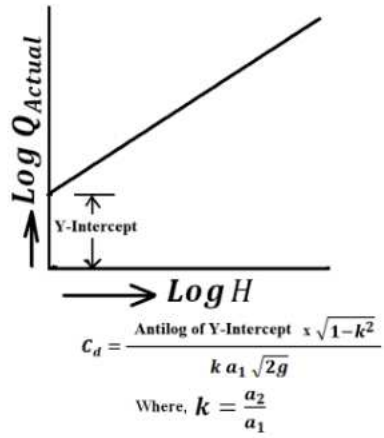


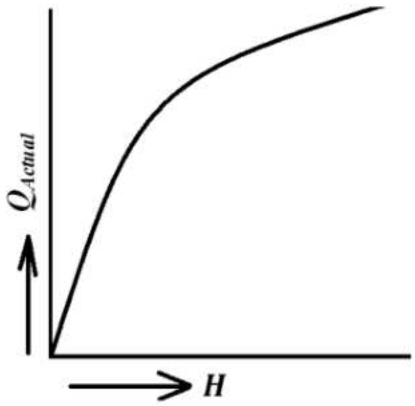
$$C_d = \frac{Q_{Actual}}{\sqrt{H}} \times \frac{\sqrt{1-k^2}}{k\, a_1 \sqrt{2g}}$$

Where, $k = \frac{a_2}{a_1}$



$$C_d = \frac{Q_{Actual}}{Q_{Theoretical}}$$





RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Ensure the priming condition of the pump during experimentation.
2. Ensure the supply condition under constant head.
3. Operate the manometer tappings properly.
4. Do not touch mercury if it is expelled out of manometer.
5. Maintain proper earthing of electrical connections.
6. Check the gate valves frequently to avoid leakages.
7. Operate the equipment under the supervision of laboratory technical staff.
8. In case of emergency, contact the laboratory technical staff.
9. The Venturimeter should be fixed in the pipeline such that the pipe on the both sides, is long enough and does not affect the flow in Venturimeter.
10. Sufficient time should be given for the flow to be become steady-uniform.
11. The air bubbles should be completely removed in the pipe connecting the manometer. This should be achieved only by opening the valves provided at the top of the manometers simultaneously. If they are opened separately, the manometric fluid (usually mercury, which is very costly) will spill out of manometer.

QUESTIONS:

1. What is the use of Venturimeter?
2. What is the basic principle on which Venturimeter works?
3. What is the range of included angle of the convergent and divergent cones?
4. What is the length of the convergent cone?
5. Whether the convergent cone is longer or divergent cone? Justify.
6. At what distance from the throat and convergent cone pressure taps are provided?

7. Can pressure taps be provided between throat and divergent cone? Why?
8. What is the difference between Venturimeter and Orifice meter?
9. Why is a Venturimeter more accurate than an orifice meter?
10. Why C_d value is high in Venturimeter?

EXPERIMENT NO. 02

Determination of C_d for Orifice meter

AIM: To determine the coefficient of discharge C_d for a given orifice meter and to study the variation of this coefficient with discharge.

THEORY: An orifice meter or orifice plate is a device used for measuring the rate of flow of a fluid through a pipe. It is a cheaper device as compared to venturimeter. The orifice is an opening on the side wall or bottom wall of a tank used for discharging fluid out of the tank or an opening on a plate which may be fitted in a pipe such that the plate is normal to the axis of the pipe. The flow is into and out of the tank is to be adjusted such that the rate of flow into the tank is equal to the rate of flow out of the tank, thus, establishing a steady flow condition so that the Bernoulli's equation is valid. The discharging fluid from the tank comes out through the orifice into the atmosphere in the form of a free jet. In the process, the total energy of the fluid in the tank is converted to kinetic energy as the fluid issues out into the atmosphere. The cross-sectional area of the jet after coming out from the orifice contracts to a minimum partly due to the viscous resistance offered by the surrounding atmosphere and partly due to the inertia of the fluid particles. The cross-section with the minimum area is known as the vena-contracta and this location is assumed to be around 0.5D downstream of the orifice where D is the diameter of the orifice. Due to this sudden contraction and expansion of the jet, loss of energy takes place. Further losses like the frictional losses occurring at the orifice edges cause the actual velocity of the water jet to be less than the theoretical velocity at the orifice.

A schematic diagram of the orifice meter is shown in Fig 2. As seen from the diagram, a differential manometer is connected at a section (1), which is at a distance of 1.5 to 2.0 times the diameter of the pipe in the upstream side of the plate and at section (2), which is at a distance of about half the diameter of the pipe on the downstream side of the orifice plate.

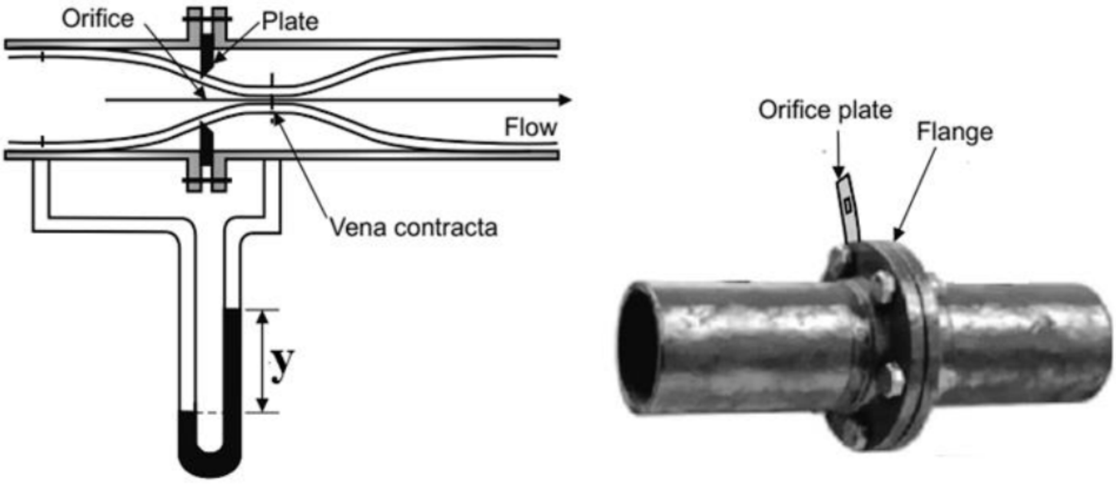


Fig. 2. Orifice meter

Calculation of actual discharge using the below formula:

Let, A = area of the collecting tank in m²

R = rise of water level taken in meters (say 0.1m or 10cm)

t = time taken for rise of water level to rise R metre

The actual discharge can be expressed in m³/sec as:

$$Q_{act} = \frac{A \times R}{t}$$

Calculation of theoretical discharge using the below formula:

Let, H = Difference in reading in the differential manometer

h = Difference of pressure heads at sections 1 and 2 in meter = $H \times \left(\frac{S_m}{S_w} - 1 \right)$

d_1 = Diameter of the inlet of the pipe at Section (1) in meter

d_2 = Diameter of the orifice

a_1 = Cross sectional area of the inlet of the pipe at Section (1) = $\frac{\pi}{4} d_1^2$

a_2 = Cross sectional area of the orifice = $\frac{\pi}{4} d_2^2$

S_m = Specific gravity of mercury

S_w = Specific gravity of water

The theoretical discharge in m[3]/sec can be expressed as:

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

Calculation of coefficient of discharge using the below formula:

The coefficient of discharge (C_d) can be expressed as:

$$C_d = \frac{Q_{act}}{Q_{th}}$$

APPARATUS:

a) Orifice meter.
b) Piping system.
c) Supply pump set
d) Measuring tank
e) Differential manometer
f) Sump
g) Stopwatch

PROCEDURE:

1. First open the inlet gate valve of the apparatus. Adjust the control valve kept at the exit end of the apparatus to a desired flow rate and maintain the flow steadily.
2. Check whether all the joints are leak proof and water tight. Fill the manometer to about half the height with mercury.
3. While taking readings, close all the cocks in the pressure feed pipes except the two (Downstream and upstream) cocks which directly connect the manometer to the required flow meter, for which the differential head is to be measured. (Make sure while taking reading that the manometer is properly primed. Priming is the operation of filling the manometer upper part and the connecting pipes with water and venting the air from the pipes).

4. Close all the cocks, pressure feed pipes and manometer to prevent damage and over loading of the manometer.
5. Check the gauge glass and meter scale assembly of the measuring tank and see that it is fixed water tight and vertically.
6. Check proper electrical connections to the switch, which is internally connected to the motor.
7. Start the motor keeping the delivery valve close. The water is allowed to flow through the selected pipe by selecting the appropriate ball valve.
8. By regulating the valve control the flow rate and select the corresponding pressure tapings (i.e. of orifice meter).
9. Make sure while taking readings, that the manometer is properly primed. Priming is the operation of filling the manometer s upper part and the connecting pipes with water by venting the air from the pipes. Note down the difference of head "*h*" from the manometer scale.
10. Note down the time required for the rise of 10 cm (i.e. 0.01 m) water in the collecting tank by using stop watch.
11. Repeat the above steps for 3 to 8 times.

Note:

1. Manometer mercury should be handled carefully to prevent spillage.
2. Always use the flow control valve at the pump outlet to control the flow rate.36
3. Open only the drain cocks connected to test the Orifice meter (through the manifold) should be opened only after confirming that the correct valves connecting the flowmeter are open and all others are closed.
4. Do not close the valve at the pipeline outlet as this would build up the pressure in the pipeline which could lead to accidental mercury (Hg) spillage. This valve is to be used only to stop the flow in that line and allow flow in other line where the Orifice meter is tested.

OBSERVATIONS:

Sl No.	Manometer reading (m)	Loss of pressure head (*h*)	Rise of the water column in the measuring tank(m)	Time for raise of water by *R* meter in sec	Actual discharge (m^3/sec)	Theoretical discharge (m^3/sec)	Coefficient of discharge (C_d)
	H	$h = H \times \left(\frac{S_m}{S_w} - 1\right)$	R (0.1 m)	T	Q_{act}	Q_{th}	$C_d = \frac{Q_{act}}{Q_{th}}$
1							
2							
3							

CALCULATION:

Area of the collecting tank (A) = …… m^2

Acceleration due to gravity (g) = 9.81 m/sec^2

S_m = Specific gravity of mercury

S_w = Specific gravity of water

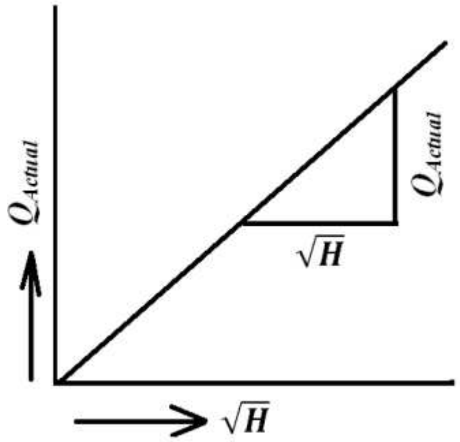
d_1 = Diameter at inlet of the pipe = …… m

d_2 = Diameter of the orifice = ……. m

a_1 = Cross sectional area at inlet = $\frac{\pi}{4} d_1^2$

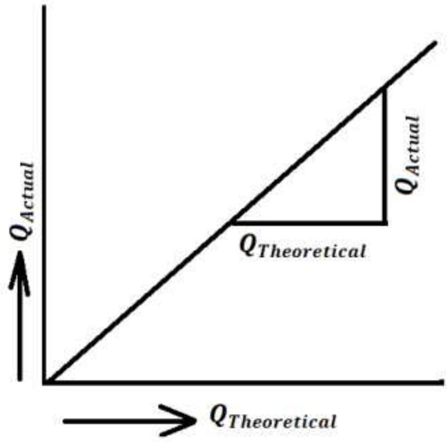
a_2 = Cross sectional area of the orifice = $\frac{\pi}{4} d_2^2$

NATURE OF GRAPH:

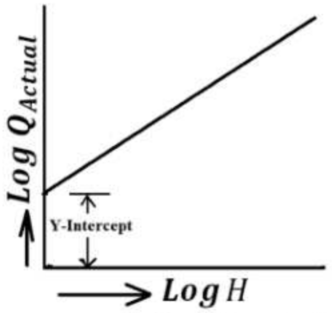


$$C_d = \frac{Q_{Actual}}{\sqrt{H}} \text{ x } \frac{\sqrt{1-k^2}}{k\, a_1 \sqrt{2g}}$$

Where, $k = \frac{a_2}{a_1}$

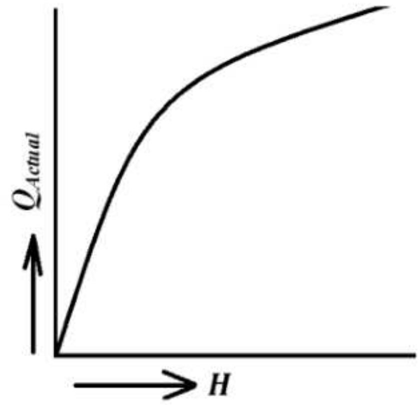


$$C_d = \frac{Q_{Actual}}{Q_{Theoretical}}$$



$$C_d = \frac{\text{Antilog of Y-Intercept x } \sqrt{1-k^2}}{k\, a_1 \sqrt{2g}}$$

Where, $k = \frac{a_2}{a_1}$



RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Ensure the priming condition of the pump during experimentation.
2. Ensure the supply condition under constant head.
3. Operate the manometer tapings properly.
4. Do not touch mercury if it is expelled out of manometer.
5. Maintain proper earthling of electrical connections.
6. Check the gate valves frequently to avoid leakages.

7. Operate the equipment under the supervision of laboratory technical staff.
8. In case of emergency, contact the laboratory technical staff

QUESTIONS:

1. What is the use of Orifice meter?
2. What is the range of orifice diameter?
3. Define the vena contracta.
4. Where does the vena contracta form in the Orifice meter?
5. What is the advantage of orifice meter as compared with Venturimeter?
6. Define the coefficient of velocity and coefficient of contraction.
7. Where is the position of pressure tap on the upstream side of the Orifice meter? Why?
8. Where will be the pressure tap on the downstream side of Orifice meter?
9. What are the other flow measuring devices used in pipes?

EXPERIMENT NO. 03

Determination of C_d, C_v and C_c for circular orifice (constant Head method)

AIM: To determine the Co-efficient of Discharge (C_d), Co-efficient of Velocity (C_v), and Co-efficient of Contraction (C_c) of a circular orifice by using constant head method.

THEORY: Orifice is a small opening of any cross-sectional shape (such as circular, triangular, rectangular etc.) on the side or at the bottom of a tank, through which a fluid is flowing. Orifices are used for measuring the rate of flow of fluid.

The orifices are classified on the basis of their size, shape, nature of discharge and shape of the upstream edge. The following are the important classifications:

1. The orifices are classified as small orifice or large orifice depending upon the size of orifice and head of liquid from the centre of the orifice. If the head of liquid from the centre of orifice is more than five times the depth of orifice, then the orifice is called as a small orifice. And if the head of liquid is less than five times the depth of orifice, then it is known as a large orifice.
2. The orifices are classified as (i) Circular orifice, (ii) Triangular orifice, (iii) Rectangular orifice and (iv) Square orifice depending upon their cross-sectional shapes.
3. The orifices are classified as (i) Sharp-edged orifice and (ii) Bell-mouthed orifice depending upon the shape of upstream edge of the orifices.
4. The orifices are classified as (i) Free discharging orifices and (ii) Drowned or submerged orifices depending upon the nature of discharge. The sub-merged orifices are further classified as (a) Fully sub-merged orifices and (b) Partially sub-merged orifices.

APPARATUS:

A circular orifice fitted to a balancing tank, meter scale to measure the internal dimensions of the collecting tank, centrifugal pump and motor for steady supply of water, stop watch to measure the time of collection of discharge for known rise of water level in the collecting tank, measuring tank with control valve to collect the water.

EXPERIMENTAL SETUP

An opening made in the side or base of a tank (thin walled) of water through which the water can flow is termed as an orifice. The co-efficient of discharge is defined as the ratio between actual discharge and theoretical discharge.

The unit consists of a M.S. supply tank of cross-sectional size 0.3 m × 0.3 m, provided with an inlet diffuser for damping level oscillations, an overflow outlet, a gauge glass tube and scale fitting and a provision for fixing interchangeable orifices and mouthpieces. The tank is connected to the main supply line and the whole unit is supported on a strong iron stand. Water flowing through the orifice is collected in the collecting tank.

A pointer gauge attached to a sliding scale apparatus is provided to measure the horizontal and vertical (*x* and *y*) co-ordinates of the jet of water from the orifice to determine the coefficient of velocity (C_v) and coefficient of contraction (C_c).

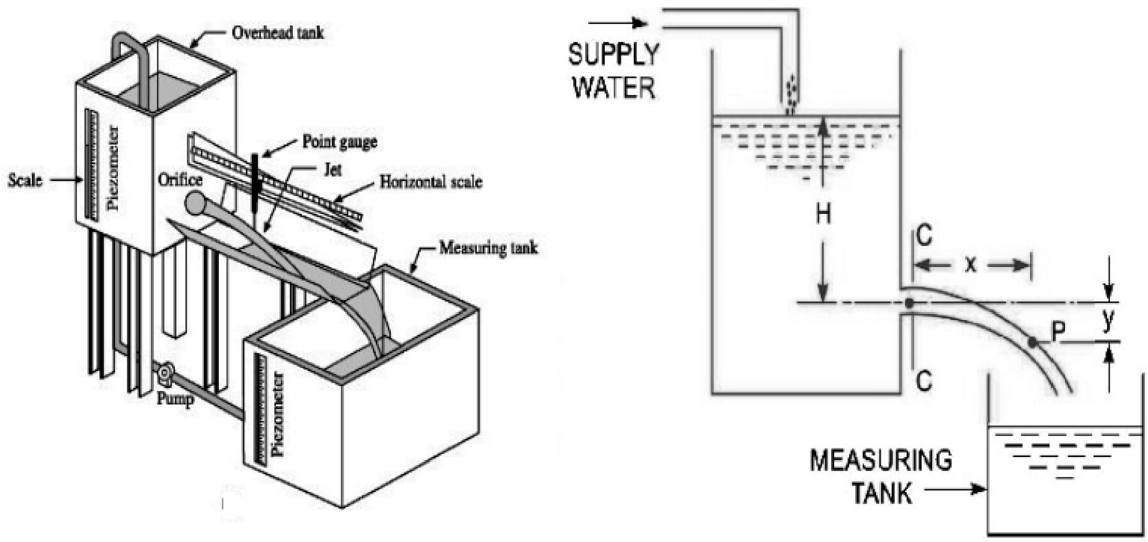


Fig. 3. Flow through orifice

PROCEDURE:

Determination of Co-efficient of discharge (C_d):

1. Fit the required orifice plate in the flange housing.
2. The gauge glass scale is set such that the zero value starts at the centre of the orifice.
3. Allow water into the tank and adjust the gate valve so that the water level remains steady at a particular height, H, which is the head of water above the centre of orifice causing the flow.
4. Close the drain valve of the collecting tank and collect the water for a certain height (say 10 cm). Note the time (*t* secs) required for water level to rise by this height in the

tank. Knowing the cross-sectional area of the tank the actual discharge rate through the orifice can be calculated.

5. Reduce the inflow in the orifice tank and let the height of water in the tank be again kept steady at a different value and repeat the experiment as before.

Determination of Co-efficient of contraction (C_c) & Co-efficient of velocity (C_v):

1. Measure the distance of `*x*' and `*y*' by means of scale and sliding apparatus fitted to the tank. The horizontal scale on the sliding apparatus is located such that the zero coincides with the plane of the orifice. Since vena contracta of the jet is located about half the orifice diameter from the orifice plane, for all practical purposes, the horizontal scale can be assumed to begin at the jet vena contracta for these small orifices. Care should be taken to keep the tip of the pointer gauge at the center of the jet while measuring the y distance.
2. The jet of water from the orifice has a horizontal velocity, *V* and is acted upon by gravity with a gravitational constant (g = 9.81 m/s2).
3. If `*x*' is the horizontal distance of the particle of water in the jet from the orifice and `*y*' the vertical distance, calculate the value of C_v using the equation, $C_v = \sqrt{\frac{x^2}{4yH}}$.
4. Coefficient of discharge, C_d being already calculated for coefficient of contraction, C_c can be obtained by using the equation, $C_v \times C_c = C_d$.

OBSERVATIONS:

Sl No.	Constant Water Head ***H*** (m)	Time for ***R*** cm rise ***t*** (s)	Actual discharge $Q_{act} = \frac{AR}{t}$ (m³/s)	Theoretical discharge $Q_{th} = a \times \sqrt{2gH}$ (m³/s)	Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$	Horizontal distance ***x*** (m)	Vertical distance ***y*** (m)	Coefficient of velocity $C_v = \sqrt{\frac{x^2}{4yH}}$	Coefficient of contraction $C_c = \frac{C_d}{C_v}$
1									
2									
3									

4									
5									
					Avg. C_d =			**Avg. C_v =**	**Avg. C_c =**

CALCULATION:

Area of collecting tank, $A = \ldots\ldots.\ m^2$

Rise in water level, $R = 0.10m$ (say)

Time taken = t sec

Actual discharge, $Q_{act} = \dfrac{AR}{t}\ m^3/s$

Diameter of Orifice, $d = \ldots\ldots.\ m$

Cross sectional area of Orifice, $a = \dfrac{\pi d^2}{4} = \ldots\ldots\ m^2$

Constant Head of water = H m

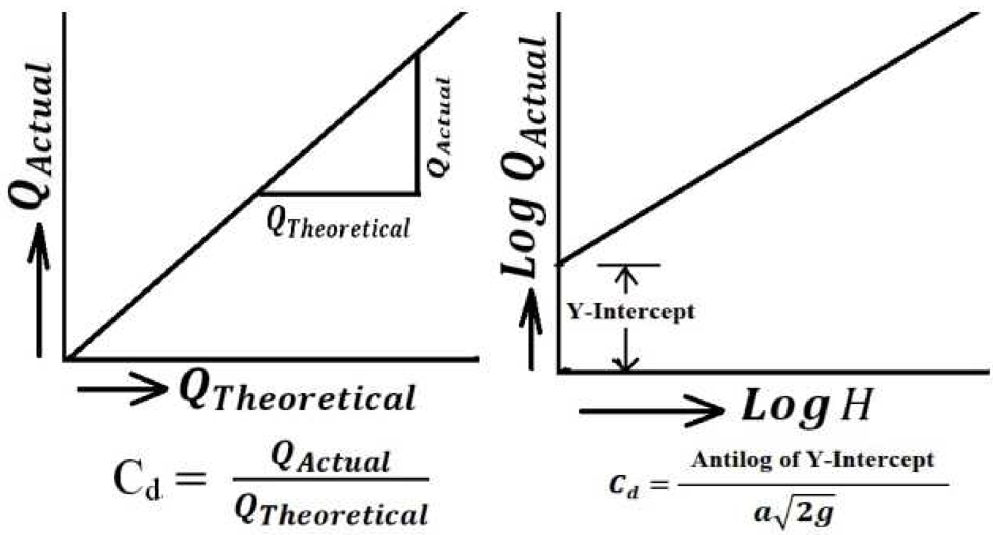
Theoretical discharge, $Q_{th} = a \times \sqrt{2gH}\ m^3/s$

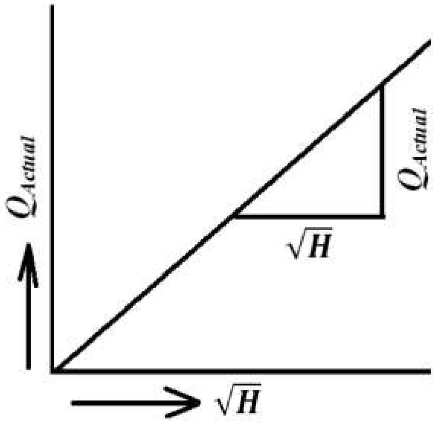
Coefficient of discharge, $C_d = \dfrac{Q_{act}}{Q_{th}}$

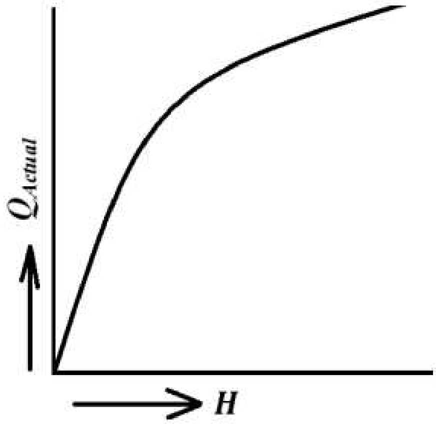
Coefficient of velocity, $C_v = \sqrt{\dfrac{x^2}{4yH}}$

Coefficient of contraction, $C_c = \dfrac{C_d}{C_v}$

NATURE OF GRAPH:







$$\frac{QActual}{\sqrt{H}} = \text{Slope}$$

$$C_d = \frac{1}{a\sqrt{2g}} \text{ x } \frac{QActual}{\sqrt{H}}$$

RESULT AND CONCLUSIONS:

PRECAUTIONS:

1 Ensure the priming condition of the pump during experimentation.
2. Ensure the supply condition under constant head.
3. Maintain proper earthing of electrical connections.
4. Check the gate valves frequently to avoid leakages.
5. Operate the equipment under the supervision of laboratory technical staff.

QUESTIONS:

1. What is an orifice?
2. What is the significance of micrometer contraction gauge when determining the coefficient of contraction of an orifice?
3. How do you determine the Cd of an orifice?
4. Differentiate between a large and small orifice.
5. Define the coefficient of resistance.
6. Differentiate Orifice and mouthpiece.

EXPERIMENT NO. 04

Determination of C_d for Mouthpiece (Falling Head method)

AIM: To determine the Co-efficient of discharge of an external cylindrical Mouthpiece.

THEORY: The apparatus consists of a mouthpiece fitted to one side of a vertical tank, main water tank and a collecting tank. Water in the main tank can be driven by means of a pump so that it flows in the mouthpiece fitted tank and thereby into the collecting tank through the mouth piece. A valve is provided at the site of pump so that the flow in the mouth piece fitted tank can be adjusted. The vertical tank is provided with some scale to measure the head of water above the mouth piece. The collecting tank is provided with some scale to read the water level in it and there by volume of water collected can be computed.

Mouth piece is a short length pipe which is not more than two or three times its diameter in length, fitted in a tank or vessel containing fluid. It is used to measure the rate of flow of fluid. Mouth piece fitted external to the tank is called external mouthpiece. The jet of liquid entering the mouth piece constructs to form a vena-contracta. Beyond this section jets again expands and fill the mouth piece completely.

APPARATUS:

External cylindrical Mouth piece fitted to a balancing tank, meter scale to measure the internal dimensions of the collecting tank, centrifugal pump and motor for steady supply of water, stop watch to measure the time of collection of discharge for known rise of water level in the collecting tank, measuring tank with control valve to collect the water.

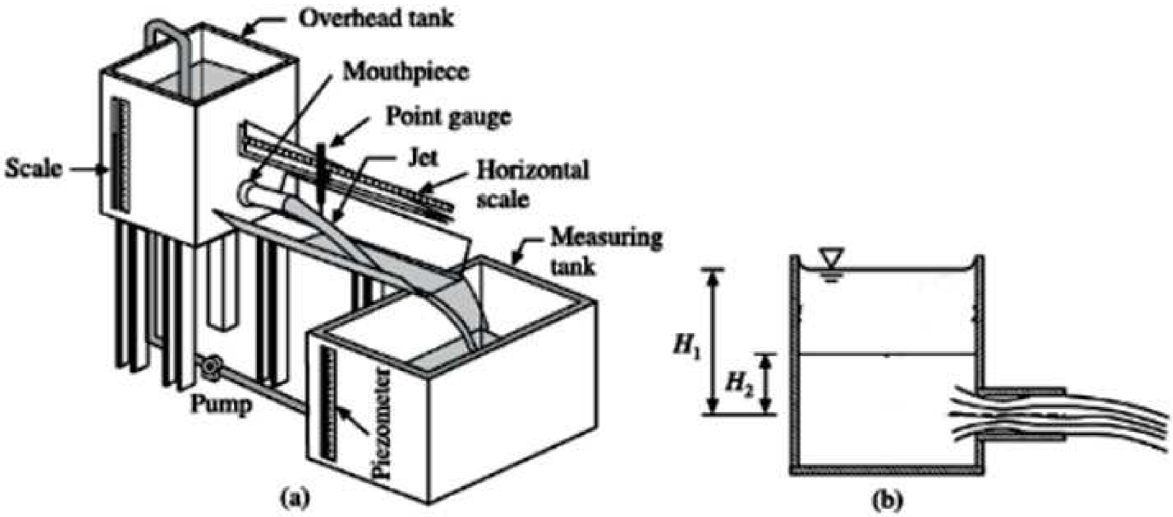


Fig. 4. (a) Experimental setup for calibration of mouthpiece, and (b) sectional view of the tank.

PROCEDURE:

Constant Head Method / Steady-State Method

1. Fit the external cylindrical mouthpiece to the tank.
2. The gauge glass scale is set such that the zero value starts at the center of the mouthpiece. Allow water in to the tank and adjust the gate valve so that the water level remains steady at a particular reading *H* m. Then *H* is defined as the head of water above the center of mouthpiece causing the flow.
3. Starting from say *H* m above the mouthpiece (i.e. head) time taken for water level to drop by say 5cm or 10 cm is noted.
4. Close the drain valve of the collecting tank and collect the water for a certain height. Note: the time (*t* s) required for water level to rise by this height in the tank. Knowing the cross-sectional area of the tank the actual discharge rate through the mouthpiece can be calculated.
5. Reduce the inflow in the tank and let the height of water in the tank be again being kept steady at a different value and similarly repeat 5 to 6 readings of the experiment.

Time of fall method

Coefficient of discharge can also be determined by using the time of fall method. Here, after the water level reaches a certain height in the supply tank, the inlet valve is quickly closed and the time taken for the fall of water head for a certain distance say from 70 cm to 40 cm or 60 cm to 40 cm to measure.

OBSERVATIONS:

Constant Head Method / Steady State Method

Sl No.	Water head H (m)	Time (t) for R m rise (s)	Actual discharge $Q_{act} = \frac{AR}{t}$ (m^3/s)	Theoretical discharge $Q_{th} = a \times \sqrt{2gH}$ (m^3/s)	Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$
1					
2					
3					
4					
5					

CALCULATION:

Area of collecting tank, $A = \ldots\ldots.\ m^2$

Rise in water level, $R = 0.10$ (say)

Time taken = t sec

Actual discharge, $Q_{act} = \frac{AR}{t}\ m^3/s$

Diameter of Mouthpiece, $d = \ldots\ldots.m$

Cross sectional area of Mouthpiece, $a = \frac{\pi d^2}{4}\ m^2$

Constant Head of water = H m

Theoretical discharge, $Q_{th} = a \times \sqrt{2gH}\ m^3/s$

Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{th}}$

Time of Fall Method / Falling Head Method / Unsteady-State Method / Time of -Emptying Method

Sl No.	Initial head H_1 (m)	Final head H_2 (m)	Time (t) for fall in level from H_1 to H_2 (s)	Coefficient of discharge $C_d = \frac{2A_s \times \left(\sqrt{H_1} - \sqrt{H_2}\right)}{t \times a \times \sqrt{2g}}$
1				
2				
3				
4				
5				

CALCULATION:

Area of supply tank, A_s = ……. m^2

Diameter of Mouthpiece, d = …….m

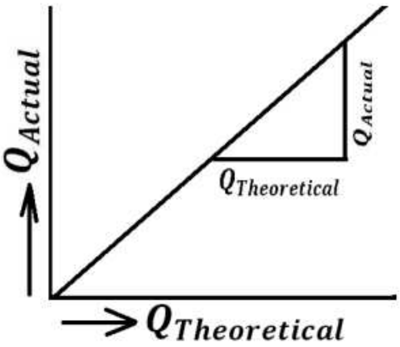
Cross sectional area of Mouthpiece, $a = \frac{\pi d^2}{4}$ m^2 =………m^2

If is the time taken for water level in the tank to fall from H_1 to H_2 m and a is the area of the mouthpiece,

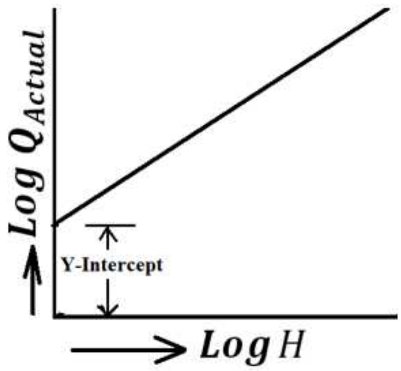
$$\text{Coefficient of discharge, } C_d = \frac{2A_s \times \left(\sqrt{H_1} - \sqrt{H_2}\right)}{t \times a \times \sqrt{2g}}$$

NATURE OF GRAPH:

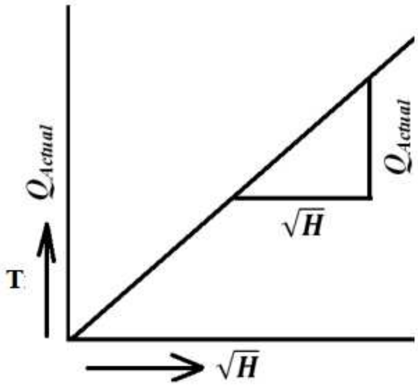
Constant Head Method / Steady State Method



$$C_d = \frac{Q_{Actual}}{Q_{Theoretical}}$$

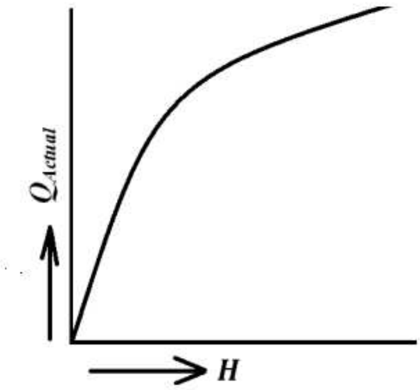


$$C_d = \frac{\text{Antilog of Y-Intercept}}{a\sqrt{2g}}$$

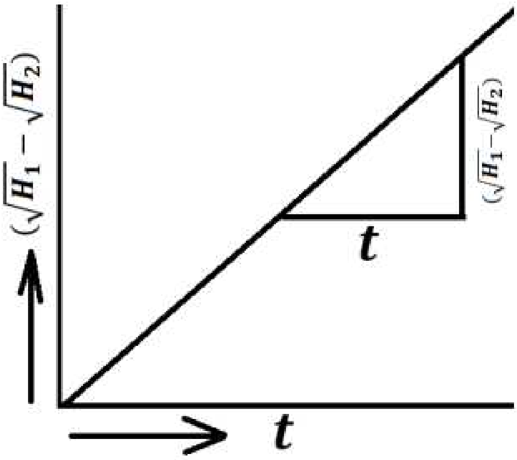


$$\frac{QActual}{\sqrt{H}} = \text{Slope}$$

$$C_d = \frac{1}{a\sqrt{2g}} \text{ x } \frac{QActual}{\sqrt{H}}$$



Falling Head Method



$$C_d = \frac{2A_s}{a \times \sqrt{2g}} \text{ x } \frac{(\sqrt{H_1} - \sqrt{H_2})}{t}$$

RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Ensure the priming condition of the pump during experimentation.
2. Ensure the supply under constant head.
3. Maintain proper earthing of electrical connections
4. Check the gate valves frequently to avoid leakages.
5. Operate the equipment under the supervision of laboratory technical staff.
6. In case of emergency, contact the laboratory technical staff.
7. Only exit diameter of the mouthpiece should be measured depending on internal or external mouthpiece.
8. Reading errors may occur at gauge and volumetric piezometric scale by not recording the readings at the eye level.
9. Synchronize the stopwatch operations for volumetric measurements.

QUESTIONS:

1. What is the mouthpiece? What are different types of mouthpieces?
2. What is the value of C_c at the outlet of the mouthpiece running full?
3. Under what condition does the mouthpiece run full?
4. What is the difference between an orifice and a mouthpiece?
5. What is the advantage of a mouthpiece over an orifice?

EXPERIMENT NO. 05

Determination of C_d for Triangular (V) notch

AIM: To determine the Co-efficient of discharge of a Triangular Notch /V-notch.

THEORY: Notches and weirs are used to measure the flow rate in canals and streams. The conditions of flow in the case of a weir are practically the same as those of a rectangular notch hence often a notch is called a weir and vice versa. Notches are generally of smaller size and are made of plates while weirs are usually made of masonry or concrete (in real application).

Notches are fitted perpendicular to the direction of flow of water. They act as an obstruction to the flow and the water flows over the sill. Hence, the upstream water level raises and a head is formed above the sill level. By measuring this head, the flow rate can be calculated. The two model notches and the rectangular weir provided with the flame are made of brass sheets with sharp level edges. The broad crested weir is made of fibre glass with sharp edges.

There are various types of notches rectangular, trapezoidal (Cippoletti), triangular notches and weirs are described briefly in the following sections.

The basic principle is that discharge is directly related to the water depth above the crotch (bottom) of the notch. This depth is called head over the notch. Due to the minimal installation costs flow rate measurement with a notch is very less expensive. The rectangular notch is the most commonly used thin plate weir. In a V-Notch, the wetted edge varies directly with the head unlike in a rectangular notch where the wetted edge remains constant. Hence, in a V – Notch C_d remains constant for all heads and hence a V – Notch gives more accurate results for low discharges. The flow pattern over a notch is complex and there is no analytical solution to the relationship between discharge and bead so that a semi-empirical approach has to be used.

The theoretical discharge over a triangular notch is given by:

$$Q_{th} = \frac{8}{15} \tan \frac{\theta}{2} \sqrt{2g} H^{5/2}$$

where,

θ = angle of notch

g = acceleration due to gravity

H = head of water above the V-notch

APPARATUS: V-Notch, vernier pointer gauge, pump and motor for steady supply of water, stop watch to measure the time of collection of discharge for known rise of water level in the collecting tank and measuring tank/ with control valve to collect the water.

EXPERIMENTAL SETUP

The equipment consists of a supply tank. Three rows of perforated sheets are fixed to the upstream side to serve as baffles. When the water flows through the baffles, the oscillations are damped out and a steady and smooth flow is obtained. The front side of the supply tank is provided with provision for fixing interchangeable notch plates. The complete supply tank is supported on a strong iron stand. A fine hook gauge or pointer gauge is fixed on a beam across the channel. The pointer gauge serves the purpose of measuring the water surface level. A collecting tank is provided to measure the actual discharge.

Water is supplied to the main channel from water mains through a gate valve that is used to regulate the flow rate. A drain cock is provided at the bottom side of the channel.

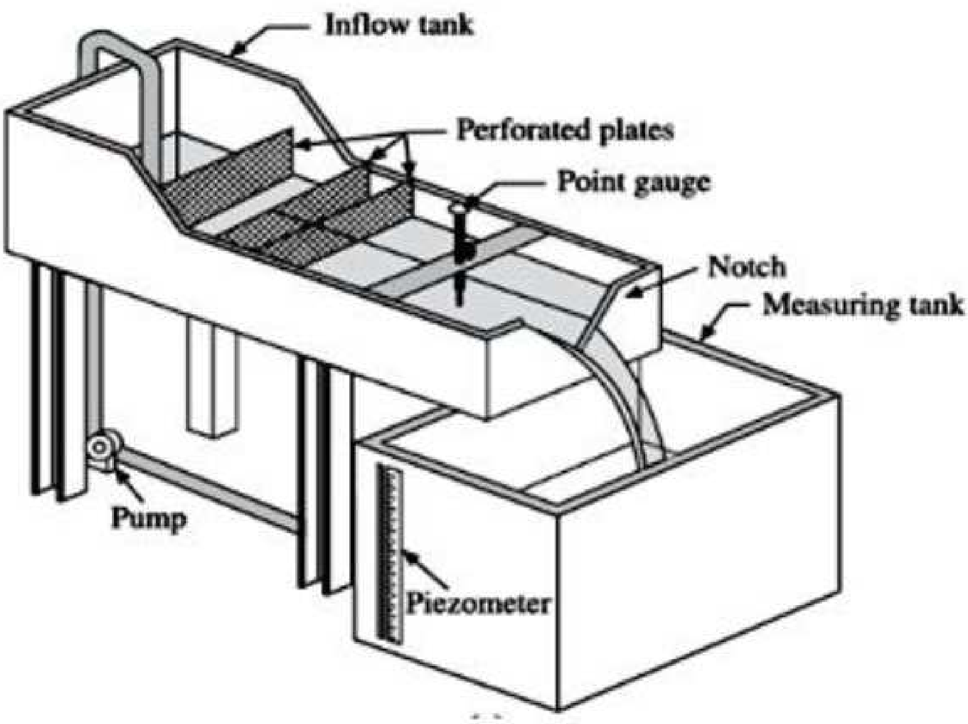


Fig. 5. Experimental Setup of Triangular Notch.

PROCEDURE:

1. Fix the required notch or weir.

2. Allow water in the channel.
3. Regulate the gate valve so that the water just flows over the still.
4. Take the reading in the point gauge. The pointer just touches the water surface. The reading is still level reading.
5. Allow more water and maintain the discharge at a constant value by regulating the gate valve.
6. Adjust the pointer gauge and take the reading.
7. Collect the water in the collecting tank for a rise of 10 cm and note the time taken in seconds to calculate the actual discharge.
8. Repeat the experiments for different heads/flow rates.

OBSERVATIONS:

Sl No.	**Vernier pointer gauge reading**		**Head of water flowing over the Notch $H = (H_2 - H_1)$ (m)**	**Time (t) for 0.1 m rise in the collecting tank (s)**	**Actual discharge Q_{act} (m^3/s)**	**Theoretical discharge Q_{th} (m^3/s)**	**Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$**
	Initial water level reading (sill level) H_1 (m)	**Final water level reading H_2 (m)**					
1							
2							
3							
4							
5							

CALCULATION:

Actual Discharge: $Q_{act} = \frac{AR}{t}$

where,

Area of tank A = ……. m^2

Rise of level, $R = 0.1$ m

Volume collected = $A \times R$ m^3

Time taken for rise of 0.1 m of water level = t sec

Theoretical Discharge: $Q_{th} = \frac{8}{15} \tan\frac{\theta}{2} \sqrt{2g} H^{5/2}$

where,

Initial water level reading (sill level) = H_1 m

Final water level reading = H_2 m

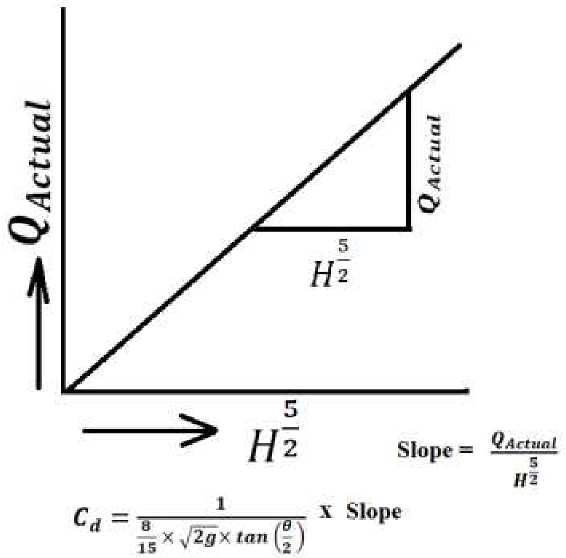
Head of water flowing over the Notch = $H = (H_2 - H_1)$ m

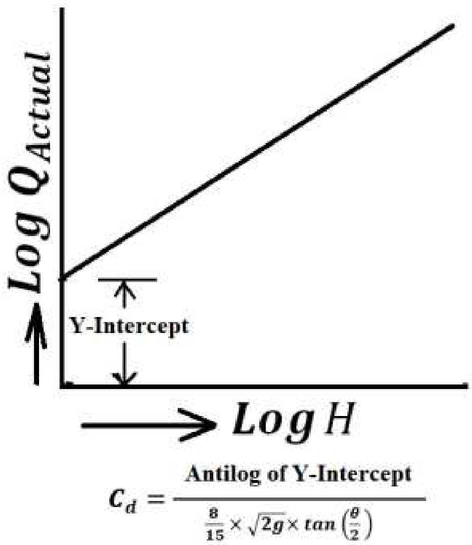
Acceleration due to gravity = g = 9.81 m/s^2

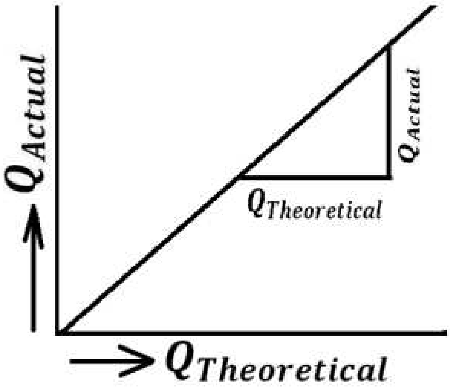
Angle of the Notch = θ = 90°

Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{th}}$

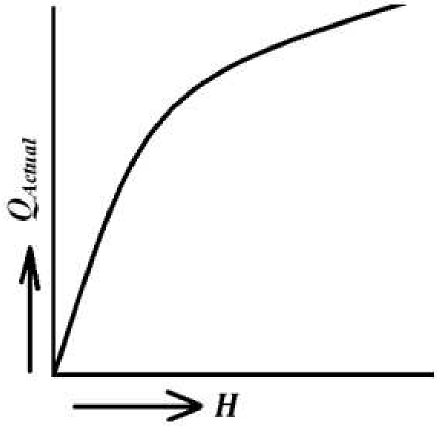
NATURE OF GRAPH:







$$C_d = \frac{Q_{Actual}}{Q_{Theoretical}}$$



RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Fix the notch model properly to the experimental set-up.
2. Ensure the proper operation of point gauge.
3. Maintain the flow under constant head conditions
4. Check the priming of the pump during experimentation.
5. Ensure proper earthing of electrical connections.
6. Confirm the gate valves condition to avoid leakages.
7. Consult the laboratory staff in any emergency
8. Operate the equipment under the supervision of laboratory technical staff.
9. The weir/notch should be fixed exactly in the vertical plane perpendicular to flow axis.
10. The weir should be fixed in a position such that it is symmetrical over vertical axis.
11. Sufficient time should be given for the flow to become steady-uniform.
12. Gauge readings should be measured only in piezometer attached to the collecting tank and not on the free surface.
13. Reading errors may occur at gauge and volumetric piezometric scale by not recording the readings at the eye level.
14. Synchronize the stopwatch operations for volumetric measurements.

QUESTIONS:

1. Define notch and explain its classifications.
2. Define the coefficient of discharge, Cd. What is its significance?
3. Explain the advantages of triangular notch over rectangular notch.
4. Under what conditions you prefer triangular notch?
5. If 10% of error is made in the measurement of head over the triangular notch, what is the corresponding error in computed discharge?
6. What is the meaning of calibration?

EXPERIMENT NO. 06

Determination of C_d for Rectangular (V) notch

AIM: To determine the Co-efficient of discharge of a Rectangular Notch.

THEORY: A notch is a device used for measuring the rate of flow of a liquid through a small channel or a tank. It may be defined as an opening in the side of a tank or vessel such as liquid surface in the tank is below the level of opening. Different types of models are available to find discharge in an open channel as notch, venturimeter notch etc. for calibration of either rectangular notch, trapezoidal notch some flow is allowed in the flume. Once the flow becomes steady and uniform discharge coefficients can be for any model. The sheet of water flowing through a notch or weir is called Nappe or Vein. The bottom edge of a notch or weir over which the water flows, is known as the sill or crest.

Notches can be of different shapes such as triangular, rectangular, trapezoidal, stepped notch, etc. the bottom of the notch over which the water flows is known as crest or sill and the thin sheet of water flowing through the notch is known as nappe or vein. The edges of the notch are bevelled on the downstream side so as to have a sharp-edged sides and crest resulting in minimum contact with the flowing fluid.

Notches are fitted perpendicular to the direction of flow of water. They act as an obstruction to the flow and the water flows over the sill. Hence, the upstream water level raises and a head is formed above the sill level. By measuring this head, the flow rate can be calculated. The two model notches and the rectangular weir provided with the flame are made of brass sheets with sharp level edges. The broad crested weir is made of fibre glass with sharp edges.

The relationship between discharge and head over the notch can be developed by making the following assumptions as to the flow behaviour:

a) Upstream of the notch, the flow is uniform and the pressure varies with depth according to the hydrostatic equation $P = \rho gh$.
b) The free surface remains horizontal as far as the plane of the notch, and all particles passing over the notch move horizontally.
c) The pressure throughout the sheet of liquid which passes over the crest of the notch is atmospheric.
d) The effect of viscosity and surface tension are negligible.
e) The velocity in the approach channel is negligible.

The theoretical discharge over a rectangular notch is given by:

$$Q_{th} = \frac{2}{3}\sqrt{2g}BH^{3/2}$$

where, Q_{th} is the discharge over a rectangular notch, B is the width of notch, H is the head over the crest of the notch and g is acceleration due to gravity.

APPARATUS: A constant steady water supply tank (Notch tank) with baffles wall, pointer gauge, collecting tank, and models.

EXPERIMENTAL SETUP

The experiment setup consists of a tank whose inlet section is provided with –2 nos. of baffles for stream line flow. While at the downstream portion of the tank one can fix a notch of rectangular notch, trapezoidal notch or V-notch. A hook gauge is used to measure the head of water over the model. A collecting tank is used to find the actual discharge through the notch. Water is supplied to the main channel from water mains through a gate valve that is used to regulate the flow rate. A drain cock is provided at the bottom side of the channel.

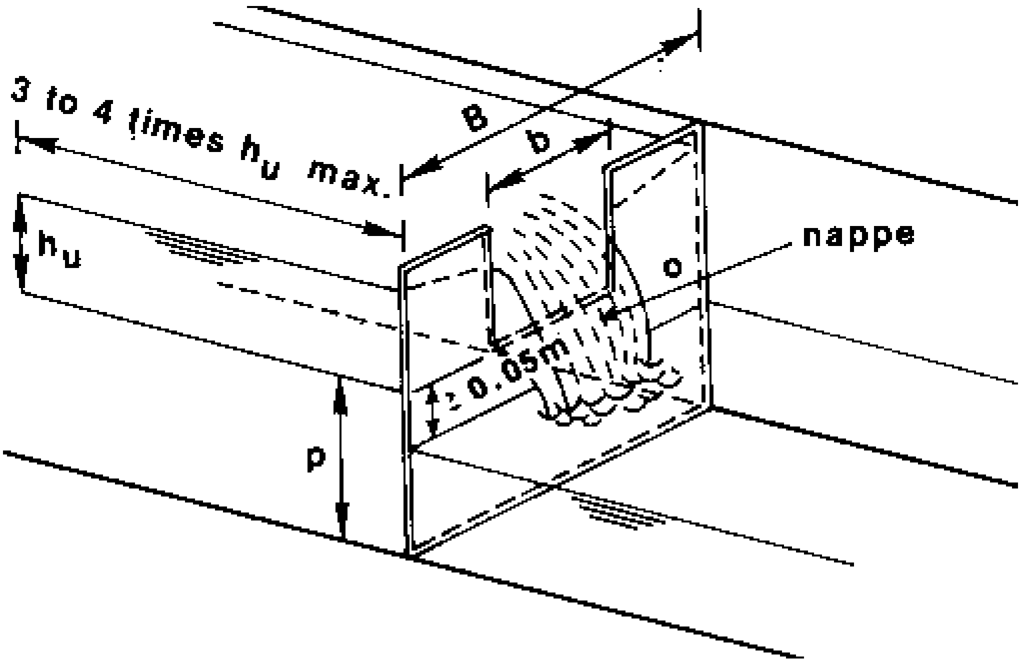


Fig. 6. Flow though Rectangular Notch.

PROCEDURE:

1. Fix the required notch or weir.
2. Allow water in the channel.
3. Regulate the gate valve so that the water just flows over the still.
4. Take the reading in the point gauge. The pointer just touches the water surface. The reading is still level reading.
5. Allow more water and maintain the discharge at a constant value by regulating the gate valve.
6. Adjust the pointer gauge and take the reading.
7. Collect the water in the collecting tank for a rise of 10 cm and note the time taken in seconds to calculate the actual discharge.
8. Repeat the experiments for different heads/flow rates.

OBSERVATIONS:

Sl No.	Vernier pointer gauge reading		Head of water flowing over the Notch $H = (H_2 - H_1)$ (m)	Time (t) for 0.1 m rise in the collecting tank (s)	Actual discharge Q_{act} (m^3/s)	Theoretical discharge Q_{th} (m^3/s)	Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$
	Initial water level reading (sill level) H_1 (m)	Final water level reading H_2 (m)					
1							
2							
3							
4							
5							

CALCULATION:

Actual Discharge: $Q_{act} = \frac{AR}{t}$

where,

Area of tank A = ……. m^2

Rise of level, $R = 0.1$ m

Volume collected = $A \times R$ m^3

Time taken for rise of 0.1 m of water level = t sec

Theoretical Discharge: $Q_{th} = \frac{2}{3}\sqrt{2g}BH^{3/2}$

where,

Initial water level reading (sill level) = H_1 m

Final water level reading = H_2 m

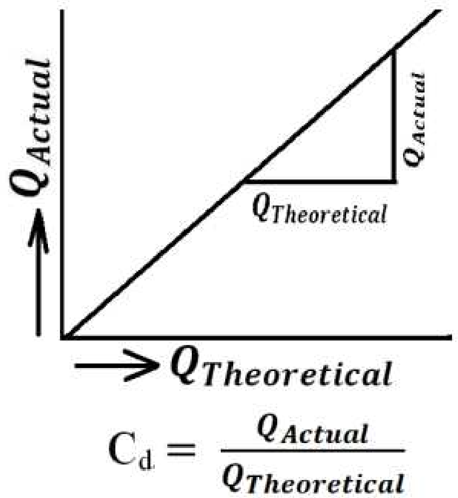
Head of water flowing over the Notch = $H = (H_2 - H_1)$ m = ……. m

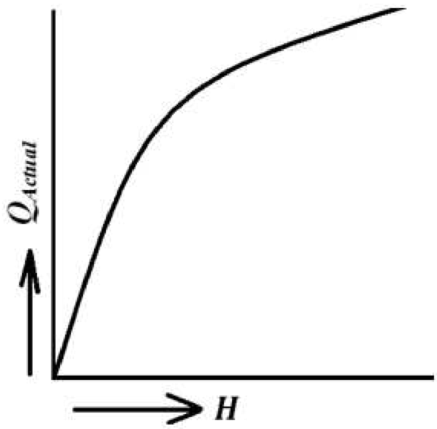
Acceleration due to gravity = g = 9.81 m/s^2

Width of the notch, B = ……m

Coefficient of discharge, $C_d = \frac{Q_{act}}{Q_{th}}$

NATURE OF GRAPH:





RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Fix the notch model properly to the experimental set-up.
2. Ensure the proper operation of point gauge.
3. Maintain the flow under constant head conditions
4. Check the priming of the pump during experimentation.
5. Ensure proper earthing of electrical connections.
6. Confirm the gate valves condition to avoid leakages.
7. Consult the laboratory staff in any emergency
8. Operate the equipment under the supervision of laboratory technical staff.
9. The weir/notch should be fixed exactly in the vertical plane perpendicular to flow axis.
10. The weir should be fixed in a position such that it is symmetrical over vertical axis.
11. Sufficient time should be given for the flow to become steady-uniform.
12. Gauge readings should be measured only in piezometer attached to the collecting tank and not on the free surface.
13. Reading errors may occur at gauge and volumetric piezometric scale by not recording the readings at the eye level.
14. Synchronize the stopwatch operations for volumetric measurements.

QUESTIONS:

1. Define notch and explain its classifications.
2. Define the coefficient of discharge, Cd. What is its significance?
3. Explain the advantages of triangular notch over rectangular notch.
4. Under what conditions you prefer triangular notch?
5. If 10% of error is made in the measurement of head over the rectangular notch, what is the corresponding error in computed discharge?
6. What is the meaning of calibration?

EXPERIMENT NO. 07

Measurement of Viscosity of liquid

AIM: To determine the dynamic viscosity, kinematic viscosity, density and specific gravity of a given liquid sample at different temperatures.

THEORY: Viscosity is the property of a fluid that offers resistance to its own flow. It is an indicator of flowability of a lubricating oil; the lowest the viscosity, greater the flowability. It is mainly due to the forces of cohesion between the molecules of lubricating oil. Coefficient of viscosity may be defined as the force per unit area required to maintain a unity velocity gradient between two parallel layers. For every degree rise in temperature, there is a decrease of roughly 2% in the coefficient of viscosity of most of liquids. Absolute viscosity may be defined as "the tangential force per unit area which is required to maintain a unit velocity gradient between two parallel layers.

In industry viscosity of lubricating oil is determined by Redwood, Saybolt and Engler instruments. In Redwood viscometer the measure of viscosity of oil is the time in seconds for 50ml of oil to flow through standard orifice under a given set of condition, where as in Saybolt viscometer, it is the time seconds required for 60ml of oil to pass through a standard orifice. In Engler viscometer the viscosity is expressed as the ratio of the time for oil to the time taken by water at 200C.

The Redwood viscometer is of two types: (i) Redwood viscometer No.1 and (ii) Redwood viscometer No.2. The Viscometer No.1 is used for determining the viscosities of thin lubricating oils and has the jet bore diameter of 1.62mm and length 10mm where on the other hand viscometer No.2 is used for determining the viscosities of thick lubricating oil. It has a jet diameter of 3.8mm and length 15mm.

Kinematic viscosity (ν):

$$\nu = \left((A \times t) - \left(\frac{B}{t} \right) \right) \times 10^{-6} m^2 / s$$

where, ν = Kinematic viscosity of oil

t = time in seconds

NOTE:

A = 0.226 and B = 180 when t = 40 to 85 seconds

A = 0.247 and B = 65 when t = 85 to 2000 seconds

Density of Oil (ρ):

$$\rho = \frac{m_2 - m_1}{50 \times 10^{-6} \times 1000} kg / m^3$$

where, m_1 = weight of measuring jar without oil, grams

m_2 = weight of measuring jar with oil, grams

Dynamic viscosity (μ):

$$\mu = \rho \times \nu \text{ Ns/m}^2$$

where, ρ = density of the oil, kg/m^3

ν = kinematic viscosity, m^2/s

Specific gravity (S):

$$S = \frac{\text{Density of the Oil Sample}}{\text{Density of the Standard liquid (water)}} = \frac{\rho_{sample}}{\rho_{water}}$$

Density of the standard liquid (water) = 1000 kg/m^3

APPARATUS: Thermometers, Kohlrausch Flask / Volumetric Flask, Stopwatch, Oil Sample and Energy Regulator.

EXPERIMENTAL SETUP

The Redwood Viscometer consists of a heavily silver plated oil cup with a dished bottom mounted in a bright chrome plated water bath. The water bath is mounted on a stand with leveling screws. The level to which the oils are to be filled into cups is given by an index (pointer) fixed to the inside wall of the oil cup. A standard size of jet of stainless steel is fitted at the center of the bottom of the cup for the flow out of oil or liquid to be measured. The cylindrical water bath spun from sheet copper surrounds the oil cup and is provided with a tap for emptying. Proper heating arrangement for the water bath is provided and is stirred manually by means of a cylinder surrounding the oil cup provided with three vanes having their upper and lower positions turned in opposite directions. A curved shield is fixed to the upper edge of the cylinder to check water spillage and is provided with insulated handle for rotating the stirrer and a support for the bath thermometer. The valve for starting and stopping the flow of the liquid from the oil cup consists of a ball carried on a stiff wire, both heavily silver plated. The upper end of the wire is bent to provide a hook by means of which the valve may be hung on the thermometer support, allowing the flow of the oil through the jet. The oil cup thermometer is supported on a spring clip on a block sliding in an upright rod at the upper edge of the oil cup diametrically opposite the oil level index. The oil cup cover is fitted with an insulated handle, and has suitable slots for the oil cup thermometer and valve rod.

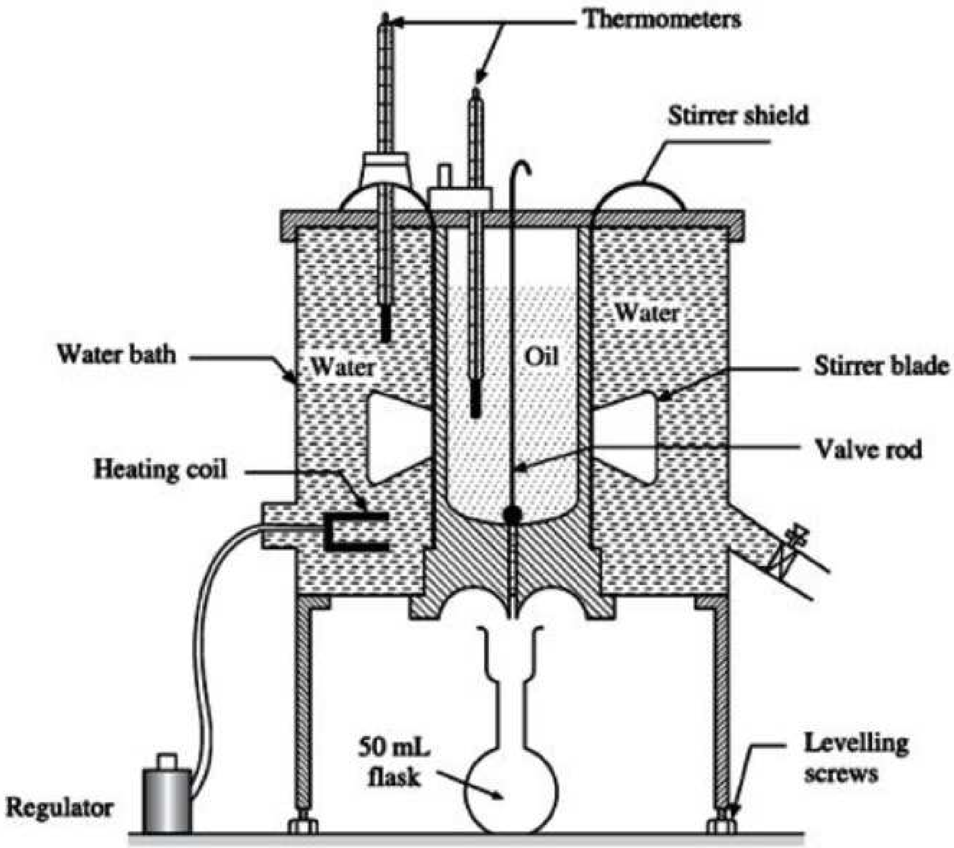


Fig. 7. Experimental setup of Redwood viscometer.

PROCEDURE:

1. Initially fill the viscometer bath with clean water.
2. Rest the ball valve in the depression in jet, pour the oil sample into the oil cup through a filter or metal gauge not coarse than BS 100mesh up to a little above index level.
3. Place two thermometers, one in the oil cup to record the oil temperature and the other in the bath to observe the temperature of water.

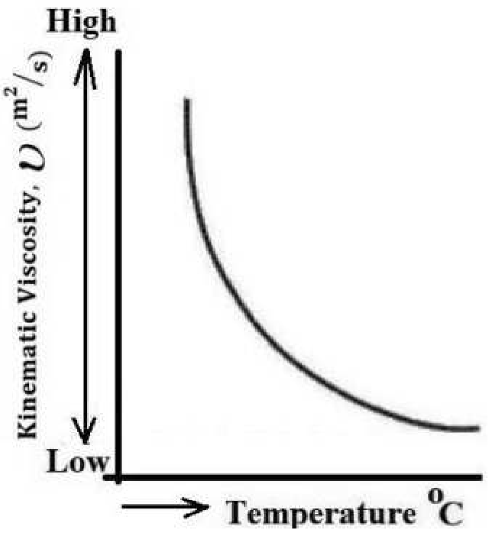
4. Heat the Viscometer bath to a few degrees above the desired temperature.
5. Adjust the temperature of the bath by stirring the contents of the bath until the sample inside the cup is maintained at the test temperature.
6. Stir the sample during the preliminary period by means of the thermometer. Place the oil cup cover, which shall be slightly warmed on the oil cup and fit a thermometer to it.
7. When the temperature of the oil sample has become quite steady at the desired value adjust the liquid level by allowing the sample to flow out until the surface of the sample touches the index.
8. Place the clean dry 50ml Kohlrausch flask below the oil cup provided with a jet of standard size and remove the ball valve depressed in the jet to allow the oil to flow in to the flask and start the time countdown.
9. Stop the time at the instant the sample reaches the graduation mark on the flask and note the time taken also the final reading of the oil cup thermometer.
10. Repeat the experiment at different temperatures of oil and the record the appropriate readings and tabulate it.

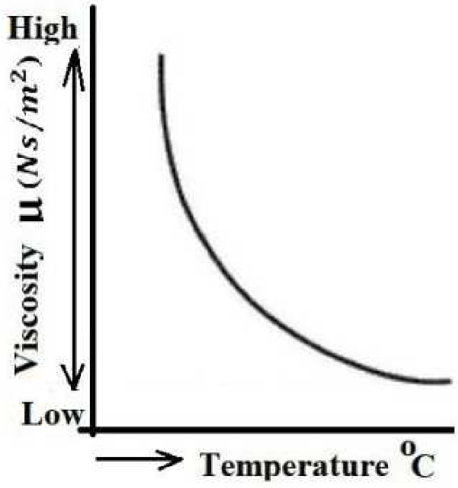
OBSERVATION:

Sl No.	Temperature	Time required to fill the volumetric flask–50 ml (seconds)	Weight of flask without oil m_1 grams	Weight of flask with oil m_2 grams	Kinematic viscosity ν (m_2/s)	Density ρ (kg/m³)	Absolute viscosity μ (Ns/m²)	Specific gravity S

CALCULATION:

NATURE OF GRAPH:





RESULT AND CONCLUSIONS:

PRECAUTIONS:

QUESTIONS:

1. What is viscosity of fluid?
2. State the Newton's law of viscosity?
3. Differentiate between Newtonian and non-Newtonian fluids.
4. Give some examples for Newtonian and non-Newtonian fluids.
5. When the temperature of the fluid is increased, what happens to its viscosity?
6. Name the different viscometers to measure viscosity of fluids.

EXPERIMENT NO. 08

Determination of Darcy Friction Factor, relative roughness for laminar and turbulent flows

AIM: To study flow in pipes and determine the major losses due to pipe friction - major losses.

THEORY: When water flows through a pipe, a certain amount of energy (or pressure energy) has to be spent to overcome the friction due to the roughness of the pipe surface. The major factor contributing to the energy loss in any pipe flow is through the boundary shear. In cases of steady flow through the pipe, a constant pressure gradient is to be maintained to overcome the frictional losses due to the boundary shear. This roughness effect or friction effect depends upon the material of pipe and scale formation if any. When the surface is smooth the friction effect is less. For an old pipe due to scale formation or chemical deposits the roughness and hence the friction effect is higher.

EXPERIMENTAL SETUP: The test rig consists of a piping circuit with three pipe lines of nominal diameter 12.5mm made of materials aluminium, copper and stainless steel for major loss studies. A fourth pipe line of nominal diameter 15 mm is provided with various pipe fittings (an elbow, a bend, sudden expansion, sudden contraction, ball valve, globe valve, gate valve) for minor losses studies. The pipes are connected in parallel and using the gate valves provided in each pipeline, water is made to flow in one pipe line at a time.

A pair of quick change cocks is fitted at the upstream and downstream of each pipe fitting under study and for the first three pipe lines at 1.25m distance apart to measure the frictional loss. The cocks are connected to two common chambers which in turn are connected to the mercury manometer. The manometer is used to measure the pressure drop, which is the head loss.

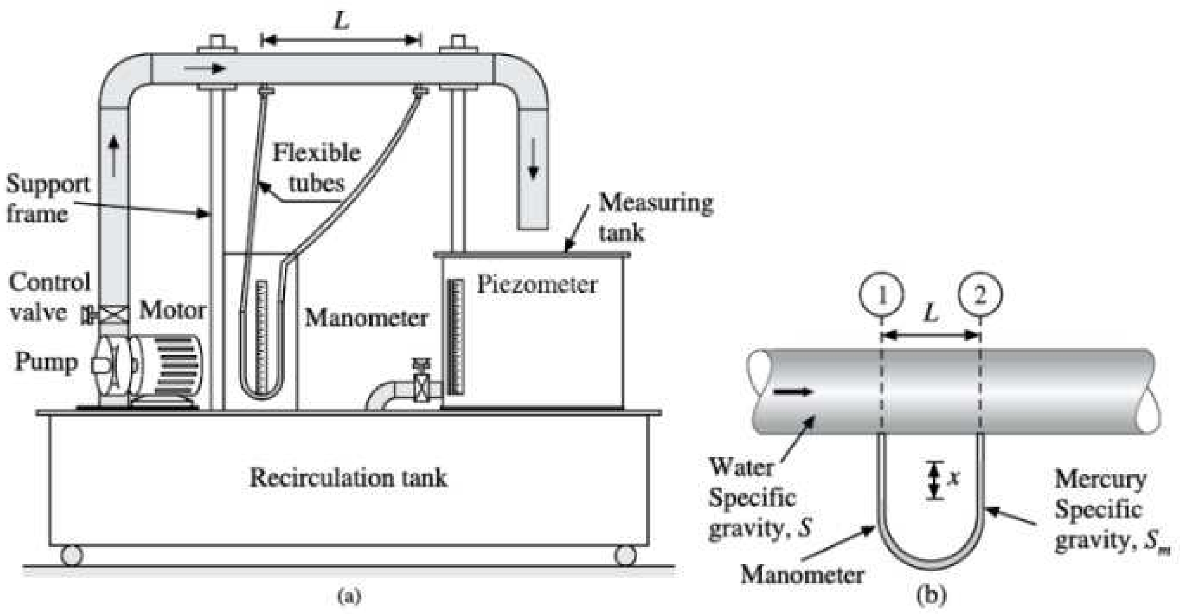


Fig. 8. (a) Experimental set-up of major Loss Apparatus (b) Details showing manometer

PROCEDURE:

1. Select the required pipe line.
2. Connect the pressure tapings of the required pipe line (or the pipe fitting for minor losses study) to the manometer by opening the appropriate pressure cocks and closing all other pressure cocks.
3. Open the flow control valve in the pipe line and allow water to pass.
4. Vent the manometers at a reduced flow rate. Care should be taken to avoid spill over of mercury into the header pipes while venting. Experiment should always be started by slowly opening the control valve and simultaneously observing the mercury columns in the manometer. For accidental spill over, stop the experiment and recover the mercury from the bottom of the header.
5. By controlling the valve, required flow rate can be obtained to get a particular Reynolds Number.
6. Note the pressure difference from the manometer mercury columns.
7. Collect the water in the collecting tank for a particular rise of level and note the time taken.
8. Repeat the experiments if required at other flow rates.

OBSERVATION:

Sl No.	Manometer reading		Head Loss $H = 12.6\ (H_1 - H_2)$ (m of water)	Time for 10 cm rise (s)	Flow rate $Q = \frac{AR}{t}$ (m^3/s)	Flow Velocity $V = \frac{Q}{a}$ (m/s)	Darcy's constant $f = \frac{2gdH}{4lV^2}$
	H_1 of Hg (m)	H_2 of Hg (m)					
1							
2							
3							
4							

CALCULATION:

1. Discharge through the pipe:

Area of the collecting tank, A = ……. m^2

Rise of level, $R = 0.10$ m

Volume collected = AR m^3

Time taken = t seconds

Discharge, $Q = \frac{AR}{t}$ m^3/s

2. Manometer readings (Mercury filled):

Reading in the left limb = h_1 m

Reading in the right limb = h_2 m

Difference level = $(h_1 - h_2)$ m of Hg

Equivalent loss of water head, $H = (13.6 - 1) \times (h_1 - h_2) = 12.6 \times (h_1 - h_2)$ m of water

Collecting tank dimensions = ……..m^2

3. Major losses:

Length of pipe = ……. m

Diameter of pipe (d) =……. m

Cross-sectional area of the pipe, (a) = $\frac{\pi}{4}d^2$ =……m^2

Velocity of water in the pipe (V)= $\frac{Q}{a}$ = ……. m/s

Acceleration due to gravity, g =9.81 m/s^2

Darcy's constant, $f = \frac{2gdH}{4lV^2}$

RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Properly check the priming of the pump during experimentation.
2. Check the supply condition for constant head.
3. Properly operate the manometer tapings.
4. Do not come in contact with mercury if it is expelled out of manometer.
5. Check proper earthing of electrical connections.
6. Ensure the proper working of gate valves to avoid leakages.
7. Operate the equipment under the supervision of laboratory technical staff.
8. In case of emergency, contact the laboratory technical staff.

QUESTIONS:

1. List (a) major losses and (b) minor losses.
2. What is practical application of Darcy-Weisbach equation?
3. Define hydraulic mean depth.
4. What is the value of hydraulic mean depth for a fully flowing pipe?
5. What is the meaning of f in Darcy-Weisbach equation?
6. Which other formulae are used to find the friction loss in pipes?
7. What is the relationship between friction factor and Reynolds number?

8. What losses expect when a pipe has many fittings and bent and change in cross sections?
9. Define the energy gradient and hydraulic gradient line.
10. What is the difference between hydraulic gradient line and total energy line?

EXPERIMENT NO. 09

Determination of minor losses in pipes

AIM: To study flow in pipes and determine the losses due to the pipe fittings - minor losses.

THEORY: In addition to the major loss in pipes due to friction, there is also loss of head or energy due to change of velocity of the fluid in magnitude or direction, which is called minor loss of energy. Pipeline systems in general include several auxiliary components in addition to pipes.

These components include the following:

1. Transitions or sudden expansion and contraction for changing pipe size.
2. Elbows and bends for changing the flow direction

These components introduce disturbances in the flow that cause turbulence and hence mechanical energy loss occurs in the basic pipe flow. Although these energy losses occur over a finite distance, when viewed from the perspective of an entire pipe system, they are localized near the component. Hence these losses are referred to as local losses or minor losses. It should be remembered that these losses sometimes are the dominant losses in a piping system and hence the term minor losses is a misnomer often.

Loss coefficient for sudden expansion:

In order to develop the expression for the loss of energy due to sudden expansion of pipe, a schematic diagram of such sudden expansion is shown in Fig. 9.

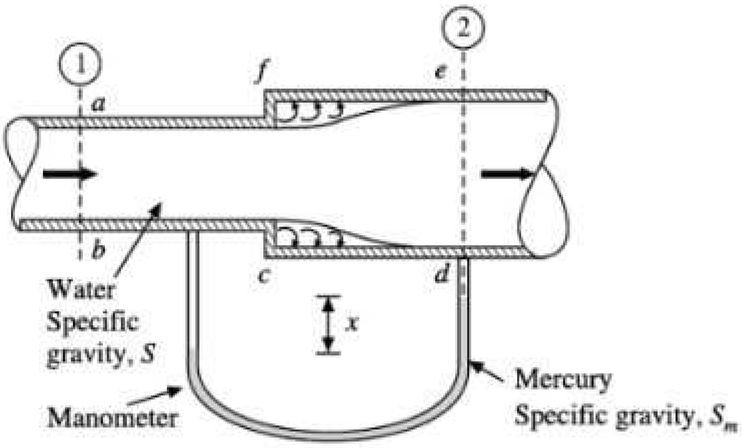


Fig. 9. Details of manometer connection showing sudden expansion

Let section 1 corresponds to uniform region upstream of the expansion and section 2 corresponds to the uniform region downstream of the expansion. Then from Bernoulli's theorem,

$$P_1 + \frac{V_1^2}{2g} + Z_1 = P_2 + \frac{V_2^2}{2g} + Z_2 + losses$$

where, P, V, Z are the static pressure, velocity and elevation of the water particle and losses is the pressure loss due to the sudden expansion. Since elevation is constant, rearranging the equation,

$$losses = P_1 - P_2 + \frac{\left(V_1^2 - V_2^2\right)}{2g}$$

But, $\left(P_1 - P_2\right)$ is the measured static pressure difference H in the manometer and $V_2/V_1 = a_1/a_2$, the area ratio of the pipes (by continuity $a_1V_1 = a_2V_2$ = flow rate). Hence,

$$losses = H + \frac{V_1^2}{2g}\left(1 - \left(\frac{a_1}{a_2}\right)^2\right)$$

Loss coefficient, $K = \frac{\text{Loss of head}}{\text{Velocity head}} = \frac{losses}{h_v}$

$$= \frac{H}{\left(\frac{V_1^2}{2g}\right)} + \left(1 - \left(\frac{a_1}{a_2}\right)^2\right)$$

Loss coefficient for sudden contraction:

In order to develop the expression for the loss of energy due to sudden contraction of pipe, a schematic diagram of such sudden expansion is shown in Fig. 10. As seen from the figure, section 1 corresponds to uniform region upstream of the contraction and section 2 corresponds to the uniform region downstream of the contraction. Besides, section c represents the section of vena contracta, where the area of flow becomes minimum.

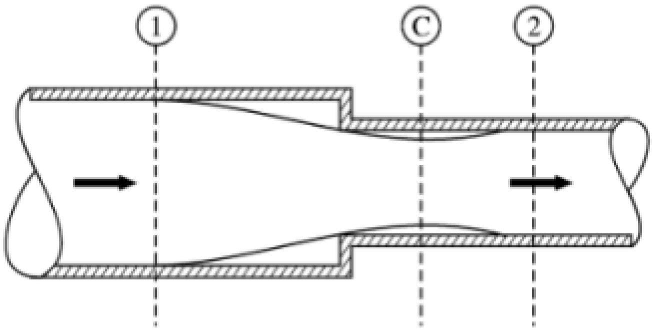


Fig. 10. Flow through Sudden contraction

Then from Bernoulli's theorem,

$$P_1 + \frac{V_1^2}{2g} + Z_1 = P_2 + \frac{V_2^2}{2g} + Z_2 + losses$$

where, P, V, Z are the static pressure, velocity and elevation of the water particle and losses is the pressure loss due to the sudden expansion. Since elevation is constant, rearranging the equation,

$$losses = P_1 - P_2 + \frac{\left(V_1^2 - V_2^2\right)}{2g}$$

But, $\left(P_1 - P_2\right)$ is the measured static pressure difference H in the manometer and $V_2/V_1 = a_1/a_2$, the area ratio of the pipes (by continuity $a_1V_1 = a_2V_2$ = flow rate). Hence,

$$losses = H - \frac{V_2^2}{2g}\left(1 - \left(\frac{a_2}{a_1}\right)^2\right)$$

$$\text{Loss coefficient, } K = \frac{\text{Loss of head}}{\text{Velocity head}} = \frac{losses}{\left(\frac{V_2^2}{2g}\right)}$$

$$= \frac{H}{\left(\frac{V_2^2}{2g}\right)} - \left(1 - \left(\frac{a_2}{a_1}\right)^2\right)$$

EXPERIMENTAL SETUP: The test rig consists of a piping circuit with three pipe lines of nominal diameter 12.5 mm made of materials aluminium, copper and stainless steel for major loss studies. A fourth pipe line of nominal diameter 15 mm is provided with various pipe fittings (an elbow, a bend, sudden expansion, sudden contraction, ball valve, globe valve, gate valve) for minor losses studies. The pipes are connected in parallel and using the gate valves provided in each pipeline, water is made to flow in one pipe line at a time.

A pair of quick change cocks is fitted at the upstream and downstream of each pipe fitting under study and for the first three pipe lines at 1.25 m distance apart to measure the frictional loss. The cocks are connected to two common chambers which in turn are connected to the mercury manometer. The manometer is used to measure the pressure drop, which is the head loss.

The dimensions of the sudden enlargement and contraction are as follows:

Sudden enlargement:

Inlet pipe diameter = 0.5 x Outlet pipe diameter

Sudden contraction:

Inlet pipe diameter = 2.0 x Outlet pipe diameter

The complete unit is supported on MS stands. Water flowing out from these pipes is collected in the collecting tank to determine the flow rate and hence the velocity in the pipe.

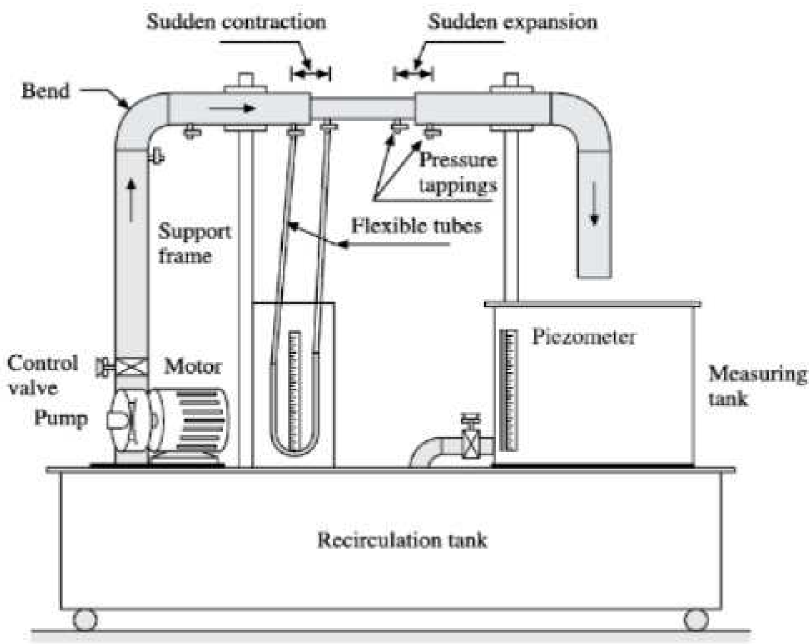


Fig. 11. Experimental set-up for Minor Loss

PROCEDURE:

1. Select the required pipe line.
2. Connect the pressure tapings of the required pipe line (or the pipe fitting for minor losses study) to the manometer by opening the appropriate pressure cocks and closing all other pressure cocks.
3. Open the flow control valve in the pipe line and allow water to pass.
4. Vent the manometers at a reduced flow rate. Care should be taken to avoid spill over of mercury into the header pipes while venting. Experiment should always be started by slowly opening the control valve and simultaneously observing the mercury columns in the manometer. For accidental spill over, stop the experiment and recover the mercury from the bottom of the header.
5. By controlling the valve, required flow rate can be obtained to get a particular Reynolds Number.
6. Note the pressure difference from the manometer mercury columns.
7. Collect the water in the collecting tank for a particular rise of level and note the time taken.
8. Repeat the experiments if required at other flow rates.

OBSERVATION:

Experiment	**Manometer reading**		**Head Loss** H= **12.6** **(**H_1**-**H_2**) (m of water)**	**Time for 10 cm rise (s)**	**Flow rate** $Q=\frac{AR}{t}$ **(m³/s)**	**Flow Velocity** $V=\frac{Q}{a}$ **(m/s)**	**Darcy's constant** $f=\frac{2gdH}{4lV^2}$	**Loss coefficient K**
	H_1 **of Hg (m)**	H_2 **of Hg (m)**						
Sudden expansion								
Sudden contraction								
Bend								
Elbow								

CALCULATION:

1. Input data:

Diameter of bend = …… m

Diameter for contraction = …… m

Diameter for expansion = ……. m

Diameter for elbow = …… m

Collecting tank dimensions = …… m^2

2. Discharge through the pipe:

Area of the collecting tank, A = ……. m^2

Rise of level, $R = 0.10$ m

Volume collected = AR m^3

Time taken = t seconds

Discharge, $Q = \frac{AR}{t}$ m^3/s

2. Manometer readings (Mercury filled):

Reading in the left limb = h_1 m

Reading in the right limb =h_2 m

Difference level = $(h_1 - h_2)$ m of Hg

Equivalent loss of water head, $H = (13.6 - 1) \times (h_1 - h_2) = 12.6 \times (h_1 - h_2)$ m of water

Collecting tank dimensions = ……. m^2

3. Minor losses:

Diameter of smaller pipe =……. m

Diameter of larger pipe =……. m

Velocity of water in the pipe $(V) = \frac{Q}{a}$ = ……. m/s

Acceleration due to gravity, g =9.81 m/s^2

Velocity head, $h_v = \frac{V^2}{2g}$ m of water

4. Loss coefficient:

For sudden expansion, Loss coefficient, $K_{exp} = \frac{H}{\left(\frac{V_1^2}{2g}\right)} + \left(1 - \left(\frac{a_1}{a_2}\right)^2\right) = \ldots\ldots$

For sudden contraction, Loss coefficient, $K_{con} = \frac{H}{\left(\frac{V_2^2}{2g}\right)} - \left(1 - \left(\frac{a_2}{a_1}\right)^2\right) = \ldots\ldots$

For bend, Loss coefficient, $K_{bend} = \frac{H}{\left(\frac{V_2^2}{2g}\right)} = \ldots\ldots$

For elbow, Loss coefficient, $K_{elbow} = \frac{H}{\left(\frac{V_2^2}{2g}\right)} = \ldots\ldots$

RESULT AND CONCLUSIONS:

PRECAUTIONS:

1. Properly check the priming of the pump during experimentation.
2. Check the supply condition for constant head.
3. Properly operate the manometer tapings.
4. Do not come in contact with mercury if it is expelled out of manometer.
5. Check proper earthing of electrical connections.
6. Ensure the proper working of gate valves to avoid leakages.
7. Operate the equipment under the supervision of laboratory technical staff.
8. In case of emergency, contact the laboratory technical staff.

QUESTIONS:

1. List (a) major losses and (b) minor losses.
2. Define hydraulic mean depth.
3. What is the value of hydraulic mean depth for a fully flowing pipe?
4. Which other formulae are used to find the friction loss in pipes?
5. What losses expect when a pipe has many fittings and bent and change in cross sections?
6. Define the energy gradient and hydraulic gradient line.
7. What is the difference between hydraulic gradient line and total energy line?