

# ***SRMVALLIAMMAI ENGINEERING COLLEGE***

(An Autonomous Institution)

SRM Nagar, Kattankulathur – 603 203

***DEPARTMENT OF CIVIL ENGINEERING***



***IV SEMESTER***

***CE3467 – FLUID MECHANICS AND MACHINERY LABORATORY***

***Regulation – 2023 Academic Year***

***2025 – 2026 (Even)***

***Prepared by Dr. J. Arunraj Christadoss, Assistant Professor (Sr.G)***

***/ CIVIL***

## PREFACE

This instruction manual has been prepared by the department of Civil Engineering to facilitate instructions doing practical classes and further to be used as a reference manual by the fourth semester Civil Engineering students of this college. This manual covers explanation of experiments included in the syllabus according to Regulation 2023 – CE3467 Fluid Mechanics and Machinery Laboratory for the B.E Civil Engineering degree course.

***Dr. J. Arunraj Christadoss***

Assistant Professor

## **1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):**

1. To produce graduates who can understand their ethical, environmental as well as professional responsibilities so that they appreciate the impact of the engineering solutions which have sustainability over society and the nation.
2. To develop the graduates who will exhibit strong technical ability to create & synthesize data using relevant tools and concepts, for providing sustainable solutions to civil engineering problems and projects.
3. To equip the graduates with suitable skills making them industry ready when they leave the portals of the Institute and to become a competent distinguished Professional Civil Engineer.
4. To produce students who can exhibit attitude, professionalism, ability to communicate with team members and adapt to the latest technology by engaging themselves in life-long learning

## **2. PROGRAMME OUTCOMES (POs):**

After going through the four years of study, our Civil Engineering Graduates will exhibit ability to:

<b><i>PO</i></b>	<b><i>Graduate Attribute</i></b>	<b><i>Programme Outcome</i></b>
1	Engineering knowledge	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.
2	Problem analysis	Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3	Design/development of solutions	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.
4	Conduct investigations of complex problems	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions
5	Modern tool usage	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and

		modelling to complex engineering activities, with an understanding of the limitations.
6	The engineer and society	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice
7	Environment and sustainability	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development. Apply
8	Ethics	ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice Function effectively as an individual, and as a member or leader
9	Individual and team work	in diverse teams, and in multidisciplinary settings Communicate effectively on complex engineering activities with
10	Communication	the engineering community and with the society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions Demonstrate knowledge and understanding of the engineering
11	Project management and finance	and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments Recognize the need for, and have the preparation and ability to
12	Life-long learning	engage in independent and life-long learning in the broadest context of technological change

### ***3. PROGRAM SPECIFIC OUTCOMES (PSOs):***

By the completion of Civil Engineering program the student will have following Program specific outcomes

1. Establish a Civil Engineering career in industry, government or academic field and achieve professional expertise as appropriate.
2. Execute innovation and excellence in Civil engineering problem solving and design in global and societal contexts.
3. Commit to lifelong learning and professional development in the Civil Engineering field to stay updated in technology, research topics and contemporary issues.
4. Understand the fundamentals of Civil Engineering in commercial contexts and in expediting construction projects.

## *Specific Rules and Hazards Associated with this Lab Include*

**Capacity**-Normal Occupancy during teaching labs is 30

Students should enter the lab with proper uniform and IDcard.

Always keep work areas clean and tidy.

Observe safety alerts in the laboratory.

Always wear shoes that completely cover your feet. No sandals or opened toed shoes are allowed.

Follow all written and verbal instructions carefully.

Observe the safety alerts in the laboratory.

Don't forget to bring Lab manual, Record, observation, calculator, graph sheet and other accessories when you come to lab.

In the absence of Instructor no student shall be allowed to work in the laboratory.

Don't use mobile phones during lab hours.

Place tools and equipment in proper place after use.

Turn off the power switches of weighing balance and equipment after used.

Report to the staff if any injuries.

Don't try to repair any faulty instruments.

Follow the COVID precautionary measures while inside the lab.

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# **CE3467 FLUID MECHANICS AND MACHINERY LABORATORY L T P C**

**0 0 4 2**

**OBJECTIVE:** •Students should be able to verify the principles studied in theory by performing the

experiments in lab.

- Reinforcing the fundamentals of fluid mechanics and machinery by hands on experiment.
- hands on experiments in calibration of flow meters
- Performance characteristics of pumps
- Performance characteristics of turbines

## **LIST OF EXPERIMENTS**

### **A. Flow Measurement**

1. Calibration of Rotameter
2. Calibration of Venturimeter / Orificemeter
3. Bernoulli's Experiment

### **B. Losses in Pipes**

4. Determination of friction factor in pipes
5. Determination of minor losses

### **C. Pumps**

6. Characteristics of Centrifugal pumps
7. Characteristics of Gear pump
8. Characteristics of Submersible pump
9. Characteristics of Multistage Centrifugal pumps
10. Characteristics of Reciprocating pump

### **D. Turbines**

11. Characteristics of Pelton wheel turbine
12. Characteristics of Francis turbine/Kaplan turbine

### **E. Determination of Metacentric height**

13. Determination of Metacentric height of floating bodies

**TOTAL: 60 PERIODS**

## **OUTCOMES:**

The students will be able to measure flow in pipes and

The students will be able to determine frictional losses

The students will be able to develop characteristics of pumps

The students will be able to develop characteristics of turbines

The students will have through knowledge on floating bodies

## **REFERENCES:**

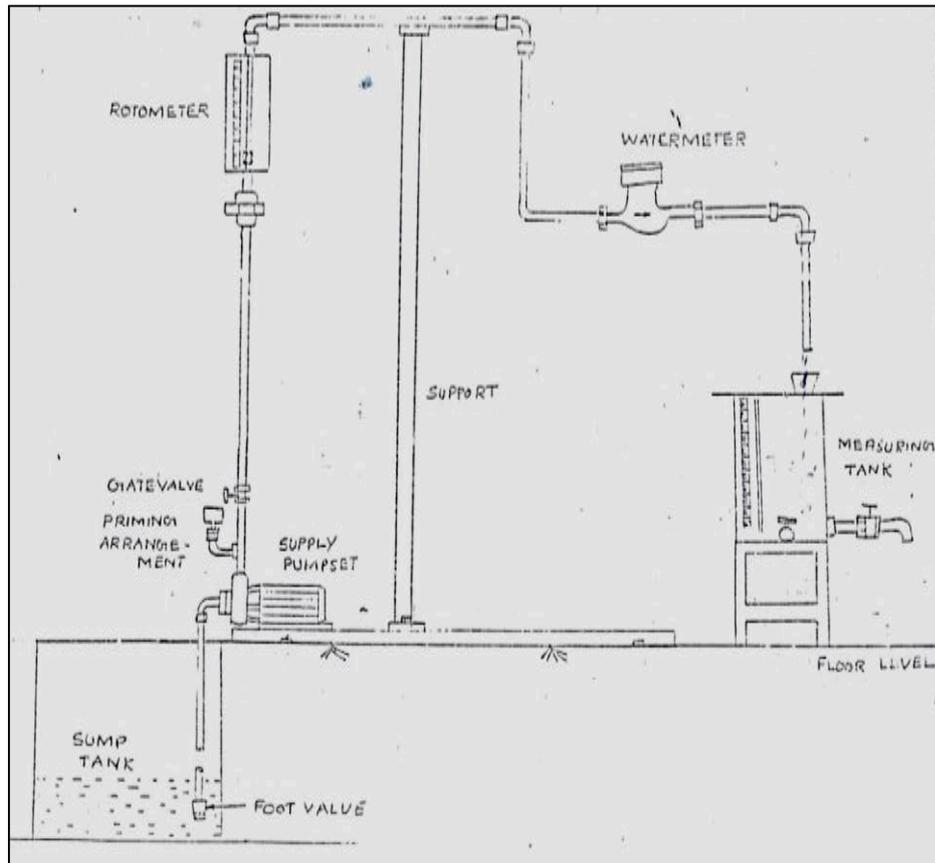
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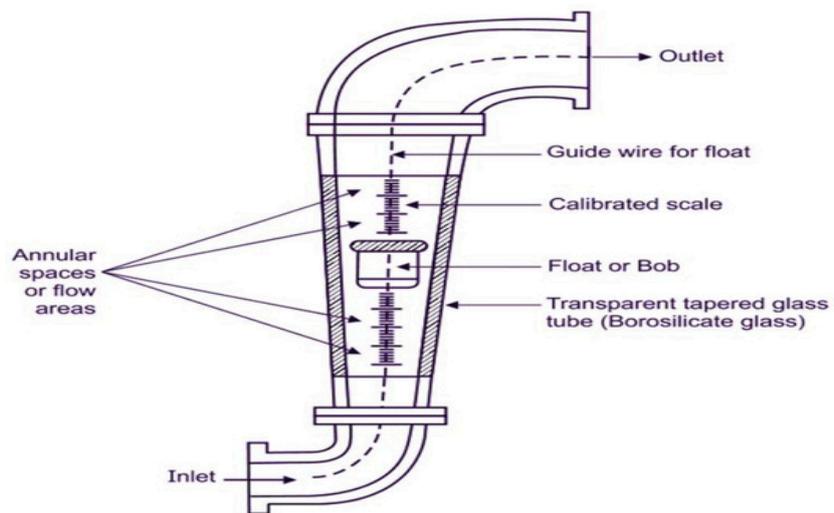
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2	3	2	1	3	1	2	2	1	2	1	1	2	3	2	3	2
3	3	3	2	3	1	2	2	1	3	1	1	2	2	3	2	3
4	3	3	2	3	1	2	2	1	3	1	1	2	3	3	3	2
5	3	3	2	3	1	2	2	1	3	1	1	2	2	2	2	3

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**Fig(1). Rotameter Setup**



**Fig(2). Rotameter**

***CALIBRATION OF ROTAMETER(FLOWMETER)***

***AIM:***

To calibrate the Rotameter (Flow meter)

***APPARATUS REQUIRED:***

1. Rota meter with all accessories
2. Stop-watch

***THEORY:***

The Rotameter is the most popular flow meter. It consists essentially of a plummet or float which is free to move up or down in a vertical slightly tapered tube having its small end down. The fluid enters the lower end of the tube and causes the float to rise until the annular area between the tube and the float is such that the pressure drop across this construction is just sufficient to support the float. Typically, the tapered tube is of glass and carries etched upon it a nearly linear scale on which the position of the float may be usually noted as an indication of the flow.

Rotameter have proved satisfactory both for gasses and for liquids at high and low pressures. Rotameter required straight runs of pipe before or after the point of installation. Pressure losses are substantially constant over the whole flow rang. In experimental work, for greatest precision, a Rotameter should be calibrated with the fluid which is to be entered. However, most modern Rotameter are precision-mode such that their performance closely corresponds to a mater calibration plate for the type in question.

***FORMULA:***

The actual volume flow rate is found from dividing the selected volume of water by the time required to accumulate that volume,

$$Q_{act} = \frac{V}{t} = \frac{Axh}{t} \times 1000 \text{ lps}$$

Where,

*V* is the volume of the water output accumulated in the storage tank, m<sup>3</sup>.

*t* is the time it takes to fill the selected volume, sec.

*A* is the cross-section area of the storage tank, m<sup>2</sup>

*h* is the height of water in the storage tank, m.

The theoretical volume flow rate is found from Rotameter device.

**OBSERVATION AND CALCULATIONS:**

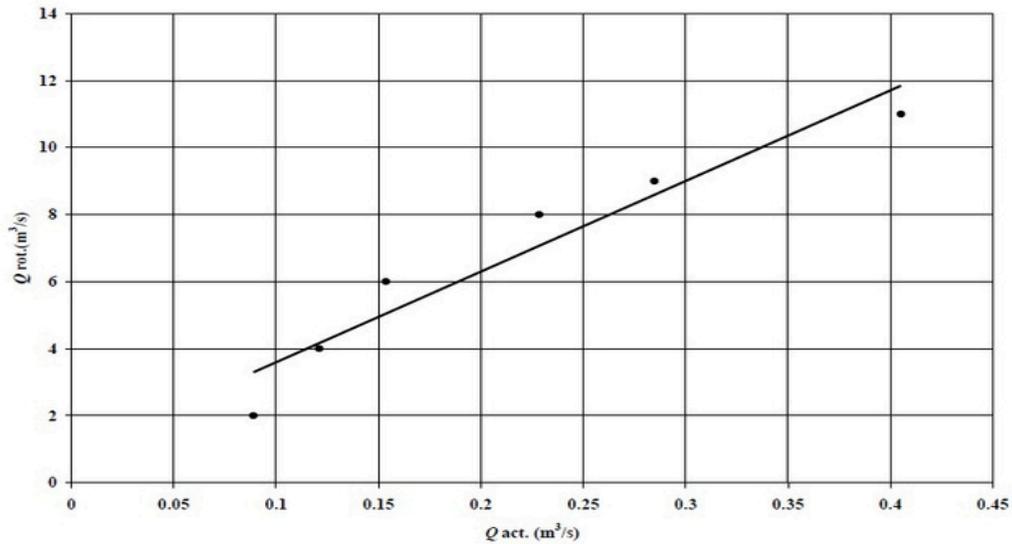
Length of the collecting tank, L = m

Breadth of the collecting tank, B = m

Area of collecting tank, A = m<sup>2</sup>

**TABULATION :**

<i>Sl.No</i>	<i>Rotameter Readings Q<sub>tr</sub>(LPH)</i>	<i>Theoretical discharge Q<sub>t</sub>(LPS)</i>	<i>Time for 10cm raise in collecting tank 't' (sec)</i>	<i>Actual discharge Q<sub>a</sub>(LPS)</i>	<i>Co-efficient of discharge C<sub>d</sub>= Q<sub>a</sub>/Q</i>



**Fig. (2).** Calibration curve for rotameter.

n– Number of division (take 20 division)

Co-efficient of discharge

$$C_d = \frac{Q_{act}}{Q_t} \quad (\text{the value varies from } 0.9 - 1.01)$$

**PROCEDURE:**

1. Select a rate of fluid flow through the rotameter.
2. Opening the inlet valve till the float reaches the selected flow rate.
3. estimating the time required to fill a fixed volume of output water.
4. The rotameter reading indicates the rotameter flow rate ( $Q_{rot.}$ ) in (L/min); while the volume selected divided by the time measured indicates the actual flow rate ( $Q_{act.}$ ) in (lit/sec).
5. Repeating the procedures from 1 to 3 for other selecting flow rate.

**Calculation and Results:**

Record the selected value of rotameter and estimated value of actual flow rate in a table as shown in table below.

Calculating correction factor ( $C_f$ ), which is the ratio between the rotameter reading ( $Q_{rot.}$ ) divided by the actual volume flow rate ( $Q_{act.}$ ), for each reading, and then finding the average value of the correction factor.

Draw the calibration curve, the reading of the rotameter (on y-axis) against the measured actual volume flow rate (on x-axis). Also, find the average correction factor from Fig. (2) shown below, by finding the slope of the line.

***Discussion:***

Discuss the relation between actual volume flow rate and rotameter reading. Also, compare between the average correction factor obtained from table and that obtain from the figure.

***RESULT:***

The co-efficient of discharge for the Rotameter is found out and the necessary graph is plotted.

- (i) From the table  $C_d =$
  - (ii) From the graph  $C_d =$
-

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**VIVA VOCE QUESTIONS**  
**ROTAMETER**

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**1. Define Rotameter**

The rota meter is an industrial flowmeter used to measure the flowrate of liquids and gases.

**2. The Advantages of rotometer are**

A rotameter requires no external power or fuel, it uses only the inherent properties of the fluid, along with gravity, to measure flow rate ,A rotameter is also a relatively simple device that can be mass manufactured out of cheap materials, allowing for its widespread use, Since the area of the flow passage increases as the float moves up the tube, the scale is approximately linear and Clear glass is used which is highly resistant to thermal shock and chemical action.

**3. The Dis-advantages of rotometer are**

Rotameters are not easily adapted for reading by machine; although magnetic floats that drive a follower outside the tube are available and Rotameters are not generally manufactured in sizes greater than 6 inches/150 mm, but bypass designs are sometimes used on very large pipes.

**4. What is steady flow?**

Flow doesn't vary with time. In steady flow velocity of fluid is constant on every point at a specific time.

**5. What is the application of Pitot-Tube?**

Pitot-Static tubes measures velocity at a point of fluid in a stream.

**6. A magnetic flow meter will not properly measure?**

It is used to measure the flow rate of oil.

**7. What is ROTAMETER?**

The rotameter is an industrial flowmeter used to measure the flowrate of liquids and gases. The rotameter consists of a tube and float. The float response to flowrate changes is linear, and a 10-to-1 flow range or turndown is standard.

***8. What is the source of error in Rotameter?***

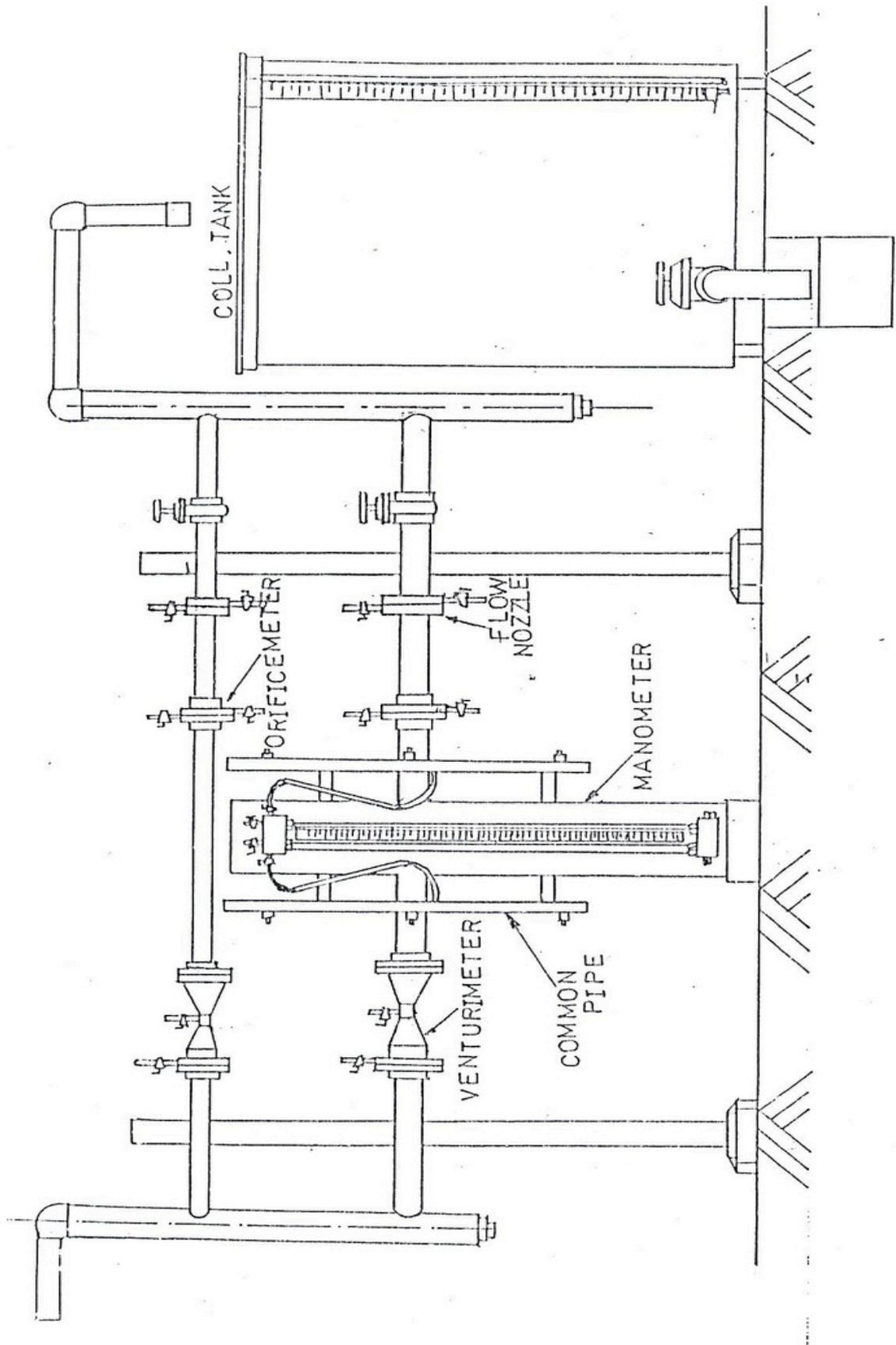
The major source of error in rotameter is due to the variation of density of the fluid. Besides, the presence of viscous force may also provide an additional force to the float.

***9. What is the working principle of Rotameter?***

Rotameter works as a constant pressure drop variable area meter.

***10. Write the disadvantage of Rotameter***

Rotameter can be only be used in a vertical pipeline.



**Ex. no: 2**

**Date:**

**DETERMINATION OF CO-EFFICIENT OF DISCHARGE  
FOR THE VENTURIMETER**

**AIM:**

To determine the coefficient of discharge for the venturimeter

**APPARATUS REQUIRED:**

1. A venturimeter with known diameters at the mouth and throat fitted with stop cocks at the mouth and throat.
2. A U-tube manometer containing mercury.
3. Water measuring tank.
4. A stop-watch.

**THEORY:**

Venturimeter is a device which works on the principle of Bernoulli's equation. It is used for measuring the rate of flow of fluid through a pipe. It consists of these parts.

1. A short converging part.
2. Throat
3. Diverging part

A U-tube manometer is connected to the pipe and through which shows the head difference between them. There will not be any datum head  $H$  the water is horizontal. Hence the pressure head is equal to the velocity head. The main principle involved is that the pressure at throat has maximum due to decreasing cross section which is measured by using manometer. Thus we measure discharge as well as co-efficient.

**FORMULA:**

1. Drop in head across meter:

$$H = (h_1 - h_2) \left\{ \frac{s_m - s_w}{s_w} \right\} \text{ (m)}$$

Where,

$H_1, H_2$  – manometer readings (m)

$S_m$  – Specific gravity of mercury (13.6)

$S_w$  – Specific gravity of water (1)

2. Theoretical discharge ( $Q_{th}$ ):

$$Q^{th} = \frac{a_1 \sqrt{2gH}}{\left( \sqrt{a_2^2 - a_1^2} \right)^2} \text{ (m}^3\text{/s)}$$

Where,

$A^1$  – Cross sectional area of pipe ( $m^2$ )

$A_2$  – Cross sectional are of throat ( $m^2$ )

**OBSERVATION AND CALCULATIONS: =**

- = = Diameter of the inlet , D1 m
- = Diameter of the throat, D2 m
- = Length of the collecting tank, L m
- Breadth of the collecting tank, B m
- Area of collecting tank, A m<sup>2</sup>

**TABULATION :**

Sl.No	ManometerReading			$\sqrt{H}$	Time for 10cm raise in collecting tank 't' (sec)	Discharge (m <sup>3</sup> /s)		Co-efficient of discharge Cd= Q <sub>a</sub> /Q
	h1(m)	h2(m)	H (m)			Actual Discharge (Q <sub>a</sub> )(m <sup>3</sup> /s)	Theoretical discharge (Q <sub>t</sub> )(m <sup>3</sup> /s)	

D1 and D2	–	Diameter of pipe and throat (m)
H	–	Drop in head across meter (m)

3. Actual discharge ( $Q_{act}$ ):

$$Q_{act} = (l \cdot b \cdot h) / t \quad ^3$$

Where,

- l – Length of collecting tank (m)
- b – Breadth of collecting tank (m)
- h – Rise of water level in tank (m)
- t – Time for ‘h’ m rise in tank (s)

4. Co-efficient of Discharge:

$$C_d = Q_{act} / Q_{th}$$

Where,

- $Q_{act}$  Actual discharge  $^3$
- $Q_{th}$  Theoretical discharge (m<sup>3</sup>/s)

**PROCEDURE:**

1. Check whether all the joints are leak proof and water tight.
2. Close all the pipes with cocks in the pressure feed pipes and manometer to prevent damage and over loading of the manometer.
3. Open the inlet valve of the pipe. Switch on the pump and adjust the control valve to allow the meter to flow through Venturimeter.
4. Open the downstream and upstream cocks that connect the manometer to the Venturimeter for which the co-efficient of discharge is to be calculated.
5. Prime the manometer properly. Adjust the control valve to maintain the flow and for the desired rate of flow.
6. Measure the manometer head to find the venturimeter discharge. Measure the time taken for 10mm rise in the collecting tank to find the actual discharge.
7. Calculate the co-efficient of discharge and repeat the procedure for the different flow rates.

**GRAPH:**

A graph is drawn between actual discharge  $Q_a$  vs  $\sqrt{h}$  taking in X-axis and  $Q_a$  in Y-axis.

**RESULT:**

The co-efficient of discharge for the Venturimeter is found out and the necessary graph is plotted.

- (i) From the table  $C_d =$
- (ii) From the graph  $C_d =$

**VIVA VOCE QUESTIONS**  
**VENTURIMETER**

**1. The rate at which fluid flows through a closed pipe can be determined by?**

Either by determining the mass flow rate or determining the volume flow rate

**2. What are the devices used for flow obstruction?**

Orifice plate, Venturi tube and Flow nozzle and Dall flow tube

**3. Venturimeter is based on integral form of Euler's equation.**

**4. Which device is used to measure the discharge?**

Venturimeter

**5. The Size of a venturimeter is specified by pipe diameter**

**6. What happens when a venturimeter is placed in a pipe?**

When a venturimeter is placed in a pipe carrying the fluid whose flow rate is to be measured, a pressure drop occurs between the entrance and throat of the venturimeter.

**7. What are the characteristics of an ideal flow of any fluid?**

It must satisfy continuity equation

**8. Define Turbulent flow**

Turbulent flow, type of fluid (gas or liquid) flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow, in which the fluid moves in smooth paths or layers.

**9. Define laminar flow**

In fluid dynamics, laminar flow (or streamline flow) occurs when a fluid flows in parallel layers, with no disruption between the layers.

**10. What is the coefficient of discharge of venturimeter?**

$C_d = 0.9 - 0.95$

**11. What is venturimeter used for?**

They can be applied to the measurement of gasses but they are mostly used for liquids.

The following is only limited to incompressible fluids

**12. What is the basic equation of venturimeter meter?**

Venturimeter follows the Bernoulli's equation i.e.  $P_1/\rho + v_1^2/2g = P_2/\rho + v_2^2/2g$

**13. Define discharge coefficient.**

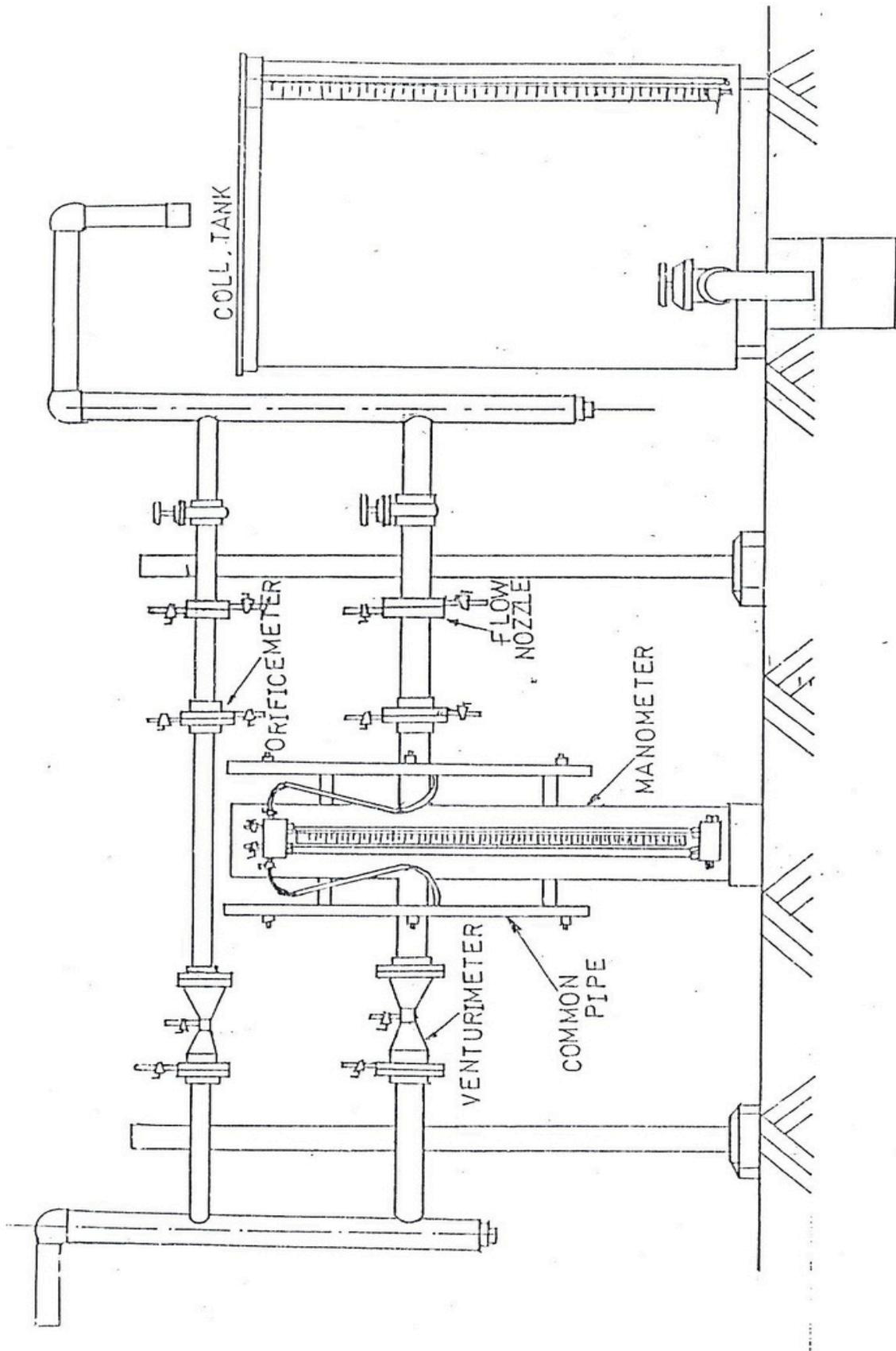
It is the ratio of actual discharge to the theoretical discharge. It is dimensionless.

**14. Why is actual discharge less than theoretical discharge in Venturi meter?**

if it is not viscous then actually is closer to theoretical but, due to discharge depends on velocity and losses also effect in form of frictional losses in pipes and fittings.

**15. Difference between the coefficient of discharge and Venturi coefficient.**

The coefficient of discharge is coefficient of the valve. It depends on how the valve controls the discharge.



*Ex. no: 3*

*Date:*

***DETERMINATION OF CO-EFFICIENT OF DISCHARGE  
FOR THE ORIFICEMETER***

**AIM:**

To determine the Coefficient of discharge ( $C_d$ ) of the given Orificemeter.

**APPARATUS REQUIRED:**

1. Orificemeter with all accessories
2. Stop watch
3. Metre scale

**THEORY:**

Orificemeter is a device, used to measure the discharge of any liquid flowing through a pipeline. The pressure difference between the inlet and the orifice is recorded using a differential Manometer, and the time is recorded for a measured discharge.

$$\text{Theoretical discharge, } Q_t = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

Where,

$a_1$  = Area of Inlet

$a_2$  = Area of Orifice

$g$  = Acceleration due to gravity

$h$  = Orifice head in terms of flowing liquid

$$= [ h_1 - h_2 ]$$

$h_1$  = Manometric head in one limb of the Manometer

**OBSERVATION:**

Diameter of the Inlet,  $d_1 =$  mm  
 Diameter of the orifice,  $d_2 =$  mm  
 Internal plan dimensions of collecting tank, Length,  $L =$  mm  
 Breadth,  $B =$  mm  
 Acceleration due to gravity,  $g = 9810 \text{ mm/sec}^2$

**TABULATION:**

Sl. No.	Manometric Readings		$\sqrt{h}$	Time for $H =$ 100mm rise of water(t) Sec	Actual Discharge $Q_a =$ $AH/t$  $\text{mm}^3/\text{s}$	Theoretical Discharge $Q_t =$ $a_1 a_2 \sqrt{(2gh)} /$ $\sqrt{a_1^2 - a_2^2}$  $\text{mm}^3/\text{s}$	Co efficient of Orificemeter $C_d = Q_a / Q_t$
	$h_1$	$h_2$  $h = h_1 - h_2$  mm of water					
1							
2							
3							
4							
5							
6							

$h_2$  = Manometric head in other limb of the Manometer.

$$\text{Actual Discharge, } Q_a = \frac{\Lambda H}{t}$$

Where ,      $\Lambda$  = Internal plan area of collecting tank  
               $H$  = Rise of liquid  
               $t$  = Time of collection

Coefficient of Orifice meter ( $C_d$ ) is the ratio between the actual discharge ( $Q_a$ ) and the theoretical discharge ( $Q_t$ )

i.e            $C_d = \frac{Q_a}{Q_t}$

**PROCEDURE:**

1. The dimensions of the inlet and orifice are recorded and the internal plan dimensions of the collecting tank are measured.
2. Keeping the outlet valve closed, the inlet valve is opened fully.
3. The outlet valve is opened slightly and the manometric heads in both the limbs ( $h_1$  and  $h_2$ ) are noted.
4. The outlet valve of the collecting tank is closed tightly and the time  $t$  required for  $H$  rise of water in the collecting tank is observed using a stopwatch.
5. The above procedure is repeated by gradually increasing the flow and observing the required readings.
6. The observations are tabulated and the coefficient of Orificemeter ( $C_d$ ) is computed.

### MODEL CALCULATION:

$$\begin{aligned} 1. \text{ Area of inlet, } a_1 &= \pi d_1^2 / 4 \\ &= \quad \quad \quad \text{mm}^2 \end{aligned}$$

$$\begin{aligned} 2. \text{ Area of Orifice, } a_2 &= \pi d_2^2 / 4 \\ &= \quad \quad \quad \text{mm}^2 \end{aligned}$$

$$\begin{aligned} 3. \text{ Internal plan area of collecting tank} \\ &= L \times B \\ &= \quad \quad \quad \text{mm}^2 \end{aligned}$$

$$\begin{aligned} 4. \text{ Actual Discharge } Q_a &= AH/t \\ &= \quad \quad \quad \text{mm}^3/\text{s} \end{aligned}$$

$$\begin{aligned} 5. \text{ Theoretical Discharge } Q_t &= a_1 a_2 \sqrt{(2gh)} / \sqrt{a_1^2 - a_2^2} \\ &= \quad \quad \quad \text{mm}^3/\text{s} \end{aligned}$$

$$\begin{aligned} 6. \text{ Co efficient of discharge} &= Q_a / Q_t \\ &= \end{aligned}$$

**Tabulation:**

S.No	C/S area m <sup>2</sup>	Time for 10 cm raise (sec)	Discharge (Q) m <sup>3</sup> /sec	Velocity (V) m/s	Velocity head $V^2/2g$ (m)	Pressure head $P/\rho g$ (m)	Datum head (m)	Total head (m)

**GRAPH:**

A graph  $Q_a$  vs.  $\sqrt{h}$  is drawn taking  $\sqrt{h}$  on X axis.

**RESULT:**

✓ Coefficient of discharge of the Orificemeter ( $C_d$ )

1. Theoretically =

2. Graphically =

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**VIVA VOCE QUESTIONS**  
**ORIFICE METER**

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**1. Manometer**

A Manometer is a device to measure pressures. A common simple manometer consists of a U shaped tube of glass filled with some liquid.

**2. Simple U-tube manometer is used to measure?**

Negative Gauge Pressures.

**3. For a stationary fluid, the local pressure of the fluid vary with?**

Depth only

**4. What is the device used for the measurement of discharge in pipe?**

Orifice meter

**5. What do you mean by large orifice?**

If the head of liquid is less than 5 times the depth of orifice is called 'large orifice'

**6. What is the coefficient of discharge for an orifice meter?**

0.58 and 0.65

**7. Piezometer is used to measure?**

Very low pressures

**8. What are the instruments used to measure flow on the application of Bernoulli's theorem?**

Venturimeter, Orifice plate, nozzle and pitot tube

**9. What is cheapest device for the measurement of flow?**

ORIFICEMETER

**10. The Ratio of inertia force to surface tension is known as Weber's number**

**11. Describe the structure of Orifice meter?**

The Orifice meter consists of a flat Orifice plate with a circular hole drilled in it. There is a pressure tap upstream from the Orifice plate and just another downstream.

12. *What are the basic differences between venturimeter and Orifice meter?*

- a) The Orifice meter can be easily changed to accommodate different flow rates, whereas throat diameter for a venturi meter is fixed.
- b) The Orifice meter has a large permanent loss of pressure which venturimeter doesn't have due to its shape which reduces the formation of Eddies and greatly reduces the permanent loss.
- c) The Orifice meter is cheap and easy to install whereas Venturi meter is expensive, as it must be carefully proportioned and fabricated.
- d) Venturi meter is only for permanent installations whereas the throat diameter of the orifice can be changed accordingly.

13. *Why is Orifice meter widely preferred over venturi meter?*

Because of there greater flexibility, i.e. Installing a new Orifice plate with a different opening is a simpler matter.

14. *What is Vena contracta?*

Vena contracta is the point in a fluid stream where the diameter of the stream is the least and fluid velocity is at its maximum, such as in the case of the stream issuing out of a nozzle.

|

## BERNOULLI'S PRINCIPLE

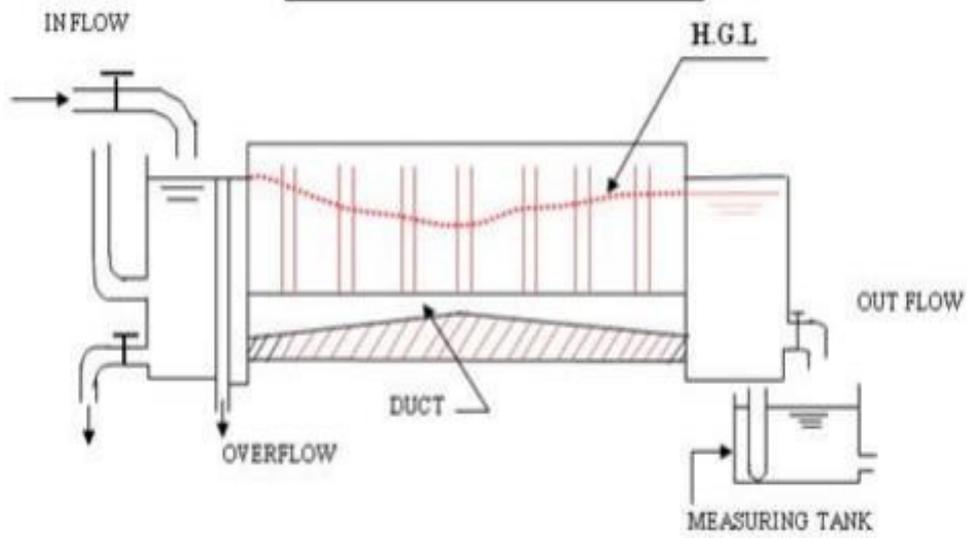


FIG.NO.1 BERNOULLI'S APPARATUS

Fig.1.1:BERNOULLI'S EXPERIMENTAL SETUP  
(3-D)

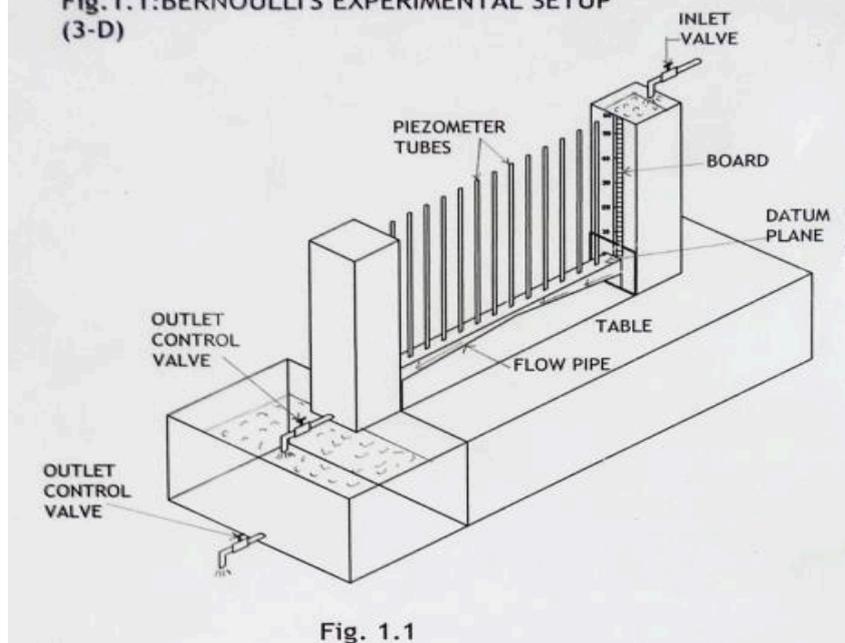


Fig. 1.1

*Fig. Bernoulli's apparatus*

**BERNOULLI'S APPARATUS**

**AIM:**

To verify Bernoulli's theorem using Bernoulli's apparatus.

**APPARATUS REQUIRED:**

1. Bernoulli's apparatus
2. A stop-watch.

**FORMULA REQUIRED:**

$$\frac{P}{\rho g} + \frac{V^2}{2g} + Z = H^{\text{total}}$$

Where,

H<sub>total</sub> – Total head

— - Velocity head

— - Pressure head  $\frac{P}{\rho g}$ , Z – Datum head

**PROCEDURE:**

1. The electric motor is started and water is allowed to flow in the given apparatus.
2. The outlet valve of the apparatus is adjusted and maintains a constant head.
3. There should not be any air bubble in the piezometric tubes and the apparatus.
4. Thus pressure head and the various section of conduit are maintained.
5. Note down the manometric readings.
6. Measure the time taken for 10cm raise in collecting tank.
7. Using Bernoulli's equations calculate the total head.

**OBSERVATION:**

Length of the collecting tank, L = ..... m

Breadth of the collecting tank, B = ..... m

Diameter of the orifice, d = ..... m

S.no	Head, 'H' (m)	Time for 10 cm rise, 't' sec.	Actual discharge, Q <sub>a</sub> (m <sup>3</sup> /s)	Theoretical discharge, Q <sub>t</sub> (m <sup>3</sup> /s)	Co-efficient of discharge Cd = Q <sub>a</sub> / Q <sub>t</sub>
1.					
2.					
3.					
4.					
5.					

**GRAPH :**

Plot the graph taking,

- (i) C/s area Vs Pressure head
- (ii) C/s area Vs Velocity head
- (iii) C/s area Vs Total head

**Result:**

Thus the Bernoulli's equation is verified by using Bernoulli's apparatus and it is also verified by graphically. The total head is \_\_\_\_\_

**VIVA VOCE QUESTIONS**  
**BERNOLLI'S APPARATUS**

**1. Why is a bernoulli's experiment carried out?**

To demonstrate the variation of pressure along the converging-diverging pipe section.

**2. What does a bernoulli's theorem represent?**

It is an approximate relation between pressure, velocity and elevation.

**3. In which kind of region is Bernoulli's theorem valid.**

It is valid in regions of steady, incompressible flow where the net frictional forces are negligible.

**4. How is a bernoulli's equation obtained?**

It is obtained when the Euler's equation is integrated along the streamline for a constant density fluid.

**5. State bernoulli's equation.**

It states that the "sum of kinetic energy, pressure energy, potential energy per unit weight of fluid at any point remains constant".

**6. How can a bernoulli's theorem be written.**

Velocity head + static head + potential head = a constant.

**7. The pressure head is given by?**

$P/w$

**8. How is the velocity head represented?**

$V^2/2g$

**9. What symbol represents the pressure head?**

Z

10. ***What is Bernoulli's equation?***

Bernoulli's equation can be given as  $P/\rho + v^2/2g + z = \text{constant}$  or we can say that sum of pressure head, velocity head and datum head is constant.

12. ***What are the assumptions of Bernoulli's equation?***

Steady flow, Incompressible flow, Irrotational, Frictionless flow, No shaft work, No transfer of heat and valid for flow along a single streamline.

13. ***What is an ideal fluid?***

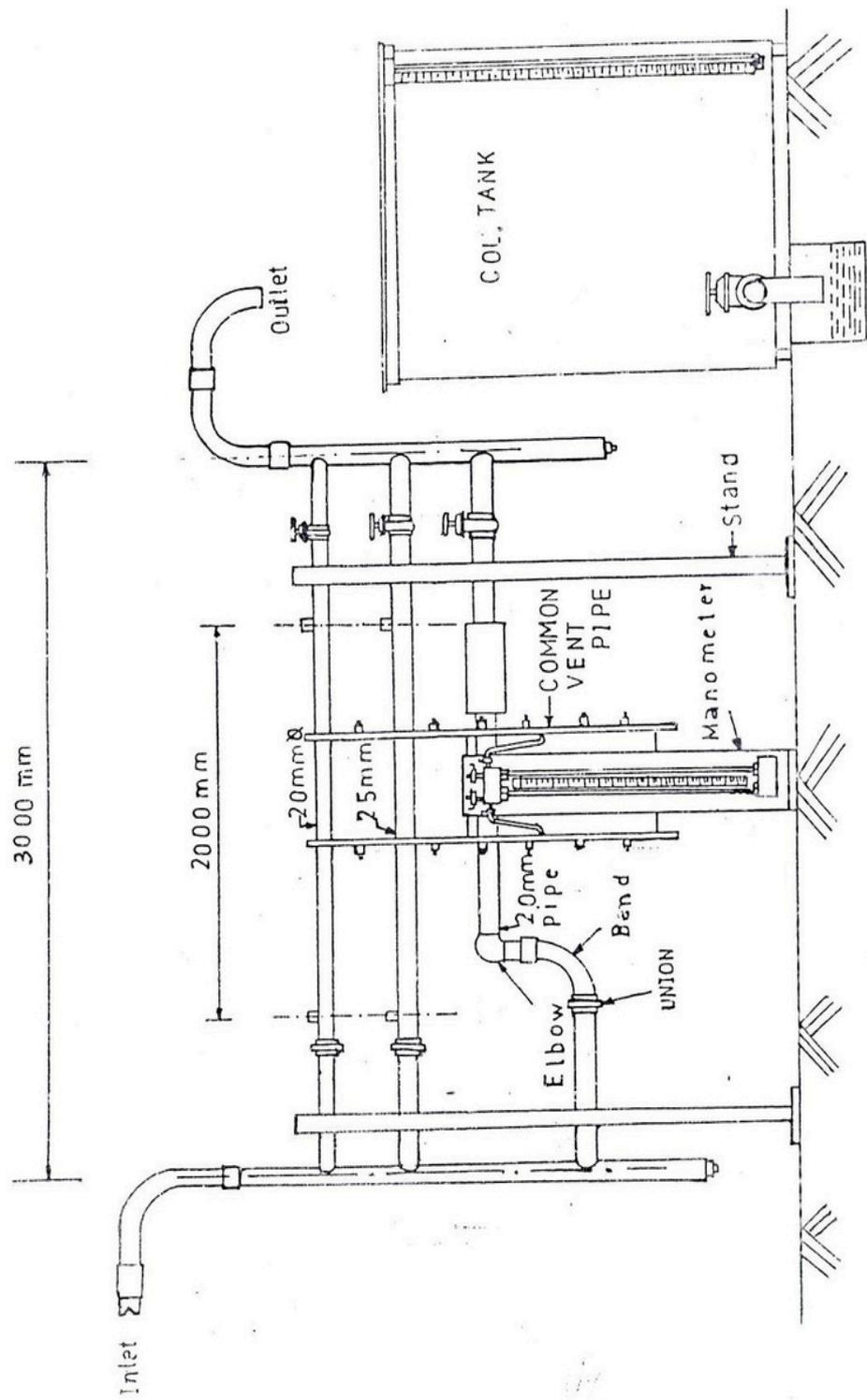
Ideal fluid is a hypothetical fluid which is assumed to be non-viscous, non-rotational, and incompressible.

14. What are the examples of Bernoulli's law?

- How an airplane takes off?
- Why a fast-moving train pulls nearby objects?
- Why a spinning ball curves.
- Why roofs are blown away in heavy winds?
- How atomizer works?
- How chimney works?

15. ***Why does pressure decrease in Bernoulli?***

From Bernoulli's principle it was found that as area decreases velocity increases and pressure at that point decreases.



LOSSES IN PIPE LINES (MINOR & MAJOR)

**STUDY OF FRICTION LOSSES IN PIPES****AIM:**

To determine the coefficient of friction (f) of the given pipe material.

**APPARATUS REQUIRED:**

1. A pipe provided with inlet and outlet valves
2. U tube Manometer
3. Collecting tank
4. Stop watch
5. Metre scale

**THEORY:**

When liquid flows through a pipe line, it is subjected to frictional resistance. The frictional resistance depends upon the roughness of the inner surface of the pipe. The loss of head between a selected length of pipe is observed for a measured discharge. The coefficient of friction (f) is calculated by using the expression

$$h_f = \frac{4fLv^2}{2gd}$$

Where,

$$h_f = \text{loss of head due to friction} = h_1 - h_2 \quad \text{mm}$$

$$h_1 = \text{Manometric head in one limb of the manometer} \quad \text{mm}$$

$$h_2 = \text{Manometric head in other limb of the manometer} \quad \text{mm}$$

**OBSERVATIONS:**

Diameter of the pipe  $d =$  mm  
 Length of the pipe  $L =$  mm  
 Internal plan dimensions of collecting tank, Length,  $L =$  mm  
 Breadth,  $B =$  mm

Acceleration due to gravity,  $g = 9810 \text{ mm/sec}^2$

**TABLULATION:**

Sl. No.	Manometric Readings		Time for H = 100mm rise of water(t) Sec	Actual Discharge $Q_a = AH/t$ mm <sup>3</sup> /s	Velocity = $Q_a/a$ mm/s	$V^2$ (mm/s) <sup>2</sup>	Co-efficient of friction $f = 2gdh_f/4LV^2$
	$h_1$	$h_2$					
mm of water							
1							
2							
3							
4							
5							
6							

Mean Value of  $f =$

L = Length of pipe between pressure tapping cocks.	mm
V = Velocity of flow in the pipe = $Q_a/a$	mm/s
$Q_a$ = Actual Discharge = $AH/t$	mm <sup>3</sup> /s
A = Internal Plan area of the collecting tank	mm <sup>2</sup>
H = Height of collection in the collecting tank	mm
T = time of collection	sec
a = cross sectional area of the pipe = $\pi d^2/4$	mm <sup>2</sup>
d = diameter of pipe	mm
g = acceleration due to gravity = 9810	mm/s <sup>2</sup>

**PROCEDURE:**

1. The diameter of the pipe, the internal plan dimensions of the collecting tank and the length of the pipe line between the pressure tapping cocks are measured,
2. Keeping the outlet valve fully closed, the inlet valve is opened completely.
3. The outlet valve of the collecting tank is closed tightly and the time t required for H rise of water in the collecting tank is observed using a stop watch.
4. The above procedure is repeated by gradually increasing the flow and observing the required readings.
5. The observations are tabulated and the coefficient of friction is computed.

**MODEL CALCULATION:**

1. Area of pipe,  $a = \pi d^2 / 4$   
 $=$  mm<sup>2</sup>

2. Internal plan area of collecting tank  
 $= L \times B$   
 $=$  mm<sup>2</sup>

3. Actual Discharge

$$Q_a = AH/t$$
$$=$$
 mm<sup>3</sup>/s

4. Velocity

$$V = Q_a / a$$
$$=$$
 mm/s

5. Coefficient of friction

$$f = 2gdh_f / 4Lv^2$$
$$=$$

**GRAPH:**

A graph  $h_f$  vs.  $v^2$  is drawn taking  $v^2$  on X axis.

**RESULT:**

The Coefficient of friction of the given pipe ( $f$ )

1. Theoretically =

2. Graphically =

**VIVA VOCE QUESTIONS**  
**FRICITION LOSSES IN PIPES**

**1. What is meant by energy loss in a pipe?**

When the fluid flows through a pipe, it loses some energy or head due to frictional resistance and other reasons. It is called energy loss. The losses are classified as; Major losses and Minor losses

**2. Explain the major losses in a pipe.**

The major energy losses in a pipe is mainly due to the frictional resistance caused by the shear force between the fluid particles and boundary walls of the pipe and also due to viscosity of the fluid.

**3. What are the factors influencing the frictional loss in pipe flow?**

Frictional resistance for the turbulent flow is,

- i. Proportional to  $v^n$  where  $n$  varies from 1.5 to 2.0.
- ii. Proportional to the density of fluid.
- iii. Proportional to the area of surface in contact.
- iv. Independent of pressure.
- v. Depend on the nature of the surface in contact.

**4. What is compound pipe or pipes in series?**

When the pipes of different length and different diameters are connected end to end, then the pipes are called as compound pipes or pipes in series.

**5. What is mean by parallel pipe and write the governing equations.**

When the pipe divides into two or more branches and again join together downstream to form a single pipe then it is called as pipes in parallel. Equations are:  $Q = Q_1 + Q_2$

**6. Define the terms a) Hydraulic gradient line [HGL] b) Total Energy line [TEL]**

**Hydraulic gradient line:**

It is defined as the line which gives the sum of pressure head and datum head of a flowing fluid in a pipe with respect the reference line.  $HGL = \text{Sum of Pressure Head and Datum head}$   
Total energy line: Total energy line is defined as the line which gives the sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line.  $TEL = \text{Sum of Pressure Head, Datum head and Velocity head}$

**7. What is meant by Moody's chart and what are the uses of Moody's chart?**

The basic chart plotted against Darcy-Weisbach friction factor against Reynold's Number (Re) for the variety of relative roughness and flow regimes. The relative roughness is the ratio of the mean height of roughness of the pipe and its diameter ( $\epsilon/D$ ). Moody's diagram is accurate to about 15% for design calculations and used for a large number of applications. It can be used for non-circular conduits and also for open channels.

**OBSERVATIONS:**

Length of collection tank, L =            m,    Breadth of collection tank, B = m

Dia of inlet pipe , d1            =            m,    Dia of outlet pipe , d2            =            m

Area of inlet pipe , a1            =            m<sup>2</sup>    Area of outlet pipe , a2            =            m<sup>2</sup>

**CALCULATION - COEFFICIENT OF EXPANSION**

Ex. no: 6

Sl. No.	Difference in mercury level $X = h_1 - h_2$ (cm)	$h_f = X \times 12.6$ (cm)	Time for 10 cm rise 't' sec.	$Q = Ay/t$ $cm^3/s$	$V_1 = Q/a_1$ $cm/s$	$V_2 = Q/a_2$ $cm/s$	$h_e = (V_1 - V_2)^2 / 2g$
1.							
2.							
3.							
4.							
5.							
6.	Date: 7.						

**STUDY OF MINOR LOSSES IN PIPES**

**AIM:**

To determine the co-efficient of minor loss of the given pipe.

**APPARATUS REQUIRED:**

1. Piping system
2. Measuring tank fitted with Piezometer
3. Differential U-tube manometer
4. Stop-watch

**FORMULA:**

Where there is any type of bend in pipe the velocity of flow changer, due to which the separation of the flow from the boundary and also formation of eddies takes place. Thus the energy is lost. The losses of head due to fittings in pipe

- i. Minor loss in bend  $h_b = V_1 / 2g$
- ii. Minor loss in contraction  $h_c = V_2 / 2g$
- iii. Minor loss in enlargement  $h_e = (V_1 - V_2)^2 / 2g$
- iv. Minor loss in elbow  $h_d = V^2 / 2g$

- Where,  $h_b$  = head loss due to bend
- $h_c$  = head loss due do contraction
- $h_e$  = head loss due to enlargement
- $h_d$  = head loss due to elbow
- $V$  = velocity of fluid
- $V_1$  = velocity of fluid in pipe of small diameter
- $V_2$  = velocity of fluid in pipe of large diameter

1. Area of the collecting tank,  $L \times B =$

L - Length of the collecting tank (cm) B

- Breadth of the collecting tank (cm)

2. Discharge,  $Q = \frac{A * y}{t}$

A = Area of the collecting tank (cm<sup>2</sup>)

y = Rise of water in the collecting tank (cm)

t = Time taken for 10 cm rise in the collecting tank (sec)

$a_1 = \frac{\pi d_1^2}{4}$  ( $d_1$  – diameter of the pipe in cm)

$a_2 = \frac{\pi d_2^2}{4}$  ( $d_2$  – diameter of the expanded pipe in cm)

$$3. \text{ Velocity, } V_1 = Q / a_1$$

$$V_2 = Q / a_2$$

$$4. \quad h_e = \frac{V_1^2 - V_2^2}{2g}$$

$h_e$  - head lost due to sudden enlargement  
 $g$  - Acceleration due to gravity (981 cm / s<sup>2</sup>)

**PROCEDURE:**

1. Close all the valves provided
2. Fill the sump tank 75% with clean water and ensure that there are no foreign particles
3. Fill the manometer with measurement of mercury up to half of its level by opening the pipe from the fitting connected to the bottom most point of the manometer and connect the pipe back to its position
4. Open bypass valve
5. Ensure that ON/OFF switch given on the panel is at OFF position
6. Switch on the main power supply and switch on the pump
7. Open flow channel control valve of pipe for bend, sudden enlargement, sudden contraction and elbow fitting on ball valve and gate valve fitting
8. Open the pressure taps of manometer of related test section, very slowly to avoid the blow of water on manometer fluids
9. Now open the air release valve provided on the manometer, slowly to release the air in manometer
10. When there is no air in the manometer close the air release valves
11. Adjust water flow rate in desired section with the help of control valve for bypass valve
12. Record the manometer reading
13. Measure the flow of water, discharged through desired test section with using stop watch and measuring tank
14. Repeat the experiment for other fittings of selected pipe
15. When experiment is over for selected pipe open the control valve of other pipe
16. Repeat the experiment same procedure for different flow rate of water operating control valve and bypass valve

**GRAPH :**

A graph,  $h \propto V^2$  is drawn taking  $V^2$  on X-axis

**RESULT**

1. The co-efficient of expansion of the given pipe  $C_e =$

i. Theoretically =

ii. Graphically =

2. The co-efficient of contraction of the given pipe  $C_c =$

i. Theoretically =

ii. Graphically =

3. The co-efficient of bend of the given pipe  $C_b =$

i. Theoretically =

ii. Graphically =

## **VIVA VOCE QUESTIONS**

### **MINOR LOSSES**

**1. Where do major losses occur?**

Major losses occur due to friction within a pipe.

**2. Where do minor losses occur?**

Minor losses occur at a change of section, valve, bend or other interruption.

**3. What is the formula to calculate major losses**

$$h_f = (f \cdot L \cdot V^2) / (D \cdot 2g)$$

**4. What contributes to significant pressure loss.**

A very sudden change to the flow path contributes to significant pressure loss.

**5. Pressure loss is proportional to .....**

L/D ratio and Velocity head.

**6. What is the role of minor losses in pipe flow.**

Minor losses are a major part in calculating the flow, pressure or energy reduction in piping systems.

**7. What is the factor used to calculate configurational head loss.**

Kinetic energy factor.

**8. What is Kinetic energy factor of return bend.**

1.5

**9. What is the formula to calculate minor losses**

$$h_f = (k \cdot V^2 / 2g)$$

**10. What do you understand by the term minor loss in pipes?**

When a fluid is flowing through a pipe, some of the energy is lost due to sudden expansion of pipe, sudden contraction, bend and pipe fitting, these are termed as minor loss.

11. **Define Reynolds number.**

Reynolds number is the dimensionless number that is inertial force per viscous force.

$$Re = \rho V D / \mu$$

It helps determine whether the flow is laminar or turbulent.

12. **Define the laminar and turbulent flow.**

**Laminar flow :**

- a. Fluid layer moves parallel to each other and does not cross each other
- b. Fluid is flowing at low velocity.
- c. The fluid flow is Laminar when the value of Reynolds number, Re is less than 2000.

**Turbulent Flow:**

- a. It occurs when fluid flows in high-velocity
- b. The fluid flow is Laminar when the value of Reynolds number, Re is greater than 4000

13. **What is transition state?**

It is the stage between Laminar and turbulent flow. i.e.  $2100 < Re < 4000$

14. **What are the minor energy losses?**

This is due to

- i. Sudden expansion in pipe .
- ii. Sudden contraction in pipe .
- iii. Bend in pipe .
- iv. Due to obstruction in pipe

15. **Give an expression for loss of head due to sudden enlargement of the pipe**

$h_e = (V_1 - V_2)^2 / 2g$ ,  $h_e$  = Loss of head due to sudden enlargement of pipe

16. **Give an expression for loss of head due to sudden contraction**

$h_c = 0.5 V^2 / 2g$ ,  $h_c$  = Loss of head due to sudden contraction

17. **Give an expression for loss of head at the entrance of the pipe**

$h_{i1} = 0.5 V^2 / 2g$ ,  $h_{i1}$  = Loss of head at entrance of pipe

*Ex. no: 7*

*Date:*

***PERFORMANCE CHARACTERISTICS OF A CENTRIFUGAL PUMP***

**AIM:**

To determine the best driving conditions of the given centrifugal pump at constant speed and to draw the characteristic curves.

**APPARATUS REQUIRED:**

1. Centrifugal pump (constant speed)
2. Metre scale
3. Stop watch

**THEORY:**

A centrifugal pump consists of an impellor rotating inside a casing. The impellor has a number of curved vanes. Due to the centrifugal force developed by the rotation of the impellor, water entering at the center flows outwards to the periphery. Here it is collected in a gradually increasing passage in the casing known as volute chamber. This chamber converts a part of the velocity head (kinetic energy) of water into pressure head (potential energy).for higher heads, multi stage centrifugal pumps having two or more impellors in series will have to be used.

Note: since the centrifugal pump is not self priming, the pump must be filled with water (priming) before starting. For this reason water should not be allowed to drain and a foot valve is provided.

**OBSERVATIONS:**

Size of the tank  
 $L =$  m  
 $B =$  m  
 $A =$  m<sup>2</sup>  
 $X =$  m  
 Area of the tank  
 Correction head  
 Energy meter constant  
 $N_e =$  rev/kwh  
 Specific weight of water  
 $w =$  9810 N/m<sup>3</sup>

**TABULATION:**

SI.No	Pressure gauge reading G	Pressure head Gx10	Vacuum gauge reading "V"	Vacuum head Vx0.0136	Total Head H = (Gx10) + (Vx0.0136)+X	Time for h=0.1m rise of water in the tank 't'	Actual discharge Q= Ah/t	Time for Nr=10 revolutions in the energy meter 'T'	Input power Pi = 3600xNr/Next	Output power Po= wQH	Efficiency = Output power/input powerx100
Unit	kg/cm <sup>2</sup>	'm' of water	'mm' of Hg	'm' of water	'm' of water	seconds	m <sup>3</sup> /sec	seconds	kW.	kW	%
1.											
2.											
3.											
4.											
5.											
6.											

1. Actual discharge  $Q_a = AH/t_1$  cumec

Where:

$A$ =area of the collecting tank  $m^2$

$H$ =rise of water in the collecting tank  $m$

$t_1$ =time taken for "  $h$ "  $m$  rise of water in the collecting tank

2. Total head  $h = G \times 10 + v \times 0.0136 + X$   $m$  of water

Where:

$G$ =pressure gauge reading

$v$ =vacuum gauge reading

$X$ =correction head = the difference in level between the centers of pressure gauge and vacuum gauge.

3. Input power  $p_i = 3600 \times nr / (n_e \times t_2)$   $kW$

Where:

$N_r$ =No of revolutions counted in energy meter disc.

$N_e$ = Energy metre constant.

$t_2$ = Time taken for  $n_r$  revolutions in the energy meter

4. Output power  $p_o = wQ_a h$   $kW$

Where:

$W$ =sp .wt of water  $9.81 \text{ kN/m}^3$

5. Efficiency  $\eta = \text{output power} / \text{input power} \times 100 \%$

#### PROCEDURE:

1 The internal plan dimensions of the collecting tank are measured.

2. Correction head. (The difference in level between the centers of pressure gauge and vacuum gauge) is measured.

3. The energy meter constant is noted down.

4. The motor is started and the following readings are noted down.
- Pressure gauge & vacuum gauge readings.
  - Time ( $t_1$ ) for "H" m rise of water in the collecting tank
  - Time ( $t_2$ ) for "nr" revolutions in the energy meter disc.
5. The above procedure is repeated varying the pressure gauge reading.

**MODEL CALCULATION:**

1. Total head (h) =  $G \times 10 + v \times 0.0136 + X$  m of water

=

2. Actual discharge =  $Q_a = AH/t_1$  cumec

=

3. Input power ( $P_i$ ) =  $3600 \times nr / (ne \times t_2)$  kW

=

4. Output power ( $P_o$ ) =  $wQ_a h$  kW

=

5. Efficiency ( $\eta$ ) =  $\text{output power} / \text{input power} \times 100 \%$

=

#### GRAPHS:

The following graphs are drawn taking discharge " $Q_d$ " on x-axis.

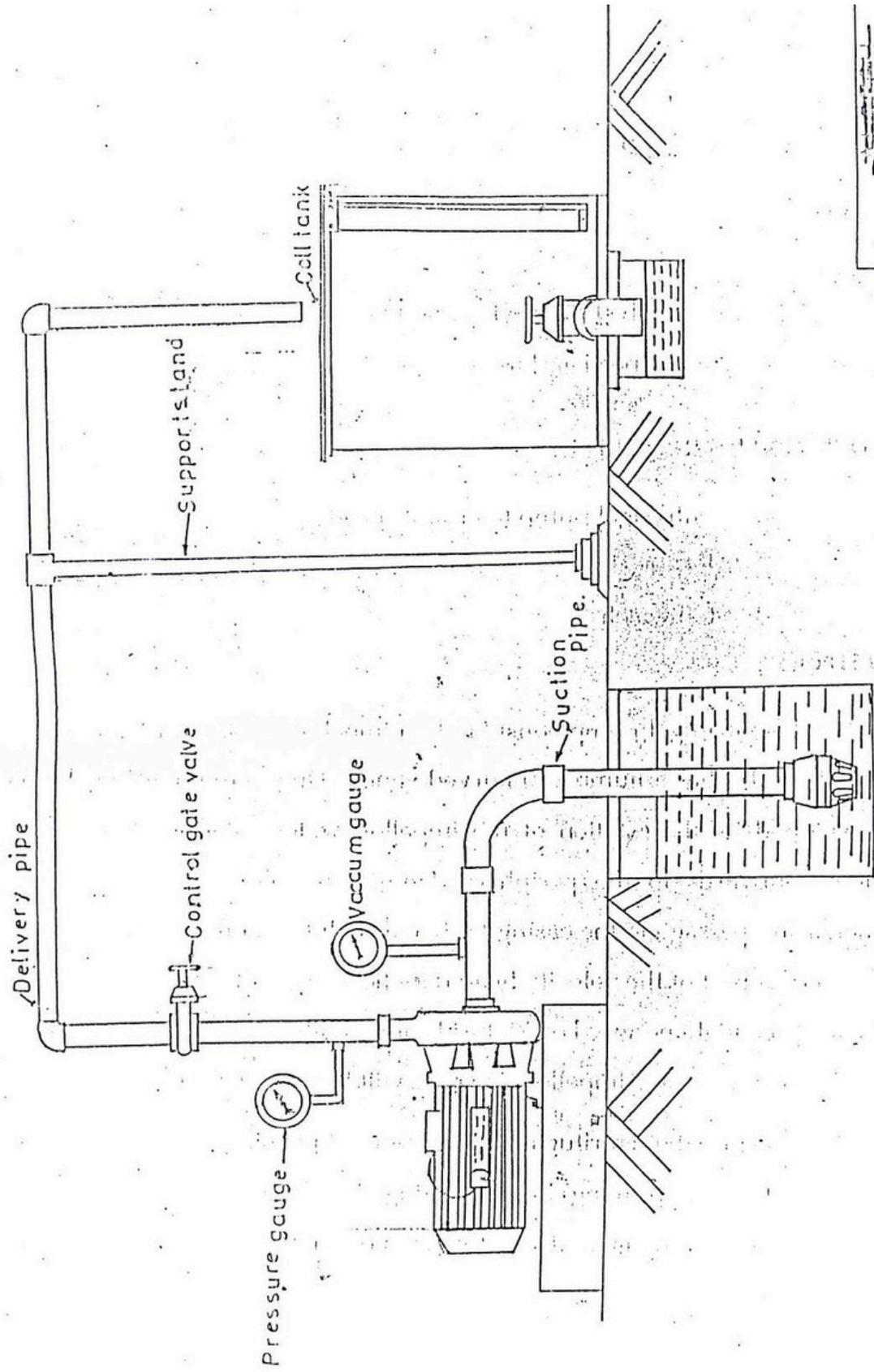
1. Discharge vs. Total head
2. Discharge vs. Input power
3. Discharge vs. Efficiency

At the point of the maximum efficiency of the graph the corresponding values of discharge, head & input power are arrived from the graph.

#### RESULT:

The characteristic curves are drawn from the point of maximum efficiency. The best driving conditions are found out and the best driving conditions of the pump are obtained when,

1. The maximum efficiency =
2. Total head =
3. Discharge =
4. Input power =



CENTRIFUGAL PUMP TEST RIG

## ***VIVA VOCE QUESTIONS***

### **CENTRIFUGAL PUMP**

#### ***1. Why the Centrifugal Pump is called High Discharge pump?***

Centrifugal pump is a kinetic device. The centrifugal pump uses the centrifugal force to push out the fluid. So the liquid entering the pump receives kinetic energy from the rotating impeller. The centrifugal action of the impeller accelerates the liquid to a high velocity, transferring mechanical (rotational) energy to the liquid. So it discharges the liquid in high rate. It is given in the following formula:

Centrifugal force  $F = (M \cdot V^2) / R$ .

Where,

M-Mass

V-Velocity

R-Radius

#### ***2. How Cavitation can be eliminated by Pump?***

Cavitation means bubbles are forming in the liquid.

To avoid Cavitation, we have to increase the Pump size to One or Two Inch;

To increase the pressure of the Suction Head, or

Decrease the Pump Speed.

#### ***3. Why Cavitation will occur in Centrifugal Pump and not in Displacement Pump?***

The formation of cavities (or bubbles) is induced by flow separation, or non-uniform flow velocities, inside a pump casing. In centrifugal pumps the eye of the pump impeller is smaller than the flow area of pipe. This decrease in flow area of pump results in increase in flow rate. So pressure drop happened between pump suction and the vanes of the impeller. Here air bubbles or cavities are formed because of liquid vapour due to increase in temperature in impeller. This air bubbles are transmitted to pump which forms cavitation.

#### ***4. Which Pump is more Efficient Centrifugal Pump or Reciprocating Pump?***

Centrifugal pump. Because flow rate is higher compared to reciprocating pump. Flow is smooth and it requires less space to install. Lower initial cost and lower maintenance cost.

#### ***5. Why Centrifugal Pump is not called as a Positive Displacement Type of Pump?***

The centrifugal has varying flow depending on pressure or head, whereas the Positive Displacement pump has more or less constant flow regardless of pressure. Likewise viscosity is constant for positive displacement pump where centrifugal pump have up and down value because the higher viscosity liquids fill the clearances of the pump causing a higher volumetric efficiency. When there is a viscosity change in supply there is also greater loss in the system. This means change in pump flow affected by the pressure change. One more example is, positive displacement pump has more or less constant efficiency, where centrifugal pump has varying efficiency rate.

#### ***6. How Cavitation can be eliminated in a Pump?***

Cavitation means bubbles are forming in the liquid.

· To avoid Cavitation, we have to increase the Pump size to One or Two Inch;

· To increase the pressure of the Suction Head, or

· Decrease the Pump Speed.

**7. Which pump is more efficient Centrifugal pump or Reciprocating pump?** Centrifugal pump. Because flow rate is higher compared to reciprocating pump. Flow is smooth and it requires less space to install. Lower initial cost and lower maintenance cost.

**8. Why Centrifugal Pump is not called as a Positive Displacement Type of Pump?**

The centrifugal has varying flow depending on pressure or head, whereas the Positive Displacement pump has more or less constant flow regardless of pressure.

Likewise viscosity is constant for positive displacement pump where centrifugal pump have up and down value because the higher viscosity liquids fill the clearances of the pump causing a higher volumetric efficiency. When there is a viscosity change in supply there is also greater loss in the system. This means change in pump flow affected by the pressure change.

One more example is, positive displacement pump has more or less constant efficiency, where centrifugal pump has varying efficiency rate.

**9. What is a radial-flow turbine?**

In a radial-flow turbine, steam flows outward from the shaft to the casing. The unit is usually a reaction unit, having both fixed and moving blades.

**10. What are four types of turbine seals?**

Carbon rings fitted in segments around the shaft and held together by garter or retainer springs.

Labyrinth mated with shaft serration's or shaft seal strips.

Water seals where a shaft runner acts as a pump to create a ring of water around the shaft. Use only treated water to avoid shaft pitting. Stuffing box using woven or soft packing rings that are compressed with a gland to prevent leakage along the shaft.

**11. Write down the use of centrifugal pump?**

Used in deep sump and basement

The high discharge capacity

It is driven by electric motors

**12. What is centrifugal pump?**

The hydraulic machines which convert mechanical energy in to pressure energy by means of centrifugal force is called centrifugal pump. It acts a reverse of inward radial flow turbine.

**13. What are the main parts of centrifugal pump?**

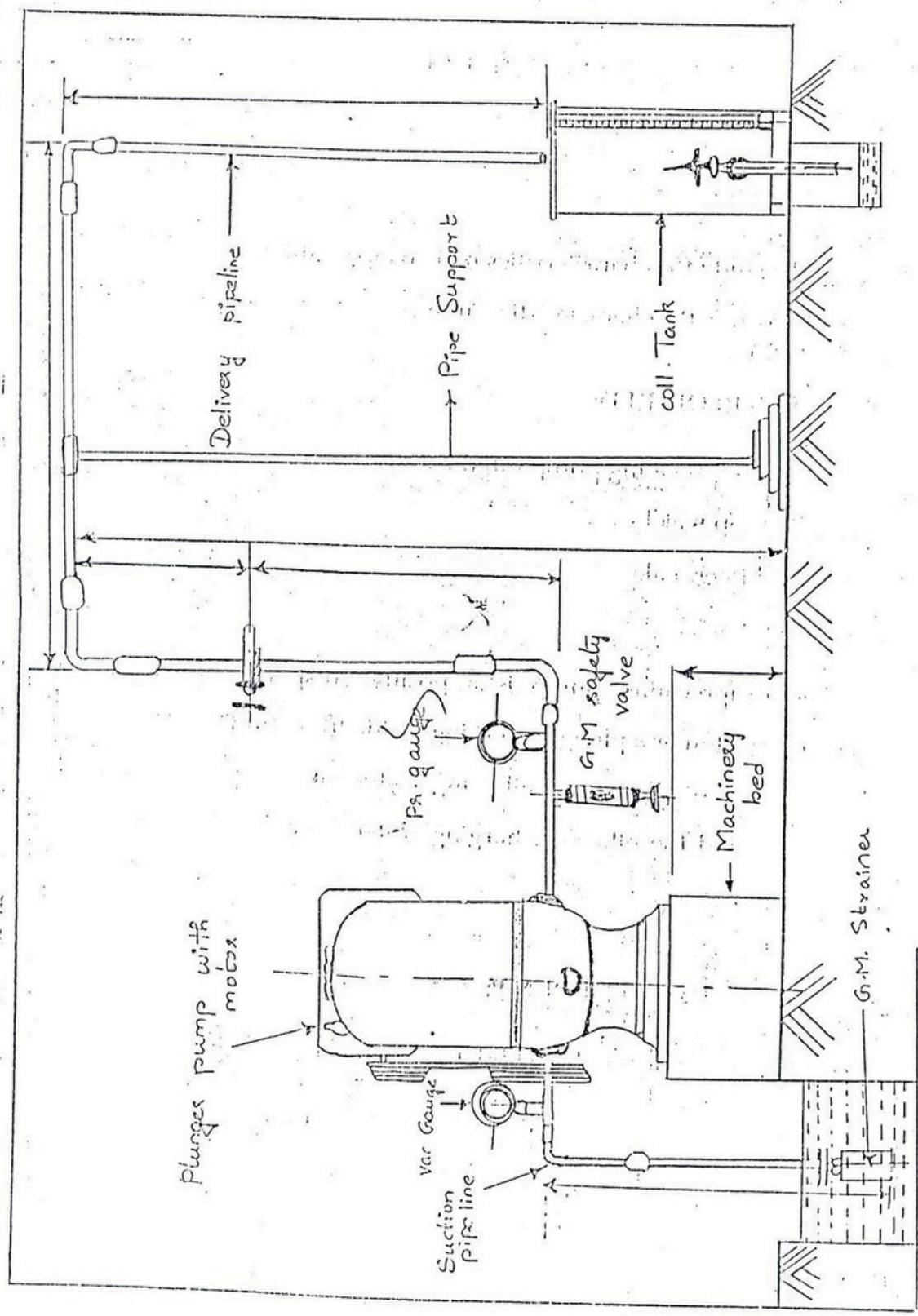
1. Suction pipe with foot valve and strainer

2. Impeller

3. casing

4. delivery pipe

EXPERIMENTAL SETUP OF RECIPROCATING PUMP



***PERFORMANCE CHARACTERISTICS OF A RECIPROCAL PUMP***

**AIM:**

To study the characteristics of a reciprocating pump at constant speed and to draw the characteristic curves.

**APPARATUS REQUIRED:**

1. Reciprocating pump fitted with all accessories
2. Stop watch
3. Meter scale

**DESCRIPTION:**

The reciprocating pump is a positive displacement pump and consists of a piston or a plunger working inside the cylinder. The cylinder has two valves. One allowing water into the cylinder from the suction pipe and the other discharging water from the cylinder into the delivery pipe.

**SPECIFICATION OF THE PUMP:**

Type - Double Acting Single Cylinder

- |                      |          |
|----------------------|----------|
| 1. Piston stroke l   | = 44.5mm |
| 2. Piston diameter   | = 38mm   |
| 3. Suction pipe dia  | = 25m    |
| 4. Delivery pipe dia | =18 mm   |

**OBSERVATION:**

- Size of the tank  
L = m  
B = m  
A = m<sup>2</sup>  
X = m
- Area of the tank
- Correction head
- Energy meter constant  
Ne = rev/kwh
- Length of stroke  
L = m
- Speed of the pump  
N = rpm
- Diameter of the cylinder  
d = m
- Specific weight of water  
w = 9810 N/m<sup>3</sup>

**TABLULATION:**

Sl. No.	Pressure gauge reading "G"	Pressure head = Gx10	Vacuum gauge reading "V"	Vacuum head Vx 0.0136	Total head H = Gx10 + Vx0.0136 + X	Time for h=0.1m rise of water in the tank 't'	Actual discharge Q=Ah/t	Theoretical discharge Qt = 2A1N/60	% of slip = Qt - Qa / Qt x 100	Time for Nr=10 revolution in the energy meter 't'	Input power Pi=3600x Nr/ Ne x t <sup>2</sup>	Output power Po = wQH	Output power / Input power X 100
Unit	kg/cm <sup>2</sup>	'm' of water	'mm' of Hg	'm' of water	'm' of water	Sec.	m <sup>3</sup> /s	m <sup>3</sup> /sec	%	sec	kW	kW	%
1													
2													
3													
4													
5													

1. Actual Discharge  $Q_a = \Delta h/t$  cumec

Where:

$\Delta$  = Area of the Collecting Tank  
 $h$  = rise of water in the tank  
 $t$  = time taken for "h" m rise of water in the tank

2. Total Head  $h = G \times 10 + V \times 0.0136 + X$  m of water

Where:

$G$  = pressure gauge reading  
 $V$  = vacuum gauge reading  
 $X$  = correction head - the difference in level between  
The center of pressure gauge & vacuum gauge

3. Input power  $P_i = 3600 \times N_r / N_e \times T$  KW

Where:

$N_r$  = No of revolutions counted in the energy meter  
disk  
 $N_e$  = energy meter constant  
 $T$  = time taken for  $N_r$  revolutions in the energy  
meter disk

4. Out power  $P_o = W \times Q_a \times h$  KW

Where:

$W$  = sp .wt of water  
 $Q_a$  = Actual discharge  
 $h$  = Total head

5. Theoretical discharge  $Q_t = 2 \Delta_1 L N / 60$  cumec

Where:

$\Delta_1$  = area of the cylinder  
 $L$  = length of the stroke  
 $N$  = speed of the pump

6. % of slip =  $(Q_t - Q_a) / Q_t \times 100$

7. Efficiency  $\eta = \text{output power} / \text{input power} \times 100$  IN%

#### PROCEDURE:

1. The internal plan dimensions of the collecting tank are measured.
2. Correction head. (The difference in level between the centers of pressure gauge and vacuum gauge) is measured.
3. The energy meter constant is noted down.
4. The motor is started and the following readings are noted down.
  - d) Pressure gauge & vacuum gauge readings.
  - e) Time ( $t_1$ ) for "h" m rise of water in the collecting tank
  - f) Time ( $t_2$ ) for "Nr" revolutions in the energy meter disc.
5. The above procedure is repeated varying the pressure gauge reading.

#### MODEL CALCULATION:

1. Actual Discharge  $Q_a = Ah/t$  cumec

=

2. Total Head  $H = GX10 + VX0.0136 + X$  m of water

=

3. Input power  $P_i = 3600 * N_r / N_e * T$  KW

=

4. Out power  $P_o = W * Q_a * H$  KW

=

5. Theoretical discharge  $Q_t = 2\pi L N / 60$  cumec

=

6. % of slip =  $(Q_t - Q_a) / Q_t \times 100$

=

7. Efficiency  $\eta$  = output power / input power  $\times 100$  IN%

=

#### GRAPHS:

The following graphs are drawn taking discharge " $Q_a$ " on x-axis.

- d) Discharge vs. Total head
- e) Discharge vs. Input power
- f) Discharge vs. Efficiency

At the point of the maximum efficiency of the graph the corresponding values of discharge, head & input power are arrived from the graph.

#### RESULT:

The characteristic curves are drawn from the point of maximum efficiency. The best driving conditions are found out and the best driving conditions of the pump are obtained when,

- 1. The maximum efficiency =
- 2. Total head =
- 3. Discharge =
- 4. Input power =

**VIVA VOCE QUESTIONS**  
**RECIPROCATING PUMP**

**1. Define pump :**

It is defined as the hydraulic machine which convert mechanical energy in to hydraulic energy

**2. What is the function of a thrust bearing?—**

Thrust bearings keep the rotor in its correct axial position.

**3. What is a stage in a steam turbine?**

In an impulse turbine, the stage is a set of moving blades behind the nozzle. In a reaction turbine, each row of blades is called a "stage." A single Curtis stage may consist of two or more rows of moving blades.

**4. What is a diaphragm?—**

Partitions between pressure stages in a turbine's casing are called diaphragms. They hold the vane-shaped nozzles and seals between the stages. Usually labyrinth-type seals are used. One-half of the diaphragm is fitted into the top of the casing, the other half into the bottom.

**5. What is Discharge through a Reciprocating Pump in Per sec ?**

For Single acting

Discharge (Q)= $ALN/60$  Where

A=Area of the Cylinder in  $m^2$

L=Length of Stroke in m. N=Speed of Crank in RPM

For Double acting  $Q=2ALN/60$

**6. What are topping and superposed turbines?**

Topping and superposed turbines are high-pressure, non-condensing units that can be added to an older, moderate-pressure plant. Topping turbines receive high-pressure steam from new high-pressure boilers. The exhaust steam of the new turbine has the same pressure as the old boilers and is used to supply the old turbines.

**7. What is a combination thrust and radial bearing?**

This unit has the ends of the Babbitt bearing extended radially over the end of the shell. Collars on the rotor face these thrust pads, and the journal is supported in the bearing between the thrust collars.

**8. How Cavitation can be eliminated in a Pump?**

- Increase the Pump size to One or Two Inch,
- Increase the pressure of the Suction Head,
- Decrease the Pump Speed.

**9. One litre = \_\_\_\_\_  $cm^3$  .**

1000  $cm^3$  .

**10. Which Pump is more Efficient Centrifugal Pump or Reciprocating Pump?**

Centrifugal pump. Because flow rate is higher compared to reciprocating pump. Flow is smooth and it requires less space to install. Lower initial cost and lower maintenance cost

**11. What is Net Positive Suction Head (NPSH) ?**

NPSH is defined as the total head required to make liquid flow through suction pipe to pipe impeller.

---

**12. Define slip of a reciprocating pump and negative slip:**

---

Slip is defined as the difference between theoretical discharge and actual discharge. If actual discharge is greater than theoretical discharge negative value is found this negative value is called negative slip.

**13. What is separation of reciprocating pump?**

If the pressure in the cylinder is below the vapour pressure, dissolved gasses will be liberated from the liquid and cavitations will takes place. The continuous flow of liquid will not exit which means separation of liquid takes place. The pressure at which separation takes place is called separation pressure and head corresponding to the separation pressure is called separation pressure head.

**14. What is an indicator diagram?**

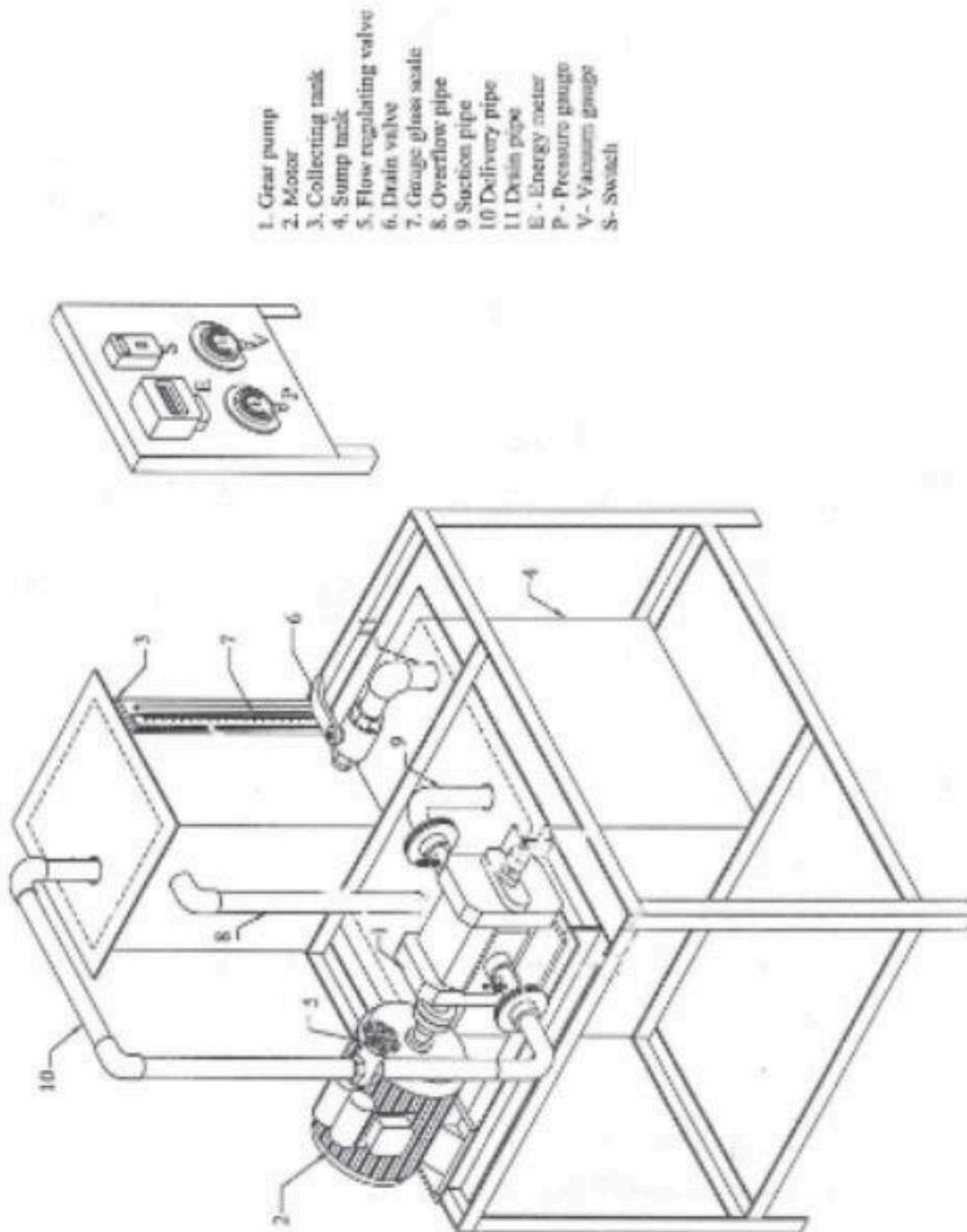
Indicator diagram is the graph between the pressure head and distance traveled by the piston from inner dead center for one complete revolution.

**15. What is Air vessel?**

Air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber. It is used to obtain a continuous supply of water at uniform rate to save a considerable amount of work and to run the pump at high speed with out separation.

**16. What is the purpose of an air vessel fitted in the pump?**

- 1.To obtain a continuous supply of liquid at a uniform rate.
- 2.To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and
- 3.To run the pump at a high speed with out separation.



- 1. Gear pump
- 2. Motor
- 3. Collecting tank
- 4. Sump tank
- 5. Flow regulating valve
- 6. Drain valve
- 7. Gauge glass scale
- 8. Overflow pipe
- 9. Suction pipe
- 10. Delivery pipe
- 11. Drain pipe
- E - Energy meter
- P - Pressure gauge
- V - Vacuum gauge
- S - Switch

**GEAR PUMP TEST RIG**

**Ex. no: 9**

**Date:**

**PERFORMANCE STUDY ON GEAR OIL PUMP**

**AIM:**

To determine the best driving conditions of the given gear oil pump at constant speed and to draw the characteristic curves.

**APPARATUS REQUIRED:**

1. Gear oil pump fitted with all accessories
2. Meter scale
3. Stop watch

**FORMULA:**

1. Actual Discharge (Q):

$$Q = \text{Ah/t cumec}$$

2. Total head (H) m of water:

$$H = \text{Pressure head} + \text{Vaccum head} + \text{Correction head (m)}$$

3. Input power:

$$I/P = (3600n) / Ect^2$$

Where,

N – no.of revolutions

Fc – Energy meter constant (rev/kwh)

T2 – time for n revolutions(s)

4. Output power:

$$O/P = VWQH \quad \text{Watts}$$

Where,

**OBSERVATIONS:**

Size of the tank  
 $L =$  m  
 $B =$  m  
 $A =$  m<sup>2</sup>  
 $X =$  m  
 Area of the tank  
 Correction head  
 Energy meter constant  
 $N_e =$  rev/kwh  
 Specific weight of water  
 $w =$  9810 N/m<sup>3</sup>

**TABULATION:**

SI.No	Pressure gauge reading G	Pressure head Gx10	Vacuum gauge reading "V"	Vacuum head Vx0.0136	Total Head H = (Gx10) + (Vx0.0136)+X	Time for h=0.1m rise of water in the tank t	Actual discharge Q = Ah/t	Time for Nr=10 revolutions in the energy meter 'T'	Input power Pi = 3600xNr/Next	Output power Po = wQH	Efficiency = Output power/input powerx100
Unit	kg/cm <sup>2</sup>	'm' of water	'mm' of Hg	'm' of water	'm' of water	seconds	m <sup>3</sup> /sec	seconds	kW.	kW	%
1.											
2.											
3.											
4.											
5.											
6.											

Q – Discharge (m<sup>3</sup>/s)

$w =$  Specific weight of water (9810N/m<sup>3</sup> )

H – Total head (m)

5. Efficiency:

$$= \{(O/P) / (I/P)\} \times 100$$

**PROCEDURE:**

1. The internal dimensions of the collecting tank and the correction head are measured.  
The energy meter constant is noted.
2. The supply tank is filled with oil to the required height wsay  $\frac{3}{4}$  of the tank.
3. The gate valve is opened in the delivery tube fully.
4. The motor is started and the following readings are noted.
  - a. Pressure gauge & vacuum gauge readings
  - b. Time for “h” m rise of oil in the tank.
  - c. Time for “Nr” revolutions in the energy meter disc
  - d. Take 4 or 5 sets of readings varying the delivery pressure.

**GRAPH:**

The following graph are drawn taking total “h” on X-axis.

1. Head Vs Discharge
2. Head Vs Input power
3. Head Vs Efficiency

**RESULT:**

1. Maximum efficiency obtained =
2. Corresponding discharge =
3. Input power =
4. Corresponding total head of water =

**VIVA VOCE QUESTIONS**  
**GEAR OIL PUMP**

**1. Define Pump?**

Pump transfers the mechanical energy of a motor or of an engine into Pressure energy, kinetic energy or both of a fluid.

**2. Define Rotary displacement pumps:**

Positive displacement rotary pumps rely on fine clearances between moving parts for their efficient operation.

**3. How the volume of oil discharge is calculate in aa gear pump?**

The Volume of oil discharged per revolution =  $2 \times a \times L \times N \text{ m}^3$

**4. Define horsepower?**

**Horsepower** (hp) is a unit of measurement of **power** (the rate at which work is done). One horsepower is equal to 735 watts

**5. What is the behavior of the pump with in-crease in pressure?**

The flow rate in gear pump more or less remains constant with in-crease in pressure

**6. Define Specific speed of pump**

“The speed of an ideal pump geometrically similar to the actual pump, which when running at this speed will raise a unit of volume, in a unit of time through a unit of head”

**7. Write the principle for operation of pump ?**

The principle of operation of pump is a partial vacuum is created at the pump inlet due to the internal operation of a pump. This allows atmospheric pressure to push the fluid out of the oil tank (reservoir) and into the pump intake. The pump then mechanically pushes fluid out of the discharge line.

**8. Why Gear pumps cannot be used as a variable displacement pump?**

In the gear pump, once the design parameters are finalized all the dimensions of gear pair is fixed and there is no way to vary the displacement.

**9. What is the reasons for the popularity of external gear pump ?**

The reasons for the popularity of external gear pump is Simple to design , Because gear pumps have only two moving parts, they are reliable, simple to operate, and easy to maintain and Low cost compared to other pumps

**10. What is the working principle of gear oil pump?** Gear pumps *use the actions of rotating cogs or gears to transfer fluids*. The rotating element develops a liquid seal with the pump casing and creates suction at the pump inlet. Fluid, drawn into the pump, is enclosed within the cavities of its rotating gears and transferred to the discharge.

**11. What are the main components of a gear pump?**

Prime Mover.

Driver gear.

Driven gear.

Inlet port or suction side.

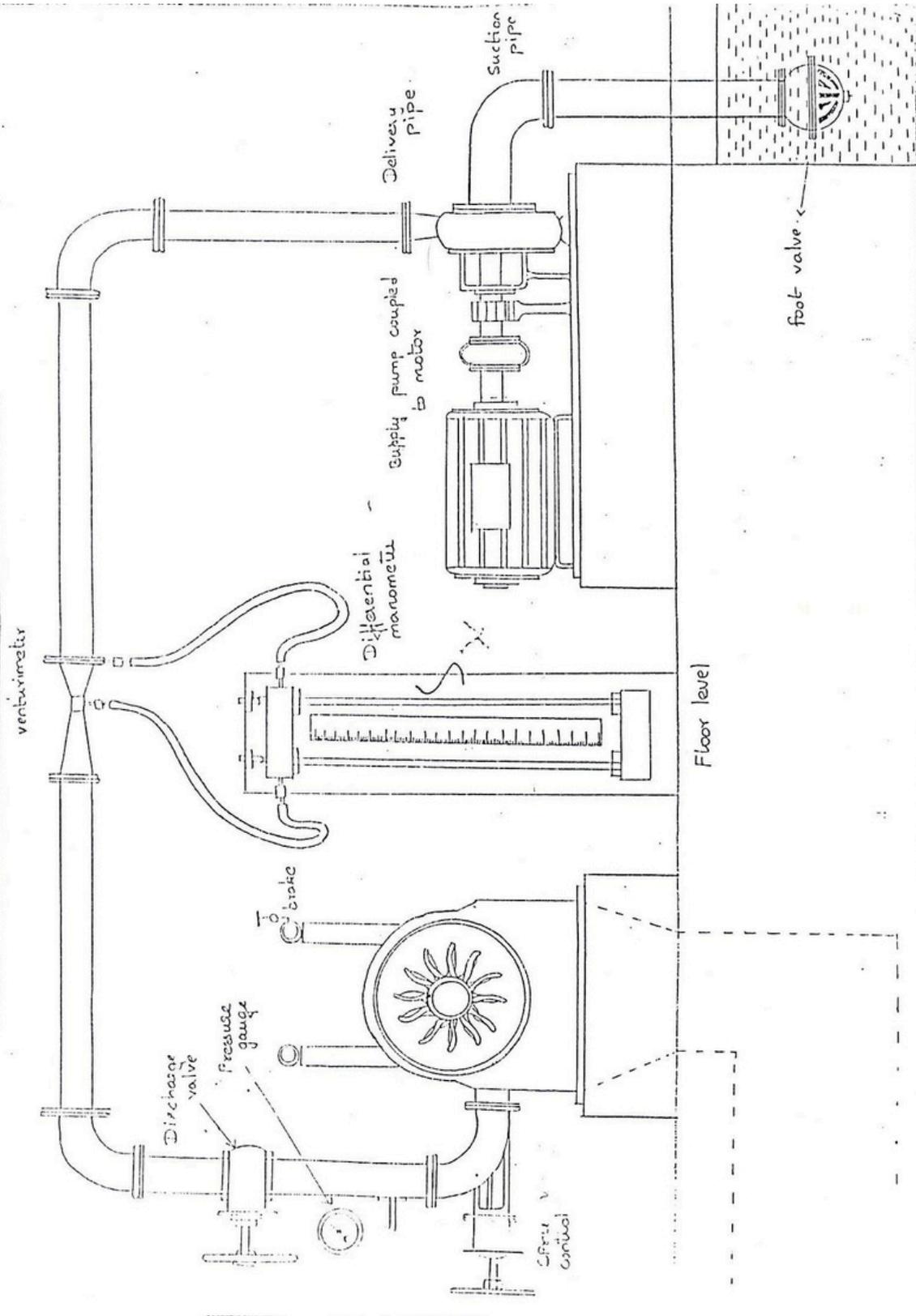
Outlet port or discharge side.

Pressure relief valve or safety valve.

**12. What are the 4 different types of gear pumps?**

The four common types of gear pump are *external gear, rotary lobe, vane pumps and internal gear pump*.

EXPERIMENTAL SETUP OF PELTON WHEEL TURBINE



***PERFORMANCE CHARACTERISTICS OF PELTON WHEEL***

**AIM:**

To conduct the load test on the given pelton wheel turbine by keeping constant gate opening, constant pressure & varying speed and draw the characteristic curves.

**APPARATUS REQUIRED:**

1. Pelton wheel turbine unit
2. Supply pump set
3. Tachometer

**DESCRIPTION:**

The pelton wheel turbine has been classified as an impulse turbine, where the available head is wholly converted into velocity energy with approximate axial flow it is used for very high heads. It is a most efficient type of impulse turbine. The jet of water impinges on the wheel from one or more nozzles and strikes on the buckets. The buckets are of double hemispherical cup shape. The flow of water is regulated by the needle nozzle. The buckets are so shaped that the jet is discharged backwards.

The supply to the turbine is affected by means of a centrifugal pump. The discharge is measured by an orifice meter. The difference in pressure is measured by a differential manometer. The pressure gauge at the inlet of the turbine measures the net head supplied by the pump to the turbine.

**OBSERVATION:**

Diameter of the brake drum,  $D = 0.3 \text{ m}$   
 Diameter of the rope,  $d = 0.016 \text{ m}$   
 Specific weight of water  $W = 9810 \text{ N/m}^3$

**TABULATION:**

Sl. No.	Gate opening %	Pressure gauge reading, $G$ kg/cm <sup>2</sup>	Pressure head, m of water	Manometer reading			Actual discharge $Q_a = 0.0055 \text{ l/h}$	Dead weight of hanger, $W_D$ kg	Weight on the hanger, $W_H$ kg	Total weight $W_b = W_D + W_H$ kg	Spring load, $W_s$ kg	Net weight on drum $W = (W_b - W_s) \times 9.81$ N	Torque, $T = (D+d/2) \times W$ N_m	Input power $P_i = 9.81 \times Q \times h$ kW	Speed (rpm)	Output power $P_o = (2\pi NT) / 60000$ kW	Efficiency, $\eta = (\text{output power} / \text{input power}) \times 100$ %		
				m of Hg	m of water	$h = (h_1 - h_2) \times 13.6$													
1.				$h_1$	$h_2$														
2																			
3																			
4																			
5																			
6																			

The input power supplied to the turbine is calculated from the net supply head on the turbine and the discharge through the turbine. The output power from the turbine is calculated from the readings on the rope brake dynamometer and the computed from the output and the input.

For any settings of the spear first the turbine is run for sometimes at a light load. In the variable speed test the brake load is increased gradually by adding dead weights on the load hangers. Until the turbine is finally ceases to revolve. The net supply head on the turbine can be varied by regulating the discharge gate valve of the pump.

Actual discharge	$Q_a = 0.0055 \sqrt{h}$	cumec
Total brake load	$W_b = W_h + W_d$	kg
Net weight on the drum	$W = (W_b - W_s) \times 9.81$	N
Torque	$T = \left\{ \frac{D+d}{2} \right\} \times W$	Nm
Input power	$P_i = 9.81 \times Q \times H$	kW
Output power	$P_o = 2 \pi NT / 60,000$	kW
Efficiency	$\eta = P_o / P_i \times 100$	%
specific speed	$N_s = N \sqrt{P_o} / (H^{5/4})$	

Where

$h$ = manometer head	in m
$W_h$ = weight on hanger	in Kg
$W_d$ =dead of the weight of hanger	in kg
$W_s$ = spring load	in Kg
$D$ = diameter of brake drum	in m

$d$ = diameter of rope	in m
$H$ = pressure head	in m of water
$N$ = Speed of the shaft	in RPM

**PROCEDURE:**

1. The supply pump is first started with the discharge valve completely closed.
2. The Gate opening is done to the required %
3. The gate valve is opened to the required head of water by regulating the discharge valve.
4. The pressure gauge readings are measured.
5. The Manometer readings ( $h_1$  &  $h_2$ ) are measured.
6. Making the spring load ( $W_s$ ) as 0.5 kg the load on the hanger is varied from 0 to 10kg. Again by making the spring load ( $W_s$ ) as 1 kg the load on the hanger is varied from 12 to 20kg.
7. The speed of the shaft is measured by tachometer at every set of loadings (0, 2, 4...20 kg).
8. After that, Discharge valve is fully closed and the motor is switched off.

**MODEL CALCULATION:**

(Formulae to be used)

Total head  $= G \times 10$

U-tube differential manometric head  $h = (h_1 - h_2) \times 12.6$

Actual discharge  $Q_a = 0.0055 \sqrt{h}$

Net weight of the drum  $W = (W_B - W_S) \times 9.81$

Input power  $P_i = 9.81 \times Q \times h$

Output power  $P_o = (2\pi NT) / 60000$

Efficiency  $\eta = (P_o / P_i) \times 100$

#### GRAPHS:

The following graphs are drawn taking speed on x- axis.

1. Speed vs Efficiency
2. Speed vs. Output power

At the point of the maximum efficiency of the graph the corresponding values of speed & output power are arrived from the graph.

#### RESULT:

The characteristic curves are drawn from the point of maximum efficiency. The best driving conditions are found out.

The best driving conditions of the turbine are obtained when,

1. Maximum efficiency  $\eta_{\max}$  =
2. Speed  $N$  =
3. Output power  $P_o$  =
4. Specific speed  $N_s$  =

## *VIVA VOCE QUESTIONS*

### *PELTON WHEEL TURBINE*

**1. In a turbine what will be considered to identify the Fluid Input Power?**

Fluid Input Power = Mechanical Loss + Hydraulic Losses + Useful shaft power output.

**2. How will you find the Hydraulic Losses?**

Hydraulic Losses = Impeller Loss + Casing Loss + Leakage Loss

**3. On what does the efficiency of a Pelton wheel turbine depends on.**

The optimum value of the overall efficiency of a Pelton turbine depends both on the values of the specific speed and the speed ratio.

**4. What is Pelton wheel:**

Pelton wheel or Pelton turbine is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The energy available at the inlet of the Turbine is only kinetic energy. This turbine is used for high heads.

**5. Define Gross Head of a turbine.**

The difference between head race level and tail race level is known as Gross Head

**6. Define Net head of a turbine.**

It is also called effective head and is defined as the head available at the inlet of the turbine.

$$H = H_g - h_f$$

**6. What are called turbines?**

Hydraulic turbines are the machines which use the energy of water and convert it into mechanical energy. The mechanical energy developed by a turbine is used in running the electrical generator which is directly coupled to the shaft.

**7. What is breaking jet?**

When the nozzle is completely closed, the amount of water striking the runner reduces to zero but the runner due to inertia goes on revolving for a long time to stop the runner in a short time a small nozzle is provided which directs the jet of water on the back of vanes. This jet of water is called breaking jet.

**8. Define Jet Ratio.**

It is defined as the ratio of the pitch diameter (D) of the Pelton wheel to the diameter of the jet (d). It is denoted by „m“ and is given as  $m = D/d$

**9. What are the types of characteristic curves**

Main characteristic curves

Operating characteristic curve

Muschel characteristic curves

**10. What is known by governing of a turbine?**

Governing of a turbine is defined as the operation by which the speed of the turbine is kept constant under all conditions of working . It is done by oilpressure generator.

**11. What are the classification of hydraulic turbine according to the type of energy at inlet ?**

- (a) Impulse turbine and
- (b) Reaction turbine

**12. What are the types of turbine according to direction of flow through runner?**

- (a) Tangential flow turbine
- (b) Radial flow turbine
- (c) Axial flow turbine
- (d) Mixed flow turbine

**13. What are the types of turbine according to the head at the inlet of the turbine?**

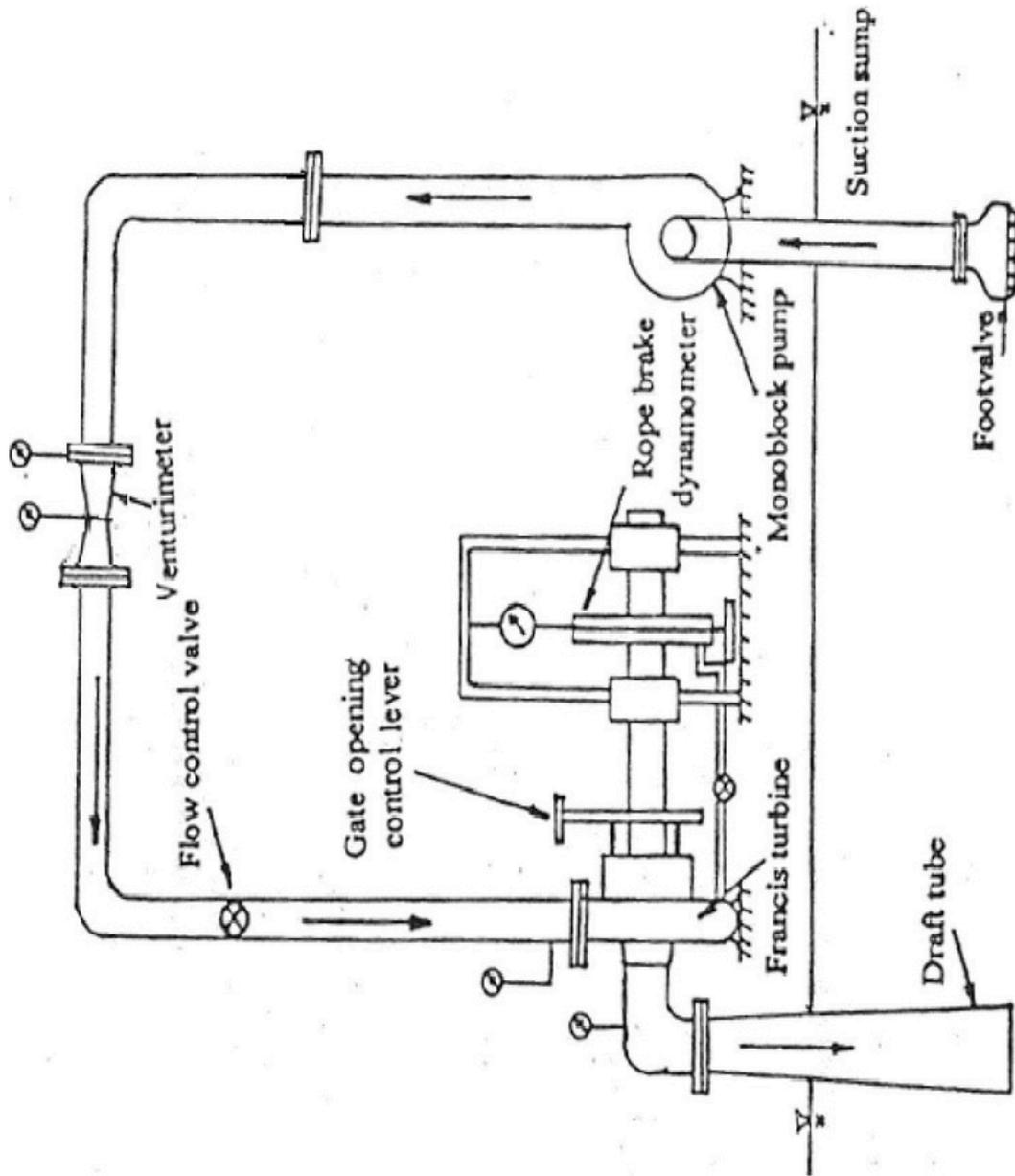
- (a) high head turbine
- (b) medium head turbine
- (c) low head turbine

**14. What are the types of turbine according to the specific speed of the turbine?**

- (a) Low specific speed turbine
- (b) Medium specific speed turbine
- (c) High specific speed turbine.

**15. Explain about characteristic curves of a hydraulic turbine.**

Characteristic curves of a hydraulic turbine are the curves with the help of which the exact behaviour and performance of the turbine under different working conditions can be known.



**FIGURE 1.** Schematic diagram of the experimental test rig of Francis turbine

***PERFORMANCE CHARACTERISTICS OF FRANCIS TURBINE***

***AIM:***

To conduct the load test on the given Francis turbine by keeping constant gate opening, constant pressure & varying speed and draw the characteristics curves.

***APPARATUS REQUIRED:***

1. Francis Turbine
2. Tachometer
3. Supply pump set

***FORMULA:***

1. Actual Discharge  $Q_a = 0.011\sqrt{h}$  cumec
2. Total Brake load  $W_b = W_h + W_d$  Kg
3. Net weight on the drum  $W = (W_b - W_s) \times 9.81$  N
4. Torque ,  $T = ((D+d)/2) \times W$  Nm
5. Input Power  $P_i = 9.81 \times Q_a \times H$  kw
6. Output Power  $P_o = 2\pi NT / 60,000$  kw
7. Efficiency ,  $\eta = P_o/P_i \times 100$  %
8. Specific Speed,  $N_s = N\sqrt{P}/H^{5/4}$  rpm

Where,

H – Manometer Head in m

W<sub>h</sub> – Weight on hanger in Kg

W<sub>d</sub> – Dead Weight of the hanger in Kg

W<sub>s</sub> – spring load in Kg

D – Diameter of brake drum in m

D – Diameter of rope

**OBSERVATIONS:**

Dia of the brake drum,  $D =$  mm, Discharge  $Q = K\sqrt{h}$  (h in m of water) ( $k = 1.0512 \times 10^{-2}$ )

Diameter of the rope,  $t =$  mm, Orificemeter Head  $P$  in m of water =  $(P_1 - P_2) \times 10$

Weight of rope & Hanger = 1kg, Effective Radius of =  $(D/2 + t) =$

Brake drum net load  $W = (W_1 + \text{weight of rope \& hanger}) - W_2$  kg.

S. No.	Pressure Gauge Kg/cm <sup>2</sup>	Orificemeter Head Pressure Gauge reading (kg/cm <sup>2</sup> )			Orifice meter Head, h(m)	Discharge, $Q$ <sub>3</sub>	Weight on hanger, W <sub>1</sub> (kg)	Spring balance reading W <sub>2</sub> (kg)	Net load W, Kg	Shaft speed rpm	Output, kW	Input, kW	Efficiency, $\eta$ (%)
		P <sub>1</sub>	P <sub>2</sub>	P									
1													
2													
3													
4													
5													
6													
7													
8													
9													

H – Total Head in m of water

N – Speed of the Shaft in rpm.

**PROCEDURE :**

1. The supply pump is first started with the discharge valve completely closed.
2. Do the gate opening to the required %.
3. The gate valve is opened to the required head of water by regulating the discharge valve.
4. Measure the pressure gauge readings.
5. Measure the manometer readings ( $h_1$  &  $h_2$ )
6. Marking the spring load  $W_s$  as 0.5 kg vary the load on the hanger 0 to 10 kg and again making the spring load  $W_s$  as 1 kg vary the head on the hanger 12 to 20 kg.
7. Measure the speed of the shaft by Tachometer and set the readings (0, 2, 4, ..., 20 rpm)
8. After that discharge valve is fully closed and note the vacuum gauge readings.

**GRAPH:**

The following graphs are drawn by taking speed on X – axis.

1. Speed Vs efficiency
2. Speed Vs output power

At the point of maximum efficiency of the graph corresponding value of speed and output power are carried from the graph.

**RESULT:**

The characteristic curves are drawn from the point of maximum efficiency. The best driving condition are formed out, and the best conditions of the turbine are obtained.

When,

1. The maximum efficiency  $\eta_{\max} =$
2. Speed  $N =$
3. Specific speed  $N_s =$

## VIVA VOCE QUESTIONS

### FRANCIS TURBINE

**1. What are fluid machines or Hydraulic machines?**

The machines which use the liquid or gas for the transfer of energy from fluid to rotor or from rotor to fluid are known as fluid machines.

**2. How are fluid machines classified?**

Fluid machines are classified into two categories depending upon transfer of energy:

1. Turbines – hydraulic energy is converted to mechanical energy and then electrical energy.
2. Pumps – electrical energy is converted to mechanical energy and then hydraulic energy.

**3. What is radial discharge?**

This means the angle made by absolute velocity with the tangent on the wheel is 90 and the component of whirl velocity is zero.

**4. What is known as Euler's equation for turbo-machines?**

The general expression for the work done per second on impeller is

$$\rho Q [V_{w1}u_1 + V_{w2}u_2]$$

**5. Explain Reaction turbine.**

If at the inlet of the turbine the water possesses kinetic energy as well as pressure energy the turbine is known as reaction turbine.

**6. Explain tangential flow turbine.**

If the water flows along the tangent of the runner, the turbine is known as the tangential flow turbine.

**7. What are the efficiencies of a turbine?**

- Hydraulic efficiency
- Mechanical efficiency
- Volumetric efficiency
- Overall efficiency

**8. Define Hydraulic efficiency.**

It is defined as the ratio of the power given by water to the runner of a turbine to the power supplied by the water at the inlet of the turbine.

**9. Define Mechanical efficiency.**

The ratio of the power available at the shaft of the turbine to the power delivered to the runner is defined as mechanical efficiency.

**10. Define volumetric efficiency.**

The ratio of the volume of the water actually striking the runner to the volume of water supplied to the turbine is defined as volumetric efficiency.

**11. Define overall efficiency**

It is defined as the ratio of shaft power by water power

**12. Explain radial flow turbine.**

If the water flows in the radial direction through the runner the turbine is called radial flow turbine.

**13. Explain inward flow radial turbine**

If the water flows from outwards to inwards radially the turbine is called inward radial flow turbine.

**14. Explain outward flow radial turbine**

If the water flows radially from inwards to outwards the turbine is known as outward radial flow turbine.

**15. What is specific speed of the turbine?**

It is defined as the speed of a turbine which will develop unit power under unit head.

**16. Define unit quantities**

Unit quantities are the quantities which are obtained when the head on the turbine are unity.



*Ex. no: 12*

*Date:*

### ***PERFORMANCE CHARACTERISTICS OF KAPLAN TURBINE***

#### ***AIM:***

To study the performance of the Kaplan turbine and to draw the characteristic curves of the Kaplan turbine

#### ***APPARATUS REQUIRED:***

4. Kaplan turbine
5. Pressure gauge
6. Scale
7. Tachometer

#### ***DESCRIPTION:***

Kaplan turbine consists of series of disc of buckets fixed around the periphery of circular disc or circular where called runner. The runner mounted on shaft water is supplied by a pump through pipe. The other end of pipe is fitted with nozzle. The amount of water flowing out of nozzle is controlled by a spear. The difference in pressure is measured by differential manometer. The rate of flow through the pipe is measured by a Venturimeter. The water is discharged through a draft tube in total race.

#### ***FORMULA:***

##### ***1. Input power (I/P):***

$$I/P = W \times Q \times H \quad \text{kW}$$

Where,

W – Specific weight of water (9810 N/m<sup>3</sup>)

Q – Discharge (m<sup>3</sup>/s)

H – Head of water at inlet of turbine (m)

##### ***2. Brakepower :***

$$BP = \{2 \pi NT \times 9.81\} / 60000 \text{ Kw}$$

Where,

N – Speed of turbine (rpm)

D – Brake down diameter (m)

**OBSERVATIONS:**

Dia of the brake drum, D=      mm, Discharge  $Q = K\sqrt{p}$  (h in m of water) ( $k = 2.3652 \times 10^{-2}$ )

Diameter of the rope, t =      mm,      Orificemeter Head P in m of water =  $P_1 - P_2 \times 10$

Weight of rope & Hanger=1kg,      Effective Radius of =  $(D/2 + t) =$

Brake drum net load  $W = (W_1 + \text{weight of rope \& hanger}) - W_2$  kg.

S.No.	Pressure Gauge Kg/cm <sup>2</sup>	Orificemeter Head Pressure Gauge reading (kg/cm <sup>2</sup> )			Discharge, Q (m <sup>3</sup> /s)	Weight on hanger, W1 (kg)	Spring balance reading W2 (kg)	Net Weight speed W, Kg	Shaft rpm	Output, kW	Input, kW	Efficiency, η (%)
		P1	P2	P								
1.												

**GRAPH**

1. Speed in rpm vs. Efficiency in %
2. Speed in rpm vs. output power

T – Turbine speed in RPM

T = Torque in kgm, (effective radius of the brakedrum in meters (R) x The net brakeload in kg. (w)

Re= 0.165 m

**4. Efficiency of turbine (η):**

$$\eta = (OP / IP) \times 100 \%$$

**5. Specific speed (Ns):**

$$N_s = N \sqrt{P} / (H)^{5/4} \text{rpm}$$

Where,

N – Speed or maximum efficiency (rpm)

P – Output power corresponding to maximum efficiency (kw)

H – Head and inlet of turbine (m)

**PROCEDURE:**

1. Keep the runner vane at require opening.Keep the guide vanes at require opening.
2. Prime the pump if necessary. Close the main sluice valve and then start the pump.
3. Open the sluice valve for the required discharge when the pump motor switches from start to delta mode.
4. Load the turbine by adding weights hanger. Open the brake drum cooling water gate valve for cooling the brake drum.
5. Measure the turbine rpm with tachometer. Note the pressure gauge and vacuum gauge readings
6. Note the orifice meter pressure readings. Repeat the procedure for other loads.

**RESULT:**

- |       |                            |   |
|-------|----------------------------|---|
| (i)   | Maximum efficiency         | = |
| (ii)  | Corresponding output power | = |
| (iii) | Corresponding input power  | = |
| (iv)  | Specific speed             | = |

**VIVA VOCE QUESTIONS**  
**KAPLAN TURBINE**

**1. Define axial flow turbine**

If the water flows through the runner along the direction parallel to the axis of rotation of the runner the turbine is called axial flow turbine.

$$\eta_o = \frac{\text{Power available at the shaft (shaft power)}}{\text{Power supplied at inlet (water power)}}$$
$$\eta_o = \eta_h \eta_m \eta_v \quad (\text{or}) \quad \eta_o = \eta_h \eta_m$$

**2. Define propeller turbine:**

This is an example of axial flow reaction turbine. Here the vanes are fixed to the hub and are not adjustable.

**3. Uses of draft tube:**

Discharges water to tail races safely  
Converts a large proportion of rejected kinetic energy into useful pressure energy  
Net head of the turbine is increased.

**4. Types of draft tube:**

Conical draft tube, Simple elbow tube, Moody spreading tube, draft tube with circular inlet and rectangular outlet.

**5. Define Runaway speed of Turbine.**

The max speed reached by the turbine after the removal of the external load is called runaway speed of turbine. The various rotating components of the turbine should be designed to remain safe at the runaway speed.

**6. What are an impulse turbine and a reaction turbine?**

**Impulse Turbine:** If at the inlet of the turbine, the energy available is only kinetic energy, the turbine is known as an impulse turbine. The pressure at the inlet of the turbine is at atmosphere. This turbine is used for high heads. The water strikes the bucket along the tangent of the runner. Ex: Pelton Wheel Turbine.  
**Reaction Turbine:** If at the inlet of the turbine, the water possesses kinetic energy as well as pressure energy, the turbine is known as a reaction turbine. As the water flows through the runner, the water is under pressure and the pressure energy goes on changing into kinetic energy. The runner is completely enclosed in an air-tight casing and the runner and casing is completely full of water. This turbine is used for medium heads. Ex: Francis Turbine

**7. Define Radial flow reaction turbine and their types.**

If water flows in the radial direction in the turbine then it is referred to as a radial flow turbine.  
Types: Inward radial flow reaction turbine: If the water flows from outward to inward through the runner, the turbine is known as an inward radial flow reaction turbine. Here the outer diameter of the runner is inlet diameter whereas the inner diameter of the runner is

outlet diameter. Outward radial flow reaction turbine: If the water flows from inwards to outwards through the runner, the turbine is called as outward radial flow reaction turbine. Here the outer diameter of the runner is outlet diameter whereas the inner diameter of the runner is inlet diameter.

**8. What do you know about Hub or Boss?**

It is the core part of the axial flow turbine where the vanes are attached.

**9. Under what head the propeller turbine take water?**

About 100 m head the propeller turbine take water. When the vanes are fixed to the hub and they are not adjustable the turbine is called propeller turbine.

**10. What are the uses of Kaplan turbine?**

To produce more output.

The efficiency of the turbine is more

**11. Define Kaplan turbine:**

This is an example of axial flow reaction turbine. Here the vanes are not fixed to the hub and are adjustable.

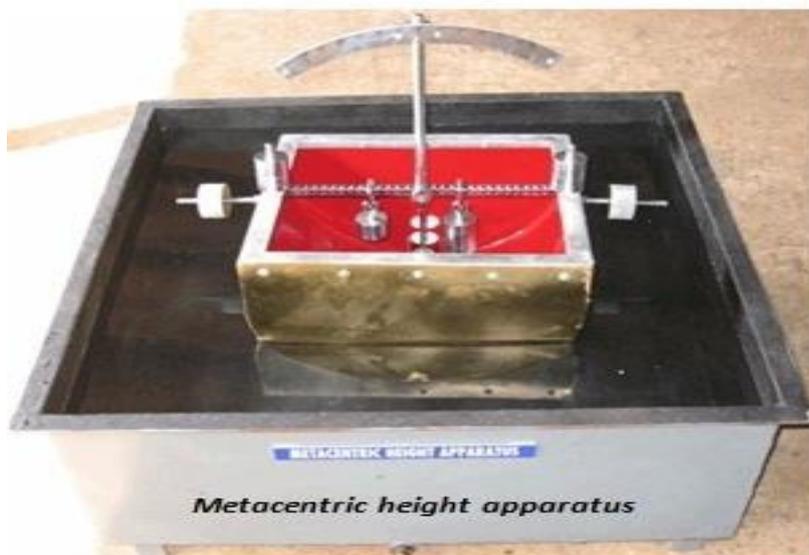
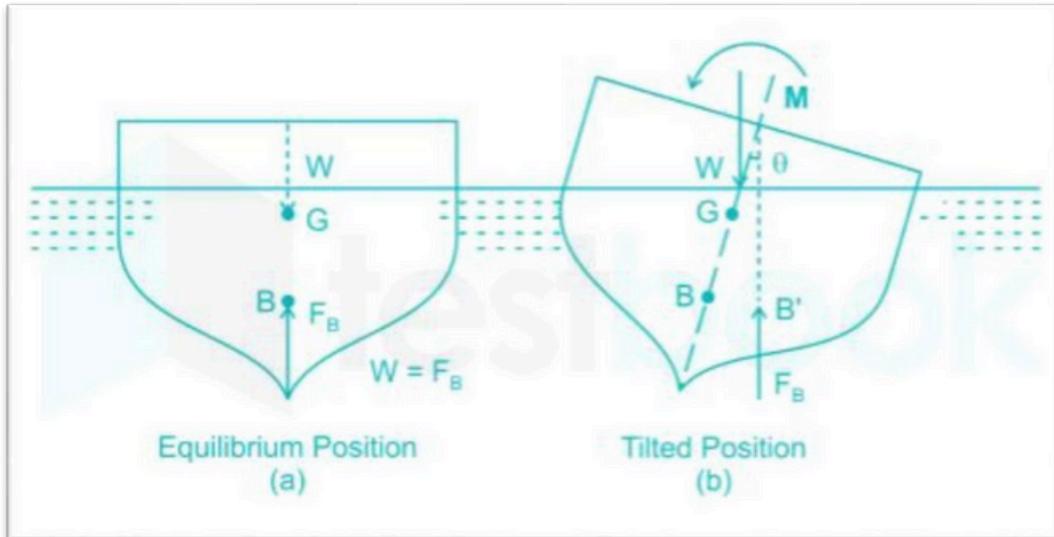


Fig. Metacentric height apparatus

**DETERMINATION OF METACENTRIC HEIGHT OF FLOATING BODIES**

**Apparatus:**

1. Water bulb
2. Metacentric height apparatus
3. Scale or measuring tube

**Procedure:**

1. First of all I adjust the movable weight along the vertical rod at a certain position and measured the distance of center of gravity by measuring tape.
2. Then I brought the body in the water tube and changed the horizontal moving load distance first towards right.
3. The piston tilted and suspended rod gave the angle of heel, I noted the angle for respective displacements.
4. I did the same procedure for movable mass by changing its position towards left.
5. Then I took the body from water tube and find another center of gravity by changing the position of vertically moving load.
6. I again brought the body in the water tube and find the angle of heel by first keeping the movable load towards right and then towards left.
7. I repeated the above procedure for another center of gravity.
8. I calculated the metacentric height by the following formula:

$$MH = w * d / W * \tan\theta$$

**Where**

- MH = Metacentric height  
w = Horizontally movable mass  
d = Distance of movable mass at right or left of center  
W = Mass of assemble position  
 $\theta$  = Respective angle of heel

**Observationcs & Calculations:**

- Horizontally movable mass = w  
Mass of assemble position = W  
Center of gravity = y1  
Center of gravity = y2  
Center of gravity = y3

Considering Right Portion

S.No	Distance of movable mass at right of center (mm)	Y1	Angle of head " $\theta$ " Y2	Y3	Y1	Metacentric height(MH) Y2	Y3
01							
02							
03							

Considering Left Portion

S.No	Distance of movable mass at left of center (mm)	Y1	Angle of head " $\theta$ " Y2	Y3	Y1	Metacentric height (MH) Y2	Y3
01							
02							
03							

**RESULT:**

Hence the metacentric height is identified.

## **VIVA VOCE QUESTIONS**

### **METACENTRIC HEIGHT**

**1. What is a metacentric height?**

It is the measurement of initial static stability of a floating body.

**2. How is the metacentric height of a ship is calculated.**

It is calculated as the distance between the centre of gravity of a ship and its metacentre.

**3. What is a metacentre?**

The point at which a body floating in a liquid starts oscillating is called metacentre.

**4. Define Buoyancy.**

It is the tendency of a fluid to lift a submerged body.

**5. Explain about force of buoyancy.**

It is the resultant upward force or thrust exerted by a fluid on submerged body.

**6. When will a body in a liquid surface be in equilibrium.**

When the gravity forces and buoyant force lie in the same vertical line the body will be in equilibrium.

**7. Write the formula for calculating metacentre.**

$$KM = KB + BM$$

**8. Write the formula to determine the metacentric height theoretically.**

$$GM = BM + OB - OG$$

**9. How is the metacentric height calculated practically.**

$$GM = Px / (W \sin(\theta))$$

**10. What is KM used in the calculation of metacentre.**

KM is the distance between the keel to metacentre.

# **TOPIC BEYOND SYLLABUS**

## **HYDRAULIC FLUME**

### **BROAD CRESTED WEIR**

In a broad-crested weir, the crest (sill) of weir is fairly wide. The water adheres to the crest and has a surface contact while passing over it. The broad-crested weir is a critical-depth meter because under suitable conditions, the critical depth ( $y_c$ ) occurs over the crest. The critical depth usually occurs at a distance of about  $3 y_c$  from the downstream edge from the downstream edge.

A broad-crested weir is used in practice for the measurement of discharge in large open channels.

### **EXPERIMENTAL SET-UP**

The set-up consists of a broad-crested weir installed in an open channel or a flume.

The water is supplied from a constant-head supply tank by a pipe. A gate valve is provided on the supply pipe for regulating the discharge.

A pointer-gauge is used for the measurement of water level. The pointer gauge can be fixed on a trolley. The trolley can be moved to and fro on the side walls of the flume. A venturimeter with a manometer is provided for the measurement of actual discharge with a  $C_d$  value of 0.95.

### **THEORY**

It can be shown that for a rectangular channel the critical depth  $y_c$  is equal to  $2/3 E$ ,

where  $E$  is the specific energy measured above the crest. The specific energy measured above the crest. The critical velocity  $v_c = \sqrt{g y_c}$ , the discharge  $Q$  is given by  $Q = 1.705 C_d L E^{3/2}$

If we neglect the velocity approach  $E = H$ , where  $H$  is the head over the crest. Thus  $Q = 1.705 C_d E^{3/2}$

Where  $C_d$  is the coefficient of discharge and  $L$  is the length of the crest. The head  $H$  is the head over the weir, measured well upstream of the sill where the water surface has no curvature.

The value of  $C_d$  depends upon the length of weir, the height of weir and on the roundness of corners.

### **PROCEDURE**

1. Measure the length  $L$  of the broad-crested weir. This usually equal to the width of the flume. Also measure the width  $B$  of the weir.
2. Take the pointer gauge reading when the point just touches the crest  $H_0$ .
3. Open the supply valve and let water flow over the crest.
4. Adjust the position of the sluice gate so that flow becomes steady and the head over crest becomes constant.
5. Take the pointer gauge reading at a section well upstream of the crest where the water surface is horizontal  $H$ .
6. Take the manometer reading of the venturimeter and calculate the actual discharge  $Q_a$ .
7. Increase the discharge and repeat steps 4 to 6.

**OBSERVATION AND CALCULATIONS**

*Length of the broad- crested weir, L=250 mm*

*Pointer gauge reading at the crest, H=0*

*Pointer gauge reading at the level of water H' =*

<i>S.NO</i>	<i>VENTURIMETER H1</i>	<i>VENTURIMETER H2</i>	<i>Pointer gauge H</i>	<i>Pointer gauge H0</i>

Calculate the actual discharge using the venturimeter  $Q = C_d a_1 \sqrt{2gh} \sqrt{a_1^2 - a_2^2}$  )

Where a1 and a2 are area of inlet and throat of the venturimeter. Cd= 0.95

Venturimeter pipe dia = 40mm

Throat dia = 24mm

H= H' - H0

The theoretical discharge Q is given by  $Q = 1.705 C_d E H^{3/2}$

**RESULT**

***THE COEFFICIENT OF DISCHARGE OF WEIR =***

## **HYDRAULIC JUMP( DEMONSTRATION)**

### **THEORY**

The title type hydraulic flume may be used for uniform flow through open channels(i.e A phenomenon of flow through open channels, in which the rate of flow, depth of flow, area of flow and slope of bed remains constant). The change in any of the above condition causes the flow to be non-uniform.

The specific energy may be defined as energy per unit weight with respect to the datum passing through the bottom of the channel  $E = h + \frac{v^2}{2g}$  where  $h$ = depth of liquid flow and  $v$ = velocity of the liquid.

Critical depth: The depth of water in a channel corresponding to the minimum specific energy is known as critical depth  $= h_c = \left(\frac{q^2}{g}\right)^{1/3}$  . the velocity of water at critical depth is known as critical velocity  $v_c = q/h_c$

A hydraulic jump occurs in an open channel when the flow changes from the supercritical to subcritical. The water level abruptly rises at the hydraulic jump. A large number of roller of turbulent eddies are formed at hydraulic jump, which cause dissipation of energy.

The hydraulic jump is analyzed by applying the impulse momentum equation to a control volume.

### **EXPERIMENT SET-UP**

The set-up consists of a rectangular tilting flume having at the inlet and exit. The water is supplied to the flume by a centrifugal pump. A sluice gate is provided in the middle portion of the flume to create supercritical flow condition on itsdown stream so that a hydraulic jump can form.

A pointer gauge trolley can move on the rails at the top of the walls for the measurement of the water depths.

An venturimeter is provided on the supply pipe for the measurement of actual discharge.

### **THEORY**

The depth  $y_1$  before hydraulic jump and the depth  $y_2$  after the hydraulic jump

The loss energy in the hydraulic jump is given by

$$dE = E_1 - E_2 = \frac{(Y_2 - Y_1)^3}{4Y_1Y_2}$$

### **PROCEDURE**

Measure the width of the flume. Take the pointer gauge at the bed of flume at suitable section upstream and downstream of the hydraulic of the hydraulic jump.  $H_0$

Open the supply valve and adjust the inlet and exit gates so that the flow becomes uniform and steady.

Gradually lower the sluice gate and adjust the exit gate so that a stable hydraulic jump is formed on the downstream of the sluice gate.

Note the deflection  $h$  of manometer liquid in the u-tube manometer attached to the venturimeter on the supply line for computation of actual discharge.

Take the pointer gauge reading of the water surface to measure the depths  $y_1$  and  $y_2$

Repeat steps 3 to 5 for different discharge.

**OBSERVATION AND CALCULATION**

Width of flume  $L = 250$  mm

Venturimeter dimension  $D_1 = 40$ mm ,  $D_2 = 24$  mm

Venturimeter coefficient  $c_d = 0.95$

s.no	VENTURIMETER		WATER DEPTH READING			$Y_1 = H_1' - H_0'$	$Y_2 = H_2' - H_0'$
	$h_1$	$h_2$	$H_1'$	$H_2'$	$H_0'$		

**RESULTS**

The loss energy in the hydraulic jump=

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**VIVA QUESTION**  
**HYDRAULIC JUMP**

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**1. Hydraulic Jump**

The rise of water level which takes place due to transformation of super critical flow to sub critical flow is termed as hydraulic jump.

**2. Expressions for Loss of Energy due to Hydraulic Jump**

The length between two sections where one section is taken just before the hydraulic jump and the other section is taken just after the hydraulic jump is termed as length of hydraulic jump.

For rectangular channels Length of hydraulic jump = 5 to 7 times the depth of hydraulic jump.

**3. Location of Hydraulic Jump**

Depends on two things.

- 1)  $d_2$  = Depth of flow just after the hydraulic jump.
- 2)  $y_c$  = Normal depth of flow at downstream.

**4. Types of Hydraulic Jump**

- |                            |                  |
|----------------------------|------------------|
| 1) $FN_1 = 1.0$ (Critical) | No jump          |
| 2) $FN_1 = 1$ to $1.7$     | Undular jump     |
| 3) $FN_1 = 1.7$ to $2.5$   | Weak jump        |
| 4) $FN_1 = 2.5$ to $4.5$   | Oscillating jump |
| 5) $FN_1 = 4.5$ to $9$     | Steady jump      |
| 6) $FN_1 = > 9$            | Strong jump      |

**5. Practical Applications of Hydraulic Jump**

To dissipate the energy of water flowing over the hydraulic structures and thus prevent the scouring of downstream structure.

To recover the head or raise the water level on the downstream side of the hydraulic structure & thus to maintain high water level in the channel for irrigation or other water distribution purposes.

To increase the weight on apron & thus reduce the uplift pressure under the structure by raising the water depth on apron.

To mix the chemicals for water purification.

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**6. Flume Advantages**

- The ability to measure higher flow rates than a comparably sized weir
- Less head loss (generally  $1/4$  that of a weir)
- The ability to pass debris more readily
- 
- Wide range of styles and sizes
- Off-the-shelf availability
- Smaller installation footprint
- Less rigorous maintenance requirements
- 

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Also, most styles of flumes are resistant to changes or restrictions in the downstream hydraulics (submergence) - something not found with weirs.

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