FLUID MECHANICS LAB-I

LAB MANUAL

Subject Code: 4ME4-22

Class: 2nd Year - IV Semester (MECH.)

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LIST OF EXPERIMENTS

1. To determine Metacentric Height of a given body.
2. To determine C_d and C_v for a given orifice.
3. To determine flow rate of water by V-notch
4. To determine velocity of water by Pitot tube
5. To verify Bernoulli's theorem
6. To determine the flow rate of air/water by Orifice meter
7. To determine the flow rate of air/water by Venturimeter
8. To determine head loss of a given length of a pipe
9. To determine flow rate of water/air by nozzle-meter
10. To study Pelton wheel and Kaplan Turbine models

EXPERIMENT NO- 1

Date:……………………………………………………

OBJECTIVE:

To determine Metacentric Height of a given body

AIM:

To determine the meta-centric height and position of the meta-centric height with angle of heel of ship model

INTRODUCTION:

- **META-CENTRE-**

It is defined as the point about which a body starts oscillating when the body is tilted by a small angle. The meta- centre may also be defined as the point at which the line of action of the force of buoyancy will meet the normal axis of the body when the body is given a small angular displacement. It is denoted by M.

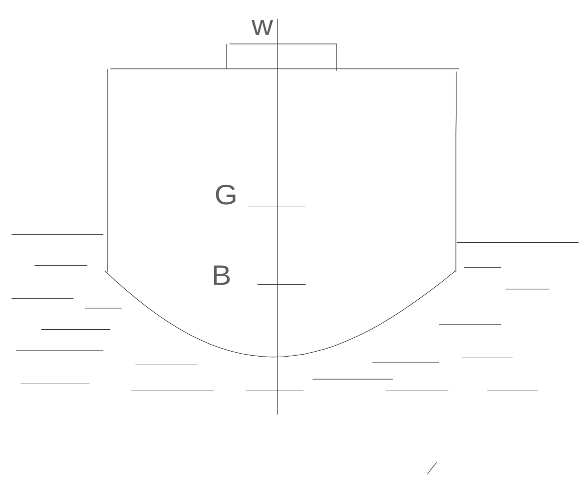
- **META-CENTRIC HEIGHT-**

The distance between the meta-centre (M) of a floating body and the centre of gravity (G) of the body is called meta-centric height.

THEORY:

- **DETERMINATION OF META-CENTRIC HEIGHT-**

For a body to be in equilibrium on the liquid surface the two forces gravity force (w) and buoyant force (F_b) must lie in the same vertical line. If the point M is above G, the floating body will be in stable equilibrium. If slight angular displacement is given to the floating body in clockwise direction, the center of buoyancy shifts from B to B_1 such that the line of action of F_b through B_1 cuts the axis at M, which is called the meta – center and the distance GM is called the meta-centric height.



The buoyant force F_b through B_1 and weight w through G constitute a couple acting in anti- clockwise direction and thus bringing the floating body in the original position.

To determine the meta-centric height of a floating body, we know the center of gravity of floating body. Place the known weight (w) over the center of the body.

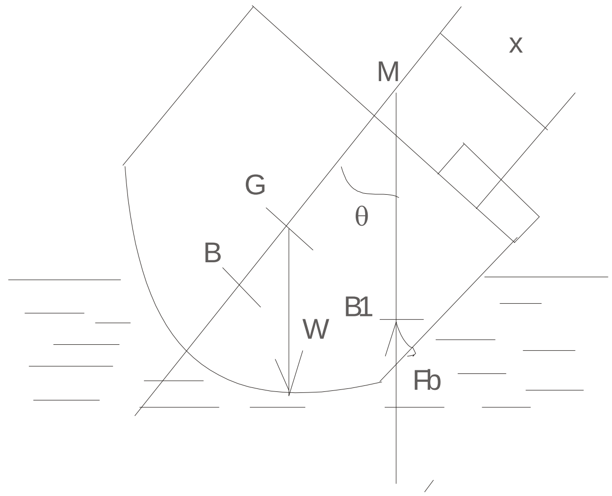
The weight w is moved across the vessel towards right through a distance x. The body will be tilted. The angle of tilt θ is measured by means of a plumb line and a protractor attached on the body. The new center of gravity of the body will shift to G_1 as the weight w has been moved towards the right .the center of buoyancy will change to B_1 as the body has tilted. Under equilibrium, the moment caused by the movement of the load w through a distance x must be equal to the moment caused by the shift of the center of gravity from G to G_1.Thus

The moment due to change of G = $G G_1 * W = W * GM \tan\theta$

The moment due to movement of w = w x

$\therefore$ $wx = W\,GM \tan\theta$

Hence $GM = wx / W \tan\theta$



Where	W	=	weight of body including w
	G	=	centre of gravity of body
	B	=	centre of buoyancy of the body
	M	=	meta-centre of the body
	w	=	applied weight
	x	=	distance moved by weight w
	θ	=	angle of tilt, radian

DESCRIPTION:

A ship model is allowed to float in a small tank having water. Removable steel strips placed in the model for the purpose of changing the weight of the model. Displacement of weight is measured with the help of a scale. By means of a pendulum the angle of tilt can be measured on a graduated arc. For tilting the model, a cross bar with movable hangers is fixed on the model. Pendulum and graduated arc are suitably fixed at the center of the cross bar.

EQUIPMENT / UTILITIES REQUIRED:

Water supply

Drain

Bench area: 1 m x 0.6 m

SPECIFICATIONS:

Pontoon Horizontal: 300 x 150 mm (approx.) with a Guide Bar for sliding weight.

Water Tank: Size 600 x 400 x 400 mm

Front Window of Tank: Made of Glass

A set of weights is supplied with the apparatus.

EXPERIMENTAL PROCEDURE:

1. Make the tank free from dust.
2. Fill tank $\frac{3}{4}$ with clean water and ensure that no foreign particles are there.
3. Weigh the ship model to find W.
4. Float the ship model in water and ensure that it is in stable equilibrium.
5. Apply the known weight (w) at the center of model.
6. Give the model a small angular displacement in clockwise direction.
7. Measure the distance moved by the weight applied with the help of scale.
8. Measure the angle of tilt on the graduated arc
9. Repeat the experiment for different weights.

FORMULAE:

Meta – centric height GM $= \frac{wx}{W \tan\theta}$

OBSERVATION & CALCULATION:

- **DATA**

Distance of grooves nos. 1, 2, 3, 4, 5 from center = 2.5 cm, 5 cm, 7.5 cm, 10 cm, 12.5 cm

Weight of ship model = 5.74 kg

Weight of big strip = 2.58 kg

Weight of small strips = 1.34 kg (2 Nos),
Weight of hanger = 180 g
Applied weights = 341 g (1 No.), 484 g (1 No.), 965 g
w = Weight of hanger + applied weight

W = Weight of ship model + weight of big strip + weight of small strip + w

S. No.	w, kg	W, kg	X cm	θ_1 rad	θ_2 rad	θ rad	Metacentric height GM, cm
1							
2							
3							
4							
5							
6							

ASSIGNMENTS:

1. Does the Metacentric height depend upon the initial submergence of the floating vessel?

2. Should the movable weight be small compared to W? Why?

3. What would happen if the Metacentric height is negative?

Date:………………………………………………

OBJECTIVE:

To determine C_d and C_v for a given orifice.

AIM:

To determine the co-efficient of discharge

To determine the co-efficient of velocity

INTRODUCTION:

Orifice is an opening or a hole of any size, shape or form, through which liquid flow such that its upper edge remains below the free surface of the liquid. Orifices are used for measurement or control of flow. Orifices may have any shape but generally they are circular, square or rectangular.

A mouthpiece is a relatively short pipe, which is fitted internally or externally to the orifice in the side of the tank. Mouthpieces are sometimes used as a flow measurement device.

THEORY:

- **ORIFICE-**

When a liquid flows from a vessel or a tank, through an orifice, it changes its direction. Due this change of direction of the liquid, the jet is acted upon by lateral or side forces, which gradually reduce its area up to certain section. This area does not reduce further beyond, which the jet ceases and streamlines, first become parallel is known as the vena-contracta.

- **MOUTHPIECE-**

A short piece of length about three times of its diameter, connected to the face of an orifice, is known as a mouthpiece. In what follows, it will be proved that under a given head, the rate of discharge through a mouthpiece will be more than that through an orifice of the same diameter. The reason being that while entering into the mouthpiece, the liquid gets contracted at vena-contracta. Due to this contraction, the velocity of liquid at increase and the pressure decreases. The pressure at vena-contracta is less then at atmosphere. This may be verified by applying Bernoulli's theorem at the outlet and at the vena-contracta.

- **CO-EFFICIENT OF VELOCITY-**

It is defined as the ratio between the actual velocity of a jet of liquid at a vena-contracta and the theoretical velocity of the jet. It is denoted by C_v and is given as:

$$C_v = \frac{\text{Actual velocity of the jet at vena - contracta}}{\text{Theoretical velocity}}$$

$$= \frac{V}{\sqrt{2gH}}$$

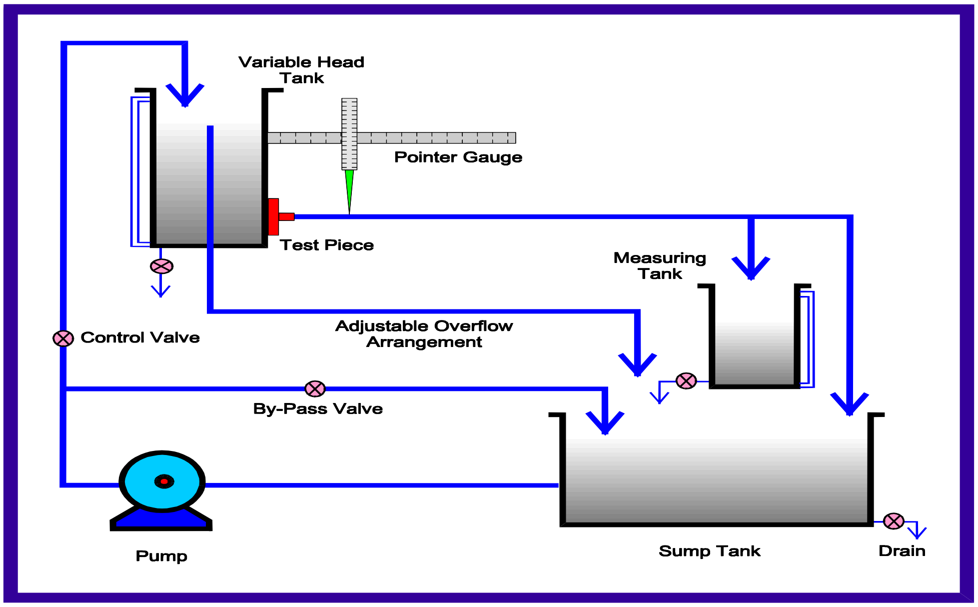
CO-EFFICIENT OF DISCHARGE, C_d

It is defined as the ratio of the actual discharged from an orifice to the theoretical discharged from the orifice. It is denoted by C_d. If Q_a the actual discharge and Q_t is the theoretical discharge then ratio of C_d is given as:

$$C_d = \frac{Q_a}{Q_t}$$

DESCRIPTION:

It consists of a constant head tank that supplies the water to orifice and mouthpiece. It has a piezometer with scale for head measurement. A measuring arrangement for X – Y co-ordinate of vena-contracta is provided. Discharge is measured in measuring tank with a help of stopwatch. Water is circulated from the sump tank through centrifugal pump.



Schematic Diagram for Orifice & Mouth piece Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 Volts, 50 Hz, 5 Amp with Earth.
2. Water Supply.
3. Drain.
4. Space required: 1.6m x 0.5m

SPECIFICATIONS:

Set of Orifices	:	Material Acrylic (2 Nos.) Dia. 10mm and 15 mm
Set of Mouthpieces	:	Material Acrylic (3 Nos.) Dia 10 mm (L/D = 2.5) Dia 10 mm (L/D = 4) Dia 10 mm (L/D = 1)
Constant Head tank	:	35 l
Hook/Pointer Gauge	:	To measure X-Y co-ordinates of Jet.
Water Circulation	:	FHP Pump.
Flow Measurement	:	Using Measuring Tank with Piezometer,
Capacity 25 l		
Sump Tank	:	Capacity 70 l
Stop Watch	:	Electronic.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Clean the apparatus and make All Tanks free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank $\frac{3}{4}$ with Clean Water and ensure that no foreign particles are there.
4. Close all Flow Control Valves given on the water line.
5. Open By-Pass Valve.
6. Fix desired Test Piece at testing section.
7. Ensure that all On/Off Switches given on the Panel are at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Operate the Flow Control Valve to regulate the flow of water in Variable Head Tank.

11. Adjust Head of water in the Tank with the help of given flexible varying head system, in the center of the tank.
12. Now fix the pointer Gauge at Vena Contracta observed in water stream, coming out from the Tank.
13. Record Head of the Water in the Tank.
14. Record pointer Gauge Reading.
15. Measure the flow of water, discharged through desired test section, using Stop Watch and Measuring Tank.
16. Repeat the experiment for different water heads.
17. When experiment is over for one desired test piece, firstly open the By-Pass Valve fully.
18. Then close the flow control valve.
19. Drain the Variable head tank in Sump Tank by means of given drain valve.
20. Change second test piece.

- **CLOSING PROCEDURE-**

1. Switch off Pump.
2. Switch off Power Supply to Panel.
3. Drain water from all tanks with the help of given drain valves.

FORMULAE:

- CO-EFFICIENT OF VELOCITY

$$C_v = \frac{V}{\sqrt{2gH}} = \frac{x}{\sqrt{4yH}}$$

- ACTUAL DISCHARGE

$$Q_a = \frac{AxR}{t}$$

- THEORETICAL DISCHARGE

Q_t = area of orifice/mouthpiece $\times \sqrt{2gH}$

- CO-EFFICIENT OF DISCHARGE

$$C_d = \frac{Q_a}{Q_t}$$

OBSERVATIONS & CALCULATIONS:

- **DATA-**

1. Diameter of Orifice = 10 mm & 15mm = 0.01m & 0.015 m.
2. Length of Orifice = 10mm = 0.01 m
3. Area of Orifice $\frac{\pi d^2}{4}$ = 7.854×10^{-5} m^2 & 1.767×10^{-4} m^2
4. Diameter of Mouthpiece = 10 mm = 0.01 m
5. Length of mouthpiece = 10 mm, 25mm, 40 mm
6. Area of mouthpiece $\frac{\pi d^2}{4}$ = $7.854 \times 10^{-5}.m^2$
7. Area of Measuring tank, (A) = 0.1 m^2

- **OBSERVATION TABLE-**

S. No.	Water head H (cm)	x (cm)	y (cm)	Rise of water level R (cm)	Time for R t (s)
1.					
2.					
3.					
4.					
5.					

CALCULATION TABLE:

S.No	H (m)	x (m)	y (m)	Q_a, m^3/s	Q_t , m^3/s	C_v, m/s	C_d
1.							
2.							
3.							
4.							
5.							

NOMENCLATURE:

V = actual velocity at vena contracta
$\sqrt{2gH}$ = theoretical velocity, m/s
R = rise of water level in measuring tank, cm
t = time taken to R in seconds
H = Water head, m
x = horizontal distance traveled by the liquid particle from Vena-contracta
y = vertical distance between vena-contracta and liquid particle

REFERENCES:

1. Streeter, V.L., Wylie, E.B., *"Fluid Mechanics"*, 1st ed., pp. 342-344, McGraw Hill, NY, 1983.
2. Garde, R.J., *"Fluid Mechanics through Problems"*, 2nd ed., pp. 133-135, New age International, ND, 1997.

EXPERIMENT NO- 3

Date:……………………………………………………

OBJECTIVE:

To determine flow rate of water by V-notch

AIM:

To determine the co-efficient of discharge through different types of notches:

1. Rectangular Notch
2. V Notch - 45°
3. V Notch - 60°

INTRODUCTION:

A notch is a device used for measuring the rate of a liquid through a small channel or a tank. It may be defined as an opening in the side of a tank or a small channel in such a way that the liquid surface in the tank or channel is below the top edge of the opening. The sheet of water flowing through the notch is called Nappe or Vein. The bottom edge of a notch over which the water flows, is known as the sill or crest.

THEORY:

- **CO-EFFICIENT OF DISCHARGE-**

The ratio of actual discharge over a notch to the theoretical discharge is known as co-efficient of discharge. Mathematically, Co-efficient of discharge:

$$C_d = \frac{\text{Actual Discharge}}{\text{Theoretical Discharge}}$$

- **DISCHARGE OVER A RECTANGULAR NOTCH-**

$$Q = 2/3\ C_d\ L\sqrt{2g}\ [H]^{3/2}$$

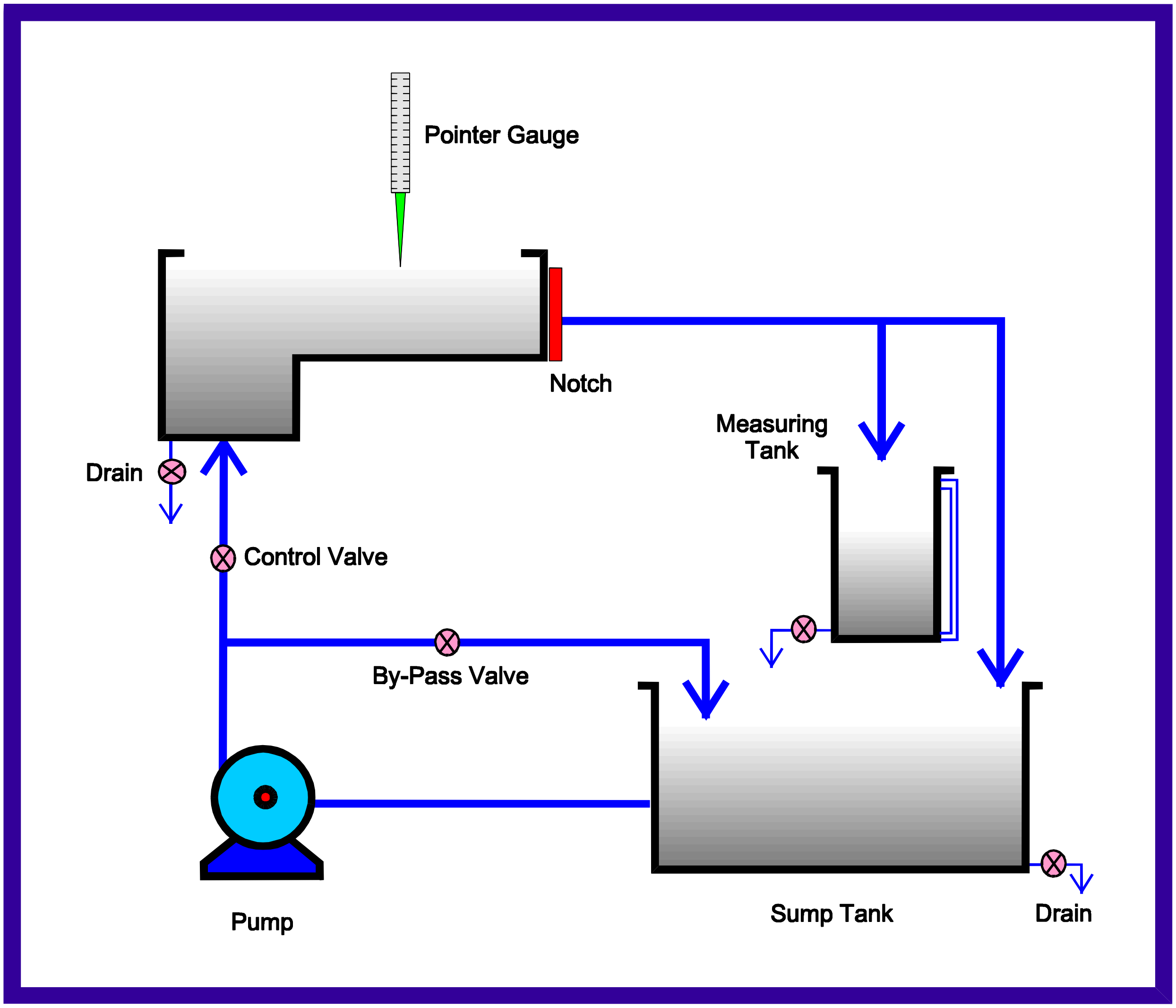
- **DISCHARGE OVER TRIANGULAR NOTCH-**

$$Q = 8/15\ C_d \tan\theta/2\sqrt{2g}\ [H]^{5/2}$$

DESCRIPTION:

The apparatus is designed and fabricated to demonstrate the notch experiments and to find the co-efficient of discharge. A set of three knife edged notch plates made up of Brass sheet is provided. One of them is rectangular other is 'V' notch having included angles 60° and third is 'V' notch having included angles 45°. Depth of each notch is 105 mm. The notches are interchangeable.

A pointer is provided to measure the height of water level over the crest of the notch. It gives the reading directly in 1/10th of mm.



Schematic Diagram for Notch Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 V, 50 Hz, 5 A.
2. Water Supply.
3. Drain.
4. Space required: 1.6m x 0.6m

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE**-

1. Clean the apparatus and make All Three Tanks free from dust.
2. Close the drain valves provided.
3. Close Flow Control Valve given in water line.
4. Open By-Pass Valve.
5. Fix desired Notch on the flow channel.
6. Fill Sump tank ¾ with Clean Water and ensure that no foreign particles are there.
7. Ensure that all On/Off Switches given on the Panel are at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Regulate Flow of water through channel with the help of given Flow Control Valve.
11. Record the height of water level in the channel with the help of pointer Gauge.
12. Measure Flow Rate using Measuring Tank and Stop Watch.

- **CLOSING PROCEDURE-**

1. When experiment is over, Switch off Pump.
2. Switch off Power Supply to Panel.
3. Drain water from all three tanks with the help of given drain valves.

SPECIFICATIONS:

Channel Test Section	:	Size 600 x 250 x 180 mm.
Notches	:	Material Brass (3 Nos.) 1. Rectangular Notch 2. 45° V Notch 3. 60° V Notch
Hook/Pointer Gauge	:	With Vernier scale.

Water Circulation	:	FHP Pump.
Flow Measurement	:	Using Measuring Tank with Piezometer,

Capacity 25 l

Sump Tank	:	Capacity 70 l
Stop Watch	:	Electronic.

FORMULAE:

- **DISCHARGE OVER A RECTANGULAR NOTCH-**

$$Q = 2/3\ C_d\ L\sqrt{2g}\ [H]^{3/2}$$

$$C_d = \frac{3Q}{2L\sqrt{2g}H^{3/2}}$$

- **DISCHARGE OVER TRIANGULAR NOTCH-**

$$Q = 8/15\ C_d\ \tan\theta/2\ \sqrt{2g}\ [H]^{5/2}$$

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

Volume, V = R x A, m^3

- **ACTUAL DISCHARGE**

$$Q = V / t,\ m^3 / s$$

OBSERVATIONS & CALCULATIONS:

- **DATA**

RECTANGULAR NOTCH:

Width(L)	=	65 mm
Depth	=	105 mm

V-NOTCH:

Depth	=	105 mm
Angle of notch	=	45^0, 60^0
Area of measuring tank	=	0.1 m^2

OBSERVATION TABLE:

S. No.	Water head over crest H (cm)	Rise of water level in measuring tank R (cm)	Time for R, t (s)
1			
2			
3			
4			
5			

CALCULATION TABLE:

S. No.	Water head over crest H (cm)	Volume V (m^3)	Q (m^3 /s)	C_d
1				
2				
3				

NOMENCLATURE:

Q = actual discharge in m^3/s

θ = angle of V- notch, deg
L = width of the rectangular notch, m
H = water head over crest, m
R = Rise of water level in measuring tank, m
t = Time for R, s
C_d = Co-efficient of discharge for rectangular notch and triangular notch

REFERENCES:

1. Streeter, V.L., Wylie, E.B., "*Fluid Mechanics*", 1st ed., pp. 357-362, McGraw Hill, NY, 1983.

EXPERIMENT NO- 4

Date:…………………………………………………

OBJECTIVE:

To determine velocity of water by Pitot tube

AIM:

- To find the co- efficient of Pitot tube.
- To find the point velocity at the center of a tube for different flow rates.
- To plot velocity profile across the cross section of pipe.

INTRODUCTION:

It is a device used for measuring the velocity of flow at any point in a pipe. It is based on the principle that if the velocity of flow at a point becomes zero, there is increase in pressure due to the conversion of the kinetic energy into pressure energy. The Pitot tube consists of a capillary tube, bent at right angle.The lower end, which is bent through 90° is directed in the up stream direction. The liquid rises up in the tube due to conversion of kinetic energy into pressure energy. The velocity is determined by measuring the rise of liquid in the tube.

THEORY:

When a Pitot tube is used for measuring the velocity of flow in a pipe or other closed conduit the Pitot tube may be inserted in the pipe as shown in figure. The Pitot tube measures the stagnation pressure head (or the total head) at its dipped end. The pressure head may be determined directly by connecting a suitable differential manometer between the Pitot tube and pressure taping at the pipe surface. Consider two points (1) and (2) at the same level in such a way that point (2) is just at the inlet of the Pitot –tube and point (1) is far away from the tube. At point (1) the pressure is p_1 and the velocity of the stream is v_1. However, at point (2), is called stagnation point, the fluid is brought to rest and the energy has been converted to pressure energy. Therefore the pressure at (2) is p_2, the velocity v_2 is zero and since (1) and (2) are in the same horizontal plane, so $z_1 = z_2$.

Applying Bernoulli's equation at points (1) and (2)

$$\frac{p_1}{w} + \frac{v_1^{\ 2}}{2g} = \frac{p_2}{w} + \frac{v^2{}_2}{2g}$$

$v_2 = 0$

$$\therefore \quad \frac{v_1^2}{2g} = \frac{p_2}{w} - \frac{p_1}{w}$$

$$v_1 = \sqrt{2g\left(\frac{p_2}{w} - \frac{p_1}{w}\right)}$$

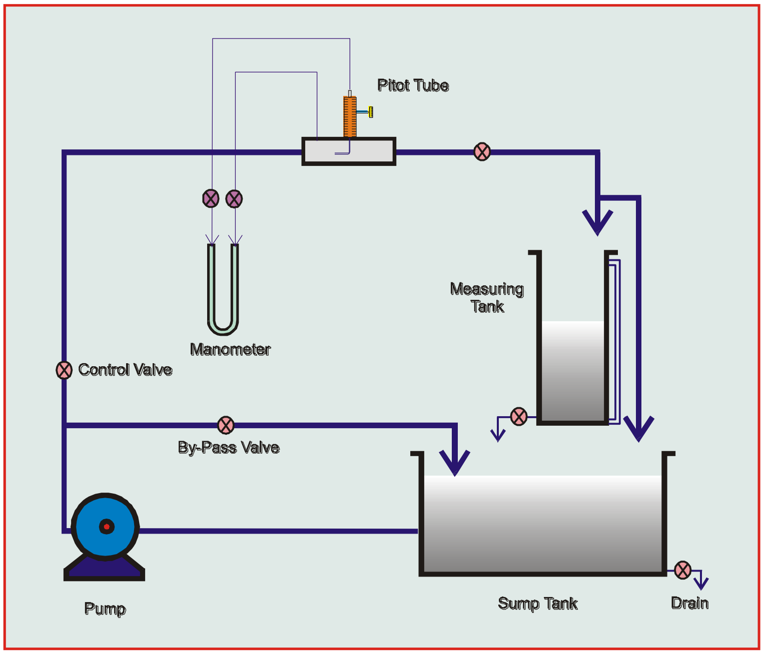
$$v_1 = \sqrt{2gH}$$

This is theoretical velocity.

Actual velocity $\quad (v_1)_{act} = C_v\sqrt{2gH}$

DESCRIPTION:

The apparatus consists of a Pitot tube made of copper and fixed below a pointer gauge. The pointer gauge is capable to measure the position of Pitot tube in transparent test section. The pipe has a flow control valve to regulate the flow. A U-tube manometer is provided to determine the velocity head. A pump is provided to circulate the water. Discharge is measured with the help of measuring tank and stopwatch.



Schematic Diagram for Pitot tube Set-up

EQUIPMENT / UTILITIES REQUIRED:

1. Water Supply.

2. Drain.
3. Electricity 0.5 kW, 220V AC, Single Phase.
4. Floor Area 1.5 x 0.75 m.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE**

1. Clean the apparatus and make Tank free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank $\frac{3}{4}$ with Clean Water and ensure that no foreign particles are there.
4. Close all Flow Control Valves given on the water line and open By-Pass Valve.
5. Check the level of CCl_4 in all the manometer tube. It should be up to half. If it is less, then fill it.
6. Close all Pressure Taps of Manometer connected to manometers.
7. Ensure that On/Off Switch given on the Panel is at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Operate the Flow Control Valve to regulate the flow of water through orifice.
11. Open the Pressure Taps of Manometer of related Test section, very slowly to avoid the blow of water on manometer fluid.
12. Now open the Air release Valve provided on the Manometer, slowly to release the air in manometer.
13. When there is no air in the manometer, close the Air release valves.
14. Adjust water flow rate to desired rate with the help of Control Valve.
15. Set the Pitot tube at the center of test section
16. Record the Manometers reading and measure the discharge with the help of measuring tank and stop watch.
17. Now move the Pitot tube up and down at the same flow rate and note the manometer readings to find out the velocity at different points in pipe.
18. Calculate the co – efficient of Pitot tube from actual and theoretical velocities and plot the velocities at different points inside the pipe.
19. Repeat the same procedure for different flow rates of water, operating Control Valve and By-Pass valve.

- **CLOSING PROCEDURE**

1. When experiment is over, close all Manometers Pressure Taps first.
2. Switch off Pump.
3. Switch off Power Supply to Panel.

SPECIFICATIONS:

Pitot tube : Material Copper of compatible size fitted with vernier scale

Test Section : Material Clear Acrylic, compatible to 1" D Pipe

Water Circulation : FHP Pump.

Flow Measurement : Using Measuring Tank with Piezometer, Capacity 40 l

Sump Tank : Capacity 70 l

Stop Watch : Electronic.

FORMULAE:

Discharge,

$$Q = \frac{A*R}{t} \quad m^3 / s$$

Velocity,

$$v = Q / a \ (m/s)$$

Actual velocity,

$$= C_v \sqrt{2gH} \ (m/s)$$

$$H = h\left(\frac{\rho_m}{\rho_w} - 1\right) \quad \text{(m of water)}$$

Co – efficient of Pitot tube,

$$C_v = \frac{Q}{a*\sqrt{2\,g\,H}}$$

OBSERVATIONS & CALCULATIONS:

- **DATA**

$A = 0.1\ m^2$

$a = 0.0005722\ m^2$

$\rho_m = 1590\ kg/m^3$

$\rho_w = 1000\ kg/m^3$

$g = 9.81\ m/s^2$

- **OBSERVATION TABLE**

S. No.	Pressure head at different points on up side, cm			Pressure head at center, cm	Pressure head at different points on down side, cm			R(cm)	t(s)
	8 mm	6 mm	4 mm	0	4 mm	6 mm	8 mm		

1.									
2.									
3.									
4.									
5.									

CALCULATION TABLE

S. No.	C_v	v_8	v_6	v_4	v_0	v_4	v_6	v_8
1.								
2.								
3.								
4.								
5.								

NOMENCLATURE:

A	=	Area of measuring tank.
a	=	Cross section area of test section
C_V	=	Co efficient of Pitot tube
g	=	Acceleration due to gravity
h	=	Manometer difference
H	=	Pressure head in meter of water.
Q	=	Discharge at outlet.
R	=	Rise of water level in measuring tank.
t	=	Time for R.
v	=	Velocity of fluid.
ρ_m	=	Density of manometer fluid i.e. CCl_4
ρ_w	=	Density of water

REFERENCES:

1. McCabe, W.L., Smith, J.C., Harriott, P., "*Unit Operations of Chemical Engineering*", 4th ed. pp. 200-202, McGraw Hill, NY, 1985.
2. Perry, R.H., Green, D.(editors), "*Perry's Chemical Engineers' Handbook*", 6th ed., pp. 5/9-10, McGraw Hill, NY, 1985.

3. Foust, A.S., et. al., *"Principles of Unit Operations"*, 2nd ed., pp. 563-564, John Wiley, NY, 1980.
4. Brown, G.G., *"Unit Operations"*, 1st ed., pp 155-156, CBS, ND, 1995.
5. Coulson, J.M., Richardson, J.F., *"Coulson & Richardson's Chemical Engineering Vol. - 1"*, 5th ed., pp. 215-216, Asian Books ltd., ND, 1996.

EXPERIMENT NO- 5

Date:………………………………………………………

OBJECTIVE:

To verify Bernoulli's theorem

AIM:

To plot the total energy line Vs distance.

INTRODUCTION:

Bernoulli's theorem states that when there is a continuous connection between particles of flowing mass of liquid, the total energy at any section of flow will remain the same provided there is no reduction or addition of energy at any point.

THEORY:

This is the energy equation and is based on the law of conservation of energy. This equation states that at two sections of flow field the total energy remains the same provided that there is no loss or gain of energy between the two sections. This equation is valid only for steady flow. This equation is expressed as:

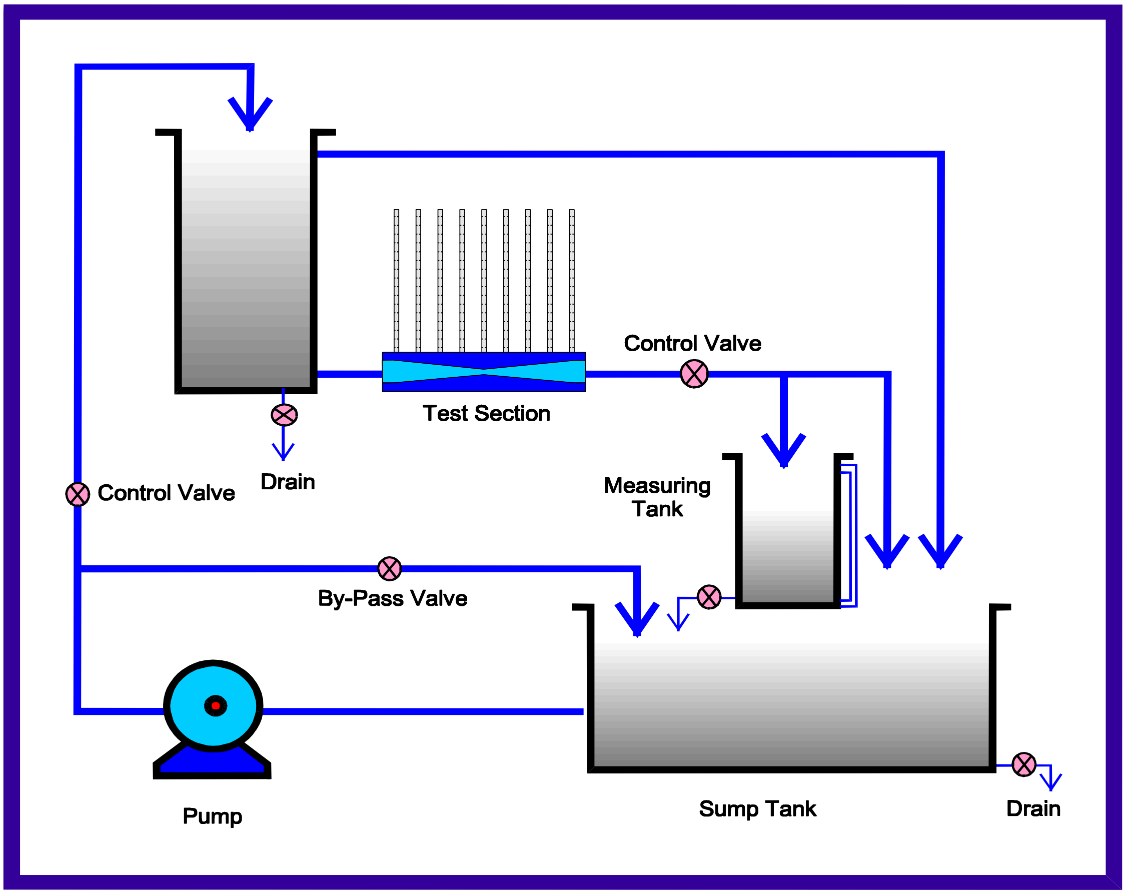
$$E = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

Where,

E	=	Total Energy.
$p_1 / \rho g$	=	Pressure energy per unit weight of fluid or pressure head at point.
$V_1^2 / 2g$	=	Kinetic energy per unit weight or kinetic head at point 1.
Z_1	=	Potential energy per unit weight of potential head at point 1.
$p_2 / \rho g$	=	Pressure energy per unit weight of fluid or pressure head at point.
$V_2^2 / 2g$	=	Kinetic energy per unit weight or kinetic head at point 2.
Z_2	=	Potential energy per unit weight of potential head at point 2.
p_1	=	Pressure of fluid at point 1.
p_2	=	Pressure of fluid at point 2.
V_1	=	Velocity of fluid at point 1.
V_2	=	Velocity of fluid at point 2.
ρ	=	Density of fluid.
g	=	Acceleration due to Gravity.

DESCRIPTION:

The present experimental set-up for Bernoulli's Theorem is self-contained re-circulating unit. The set-up accompanies the Sump tank, Constant Head Tank, Centrifugal Pump for water lifting, Measuring tank etc. Control Valve and By-Pass Valve is provided to regulate the flow of water in Constant Head Tank. A conduit, made of Perspex, of varying cross section is provided, which is having converging and diverging section. Piezometer tubes are fitted on this test section at regular interval. The inlet of the conduit is connected to constant head tank. At the outlet of conduit, a valve is provided to regulate the flow of water through the test section. After achieving the steady state, discharge through test section can be measured with the help of measuring tank and Stop Watch.



Schematic Diagram for Bernoulli's Theorem Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 V, 50 Hz, 5 A with Earth connection.
2. Water Supply.
3. Space required : 1.6m x 0.5m

4. Drain

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Clean the apparatus and make all the tanks free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank ¾ with Clean Water and ensure that no foreign particles are there.
4. Close Flow Control Valve given at the end of Test Section.
5. Open Flow Control Valve and By-Pass Valve given on the water supply line to Overhead Tank.
6. Ensure that all On/Off Switches given on the Panel are at OFF position.
7. Now switch On the Main Power Supply (220 V AC, 50 Hz).
8. Switch on the Pump.
9. Regulate Flow of water through Test Section with the help of given Gate Valve at the end of Test Section.
10. Measure Flow Rate using Measuring Tank and Stop Watch.

- **CLOSING PROCEDURE-**

1. When experiment is over, Switch off Pump.
2. Switch off Power Supply to Panel.
3. Drain water from all tanks with the help of given drain valves.

SPECIFICATIONS:

Test Section	: Material Acrylic.
Piezometer Tubes	: Material P.U. Tubes (9 Nos.)
Water Circulation	: FHP Pump.
Flow Measurement	: Using Measuring Tank with Piezometer, Capacity 25 l
Sump Tank	: Capacity 70 l
Inlet Tank	: Capacity 20 l
Stop Watch	: Electronic.

FORMULAE:

Total Energy (E) : $E = \frac{p_1}{\rho g} + \frac{v^2}{2g} + Z$

Velocity of Fluid (V) : $\mathbf{V = \frac{Q}{a}}$

Discharge (Q) : $Q = \frac{AxR}{t}$

$p/\rho g = h$

OBSERVATIONS & CALCULATIONS:

- **DATA**

g = Acceleration due to Gravity = 9.81 m/s^2.
A = Area of Measuring Tank = 0.1 m2.

S. No. of Test points	Cross- Sectional Area a (m^2.)	Distance from Reference point S (m)
1.	6.1707×10^{-4}	0.03
2.	5.0074×10^{-4}	0.07
3.	4.1620×10^{-4}	0.11
4.	3.3329×10^{-4}	0.15
5.	2.7172×10^{-4}	0.19
6.	3.3006×10^{-4}	0.23
7.	4.2273×10^{-4}	0.27
8.	5.1794×10^{-4}	0.31
9.	6.4063×10^{-4}	0.35

OBSERVATION TABLE

S. No.	R (cm)	t (s)	h (cm) at Piezometric Tube No.								
			1	2	3	4	5	6	7	8	9
1.											
2.											
3.											
4.											
5.											

CALCULATION TABLE:

Run No. =
Discharge = m^3/s

Tube No.	1	2	3	4	5	6	7	8	9
V (m/s)									
$p/\rho g = h$									
$V^2/2g$									
Z									
E									

NOMENCLATURE-

E = Total Energy.
p / ρg = Pressure energy per unit weight of fluid or pressure head.
V^2 / 2g = Kinetic energy per unit weight or kinetic head.
Z = Potential energy per unit weight of potential head.
p = Pressure of fluid (m of water).
V = Velocity of fluid (m/s).
Q = Discharge through test section.
v = Volume of water collected in measuring tank.
R = Rise of water level in Measuring Tank.
t = Time taken for R.

REFERENCES:

1. McCabe, W.L., Smith, J.C., Harriott, P., "*Unit Operations of Chemical Engineering*", 4th ed. pp. 61-69, McGraw Hill, NY, 1985.

EXPERIMENT NO- 6

Date:……………………………………………………

OBJECTIVE:
To determine the flow rate of air/water by Orificemeter.

AIM:

To determine the co-efficient of discharge.
To determine the co-efficient of velocity.

INTRODUCTION:

Orifice is an opening or a hole of any size, shape or form, through which liquid flow such that its upper edge remains below the free surface of the liquid. Orifices are used for measurement or control of flow. Orifices may have any shape but generally they are circular, square or rectangular.

A mouthpiece is a relatively short pipe, which is fitted internally or externally to the orifice in the side of the tank. Mouthpieces are sometimes used as a flow measurement device.

THEORY:

- **ORIFICE-**

When a liquid flows from a vessel or a tank, through an orifice, it changes its direction. Due this change of direction of the liquid, the jet is acted upon by lateral or side forces, which gradually reduce its area up to certain section. This area does not reduce further beyond, which the jet ceases and streamlines, first become parallel is known as the vena-contracta.

- **MOUTHPIECE-**

A short piece of length about three times of its diameter, connected to the face of an orifice, is known as a mouthpiece. In what follows, it will be proved that under a given head, the rate of discharge through a mouthpiece will be more than that through an orifice of the same diameter. The reason being that while entering into the mouthpiece, the liquid gets contracted at vena-contracta. Due to this contraction, the velocity of liquid at increase and the pressure decreases. The pressure at vena-contracta is less then at atmosphere. This may be verified by applying Bernoulli's theorem at the outlet and at the vena-contracta.

- **CO-EFFICIENT OF VELOCITY-**

It is defined as the ratio between the actual velocity of a jet of liquid at a vena-contracta and the theoretical velocity of the jet. It is denoted by C_v and is given as:

$$C_v = \frac{\text{Actual velocity of the jet at vena - contracta}}{\text{Theoretica l velocity}}$$

$$= \frac{V}{\sqrt{2gH}}$$

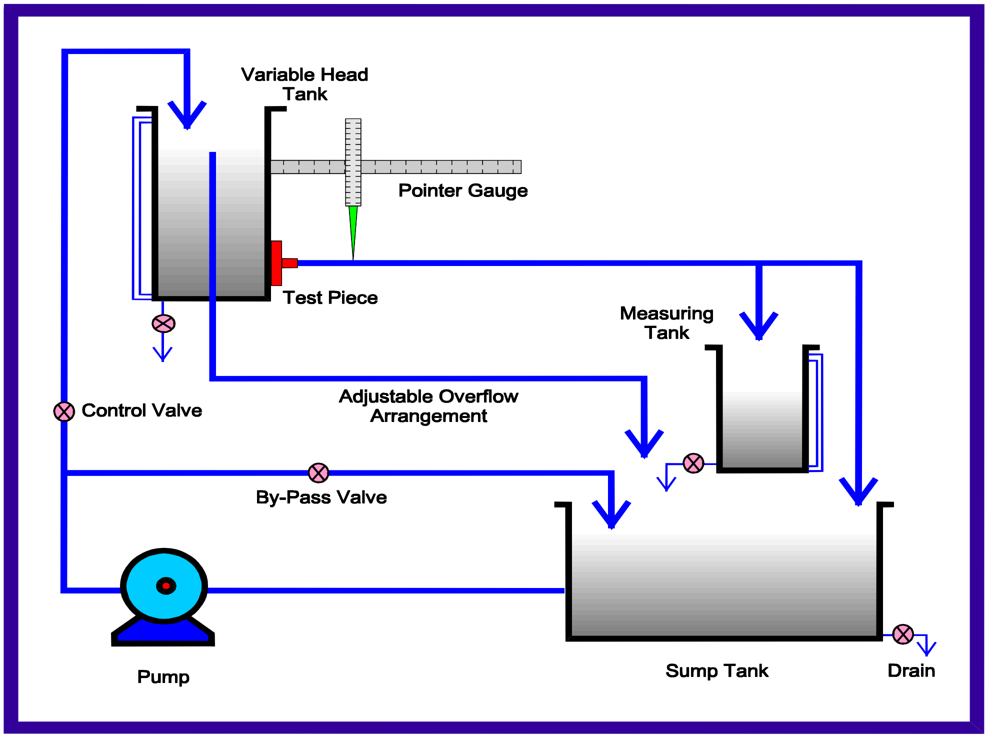
- **CO-EFFICIENT OF DISCHARGE, C_d -**

It is defined as the ratio of the actual discharged from an orifice to the theoretical discharged from the orifice. It is denoted by C_d. If Q_a the actual discharge and Q_t is the theoretical discharge then ratio of C_d is given as:

$$C_d = \frac{Q_a}{Q_t}$$

DESCRIPTION:

It consists of a constant head tank that supplies the water to orifice and mouthpiece. It has a piezometer with scale for head measurement. A measuring arrangement for X – Y co-ordinate of vena-contracta is provided. Discharge is measured in measuring tank with a help of stopwatch. Water is circulated from the sump tank through centrifugal pump.



Schematic Diagram for Orifice & Mouth piece Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 Volts, 50 Hz, 5 Amp with Earth.
2. Water Supply.
3. Drain.
4. Space required: 1.6m x 0.5m

SPECIFICATIONS:

Set of Orifices	: Material Acrylic (2 Nos.) Dia. 10mm and 15 mm
Set of Mouthpieces	: Material Acrylic (3 Nos.) Dia 10 mm (L/D = 2.5) Dia 10 mm (L/D = 4) Dia 10 mm (L/D = 1)
Constant Head tank	: 35 l
Hook/Pointer Gauge	: To measure X-Y co-ordinates of Jet.
Water Circulation	: FHP Pump.
Flow Measurement	: Using Measuring Tank with Piezometer, Capacity 25 l
Sump Tank	: Capacity 70 l
Stop Watch	: Electronic.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Clean the apparatus and make All Tanks free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank ¾ with Clean Water and ensure that no foreign particles are there.
4. Close all Flow Control Valves given on the water line.
5. Open By-Pass Valve.
6. Fix desired Test Piece at testing section.
7. Ensure that all On/Off Switches given on the Panel are at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Operate the Flow Control Valve to regulate the flow of water in Variable Head Tank.
11. Adjust Head of water in the Tank with the help of given flexible varying head system, in the center of the tank.
12. Now fix the pointer Gauge at Vena Contracta observed in water stream, coming out from the Tank.
13. Record Head of the Water in the Tank.
14. Record pointer Gauge Reading.
15. Measure the flow of water, discharged through desired test section, using Stop Watch and Measuring Tank.
16. Repeat the experiment for different water heads.
17. When experiment is over for one desired test piece, firstly open the By-Pass Valve fully.

18. Then close the flow control valve.
19. Drain the Variable head tank in Sump Tank by means of given drain valve.
20. Change second test piece.

CLOSING PROCEDURE:

1. Switch off Pump.
2. Switch off Power Supply to Panel.
3. Drain water from all tanks with the help of given drain valves.

FORMULAE:

- **CO-EFFICIENT OF VELOCITY-**

$$C_v = \frac{V}{\sqrt{2gH}} = \frac{x}{\sqrt{4yH}}$$

- **ACTUAL DISCHARGE-**

$$Q_a = \frac{AxR}{t}$$

- **THEORETICAL DISCHARGE-**

Q_t = area of orifice/mouthpiece x $\sqrt{2gH}$

- **CO-EFFICIENT OF DISCHARGE-**

$$C_d = \frac{Q_a}{Q_t}$$

OBSERVATIONS & CALCULATIONS:

- **DATA:**

1 Diameter of Orifice = 10 mm & 15mm = 0.01m & 0.015 m.
2 Length of Orifice = 10mm = 0.01 m
3 Area of Orifice $\frac{\pi d^2}{4}$ = 7.854×10^{-5} m^2 & 1.767×10^{-4} m^2
4 Diameter of Mouthpiece = 10 mm = 0.01 m
5 Length of mouthpiece = 10 mm, 25mm, 40 mm
6 Area of mouthpiece $\frac{\pi d^2}{4}$ = $7.854 \times 10^{-5}.m^2$
7 Area of Measuring tank, (A) = 0.1 m^2

OBSERVATION TABLE:

S. No.	Water head H (cm)	X (cm)	y (cm)	Rise of water level R (cm)	Time for R, t (s)

1.					
2.					
3.					
4.					
5.					

CALCULATION TABLE:

S. No	H (m)	x (m)	y (m)	Q_a, m^3/s	Q_t, m^3/s	C_v, m/s	C_d
1.							
2.							
3.							
4.							
5.							

NOMENCLATURE:

V = actual velocity at vena contracta
$\sqrt{2gH}$ = theoretical velocity, m/s
R = rise of water level in measuring tank, cm
T = time taken to R in seconds
H = Water head, m
x = horizontal distance traveled by the liquid particle from Vena-contracta
y = vertical distance between vena-contracta and liquid particle

REFERENCES:

1. Streeter, V.L., Wylie, E.B., "*Fluid Mechanics*", 1st ed., pp. 342-344, McGraw Hill, NY, 1983.
2. Garde, R.J., "*Fluid Mechanics through Problems*", 2nd ed., pp. 133-135, New age International, ND, 1997.

EXPERIMENT NO- 7

Date:……………………………………………………

OBJECTIVE:
To determine the flow rate of air/water by Venturimeter

AIM:

- To determine the co-efficient of discharge through Venturimeter & Orificemeter.
- To calibrate the Rotameter.

INTRODUCTION:

If a constriction is placed in a closed channel carrying a stream of fluid, there will be increase in velocity, and hence increase in Kinetic Energy, at the constriction, from an energy balance, as given by Bernoulli's Theorem, there must be a corresponding reduction in pressure. Rate of discharge from the constriction can be calculated by knowing this pressure reduction, the area available for flow at the constriction, the density of fluid, and the Co-efficient of discharge C_d. The C_d is defined as the ratio of actual flow to the theoretical flow and makes allowance for stream contraction and frictional effects.

THEORY:

- **VENTURIMETER-**

A Venturimeter consists of;

1. An inlet section followed by a convergent cone.
2. A Cylindrical Throat.
3. A gradually divergent cone.

The inlet section of the Venturimeter is of the same diameter as that of the pipe, which is followed by a convergent cone. 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 gradually diverging pipe with its cross-sectional area increasing from that of the Throat to the original size of the pipe. At inlet section & Throat of the Venturimeter, pressure taps are provided.

- **ORIFICEMETER-**

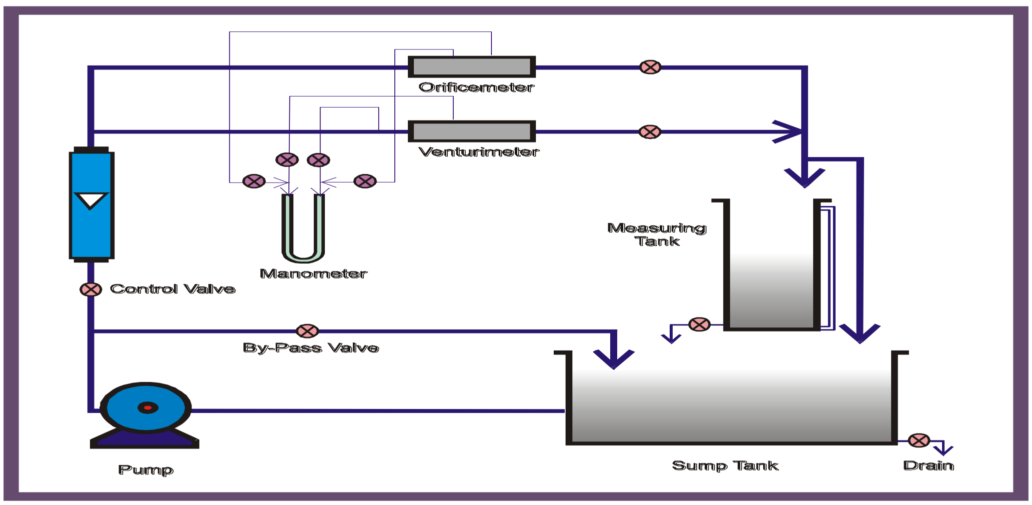
An Orificemeter consists of a flat circular plate with a circular hole called Orifice, which is concentric with the pipe axis.

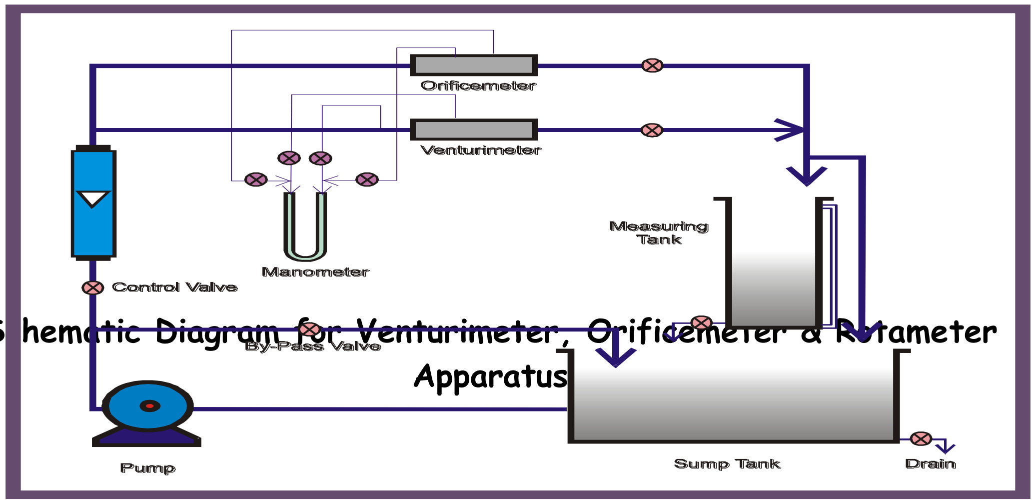
- **ROTAMETER-**

The Rotameter is a variable- area meter that consists of an enlarging transparent tube and a metering "float" (actually heavier than the liquid) that is displaced upward by the upward flow fluid through the tube. The tube is graduated to read the flow directly. Notches in the float cause it to rotate and thus maintain a central position in the tube.

DESCRIPTION:

The apparatus consists of a Venturimeter, an Orificemeter and a Rotameter, fitted in pipeline. The pipeline is taken out from a common inlet. At the down stream end of the pipeline, separate control valves are provided to regulate the flow through the Venturimeter and Orificemeter to conduct experiment separately. Pressure tapings are taken out from inlet and Throat of Venturimeter, inlet and outlet of Orificemeter, and are connected to a differential manometer. Discharge is measured with the help of measuring tank & Stop watch.





Schematic Diagram for Venturimeter, Orificemeter & Rotameter Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 V, 50 Hz, 5 A with Earthing.
2. Water Supply.

3. Drain.
4. Space required: 1.6m x 0.5m

SPECIFICATIONS:

Venturimeter	:	Material Clear Acrylic compatible to 1"D pipe
Orificemeter pipe	:	Material Clear Acrylic compatible to 1" D
Rotameter	:	Compatible Range.
Water Circulation	:	FHP Pump.
Flow Measurement	:	Using Measuring Tank, Capacity 25 l
Sump Tank	:	Capacity 50 l
Stop Watch	:	Electronic.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Clean the apparatus and make All Tanks free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank ¾ with Clean Water and ensure that no foreign particles are there.
4. Close all Flow Control Valves given on the water line and open By-Pass Valve.
5. Check the level of Hg in manometer tube. It should be up to half. If it is less, then fill it.
6. Close all Pressure Taps of Manometer connected to Venturimeter & Orificemeter.
7. Ensure that On/Off Switch given on the Panel is at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Operate the Flow Control Valve to regulate the flow of water in the desired Test Section.
11. Open the Pressure Taps of Manometer of related Test section, very slowly to avoid the blow of water on manometer fluid.
12. Now open the Air release Valve provided on the Manometer, slowly to release the air in manometer.
13. When there is no air in the manometer, close the Air release valves.
14. Adjust water flow rate in desired section with the help of Control Valve.
15. Record the Manometer reading.
16. Measure the flow of water, discharged through desired test section, using Stop Watch and Measuring Tank.
17. Repeat Steps the same procedure for different flow rates of water, operating Control Valve and By-Pass valve.

18. When experiment is over for one desired test section, open the By-Pass Valve fully. Then close the flow control valve of running test section and open the Control valve of secondly desired test section.

- **CALIBRATION OF ROTAMETER-**

1. Close the ball valves provided in the Venturimeter and Orificemeter pipelines.
2. Open the ball valve provided in the Rotameter pipeline.
3. Now switch on the main power supply and switch on the pump.
4. Set the flow rate with the help of by pass and flow control valves provided in Rotameter pipeline.
5. Measure the discharge with the help of measuring tank and stopwatch.
6. The actual discharge, verify the set value of Rotameter.
7. Repeat the same procedure for different flow rates.

- **CLOSING PROCEDURE-**

1. When experiment is over, close all Manometers Pressure Taps first.
2. Switch off Pump.
3. Switch off Power Supply to Panel.

FORMULAE:

FOR BOTH VENTURIMETER & ORIFICEMETER

Theoretical discharge (Q_t):

$$Q_t = \frac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}}$$

H=12.6*h

Actual discharge (Q_a):

$$Q_a = \frac{AxR}{t}$$

Co-efficient of discharge (C_d):

$C_d = Q_a/Q_t$

FOR ROTAMETER

Actual discharge:

$$Q_a = \frac{AxR}{t} x3600x1000$$

OBSERVATIONS & CALCULATIONS:

- **DATA-**

A = $0.1\ m^2$

s = Specific gravity of Hg = 13.6

g = Acceleration due to Gravity = $9.81\ m/sec^2$

- **FOR VENTURIMETER-**

d_1 = Dia. at inlet of the Venturimeter = 28mm = 0.028m

d_2 = Dia. at throat of the Venturimeter = 14mm = 0.014m

a_1 = Area at inlet of Venturimeter = $\pi d_1^2/4$ = $6.157 * 10^{-4}\ m^2$

a_2 = Area at throat of Venturimeter = $\pi d_2^2/4$ = $1.539* 10^{-4}\ m^2$

FOR ORIFICEMETER:

d_1 = Dia. at inlet of Orifice meter = 28mm. = 0.028m

d_2 = Dia. of Orifice Plate = 14mm. = 0.014m

a_1 = Area at inlet of Orifice meter = $\pi d_1^2/4$ = $6.157 * 10^{-4} m^2$

a_2 = Area of Orifice Plate = $\pi d_2^2/4$ = $1.539* 10^{-4} m^2$

OBSERVATION TABLE FOR VENTURIMETER & ORIFICEMETER

S. No.	Pressure difference h (cm)	Rise of Water level in Measuring Tank, R (cm)	Time taken for R, t (s)
1.			
2.			

3.			
4.			
5.			

CALCULATION TABLE:

S. No.	Actual discharge Q_a , m^3/s	Theo. Discharge Q_t , m^3/s	$C_d = Q_a/Q_t$
1.			
2.			
3.			
4.			
5.			

AVERAGE CO-EFFICIENT OF DISCHARGE:

- **OBSERVATION TABLE FOR ROTAMETER**

S.No.	Rotameter Reading in LPH, Q_{th}	Rise of Water level in Measuring Tank, R (cm)	Time taken for R, t (s)

1.			
2.			
3.			
4.			
5.			

CALCULATION TABLE:

S. No.	Rotameter Reading in Q_{th} m^3/s	Theo. Discharge Q_t m^3/s	$C_d = Q_a/Q_t$
1.			
2.			
3.			
4.			
5.			

NOMENCLATURE

H = 12.6 x h
h = Pressure Difference in m of Hg.
A = Area of Measuring Tank (m^2)
R = Rise of Water level in Measuring Tank (m)
t = Time taken for Rise of water level in measuring tank, s

Q_a	=	Actual discharge.
Q_t	=	Theoretical discharge.
s	=	Specific gravity of Hg

REFERENCES

1. McCabe, W.L., Smith, J.C., Harriott, P., *"Unit Operations of Chemical Engineering"*, 4th ed. pp. 191-205, McGraw Hill, NY, 1985.
2. Perry, R.H., Green, D.(editors), *"Perry's Chemical Engineers' Handbook"*, 6th ed., pp. 5/12-18, McGraw Hill, NY, 1985.
3. Foust, A.S., et. al., *"Principles of Unit Operations"*, 2nd ed., pp. 560-566, John Wiley, NY, 1980.
4. Brown, G.G., *"Unit Operations"*, 1st ed., pp 156-162, CBS, ND, 1995.
5. Coulson, J.M., Richardson, J.F., *"Coulson & Richardson's Chemical Engineering Vol. - 1"*, 5th ed., pp. 219-231, Asian Books ltd., ND, 1996.

EXPERIMENT NO- 8

Date:……………………………………………………

OBJECTIVE:

To determine head loss of a given length of a pipe

AIM:
To determine the friction factor for Darcy - Weisbach equation

INTRODUCTION:
When a fluid is flowing through a pipe, the fluid experiences some resistance due to which some of the energy of fluid is lost. This loss of energy in the pipelines comes under major energy losses and minor energy losses. In long pipelines the friction losses are much larger than the minor losses and hence, the latter are often neglected. The losses due to friction in the pipelines are known as major energy losses. The friction in the pipeline is due to a viscous drag between the stream bands of fluid. The stream bands of adjacent to the solid surface are always at rest relative to the wetted surface. The viscous drag is due to the molecular attractions between the molecular of the fluid.

THEORY:
It is found that the total friction resistance to fluid flow depends on the following:

1. The area of the wetted surface
2. The density of the fluid
3. The surface roughness
4. It is independent of the fluid pressure
5. It increase with the square of the velocity

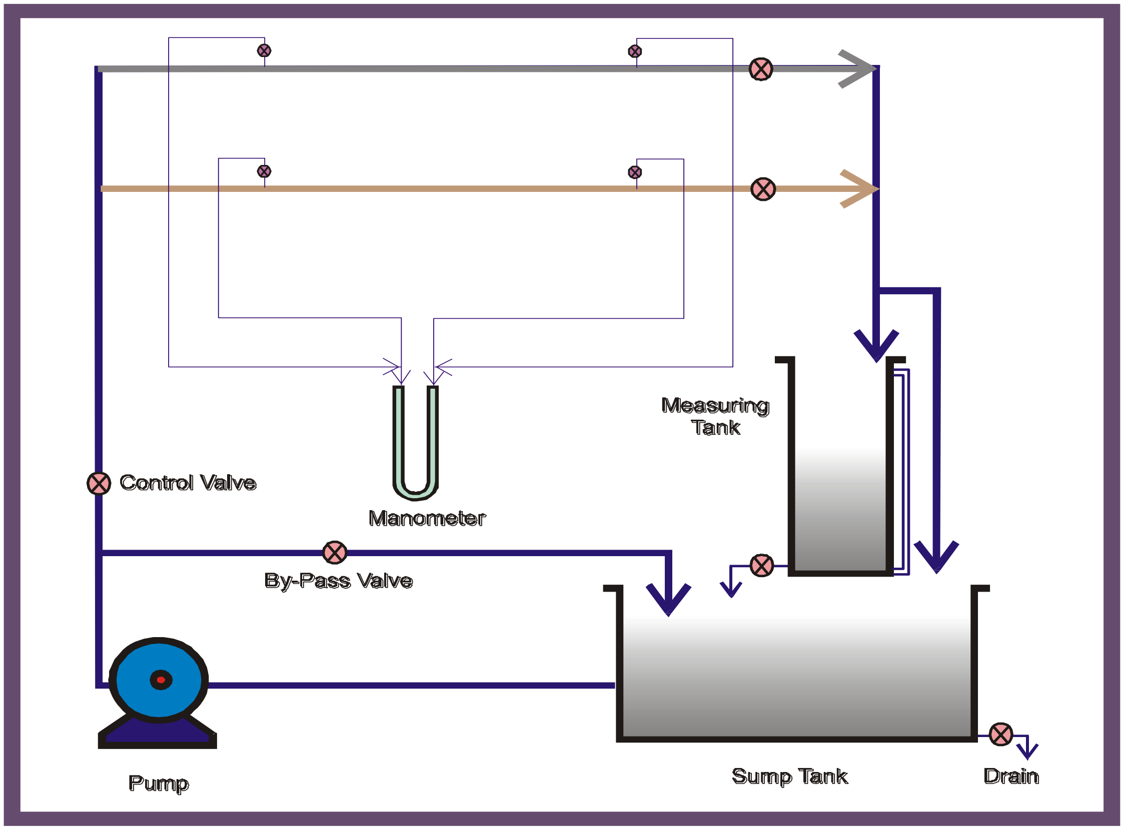
The loss of head in pipe due to friction is calculated from Darcy-Weisbach equation which has been given by:

$$h_f = \frac{4 f L V^2}{2 g d}$$

h_f	=	loss of head due to friction
f	=	Co-efficient of friction
L	=	distance between pressure point
V	=	mean velocity of fluid
d	=	diameter of pipe
g	=	Acceleration due to Gravity

DESCRIPTION:
The apparatus consists of two pipes of different material for which common inlet connection is provided with control valve to regulate the flow, near the

down stream end of the pipe. Pressure tapings are taken at suitable distance apart between which a manometer is provided to study the pressure loss due to the friction. Discharge is measured with the help of measuring tank and stopwatch.



Schematic Diagram for Friction in Pipe Lines Apparatus

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 V, 50 Hz, 5 A with Earthing.
2. Water Supply.
3. Drain.
4. Space required : 1.6m x 0.6m

SPECIFICATIONS:

Pipes (2 Nos.) : Material GI of $\frac{1}{2}$" & 1" diameter.
Pipe Test Section : Length 1 m.
Water Circulation : FHP Pump.
Flow Measurement : Using Measuring Tank with Piezometer, Capacity 25 l
Sump Tank : Capacity 50 l
Stop Watch : Electronic.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Clean the apparatus and make All Tanks free from Dust.
2. Close the drain valves provided.
3. Fill Sump tank $\frac{3}{4}$ with Clean Water and ensure that no foreign particles are there.
4. Close all Flow Control Valves given on the water line and open By-Pass Valve.
5. Check the level of Hg in manometer tube. It should be up to half. If it is less, then fill it.
6. Close all Pressure Taps of Manometer connected to pipes.
7. Ensure that On/Off Switch given on the Panel is at OFF position.
8. Now switch on the Main Power Supply (220 V AC, 50 Hz).
9. Switch on the Pump.
10. Operate the Flow Control Valve to regulate the flow of water in the desired Test Section.
11. Open the Pressure Taps of Manometer of related Test section, very slowly to avoid the blow of water on manometer fluid.
12. Now open the Air release Valve provided on the Manometer, slowly to release the air in manometer.
13. When there is no air in the manometer, close the Air release valves.
14. Adjust water flow rate in desired section with the help of Control Valve.
15. Record the Manometer reading.
16. Measure the flow of water, discharged through desired test section, using Stop Watch and Measuring Tank.
17. Repeat same procedure for different flow rates of water, operating Control Valve and By-Pass valve.
18. When experiment is over for one desired test section, open the By-Pass Valve fully. Then close the flow control valve of running test section and open the Control valve of secondly desired test section.
19. Repeat the same procedure for selected test section and so on.

- **CLOSING PROCEDURE-**

1. When experiment is over, close all Manometers Pressure Taps first.
2. Switch off Pump.
3. Switch off Power Supply to Panel.

FORMULAE:

Loss of Head due to Friction:

$$h_f = \frac{4 f L V^2}{2 g d}$$

Co-efficient of Friction:

$$f = \frac{h_f 2 g d}{4 L V^2}$$

Discharge (Q):

$$Q = \frac{A x R}{t} m^3/s$$

Velocity of Fluid:

$$V = \frac{Q}{A} m/s$$

OBSERVATIONS & CALCULATION:

- **DATA**

A	=	Area of measuring tank	=	$0.1 m^2$
s	=	Sp. gravity of Hg	=	13.6
g	=	Acceleration due to gravity	=	$9.81 m/sec^2$
d	=	Inside Diameter of Pipe		
		For GI pipe (1")	=	0.028m
		For GI pipe (1/2")	=	0.016m
a	=	Cross-section area of pipe		
		For GI pipe (1")	=	$6.157 \times 10^{-4} m^2$
		For GI pipe (1/2")	=	$2.0106 \times 10^{-4} m^2$
L	=	Distance between pressure points	=	1.2 m
h_f	=	12.6 x h		

OBSERVATION TABLE:

S. No	Pressure difference h (cm)	Rise of water level in measuring Tank R (cm)	Time taken for R, t (s)
1.			
2.			
3.			
4.			
5.			

CALCULATION TABLE:

S. No.	h_f (m)	Volume, v (m^3)	Velocity of Fluid, V (m/s)	Discharge, Q (m^3/s)	Friction actor $f = \frac{h_f 2g d}{4LV^2}$
1					
2.					
3.					
4.					
5.					

NOMENCLATURE:

A = Area of measuring tank
a = Cross-section area of pipe
d = Inside Diameter of Pipe
L = distance between two points
R = Rise of water level in measuring Tank (m)
t = Time taken for R (s)
v = Volume of water collected in measuring Tank (m^3)

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EXPERIMENT NO- 9

Date:…………………………………………………

OBJECTIVE:

To determine flow rate of water/air by nozzle-meter

AIM:

To determine the Coefficient of discharge, C_d

INTRODUCTION:

The most important class of flow meter is that in which the fluid is either accelerated or retarded at the measuring section by reducing the flow area, and the change in the kinetic energy is measured by recording the pressure difference produced. The Nozzle meter is one of them. The Nozzle, in which the fluid is gradually accelerated up to the throat of the instrument but expansion to pipe diameter is sudden as with an orifice. This instrument is again expensive because of the accuracy required over the inlet section. This is similar to the orifice meter but has a converging tube in place of the orifice plate.

THEORY:

The velocity of the fluid is gradually increased and the contours are so designed that almost frictionless flow takes place in the converging portion; the outlet corresponds to vena contracta on the orifice meter. The nozzle has a constant high coefficient of discharge (C_d = 0.99) over a wide range of conditions because the coefficient of contraction is unity, though because the simple nozzle is not fitted with a diverging cone, the head lost is very nearly the same as with an orifice. For standard nozzle where A_0 / A_1 is greater than 0.45

A_0 = Area of the nozzle

A_1 = Area of the pipe

- **Coefficient of discharge (C_d):**

It is defined as the ratio of the actual discharge from the nozzle to the theoretical discharge. It is denoted by C_d. If Q is the actual discharge and Q_{th} is the theoretical discharge then mathematically , is given as :

$$C_d = \frac{Q}{Q_{th}} = \frac{\text{actual discharge}}{\text{theoretical discharge}}$$

DESCRIPTION:

The apparatus consists of Nozzle meter, fitted in a pipeline. The Water is supplied from the sump tank with the help of pump and flow rate can be controlled by the valve provided at the at the outlet of the pipeline. Pressure tapings are taken out from inlet and outlet of Nozzle meter, and are connected to a differential manometer. Discharge is measured through the measuring tank and stop watch.

EQUIPMENT / UTILITIES REQUIRED:

1. Power supply: Single Phase, 220 V, 50 Hz, 16 A with Earthing.
2. Water Supply

SPECIFICATIONS:

Nozzle meter	:	Nozzle of Stainless Steel, Housing of Clear Acrylic. Compatible to 1" dia pipe.
Water Circulation	:	FHP Pump.
Flow Measurement	:	Using Measuring Tank, Capacity 30 Ltrs.
Sump Tank	:	Capacity 60 l
Stop Watch	:	Electronic.

EXPERIMENTAL PROCEDURE:

- **STARTING PROCEDURE-**

1. Close Pressure Taps of Manometer connected to nozzle meter.
2. Ensure that On/Off Switch given on the Panel is at OFF position.
3. Now switch on the Main Power Supply (220 V AC, 50 Hz).
4. Operate the Flow Control Valve to regulate the flow of water to the nozzle meter.
5. Open the Pressure Taps of Manometer of related nozzle meter
6. Adjust water flow rate as desired for nozzle meter with the help of Control Valve.
7. Record the Manometer reading.
8. Measure the flow of water with measuring tank and sop watch.
9. Repeat Steps 4 to 8 for different flow rates of water, operating Control Valve and By-Pass valve.

➢ **CLOSING PROCEDURE-**

1. When experiment is over, close all Manometers Pressure Taps first.
2. Switch off Pump.
3. Switch off Power Supply to Panel.

FORMULAE:

1. THEORETICAL DISCHARGE (Qth):

$$Q_{th} = \frac{A_o A_1 \sqrt{2gH}}{\sqrt{(A_1^2 - A_o^2)}}$$

2. ACTUAL DISCHARGE (Qa) :

$$Q = \frac{A * R}{t}$$

3. CO-EFFICIENT OF DISCHARGE (Cd) :

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

4. PRESSURE HEAD FROM MANOMETER (H):

$$H = 12.6 * h$$

OBSERVATIONS & CALCULATION

DATA:

A	=	0.1 m^2		
s	=	13.6		
g	=	9.8 m/sec^2		
D_1	=	0.028 m		
D_0	=	0.014 m		
A_1	=	$\pi D_1^2/4$ cm^2	=	0.00061575 m^2
A_0	=	$\pi D_0^2/4$ cm^2	=	0.00015393 m^2

OBSERVATION TABLE:

S. No.	H (cm)	R (cm)	t (s)
1.			
2.			
3.			
4.			
5.			

CALCULATIONS:

S. No.	h (m)	R (m)	H (m)	Q (m^3/s)	Q_{th} (m^3/s)	$C_d = Q_a/Q_t$
1.						
2.						
3.						
4.						
5.						

NOMENCLATURE:

h = Pressure Difference in m of Hg.
A = Area of Measuring Tank (m^2)
R = Rise of Water level in Measuring Tank (m)
t = Time taken for Rise of water level in measuring tank (sec).
A = Area of measuring tank
s = Specific gravity of Hg
g = Acceleration due to gravity
D_1 = Dia. At inlet of the nozzle meter
D_0 = Dia. At throat of the nozzle meter
A_1 = Area at inlet of nozzle meter
A_0 = Area at throat of nozzle meter

EXPERIMENT NO- 10

Date:……………………………………………………

OBJECTIVE:

To study Pelton wheel and Kaplan Turbine models

EQUIPMENT:

Models of Pelton & Kaplan Turbine

INTRODUCTION:

According to the action of water flowing through the turbine runners the turbines may be classified as impulse turbines and reaction turbines.

In an **impulse turbine**, all the available energy of water is converted into kinetic energy or velocity head by passing it through contracting nozzle provided at the end of the penstock. Impulse turbines are used for low specific speed, high head and low discharge.

Pelton wheel, an impulse turbine consists of a penstock which supplies water from the high head reservoir through one or more nozzles at its exit. The flow through the nozzle is controlled by means of a *spear valve* constituted by a spear rod which may slide in and out either mechanically or by means of a servomechanism device actuated automatically by the changes in the speed of rotation of the runner wheel of the turbine. The jet of water impinges the bucket vanes installed at the periphery of the runner, thus causing it to revolve. A casing is provided for a Pelton wheel to prevent splashing of water, to lead water to the *tail-race* and also to act as a safeguard against accidents.

In a **reaction turbine**, at the entrance to the *runner*, only a part of the available energy of the water is converted into kinetic energy and a substantial part remains in the form of pressure energy. As water flows through the runner the change from pressure to kinetic energy takes place gradually.

The main components of **Kaplan turbine** are *scroll casing*, *stay ring*, arrangement of *guide-vanes* and *draft tube*. Between the guide vanes and the runner the water in a Kaplan turbine has four or six blades (or vanes). The blades attached to hub or bosses are so shaped that water flows axially through the runner. The runner blades of Kaplan turbine can be turned about their own axis, so that their angle of inclination may be adjusted while the turbine is in motion. This adjustment of runner blades is usually carried out automatically by means of a servomotor operating inside the hollow coupling of turbine and generator shaft

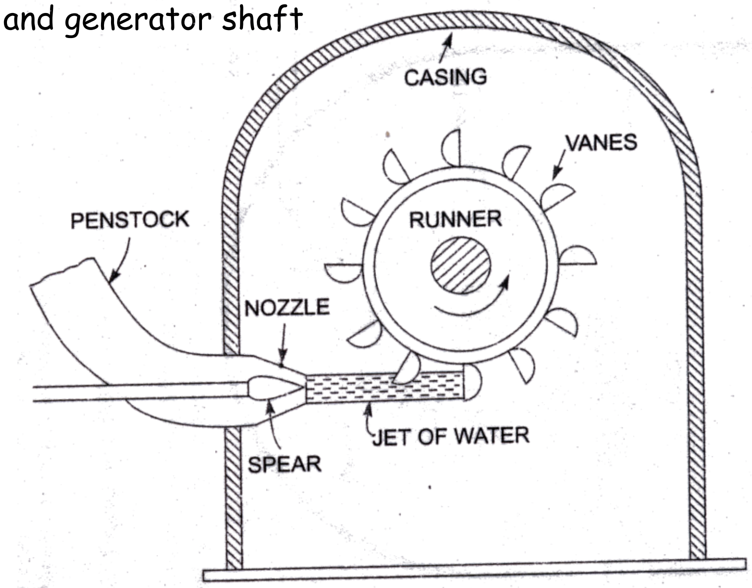

Fig.1 Pelton wheel Turbine

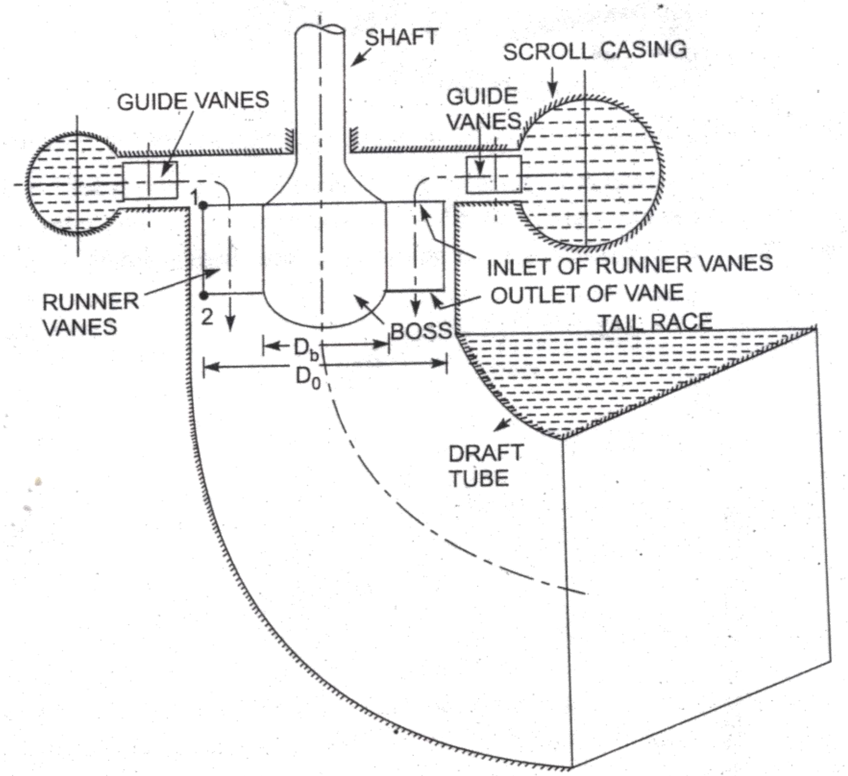

Fig.2. Kaplan turbine