# FLUID MECHANICS AND MACHINES LAB 17MEL57

## FIFTH SEMESTER

## DEPARTMENT OF MECHANICAL ENGINEERING

**NAME OF THE STUDENT:……………………………………………….**

**USN:……………………………………………………………………....**

**BATCH NO:…………… SECTION……………………**

# SYLLABUS

## FLUID MECHANICS & MACHINERY LAB
## [AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME]

| | |
|---|---|
| **SEMESTER – V** | **Subject Code 17MEL57** |
| **CIE Marks :40** | **CREDITS – 02** |
| **SEE Marks: 60** | **Exam Hours 03** |

**Co-requisite Courses:** Turbo Machines

**Pre requisites:** Fluid Mechanics and Thermodynamics

**Course Objectives:**

1. This course will provide a basic understanding of flow measurements using various types of flow measuring devices, calibration and losses associated with these devices.
2. Energy conversion principles, analysis and understanding of hydraulic turbines and pumps will be discussed. Application of these concepts for these machines will be demonstrated. Performance analysis will be carried out using characteristic curves.

**Course Outcomes:**

At the end of this course students are able to,

1. Perform experiments to determine the coefficient of discharge of flow measuring devices.
2. Conduct experiments on hydraulic turbines and pumps to draw characteristics.
3. Test basic performance parameters of hydraulic turbines and pumps and execute the knowledge in real life situations.
4. Determine the energy flow pattern through the hydraulic turbines and pumps
5. Exhibit his competency towards preventive maintenance of hydraulic machines

**PART – A**

1. Lab layout, calibration of instruments and standards to be discussed
2. Determination of coefficient of friction of flow in a pipe.
3. Determination of minor losses in flow through pipes.
4. Application of momentum equation for determination of coefficient of impact of jets on flat and curved blades
5. Calibration of flow measuring devices: Orifice meter ,Nozzle ,Venturimeter, V-notch

**PART – B**

7. Performance on hydraulic Turbines

a. Pelton wheel

b. Francis Turbine

c. Kaplan Turbines

8. Performance hydraulic Pumps

d. Single stage and Multi stage centrifugal pumps

e. Reciprocating pump

9. Performance test on a two stage Reciprocating Air Compressor

10. Performance test on an Air Blower

**PART – C (Optional)**

11. Visit to Hydraulic Power station/ Municipal Water Pump House and Case Studies

12. Demonstration of cut section models of Hydraulic turbines and Pumps.

**Reading:**

1. K.L.Kumar."Engineering Fluid Mechanics" Experiments, Eurasia Publishing House, 1997

2. Jagdish Lal, Hydraulic Machines, Metropolitan Book Co, Delhi, 1995

3. George E. Totten , Victor J. De Negri "Handbook of Hydraulic Fluid Technology, Second Edition, 2011.

**Scheme of Examination:**

ONE question from part -A: 50 Marks

ONE question from part -B: 30 Marks

Viva –Voice: 20 Marks

Total: 100 Marks

# CONTENTS

**AIM: -** To caliberate the given Orifice meter and also to find the co-efficient of discharge and Reynolds number for different flows.

**INTRODUCTION: -** Orifice meter is a device which is used for measuring the rate of flow of a fluid through the pipe. It works on the same principle as that of the Venturimeter. It consists of a flat circular plate which has circular sharp edged hole called orifice, which is concentric with the pipe. The orificemeter diameter is kept generally 0.5 times the diameter of the pipe. The orifice plate is provided with the pressure tapings – one upstream at a distance of approximately equal to pipe diameter and another down stream at a distance of 0.5 times pipe diameter. The pressure difference is used a measure of discharge.

**TEST RIG DETAILS:-**

1. Pipe line fitted with Orifice meter and flow control valve.
2. Differential U –tube mercury manometer.
3. Measuring tank with piezometer and scale.
4. Storage tank (sump) and centrifugal pump.

**SPECIFICATIONS:-**

$d_1$= Diameter of the pipe = 25 mm

$d_2$ = Throat diameter = 12.5 mm

$a_1$ = Area of the pipe = 490.87 $mm^2$

$a_2$ = Area of the throat = 122.72 $mm^2$

$A_1$ = Area of the measuring tank = 500 mm × 250 mm = 112500 $mm^2$

D = Diameter of the pipe in the measuring tank = 75 mm

$A_2$ = Area of the pipe in the measuring tank = 4417.86 $mm^2$

**A = Effective area of the measuring tank = $A_1 – A_2$ = $mm^2$**

**PROCEDURE:-**

1. Start the pump and check the flow of water through the meter.
2. Note down the inlet pipe and throat diameter.
3. Air if any in the manometer must be removed and the pressure difference of the two limbs of the U tube differential manometer.
4. Adjust the control valve for maximum discharge.
5. Note down the left and right limb readings of the manometer.
6. Measure the flow rate with the help of discharge measuring tank with the stop watch.
7. Repeat he experiment for 4 – 5 set of readings for different flow rate by regulating the control valve.
8. After completion of the experiment close the valve and stop the pump.

**TABLE OF READINGS:-**

| Sl.No. | Manometer reading of mercury | | | Time taken for R cm rise of water in the storage tank (t) in sec |
|---|---|---|---|---|
| | $h_1$ in cm | $h_2$ in cm | $h_m = (h_1 - h_2)$ in m | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

**SPECIMEN CALCULATIONS:-**

1. **Actual Discharge $Q_a$** = $\dfrac{A\,R \times 10^{-2}}{t}$

   A = Effective area of the measuring tank in $m^2$

   R = Rise of water level in the tank for time t in cm

   t = Time taken for R cm rise in the tank in s.

2. **Theoretical Discharge $Q_{th}$**

   $$H = hm\left[\frac{S_m}{S_w} - 1\right] \text{ in m of water}$$

   hm = head of mercury in the manometer in m

   Sm = Specific gravity of mercury =13.6

   $S_W$ = specific gravity of the standard fluid (water) =1

   **Theoretical discharge $Q_{th}$** = $\dfrac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}}$

3. **Co- efficient of discharge $C_d$** = $\dfrac{Q_{actual}}{Q_{Theoretical}}$

4. **Reynolds Number Re**

   Velocity of flow = V = $\dfrac{Q_{actual}}{a_1}$

   Reynolds number = Re = $\dfrac{\rho V d_1}{\mu}$

   Where,

   $\rho$ = Density of water in $kg/m^3$

   $\mu$ = Dynamic viscosity of water in $N\text{-}S/m^2$

   $d_1$= Diameter of the pipe in m

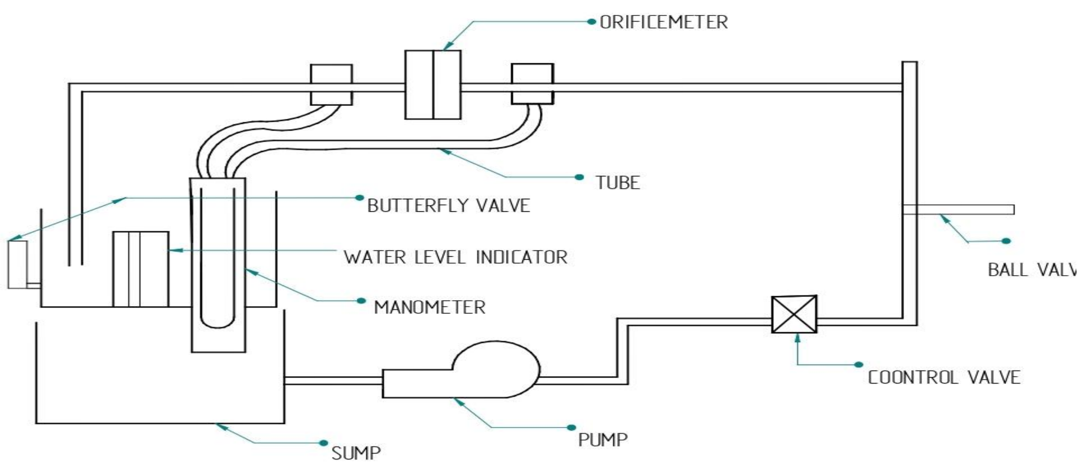
**TABLE OF RESULTS:-**

| SL. No. | Manometer reading H in m of water | Actual discharge Qa in $m^3/s$ | Theoretical discharge $Q_{th}$ in $m^3/s$ | Velocity of flow V in m/s | Co-efficient of Discharge Cd | Reynolds number Re |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

**RESULT:-**

The co-efficient of discharge and Reynolds number of the orifice meter for different flows ----------.

Plot the graph of **Cd verses Re.**




EXPERIMENTAL SETUP

**AIM: -** To calibrate the given Venturimeter and also to find the co-efficient of discharge and Reynolds number for different flows.

**INTRODUCTION: -** Venturimeter is a device which is used for measuring the rate of flow of fluid through a pipe. The basic principle of Venturimeter is that by reducing the cross- sectional area of flow passage a pressure difference is created. The pressure difference is used to measure the discharge through the pipe.

A Venturimeter consists of an inlet section followed by a diverging cone. The inlet section of the Venturimeter is of the same diameter as that of the outlet section followed by a divergent cone. This converges to form a throat which is a short parallel sided tube. The entrance and exit diameters will be same as that of the pipe line to which the Venturimeter is fitted. The convergent cone has a total included angle of 21° and that of the divergent cone is 5° - 15°. Hence the divergent cone is longer than the convergent cone. The function of the converging cone is to increase the velocity of the liquid and lower its pressure. A pressure difference between the inlet and throat id thus developed and this pressure difference is co-related with the flow rate. The diverging cone serves to change the area of the stream back to the entrance area and to convert the velocity pressure back into the static pressure. Since the separation of flow may occur in the diverging cone, this portion is not used for discharge measurement.

**TEST RIG DETAILS:-**

1. Pipe line fitted with Venturimeter and flow control valve.
2. Differential U –tube mercury manometer.
3. Measuring tank with piezometer and scale.
4. Storage tank (sump) and centrifugal pump.

**PROCEDURE:-**

1. Start the pump and check the flow of water through the meter.
2. Note down the inlet pipe and throat diameter.
3. Air if any in the manometer must be removed and the pressure difference of the two limbs of the U tube differential manometer.
4. Adjust the control valve for maximum discharge.

5. Note down the left and right limb readings of the manometer.
6. Measure the flow rate with the help of discharge measuring tank with the stop watch.
7. Repeat he experiment for 4 – 5 set of readings for different flow rate by regulating the control valve.
8. After completion of the experiment close the valve and stop the pump.

**SPECIFICATIONS:-**

$d_1$= Diameter of the pipe = 25 mm

$d_2$ = Throat diameter = 12.5 mm

$a_1$ = Area of the pipe = 490.87 $mm^2$

$a_2$ = Area of the throat = 122.72 $mm^2$

$A_1$ = Area of the measuring tank = 500 mm × 250 mm = 112500 $mm^2$

D = Diameter of the pipe in the measuring tank = 75 mm

$A_2$ = Area of the pipe in the measuring tank = 4417.86 $mm^2$

**A = Effective area of the measuring tank = $A_1 – A_2$ = $mm^2$**

**TABLE OF READINGS:-**

| Sl.No. | Manometer reading in of hg | | | Time taken for R cm rise of water in the storage tank (t) in sec |
|---|---|---|---|---|
| | $h_1$ in cm | $h_2$ in cm | $h_m$ = ($h_1$- $h_2$) in m | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

**SPECIMEN CALCULATIONS:-**

1. **Actual Discharge $Q_a$** = $\frac{AR \times 10^{-2}}{t}$

   A = Area of the measuring tank in $m^2$

   R = Rise of water level in the tank for time t in cm

   t = Time taken for R cm rise in the tank in s.

2. **Theoretical Discharge $Q_{th}$**

   $$H = h_m \left[ \frac{S_m}{S_w} - 1 \right] \text{ in m of water}$$

   hm = head of mercury in the manometer in m

   Sm = Specific gravity of mercury

   $S_w$ = specific gravity of the standard fluid (water)

   **Theoretical discharge $Q_{th}$** = $\frac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}}$

3. **Co- efficient of discharge $C_d$** = $\frac{Q_{actual}}{Q_{theoretical}}$

4. **Reynolds Number Re**

   Velocity of flow = V = $\frac{Q_{actual}}{a_1}$

   Reynolds number = Re = $\frac{\rho V d_1}{\mu}$

   Where,

   $\rho$ = Density of water in $kg/m^3$

   $\mu$ = Dynamic viscosity of water in $N\text{-}S/m^2$

   $d_1$= Diameter of the pipe in m.

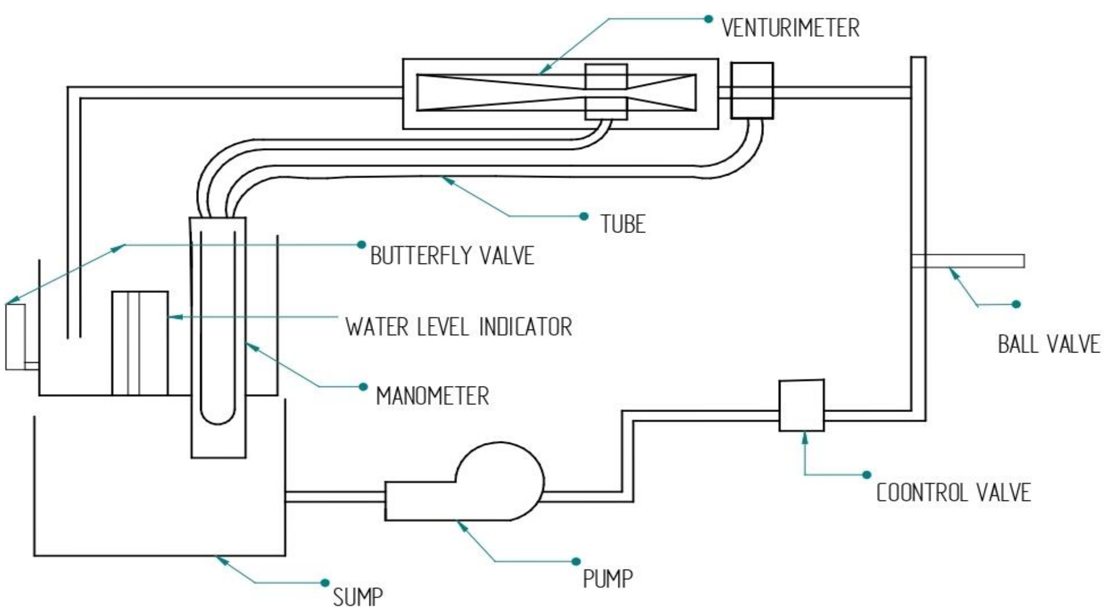
**TABLE OF RESULTS:-**

| SL. No. | Manometer reading H in m of water | Actual discharge Qa in $m^3/s$ | Theoretical discharge $Q_{th}$ in $m^3/s$ | Velocity of flow V in m/s | Co-efficient of Discharge Cd | Reynolds number Re |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

**RESULT:-**

The co-efficient of discharge and Reynolds number of the Venturimeter for different flows ________

Plot the graph of $\mathbf{C_d}$ verses **Re**



EXPERIMENTAL SETUP

**AIM:-**

To determine the Co-efficient of discharge for given notch.

**INTRODUCTION:-**

A notch is defined as sharp edged obstruction over which fluid flow occurs. Notches are used for measuring the rate of flow of liquid from a reservoir, small channel and tank. Generally notches are rectangular, triangle (V-notch) or trapezoidal notch. Triangular notch has advantage of greater accuracy at reduced flow rates compared to other shapes. The co0efficient of contraction will be constant for all heads. The sheet of water discharged by a notch is called "Nappe" or Vein.

**TEST RIG DETAILS:-**

1. Given notch in open channel provided with piezometer to measure the head over the notch.
2. A discharge measuring tank fitted with a piezometer and graduated scale.
3. Storage tank (sump) and centrifugal pump.

**SPECIFICATIONS:-**

Angle of V notch = 90° & 60°

Length of measuring tank = L = 500 mm

Breadth of measuring tank = B= 500mm

$A_1$ = Area of the measuring tank = 500 mm × 500 mm =______ $mm^2$

D = Diameter of the pipe in the measuring tank = __110__ mm

$A_2$ = Area of the pipe in the measuring tank = ______ $mm^2$

**$A_E$ = Effective area of the measuring tank = $A_1 - A_2$ =______ $mm^2$**

**PROCEDURE:-**

1. Place the notch under test at the end of the approach channel, in the vertical plane, with the sharp edge on the up-stream side.
2. Record the geometric shape of the notch.
3. Allow the water in the tank till it just passes over the notch (up to the crest level).
4. Start the water supply and record the water level by the gauge when water just passes over the notch.
5. Collect the water discharging from the notch in measuring tank and measure the rise of water level 'h' in the tank for certain period of time't' seconds.
6. Repeat the above procedures for various discharges by operating the regulating valve. And different notch.

**TABLE OF READINGS:-**

| Sl. No. | Type of notch | Manometer reading in (mm) of water | | | Time taken for h rise of water in the storage tank (t) in sec |
|---|---|---|---|---|---|
| | | h1 | h2 | hw | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

**SPECIMEN CALCULATIONS:-**

1. **Actual Discharge**

$$Q_a = \frac{A_E R}{t}$$

A = Area of the measuring tank in $m^2$

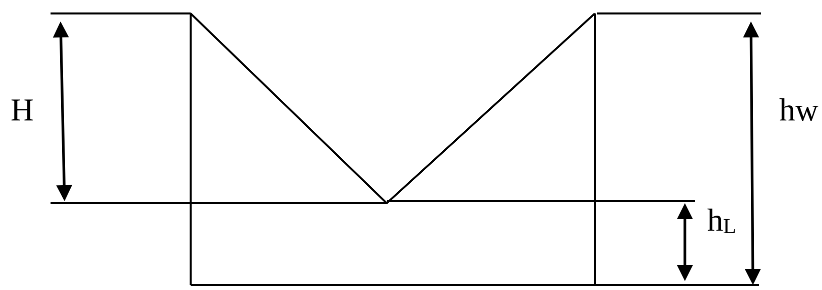
R = Rise of water level in the tank for time t

t = Time taken for R cm rise in the tank in s.

2. **Theoretical discharge**

For v notch $Q_{Theo} = 8/15 \times \sqrt{2g\tan\theta/2} \times H^{5/2}$

H = Head over the notch in m of water column




$H = hw - h_L$

For rectangular notch $Q_{Theo} = 2/3 \times L \times \sqrt{2g} \times H^{3/2}$

Where L = length of notch

H = Head over the notch in m of water column

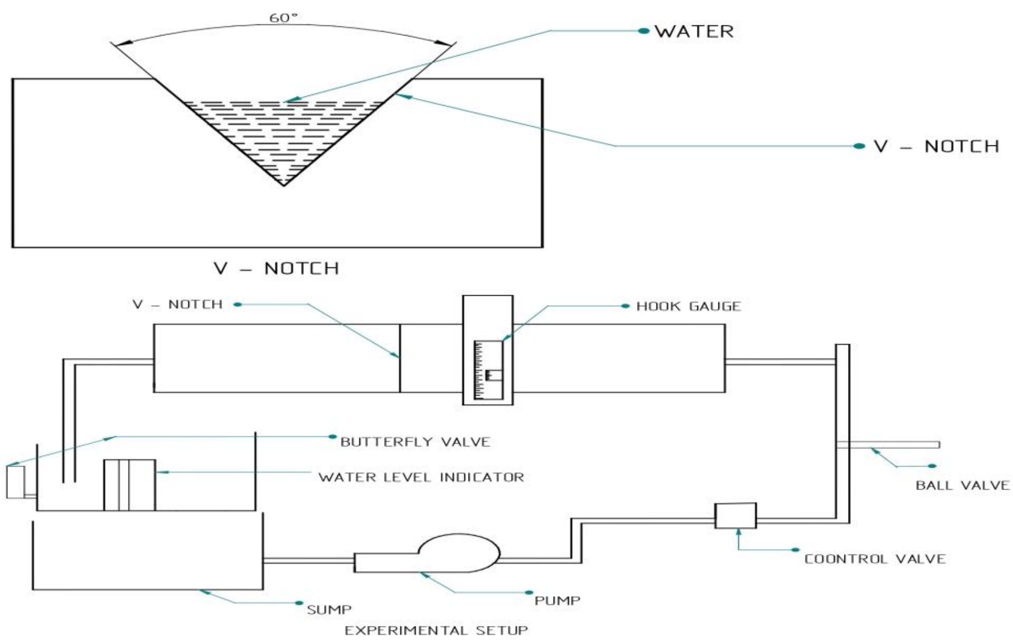
3. **Co-efficient of discharge = Cd** = $\frac{Q_{act}}{Q_{Theo}}$

**TABLE OF RESULTS:-**

| Sl. No. | Actual discharge $Q_{act}$ in $m^3$/sec | Theoretical discharge $Q_{Theo}$ in $m^3$/sec | $C_d$ |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

**RESULT:-**

The co-efficient of discharge of the given notch = __________



## *EXPERIMENT 4:* MINOR LOSSES IN FLOW THROUGH PIPES

**AIM:** To determine minor losses in flow through pipes.

**APPARATUS:** Minor Losses set up with different pipe fittings.

**THEORY:** when a fluid flows through a pipe, certain resistance is offered to the flowing fluid, which results in causing a loss of energy. The various energy losses in pipes may be classified as: a) Major loss b) Minor loss.

The minor loss of energy is those which are caused on account of the change in the velocity of flowing fluid (either in magnitude or direction). In case of long pipes these are usually quite small as compared with the loss of energy due to friction and hence these are termed as 'minor loss' which may even be neglected without serious error. However, in short pipes these losses may sometimes outweigh the friction loss. Some of the losses of energy which may be caused due to the change to velocity are indicated below:

1. **The** frictional resistance causes loss of head $h_f$ , is given by Darcy Weisbach equation
   $h_f = \frac{4fLV^2}{2gd}$ , where f is coefficient of friction
2. The Loss of Head due to Sudden Enlargement
   $h_f = \frac{(V_1-V_2)^2}{2g}$
3. The Loss of Head due to Sudden Contraction
   $h_f = \frac{0.5{V_2}^2}{2g}$

4. The Loss of Head due to Pipe Fittings
   $h_f = \frac{KV_2}{2g}$ **,** The value of 'K' for different types of valves and for different ratios of the height of opening to the diameter.

**PROCEDURE:**

**PROCEDURE:**

1. Select a particular pipeline.

2. Connect the pressure tapings between the pipes fittings in which minor losses are to be determined.

3. Gradually vary the discharge through the pipeline

4. Note down the corresponding deflection in mercury column and the actual discharge by using a collecting tank.

5. Find out the loss coefficient for each pipe line.

**OBSERVATIONS:**

$A_1$ = Area of the measuring tank = L mm × B mm = ___________ $mm^2$

D = Diameter of the pipe in the measuring tank = _______ mm

$A_2$ = Area of the pipe in the measuring tank = _______ $mm^2$

1. **$A_E$ = Effective area of the measuring tank = $A_1 - A_2$ =__________ $mm^2$**
2. Pipe fittings : Contraction , Expansion , Elbow, long bend

**TABULATION:**

1. **The Loss of Head due to Sudden Enlargement or Expansion:**

| Sl. No | Manometer Readings | | | Head loss hf m of water | Time taken to collect R cm in 'T' sec | Actual discharge Qact $m^3/s$ | Velocity of flow m/s | | Head loss due to expansion |
|---|---|---|---|---|---|---|---|---|---|
| | h1 | h2 | h=(h1-h2) m | | | | $V_1$ | $V_2$ | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

2. **The Loss of Head due to Sudden Contraction:**

| Sl. No | Manometer Readings | | | Head loss hf m of water | Time taken to collect R cm in 'T' sec | Actual discharge Qact $m^3/s$ | Velocity of flow , m/s | Head loss due to contraction |
|---|---|---|---|---|---|---|---|---|
| | h1 | h2 | h=(h1-h2) m | | | | $V_2$ | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

3. **$90^0$ Elbow:**

| Sl. No | Manometer Readings | | | Head loss hf m of water | Time taken to collect R cm in 'T' sec | Actual discharge Qact $m^3/s$ | Velocity of flow , m/s | Head loss due to elbow |
|---|---|---|---|---|---|---|---|---|
| | h1 | h2 | h=(h1-h2) m | | | | V | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

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## 4. Bend:

| Sl. No | Manometer Readings | | | Head loss hf m of water | Time taken to collect R cm in 'T' sec | Actual discharge Qact $m^3/s$ | Velocity of flow , m/s | Head loss due to bend |
|---|---|---|---|---|---|---|---|---|
| | h1 | h2 | h=(h1-h2) m | | | | V | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## CALCULATIONS:

### 1. Contraction:

1. **Actual Discharge $Q_{act}$=** $\dfrac{A_E \times R \times 10^{-2}}{T}$

$A_E$ = Area of the measuring tank in $m^2$

R = Rise of water level in the tank for time T in cm

2) **Frictional loss**

$$h_f = h(13.6 - 1) \; in\; m\; of\; water$$

3) **Velocity at inlet :**

$$V_1 = \frac{Q_{act}}{a_1} \; m/s$$

$$inlet\; area\; a_1 = \frac{\pi}{4} d_1^2 \; m^2$$

**Inlet diameter $d_1$= mm**

4) **Velocity at outlet :**

$$V_2 = \frac{Q_{act}}{a_2} \; m/s$$

$$outlet\; area\; a_2 = \frac{\pi}{4} d_2^2 \; m^2$$

**Outlet diameter $d_2$= mm**

5) **The Loss of Head due to Sudden Contraction**

$$h_l = \frac{0.5{V_2}^2}{2g} \; in\; m$$

### 2. Expansion:

**1.Actual Discharge $Q_{act}$:** $Q_{act}$= $\dfrac{A_E \times R \times 10^{-2}}{T}$

$A_E$ = Area of the measuring tank in $m^2$

R = Rise of water level in the tank for time T in cm

**Frictional loss**

$$h_f = h(13.6 - 1)\ in\ m\ of\ water$$

**3) Velocity at inlet :**

$$V_1 = \frac{Q_{act}}{a_1}\quad m/s$$

$inlet\ area\ a_1 = \frac{\pi}{4} d_1^2$ **m²**

**Inlet diameter $d_1$= mm**

**4)Velocity at outlet :**

$$V_2 = \frac{Q_{act}}{a_2}\quad m/s$$

$outlet\ \ area\ a_2 = \frac{\pi}{4} d_2^2$ **m²**

**Outlet diameter $d_2$= mm**

**5) The Loss of Head due to Sudden Expansion**

$$h_l = \frac{(V_1 - V_2)^2}{2g}$$

**3. 90⁰ Elbow**

1. **1.Actual Discharge $Q_{act}$:** $\quad Q_{act} = \frac{A_E \times R \times 10^{-2}}{T}$

$A_E$ = Area of the measuring tank in $m^2$

R = Rise of water level in the tank for time T in cm

**2)Frictional loss**

$$h_f = h(13.6 - 1)\ in\ m\ of\ water$$

**3)Velocity at outlet :** $V = \frac{Q_{act}}{a}\quad m/s$

**Area** $a = \frac{\pi}{4} d^2$ **m²**

**Diameter of elbow d= mm**

**4) The Loss of Head due to elbow**

$$h_l = \frac{2g \times hf}{V^2}$$

4. **Long bend:**

**1)Actual Discharge $Q_{act}$:** $Q_{act} = \frac{A_E \times R \times 10^{-2}}{T}$

$A_E$ = Area of the measuring tank in $m^2$

R = Rise of water level in the tank for time T in cm

**2)Frictional loss**

$$h_f = h(13.6 - 1)\ in\ m\ of\ water$$

**3)Velocity at outlet :**

$$V = \frac{Q_{act}}{a}\ \ m/s$$

**Area** $a = \frac{\pi}{4} d^2$ **m²**

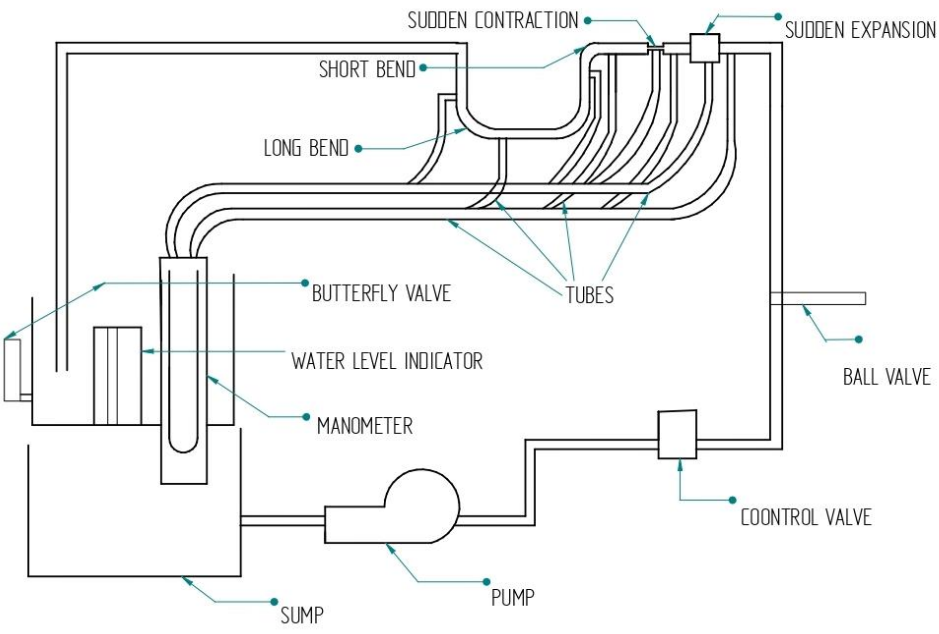
**Diameter of bend d= mm**

**4) The Loss of Head due to elbow**

$$h_l = \frac{2g \times hf}{V^2}$$

**RESULTS:**

1. **Loss of head due to**
   - **a.** Sudden contraction=………..
   - **b.** Sudden enlargement=………
   - **c.** $90^0$ elbow=……………
   - **d.** Long bend=………….



EXPERIMENTAL SETUP

# FRICTION IN PIPES (Major)

**AIM:-** To determine the Darcy's friction co-efficient and Reynolds number for different flows through the pipes of different diameters.

**INTRODUCTION:-**

A closed of any cross-section and material are used for flow of liquid is known as pipe. Generally the pipes are assumed to be running full and of circular cross-section. Liquids flowing through pipes are subjected to resistance resulting in loss of head or energy. This resistance is of two types depending on the velocity of flow a) Viscous resistance b) Frictional resistance.

Viscous resistance is due to molecular attraction between the molecules of the fluid. At low velocity flow is laminar or in the layers and hence this flow is called laminar flow. When the velocity of liquid is gradually increased to lower critical velocity, the parallel layers of the liquid will become wavy and further increase in the velocity flow becomes diffused and is known as turbulent flow. In turbulent flow, the resistance to motion is due to the resistance of the pipe surface for the flow.

**TEST RIG DETAILS:-**

1. Pipeline with U- tube differential manometer connections to measure the pressure difference between the tapings of one at either end of the pipe line.
2. Flow control valve to control the flow rate.
3. Measuring tank with piezometer and scale.
4. Storage tank (sump) and pump.

**OBSERVATIONS:-**

Length of the pipe = L = 1.2 m

Diameter of the pipe GI = D1 = 16mm

GI = D2 = 18mm

PVC = D3 = 26mm

GI =D4 = 27mm

$A_1$ = Area of the measuring tank = 500mm × 400 mm=100000 mm$^2$

D = Diameter of the pipe in the measuring tank = 75 mm

$A_2$ = Area of the pipe in the measuring tank = 4417.86 mm$^2$

**A = Effective area of the measuring tank = $A_1$ – $A_2$ = __________ mm$^2$**

**PROCEDURE:-**

1. Switch on the equipment and check for the flow of water.
2. Note down the length and the diameter of the pipe.
3. Open the valve connections of the specified pipe to manometer.
4. Open the control valve on the pipe for a small discharge.
5. Record the following readings
   - The left and right limb readings of the manometer.
   - Time required for raising ‘R’ in the measuring tank.
6. Repeat the experiment for different heads of manometers for different discharge. Discharge is controlled by operating the valve.

**TABLE OF READINGS:-**

| SL NO | PIPE TYPE | Manometer reading | | | Head loss $h_f$ m of water | Time for collecting r cm of water in 't' sec |
|---|---|---|---|---|---|---|
| | | $h_1$ in cm | $h_2$ in cm | $h_m$ in m | | |
| 1 | 16 mm | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 1 | 18 mm | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 1 | 26 mm G.I | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 1 | 27 mm | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |

**SPECIMEN CALCULATIONS:-**

1. Actual Discharge $Qa = \frac{A_E \times R \times 10^{-2}}{t}$

   $A_E$ = Area of the measuring tank in $m^2$

   R = Rise of water level in the tank for time t in cm.

2. Cross sectional area of the pipe $Ap = \frac{\pi D^2}{4}$

   D = diameter of the pipe

3. Velocity of flow = $V = \frac{Q\ actual}{Ap}$

4. Loss of head due to friction $hf = hm \left[\frac{Sm}{Sw} - 1\right]$ in m of water

   Where hm = Head difference of mercury in m

   Sm = Specific gravity of the mercury

   Sw = Specific gravity of the standard fluid (water)

5. Darcy's co-efficient of friction between the fluid and the pipe

$$f = \frac{2gDh_f}{LV^2}$$

   Where,

   D = Diameter of the pipe in m

   L = Length of the pipe in m

   V = velocity of flow

   $h_f$ = loss of head due to friction in m

6. Reynolds number = $Re = \frac{\rho VD}{\mu}$

   Where,

   $\rho$ = Density of water in $kg/m^3$

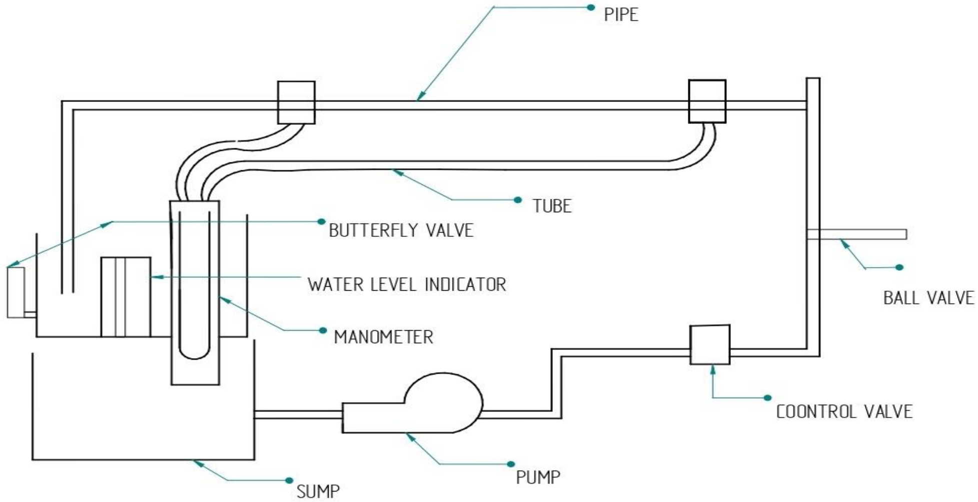
   $\mu$ = Dynamic viscosity of water in $N\text{-}S/m^2$

**TABLE OF RESULTS:-**

| Sl.No. | Head loss $h_f$ in m of water | Actual discharge $Q_a$ in $m^3/s$ | Velocity of flow V in m/s | Co-efficient of friction f | Reynolds number Re |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

**RESULT:-**

Find out the Darcy's friction co-efficient for and Reynolds number for different flows and plot he graph of **f verses $R_e$**



EXPERIMENTAL SETUP

**Fluid Mechanics and Machinery Lab – Viva Question**

1. Differentiate between Absolute and gauge pressures.
2. Mention two pressure measuring instruments.
3. What is the difference weight density and mass density?
4. What is the difference between dynamic and kinematic viscosity?
5. Differentiate between specific weight and specific volume.
6. Define relative density.
7. What is vacuum pressure?
8. What is absolute zero pressure?
9. Write down the value of atmospheric pressure head in terms of water and Hg.
10. Differentiate between laminar and turbulent flow.
11. How will you classify the flow as laminar and turbulent?
12. Mention few discharge measuring devices
13. Draw the venturimeter and mention the parts.
14. Why the divergent cone is longer than convergent cone in venturimeter?
15. Compare the merits and demerits of venturimeter with orifice meter.
16. Why Cd value is high in venturimeter than orifice meter?
17. What is orifice plate?
18. What do you mean by vena contracta?
19. Define coefficient of discharge.
20. Write down Darcy -weisback's equation.
21. What is the difference between friction factor and coefficient of friction?
22. What do you mean by major energy loss?
23. List down the type of minor energy losses.
24. Define turbine
25. What are the classifications of turbine
26. Define impulse turbine.
27. Define reaction turbine.
28. Differentiate between impulse and reaction turbine.
29. What is the function of draft tube?
30. Define specific speed of turbine.
31. What are the main parameters in designing a Pelton wheel turbine?
32. What is breaking jet in Pelton wheel turbine?
33. What is the function of casing in Pelton turbine
34. Draw a simple sketch of Pelton wheel bucket.
35. What is the function of surge tank fixed to penstock in Pelton turbine?
36. How the inlet discharge is controlled in Pelton turbine?
37. What is water hammer?
38. What do you mean by head race?
39. What do you mean by tail race?
40. What is the difference between propeller and Kaplan turbine?
41. Mention the parts of Kaplan turbine.
42. Differentiate between inward and outward flow reaction turbine.
43. What is the difference between Francis turbine and Modern Francis turbine?
44. What is mixed flow reaction turbine? Give an example.

45. Why draft tube is not required in impulse turbine?
46. How turbines are classified based on head. Give example.
47. How turbines are classified based on flow. Give example
48. How turbines are classified based on working principle. Give example.
49. What does velocity triangle indicates?
50. Draw the velocity triangle for radial flow reaction turbine.
51. Draw the velocity triangle for tangential flow turbine.
52. Mention the type of characteristic curves for turbines.
53. How performance characteristic curves are drawn for turbine.
54. Mention the types of efficiencies calculated for turbine.
55. Define pump.
56. How pumps are classified?
57. Differentiate pump and turbine.
58. Define Rotodynamic pump.
59. Define Positive displacement pump.
60. Differentiate between Rotodynamic and positive displacement pump.
61. Define cavitation in pump.
62. What is the need for priming in pump?
63. Give examples for Rotodynamic pump
64. Give examples for Positive displacement pump.
65. Mention the parts of centrifugal pump.
66. Mention the type of casing used in centrifugal pump.
67. Why the foot valve is fitted with strainer?
68. Why the foot valve is a non return type valve?
69. Differentiate between volute casing and vortex casing.
70. What is the function of volute casing?
71. What is the function of guide vanes?
72. Why the vanes are curved radially backward?
73. What is the function of impeller?
74. Mention the types of impeller used.
75. Define specific speed of pump.
76. Mention the type of characteristic curves for pump
77. How performance characteristic curves are drawn for pump.
78. Mention the parts of reciprocating pump.
79. What is the function of air vessel?
80. What is slip of reciprocating pump?
81. What is negative slip?
82. What is the condition for occurrence of negative slip?
83. What does indicator diagram indicates?
84. What is the difference between actual and ideal indicator diagram?
85. Briefly explain Gear pump.
86. Differentiate between internal gear pump and external gear pump.
87. Briefly explain vane pump.
88. What is rotary pump?
89. Draw the velocity triangle for centrifugal pump.
90. Draw the indicator diagram fro reciprocating pump.

91. What is the amount of work saved by air vessel?
92. Mention the merits and demerits of centrifugal pump.
93. Mention the merits and demerits of reciprocating pump.
94. What is separation in reciprocating pump?
95. How separation occurs in reciprocating pump?
96. Differentiate single acting and double acting reciprocating pump.

# IMPACT OF JET ON VANES

**Aim:** To determine the co-efficient of impact on vanes

**Theory:**

The liquid comes out in the form of a jet from the outlet of a nozzle, which is fitted to a pipe through which the liquid is flowing under pressure. If some plate, which may be fixed or moving, is placed in the path of the jet, the jet on the plate exerts a force. This force is obtained from Newton's second law of motion or from impulse momentum equation. Thus impact of jet means the force excited by the jet on a plate, which may be stationary or moving.

a) Force exerted by the jet on a stationary plate is when,
   i) Plate is vertical to jet    ii) plate is inclined to jet
   iii) Plate is curved.
b) Force exerted by the jet on a moving plate is when
   i) Plate is vertical to jet    ii) plate is inclined to jet.
   iii) Plate is curved.

**Apparatus used:**

1. Vanes (flat, inclined with $\theta = 60^0$ and hemispherical), experimental setup comprising rota meter, nozzles of different diameter, steady supply of water using pump.

**Procedure:**

1. Fix the required diameter of nozzle and the vane of the required shape in position.
2. Bring the force indicator position to zero.
3. Keep the delivery valve closed and switch on the pump.
4. Close the front transparent glass tightly.
5. Open the delivery valve and adjust the flow rate.
6. Observe the force as indicated on the force indicator.
7. Note down the diameter of the pipe of the jet and shape of the vane and the discharge is calculated.

**Observation:**

Area of jet or nozzle $A_n = \frac{\pi d^2}{4}$ $m^2$

Where, d= diameter of the nozzle in m.

Area of jet $A_j = C_c \times A_n$ $m^2$

Where, $C_c$ = Co-efficient of friction =0.96

**Formula Used:**

Velocity of jet, V = $\mathbf{Q_{act}} / \mathbf{A_j}$ m/s  Where Q is discharge in $m^3/s$

Theoretical force,

$F_{the} = \rho \mathbf{A_j} V^2$ N  [Flat plate]

$F_{the} = \rho \mathbf{A_j} V = 2\rho \mathbf{A_j} V^2$ N  [Hemispherical plate]

$F_{the} = \rho \mathbf{A_j} V^2 \sin^2\theta$ N  [Inclined plate]

Actual force = $F_{act}$ (observed in force indicator).

**Co-efficient of impact, k =** $\frac{F_{act}}{F_{the}}$

**Table of readings:**

| SL NO | Type of Vane | Dia of Jet, d (m) | $Q_{act}$ | | Force(digital) indicator $F_{act}$ | |
|---|---|---|---|---|---|---|
| | | | lpm | $m^3/s$ | kgf | N |
| | **Hemispherical** | | | | | |
| | | | | | | |
| | | | | | | |
| | **Flat** | | | | | |
| | | | | | | |
| | | | | | | |
| | **Inclined** | | | | | |
| | | | | | | |
| | | | | | | |

**Observation:**

Area of jet or nozzle $A_n = \frac{\pi d^2}{4}$ $m^2$

Where, d= diameter of the nozzle in m.

Area of jet $A_j = C_c \times A_n$ $m^2$

Where, $C_c$ = Co-efficient of friction =0.96

**Formula Used:**

Velocity of jet, $V = \mathbf{Q_{act}/A_j}$ m/s Where $Q_{act}$ is discharge in $m^3/s$

Theoretical force,

$F_{the} = \rho \mathbf{A_j} V^2$ N [Flat plate]

$F_{the} = \rho \mathbf{A_j} V^2(1+\cos\theta) = 2\rho \mathbf{A_j} V^2$ N [Hemispherical plate]

$F_{the} = \rho \mathbf{A_j} V^2 \sin^2\theta$ N [Inclined plate]

Actual force = $F_{act}$ (observed in force indicator).

Co-efficient of impact, $k = \frac{F_{act}}{F_{the}}$

**Table of calculations:**

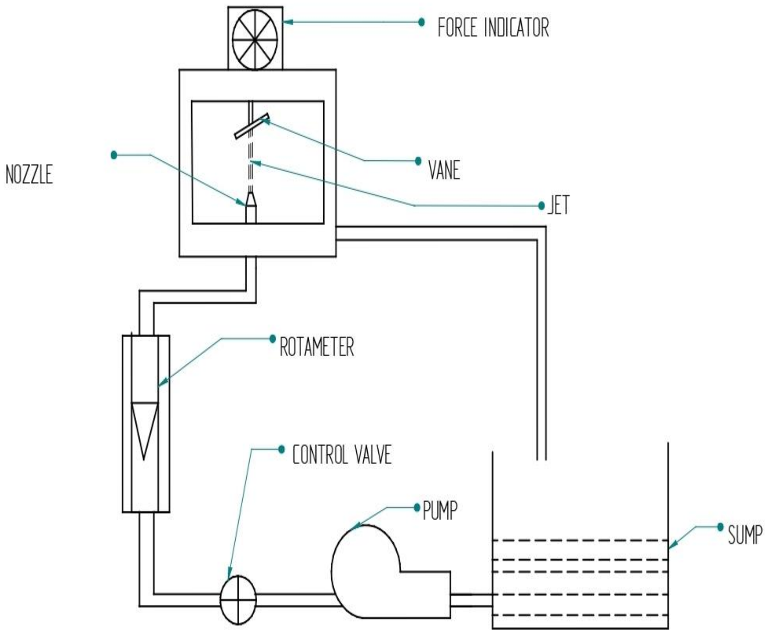
| **Type of vane** | **Dia of jet d (m)** | $\mathbf{F_{the}}$ | $\mathbf{k = \frac{F_{act}}{F_{the}}}$ | **Avg. k** |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**RESULT:-**

**The co-efficient of impact on**

1. **Flat vane**
2. **Inclined vane**
3. **Hemispherical vane**

Graph k v/s $Q_{act}$




EXPERIMENTAL SETUP

# MULTI STAGE CENTRIFUGAL PUMP

**AIM: -** To study the performance characteristics of the single stage centrifugal pump and to draw the characteristic curves.

**INTRODUCTION: -** Centrifugal pump is a hydraulic machine which converts the mechanical energy into hydraulic energy in the form of pressure energy. Here the conversion of mechanical energy into pressure energy is by means of centrifugal force acting on the fluid. Due to liquid discharge at the outlet with a high pressure head, the liquid can be shifted to a high level. The main parts are as shown in the figure. Brief explanation of them is as follows: Impellor which consists of a series of backward curved vanes is the rotating part of the pump. It is mounted on a shaft which is driven by an electric motor. Casing is an air tight passage surrounding the impellor and is designed in such a way that the kinetic energy of the water discharged at the outlet of the impellor is converted into pressure energy before water enters the delivery pipe. Suction pipe is connected to the inlet of the pump at one end and the other end dips into the water in a tank. A foot valve which is a non-return valve is fitted to the end of the suction pipe dipped in water. Strainer prevents the entry of large waste materials such as grass etc.

**TEST RIG DETAILS:-**

1. Multi stage centrifugal pump with motor and provided with energy meter.
2. Collecting tank with piezometer and graduated scale.
3. Discharge control valves and pressure gauges.

**SPECIFICATIONS:-**

Energy meter constant K = 3200 imp/KWH

Efficiency of the motor $\eta$ = 0.75

$A_1$ = Area of the measuring tank = L mm × B mm = ______________ $mm^2$

D = Diameter of the pipe in the measuring tank =_______mm

$A_2$ = Area of the pipe in the measuring tank = ____ $mm^2$

**$A_E$ = Effective area of the measuring tank = $A_1 - A_2$ = ______________ $mm^2$**

**PROCEDURE:-**

1. Prime the pump with water.
2. Start the pump with the delivery valve completely closed.
3. Open the delivery valve by one revolution and note down
    - Speed of the motor
    - Pressure gauge reading of all stages.
    - Vacuum gauge reading.
    - Time taken for 10cm rise of water in collecting tank.
    - Time taken for 10 revolutions of the energy meter.
4. Repeat the experiment for different trails by operating the discharge valve.

**TABLE OF READINGS:-**

| Sl. NO. | Speed N in rpm | Suction head $P_s$ (mm of Hg) | Delivery pressure Pd in (kg/cm$^2$) | Time taken for 'n' revolutions of energy meter $t_1$ in (s) | Time Taken for 'R' m rise of water $t_2$ in (s) |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

**SPECIMEN CALCULATIONS:-**

1. **Input power IP** = $\dfrac{n \times 3600 \times \eta}{t_1 \times K}$ kW

2. **Calculation of discharge**

$$Q = \frac{A_E \times R}{t_2} \quad m^3/s$$

3. **Head against which the pump is working H** = $H_s + H_d$

$$H_s = \text{suction head} = \frac{h_{m1} \times Sm\,(13.6)}{1000} \quad \text{in m of water}$$

$$H_d = \text{Delivery head} = P_d \times 10 \quad \text{in m of water}$$

4. **Output power = OP** = $\dfrac{W \times Q \times H}{1000}$ kW

W = specific weight of water = 9810 kg/$m^3$

5. **Efficiency** **= η** = $\dfrac{OP}{IP} \times 100$

## TABLE OF RESULTS:-

| Sl.No. | Suction head Hs (m of water) | Delivery head Hd in (m of water) | Total head H (m of water) | OP in (kW) | IP in (kW) | Discharge Q in ($m^3/s$) | Efficiency η (%) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## RESULT:-

***Draw the performance characteristics like,***

- Input power (IP) vs. Discharge (Q)
- Efficiency (η) vs. Discharge (Q)
- Head (H) vs. Discharge (Q)

# MULTI STAGE CENTRIFUGAL PUMP

**AIM: -** To study the performance characteristics of the multi stage centrifugal pump and to draw the characteristic curves.

**INTRODUCTION: -** The head produced by a centrifugal pump depends on the rim speed of the impeller. To increase the rim speed either the relative speed or the diameter of impeller or both need to be increased. But this leads to increased stress on the impeller material which is not desirable. This is overcome by multi staging of pumps. This involves mounting two or more impellers on a common shaft and enclosed in the same casing. All the impellers are connected in series so that the liquid discharged from one passes through the connecting passages to the inlet of next impeller and so on till the last impeller discharges the liquid into the delivery pipe.

**TEST RIG DETAILS:-**

1. Multi stage centrifugal pump with motor and provided with energy meter.
2. Collecting tank with piezometer and graduated scale.
3. Discharge control valves and pressure gauges.

**SPECIFICATIONS:-**

Energy meter constant K = 3200 imp/KWH

Efficiency of the motor $\eta$ = 0.75

$A_1$ = Area of the measuring tank = mm × mm =______________ $mm^2$

D = Diameter of the pipe in the measuring tank =_______mm

$A_2$ = Area of the pipe in the measuring tank = ____ $mm^2$

**$A_E$ = Effective area of the measuring tank = $A_1 – A_2$ =______________ $mm^2$**

**PROCEDURE:-**

1. Prime the pump with water.
2. Start the pump with the delivery valve completely closed.
3. Open the delivery valve by one revolution and note down
   - Speed of the motor
   - Pressure gauge reading of all stages.
   - Vacuum gauge reading.
   - Time taken for 10cm rise of water in collecting tank.
   - Time taken for 10 revolutions of the energy meter.
4. Repeat the experiment for different trails by operating the discharge valve.

**TABLE OF READINGS:-**

| Sl. NO. | Suction head $P_s$ (mm of Hg) | Stage pressure | | Speed N in rpm | Delivery pressure Pd in ($kg/cm^2$) | Time taken for 'n' revolutions of energy meter $t_1$ in (s) | Time Taken for 'R' m rise of water $t_2$ in (s) |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |

**SPECIMEN CALCULATIONS:-**

1. **Input power IP** = $\frac{n \times 3600 \times \eta}{t_1 \times K}$

2. **Calculation of discharge**

$$\mathbf{Q} = \frac{A_E \times R}{t_2}$$

3. **Head against which the pump is working H** = $H_s + H_d$

$H_s$ = suction head = $\frac{h_{m1} \times Sm\ (13.6)}{1000}$ in m of water

$H_d$ = Delivery head = $P_d \times 10$ in m of water

4. **Output power = OP** = $\frac{W \times Q \times H}{1000}$

W = specific weight of water = 9810 $kg/m^3$

5. **Efficiency** **= η** = $\frac{OP}{IP} \times 100$

**TABLE OF RESULTS:-**

| Sl.No. | Suction head Hs (m of water) | Delivery head Hd in (m of water) | Total head H (m of water) | OP in (kW) | IP in (kW) | Discharge Q in ($m^3/s$) | Efficiency η (%) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**RESULT:-**

***Draw the performance characteristics like,***

- Input power (IP) vs. Discharge (Q)
- Efficiency (η) vs. Discharge (Q)
- Head (H) vs. Discharge (Q)

**AIM:-** To study the performance characteristics of a Pelton wheel and to draw the main and operating characteristic curves.

**INTRODUCTION:-** Pelton wheel turbine is a tangential flow impulse turbine used for high head conditions. Water is made to pass through a set of nozzles wherein the high pressure energy is converted into kinetic energy. High velocity water jet is made to impinge on a set of cups mounted on the periphery of a wheel (runner). The cups have a double semi-ellipsoidal shape to avoid axial thrust and are provided with a notch at the bottom to optimize time of energy transfer. In this test rig the output is measured by a brake drum dynamometer coupled to the turbine. The input power to the turbine is calculated by means of a V - Notch to measure discharge, and a pressure gauge to measure the inlet pressure to the turbine

**TEST RIG DETAILS:-**

1. Pelton wheel with rope brake dynamometer.
2. Pressure gauge to measure turbine entry pressure.
3. Storage tank with centrifugal pump powered by a motor.
4. V – Notch with height gauge.

**SPECIFICATIONS:-**

- Brake drum diameter D = 300 mm
- Rope diameter = d = 20 mm

## PROCEDURE:-

### MAIN CHARACTERISTICS OF PELTON WHEEL (CONSTANT HEAD)

1. Adjust the gate opening to the specified value.
2. With the discharge valve of the pump closed, start the centrifugal pump.
3. Adjust the inlet valve of the turbine to give the specified head on the turbine.
4. Note down the readings such as pressure gauge reading, Vacuum gauge reading and the speed of the turbine.
5. Now load the turbine by adding weight on the rope brake dynamometer.
6. Adjust the inlet valve to give the same head and to note down all the previously mentioned reading along with the load and the spring balance reading.
7. Repeat the experiment at different loads.
8. Change the gate opening to the other specified values and repeat the experiment.

### OPERATING CHARACTERISTICS (CONSTANT SPEED):-

1. Keep the gate opening at the specified value and adjust the inlet valve to give a specific speed for different loads on the turbine.
2. Take the readings on the pressure gauge, speed, weight and the spring balance reading.
3. Repeat the experiment for different loads on the turbine.

## TABLE OF READINGS:- (FOR CONSTANT HEAD)

| Sl.No. | Delivery pressure $P_d$ in ($kg/cm^2$) | Speed N in (rpm) | Venturimeter head h | | Load on brake drum 'F1' in kgf | Load on brake drum 'F2' in kgf |
|---|---|---|---|---|---|---|
| | | | $P_1$ in ($kg/cm^2$) | $P_2$ in ($kg/cm^2$) | | |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

## SPECIMEN CALCULATIONS:-

1. **Torque transmitted T** = $[(F_1-F_2) + \text{hanger weight}] \times 9.81 \times R_{effective}$ N-m

   Where $R_{effective}$ = Radius of brake drum + radius of rope = 0.16m

2. **Output power OP** = $\frac{2 \times \pi \times N \times T}{60000}$ kW

3. **Venturimeter head h=** $10\times(P_1-P_2)$ in m of water

   **Theoretical discharge $Q_{th}$** = $\frac{a_1 a_2 \sqrt{2g\,h}}{\sqrt{a_1^2 - a_2^2}}$ $m^3/s$

   $a_1$ = Area of pipe in $m^2$

   $a_2$ = Area of throat $m^2$

4. **Delivery Head H** = $10 \times P_d$ in m of water

5. **Input power = IP** = $\frac{WQH}{1000}$ in KW

W= Weight density of water = ∫g= 9810

6. **Efficiency = η =** $\frac{OP}{IP} \times 100$

7. **Specific speed = Ns** = $\frac{N\sqrt{OP}}{H^{5/4}}$

8. **Unit Speed = Nu** = $\frac{N}{\sqrt{H}}$

9. **Unit discharge = Qu** = $\frac{N}{\sqrt{H}}$

10. **Unit Power = Pu** = $\frac{OP}{H^{3/2}}$

**TABLE OF RESULTS:-**

| Delivery head H in (m) | Discharge Q in ($m^3/s$) | Torque T in N-m | OP in (KW) | IP in (KW) | % Efficiency | Ns in SI units | Nu in rpm | Qu in ($m^3/s$) | Pu in (KW) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

*Draw the graph of main characteristics of the Pelton wheel*

- Unit power (Pu) Vs. unit speed (Nu)
- Efficiency (η) Vs. Unit speed (Nu)
- Unit discharge (Qu) Vs. Unit Speed (Nu)

**TABLE OF READINGS:- (FOR CONSTANT SPEED)**

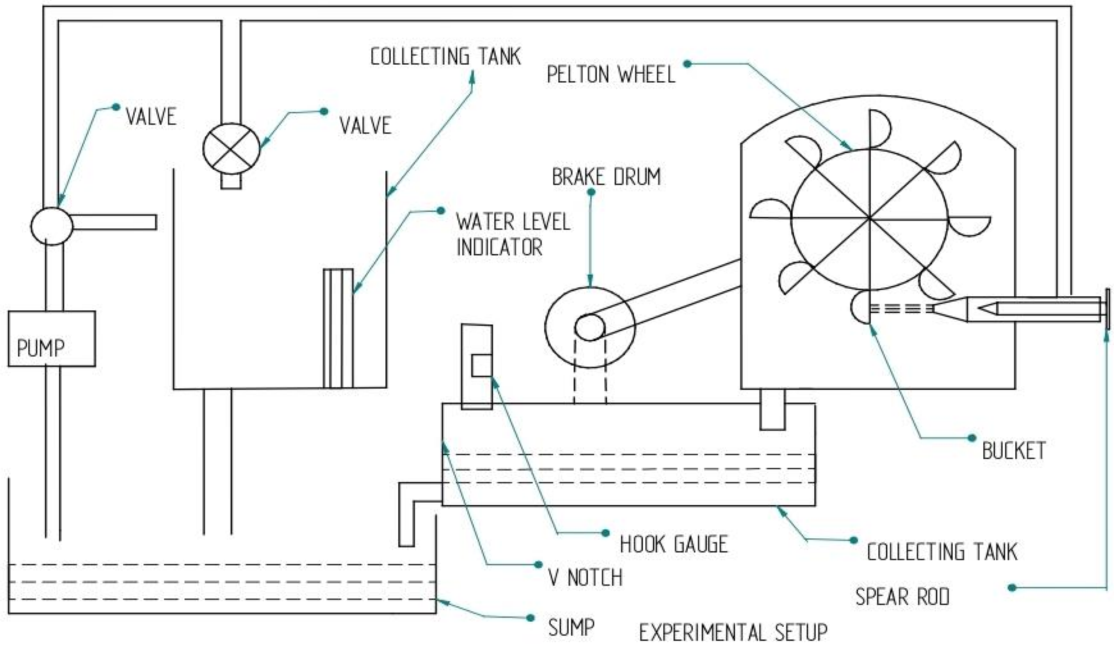
| Sl.No. | Delivery pressure $P_d$ in (kg/cm$^2$) | Speed N in (rpm) | Venturimeter head h | | Load on brake drum 'F1' in kgf | Load on brake drum 'F2' in kgf |
|---|---|---|---|---|---|---|
| | | | $P_1$ in (kg/cm$^2$) | $P_2$ in (kg/cm$^2$) | | |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

**RESULT:-**

***Draw the graph of Operating characteristics of the Pelton wheel***

- Output power (OP) Vs. Discharge (Qu)
- Percentage efficiency (η) Vs. Discharge (Qu)

## Pelton Wheel



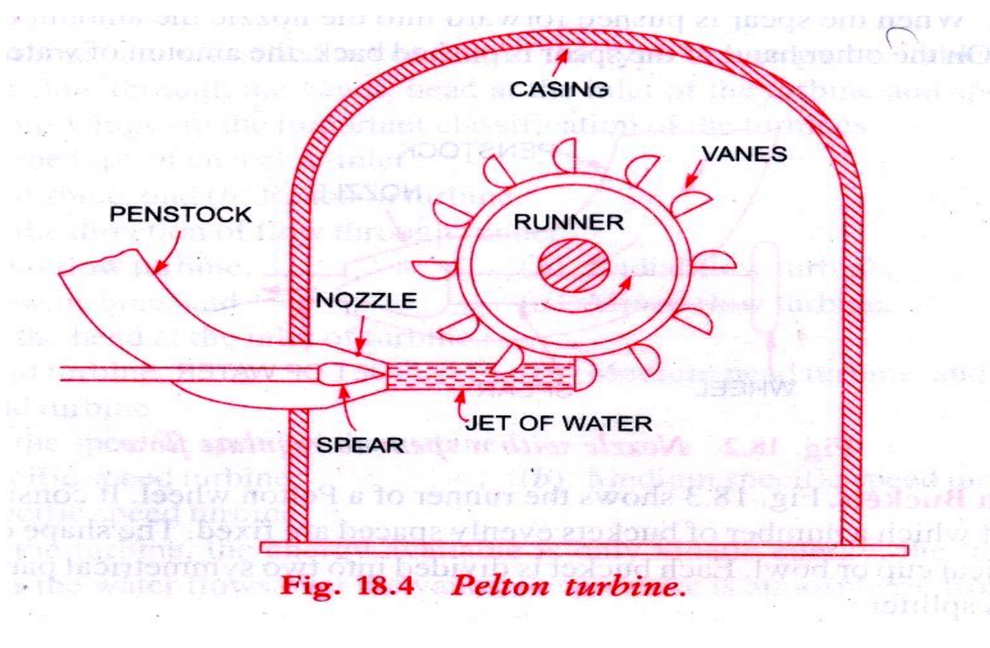




**Fig. 18.4** ***Pelton turbine.***

## *EXPERIMENT 9*: **PERFORMANCE TEST ON FRANCIS TURBINE**

**AIM:** To study the performance characteristics of the Francis turbine and to find efficiency at constant head and constant speed.

**APPARATUS:** Centrifugal pump set up, Turbine unit, Venturi meter, Pressure gauges, sump tank, and recirculation water system.

**THEORY:** Francis turbine is an inward mixed flow reaction turbine named after the American Engineer James D Francis. In a Francis turbine, water enters the runner at its outer periphery and flows out axially at its centre. It operates under medium heads (25 to 100 m of water). A spiral casing enclosing a number of stationary guide blades fixed all around the circumference of an inner ring of moving vanes forming the runner. Water at high pressure enters through the inlet in the casing and flows radially inwards to the outer periphery of the runner through the guide blades. From outer periphery of runner the water flows inwards through the moving vanes and discharged at the center of the runner at low pressure. During flow over the moving blades it imparts kinetic energy to the runner to set it in to rotational motion. To enable discharge of water at lower pressure a diverging conical tube called draft tube is fitted at the center of runner. The other end of the draft tube is immersed in the discharging side of water called tail race.

**PROCEDURE**:

1. Connect the supply pump-motor unit to 3 ph, 440V, 30A, electrical supply, with neutral and earth connections and ensure the correct direction of pump-motor unit.
2. Keep the gate closed.
3. Keep the load on brake drum (spring balance) at minimum.
4. Press the green button of the supply pump starter & then release.
5. Slowly, open the gate so that the turbine rotor picks up the speed and attains maximum at full opening of the gate
6. Select the guide vane position by operating the hand wheel for required position.
7. Slowly open the brake drum cooling valve and allow very little water before loading the brake drum.
8. Slowly operate the hand wheel on the rope of spring balance to increase the load on the brake drum. Set the spring balance reading, say, 2 Kg, 3 Kg, 4 Kg, etc.
9. For different loads on the brake drum, note down the speed, head on turbine, Venturimeter pressure gauge readings and draft tube vacuum.
10. Change the position of guide vane angles and repeats the experiment, and if necessary, the gate valve (butterfly valve) can also be used for speed control.
11. Close the gate and then switch OFF the supply water pump set.
12. Follow the procedure described below for taking down the reading for evaluating the performance characteristics of the Francis Turbine.

**TO OBTAIN CONSTANT SPEED CHARACTERISTICS: (Operating Characteristics)**

1. Keeps the guide vane opening for the required position.
2. For different loads on the turbine, change the gate valve position, so that the speed is held constant.
3. Repeat the experiment for different speeds, say 1500 rpm, 1000 rpm and tabulate the results.

**TO OBTAIN CONSTANT HEAD CHARACTERISTICS: (Main Characteristics)**

1. Select the guide vane angle position.
2. Keep the gate valve closed, and start the pump.
3. Slowly open the gate valve and set the pressure on the gauge (head on turbine).
4. For different loads on the brake drum, set the pressure constant by operating the gate valve to maintain the constant head and tabulate the results.

**TABULATION:**

| **SL NO** | **CONDITION** | **Speed in rpm** | **Head over venturimeter** | | **Head on turbine Pt Kg/cm$^2$** | **Total head on turbine H in m of water** | **Load on brake drum 'F' in kgf** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Pressure gauge reading P in kg/cm$^2$** | **vacuum gauge $p_V$ in mm of Hg** | | | **$F_1$** | **$F_2$** | **F** |
| **1** | **Constant speed** | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |

| **SL NO** | **CONDITION** | **Speed in rpm** | **Head over venturimeter** | | **Head on turbine Pt Kg/cm$^2$** | **Total head on turbine H in m of water** | **Load on brake drum 'F' in kgf** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Pressure gauge reading P in kg/cm$^2$** | **vacuum gauge $p_V$ in mm of Hg** | | | **$F_1$** | **$F_2$** | **F** |
| **1** | **Constant Head** | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |

**CALCULATION:**

1. **Differential head of the venturimeter:**

$$h = \left(P + \frac{P_v}{760}\right) \times 10\ m\ of\ water$$

**Where,** P = Delivery Pressure, kg/cm²

$P_v$ = Vacuum Pressure, mm of Hg

Note: if throat pressure $P_v$ is positive, **h= (P-$P_t$)10 m of water**

2. **Total Head on the turbine H:**

$$H = 10(P_t)\ m\ of\ water$$

**Where,** $P_t$ is head on turbine in kg/cm$^2$

3. **Discharge Qact:**

$$Qact = \frac{C_d a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}\ \ m^3/s$$

$a_1 = \frac{\pi}{4} d_1^2$ *where* $d_1$ **Is inlet diameter of venturi meter= mm**

$a_2 = \frac{\pi}{4} d_2^2$ *where* $d_2$ **Is outlet diameter of venturi meter= mm**

$C_d = 0.95$

4. **Input to the turbine IP( hydraulics):**

$$IP = \frac{\rho g Q H}{1000}\ \ kW$$

**Where Q is discharge in m$^3$/s**

**H is Total head on turbine in m of water**

5. **Output from turbine OP( mechanical work done):**

$$BP = \frac{2\pi NT}{60000}\ kW$$

**Where, T is torque in Nm**

$T = F \times r \times 9.81\ \ Nm$ **F is load in kgf and**

**r is brake drum radius = 0.16 m**

**N is turbine speed in rpm**

6. **Efficiency:**

$$\eta = \frac{BP}{IP} \times 100$$

7. **Unit quantities:**
   a. **Unit Speed** $N_u = \frac{N}{\sqrt{H}}$
   b. **Unit Power** $P_u = \frac{BP}{H^{3/2}}$
   c. **Unit Discharge** $Q_u = \frac{Q}{\sqrt{H}}$

8. **Specific Speed** $N_s = \frac{N\sqrt{BP}}{H^{5/4}}$

**BP** is in **kW**

**RESULTS:**

| Condition | Net force F in newton | Total Head on turbine H in m of water | Discharge Qact in $m^3/s$ | Input power in kW | Output power in kW | Efficiency | Unit quantities | | | Specific speed Ns |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Nu rpm | Pu watt | Qu $m^3/s$ | |
| Constant speed | | | | | | | | | | |
| Constant Head | | | | | | | | | | |

## NATURE OF GRAPH:

1. **Main characteristics curve (constant head)**
2. **Operating characteristics curve( constant speed)**

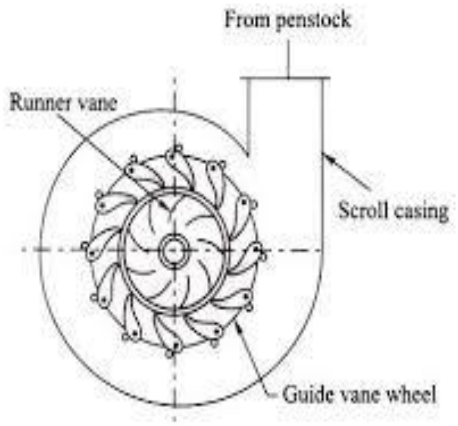
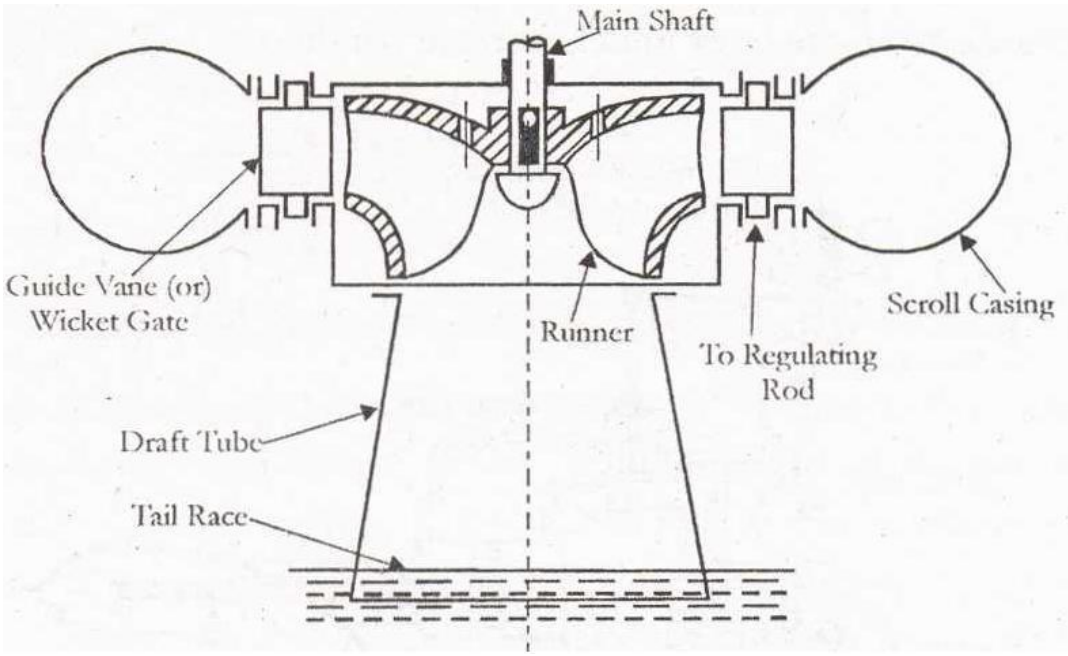



Fig. 5.8 Francis turbine components



*EXPERIMENT 13:*

# PERFORMANCE TEST ON KAPLAN TURBINE

**AIM:** To study the performance characteristics of the Kaplan turbine and to find efficiency at constant head and constant speed.

**APPARATUS:**

**DESCRIPTION:**

Kaplan Turbine, the reaction type which is of present concern consists of main components such as propeller (runner) scroll casing and draft tube. Between the scroll casing and the runner, the water turns through right angle and passes through the runner and thus rotating the runner shaft. When guide vane angles are varied, high efficiency can be maintained over wide range of operating conditions. The actual experimental Set-up consists of a Centrifugal Pump set, Turbine Unit, Sump Tank, arranged in such a way that the whole Unit works on Re circulating Water System. The centrifugal pump supplies the water from the sump tank to the turbine through gate valve. The water after passing through the Turbine Unit enters the Sump Tank through the Draft Tube.

The Loading of the Turbine is achieved by Rope Brake Drum connected to Spring Balance. The provision for measurements of Brake Force (Spring Balance), Turbine Speed (Digital RPM Indicator), Head on Turbine ( Pressure Gauge ), Draft Tube Vacuum by Vacuum Gauge and Pressure difference across Venturimeter measured by Inlet Pressure & Throat Pressure are provided.

**PROCEDURE:**

**<u>Procedure (General):</u>**

1. Connect the supply pump-motor unit to 3 ph, 440V, 30 A, electrical supply, with neutral and earth connections and ensure the correct direction of pump-motor unit.
2. Keep the gate closed.
3. Keep the load on brake drum (spring balance) at minimum.
4. Press the green button of the supply pump starter & then release.

a) Slowly, open the gate so that the turbine rotor picks up the speed and attains maximum at full opening of the gate.

b) Slowly open the brake drum cooling valve and allow very little water before loading the brake drum.

c) Slowly operate the hand wheel on the rope of spring balance to increase the load on the brake drum. Set the spring balance reading.

d) For different loads on the brake drum, note down the speed, head on turbine, venturimeter pressure gauge readings and draft tube vacuum.

5.Close the gate and then switch OFF the supply water pumpset.

6.Follow the procedure described below for taking down the reading for evaluating the performance characteristics of the Kaplan Turbine.

## A. To obtain constant speed characteristics:

**(Operating Characteristics)**

a) For different loads on the turbine, change the gate valve position, so that the speed is held constant.
b) Repeat the experiment for different speeds, say 1500 rpm, 1000 rpm and tabulate the results.
c) The above readings will be utilized for drawing constant speed characteristics Viz.,
    a) Percentage of Full Load V s Efficiency.
    b) Efficiency and BFBP Vs Discharge characteristics.

## B. To obtain constant head characteristics :( main characteristics)

1. Keep the gate valve closed, and start the pump.
2. Slowly open the gate valve and set the pressure on the gauge (head on turbine).
3. For different loads on the brake drum, set the pressure constant by operating the gate valve to maintain the constant head and tabulate the results as given in Table -II.

**TABULATION:**

| SL NO | CONDITION | Speed in rpm | Head over venturimeter | | Head on turbine Pt Kg/cm$^2$ | Total head on turbine H in m of water | Load on brake drum 'F' in kgf | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pressure gauge reading P in kg/cm$^2$ | vacuum gauge $p_V$ in mm of Hg | | | $F_1$ | $F_2$ | F |
| **1** | **Constant speed** | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |

| SL NO | CONDITION | Speed in rpm | Head over venturi meter | | Head on turbine Pt Kg/cm$^2$ | Total head on turbine H in m of water | Load on brake drum 'F' in kgf | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pressure gauge reading P in kg/cm$^2$ | vacuum gauge $p_V$ in mm of Hg | | | $F_1$ | $F_2$ | F |
| **1** | **Constant head** | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |

**CALCULATION:**

1. **Differential head of the venturimeter:**

$$h = \left(P + \frac{P_v}{760}\right) \times 10\ m\ of\ water$$

**Where,** P = Delivery Pressure, kg/cm²

$P_v$ = Vacuum Pressure, mm of Hg

Note: if throat pressure $P_v$ is positive, **h= (P-$P_t$)10 m of water**

2. **Total Head on the turbine H:**

$$H = 10(P_t)\ m\ of\ water$$

**Where,** $P_t$ is head on turbine in kg/cm$^2$

3. **Discharge Qact:**

$$Qact = \frac{C_d a_1 a_2 \sqrt{2gh}}{\sqrt{{a_1}^2 - {a_2}^2}} \quad m^3/_s$$

$a_1 = \frac{\pi}{4}{d_1}^2$ $where\ d_1$**Is inlet diameter of venturi meter= mm**

$a_2 = \frac{\pi}{4}{d_2}^2$ $where\ d_2$**Is outlet diameter of venturi meter= mm**

$C_d = 0.95$

4. **Input to the turbine IP( hydraulics):**

   $IP = \frac{\rho g Q H}{1000}\ kW$

   **Where Q is discharge in $m^3/s$**

   **H is Total head on turbine in m of water**

5. **Output from turbine OP( mechanical work done):**

   $BP = \frac{2\pi NT}{60000}\ kW$

   **Where, T is torque in Nm**

   $T = F \times r \times 9.81\ \ Nm$ **F is load in kgf and**

**r is brake drum radius = 0.16 m**

**N is turbine speed in rpm**

6. **Efficiency:**

   $\eta = \frac{BP}{IP} \times 100$

7. **Unit quantities:**

   d. **Unit Speed** $N_u = \frac{N}{\sqrt{H}}$

   e. **Unit Power** $P_u = \frac{BP}{H^{3/2}}$

   f. **Unit Discharge** $Q_u = \frac{Q}{\sqrt{H}}$

8. **Specific Speed** $N_s = \frac{N\sqrt{BP}}{H^{5/4}}$

   **BP** is in **kW**

**RESULTS:**

| Condition | Net force F in newton | Total Head on turbine H in m of water | Discharge Qact in $m^3/s$ | Input power in kW | Output power in kW | Efficiency | Unit quantities | | | Specific speed Ns |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Nu rpm | Pu watt | Qu $m^3/s$ | |
| Constant speed | | | | | | | | | | |
| Constant Head | | | | | | | | | | |

**NATURE OF GRAPH:**

1. **Main characteristics curve (constant head)**
2. **Operating characteristics curve( constant speed)**

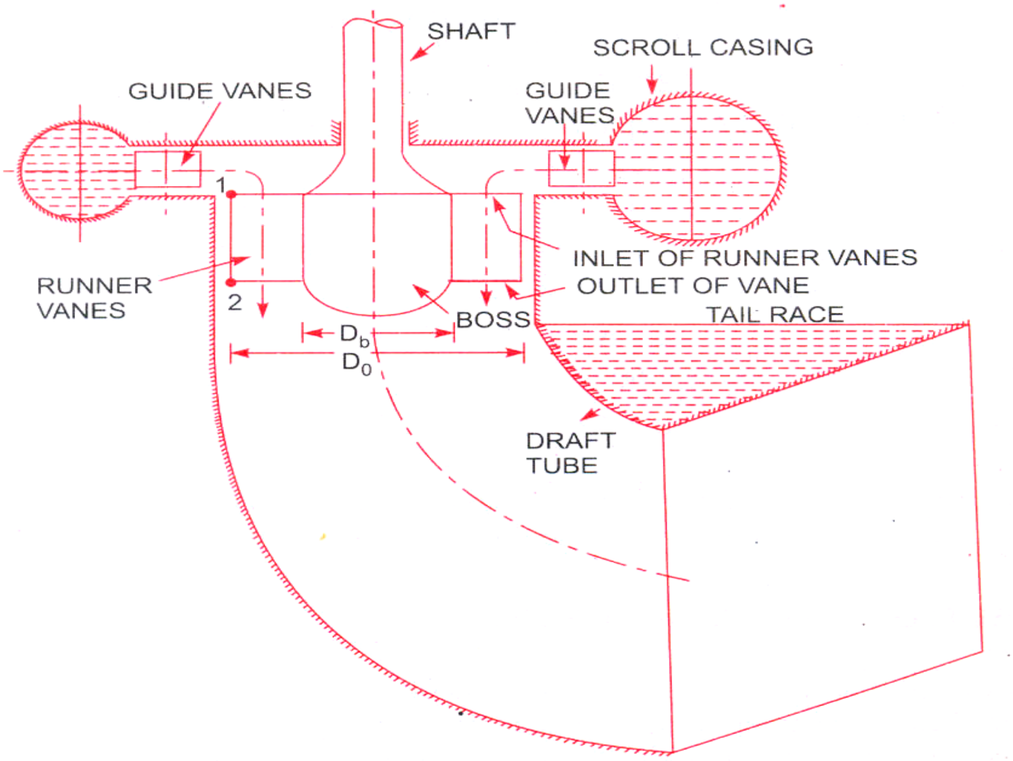



Fig. 18.26 *Main components of Kaplan turbine.*

**AIM:-**To conduct a performance test on the two stage air compressor and to determine the volumetric efficiency and isothermal efficiency at various pressures.

**TEST RIG DETAILS:-**

- Air chamber containing an orifice plate provided with a manometer connected to the compressor.
- Air reservoir provided with a pressure gauge and the discharge valve.
- Compressor powered by an induction motor by means of a belt drive.
- A fan provided for cooling the cylinders and an energy meter is provided to measure the input energy to the motor.
- Intercooler between the high and low pressure cylinders with the thermometers provided at the inlet section and pipe at the outlet of the intercooler to measure the intercooler efficiency.

**OBSERVATIONS:-**

Diameter of the low pressure Cylinder $D_{LP}$= 100 mm

Stroke of the low pressure Cylinder L = 85mm

Diameter of the high pressure Cylinder $D_{HP}$= 60 mm

Diameter of the orifice d = 15mm

$C_d$ of orifice = 0.62

Energy meter Constant k = 1600 IMP/ kW-H

**SPECIFICATIONS:-**

Engine

Type: - Reciprocating, Air cooled, Splash Lubricated

Working Pressure = 12 kg/cm$^2$.

**NOTE:-** Diameter of high pressure cylinder (D) must be used for Theoretical Volume of Air (**$Q_{th}$**)

**PROCEDURE:-**

1. The outlet valves are closed and check the manometer connections.
2. The compressor is started by switching on the motor.
3. The slow increase of the pressure inside the air reservoir is observed.
4. At the required pressure discharge valve is opened slowly and adjusted so that the pressure is maintained constant.
5. Note down the readings such as speed of the compressor, manometer readings pressure gauge readings, room temperature, energy meter reading.
6. Repeat the experiment for different delivery pressures.

**TABLE OF READINGS:-**

| SL NO | Speed of the compressor in rpm N | Inter cooler pressure in $kg/cm^2$ | Delivery pressure in $kg/cm^2$ | TEMPERATURE | | | | Manometer difference in mm of water $h_w$ | | | Time taken for 10 impulse of energy meter in "t" sec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $h_1$ in cm | $h_2$ in cm | $h_w$ in m | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |

**SPECIMEN CALCULATIONS:-**

***1. To determine Volumetric Efficiency***

$$ha = \frac{h_w \times \rho_{water}}{\rho_{air}} \quad \text{in m of air}$$

$$\mathbf{Q}_a = C_d \times a \times \sqrt{2g\,ha} \quad \text{in } m^3/s$$

a= area of orifice in $m^2$

$$\mathbf{Q_{th}} = \frac{\pi \times D^2 \times L \times N}{4 \times 60} \quad \text{in } m^3/s$$

$$\eta_{vol} = \frac{\mathbf{Q}_a}{\mathbf{Q_{th}}} \times 100$$

***2. To determine Isothermal Efficiency***

$$\text{Input Power} = IP = \frac{3600 \times 5 \times \eta_m}{k \times T} \quad \text{in kW}$$

$$r = \frac{\text{Delivery pressure + Atmospheric pressure}}{\text{Atmospheric pressure}}$$

$$Wiso = \rho_a \times Q_a \times \ln(r) \quad \text{in KW}$$

$$\eta_{iso} = \frac{Wiso}{IP} \times 100$$

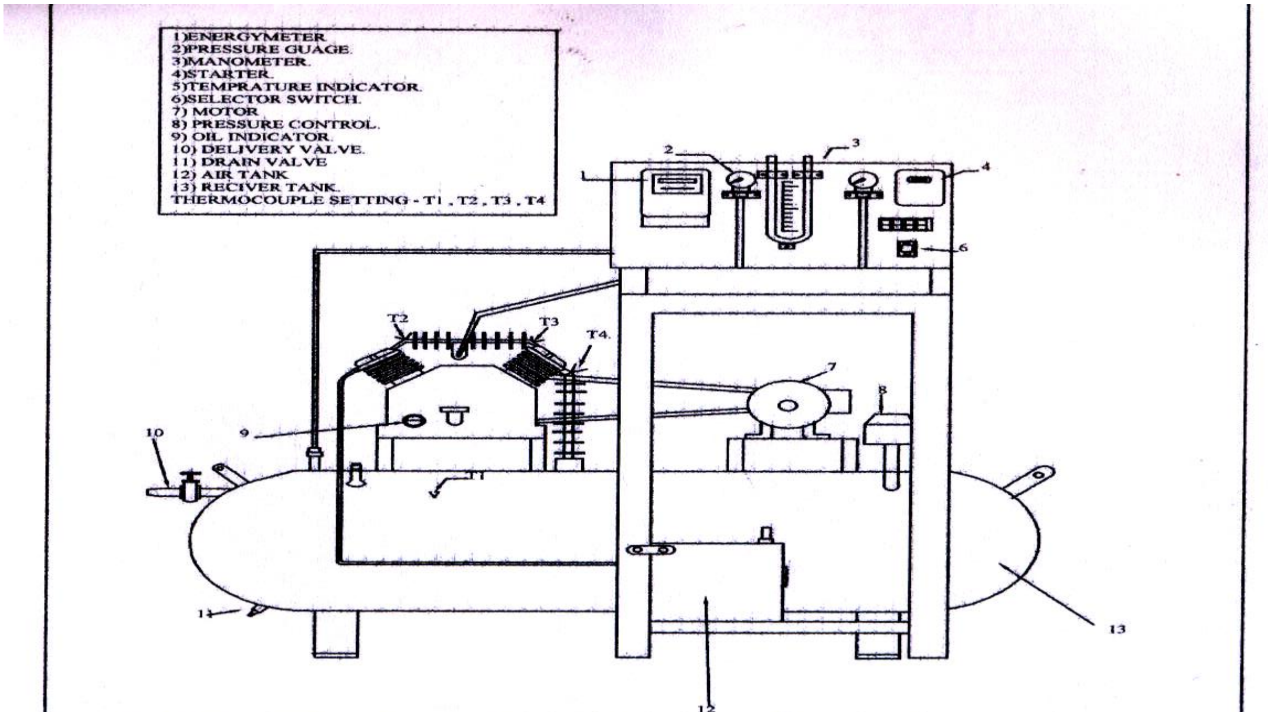
**TABLE OF RESULTS:-**

| SL.NO. | Delivery Pressure $P_d$ in ($Kg/cm^2$) | Head of air ha in (m) | **Q**a in $m^3/s$ | $\mathbf{Q_{th}}$ in $m^3/s$ | Isothermal Work done Wiso in kW | Input power IP in kW | Isothermal Efficiency $\eta_{iso}$ in % | Volumetric Efficiency $\eta_{vol}$ in % |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |

**RESULT:-**

Draw the graphs such as

- Isothermal Efficiency versus Delivery Pressure
- Volumetric Efficiency versus Delivery Pressure
- Input power versus Delivery Pressure




TWO STAGE AIR COMPRESSOR TEST RIG.

# RECIPROCATING PUMP TEST RIG

***INTRODUCATION:***

In general , a pump may be defined, as a Mechanical Device which when interposed in a pipe Line, converts Mechanical Energy supplied to it from some External Source into Hydraulic Energy thus result in he flow of liquid from he lower to the higher potential / Head.

The pumps are of major concern to most Engineers and Technicians. The types of pump vary in principle and design. The selection of pump for any particular application is to be done by undcrstanding thcir characteristics. The most commonly used pumps are classified under major headings, Namely; RotoDynamic, positive Displacement, and Air operated pumps.

While the principle of operation of other pumps discussed elsewhere in Standard Text Books, the reciprocating pump falling under the category of positive Displacement pumps, which is of our present concern, has plunger (piston) moves to and fro in a closed cylinder. The cylinder is connected to suction and delivery pipes and are fitted with non – return valves to admit the liquid in one direcation only. The suction non – return valve allows the liquid

Only to enter the cylinder and the delivery non – return valve allows the li9quid only to escape out from the cylinder to the deliver line.

The piston is connected to crank by means of connecting rod. As the crank is rotated at uniform speed by primover, the plunger moves to and fro thus creating continuous flow of liquid.

## *DESCRIPTION:*

The present pump test rig is a self – contained unit operated unit operated on closed circuit (recirculation) basis. The reciprocating pump, DC motor, sump tank, collecting tank, control panel are mounted on rigid frame work with anti – vibration mounts and arranged with the following provisions:

1. For conducting the experiments at three speeds using DC motor and DC drive.
2. To measure overall input power to the DC motor using energy meter For recording the Pressure & Vacuum.
3. For recording the speed using Digital RPM Indicator.
4. For changing the pressure (Delivery Head) and Vacuum (Suction Head) by operating the valves.
5. For measuring the discharge by Collecting Tank Level Gauge provision.
6. For recirculation of water back to the sump tank by overflow overflow provision.

## *SPECIFICATION:*

| | |
|---|---|
| Cylinder bore diameter | =D=0.055m |
| Stroke | = L=0.040m |
| Energy meter constant | =k=3200 imp/kwh |
| Efficiency of motor | = $n_m$ = 60% |
| Area of measuring tank | =$A_1$ =0.1225 $m^2$ |
| Area of Pipe in tank | = $A_2$ = $m^2$ |
| Effective area of tank | = $A_E = A_1 - A_2$ $m^2$ |

Procedure

1. Open the delivery valve completely
2. Start the pump
3. Adjust the delivery pressure to the required reading by operating the delivery valve.
4. Note down the following readings.

a. Vaccum gauge reading.

b. Delivery pressure reading.

c. Pump reading.

d. Time for R cm rise of water.

e. Energy meter reading.

5. Repeat the experiment for different values of delivery pressure.

**Table of Reading**

| SL.No. | Delivery Pressure Pd in kg/cm$^2$ | Suction Pressure hs in mm of hg | Speed in N rpm | Time for 5 blinks of energy meter T1 in sec | Time for R cm in water scale T2 sec |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

## Specimen Calculations

### 1. Basic Data / Constants

1 hp = 736 watts

1 Kg / cm$^2$ = 760 mm of Hg. (10m of water)

Density of Water 'W ' = 1000 Kg / m$^3$

### 2 . Electrical power as indicated by energy meter:

$$\text{Input power} = \frac{n \times 3600 \times \eta_m}{k \times T1} \text{ kW}$$

Where, n = no of blinks of energy meter.

3. **Discharge Rate 'Q' in $m^3$ / Sec.**

**Actual Discharge $Q_a$ =** $$\frac{A_E R \times 10^{-2}}{T}$$

$A_E$ = Effective area of the measuring tank in $m^2$

R = Rise of water level in the tank for time t in cm

T = Time taken for R cm rise in the tank in s.

$$Q_{the} = \frac{2LAN}{60}$$

**A= Area of bore in $m^2$**

**Total Head ' H ' in m**

H = 10 (Delivery pressure + Vacuum Head)

= 10 ($P_d$ + $P_s$ / 760)

Where, '$P_d$ 'is the pressure in Kg / $Cm^2$

'P 'is the Vacuum in mm of Hg.

4. **Output power ( Delivered by the pump )**

$$BP_{pump} = \frac{\rho\, g\, Q_{act}\, H}{1000} \text{ KW}$$

Where, ρ = 1000 Kg / $m^3$

Pump Efficiency

$$\%n_{pump} = \frac{BP_{pump}}{IP_{shaft}} \times 100$$

5. $_{Percentrage}$ slip = $\frac{\mathbf{Q_{the} - Q_a}}{\mathbf{Q_{the}}}$ X 100

***TABLE OF REULTS***

| SL NO. | Head in mtrs | Discharge in $m^3$ /sec | Electrical input IP $_{Pump}$ in kw | Hydraulic out put OP $_{Pump}$ in kw | Pump efficiency η % | % Slip |
|---|---|---|---|---|---|---|
| | | | | | | |

**Result:**

**Draw the performance characteristics like**

- **IP v/s Q**
- **Efficiency v/s Discharge**