First Edition

FLUID MECHANICS AND MACHINES

Practical Manual

Dr. MANICKAVASAHAM G

Dr. R. ELANGOVAN

Empowering Gen Z
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Z Alpha Research and Publishing Hub ™
Tiruchirappalli – Tamil Nadu.

FLUID MECHANICS AND MACHINES PRACTICAL MANUAL

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First Edition: 2025

ISBN (Paperback): 978-81-994040-3-8

ISBN (e-Book): 978-81-994040-9-0

Published and Printed by:

Z Alpha Research and Publishing Hub ™

No. 14, Muthumanitwon, 3rd Cross, Senthaneerpuram,

Tiruchirappalli – 620 004.

Tamil Nadu. India.

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Printed in India

Preface

The field of Fluid Mechanics and Machines forms a fundamental part of Mechanical Engineering, bridging theoretical concepts with practical applications. While students often gain exposure to the theoretical aspects of the subject in classrooms, the true understanding comes through hands-on experimentation. This manual has been prepared to serve as a structured guide for students in conducting laboratory experiments effectively.

Why this manual was prepared

This manual was developed to provide Mechanical Engineering students with a clear, systematic, and practice-oriented resource for their laboratory courses. Many existing resources focus either on theoretical knowledge or provide limited experimental guidance. To fill this gap, this manual compiles essential experiments, procedures, observations, and analysis methods in a concise and accessible manner.

Aim and Scope

The primary aim of this manual is to help students:

- Understand the fundamental principles of fluid mechanics and hydraulic machines.
- Acquire experimental skills that complement classroom teaching.
- Learn the correct procedure for recording, analyzing, and interpreting data.
- Develop a professional approach to handling laboratory equipment and experimental outcomes.

The scope of the manual covers a wide range of experiments related to fluid properties, flow measurements, losses in pipes, and the performance of hydraulic machines such as turbines and pumps.

Intended Audience

This manual is designed for undergraduate Mechanical Engineering students, particularly those enrolled in courses on Fluid Mechanics and Hydraulic Machines. It may also serve as a reference for diploma students, postgraduate learners, and faculty members supervising laboratory sessions.

Special Features of this Edition

- Step-by-step instructions for each experiment.
- Well-structured observation tables and calculation formats.
- Safety precautions and best practices for laboratory work.
- Illustrations and diagrams to aid understanding.
- Space provided for students' remarks, results, and evaluations.

It is our hope that this manual will not only serve as a guide for laboratory exercises but also inspire students to appreciate the practical applications of fluid mechanics in engineering systems.

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Dr. R. ELANGOVAN

Acknowledgements

We sincerely express our gratitude to all those who have contributed to the preparation of this manual. We acknowledge that some figures and diagrams in this manual are reproduced or adapted from textbooks, research publications, and online sources, with due credit to the original authors. These sources include textbooks by renowned authors, academic journals, and publicly available educational websites.

It is our hope that this manual serves as a valuable resource for students, helping them gain practical skills and a deeper understanding of fluid mechanics and machines.

This manual is made available to students exclusively for educational purposes and is not intended for commercial sale.

Dr. MANICKAVASAHAM G

Dr. R. ELANGOVAN

Safety Precautions in the Fluid Mechanics Laboratory

Working in a Fluid Mechanics Laboratory involves handling fluids, machinery, and experimental setups. To ensure safety and prevent accidents, students must adhere to the following precautions:

1. General Laboratory Conduct

- Always follow the instructions of the laboratory supervisor or instructor.
- Do not engage in horseplay or unnecessary movement in the lab.
- Keep your work area clean and organized. Remove unnecessary items before starting experiments.
- Report any damaged equipment or spillage immediately to the supervisor.

2. Personal Safety

- Wear appropriate personal protective equipment (PPE):
    - ❖ Lab coat or apron
    - ❖ Safety goggles or glasses
    - ❖ Closed-toe shoes
- Avoid loose clothing, jewelry, or long hair that may get caught in equipment.
- Wash hands thoroughly after handling fluids, lubricants, or chemicals.

3. Electrical Safety

- Ensure that all electrical equipment (pumps, motors, sensors) is properly grounded.
- Do not touch electrical switches or equipment with wet hands.
- Switch off and unplug equipment before performing maintenance or adjustments.

4. Handling Fluids

- Always handle fluids with care to avoid spills and splashes.
- Use proper containers when transferring fluids.
- Avoid inhalation of vapors or fumes from any lubricants or working fluids.

5. Equipment Operation

- Only operate machines after receiving proper instruction.
- Never bypass safety guards or interlocks on experimental setups.
- Ensure valves, clamps, and connections are secured before starting experiments.
- Do not leave equipment running unattended.

6. Emergency Procedures

- Be aware of the location of fire extinguishers, first aid kits, and emergency exits.
- In case of spillage, electrical fault, or injury, inform the lab supervisor immediately.
- For burns, cuts, or exposure to harmful fluids, seek medical attention promptly.

7. Waste Disposal

- Dispose of fluids, lubricants, and other materials as per laboratory guidelines.
- Never pour chemicals or oil into drains.

Institute Vision and Mission

Vision
Mission

Department Vision and Mission

Vision
Mission

Program Educational Objectives (PEOs)

Program Specific Outcomes (PSOs)

Course Outcomes (COs)

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Expt. No.:

Date:

Flow through Venturimeter

Aim:

To determine the coefficient of discharge (C_d) for a Venturimeter.

Outcome:

The student will be able to find the actual and theoretical discharges as well as the coefficient of discharge.

Apparatus:

Venturimeter meter fitted across a pipeline leading to a collecting tank, stopwatch, U-tube manometer connected across the entry and throat sections, etc.

Theory:

Clemens Herschel (1842–1930) was an American hydraulic engineer whose career spanned from approximately 1860 to 1930. He is best known for inventing the Venturimeter, the first large-scale, accurate device for measuring water flow.

A Venturimeter consists of a short converging section followed by a throat and a long diverging section. Pressure tapping is provided before the converging section begins, and another tapping is located at the throat. The pressure difference between these two points is measured using a U-tube manometer.

The Venturimeter operates based on Bernoulli's principle, which states that an increase in the velocity of a fluid results in a decrease in pressure. As fluid enters the converging section, its velocity increases, causing a drop in pressure. This pressure difference between the inlet and the throat is used to determine the flow rate through the pipe. The diverging section helps in recovering pressure, minimizing energy loss.

By using the continuity equation and Bernoulli's equation, the discharge through the Venturimeter can be calculated. The coefficient of discharge (C_d) is introduced to account for minor losses and deviations from the theoretical flow rate.

Observation:

Diameter of inlet d_1 =

Diameter of throat d_2 =

Internal plan dimensions of collecting tank, Length (L) =

Breadth (B) =

Tabulation:

Reading No.	Manometric Readings (m of Hg)			$h = \frac{X(S_m - S_f)}{S_f}$ (m)	$\sqrt{h}$ (m)	Time for H=___m rise time (t) (sec)	Discharge (m^3/sec)		Coefficient of discharge (C_d)
	h_1	h_2	$X=h_1-h_2$				Q_A	Q_T	

Where:

h_1 = manometric head in one limb of the manometer.

h_2 = manometric head in other limb of the manometer.

h = difference in head in terms of flowing liquid.

S_m = specific gravity of the manometric liquid (mercury) = 13.6

S_f = specific gravity of the flowing liquid (water) = 1.0

Experimental Setup:

The Venturimeter meter operates based on Bernoulli's equation. A Venturimeter is a device used to measure the flow rate of a fluid through a pipe. The Venturimeter (Fig. 1) consists of three main parts:

1. Converging cone
2. Throat
3. Diverging cone.

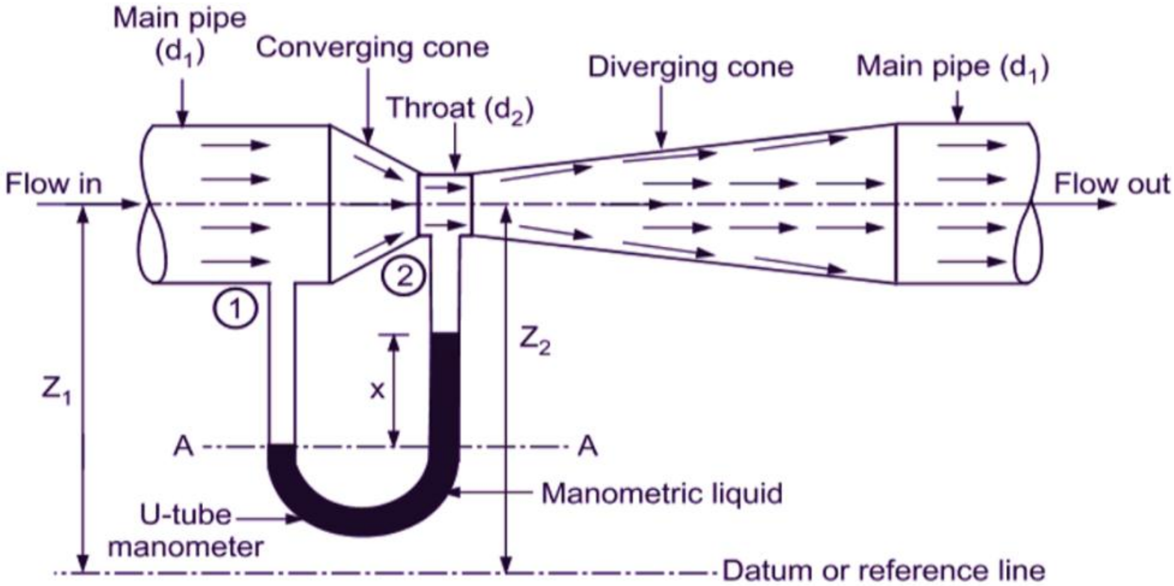


Figure 1. Venturimeter setup

Procedure:

1. The diameters of the inlet and throat are noted, and the internal plan dimensions of the collecting tank are measured.
2. With the outlet valve closed, the inlet valve is fully opened.
3. The outlet valve is slightly opened, and the manometric heads in both limbs are recorded.
4. The outlet valve of the collecting tank is tightly closed, and the time t required for the water level to rise by H in the collecting tank is measured using a stopwatch.
5. The above procedure is repeated by gradually increasing the flow and recording the required readings.
6. The observations are tabulated, and the coefficient of the Venturimeter is calculated.

Formulas Used:

1. Theoretical discharge $(Q_T) = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1{}^2 - a_2{}^2}} \left(\frac{m^3}{sec}\right)$

2. Actual discharge (Q_A)

$$= \frac{\text{Internal plan area of the collecting tank (A)} \times \text{Rise of liquid (H)}}{\text{Time for collection (t)}} \left(\frac{m^3}{sec}\right)$$

3. Coefficient of discharge $(Cd) = \frac{Q_A}{Q_T}$

Where:

a_1 = area of the inlet (m^2). ($\frac{\pi}{4} d_1{}^2$)

a_2 = area of the throat (m^2). ($\frac{\pi}{4} d_2{}^2$)

A = L x B (m^2).

g = acceleration due to gravity. (9.81 $\frac{m}{s^2}$)

Graph:

Graph 'Q_A' vs 'h' and 'Q_A' vs '$\sqrt{h}$' are plotted, taking 'h' and '$\sqrt{h}$'on X axis, respectively.

Result:

Coefficient of discharge (Cd) = ___________________

Viva Voce Questions and Answers

1. What is a Venturimeter?

   A Venturimeter is a device used to measure the flow rate of fluid in a pipeline based on Bernoulli's principle.

2. What principle does the Venturimeter work on?

   It works on Bernoulli's theorem, which states that an increase in fluid velocity results in a decrease in pressure.

3. What are the main components of a Venturimeter?

   - Converging section
   - Throat
   - Diverging section
   - Pressure tappings (before the converging section and at the throat)

4. Why is the throat provided in a Venturimeter?

   The throat reduces the cross-sectional area, increasing the velocity and reducing the pressure, which helps measure the flow rate.

5. What is the function of a U-tube manometer in this experiment?

   It measures the pressure difference between the inlet and the throat, which is used to calculate the discharge.

6. Why is Cd always less than 1?

   Due to energy losses caused by friction, turbulence, and viscosity.

7. Why is the diverging section longer than the converging section?

   To prevent flow separation and minimize energy losses.

8. What is the expected shape of the graph Q_actual vs. √h?

   It should be a straight line, as theoretical discharge is proportional to the square root of the pressure head difference.

9. What are the advantages of using a Venturimeter?

   - High accuracy
   - Low energy loss
   - Suitable for large flow rates

10. What are the limitations of a Venturimeter?

    - High installation cost
    - Requires a long straight pipe for accurate readings

11. How does viscosity affect Venturimeter readings?
    High viscosity increases frictional losses, reducing the accuracy of discharge measurement.
12. Why is Venturimeter preferred over an Orifice meter?
    It has lower energy losses and provides more accurate and stable readings.

Applications of Venturimeter

1. Flow Measurement in Pipelines

   Used in industries to measure the discharge of liquids and gases in pipelines.

2. Water Supply Systems

   Helps monitor and regulate water flow in municipal water distribution networks.

3. Oil and Gas Industry

   Used to measure crude oil, natural gas, and petroleum product flow in refineries and pipelines.

4. Chemical and Process Industries

   Helps in the precise measurement of liquid chemicals and gases in various chemical processes.

5. Irrigation Systems

   Used to measure and control water flow in agricultural irrigation channels.

6. Hydraulic and Aerodynamic Studies

   Applied in research laboratories for studying fluid flow behavior and validating Bernoulli's theorem.

7. Ventilation and HVAC Systems

   Measures airflow in heating, ventilation, and air conditioning (HVAC) systems to ensure efficient operation.

8. Steam Power Plants

   Used to monitor steam flow in power generation plants for efficiency and safety.

9. Medical Applications

   The principle of the Venturimeter is used in Venturi masks to regulate oxygen flow for patients.

10. Automobile Industry

    Used in carburetors to regulate the fuel-air mixture for combustion in internal combustion engines.

Expt. No.:

Date:

Determination of Friction Factor for Flow through Pipes

Aim:

To determine the friction factor (f) in a pipe carrying water.

Outcome:

The student will be able to determine the major loss due to friction and its effects in pipe flow.

Apparatus:

U-tube manometer connected across a pipeline, stopwatch, and collecting tank.

Theory:

In fluid dynamics, the Darcy–Weisbach equation is an empirical equation that relates head loss (or pressure loss) due to friction along a given length of pipe to the average velocity of an incompressible fluid. The equation is named after Henry Darcy and Julius Weisbach (1806–1871).

A pipe is a closed conduit used for carrying fluids under pressure. Pipes are commonly circular in cross-section. Since they transport fluids under pressure, they always run full.

When fluid flows through a pipe, it experiences resistance due to shear forces between fluid particles and the boundary walls of the pipe, as well as between the fluid particles themselves. This resistance is caused by the viscosity of the fluid and is generally known as frictional resistance. Since a certain amount of energy is consumed in overcoming this resistance, there is always some loss of energy in the direction of flow. The extent of this loss depends on the type of flow.

W. Froude conducted a series of experiments to investigate the frictional resistance offered to flowing water by different surfaces.

According to the Darcy–Weisbach equation:

$$\text{Loss of head due to friction } (h_f) = \frac{4flv^2}{2gd}$$

This equation is used to determine the head loss due to friction in pipes.

Observation:

Diameter of the pipe d = m

Length of the pipe l = m

Internal plan dimensions of collecting tank, Length (L) = m

Breadth (B) = m

Tabulation:

Reading No.	Manometric readings (m of Hg)			Frictional head loss $h_f = \frac{X(S_m - S_f)}{S_f}$ (m)	Time for H=___m rise time (t) (sec)	Actual discharge $(\frac{m^3}{sec})$	Velocity (V) $(\frac{m}{sec})$	V^2 $(\frac{m}{sec})^2$	Friction factor (f)
	h_1	h_2	$X=h_1-h_2$						

Where:

h_1 = manometric head in one limb of the manometer.

h_2 = manometric head in other limb of the manometer.

h_f = frictional head loss.

S_m = specific gravity of the manometric liquid (mercury) = 13.6

S_f = specific gravity of the flowing liquid (water) = 1.0

To accurately determine the head loss due to friction, it is essential to estimate the friction factor (f) correctly. When fluid flows through a pipe, it encounters resistance, which results in energy loss.

The energy losses in pipes are classified into two types:

Major losses – caused by friction along the length of the pipe.

Minor losses – caused by pipe fittings, bends, valves, expansions, and contractions.

The major energy loss in pipe flow is primarily due to friction, which can be calculated using the Darcy–Weisbach equation. This type of energy loss is considered significant because, in long pipelines, it is often much greater than energy losses from other causes.

Experimental Setup:

The equipment used in the experiment included the fluid flow setup, while the materials used were a steel tape, stopwatch, and thermometer. Water was used as the working fluid. The pump was primed and started to initiate the flow along the pipelines. The collecting tank was used to collect water for calculating the volumetric flow rate. Figure 1 shows the experimental setup for fluid flow measurement.

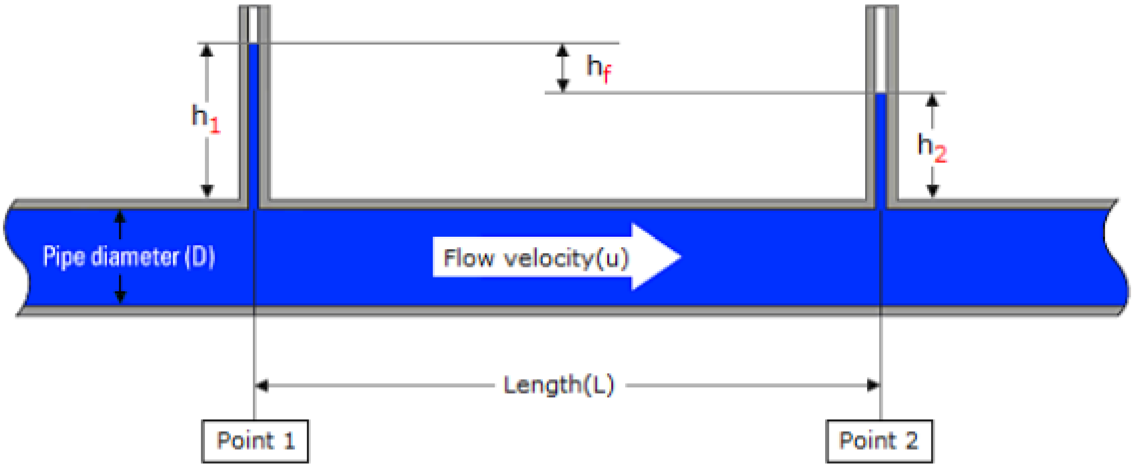


Figure 1. Experimental setup for fluid flow measurement

Procedure:

1. Setup Preparation:
   - Ensure that all equipment, including the fluid flow setup, pump, U-tube manometer, collecting tank, stopwatch, and thermometer, is properly installed and functional.

- Check for any leaks in the pipeline system and ensure that all valves are in the closed position before starting.

2. Priming and Starting the Pump:

- Prime the pump to remove air from the system and ensure smooth operation.
- Start the pump to initiate fluid flow through the pipeline.

3. Adjusting the Flow Rate:

- Gradually open the inlet valve to allow water to flow through the pipeline.
- Adjust the outlet valve to set the desired flow rate for measurement.

4. Measuring Pressure Head:

- Observe the U-tube manometer readings at the inlet and throat sections of the pipe.
- Record the difference in manometer levels (h) to determine the pressure drop.

5. Measuring the Flow Rate:

- Close the outlet valve of the collecting tank.
- Using a stopwatch, record the time (t) taken for a known rise in water level (H) in the collecting tank.
- Repeat this process for different flow rates by adjusting the outlet valve.

6. Repeating the Readings:

- Take multiple sets of readings by varying the flow rate and recording corresponding pressure head differences.
- Ensure consistent readings to improve accuracy.

7. Calculating the Friction Factor:

- Use the recorded data to compute the friction factor (f) using the Darcy-Weisbach equation.

8. Shutting Down the System:

- Gradually close the inlet valve and turn off the pump.
- Drain any remaining water and clean the equipment for the next experiment.

Formulas Used:

1. Actual discharge $(Q_A) = \frac{\text{Internal plan area of the collecting tank (A)} \times \text{Rise of liquid (H)}}{\text{Time for collection (t)}} \left(\frac{m^3}{sec}\right)$

2. Velocity $(V) = \frac{Q_A}{a} \ (\frac{m}{sec})$

3. Friction factor $(f) = \frac{h_f \, 2gd}{4lv^2}$

Where:

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

A = L x B (m^2).

g = acceleration due to gravity. (9.81 $\frac{m}{S^2}$)

Graph:

A graph of 'h_f' vs 'V^2' are plotted, taking 'h_f' on X axis, respectively.

Result:

The friction factor 'f' for the pipe is found to be = ______________________

Viva Voce Questions and Answers

1. What is the friction factor in fluid flow?

   The friction factor (f) is a dimensionless quantity that represents the resistance to flow due to friction within a pipe. It is used in the Darcy-Weisbach equation to calculate head loss.

2. What are the major and minor losses in pipe flow?

   - Major losses occur due to friction within the pipe.
   - Minor losses occur due to fittings, bends, valves, and sudden expansions or contractions in the pipe.

3. How is the friction factor determined experimentally?

   The friction factor is determined by measuring the pressure drop across a known length of pipe and using the Darcy-Weisbach equation.

4. What are the factors affecting the friction factor?

   The friction factor depends on the Reynolds number, pipe roughness, pipe diameter, and flow velocity.

5. What is the difference between laminar and turbulent flow in terms of friction factor?

   - In laminar flow (Re < 2000), the friction factor is given by $f = \frac{64}{Re}$
   - In turbulent flow (Re > 4000), the friction factor is determined using the Moody chart or empirical correlations like Colebrook's equation.

6. How does Reynolds number influence the friction factor?

   Reynolds number (Re) helps classify the flow as laminar, transitional, or turbulent. The friction factor decreases with increasing (Re) in turbulent flow.

7. What is the significance of the Moody diagram?

   The Moody diagram is a graphical representation of the friction factor as a function of Reynolds number and relative roughness of the pipe.

8. Why do we use a U-tube manometer in this experiment?

   A U-tube manometer is used to measure the pressure difference across the pipe, which helps determine head loss due to friction.

9. What is the relationship between head loss and velocity?

   Head loss due to friction (h_f) is proportional to the square of velocity (V^2), as given by the Darcy-Weisbach equation.

10. Why is friction loss more significant in longer pipelines?

    As the pipe length increases, the frictional resistance to flow increases, leading to greater energy loss.

Applications of Friction Factor Analysis

11. Pipeline Design and Optimization

    Used in designing water supply, oil, and gas pipelines to minimize energy losses. Helps in selecting appropriate pipe diameters and materials for efficient fluid transport.

12. Water Distribution Systems

    Determines pressure loss in municipal water supply networks. Ensures efficient water flow in irrigation and drainage systems.

13. HVAC (Heating, Ventilation, and Air Conditioning) Systems

    Helps in calculating pressure drops in air ducts and cooling systems. Ensures optimal airflow in ventilation systems.

14. Chemical and Process Industries

    Essential for designing chemical reactors and heat exchangers. Helps in controlling fluid flow in industrial processing pipelines.

15. Oil and Gas Industry

    Used in petroleum pipeline transportation to reduce pumping power requirements. Helps in designing offshore and onshore pipelines.

16. Power Plants

    Used in boiler feedwater systems to analyze frictional losses. Helps in cooling water circulation systems.

17. Automotive and Aerospace Engineering

    Determines fuel flow characteristics in engine fuel injection systems. Analyzes aerodynamic drag and coolant flow in vehicle radiators.

18. Firefighting Systems

    Ensures adequate water pressure in fire hydrants and sprinkler systems.

19. Wastewater Treatment Plants

    Helps in designing sewage and wastewater pipelines for efficient flow.

20. Hydraulic Engineering

    Used in designing canals, stormwater drainage, and flood control systems.

Expt. No.:

Date:

Determination of Metacentric Height

Aim:

To determine the Metacentric Height (GM) of a floating body and analyze the stability conditions under various loading conditions.

Outcome:

Students will understand the concept of metacentric height and its significance in ship stability. They will also learn how to practically determine GM using experimental data.

Apparatus:

- Floating vessel (pontoon or barge-type model)
- Water tank
- Movable weight (sliding mass)
- Weight scale
- Ruler or measuring scale
- Plumb line or pointer scale
- Spirit level

Theory:

The metacentric height (GM) is a measure of the static stability of a floating body. It is the distance between the center of gravity (G) and the metacenter (M). When a floating body is tilted, the point where the line of action of buoyant force intersects the vertical axis is the metacenter.

The stability conditions are:

- If $GM > 0 \rightarrow$ Stable equilibrium
- If $GM = 0 \rightarrow$ Neutral equilibrium
- If $GM < 0 \rightarrow$ Unstable equilibrium

Observation:

Weight of the ship model W_s = 4.9 kgs

Tabulation:

Sl. No.	W_1 (kg)	W_2 (kg)	l_1 (m)	l_2 (m)	θ	GM

Experimental Setup:

A model barge or pontoon is placed in a water tank. A movable weight is placed on the deck of the floating body. When this weight is shifted laterally, the floating body tilts and the tilt angle is measured using a plumb line or pointer. The tilt causes a shift in the center of buoyancy, and the point of intersection of the vertical through the new buoyant force line with the original vertical is called the metacenter. Figure 1 shows the experimental setup for metacentric height and stability of floating body.

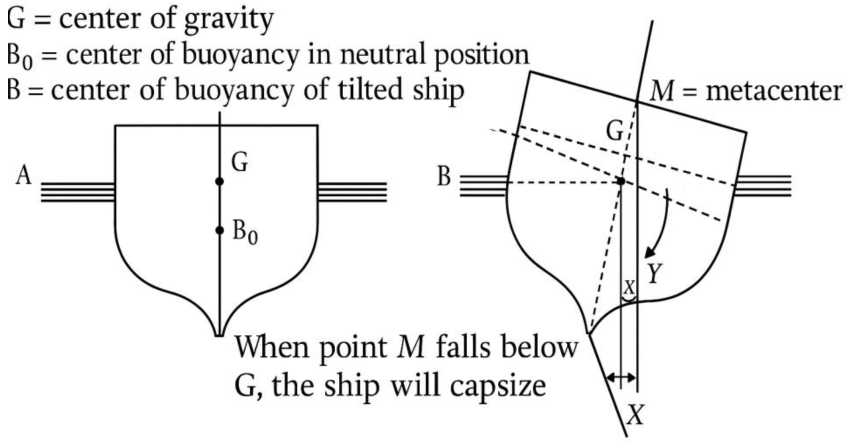


Figure 1. Metacentric Height and Stability of Floating Body.

Procedure:

1. Fill the tank with water and place the floating vessel in it so that it floats freely.
2. Ensure the vessel is balanced and the pointer or plumb line reads zero at the center.
3. Measure and note down the weight of the floating vessel and the sliding weight.
4. Move the sliding weight to a known distance 'x' from the centerline and note the tilt angle ‘θ’ using the scale.
5. Repeat the procedure by changing the position of the weight (increasing x).
6. Record the readings for different values of x and corresponding angle θ.
7. Use the formula to compute GM for each set of readings.

Formulas Used:

1. Metacentric Height (GM) $= \frac{W_1 \, W_2 - l_1 \, l_2}{W_s \tan\theta}$

Where:

W_1 and W_2: Movable weights on either side of the tilting beam.

l_1 and l_2: Corresponding distances of the weights from the centerline.

W_s : Total weight of the floating body (ship model).

θ: Angle of heel (in radians).

Result:

The average value of metacentric height (GM) of the floating body was found to be in the range of ________ meters, indicating the vessel is (stable/unstable/neutrally stable) under the given conditions.

Viva Voce Questions and Answers

1. What is metacentric height?

   Metacentric height (GM) is the distance between the center of gravity (G) and the metacenter (M) of a floating body. It is a key parameter in determining the stability of the body. A larger GM implies better stability.

2. Define center of buoyancy and metacenter.

   Center of Buoyancy (B): It is the point through which the buoyant force acts, and it is the centroid of the displaced volume of fluid.

   Metacenter (M): It is the point of intersection of the buoyant force line before and after a small angular tilt. It lies above the center of buoyancy for a stable floating body.

3. What does a positive GM indicate?

   A positive GM means the metacenter is above the center of gravity, indicating that the floating body is stable and will return to its original position after tilting.

4. How does the weight shift affect the stability of a floating body?

   When a weight is shifted laterally, it creates a moment that tilts the body. This causes a shift in the center of buoyancy, and the body's ability to return to equilibrium depends on the GM. A smaller GM leads to lower stability.

5. Why is the angle of tilt important in this experiment?

   The angle of tilt (θ) is essential to calculate the metacentric height using the moment equilibrium. Accurate measurement of θ ensures correct determination of GM.

6. What are the limitations of this experimental method?

   Water surface may not remain perfectly still, causing measurement errors.

   Friction in the pivot or beam may affect results.

   Inaccurate weight placement or measurement affects precision.

7. What happens if the metacenter lies below the center of gravity?

   If the metacenter (M) lies below the center of gravity (G), the metacentric height (GM) is negative, and the floating body becomes unstable, leading to capsizing.

8. What is the use of determining the metacentric height?

   It helps in designing stable ships and floating structures. A sufficient GM ensures safety against tilting and capsizing under external disturbances.

Practical Applications of Metacentric Height

1. Ship design and naval architecture

   Metacentric height is crucial in designing ships, submarines, and boats. A proper GM ensures that the vessel remains stable even in rough seas or when cargo shifts.

2. Floating platforms and offshore structures

   Structures like oil rigs, floating cranes, and pontoons rely on metacentric height for stability during operations in water bodies.

3. Submarines and underwater vehicles

   Understanding GM helps in balancing buoyancy and weight distribution to ensure controlled diving and surfacing of submarines.

4. Buoy design

   Navigation buoys and other floating markers are designed to remain upright using appropriate metacentric height to prevent tilting due to wind or current.

5. Marine safety assessments

   Before setting out to sea, marine engineers use GM to evaluate the vessel’s stability with varying load conditions and during fuel consumption.

6. Floating bridges and modular pontoon systems

   These systems need to maintain horizontal alignment despite movement; a calculated GM ensures they don’t tilt or become unstable under load.

7. Water sports equipment

   Equipment like kayaks, paddleboards, and floating docks also depend on a stable metacentric height to ensure balance and user safety.

Expt. No.:

Date:

Determination of Forces Due to Impact of Jet on a Fixed Plate

Aim:

To determine the force exerted by a jet of water on different types of stationary plates (flat plate, inclined plate, and curved plate) and to compare the experimental and theoretical forces.

Outcome:

After performing this experiment, students will be able to:

- Understand the impact of a jet on different plate orientations.
- Determine the theoretical and experimental forces exerted by a jet.
- Analyze the variation of force with velocity and angle of impact.

Apparatus:

- Impact of jet apparatus (including nozzle and plates: flat, inclined, curved)
- Water supply system
- Measuring tank (for collecting discharged water)
- Stopwatch
- U-tube manometer (for pressure measurement)
- Scale or Vernier calipers (for measuring dimensions)

Theory:

When a jet of water strikes a stationary plate, it exerts a force due to the change in momentum of the fluid. The force exerted by the jet depends on the velocity, cross-sectional area of the jet, and angle of impact.

Experimental Setup:

The impact of jet apparatus consists of a water nozzle that directs a jet onto a stationary plate (which can be flat, inclined, or curved). The water flow rate is controlled by a valve, and the force exerted is measured by balancing the deflected plate with weights. Figure 1 shows the experimental setup for jet of water striking a fixed plate a) jet striking a fixed flat plate at centre, b) jet striking a inclined flat plate at centre and c) jet striking a fixed curved plate at centre.

Observation:

Diameter of the jet, d = m

Tabulation:

Sl. No.	Plate type	Total head (h) (m)		Mass (kg)	Experimental Force (N)	Theoretical Force (N)	% Error
		kg/cm^2	m				

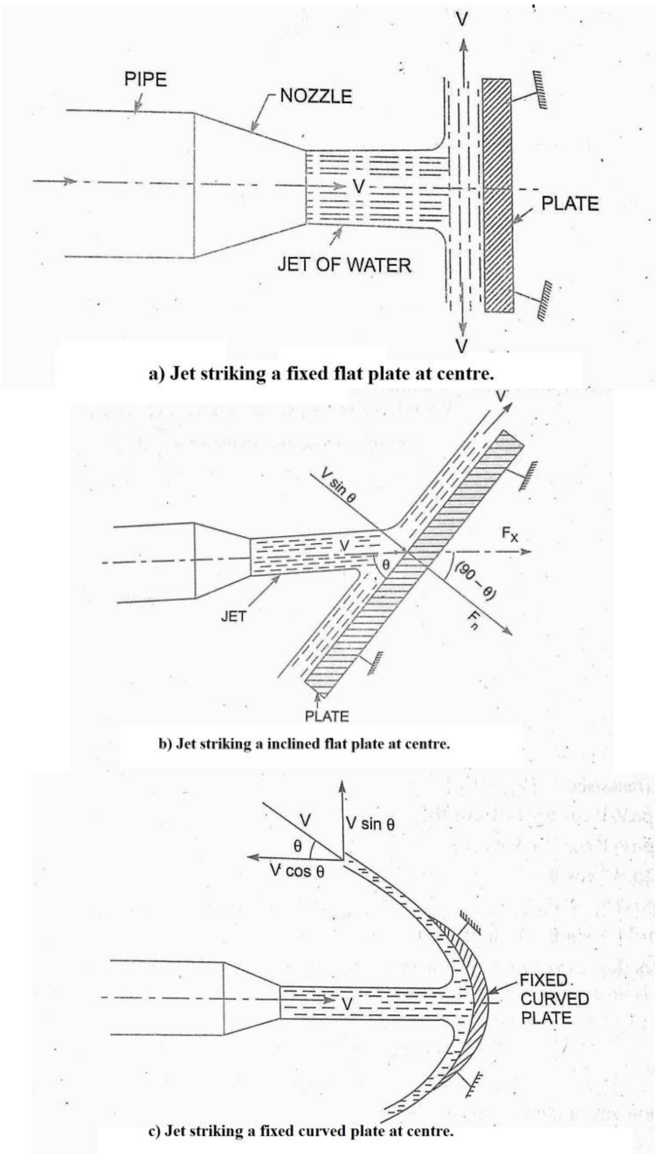


Figure 1. Experimental setup for jet of water striking a fixed plate

Procedure:

1. Set the apparatus with the required plate (flat, inclined, or curved).
2. Ensure the water supply is steady and set the desired flow rate.
3. Record the force reading by balancing the plate using weights.
4. Repeat steps 2 to 5 for different flow rates and different plates.
5. Calculate the theoretical force using the formulas provided.
6. Compare the theoretical and experimental forces for validation.

Formulas Used:

1. Experimental Force (F_{EXP})

F_{EXP} = W = mxg

Where:

W = weight required to balance the force exerted by the jet on the plate (N)

m = Mass added to balance the force (kg)

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

2. Theoretical Force

a) Force on a stationary flat plate (normal to the jet):

$F = \rho a V^2$ (N)

b) Force on an inclined plate (normal component):

$F_n = \rho a V^2 \sin\theta$ (N)

c) Force on an inclined plate (along the direction of the jet):

$F_x = \rho a V^2 \sin^2\theta$ (N)

d) Force on a curved plate (for full deflection):

$F_x = \rho a V^2 (1+\cos\theta)$ (N)

Where:

ρ = density of water (1000 kg/m^3)
a = area of jet ($\frac{\pi}{4} d^2$) (m^2)
V = velocity of jet (m/s) ($V = \sqrt{2gh}$)
h = head causing the jet to flow (m)

θ = angle of the inclined plate

For inclined flat plates: θ = inclination angle.

For curved plates (deflecting the jet): θ = 180° − deflection angle.

3. % Error

$$\% \text{ Error} = \frac{(\text{Theoretical Force} - \text{Experimental Force})}{\text{Theoretical Force}} \text{ X } 100$$

Result:

The force exerted by the jet on different plates is determined, and the experimental values are compared with theoretical values.

Viva Voce Questions and Answers

1. What is the impact of a jet?

   It is the force exerted by a fluid jet when it strikes a surface.

2. What is the principle behind the impact of a jet experiment?

   The experiment is based on the principle of momentum change. When a jet of water strikes a surface, it changes direction, resulting in a change in momentum, which exerts a force on the plate.

3. What factors affect the force exerted by a jet?

   Velocity of the jet, mass flow rate, density of fluid, and plate orientation.

4. What is the difference between theoretical and experimental force?

   Theoretical force is calculated using ideal conditions, while experimental force is measured from actual jet impact.

5. Why do we use different types of plates in this experiment?

   Different plates help analyze how the angle and shape of the surface affect the force exerted by the jet. Inclined and curved plates demonstrate how the direction of impact influences momentum change and force distribution.

6. Why do we use a curved plate in the experiment?

   A curved plate changes the jet direction, leading to higher force due to added reaction force.

7. What factors affect the force exerted by the jet?

   The force depends on:

   - The velocity of the jet
   - The mass flow rate of water
   - The density of water
   - The angle of impact
   - The shape of the plate

8. How can the accuracy of this experiment be improved?

   - Reducing friction and leakage in the apparatus
   - Ensuring precise measurement of velocity and weight
   - Minimizing parallax errors while taking readings
   - Using a well-calibrated flow measurement system

Applications of the Impact of Jet Experiment

8. Hydraulic Turbines:
   This experiment helps in understanding the working principle of impulse turbines (e.g., Pelton wheel), where high-velocity jets strike turbine blades to generate power.
9. Water Jet Cutting:
   Used in industrial applications for precision cutting of materials like metals, glass, and ceramics using high-pressure water jets.
10. Design of Hydraulic Structures:
    Helps in designing spillways, weirs, and dam structures where water impact forces need to be analyzed for safety and efficiency.
11. Firefighting Equipment:
    The principle is applied in firefighting nozzles to optimize jet force and direction for maximum impact.
12. Cleaning Systems:
    High-pressure jets are used in industrial cleaning systems, such as car washes, ship hull cleaning, and pipeline maintenance.
13. Rocket and Jet Propulsion:
    The momentum change concept is applied in jet engines and rockets where high-speed exhaust gases produce thrust.
14. Agricultural Irrigation Systems:
    Sprinkler systems use jet impact principles to distribute water efficiently over crops.

Expt. No.:

Date:

Characteristics of Centrifugal Pump

Aim:

To determine the performance characteristics of a centrifugal pump and evaluate its discharge, head, input power, output power, and efficiency.

Outcome:

Students will be able to understand the working principle of a centrifugal pump and analyze its performance characteristics by evaluating discharge, head, power, and efficiency under various operating conditions.

Apparatus:

- Centrifugal Pump Test Rig
- Pressure Gauges
- Measuring Tank
- Stopwatch
- Energy Meter

Theory:

A centrifugal pump is a dynamic pump that works on the principle of centrifugal force. When the impeller rotates, it imparts kinetic energy to the fluid, which is then converted into pressure energy at the pump outlet. It is commonly used for transporting liquids over various flow rates and heads.

Experimental Setup:

The centrifugal pump is connected to a water tank and is powered by an electric motor. Pressure gauges are installed at the suction and delivery pipes. A measuring tank and stopwatch are used to determine the flow rate, and the energy meter records power input. Figure 1 illustrates the schematic diagram of a centrifugal pump.

Observation:

Energy meter constant (N_c) =
Specific weight of water = 9810 N/m^3
Level difference between the suction and delivery pressure gauges = (m)

Tabulation:

Sl. No.	Suction Head H_s		Pressure Head H_d		Total Head $h = X+(H_s+H_d)$ (m of H_2O)	Manometer readings (m)			Time for N_r revolutions of energy meter disc. T (sec)	Actual Discharge Q_A		Input Power P_I (Watts)	Output Power P_O (Watts)	Efficiency (%)
	mm of H_g	m of H_2O	kg/cm^2	m of H_2O		h_1	h_2	h_1-h_2		Lpm	(m^3/sec)			

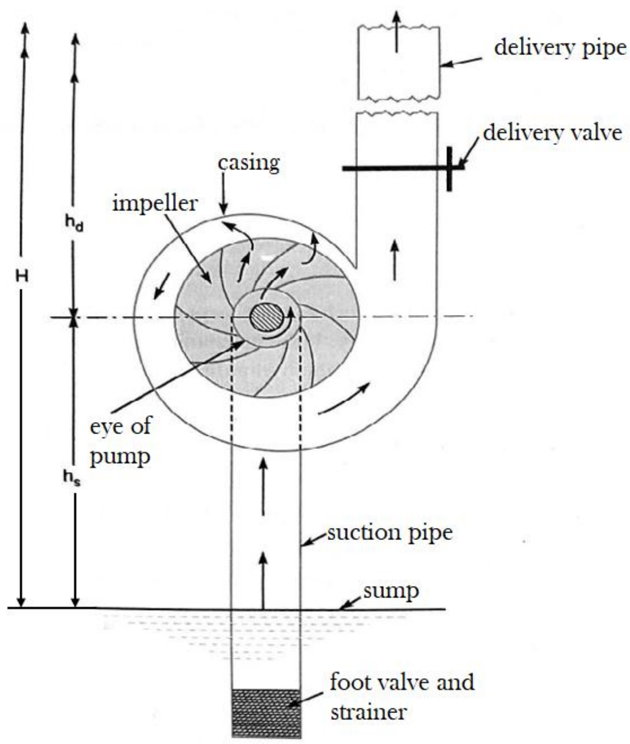


Figure 1. Schematic diagram of a centrifugal pump.

Procedure:

1. Fill the sump tank and prime the centrifugal pump properly to remove air inside.
2. Start the motor and allow it to reach a steady speed.
3. Record suction and delivery pressure readings from the gauges.
4. Use the discharge vs head calibration graph provided with the setup to determine the discharge corresponding to the observed delivery head (instead of using a measuring tank and stopwatch).
5. Measure the input power using the energy meter.
6. Repeat the procedure by adjusting the delivery valve to vary the flow rate and note down the corresponding pressures and input power.
7. Calculate discharge, total head, input power, output power, and efficiency for each set of readings.

Formulas Used:

1. $\text{Input Power } (P_I) = \dfrac{3600 \text{ x } N_r \text{ x } 1000}{N_c \text{ x } T}$ (Watts)

2. $\text{Output Power } (P_O) = W \text{ x } Q_A \text{ x } h$ (Watts)

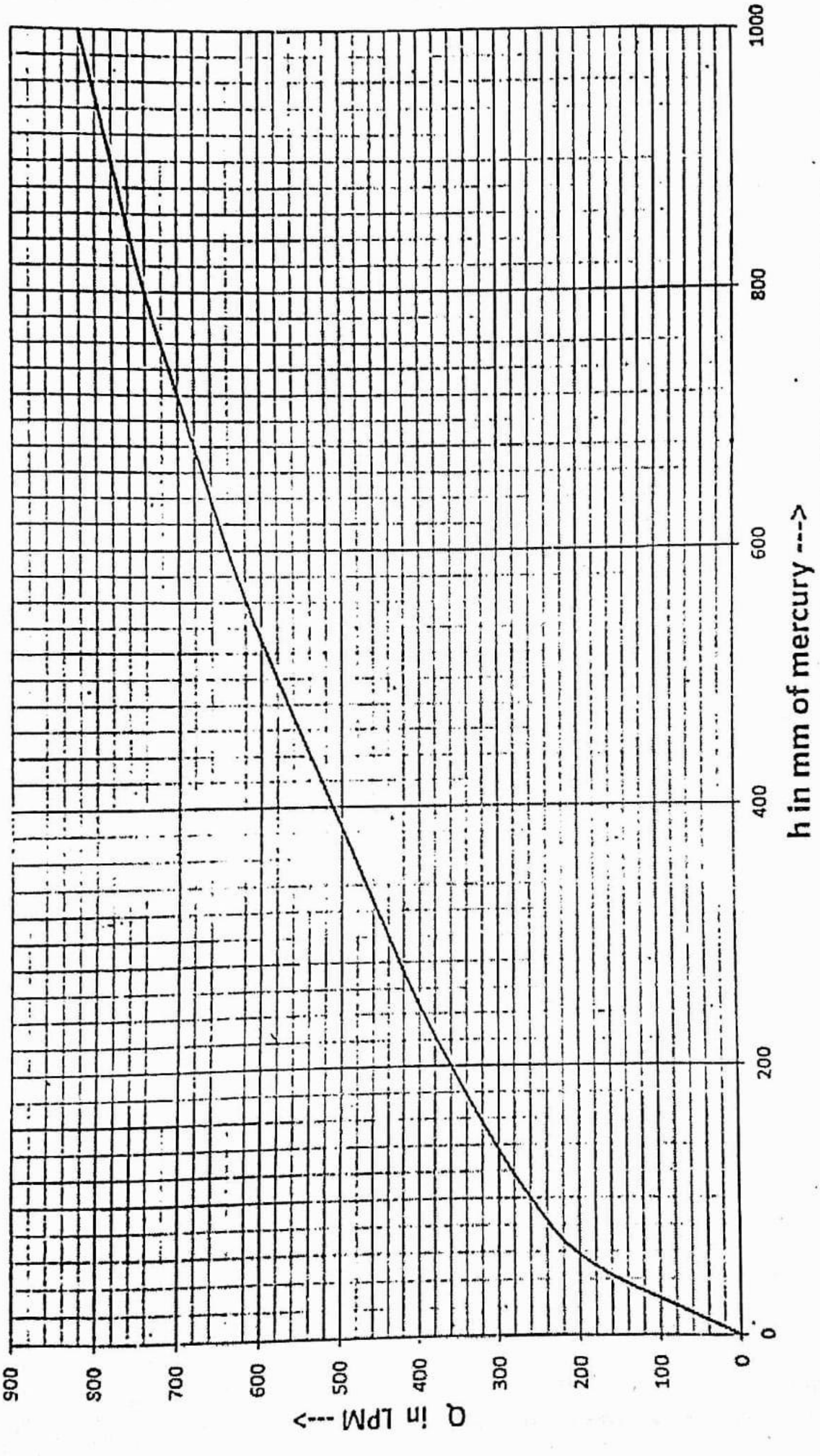
3. $\text{Efficiency} = \dfrac{\text{Output Power } (P_O)}{\text{Input Power } (P_I)} \text{ x } 100$

Graph: The following curves are drawn, taking actual discharge on the X-axis:

- Discharge vs Head
- Discharge vs Efficiency
- Discharge vs Input Power

Result:

The performance characteristics of the centrifugal pump were determined, and the efficiency of the pump ________________.



CALIBRATION CHART FOR 60mm ORIFICEMETER WITH AREA RATIO 0.45

Viva Voce Questions and Answers

1. What is the working principle of a centrifugal pump?

   A centrifugal pump works on the principle of centrifugal force-fluid enters the impeller eye, is accelerated radially outward, and gains kinetic and pressure energy.

2. How is a centrifugal pump different from a reciprocating pump?

   A centrifugal pump is a dynamic pump with continuous flow, whereas a reciprocating pump is a positive displacement pump that delivers intermittent flow.

3. What is the significance of pump priming?

   Priming removes air from the suction line, ensuring the pump casing is filled with liquid for proper functioning and avoiding cavitation.

4. Define total head.

   Total head is the sum of suction head and delivery head; it represents the energy per unit weight the pump adds to the fluid.

5. What factors affect the performance of a centrifugal pump?

   Flow rate, impeller design, fluid viscosity, speed, and system resistance affect the performance.

6. What is cavitation in centrifugal pumps and how can it be prevented?

   Cavitation occurs when pressure in the pump falls below the vapor pressure of the liquid, forming vapor bubbles that collapse and damage the pump. It can be prevented by proper priming and maintaining Net Positive Suction Head (NPSH).

7. What is Net Positive Suction Head (NPSH)?

   NPSH is the difference between the suction pressure and the vapor pressure of the fluid. It ensures the fluid remains in liquid state and avoids cavitation.

8. What is the role of the delivery valve in the experiment?

   The delivery valve regulates flow rate and head, allowing the pump to operate under different load conditions.

9. Why is efficiency not 100% in real pumps?

   Due to hydraulic losses, mechanical losses, and leakage, some input energy is lost, reducing efficiency.

10. What happens if the pump runs without priming?

    It may suck air, cause cavitation, overheating, and damage to the impeller or motor.

Practical Applications of Centrifugal Pump

15. Water Supply Systems

    Used in domestic, municipal, and industrial water distribution networks.

16. Irrigation and Agriculture

    Pumps water from wells, canals, or reservoirs to fields via pipelines or sprinklers.

17. Chemical and Petrochemical Industries

    Used to handle chemicals, solvents, and fuels due to their ability to handle various fluid types.

18. Power Plants

    Circulates cooling water, boiler feed water, and condenser water.

19. HVAC Systems (Heating, Ventilation, and Air Conditioning)

    Moves chilled or hot water through heat exchangers and coils.

20. Food and Beverage Industry

    Transfers dairy products, juices, syrups, and other liquids hygienically.

21. Wastewater Treatment Plants

    Pumps sewage, sludge, and treated water at different stages of treatment.

22. Fire Protection Systems

    Installed in buildings and industrial setups for emergency fire water supply.

23. Mining and Construction

    Used for dewatering, slurry transport, and material handling.

Expt. No.:

Date:

Characteristics of Reciprocating Pump

Aim:

To determine the performance characteristics of a reciprocating pump by evaluating its discharge, input power, output power, and overall efficiency.

Outcome:

After performing this experiment, students will be able to:

- Understand the working principle and operation of a reciprocating pump.
- Analyze the relationship between discharge, head, and efficiency.
- Calculate the input power, output power, and efficiency of the pump.
- Develop characteristic curves to evaluate pump performance.
- Compare theoretical and experimental results to assess accuracy.

Apparatus:

- Reciprocating Pump Test Rig
- Measuring Tank
- Stopwatch
- Pressure Gauges
- Energy Meter

Theory:

A reciprocating pump is a positive displacement pump that moves fluid using a piston or plunger inside a cylinder. It operates by drawing fluid into the cylinder through an inlet valve during the suction stroke and discharging it through an outlet valve during the delivery stroke. Reciprocating pumps are used in applications requiring high-pressure fluid delivery.

Experimental Setup:

The reciprocating pump test rig consists of a reciprocating pump connected to a water tank, pressure gauges, an energy meter, and a flow measuring system. The pump is driven by

Observation:

Specific weight of water (w) = 9810 N/m^3

Internal plan dimensions of collecting tank, Length (L) = m

Breadth (B) = m

Energy meter constant, (N_c) = rev/kWh

Number of revolutions of energy meter disc (N_r) =

Difference in level between the centres of the vacuum & pressure gauges, (X) = m

Tabulation:

Sl. No.	Suction Head H_s		Pressure Head H_d		Total Head $h = X+(H_s+ H_d)$ (m of H_2O)	Time for H = __m rise of water, t (sec)	Time for N_r revolutions of energy meter disc. T (sec)	Actual Discharge Q_A (m^3/sec)	Input Power P_I (Watts)	Output Power P_O (Watts)	Efficiency (%)
	mm of H_g	m of H_2O	kg/cm^2	m of H_2O							

an electric motor, and the readings of discharge, pressure, and power consumption are recorded for analysis. Figure 1 shows the experimental setup for reciprocating pump test rig.

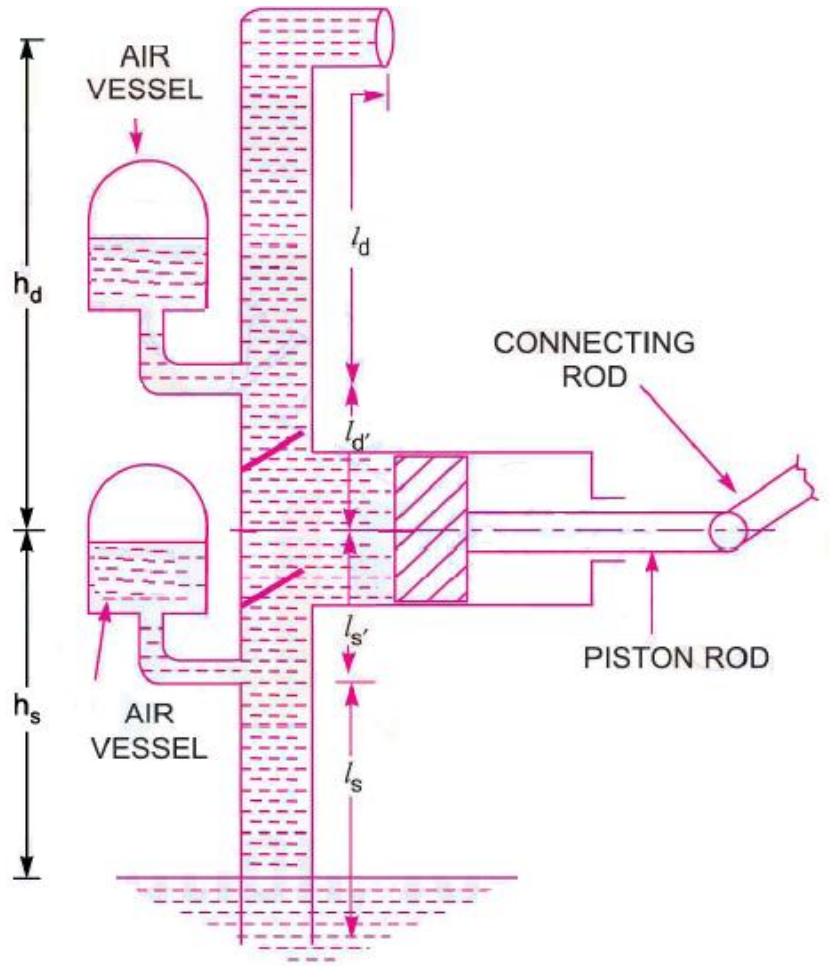


Figure 1. Reciprocating pump test rig setup.

Procedure:

1. Check the water level in the sump tank and ensure the pump is primed.
2. Start the motor and allow the pump to run at a steady speed.
3. Record the suction and delivery pressures from the pressure gauges.
4. Measure the power consumption using the energy meter.
5. Collect a known volume of water in the measuring tank and note the time using a stopwatch.
6. Repeat the procedure for different flow rates by adjusting the delivery valve.
7. Calculate the discharge, head, input power, output power, and efficiency using the formulas provided.

Formulas Used:

1. Actual discharge (Q_A)

$$= \frac{\text{Internal plan area of the collecting tank (A)} \times \text{Rise of liquid (H)}}{\text{Time for collection (t)}} \left(\frac{m^3}{sec}\right)$$

Where:

A = L x B (m^2).

2. $\text{Input Power } (P_I) = \frac{3600 \text{ x } N_r \text{ x } 1000}{N_c \text{ x } T} \quad \text{(Watts)}$

3. $\text{Output Power } (P_O) = W \text{ x } Q_A \text{ x } h \quad \text{(Watts)}$

Where:

W = Specific weight of water. (9810 N/m^3)

4. $\text{Efficiency} = \frac{\text{Output Power } (P_O)}{\text{Input Power } (P_I)} \text{ x } 100$

Graph:

The following graph is drawn, taking Head (h) on the X-axis: Head (h) vs Efficiency (%).

Result:

The performance characteristics of the reciprocating pump were determined, and the efficiency of the pump ________________.

Viva Voce Questions and Answers

1. What is a reciprocating pump?

   A reciprocating pump is a positive displacement pump that uses a piston or plunger to move fluid through a cylinder.
2. What are the main components of a reciprocating pump?

   Cylinder, piston/plunger, suction and delivery valves, crankshaft, and connecting rod.
3. What is meant by the performance characteristics of a pump?

   It refers to how the discharge, head, power, and efficiency vary with changes in operating conditions.
4. What is theoretical discharge in a reciprocating pump?

   It is the ideal discharge calculated from the pump's geometry and speed without considering losses.
5. What factors affect the efficiency of a reciprocating pump?

   Frictional losses, leakage, valve timing, speed, and wear and tear.
6. Why is it important to determine the efficiency of a pump?

   To evaluate energy losses and the overall performance of the pump for proper selection and operation.
7. What is cavitation, and how can it affect a reciprocating pump?

   Cavitation is the formation of vapor bubbles due to low pressure; it can damage pump components and reduce efficiency.
8. What is slip in a reciprocating pump?

   The difference between theoretical discharge and actual discharge due to leakage or valve inefficiencies.
9. What is the difference between a centrifugal pump and a reciprocating pump?

   A centrifugal pump is a rotodynamic pump using centrifugal force for fluid motion, suitable for high flow rates.

   A reciprocating pump is a positive displacement pump that moves a fixed volume of fluid per cycle, suitable for high-pressure, low-flow applications.
10. How does the speed of the pump affect its discharge?

    An increase in speed increases the number of strokes per minute, which directly increases the discharge.

11. Why is priming necessary in a reciprocating pump?

    Priming removes air from the suction line, allowing atmospheric pressure to push the fluid into the pump cylinder.

Applications of the Impact of Jet Experiment

1. Boiler feed applications

   Used to feed water into boilers where high pressure is required.
2. Oil and gas industries

   Ideal for pumping crude oil, refined petroleum, and natural gas under high pressure.
3. Hydraulic systems

   Used in hydraulic presses, jacks, and lifts for transmitting hydraulic power.
4. Water supply systems

   Suitable for domestic and industrial water supply, especially in areas with low water pressure.
5. Chemical industries

   Used to pump corrosive or viscous fluids accurately.
6. Irrigation systems

   Helps in lifting water from wells, canals, or reservoirs to fields.
7. High-Pressure cleaning

   Used in pressure washers for cleaning with high-velocity water jets.
8. Dosing and metering applications

   Suitable for precise volume delivery of liquids, like in pharmaceuticals or food processing.

Expt. No.:

Date:

Characteristics of Pelton Wheel Turbine

Aim:

To determine the performance characteristics of a Pelton wheel turbine and plot the curves of efficiency versus speed and efficiency versus load.

Outcome:

Students will understand the working principle of an impulse turbine, particularly the Pelton wheel, and analyze how load and speed influence its efficiency.

Apparatus:

- Pelton Wheel Turbine Test Rig
- Loading Arrangement (Dynamometer)
- Pressure Gauge
- Tachometer
- Stopwatch
- Measuring Tank or Flow Meter
- Weighing Scale (if applicable)

Theory:

The Pelton wheel is an impulse turbine used for high-head, low-flow hydro applications. Water from a reservoir is directed through a nozzle to form a high-speed jet, which strikes the buckets (or cups) mounted on the periphery of a runner. The force of the water turns the runner, converting kinetic energy of water into mechanical energy.

Experimental Setup:

The test rig consists of a Pelton wheel enclosed in a casing. Water is supplied from a tank or reservoir under high head through a nozzle and spear mechanism that regulates the jet. The jet impinges on the buckets mounted on a runner, which is connected to a shaft and brake drum for load application. The flow rate and pressure are measured, and load is varied to assess performance. Line diagram of Pelton wheel turbine is shown in Figure 1 below.

Observation:

Venturimeter constant = 0.00254

Brake drum diameter = 0.2 m

Rope diameter = 0.015 m

Equivalent drum diameter (D) = 0.215 m (Brake drum diameter + Rope diameter)

Equivalent drum radius (R) = 0.1075 m

Weight of empty hanger (W_0) = 1kg

Tabulation:

Sl. No.	Inlet Pressure (P) (kg/cm^2)	Total Head (H) m of water	Venturimeter Pressure Gauge Readings			Flow Rate (Q) (m^3/sec)	Speed (N) (rpm)	Wt. on Hanger (W_1) (kg)	Wt. on Spring Balance (W_2) (kg)	Net Wt. (W) (kg)	Maxi. Load (W_{max})	Output Power (P_O) (kW)	Input Power (P_I) (kW)	Efficiency (%)
			P_1 (kg/cm^2)	P_2 (kg/cm^2)	h m of water									

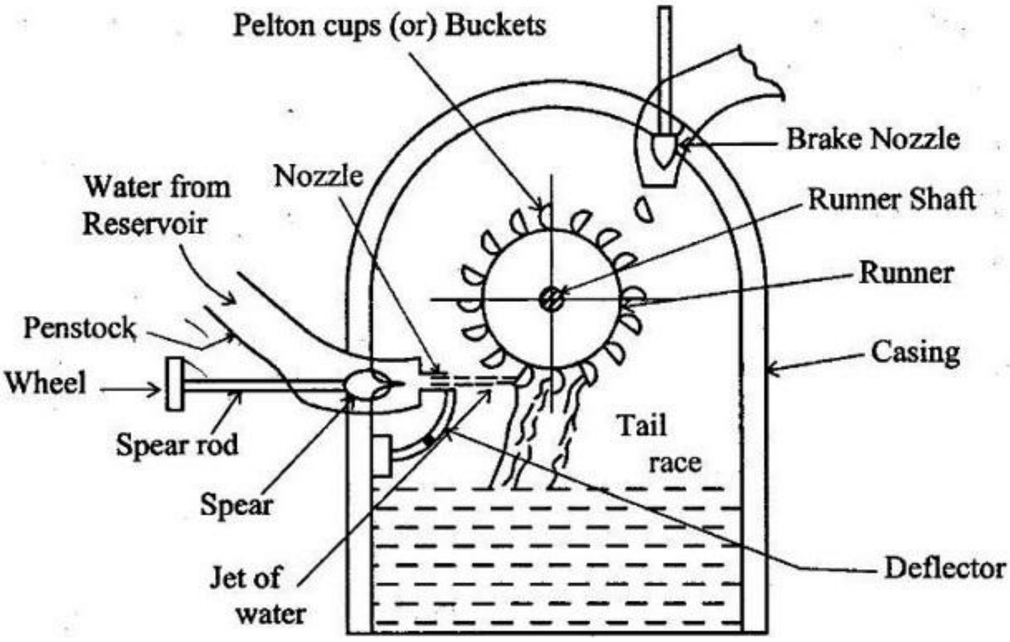


Figure 1. Schematic diagram of a Pelton wheel turbine.

Procedure:

1. Check for leakage and ensure the turbine setup is properly primed.
2. Start the pump to allow water flow through the nozzle.
3. Adjust the spear to regulate the jet striking the buckets.
4. Vary the load on the turbine using the brake drum or dynamometer.
5. For each load, record:
   - Pressure at the nozzle
   - Speed of the turbine (RPM)
   - Discharge rate
   - Torque or force applied
6. Repeat the experiment for various loads.
7. Calculate input power, output power, and efficiency for each set of readings.

Formulas Used:

1. Total head (H) = 10 (P) m of water

2. Difference in pressure head (h) = $(P_1\text{-}P_2)$ x 10 m of water

3. Discharge (Q) = 0.00254 (h) x 0.5 m^3/sec

4. Brake drum net weight (W) = $(W_0 + W_1\text{-}W_2)$ kg

5. Maximum load (Wmax) $= \dfrac{HP_{max} \text{ x } 4500}{2 \text{ x } \pi \text{ x } R \text{ x } N}$

6. Input Power (P_I) = 9.81 x Q x h (kW)

7. Output Power $(P_O) = \dfrac{\pi \text{ x } D \text{ x } N \text{ x } W \text{ x } 9.81}{1000 \text{ x } 60}$ (kW)

8. Efficiency $= \dfrac{\text{Output Power } (P_O)}{\text{Input Power } (P_I)}$ x 100

Graph:

A graph of W_{max} vs efficiency are plotted, taking W_{max} on X axis, respectively.

Result:

The performance characteristics of the Pelton wheel turbine were determined, and the graph for **W_{max} vs efficiency** were plotted.

Viva Voce Questions and Answers

1. What is a Pelton wheel turbine?

   A Pelton wheel is an impulse turbine used to extract energy from high-head, low-flow water sources. It converts the kinetic energy of a water jet into mechanical energy.

2. What is the working principle of a Pelton wheel?

   The Pelton wheel works on Newton's Second Law of Motion. Water jets strike the buckets, causing the wheel to rotate and generate mechanical power.

3. What are the main components of a Pelton turbine?

   Nozzle, spear, runner, buckets, casing, and braking jet.

4. Why is a Pelton wheel suitable for high-head applications?

   Because it uses the high velocity of water jets to rotate the runner, making it efficient under high-head, low-flow conditions.

5. Why do Pelton turbines have split buckets?

   To divide the water jet evenly and reduce axial thrust, improving efficiency and reducing wear.

6. What factors affect the efficiency of a Pelton wheel?

   Jet velocity, nozzle angle, wheel speed, and load.

7. How can we increase the efficiency of a Pelton turbine?

   By optimizing jet alignment, reducing friction, and using proper nozzle design.

8. What is the specific speed of a Pelton turbine?

   It is a dimensionless number that indicates the type of turbine suitable for a given head and flow. For Pelton turbines, it is typically low (10–35).

9. What is the function of the nozzle and spear in a Pelton turbine?

   The nozzle directs the high-pressure water into a jet, and the spear controls the flow rate of the jet.

10. Why is a casing used in the Pelton turbine?

    To prevent splashing, guide used water to the tailrace, and ensure safety.

11. What is the role of the brake drum or dynamometer in the experiment?

    To apply a braking force on the runner and measure output power by torque and rotational speed.

12. What is the effect of jet deflection angle on performance?

    An ideal deflection angle of around 165°–170° maximizes efficiency by transferring maximum momentum.

13. What are the losses that occur in a Pelton wheel?

    Hydraulic losses (friction, jet spread), mechanical losses (bearing friction), and leakage losses.

14. What are the advantages of impulse turbines like Pelton wheels?

    Simple construction, high efficiency under varying loads, and suitability for high-head sites.

Practical Applications of Pelton Wheel Turbine

1. Hydropower Stations

   Used in high-head hydroelectric plants such as mountainous regions.

2. Remote Power Generation

   Ideal for small-scale or micro-hydropower systems in rural areas.

3. Pumped Storage Plants

   Used in reversible turbine systems where water is pumped and stored for peak-time electricity demand.

4. Industrial Applications

   Sometimes used to recover energy from pressurized water in industrial systems.

5. Educational Laboratories

   Commonly used in engineering labs for demonstrating hydraulic machinery principles.

FLUID MECHANICS AND MACHINES
Practical Manual

Fluid Mechanics and Machines – Practical Manual bridges theory and practice for undergraduate Mechanical Engineering students. It offers clear, step-by-step experimental procedures, observation tables, calculation guidelines, and result formats, while emphasizing safety and accurate reporting. With space for notes and alignment to academic outcomes, this manual is a practical, student-friendly resource for both learners and faculty.

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