

LAB MANUAL

ENGINEERING FLUID MECHANICS LAB (23AE51)

Prepared by

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Lakireddy Bali Reddy College of Engineering (A)

Mylavaram, NTR (Dt.), Andhra Pradesh, India - 521 230

Affiliated To

Jawaharlal Nehru Technological University, Kakinada, Andhra Pradesh, India

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To empower students to become technologically vibrant, innovative, and emotionally mature; and to train them to face the challenges of the quality-conscious globalized world economy.

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2. To achieve Academic Excellence.
3. To ensure a holistic development of personality.
4. To spread education to rural areas.
5. To establish partnership between Institution & Industry.

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2. To nurture nation-building skills with emphasis on developing a well built in personality.
3. To ensure that education spreads to rural areas.
4. To establish partnership between Institute and Industry.
5. To explore the Innate Caliber of the students by providing a unique learning experience.
6. To inculcate acquisition of superior intellectual and interpersonal skills.
7. To improve analytical thinking and problem-solving skills.
8. To understand teamwork dynamics and decision-making process.
9. To enable to cope with intense pressure over an extended period.
10. To improve the communication skills so that the students communicate cogently, rationally, and convincingly through acceptable social behaviour.
11. To generate competence to build, motivate and lead project teams effectively.
12. To make learning highly interactive and object-oriented by adopting innovative methods.

DEPARTMENT OF AEROSPACE ENGINEERING

VISION

Department of Aerospace Engineering aims to be indispensable source in Aerospace Engineering which has a zeal to provide the value driven platform for the students to acquire knowledge and empower themselves to shoulder higher responsibility in building a strong nation.

MISSION

The primary mission of the department is to promote engineering education and research. To strive consistently to provide quality education, keeping in pace with time and technology. Department passions to integrate the intellectual, spiritual, ethical, and social development of the students for shaping them into dynamic engineers.

QUALITY POLICY STATEMENT

Impart up-to-date knowledge to the students in Aerospace area to make them quality engineers. Make the students experience the applications on quality equipment and tools. Provide systems, resources, and training opportunities to achieve continuous improvement. Maintain global standards in education, training, and services

LIST OF EXPERIMENTS

1. Verification of Bernoulli's theorem
2. Calibration of Venturi meter
3. Calibration of Orifice meter.
4. Determination of friction factor for a given pipeline
5. Determination of loss of head due to sudden contraction in a pipeline
6. Determine Co-Efficient of Impact of jets on Vanes.
7. Performance Test on Pelton Wheel.
8. Performance Test on Kaplan Turbine.
9. Performance Test on Single Stage Centrifugal Pump.
10. Performance Test on Reciprocating Pump.
11. Determination Of Co-Efficient of flow using Turbine flow meter.
12. Flow visualization using Reynolds experiment.
13. Flow Visualization study using Water Flow Channel

Note: At least 10 Experiments are required to be conducted.

Reference: Lab Manual

EXPERIMENT-1

VERIFICATION OF BERNOULLI'S THEOREM

AIM

1. To verify the validity of Bernoulli's equation for incompressible flow
2. To demonstrate the variation of the pressure along a converging-diverging pipe section.
3. The objective is to validate Bernoulli's assumptions and theorem by experimentally proving that the sum of the terms in the Bernoulli equation along a streamline always remains a constant.

APPARATUS

Apparatus for the verification of Bernoulli's theorem and measuring tank with stop watch setup for measuring the actual flow rate.

THEORY

The Bernoulli theorem is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible. The equation is obtained when the Euler's equation is integrated along the streamline for a constant density (incompressible) fluid. The constant of integration (called the Bernoulli's constant) varies from one streamline to another but remains constant along a streamline in steady, frictionless, incompressible flow. Despite its simplicity, it has been proven to be a very powerful tool for fluid mechanics.

Bernoulli's equation states that the "sum of the kinetic energy (velocity head), the pressure energy (static head) and Potential energy (elevation head) per unit weight of the fluid at any point remains constant" provided the flow is steady, irrotational, and frictionless and the fluid used is incompressible. This is however, on the assumption that energy is neither added to nor taken away by some external agency. The key approximation in the derivation of Bernoulli's equation is that viscous effects are negligibly small compared to inertial, gravitational, and pressure effects. We can write the theorem as

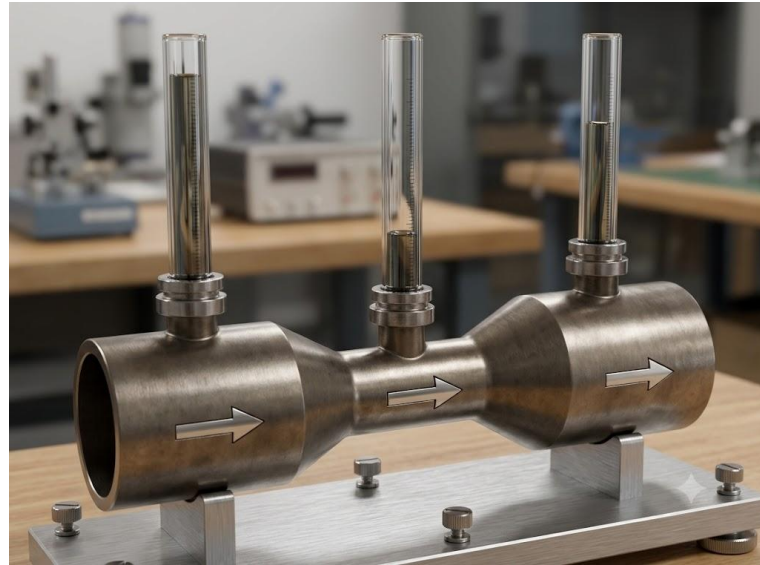


Figure 1.1: Pressure head increases with decrease in velocity head.

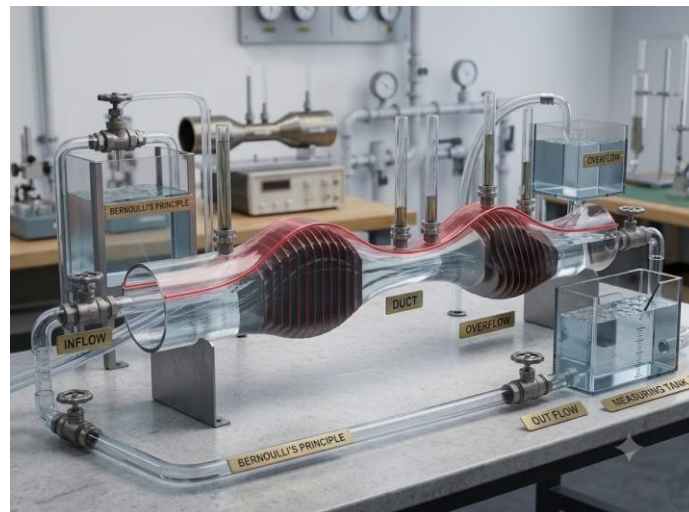


Figure 1.2(a): Bernoulli's Apparatus



Figure 1.2(b): Bernoulli's Apparatus

Here is the equation rewritten clearly in standard engineering notation:

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

Where:

- $\frac{P}{\gamma}$ = **Pressure Head (m)**
- $\frac{V^2}{2g}$ = **Velocity Head (m)**
- Z = **Elevation (Potential) Head (m)**

Symbols:

- P = Pressure (Pa or N/m²)
- $\gamma = \rho g$ = Specific weight of the fluid (N/m³)
- V = Flow velocity (m/s)
- g = Acceleration due to gravity (9.81 m/s²)
- Z = Elevation above the reference datum (m)

Or, in its general form,

$$\frac{P}{\gamma} + \frac{V^2}{2g} + Z = \text{Constant}$$

In this equipment the Z is constant and is not taken for calculation.

The Bernoulli's equation forms the basis for solving a wide variety of fluid flow problems such as jets issuing from an orifice, jet trajectory, flow under a gate and over a weir, flow metering by obstruction meters, flow around submerged objects, flows associated with pumps and turbines etc.

The equipment is designed as a self-sufficient unit it has a sump tank, measuring tank and a pump for water circulation as shown in figure1. The apparatus consists of a supply tank, which is connected to flow channel. The channel gradually contracts for a length and then gradually enlarges for the remaining length.

PROCEDURE

1. Fill in the sump tank with clean water and add some quantity of coloured ink to it.
2. Keep the delivery valve open.
3. Switch on the pump. Now, you will find water flowing to the collecting tank through Venturi meter.
4. Now, you find the different piezometric heads for corresponding points of Venturi meter for constant supply head and delivery head.
5. Note down all the piezometric readings and velocity head at point is also noted separately by bringing the inserted probe to that point.
6. Note down height of water at supply tank and delivery tank
7. Change the delivery head by pushing down the overflow pipe and repeat the experiment.
8. Also, change flow rate and repeat the experiment.

OBSERVATIONS

A_c = Area of Collecting Tank = _____ m^2

w = Specific Weight of Water = _____ N/m^3

TABLE OF OBSERVATIONS

S.No	No. of Points 'i'	Area of points ' A_i '	Piezometer Reading P/w		Rise of water level in collecting tank 'r'		Datum Head Z		Time taken for 'r' rise of water 't'
			cm	m	cm	m	cm	m	
		m^2							Sec
1	1	4.91×10^{-4}							
2	2	3.57×10^{-4}							
3	3	2.45×10^{-4}							
4	4	1.53×10^{-4}							
5	5	1.23×10^{-4}							
6	6	1.53×10^{-4}							
7	7	2.02×10^{-4}							
8	8	2.79×10^{-4}							
9	9	3.60×10^{-4}							
10	10	4.71×10^{-4}							

TABLE OF CALCULATIONS

S.No	No. of Points 'i'	Area of points 'A _i '	Discharge $Q = \frac{A_c \times r}{t}$	Velocity(V) $V = \frac{Q}{A_i}$	Kinetic head $\frac{V^2}{2g}$	Total Head $\frac{P}{w} + \frac{V^2}{2g} + Z$
		m ²	m ³ /sec	m/sec	m	m
1	1	4.91x 10 ⁻⁴				
2	2	3.57x 10 ⁻⁴				
3	3	2.45x 10 ⁻⁴				
4	4	1.53x 10 ⁻⁴				
5	5	1.23x 10 ⁻⁴				
6	6	1.53x 10 ⁻⁴				
7	7	2.02x 10 ⁻⁴				
8	8	2.79x 10 ⁻⁴				
9	9	3.60x 10 ⁻⁴				
10	10	4.71x 10 ⁻⁴				

PRECAUTIONS

1. Readings be recorded under steady condition of flow.
2. Time interval is to be preferably large and same for each discharge measurement reading.
3. There should be no bubble in any piezometer tube.

GRAPH

The following curves are drawn on the same

graph X-axis: direct points (1,

2,3,4,5,6,7,8,9,10)

Y-axis: pressure head, velocity head, elevation head and total head

RESULT

The total head decreases gradually due to various losses. If the losses are ignored the total head remains the same at all sections.

VIVA VOICE QUESTIONS

1. Write Bernoulli's equation.
2. Differentiate between Absolute and gauge pressures.

3. Mention two pressure measuring instruments.
4. What is the difference weight density and mass density?
5. What is vacuum pressure?
6. What is absolute zero pressure?

EXPERIMENT 2

Calibration of Venturi meter

AIM

To determine the coefficient of discharge of given Venturi meter.

APPARATUS

1. Collecting tank to measure the flow rate.
2. A pipeline with a Venturi meter
3. Tapings with ball valves are provided at inlet and throat of Venturi meter.
4. A constant steady supply of water with a means of varying the flow rate using mono block centrifugal pump.
5. Separate valve for Venturi meter.

THEORY

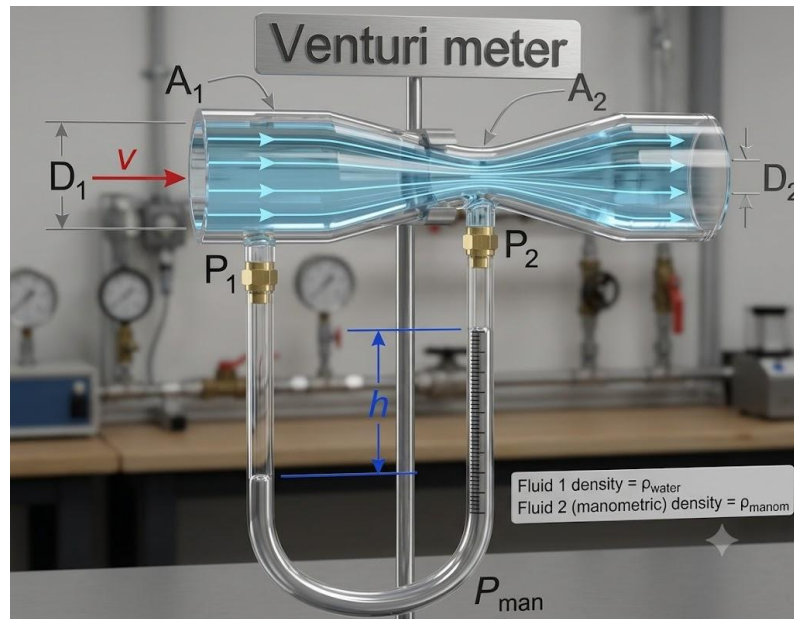
A Venturi meter is a device which is used for measuring the rate of flow of fluid through pipe line. The principle of Venturi meter was first demonstrated by Italian physicist G.B.Venturi. The basic principle on which a Venturi meter works is that by reducing the cross – sectional area of the flow passage, a pressure difference is created between the inlet and throat and the measurement of the pressure difference enables the determination of the discharge through the pipe.

A Venturi meter consists of (i) An inlet section followed by a convergent cone (ii) A cylindrical throat (iii) A gradually divergent cone. The inlet section of the Venturi meter is of the same diameter as that of the pipe which is followed by a convergent cone. The convergent cone is a short pipe which tapers from the original size of the pipe to that of the throat of the Venturi meter. The throat of the Venturi meter is a short parallel tube having its cross – sectional area smaller than that of the pipe. The divergent cone of the Venturi meter is gradually diverging pipe with its cross sectional area increasing from that of the throat to the original size of the pipe.

The convergent cone of a Venturi meter has a total included angle of $21^\circ \pm 1^\circ$ and its length parallel to the axis is approximately equal to $2.7 (D-d)$, where ‘D’ is the diameter of the inlet section and ‘d’ is the diameter of the throat. The length of the throat is equal to ‘d’. The divergent cone has a total included angle lying between 5° to 15° . This results in the convergent cone of the Venturi meter to be of smaller length than its divergent cone.

The cross-sectional area of the throat is smaller than the cross-sectional area of the inlet section, the velocity of flow at the throat will become greater than that at the inlet section. The increase

in the velocity of flow at the throat results in the decrease in the pressure at this section. As such a pressure difference is developed between the inlet section and the throat of the Venturi meter. The pressure difference between these sections can be determined either by connecting a differential manometer between the pressure taps provided at these sections or by connecting a separate pressure gauge at each of the pressure taps. The measurement of the pressure difference between these sections enables the rate of flow of fluid to be calculated.



PROCEDURE

1. Fill the sump tank with clean water.
2. Keep the delivery valve closed.
3. Switch on the pump and open the delivery valve
4. Adjust the flow through the control valve of the pump
5. Open the corresponding ball valves filleted to venturi tapings
6. Note down the differential head reading in the manometer (expel if any air is their by opening the drain cocks provided with the manometer)
7. Operate the butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken
8. Change the flow rate and repeat the experiment

FORMULAE**1. Theoretical Discharge, Q_{th}**

$$Q_{th} = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gH} \quad \text{m}^3/\text{s}$$

Where, A_1 = Area of the inlet section of the Venturimeter = $\frac{\pi D^2}{4}$ (m²), A_2 =

Area of the throat section of the Venturimeter = $\frac{\pi d^2}{4}$ (m²), H = Differential head (water head) =

12.6 h' (m of H₂O)

Symbols

Symbol	Description	Unit
Q_{th}	Theoretical discharge	m ³ /s
A_1	Cross-sectional area of inlet pipe	m ²
A_2	Cross-sectional area of venturi throat	m ²
D	Diameter of inlet pipe	m
d	Diameter of venturi throat	m
H	Differential head expressed as water head	m of H ₂ O
h'	Differential manometer reading (mercury)	m of Hg
g	Acceleration due to gravity (9.81 m/s ²)	m/s ²

2. Actual Discharge, Q_{act}

$$Q_{act} = \frac{A_c \times r}{t} \quad \text{m}^3/\text{s}$$

Where,

A_c = Area of the collecting tank (m²)

r = Rise of water level in the collecting tank (m)

t = Time taken for a rise of r (s)

3. Coefficient of Discharge, C_d

$$C_d = \frac{\text{Actual Discharge}}{\text{Theoretical Discharge}} = \frac{Q_{act}}{Q_{th}}$$

Unit: Dimensionless (No unit)

OBSERVATIONS

Parameter	Description	Unit
A_c	Area of collecting tank	m^2
d	Diameter of the Venturimeter throat	m
D	Diameter of the inlet pipe of the Venturimeter	m

TABLE OF READINGS

S.No	Differential Head 'h'		Rise of water level in collecting tank 'r'		Time taken for 'r' rise of water 't'
Units	mm of Hg	m of Hg	cm	m	sec
1					
2					
3					
4					
5					
6					

TABLE OF CALCULATIONS

S.No	Loss Of Head (12.6 x h) 'H'	Actual Discharge Q_{act}	Theoretical Discharge Q_{th}	Coefficient of Discharge C_d
Units	m	m^3/sec	m^3/sec	
1				
2				
3				
4				
5				
6				

PRECAUTIONS

- 1) Manometer readings should not be taken while the water levels fluctuated in the limbs.
- 2) The rise 'r' in the collecting tank should not be taken a very small value
- 3) Readings should not take till the flow stabilizes.

GRAPH

A graph between Q_{act} and $\sqrt{H}$.

RESULT

Co-efficient of Discharge for Venturi meter from Experiment =

Co-efficient of Discharge for Venturi meter from graph =

VIVA VOICE QUESTIONS

1. Draw the Venturi meter and mention the parts.
2. Why the divergent cone is longer than convergent cone in Venturi meter?
3. Compare the merits and demerits of Venturi meter with orifice meter.
4. Why C_d value is high in Venturi meter than orifice meter?
5. What is the use of Venturi meter?
6. Define coefficient of discharge.

EXPERIMENT-3

Calibration Of Orifice Meter

AIM

To determine the coefficient of discharge of given Orifice meter.

APPARATUS

1. Measuring tank to measure the flow rate
2. A pipe line with Orifice meter
3. Tapings with ball valves are provided at inlet and outlet of Orifice meter and these are connected to manometer.
4. A constant steady supply of water with a means of varying the flow rate using mono block centrifugal pump.
5. Separate valve for Orifice meter.

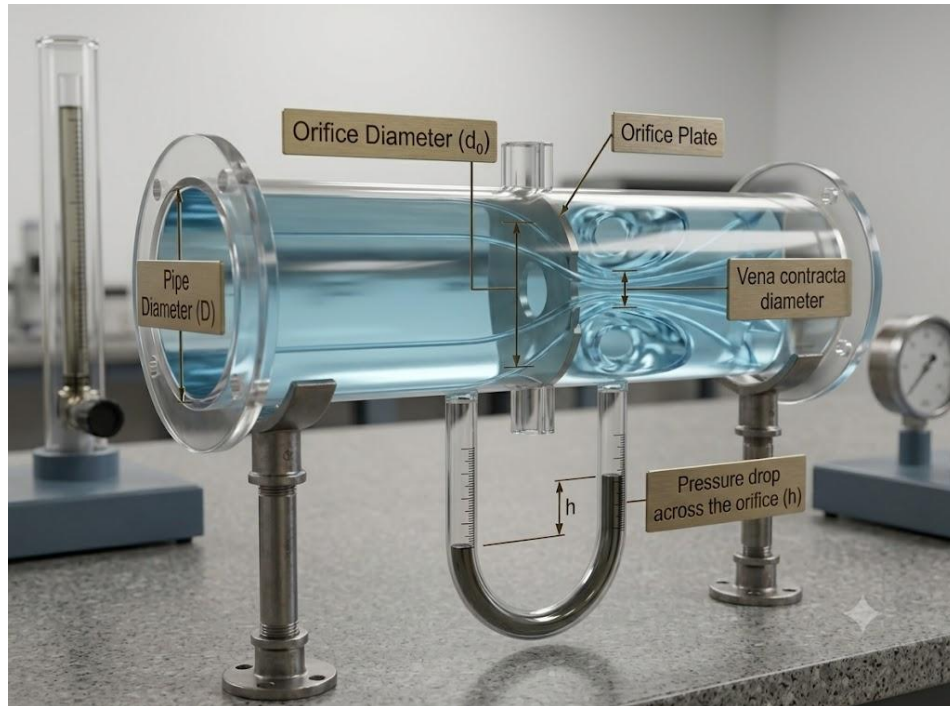
THEORY

An Orifice meter is another simple device used for measuring the discharge through pipes. Orifice meter also works on the same principle as that of Venturi meter i.e.; by reducing the cross sectional area of the flow passage, a pressure difference between the two sections before and after orifice is developed and the measurement of the pressure difference enables the determination of the discharge through the pipe.

However, an orifice meter is a cheaper arrangement for discharge measurement through pipes and its installation requires a smaller length as compared may be used for measurement of discharge through pipes.

It consists of a plate containing a sharp-edged orifice introduced in the pipeline. The orifice plate can be fitted to the pipe by flanged joint (same as Venturi meter)

An Orifice meter consists of a flat circular plate with a circular hole called orifice, which is concentric with the pipe axis. The thickness of the plate is less than or equal to 0.05 times the diameter of the pipe.



PROCEDURE

- 1) Fill in the sump tank with clean water.
- 2) Keep the delivery valve closed.
- 3) Switch on the pump and open the delivery valve.
- 4) Adjust the flow through the control valve of the pump.
- 5) Open the corresponding ball valves of the Orificemeter
- 6) Open the corresponding ball valves fitted to orifice tapings.
- 7) Note down the differential head reading in the manometer (expel if any air is their by opening the drain cocks provided with the manometer).
- 8) Operate the butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.
- 9) Change the flow rate and repeat the experiment

FORMULAE

1. Theoretical Discharge, Q_{th}

$$Q_{th} = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gH} \quad \text{m}^3/\text{s}$$

Where, A_1 = Area of the inlet section of the Orifice = $\frac{\pi D^2}{4}$ (m²), A_2 =

Area of the throat section of the Venturimeter = $\frac{\pi d^2}{4}$ (m²), H = Differential head (water head) = 12.6 h' (m of H₂O)

Symbols

Symbol	Description	Unit
Q_{th}	Theoretical discharge	m ³ /s
A_1	Cross-sectional area of inlet pipe	m ²
A_2	Cross-sectional area of venturi throat	m ²
D	Diameter of inlet pipe	m
d	Diameter of venturi throat	m
H	Differential head expressed as water head	m of H ₂ O
h'	Differential manometer reading (mercury)	m of Hg
g	Acceleration due to gravity (9.81 m/s ²)	m/s ²

2. Actual Discharge, Q_{act} $Q_{act} = \frac{A_c \times r}{t}$ m³/s

Where,

A_c = Area of the collecting tank (m²)

r = Rise of water level in the collecting tank (m)

t = Time taken for a rise of r (s)

3. Coefficient of Discharge, C_d

$$C_d = \frac{\text{Actual Discharge}}{\text{Theoretical Discharge}} = \frac{Q_{act}}{Q_{th}}$$

OBSERVATIONS

Parameter	Description	Unit
A_c	Area of collecting tank	m ²
d	Diameter of the Venturimeter throat	m
D	Diameter of the inlet pipe of the Venturimeter	m

TABLE OF READINGS

S.No	Differential Head 'h'		Rise of water level in collecting tank 'r'		Time taken for 'r' rise of water 't'
Units	mm of Hg	m of Hg	cm	m	sec
1					
2					
3					
4					
5					
6					

TABLE OF CALCULATIONS

S.No	Loss Of Head (12.6 x h) 'H'	Actual Discharge Q_{act}	Theoretical Discharge Q_{th}	Coefficient of Discharge C_d
Units	m	m ³ /sec	m ³ /sec	
1				
2				
3				
4				
5				
6				

PRECAUTIONS

- 4) Manometer readings should not be taken while the water levels fluctuated in the limbs.
- 5) The rise 'r' in the collecting tank should not be taken a very small value
- 6) Readings should not take till the flow stabilizes.

GRAPH

A graph between Q_{act} and $\sqrt{H}$.

RESULT

Co-efficient of Discharge for Orifice meter from Experiment =

Co-efficient of Discharge for Orifice meter from graph =

VIVA VOICE QUESTIONS

1. What is orifice plate?
2. What do you mean by vena-contracta?
3. Describe the principle of manometers and its uses.
 - a. What is density of mercury?
4. Calculate head of 10.3 meters of water in terms of head of mercury
5. What is meant by coefficient of discharge?

EXPERIMENT-4

Determination Of Friction Factor in A Given Pipeline

AIM

To Determine Darcy's Friction Co-efficient for different pipes with different materials

APPARATUS

1. Pipe line of four different diameters of GI & PVC
2. U-tube manometer with a stabilizing valve to measure the pressure difference across the tapping, one at either end of the pipe line fitted with a ball valve.
3. A constant steady supply of water with a means of varying the flow rate using mono block centrifugal pump.
4. Collecting tank to measure the flow rate.
5. Each pipe line is provided with separate control valve to conduct experiment separately.

THEORY

A closed circuit or conduit of any cross –section used for flow of liquid is known as a pipe, generally pipes are assumed to be running full and of circular cross section. Liquids flowing through pipes are encountered with resistance resulting in loss of head or energy of liquids. The resistance due to shear forces between fluid particles and the boundary walls of the pipe and between the fluid particles themselves results from the viscosity of the fluid. The resistance to the flow of fluid is in general known as frictional resistance, since certain amount of energy possessed by the flowing fluid will be consumed in overcoming this resistance to the flow, there will always be some loss of energy in the direction of flow, which however depends on the type of flow. The flow of fluid in a pipe may be either laminar or turbulent.



Figure 4.1 Determination Of Friction Apparatus

PROCEDURE

1. Fill in the sump tank with clean water
2. Keep the delivery valve closed
3. Switch on the pump & open the delivery valve
4. Open the corresponding ball valve of the pipe line
5. Adjust the flow through the control valve of the pump
6. Open the corresponding ball valves
7. Note down the differential head reading in the manometer (expel if any air is there by opening the drain cocks provided with the manometer)
8. Operate the butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.
9. Change the flow rate and repeat the experiment for different diameter of pipes.

For Straight Pipes**Darcy–Weisbach Equation for Head Loss Due to Friction**

$$h_f = \frac{4fLV^2}{2gd} \text{ m}$$

Where,

$$h_f = \text{Head loss due to friction} = 12.6 h(\text{m})$$

$$h = \text{Differential head (Manometer reading)}(\text{m of Hg})$$

$$f = \text{Coefficient of friction}(\text{Dimensionless})$$

$$L = \text{Length of the pipe}(\text{m})$$

$$d = \text{Internal diameter of the pipe}(\text{m})$$

$$V = \text{Average velocity of fluid}(\text{m/s})$$

$$g = \text{Acceleration due to gravity} = 9.81 \text{ m/s}^2$$

Therefore,**Coefficient of Friction**

$$\text{Rearranging Darcy's equation, } f = \frac{h_f 2gd}{4LV^2} = f = \frac{h_f gd}{2LV^2}$$

$$\text{Velocity of Fluid } V = \frac{Q_{act}}{A} \text{ m/s}$$

$$\text{where, } A = \frac{\pi d^2}{4} \text{ is the cross-sectional area of the pipe.}$$

Note: When a mercury differential manometer is used, the head loss is commonly expressed as:

$$h_f = 12.6 h$$

Summary of Symbols

Symbol	Description	Unit
h_f	Head loss due to friction	m
h	Differential manometer reading	m of Hg
f	Darcy coefficient of friction	Dimensionless
L	Length of the test pipe	m
d	Internal diameter of the pipe	m
V	Average velocity of fluid	m/s
Q_{act}	Actual discharge	m ³ /s
A	Cross-sectional area of the pipe	m ²
g	Acceleration due to gravity (9.81 m/s ²)	m/s ²

Actual Discharge, Q_{act} $Q_{act} = \frac{A_c \times r}{t} \text{ m}^3/\text{s}$

Where,

A_c = Area of the collecting tank(m^2)

r = Rise of water level in the collecting tank(m)

t = Time taken for a rise of r (s)

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

d = Internal diameter of the pipe(m)

Summary of Symbols

Symbol	Description	Unit
Q_{act}	Actual discharge	m^3/s
A_c	Area of the collecting tank	m^2
r	Rise of water level in the collecting tank	m
t	Time taken for the rise of water level	s
A	Cross-sectional area of the pipe ($\frac{\pi d^2}{4}$)	m^2
d	Internal diameter of the pipe	m

OBSERVATIONS

Record the dimensions of the experimental setup before conducting the test.

Parameter	Description	Value	Unit
L	Length of the test pipe	_____	m
d	Internal diameter(s) of the test pipe(s)	_____	m
A_c	Area of the collecting tank	_____	m^2

Symbols

- L = Length of the test pipe (m)
- d = Internal diameter of the pipe (m)
- A_c = Cross-sectional area of the collecting tank (m^2)

TABLE OF READINGS

Sl.No	Type of Pipe	Diameter of the Pipe 'd'		Differential Head 'D'		Rise of water level in collecting tank 'r'		Time taken for 'r' rise of water 't'
		mm	m	mm of Hg	m of Hg	cm	m	
1								
2								
3								
4								
1								
2								
3								
4								

TABLE OF CALCULATIONS

Sl.No	Type of Pipe	Loss Of Head (12.6 x h) 'hf'	Actual Discharge Qact	Theoretical Velocity V	co-efficient of friction f	Average co-efficient of friction
		m	m ³ /sec	m ³ /sec		
1						
2						
3						
4						
1						
2						
3						
4						

PRECAUTIONS

1. Take care that there is no air bubble entrapped in the apparatus when noting manometer reading.
2. The head loss measurement in each pipe should be made over the length of the pipe where fully developed flow actually exists.

GRAPH

A graph between V^2 on X-axis and h_f on Y-axis is drawn.

RESULTS

Friction factor for -----pipe from experiment = -----

Friction factor for-----pipe from graph = -----

Friction factor for -----pipe from experiment = -----

Friction factor for-----pipe from graph = -----

VIVA VOICE QUESTIONS

1. What is the cause of friction?
2. What is the unit of density?
3. What is the difference between kinematic and dynamic viscosity?
4. Write down Darcy -Weisbach's equation.
5. What is the difference between friction factor and coefficient of friction?
6. What do you mean by major energy loss?
7. List down the type of minor energy losses.

EXPERIMENT-5

Determine Coefficient of Impact of jets on Vanes.

AIM

To determine the Co-efficient of impact jet, vane combination by comparing the actual force with the theoretical force for stationary vanes of different shapes viz., Hemi-spherical, Flat plate & Inclined plate.

THEORY

A jet of water issuing from a nozzle has some velocity and hence it possesses a certain amount of kinetic energy. If this jet strikes an obstruction (plate) placed in its path, it will exert a force on the obstruction. This impressed force is known as impact of the jet and it is designated as hydrodynamic force. This force is due to the change in the momentum of the jet as a consequence of the impact. This force is equal to the rate of change of momentum i.e.; the force is equal to (mass striking the plate per second) $\times$ (change in velocity)

The amount of force exerted depends on the diameter of jet, shape of vane, fluid density, flow rate of water. More importantly, it also depends on whether the vane is moving or stationary. In our case, we are concerned about the force exerted on the stationary vanes.

DESCRIPTION

It is a closed circuit water re- circulation system consisting of sump tank, mono block centrifugal pump set, jet/vane chamber, Rota meter for flow rate measurement, direct reading Amalog force indicator. The water is drawn from the sump tank by mono block centrifugal pump and delivers it vertically to the nozzle through rotameter. The rotameter is a direct indicating flow rate instrument which gives the discharge in liters per minute (LPM) which is determined by the top position of the float. The flow control valve is also provided for controlling the water into the nozzle. The water is issued out of nozzle as jet. The jet is made to strike the vane, the force of which is transferred directly to the force indicator. The force is read in Kgf or N. The provision is made to change the size of nozzle / jet and the vane of different shapes.

PROCEDURE

1. Fix the required diameter jet, and the vane of required shape in position and zero the force indicator
2. Keep the delivery valve closed and switch on the pump
3. Close the front transparent cover tightly
4. Open the delivery valve and adjust the flow rate of water as read on the Rota meter
5. Observe the force as indicated on force indicator
6. Note down the diameter of the jet, shape of vane , flow rate and force and tabulate the results
7. Switch off the pump after the experiment is over and close the delivery valve.



Figure 5.1 Impact of Jet on Vanes Apparatus

FORMULAE**Flat Plate**

Theoretical Force, F_t $F_t = \rho AV^2$ N

Where,

ρ = Density of water = 1000 kg/m³

A = Cross-sectional area of the jet = $\frac{\pi d^2}{4}$ (m²)

d = Diameter of the jet(m)

V = Velocity of the jet(m/s)

Actual Force, F_a

F_a = Actual force measured by the analog force indicator N

Coefficient of Impact Coefficient of Impact = $\frac{F_a}{F_t}$

Summary of Symbols

Symbol	Description	Unit
F_t	Theoretical force exerted by the jet	N
F_a	Actual force measured using the force indicator	N
ρ	Density of water (1000 kg/m ³)	kg/m ³
A	Cross-sectional area of the jet $\left(\frac{\pi d^2}{4}\right)$	m ²

Symbol	Description	Unit
d	Diameter of the jet	m
V	Velocity of the water jet	m/s
F_a/F_t	Coefficient of Impact	Dimensionless

Inclined Plate

Theoretical Force, F_t

$$F_t = (\rho AV^2) \sin^2 \theta \quad \text{N}$$

Where,

$$\rho = \text{Density of water} = 1000 \text{ kg/m}^3$$

$$A = \text{Cross-sectional area of the jet} = \frac{\pi d^2}{4} \text{ (m}^2\text{)}$$

$$d = \text{Diameter of the jet (m)}$$

$$V = \text{Velocity of the jet (m/s)}$$

$$\theta = \text{Angle of inclination of the plate (}^\circ\text{)}$$

Actual Force, F_a

$$F_a = \text{Actual force measured using the analog force indicator} \quad \text{N}$$

Coefficient of Impact

$$\text{Coefficient of Impact} = \frac{F_a}{F_t}$$

Summary of Symbols

Symbol	Description	Unit
F_t	Theoretical force on the inclined plate	N
F_a	Actual force measured by the force indicator	N
ρ	Density of water (1000 kg/m ³)	kg/m ³
A	Cross-sectional area of the jet $\left(\frac{\pi d^2}{4}\right)$	m ²
d	Diameter of the jet	m
V	Velocity of the water jet	m/s
θ	Inclination angle of the plate	Degrees (°)

Symbol	Description	Unit
F_a/F_t	Coefficient of Impact	Dimensionless

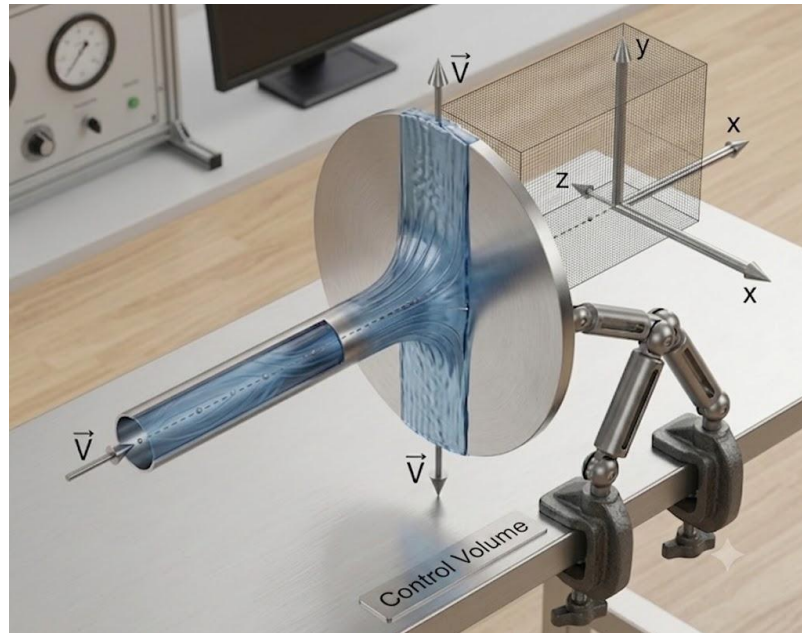


Figure 5.2 Impact of Jet on Flat Plate

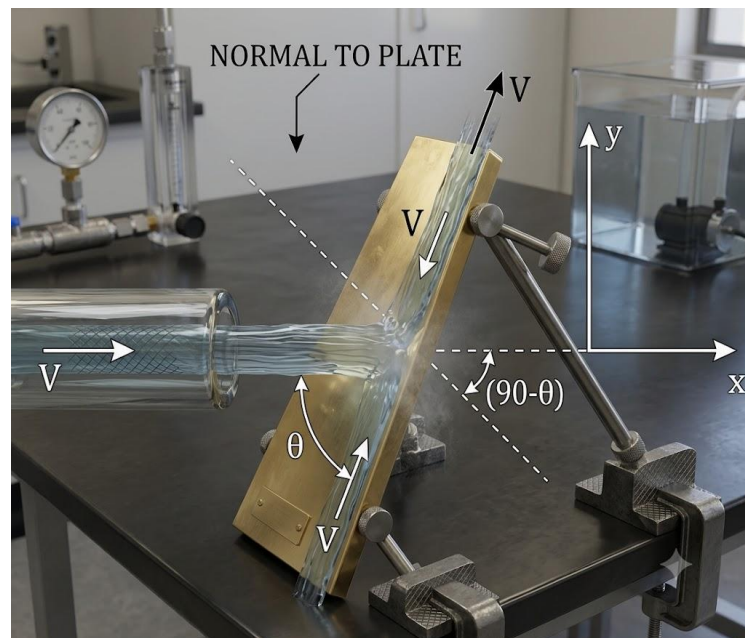


Figure 5.3 Impact of Jet on Inclined Plate

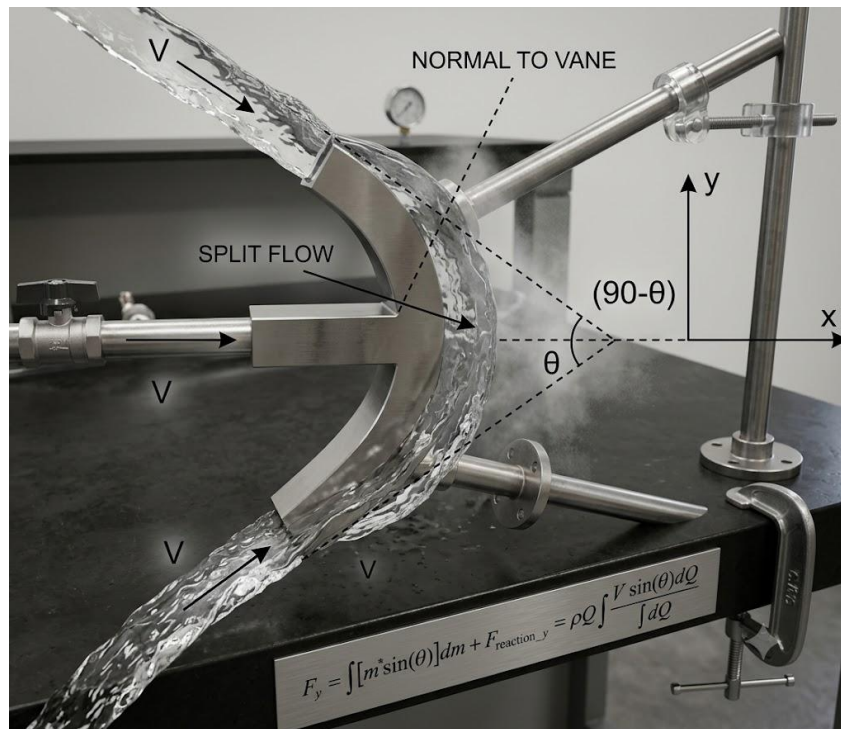


Figure 5.4 Impact of Jet on Hemi – Spherical Plate

OBSERVATIONS

D = Diameter of Jet = 5×10^{-3} m

Hemi-Spherical Plate**Theoretical Force, F_t**

$$F_t = 2\rho AV^2 \text{ N}$$

Where:

- ρ = Density of water = **1000 kg/m³**
- A = Area of jet $A = \frac{\pi d^2}{4} \text{ m}^2$
- d = Diameter of jet (m)
- V = Velocity of jet $V = \frac{Q}{A} \text{ m/s}$

Actual Force, F_a

F_a = Actual force developed as indicated by the analog force indicator.

Coefficient of Impact

$$\text{Coefficient of Impact} = \frac{F_a}{F_t}$$

TABLE OF READINGS

S.No	Vane type	Discharge 'Q'		Force Indicator Reading 'Fa'
		LPM	m ³ /sec	Kg f
1	Flat Plate			
2				
3				
1	Inclined plate			
2				
3				
1	Hemi – Spherical plate			
2				
3				

TABLE OF CALCULATIONS

S.No	Vane type	Velocity $V=Q/A$	Actual Force F_a	Theoretical Force F_t	Co-efficient of Impact F_a/F_t
		m/s	N	N	
1	Flat Plate				
2					
3					
1	Inclined plate				
2					
3					
1	Hemi – Spherical plate				
2					
3					

PRECAUTIONS

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady conditions.
3. Discharge must be varied very gradually from a higher to smaller value.

GRAPH

Draw the graph F_a vs V^2 . From this compute the value of the co-efficient of impact

RESULT

Value of the coefficient of impact for Flat plate from experiment	= -----
Value of the coefficient of impact for inclined plate from experiment	= -----
Value of the coefficient of impact for Hemi-Spherical plate from experiment	= ----
Value of the coefficient of impact for Flat plate from graph	= -----
Value of the coefficient of impact for inclined plate from graph	= ----
Value of the coefficient of impact for Hemi-Spherical plate from graph	= ----

VIVA VOICE QUESTIONS

1. What is a fluid jet?
2. Point out the significance of word 'Free' in impact of free jets.
3. What is an expression for impact of jet on fixed flat plate?
4. What is an expression for impact of jet on moveable flat plate?
5. What is an expression for impact of jet on fixed inclined plate?

EXPERIMENT-6

Performance Test on Pelton Wheel.

AIM

To calculate turbine efficiency and to draw the performance characteristics of Pelton Wheel Turbine at Constant Speed

THEORY

Pelton wheel is only impulse type of hydraulic turbine now in common use. It is named after Lester A Pelton (1829-1908), the American Engineer who contributed much to its development in about 1880. It is well suited for operating under high heads.

Fig. shows the elements of a typical Pelton wheel installation; the runner consists of a circular disc with a number of buckets have a shape of double semi ellipsoidal cups. Each bucket is divided into two symmetrical parts by a sharp – edged known as splitter one or more nozzles are mounted so, that each directs a jet along a tangent to the circle through the centres of the buckets called the pitch circle.

The jet of water impinges on the splitter, which duress the jet into two equal portions, each of which after flowing round the smooth inner surface of the bucket leaves it at its outer edge. The buckets are so shaped that the angle at the out tip varies from 100 to 200 (usually kept as 150) so that the jet of water gets deflected through 1600 to 1700

The advantage of having a double cup shaped buckets is that the axial thrusts neutralize each other, being equal and opposite, and hence the bearings supporting the wheel shaft are not subjected to any axial or end thrust. The back of the bucket is so shaped that as it swings downward into the jet no water is wasted by splashing, further at the lower tip of the bucket a notch is cut which prevents the jet striking the preceding bucket intercepted by the next bucket very soon, and it also avoids the deflection of water towards the center of the wheel as the buckets first meets the jet.

For low heads the buckets are made of cast iron, but for higher heads they are made of cast steel, bronze or stainless steel.

In order to control the quantity of water striking the runner, the nozzle fitted at the end of the penstock is provided with a spear or needle having a stream lined head which is fitted to the end of a rod as shown in fig: the spear may be operated either by a wheel in case of very small units or automatically by a governor in case of almost all the bigger units. A casing made of cast iron or fabricated steel plates are usually provided for a Pelton wheel as shown in fig. It has no hydraulic function to perform. It is provided only to prevent splashing of water, to read water to the tail race and also to acts as a safeguard against accidents.

DESCRIPTION

The present experimental facility supplied consist of multistage Centrifugal pump set. Turbine unit, sump tank, collecting tank, notch tank arranged in such a way that the whole unit works as re-circulating water system. The centrifugal pump set supplies the water from sump tank to the turbine through control valve which has the marking to meter the known quantity of water. The water after passing through the turbine unit enters the collecting tank.

The water then flows back to sump tank through the notch tank which is fixed with 600 V- notch for the measurement of flow rate.

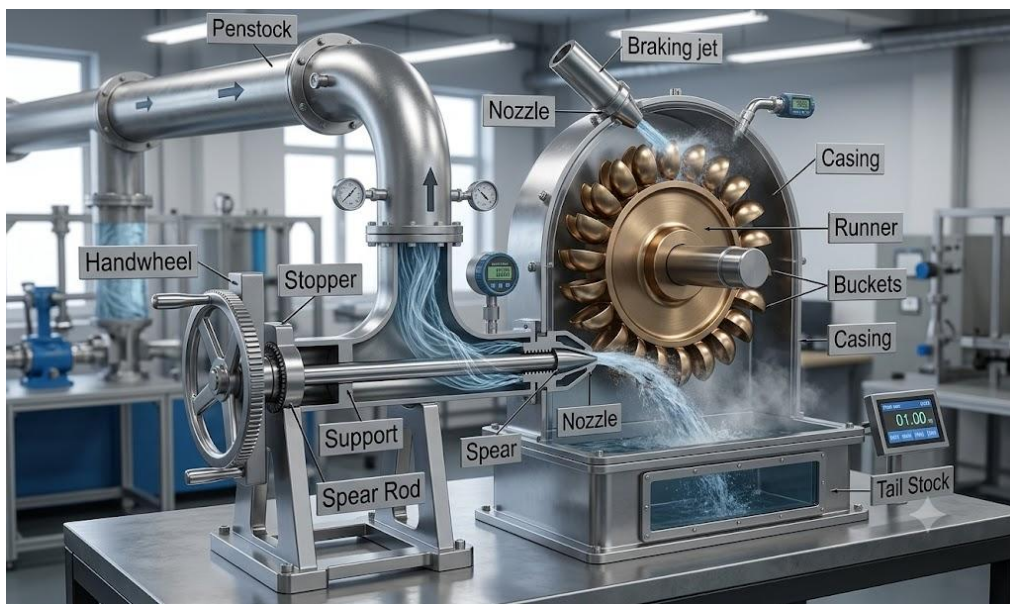


Figure 6.1: Schematic diagram of a Pelton Turbine

Supply Pump / Motor Capacity

- Power Rating = 7.5 HP
- Phase = 3-Phase
- Voltage = 440 V
- Frequency = 50 Hz
- Supply = AC

Turbine Specifications

Parameter	Specification
Mean Diameter	250 mm
Number of Buckets	20
Jet Diameter	20 mm

Parameter	Specification
Runaway Speed	2000 RPM
Flow Rate	165 LPM ($2.72 \times 10^{-3} \text{ m}^3/\text{s}$)
Maximum Head	100 m

Loading Arrangement

- **Electrical Alternator**
- **Single Phase**
- **Speed: 1500 RPM**
- **Efficiency: 90%**

Maximum Shaft Output

- **Approximately 1.5 HP**

Provision

- **Flow rate measurement using a V-Notch Weir**
- **Coefficient of Discharge, $C_d = 0.6$**

OPERATION

1. Connect the supply water pump water unit to 3Ph, 440V, 20A electrical supply, with neutral and earth connections and ensure the correct direction of pump motor unit.
2. Keep the gate valve and sphere valve closed.
3. Keep the electrical load at maximum by keeping the all switches at “ON”
4. Starts the supply pump, now the pump picks – up the full speed and becomes operational
5. Slowly open the sphere valve so that the Turbine rotor picks up the speed and attains the maximum at full opening of the valve.

To Obtain Constant Speed Characteristics

1. Keep the gate valve opening at maximum.
2. For different electrical loads on the turbine change the sphere rod setting between maximum and minimum so, that the speed is held constant and note down the head over the notch, and head on turbine

FORMULAE**1. Head of Water (H)**

$$H = \frac{P}{w} \text{ m}$$

Where:

- P = Pressure (N/m^2)
- w = Specific weight of water (N/m^3)

2. Discharge Through the Turbine (Q)

The discharge through the turbine is equal to the flow rate over the V-Notch.

$$Q = \left(\frac{8}{15}\right) C_d \tan\left(\frac{\theta}{2}\right) \sqrt{2g} h^{5/2} \text{ m}^3/\text{s}$$

Assumptions and Constants

- Coefficient of discharge, $C_d = 0.6$
- Acceleration due to gravity, $g = 9.81 \text{ m/s}^2$
- Notch angle, $\theta = 60^\circ$
- h = Head over the notch (**m**)

3. Hydraulic Input to the Turbine (P_H)

$$P_H = \frac{wQH}{1000} \text{ kW}$$

Where:

- w = Specific weight of water (N/m^3)
- Q = Discharge (m^3/s)
- H = Head of water (**m**)

4. Output Power from the Alternator (P_A)

$$P_A = \frac{x}{t} \times \frac{3600}{K}$$

Unit: kW**Where:**

- x = Number of revolutions of the energy meter disc
- K = Energy meter constant (**rev/kWh**)
- t = Time taken for x revolutions (**s**)

5. Brake Power of the Turbine (BP)

The brake power developed by the turbine is calculated from the alternator output power and the alternator efficiency.

$$BP = \frac{\text{Output Power from the Alternator } (P_A)}{\eta_A}$$

or,

$$BP = \frac{P_A}{\eta_A} \text{ kW}$$

Where:

- BP = Brake power of the turbine (**kW**)
- P_A = Output power from the alternator (**kW**)
- η_A = Alternator efficiency (decimal)

Note: If the alternator efficiency is **90%**, then

$$\eta_A = 0.90$$

and

$$BP = \frac{P_A}{0.90}$$

6. Turbine Efficiency (η_T)

The efficiency of the turbine is the ratio of the brake power developed by the turbine to the hydraulic input power supplied to the turbine.

$$\eta_T = \frac{\text{Brake Power from the Turbine}}{\text{Hydraulic Input to the Turbine}} \times 100$$

or,

$$\eta_T = \frac{BP}{P_H} \times 100 \%$$

Where:

- η_T = Turbine efficiency (%)
- BP = Brake power of the turbine (**kW**)
- P_H = Hydraulic input power to the turbine (**kW**)

7. Percentage of Full Load

The percentage of full load is calculated as:

$$\% \text{Load} = \frac{\text{Brake Power}}{\text{Maximum Brake Power}} \times 100$$

or,

$$\% \text{Load} = \frac{BP}{BP_{\max}} \times 100 \%$$

Where:

- BP = Brake power developed by the turbine (**kW**)
- $BP_{\max}$ = Maximum brake power of the turbine (**kW**)

OBSERVATIONS

1. Specific weight of Water = 9810 N/m^3
2. Efficiency of the Alternator = 0.9
3. Energy meter Constant = 1500 rev/KWH
4. 40 for V-Notch = 60^0
5. Coefficient of Discharge for V-Notch = 0.6

Note: 760 mm of Hg = $1.01325 \times 10^5 \text{ N/m}^2 = 1.0332 \text{ Kg/cm}^2$.

TABLE OF READINGS

S.No	Speed	Load	Pressure		Head over the Notch		Time taken by Energy meter reading for 'X' revolutions
	'N'		'P'		'h'		
	RPM	Watts	Kg/cm ²	N/m ²	cm	m	sec
1							
2							
3							
4							
5							
6							

TABLE OF CALCULATIONS

Sl.No	Speed	Head of water	Rate of flow through Turbine	Hydraulic input to the turbine P_H	Output power from the Alternator P_A	Break Power from the turbine BP	Turbine efficiency $\% \eta_T$	% full load
	'N'	'H'	'Q'					
	RPM	m	m ³ /sec	KW	KW	KW		
1								
2								
3								
4								

5								
6								

PRECAUTIONS

1. Don't start pump set if the supply voltage is less than 300V (Phase to Phase Voltage)
2. Don't forget to give electrical earth and neutral connections correctly, otherwise the RPM indicator gets burnt if connections are wrong.
3. Frequently, at least once in three months, grease all visual moving parts.
4. Initially, fill in the tank with clean water free from foreign material, change the water every six months
5. At least every week, operate the unit for five minutes to prevent any clogging of moving parts.
6. To start and stop supply pump, always keep gate valve closed.
7. It is recommended to keep sphere rod setting at close position before starting the turbine. This is to prevent racing of the propeller shaft without load.
8. In case of any major faults, please write to the manufacturer, and do not attempt to repair.

GRAPHS

At Constant Speed Characteristics

1. Percentage of Full load Vs Efficiency
2. Efficiency V/s Discharge
3. BP V/s Discharge

RESULT

1. Efficiency of Pelton Wheel Turbine at Constant Speed: ($\% \eta_T$) =
2. % full load at Constant Speed =

VIVA VOICE QUESTIONS

1. Differentiate between impulse and reaction turbine.
2. What is the function of draft tube?
3. What are the main parameters in designing a Pelton wheel turbine?
4. What is breaking jet in Pelton wheel turbine?
5. What is the function of casing in Pelton turbine?
6. Draw a simple sketch of Pelton wheel bucket

EXPERIMENT-7

PERFORMANCE TEST ON KAPLAN TURBINE

AIM

To calculate turbine efficiency and to draw the performance characteristics of Kaplan Turbine at Constant Head

THEORY

The Kaplan turbine consists of main components such as Propeller (Runner) scroll casing and draft tube. Between the scroll casing, the runner, the water turns through right angle into the axial direction and passes through the runner and thus rotating the runner shaft. The runner has four blades which can be turned about their own axis. So, that the angle of inclination may be adjusted while the turbine is in motion. When runner blade angles are varied, high efficiency can be maintained over wide range of operating conditions. In other words even at the part loads, when a low discharge is flowing through the runner, a high efficiency can be attained in case of Kaplan turbine, where as this provision does not exist in Francis and Propeller turbines where, the runner blade angles are fixed and the integral with hub.

The actual experimental facility supplied consists of a centrifugal pump set, turbine unit, sump tank, collecting tank, notch tank arranged in such a way that the whole unit works on reciprocating water system. The centrifugal pump set supplies the water from the sump tank to the turbine through gate valve which has the marking to meter the known quantity of water. The water after passing through the turbine unit enters the collecting tank through the draft tube. The water then flows back to the sump tank through the notch tank with rectangular notch for the measurement of flow rate. The loading of the turbine is achieved by electrical AC generator connected to lamp bank. The provisions for measurement of electrical energy AC Voltmeter and Ammeter, turbine Speed indicator, head on the turbine (Pressure Gauge), are built-in on the control panel.

SPECIFICATIONS

* Supply Pump / Motor Capacity	=	10 HP, 3Ph, 440V, 50HZ, AC
* Turbine Diameter of Propeller	=	150mm
No of blades	=	04 Nos
Run away speed	=	2500 RPM(approx)
Flow rate	=	250 LPM
Head	=	10 m. (approx)
Propeller Blade angles adjustable from Maximum to Minimum		

* Loading : AC Alternator

*Provision:

1. Flow rate by Notch, $C_d = 0.6$
2. Head on turbine by pressure gauge of range: 0 - 2 Kg/C
3. Vacuum gauge of range 0 – 760 mm of Hg
4. Electrical load change by toggle Switch (Max. Connected load : 2000Watts)
5. Electrical load measurement by energy meter
6. Voltage and Current of generator by analogue meters
7. Propeller speed by digital RPM indicator
8. Supply water control by gate vane
9. Electrical Supply :3Ph 440V, AC, 30A with Neutral & Earth.
10. Volume of water required for operation unit: 3000 Ltr (approx)

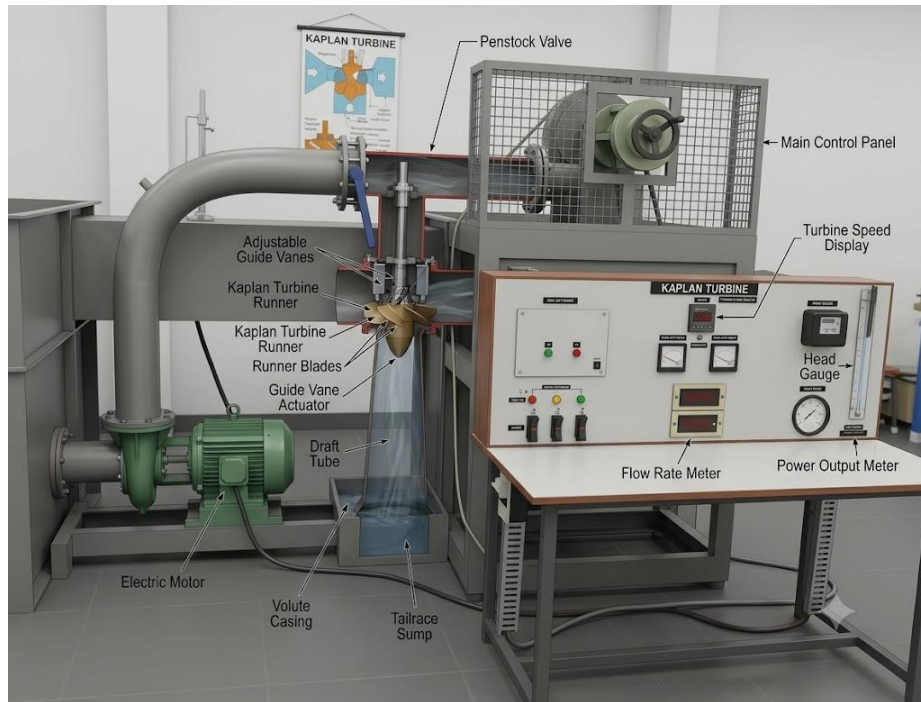


Fig1. Kaplan Turbine

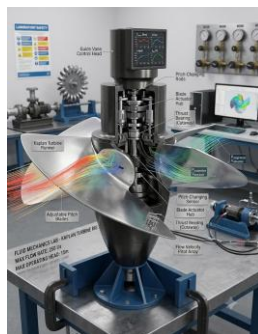


Fig 2 Blades of Kaplan Turbine

OPERATION

1. Connect the supply water pump water unit to 3ph, 440V, 20A electrical supply, with neutral and earth connections and ensure the correct direction of pump motor unit.
2. Keep the gate valve closed.
3. Keep the electrical load at maximum by keeping the all switches at “ON”
4. Press the green button of the supply pump starter and then release.
5. Slowly, open the gate valve so, that the turbine rotor picks up the speed and attains maximum at full opening of the gate valve.
6. Note down the voltage and current, speed, pressure vacuum on the control panel, head over the notch, and tabulate the results.
7. Close the gate valve and then switch off the supply water pump set.
8. Follow the procedure discussed below for taking down the readings for evaluating the performance characteristics of the Kaplan turbine.

To Obtain Constant Head Characteristics

1. By keeping the gate position variable & by constant the rotor pitch
2. Select the propeller vane angle position.
3. Keep the gate valve closed and start the pump
4. Slowly open the gate valve and set the pressure on the gauge
5. For different electrical loads on the turbine change the rotor pitch position and maintain the constant head and tabulate.

FORMULAE**1. Head of Water**

$$H = \frac{P}{w}$$

Where:

$$P = P_d + P_v$$

Symbol	Description	Unit
H	Head of water	m
P	Total pressure	N/m ²
P_d	Delivery pressure	N/m ²
P_v	Suction pressure	N/m ²
w	Specific weight of water (9810)	N/m ³

2. Discharge Through Turbine (Rectangular Notch Method)

$$Q = \frac{2}{3} C_d b \sqrt{2g} h^{3/2}$$

Where:

Symbol	Description	Unit
Q	Discharge (Flow rate)	m ³ /s
C_d	Coefficient of discharge (assumed 0.6)	–
b	Crest width of the notch	m
g	Acceleration due to gravity (9.81)	m/s ²
h	Head over the notch	m

Assumptions:

- $C_d = 0.6$
- $g = 9.81 \text{ m/s}^2$

3. Hydraulic Input to the Turbine

$$P_H = \frac{wQH}{1000}$$

Where:

Symbol	Description	Unit
P_H	Hydraulic input power to the turbine	kW
w	Specific weight of water	N/m ³
Q	Discharge	m ³ /s
H	Head on the turbine	m

4. Output Power from the Alternator

$$P_A = \frac{x}{t} \times \frac{3600}{K}$$

Where:

Symbol	Description	Unit
P_A	Output power from the alternator	kW
x	Number of revolutions of the energy meter disc	rev
t	Time taken for x revolutions	s

Symbol	Description	Unit
K	Energy meter constant	rev/kWh

5. Brake Power of the Turbine

$$BP = \frac{P_A}{\eta_A}$$

Where:

Symbol	Description	Unit
BP	Brake power of the turbine	kW
P_A	Output power from the alternator	kW
η_A	Alternator efficiency (expressed as a decimal)	–

Note: If the alternator efficiency is given as a percentage, convert it to decimal before substitution:

$$\eta_A = \frac{\text{Efficiency (\%)}}{100}$$

6. Turbine Efficiency

$$\eta_T = \frac{\text{Brake Power}}{\text{Hydraulic Input Power}} \times 100 = \frac{BP}{P_H} \times 100$$

Where:

Symbol	Description	Unit
η_T	Turbine efficiency	%
BP	Brake power of the turbine	kW
P_H	Hydraulic input power to the turbine	kW

7. Percentage of Full Load

$$\% \text{Load} = \frac{\text{Brake Power}}{\text{Maximum Brake Power}} \times 100$$

Where:

Symbol	Description	Unit
$\% \text{Load}$	Percentage of full load	%
BP	Brake power of the turbine	kW
$BP_{\max}$	Maximum brake power	kW

OBSERVATIONS

1. Specific weight of Water = 9810 N/m^3
2. Efficiency of the Alternator = 0.9
3. Energy meter Constant = 750 rev/KWH
4. Crest Width for Rectangular Notch, $b = 400 \text{ mm}$
5. Co-efficient of Discharge for Rectangular Notch = 0.6 Note: $760 \text{ mm of Hg} = 1.01325 \times 10^5 \text{ N/m}^2 = 1.0332 \text{ kgf/cm}^2$.

TABLE OF READINGS

S.No	Load	Speed N'	Head on Turbine			Head on Turbine		Time taken by Energy meter reading for 'X' revolutions
			Pressure 'P'		Pressure 'P'			
	watts	rpm	kg/cm^2	N/m^2	mm of Hg	cm	m	sec
1								
2								
3								
4								
5								
6								

TABLE OF CALCULATIONS

S.No	Head of water 'H'	Rate of flow through Turbine 'Q'	Hydraulic input to the turbine PH	Output power from the Alternator PA	Break Power from the turbine BP	Turbine efficiency % η_T	% full load
	m	m^3/sec	KW	KW	KW		
1							
2							
3							

4							
5							
6							

PRECAUTIONS

1. Don't start pump set if the supply voltage is less than 300V (Phase to Phase Voltage)
2. Don't forget to give electrical earth and neutral connections correctly, otherwise the RPM indicator gets burnt if connections are wrong.
3. Frequently, at least once in three months, grease all visual moving parts.
4. Initially, fill in the tank with clean water free from foreign material, change the water every six months
5. At least every week, operate the unit for five minutes to prevent any clogging of moving parts.
6. To start and stop supply pump, always keep gate valve closed.
7. It is recommended to keep sphere rod setting at close position before starting the turbine. This is to prevent racing of the propeller shaft without load.
8. In case of any major faults, please write to the manufacturer, and do not attempt to repair.

GRAPHS

At Constant Head Characteristics

1. Percentage of Full load Vs Efficiency
2. Efficiency V/s Speed
3. BP V/s Speed

RESULT

1. Efficiency of Kaplan Turbine at Constant Head: ($\% \eta_T$) =
2. % full load at Constant Head =

VIVA VOICE QUESTIONS

1. What is specific speed?
2. Give expression for water Power.
3. Give expression for shaft power.
4. Differentiate between power and work.
5. What is the difference between propeller and Kaplan turbine?
6. Mention the parts of Kaplan turbine.

EXPERIMENT-8

PERFORMANCE TEST ON SINGLE STAGE CENTRIFUGAL PUMP

AIM : To draw the operating characteristics curves under various heads, flow rates and speeds.

APPARATUS REQUIRED:

Centrifugal pump test rig, stop watch. The present Pump Test Rig is a self – contained unit operated on Closed Circuit (Recirculation) Basis. The Centrifugal Pump, AC Motor, Sump Tank, Collecting Tank, control Panel are mounted on rigid frame work with anti-vibration mounts and arranged with the following provisions:

THEORY:

In general a pump may be defined as a mechanical device which, when interposed in a pipe line, converts the mechanical energy supplied to it from some external source into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

A centrifugal pump consists of an impeller rotating inside a casing. The impeller has a number of curved vanes. Due to the centrifugal head impressed by the rotation of the impeller, the water enters at the centre and flows out wards to the periphery. There it is collected in a gradually increasing passage in the casing known as involute chamber which serves to convert a part of the velocity head into pressure head. For higher heads multistage centrifugal pumps having two or more impellers in series will have to be used.

The centrifugal pump which is of present concern falls into the category of Rotodynamic pumps. In this pump, the liquid is made to rotate in a closed chamber (volute casing) thus, creating a centrifugal action which gradually built up the pressure gradient towards outlet, thus, resulting in the continuous flow. These pumps compared to reciprocating pumps are simple in construction, more suitable for handling viscous, turbid liquids can be directly coupled to high-speed electric motors and easy to maintain. But, their hydraulic heads at low flow rates is limited and hence, not suitable for very high heads compared to reciprocating pump of same capacity. But, still in most cases, this is the only type of pump which is being widely used for agricultural applications because of its practical suitability.

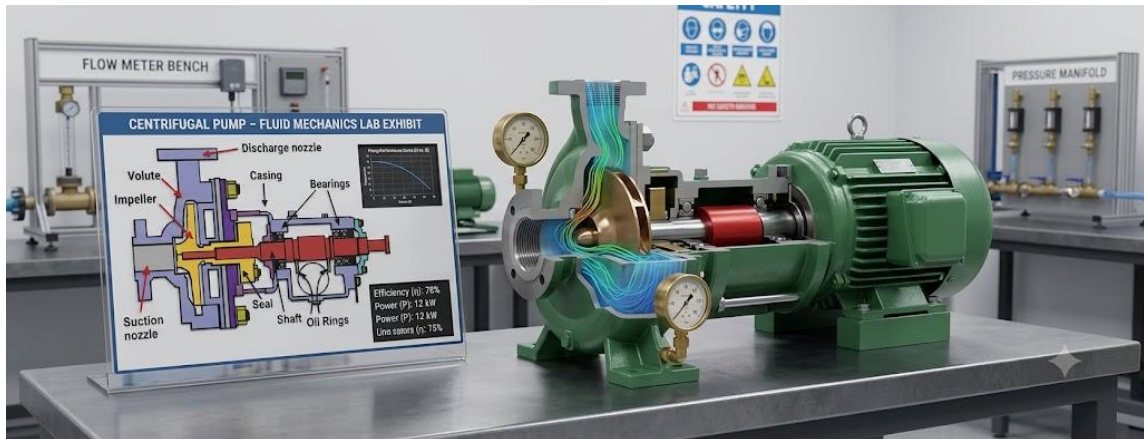
DESCRIPTION

The present test rig is a self-contained unit operated on closed circuit basis. The pump, electric Dc motor, collecting- measuring tank set control panel are the main components of the unit. The following are the provisions incorporated with the unit.

1. The speed variation is achieved by thyristor-controlled drive.
2. The speed is indicated on digital RPM indicator.
3. The torque is indicated on the spring balance in terms of force.
4. The electric power input is measured using 1PH energy meter.

5. The delivery and suction head are measured by using pressure and vacuum gauges.
6. The flow rate is calculated using measuring (collecting) tank.
7. The over flow and butterfly valve are provided in collecting tank for recirculation of water for closed circuit operation.

Photograph of the setup:



PROCEDURE:

All the necessary instrumentations along with its accessories are readily connected. It is just enough to follow the instructions below

1. Fill in the Sump Tank with clean water.
2. Keep the delivery valve closed and suction valve open, after initially priming the pump.
3. Connect the power cable to 1 Ph, 230V, 15A with earth connection.
4. Confirm the belt is put to the lowest speed position.

5. Switch ON the Mains, so that the Mains On Indicator glows. Now, switch-ON the starter.
6. Now you will find the water starts flowing to the Measuring Tank.
7. Close the delivery valve slightly, so that the delivery pressure is readable!
8. Operate the Butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.
9. Note down the Pressure Gauges, Vacuum Gauges, and time for number of revolutions of Energy Meter Disc.
10. Note down the other readings as indicated in the tabular column.
11. Repeat the experiment for different openings of the Delivery Valve and Suction Valve.
12. Change the belt to different speed positions and repeat the experiment.
13. After the experiment is over, keep all the delivery and suction valves open.

FORMULAE

1) Electrical power as indicated by energy meter, P_E

$$P_E = \frac{x}{t_s} \times \frac{3600}{K} \quad \text{KW}$$

Where,

x is no. of revolutions of energy meter disc

K is Energy meter Constant

rev/KWH

t_s is time taken for ' x ' revolutions

sec

2) Shaft Power as indicated by Field Dynamometer, P_s

$$P_s = \frac{2\pi NT}{60 \times 1000} \quad \text{KW}$$

$$T = F \times 9.81 \times R$$

Where,

T is Torque

N-m

R is radius of swinging field arm

m

‘ F ’ is the force in Spring Balance

kgf

‘ N ’ is the speed of DC Motor

rpm



3) Discharge ‘ Q ’

$$Q = \frac{A \times r}{t}$$

m³ / sec

Where,

A = area of the collecting tank

m²

r = rise of water

m

t = time taken for ‘ r ’ rise of water

sec

4) Total Head ‘ H ’

$$H = \frac{P}{w}$$

m

$$P = (P_d + P_v)$$

N/m²

Where,

P is the Pressure

N/m²

w = Specific weight of Water = 9810

N/m³

P_d is the Delivery Pressure

N/m²

P_v is the Suction Pressure

N/m²

5) Hydraulic Power (Delivered by the Pump), P_H

$$P_H = \frac{wQH}{1000}$$

KW

Where,

w = Specific weight of Water = 9810

N/m³

Q = Discharge

m³ / sec

H = Total Head

m

6) Hydraulic Efficiency of Pump

$$\eta_{\text{pump}} = \frac{P_H}{P_S} \times 100$$

7) Overall Efficiency of pump

$$\eta_{\text{overall}} = \frac{P_H}{P_E} \times 100$$

TABLE OF READINGS

Sl.No	Speed of Motor	Delivery Pressure		Suction Pressure (Vacuum)		Time taken by Energy meter reading for 'X' revolutions	Swinging Field spring Balance reading	Water collected in collecting tank		Time taken for 'r' rise of water
	rpm	Kg /cm ²	N/m ²	mm of Hg	N/m ²	sec	kgf	cm	m	sec
1										
2										
3										
4										
5										
6										

TABLE OF CALCULATIONS

Sl.No	Pressure P		Total Head H	Rate of flow Q	Hydraulic Power P _H	Shaft Power P _S	Electrical Power P _E	%η of pump	%η of overall
	Kg/cm ²	N/m ²	m	m ³ /s	KW	KW	KW		
1									

2									
3									
4									
5									
6									

PRECAUTIONS

1. Avoid starting the unit if the 3PH voltage is less than 300V. AC
2. Avoid starting the unit by keeping delivery and suction valves open
3. Avoid switching ON motor controller when speed setting knob is not at zero.
4. Frequently oil / grease the rotating parts
5. Periodically check the spring balance reading using wheel provided at top of spring balance.

GRAPHS

The characteristics curves namely for centrifugal pump,

1. Flow rate vs Head
2. Flow rate vs Pump Efficiency
3. Flow rate vs Shaft Horse Power

RESULT

1. Pump Efficiency of the Centrifugal Pump =
2. Overall Efficiency of the Centrifugal Pump =

APPLICATIONS: The most commonly used pumps for domestic, agricultural and industrial purposes are;

Centrifugal pumps. These pumps fall into the main class, namely, Rotodynamic pumps.

VIVA VOICE QUESTIONS

1. Differentiate pump and turbine.
2. What is the need for priming in pump?
3. Mention the parts of centrifugal pump.
4. Mention the type of casing used in centrifugal pump.
5. Why is the foot valve fitted with strainer?
6. Why the foot valve is a non-return type valve?

EXPERIMENT-9

PERFORMANCE TEST ON RECIPROCATING PUMP

AIM:

To find the overall efficiency of a Reciprocating Pump and plot the following characteristics.

- a. $HP_{Hydraulic}$ Vs $HP_{Electric}$
- b. $\eta_{overall}$ Vs $HP_{Electric}$

THEORY:

In general, a pump may be defined as a mechanical device which, when interposed in a pipe line, converts the mechanical energy supplied to it from some external source into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

The pumps are of major concern to most Engineers and Technicians. The types of pump vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial purposes are: Centrifugal, Piston, Axial Flow (Stage pumps), Air Jet, Diaphragm and Turbine pumps. Most of these pumps fall into the main class, namely, Rotodynamic, Reciprocating (Positive Displacement), Fluid (Air) operated pumps.

APPARATUS:

Reciprocating pump test rig, stopwatch.

The present Reciprocating Pump Test Rig is a self-contained unit operated on Closed Circuit (Recirculation) Basis. The main components are single acting Single Cylinder Reciprocating Pump, AC Motor, Sump Tank, Collecting Tank, control Panel are mounted on rigid frame work with anti-vibration mounts and arranged with the following provisions:

1. To run the pump at 3 different speeds using Stepped Cone Pulley arrangement and AC Motor.
2. To measure the input horse power to the pump using energy meter reading.
3. To measure the speed in rpm of the motor and the pump, separately.
4. To measure the delivery and suction heads using pressure and vacuum gauges separately. (The delivery head pressure tapping is connected, upstream of delivery valve, and that of the suction tapping downstream of suction valve).
5. To change the head and flow rate using control valves.
6. To measure the discharge using collecting tank fitted with tank level indicator.

SPECIFICATIONS:

Electrical Supply	: 230V, AC, 1 Phase, 50 Hz with Neutral & Earth Connections.
Motor	: AC Motor, 1.5 HP, 1500 RPM.
Reciprocating Pump	: Single acting single cylinder.
Pressure Gauge	: 2 kg / cm ²
Vacuum Gauge	: 0 – 760 mm of Hg
Energy Meter Constant	: 1500 rev / kWh.
Speed Indicator	: 0 – 9999 rpm (Digital type).
Control Valves	: For suction & delivery.
Measuring (Metering) Tank	: 0.25m ²

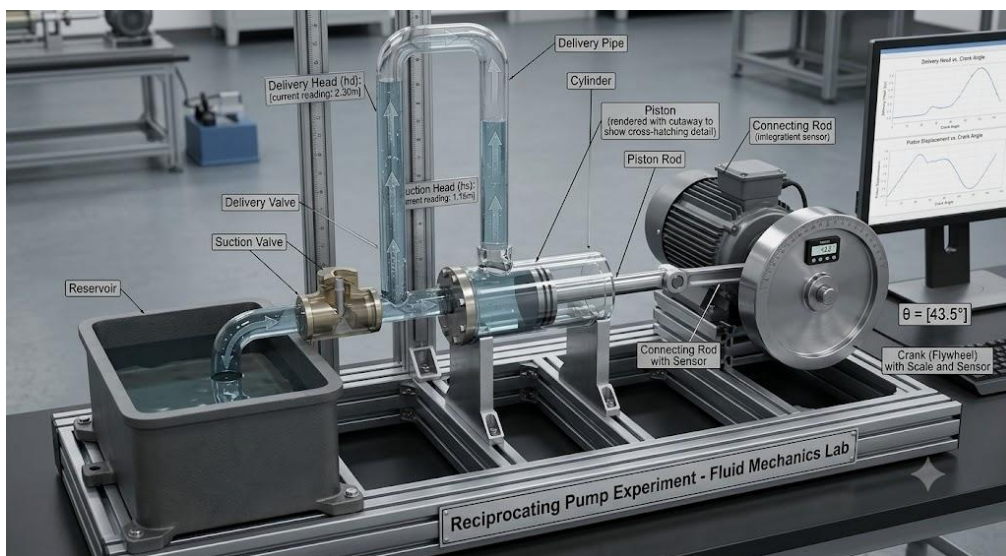


Fig 1: Reciprocating Action of The Piston



Fig 2: Experimental setup of the Reciprocating pump Testing Rig.

Procedure:

All the necessary instrumentation along with its accessories are readily connected. It is just enough to follow the instructions below:

1. Fill in the sump tank with clean water.
2. Keep the delivery and suction valves open.
3. Connect the power cable to 1 Phase, 220 V, 15 Amps.
4. Select the required speed using stepped cone pulley arrangement.
5. Switch ON the mains so that the mains ON indicator glows. Now, switch on the motor.
6. Note down the speed from digital rpm indicator.
7. Note down the Pressure Gauge, Vacuum Gauge and time for number of revolutions of energy meter disc at full opening of delivery and suction valve.
8. Operate the butterfly valve to note down the collecting tank reading against the known time, and keep it open when the readings are not taken.
9. Repeat the experiment for different openings of the delivery valve (Pressure & Flow Rate). Note down the readings as indicated in tabular column.
10. Repeat the experiment for different speeds and repeat the steps (4 & 9).
11. After the experiment is over, keep the delivery valve open and switch OFF the mains.

Observation Table:

Speed of Pump in rpm	Delivery Pressure Head 'P' kg / cm ²	Vacuum pressure 'P _v ' in mm of Hg	Time taken for 5 rev. of Energy meter in sec.	Discharge height 'h' of water collected in cm	Time taken for rise of water in sec

Calculations:

Speed of Pump in rpm	Total pressure head in m	Discharge in m ³ / Sec	HP _{pump}	Input to Motor HP _{electric}	% pump Efficiency

1. Basic Data / Constants:

1 HP	=	736 Watts
1 kg / cm ²	=	760 mm of Hg (10m of water)
Specific weight of water	=	1000 kgf / m ³
Energy Meter Constant	=	1500 rev. / kWh
Area of Collecting Tank	=	0.125 m ²

2. Electrical Power as indicated by Energy Meter:

$$HP_{elec} = \frac{5}{1500} \times \frac{1000}{736} \times \frac{60 \times 60}{t}$$

$$HP_{elec} = \frac{16.3}{t}$$

Where, “t” is the time taken by the Energy meter for 5 revolutions, in seconds.

$$HP_{shaft} = \eta_{motor} \times HP_{elec} = 0.75 \times HP_{elect}$$

(Efficiency of Motor, $\eta_{motor} = 75\%$)

3. Discharge Rate “Q” in m³ / Sec.

$$Q = \frac{A \times h}{1000 \times T} = \frac{0.125 \times h}{1000 \times T} \text{ m}^3/\text{sec}$$

Where, “A” = 0.125 m² is the area of collecting tank,
 “h” = the height of water collected in cm.
 “T” = the time taken in seconds for collecting tank.

4. Total Head ‘H’ in m.:

$$H = 10 \text{ (Delivery Pressure + Vacuum Head)}$$

$$= 10 [P + (P_v / 760)]$$

Where, “P” is the pressure in kg / cm²,
 “P_v” is the vacuum in mm of Hg.

5. Hydraulic Horse Power (Delivered by the Pump):

$$HP_{pump} = \frac{WQH}{75}$$

Where, “W” = 1000 kgf / m³
 “Q” = from Formulae 3.
 “H” = from Formulae 4.

6. Overall Efficiency:

$$\% \eta_{\text{overall}} = \frac{HP_{\text{pump}}}{HP_{\text{elec}}} = \frac{\text{from formula 5}}{\text{from formula 3}} \times 100$$

Graph:

Plot the following characteristics.

- a. $HP_{\text{Hydraulic}}$ Vs HP_{Electric}
- b. η_{overall} Vs HP_{Electric}

Precautions:

1. Do not start the pump if the voltage is less than 180 V.
2. Frequently (at least once in three months) grease / oil the rotating parts.
3. Initially, put clean water free from foreign material, and change once in three months.
4. At least every week, operate the unit for five minutes to prevent clogging of the moving parts.
5. Don't exceed 5kg / cm² on pressure gauge reading and never fully close the delivery valve.

Result /Conclusion:

The overall efficiency for different speeds were calculated and graphs plotted.

1. For belt position 1, the overall efficiency was found out to be _____.
2. For belt position 2, the overall efficiency was found out to be _____.
3. For belt position 3, the overall efficiency was found out to be _____.

Extension:

1. At any particular speed, to draw the characteristics of Total Head versus Flow rate (Total Head = Delivery Head + Suction Head)
2. To conduct experiments, at any particular speed, by changing only the Suction Head.
3. To conduct experiments, at any particular speed, by changing only the Deliver Pressure.
4. To change the speed and to repeat any of the above (1, 2, 3).
5. To draw speed versus Flow rate characteristics at constant Head.
6. To draw iso-efficiency curves for various speeds.
7. To determine specific speed of the pump.

Applications:

1. To drill oil from deep wells.
2. To pump any liquid which is free from debris.

Viva Questions:

1. What is the main aim of the experiment?
2. What is meant by a positive displacement pump?
3. What types of fluids are pumped by Reciprocating pumps?
4. What are the pumping characteristics of a Reciprocating pump?
5. What is the normal efficiency of a Reciprocating pump?
6. What are the normal precautions to be taken when operating a pump?

What is the function of air vessel?

EXPERIMENT-10

DETERMINATION OF CO-EFFICIENT OF FLOW USING TURBINE FLOW METER

AIM

To Determination of Co-Efficient Of Flow Using Turbine Flow Meter

THEORY

It operates on the principle that when a turbine wheel is placed in a pipe containing a flowing fluid, its rotary speed depends on the flow rate of fluid. If the bearing friction is reduced and the losses are kept to a minimum, the speed of turbine varies with flow rate. Therefore, the flow rate can be measured by measuring the speed of the turbine. A turbine flow meter is known as inferential meter because the operation depends upon the rotating form of the turbine and the stream velocity of the liquid in which it rotates. They are volumetric flow meters and are available in wide ranges. The output is usually in the form of a digital electrical signal whose frequency is directly proportional to flow rate and whose total count is proportional to the total quantity, as each pulse represents a discrete volume.

DESCRIPTION

Turbine flow meter consists of freely rotating wheel (or propeller) with multiple blades. The rotor(supported by ball or sleeve bearings) is located centrally in the pipe along which flow occurs. The flowing fluid impinging on the turbine blades imparts a force on the blade surfaces and sets the rotor in motion with an angular speed proportional to the fluid velocity. The rotor speed is measured with a mechanical counter or the electromagnetic pickup and associated counter. The electromagnetic pickup would be a small permanent magnet mounted at the tip of one of the rotor blades with a coil being placed just outside the tube. As the magnet moves past the coil, an e.m.f. is induced. Faster the fluid flow the greater the counter per second. Each pulse represents a definite flow quantity, and the total number of pulses may be taken as an indication of total flow.

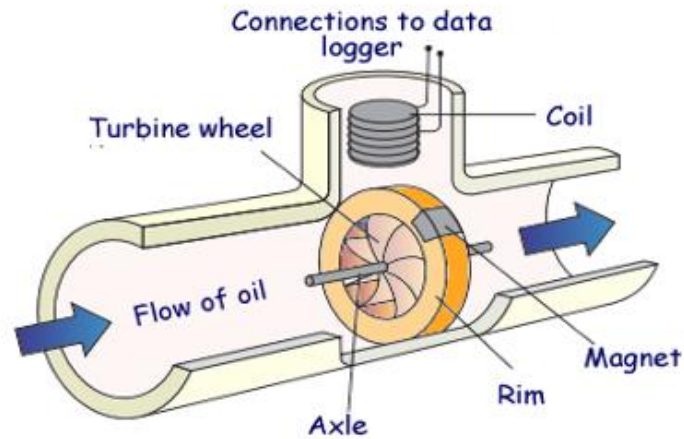


Fig 1 Schematic of the Turbine Flow Meter



Fig 2 Experimental Setup for testing the Turbine Flow Meter

PROCEDURE:

1. Fill the sump tank with clean water.
2. Initial Setting: Open the regulate valve fully and switch on the pump
3. Note down the collecting time for 'r' cm rise in measuring tank for the above Setting.
4. Observe the digital flow indicator, note down the reading in pulse per second shown at the upper indication.
5. Now using the equation given calculates the 'Factor' and enters it in the indicator using button "SET".
6. Once SET button is pressed, using upper ward arrow and downward arrow button 'Factor' can be fed to the indicator.
7. Now press "ENT" button to get the discharge in LPM through the Turbine flow meter.

8. To get different set of readings, using valve set different flow rate at digital Indicator and also note down the time taken each 'r' cm rise in water level in the measuring tank.
9. Calculate the actual discharge from the equation.
10. Repeat the experiment for different discharges and plot the graph.

FORMULAE

Actual Discharge, Q_{act}

$$Q_{act} = \frac{A \times r}{t} = (0.11565 \times 0.20) \times (1000 \times 60) / t = \frac{1387.8}{t} \text{ LPM}$$

Where,

A = area of measuring tank m^2
 r = rise of water in measuring tank 0.2 m
 t = time taken for 'r' rise of water sec

Calculation for the "Factor":

$$\text{Factor} = \frac{Q_{act}}{\text{Turbine Flowmeter rotation in pulse per sec}}$$

Observations

Area of collecting tank = m^2

Tabular Column

S.No	Flow rate (Digital) $Q_{digital}$	Flow rate (Digital)	Time taken for 'r cm' rise of water 't'	Actual Discharge Q_{act}	Factor
	LPM	Pulse / sec	sec	LPM	
1					
2					
3					
4					
5					
6					

PRECAUTIONS

1. Reading must be taken in steady conditions.
2. Discharge must be varied very gradually from a higher to smaller value.

GRAPH

Draw a graph between Q_{digital} Vs Q_{act}

RESULT

The given Turbine Flow Meter was calibrated.

VIVA VOICE QUESTIONS

1. How turbines are classified based on head. Give example.
2. How turbines are classified based on flow. Give example.
3. How turbines are classified based on working principle. Give example.
4. What does velocity triangle indicate?
5. Mention the type of characteristic curves for turbines.
6. Mention the types of efficiencies calculated for turbine.

EXPERIMENT-11

FLOW VISUALIZATION USING REYNOLDS EXPERIMENT

AIM:

Determine the Reynold's Number and hence the Type of Flow and perform the Reynolds experiment for determination of different regimes of flow.

APPARATUS:

A stopwatch, a graduated cylinder, and Reynolds apparatus which consists of water tank having a glass tube leading out of it. The glass tube has a bell mouth at entrance and a regulating valve at outlet, a dye container with an arrangement for injecting a fine filament of dye at the entrance of the glass tube. Potassium permanganate (to give brightly reddish colour streak), thermometer measuring tank.

THEORY:

The flow of real fluids can basically occur under two very different regimes namely laminar and turbulent flow. The laminar flow is characterized by fluid particles moving in the form of lamina sliding over each other, such that at any instant the velocity at all the points in particular lamina is the same. The lamina near the flow boundary move at a slower rate as compared to those near the center of the flow passage. This type of flow occurs in viscous fluids, fluids moving at slow velocity and fluids flowing through narrow passages.

The turbulent flow is characterized by constant agitation and intermixing of fluid particles such that their velocity changes from point to point and even at the same point from time to time. This type of flow occurs in low density Fluids flow through wide passage and in high velocity flows. Reynolds conducted an experiment for observation and determination of these regimes of flow. By introducing a fine filament of dye in to the flow of water through the glass tube, at its entrance he studied the different types of flow. At low velocities the dye filament appeared as straight line through the length of the tube and parallel to its axis, characterizing laminar flow. As the velocity is increased the dye filament becomes wavy throughout indicating transition flow. On further increasing the velocity the filament breaks up and diffuses completely in the water in the glass tube indicating the turbulent flow. After conducting his experiment with pipes different diameters and with water at different temperatures Reynolds concluded that the various parameters on which the regimes of flow depend can be grouped together in a single non dimensional parameter called Reynolds number. Reynolds number is defined as, the ratio of inertia force to the viscous force. Where viscous force is shear stress multiplied area and inertia force is mass multiplied acceleration.

$$Re = VD\rho/\mu = VD/v \quad (v = \frac{\mu}{\rho})$$

Where Re-Reynolds number

V - Velocity of flow

D - Characteristic length=diameter in case of pipe flow

P - Mass density of fluid =1000

μ - dynamic viscosity of fluid = 0.55×10^{-3}

ν (nu) - Kinematic viscosity of fluid

Reynolds observed that in case of flow through pipe for values of $Re < 2000$ the flow is laminar while for $Re > 4000$ it is turbulent and for $2000 < Re < 4000$ it is transition flow.

Type of flow	Reynolds number	
	Pipe flow	Canal flow
Laminar flow	< 2000	< 500
Transition flow	2000 to 4000	500 to 2000
Turbulent flow	> 4000	> 2000

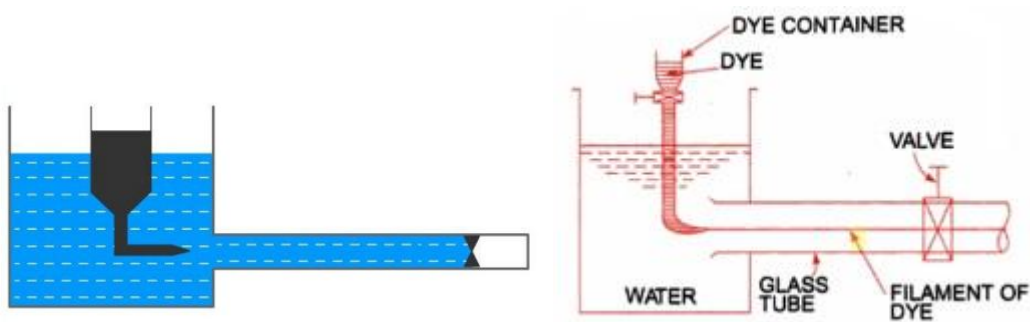


Fig 1: Experimental setup for the flow visualization using Reynolds experiment.

Observations:

Inner diameter of glass tube, $D =$

Cross - sectional area of glass tube, $A = (\pi/4) \times D^2$

Mean temperature of water – $t =$

Kinematic viscosity of water- $\nu =$

	Discharge 'q' in (liters)	Time taken for discharge 't' in (sec)	Discharge 'Q' in (cm ³ /sec)	Velocity 'V' (cm/sec)	Reynold's Number 'Re'	Type of flow
1						
2						
3						
4						

Perform the following calculations for each set of readings

$$\text{Discharge } - Q = \frac{Akh}{t}$$

$$\text{Velocity of flow } - V = \frac{4NQ}{\pi D^2}$$

PROCEDURE:

Start the experiment by pressing start button with default values of temperature of water and time taken and diameter of pipe. Then pass the experiment with few cycles and note the observation.

Observation1:

1. Start the experiment and allow the water to flow in to the tank of the apparatus. Water level in the pyrometer is slightly rising along with rise in tank. Control valve of the glass tube should be slightly opened for removing air bubbles.
2. After the tank is filled outlet valve of the glass tube and inlet valve of the tank should be closed, so that water should be at rest.

Observation2:

1. Keeping the velocity of flow is very small and inlet of the die injector is slightly opened, so that the die stream moves at a straight line throughout the tube showing the flow is laminar.
2. Again, measure the discharge and increase the velocity of flow.

Observation3:

1. Note the observations till the die stream in the glass tube breaks up and gets diffused in water.
2. Repeat the experiment by decreasing the rate of flow and by changing the temperature and diameter of pipe.

Tabular Column

Observed Flow Regime	Volume (L)	Time (sec)	Temperature ($^{\circ}C$)

Calculations:

Observed Flow Regime	Discharge $Q(m^3/sec)$	Velocity $v(m/sec)$	Kinematic Viscosity $\nu(m^2/s)$	Renolds Number	Flow Regime Classified using Reynolds Number

RESULT:

1) Reynolds number $-Re = VD/\nu$

2) Regime of flow =

EXPERIMENT-12

FLOW VISUALIZATION STUDY USING WATER FLOW CHANNEL

AIM:

To visualize the flow filed over given objects at various Reynolds numbers.

APPARATUS:

Water flow channel, models, Dye and stopwatch.

THEORY:

Vortex motion is a fluid flow in which the streamlines are concentric circles. The flow process behind the object establishes the twin-vortex. On reaching the forward stagnation point, the flow encounters a positive pressure zone at the face of the body, popularly termed pressure uphill. The streamlines on either side of the stagnation streamline take an outward deflection, negotiating the pressure uphill, before reaching the edges of the body. On reaching the edge, these curved streamlines on either side of the body find a large space at the back of the body, and therefore, on reaching the edges, turn towards the body base. This process of turning towards the base results in the formation of two vortices of opposite nature soon after starting the flow. The formation of these vortices creates a low-pressure region at the base body. Suction at the base body increases with an increase of free stream velocity. This low-pressure region at the base attracts flow from the zone just downstream of the vortices towards the base, thus establishing a reverse flow towards the base.

Von Karman Vortex Street: A very interesting sequence of events begins to develop when the Reynolds number is increased beyond 40, at which point the wake behind the cylinder becomes unstable. It is observed that the wake develops a slow oscillation in which the velocity is periodic in time and downstream distance, with the amplitude of the oscillation increasing downstream. The oscillating wake rolls up into two staggered rows of vortices with opposite sense of rotation.

WATER FLOW CHANNEL:

Water flow channel is a simple duct through which water is made to flow with uniform velocity over the length of the channel. The uniform flow portion can be used to visualize flow past objects. The channel is made of Stainless-Steel sheet of 3 mm thickness, the sheet is bent into the shape as shown in the below Fig. 1. The width of the test section is about 280mm, and the depth of water will be maintained at 8mm. A pictorial view of a water flow channel, of rectangular cross-section is shown in the below Fig. 2. Water from the chamber spills over the inclined plate and is conditioned using an array of wire-meshes, before reaching the test-section. It is essential to ensure that the flow quality is uniform in the test section. For this a colour dye may be injected at specified locations across the test-section width. If the dye streaks in the test-section are parallel and smooth, the quality of flow can be taken as good for any visualization

study. The velocity of the flow may be measured using the floating-particle method technique, over the length of the test-section. The uniformity of the flow may also be checked by observing a floating body (say, a tiny bit of paper) moving from the beginning to the end of test-section of the channel. If the test-section flow is uniform, a tiny floating object will travel straight and parallel to the channel floor and sidewalls.

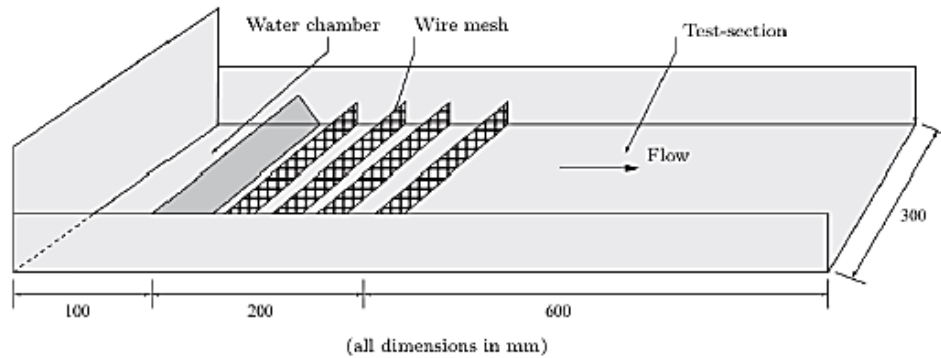


Fig 1. Schematic diagram of water flow channel

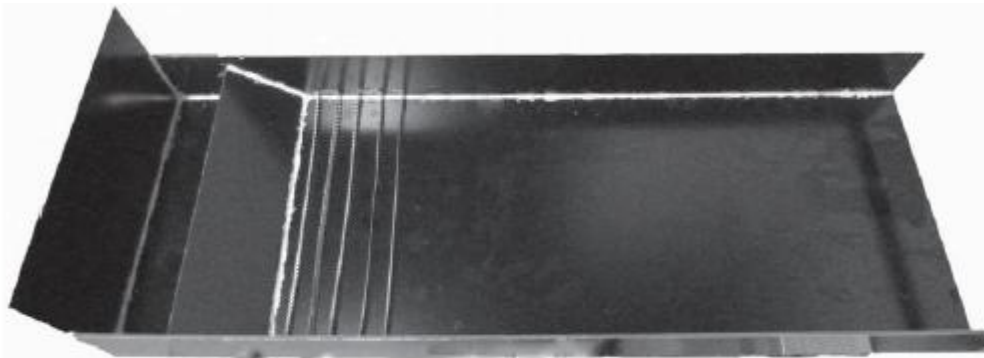


Fig 2. Pictorial view of water flow channel

Procedure:

1. Place the channel on a flat surface which has no inclination.
2. Now give the water supply to the channel at the water chamber so that the uniform flow will be entering into the test section due to the effect of wedge and screens.
3. Test for the uniformity of flow i.e., whether the streamline going in a straight line from starting to the end of the channel, otherwise make some adjustments to get the uniform flow.
4. In this step flow velocity to be set in the channel according to the requirement, by using the floating particle method calculate the corresponding Reynolds number based on the characteristic dimension of the model.
5. Place the experimental model at the center of the test-section

6. Now inject enough dye at the second screen which helps to get the streamline flow and take the video from starting to the end of flow pattern over the object for further investigation.
7. Repeat the above step for different Reynolds numbers and models.
8. Repeat the experiment for another model.
9. From the video extract the frames and necessary information for the analysis.

Calculation of Reynold's Number:

In the floating particle method, time taken for the travel of floating particle over a distance is estimated. The velocity can be calculated by dividing the distance with the time. After finding out the velocity the Reynolds number can be calculated with reference to the width of the model by using the following formula.

$$Re = (\rho VD) / \mu = (VD) / \nu$$

Where ,

Re is the Reynolds number,

ρ is the density of the fluid (for Water $\rho=1000\text{Kg/m}^3$),

D is the characteristic dimension of the body. (Diameter for circle and width for flat plate).

' μ ' is the dynamic viscosity of the fluid (At atmospheric conditions).

Table of Observations:

S. No	Reynolds Number	Vortex size (mm)		Reverse flow distance (mm)	
		Object 1	Object 2	Object 1	Object 2
1					
2					
3					
4					

Precautions:

- 1) Before starting of the experiment, make sure that the flow is uniform.
- 2) Do not inject too much amount of dye.
- 3) Flow should not be disturbed by any means.
- 4) The flow should be left to right in the video graph.
- 5) Take care while measuring the velocity of the flow.

Plots: Reynolds number Vs Reverse flow Distance