LABORATORY MANUAL

FMHM LAB

II B.TECH -II Semester (R13)

AY-2017-2018

Prepared by

Assistant Professor

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DEPARTMENT OF MECHANICAL ENGINEERING

CMR ENGINEERING COLEGE
(Approved by AICTE, New Delhi & Affiliated JNTU, Hyderabad)
Kandlakoya (V), Medchal Road, RR.Dist – 501401

VISION OF THE INSTITUTE

- To be recognized as a premier institution in offering value based and futuristic quality technical education to meet the technological needs of the society

MISSION OF THE INSTITUTE

1. To impart value based quality technical education through innovative teaching and learning methods
2. To continuously produce employable technical graduates with advanced technical skills to meet the current and future technological needs of the society
3. To prepare the graduates for higher learning with emphasis on academic and industrial research.

VISION OF THE DEPARTMENT

To be a center of excellence in offering value based and futuristic quality technical education in the field of mechanical engineering.

MISSION OF THE DEPARTMENT

M1. To impart quality technical education imbibed with values by providing state of the art laboratories and effective teaching and learning process.

M2. To produce industry ready mechanical engineering graduates with advanced technical and lifelong learning skills.

M3. To prepare graduates for higher learning and research in mechanical engineering and its allied areas.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS):

PEO 1: The Graduates will exhibit strong knowledge in mathematics, sciences and engineering for successful employment or higher education in mechanical engineering.

PEO 2: The Graduates will design and implement complex modeling systems, conduct research and work with multi disciplinary teams.

PEO 3: The Graduates will be capable of communicating effectively with lifelong learning attitude and function as responsible members of global society.

PROGRAM OUTCOMES (POS):

1.Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2.Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3.Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

5.Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

6.Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

7.The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

8.Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

9.Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

10.Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

11.Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11.Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12.Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

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PROGRAM SPECIFIC OUTCOMES(PSOS):

PSO.1 Design a Thermal system for efficiency improvement as per industrial needs.
PSO.2 Design and manufacture mechanical components using advanced manufacturing technology as per the industrial needs.

Course Name: Mechanics of Fluids and Hydraulic Machines Lab (C228)

Course Code	CO No.	Course Outcome (CO's)
C228	CO1	Analyze the performance of Pelton wheel, Francis turbine and Kaplan turbine by drawing its performance curves.
C228	CO2	Analyze the performance of centrifugal pump and reciprocating pump by drawing its performance curves.
C228	CO3	Determine the coefficient of discharge for orifice meter, venturimeter by applying Bernoulli's equation.
C228	CO4	Estimate the major and minor Losses in a Pipe line.
C228	CO5	Apply momentum equation to determine impact of jet on vanes.
C228	CO6	Verify Bernoulli's theorem and explain the equation.

Course Outcome (CO) – Program Outcome (PO) Matrix:

CO's/PO's	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	-	-	-	-	-	-	3
CO2	3	3	3	3	-	-	-	-	-	-	-	3
CO3	3	3	3	3	-	-	-	-	-	-	-	3
CO4	3	3	3	3	-	-	-	-	-	-	-	3
CO5	3	3	3	3	-	-	-	-	-	-	-	3
CO6	3	3	3	3	-	-	-	-	-	-	-	3

CO's/PSO's	PSO1	PSO2
CO1	-	-
CO2	-	-
CO3	-	-
CO4	-	-
CO5	-	-
CO6	-	-

GENERAL INSTRUCTIONS FOR LABORATORY CLASSES

1. All the students must follow the prescribed dress code (apron, formals, shoes) wear their ID cards
2. All the students should sign in login register.
3. All students must carry their observation books and records without fail.
4. Students must take the permission of the laboratory staff before handling the machines in order to avoid any injury.
5. The students must have basic understanding about the theory and procedure of the experiment to be conducted.
6. Power supply to the test table/test rig should be given in the presence of only through the lab technician.
7. Do not LEAN on and do not come CLOSE to the equipment.
8. Instruments like TOOLS, APPARATUS and GUAGE sets should be returned before leaving the lab.
9. Every student is required to handle the equipment with care and follow proper precautions
10. Students should ensure that their work areas are clean.
11. At the end of each experiment, the student must take initials from the staff on the data / observations taken after completing the necessary calculations.
12. The record should be properly written with following section in each experiment:
    a) Aim of the experiment
    b) Apparatus / Tools / Instruments required
    c) Procedure / Theory
    d) Model Calculations
    e) Schematic Diagram
    f) Specifications / Designs Details
    g) Tabulations.
    h) Graph
    i) Result and discussions.
13. Students should attend regularly to all lab classes.
14. Day- to- day evaluation of student performance is carried out and recorded for finalizing internal marks.

SCHEME OF EVALUATION FOR EXTERNAL LABS

Correctness of Write up and Precautions	Conduct Experiment & observations	Model Calculations	Results and Graphs	Viva
Marks: 5	**Marks: 15**	**Marks: 10**	**Marks: 10**	**Marks: 10**
Total Marks: 50 Marks				

SCHEME OF EVALUATION FOR INTERNAL LABS

Day to Day Evaluation ------15 Marks					Internal Exam------10 Marks				
Uniform	Observation &Record	Performance of experiment	Results	Viva Voce	Correctness of Write up and Precautions	Conduct Experiment & observations	Model Calculations	Results and Graphs	Viva Voce
Marks:2	**Marks:3**	**Marks:3**	**Marks:4**	**Marks:3**	**Marks:2**	**Marks:2**	**Marks:2**	**Marks:2**	**Marks:2**
Total Marks: 15+10=25 Marks									

LIST OF EQUIPMENT

1	Kaplan Turbine Test Rig
2	Pelton Wheel Test Rig
3	Francis Turbine Test Rig
4	Multistage Centrifugal Pump Test Rig
5	Venturi & Orifice Meter Set up
6	Major & Minor Losses set up
7	Impact of Jet on Vanes-Digital Version
8	Centrifugal Test Rig (Ac Version)
9	Reciprocating Pump Test Rig (Ac Version)
10	Bernoulli's Theorem

LIST OF CONTENTS

IMPACT OF JET ON VANES

1. INTRODUCTION:

When a jet of water is directed to hit a vane of any particular shape, the force is exerted on it by the fluid in the opposite direction. The amount of force exerted depends on the diameter of the jet, shape of the vane and flow rate of water. The force also depends on whether the vane is moving or stationary. The current experiment deals with the force exerted on stationary vanes.

The following are the theoretical formulae for calculating the force for different shapes of vanes based on the flow rate.

1. Hemi – spherical Plate: $F_t = 2\rho\ A\ V^2/g$
2. Flat Plate: $F_t = \rho\ A\ V^2/g$
3. Inclined Plate: $F_t = (\rho\ A\ V^2/g)\ \text{Sin}\ \theta$

Where,

‘g’	=	9.81 m/s
‘A’	=	Area of jet in m^2
‘ρ’	=	Density of water = 1000 Kg/m^2
‘V’	=	Velocity of jet in m/s
‘θ’	=	Angle the deflected jet makes with the axis of the striking jet = 60°
‘F_t’	=	Theoretical force acting parallel to the direction of the jet.

2. DESCRIPTION OF APPARATUS

1. The equipment has the following types of specially designed ACRYLIC Vanes. Different Diameters of Jet sections are provided.
   - i. Flat
   - ii. Inclined
   - iii. Curved

2. The equipment is a closed circuit system consisting of sump tank, pump set, jet chamber, Rotameter for flow measurement and direct analog force indicator.
3. Water in the sump tank is pumped using a Monoblock Centrifugal pump, which passes through an ACRYLIC Rotameter and the control valve to the Jet.
4. The vanes are fitted to the force balancing mechanism, which is placed on a specially built Transparent ACRYLIC chamber with digital force indicator for direct force measurement.
5. The jets and vanes can be interchanged through this acrylic chamber.
6. The equipment is designed for a closed circuit operation and all the controls are placed on the panel provided in front of the apparatus for a direct and clear-cut view during operation.

3. EXPERIMENTATION

i. AIM:

The experiment is conducted to determine

- The Coefficient of impact by comparing the momentum in a fluid jet with the force generated when it strikes a fixed surface.

ii. PROCEDURE:

a. Fill in the sump tank with clean water.

b. Keep the delivery valve closed.

c. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.

d. Fix the vane & jet in position with care applying minimum force.

e. Press tare button on the force indicator to balance (if zero does not appear).

f. Switch on the pump & open the delivery valve.

g. Adjust the flow using control valve of the Rotameter.

h. Note down the force exerted by the jet on the vane indicated by force indicator.

i. Change the flow rate and repeat the above steps.

j. Also change the vanes and jets and repeat the experiment.

iii. OBSERVATIONS

Sl. No.	Dia of Jet	Type of vane	Rotameter Reading LPM 'Q' in lpm	Pressure gauge 'P' in Kg/Cm^2	Force Indicator 'F_a' Kgf
1	4mm	FLAT VANE	5	0.25	0.042
			7.5	0.60	0.113
			10	1.20	0.224
2	4mm	INCLINED VANE	5	0.24	0.035
			7.5	0.85	0.095
			10	1.29	0.184
3	4mm	HEMISPHERICAL VANE	5	0.25	0.041
			7.5	0.41	0.082
			10	.95	0.174

iv. CALCULATIONS:

1. **Calculation of Theoretical Force**: F_t

1. Hemi – spherical Plate: $F_t = 2\rho A V^2/g$
2. Flat Plate: $F_t = \rho A V^2/g$
3. Inclined Plate: $F_t = (\rho A V^2/g) \sin\theta$

Where,

'g' = $9.81\ m/s^2$

'A' = Area of jet in m^2

A= $\prod d^2/4$

where d = dia of the jet in 'm'.

'ρ' = Density of water = $1000\ Kg/m^3$

‘V’ = Velocity of jet in m/s

$$= \frac{\text{Rotameter reading}}{1000 \times 60 \times A}$$

where terms have their usual meaning.

‘θ’ = Angle the deflected jet makes with the axis of the striking jet = 60°

‘F_t’ = Theoretical force acting parallel to the direction of the jet.

VELOCITIES AT DIFFERENT FLOWRATES

5 LPM :

$V=5/1000\times60\times0.01256=0.06634$ m/s

7.5 LPM:

$V=7.5/1000\times60\times0.01256=0.09952$ m/s

10 LPM:

$V=10/1000\times60\times0.01256=0.01326$ m/s

FLAT:

$F_{th}=1000\times0.01256\times(0.06634)^2=0.0552$ kgf

$F_{th}=1000\times0.01256\times(0.09952)^2=0.1243$ kgf

$F_{th}=1000\times0.01256\times(0.01326)^2=0.02083$ kgf

INCLINED:

$F_{th}=1000\times0.01256\times(0.06634)^2\sin^2\theta=0.0478$ kgf

$F_{th}=1000\times0.01256\times(0.09952)^2\sin^2\theta=0.1077$ kgf

$F_{th}=1000\times0.01256\times(0.01326)^2\sin^2\theta=0.01326$ kgf

HEMISPHERICAL:

$F_{th}=2\times1000\times0.01256\times(0.06634)^2=0.1105$ kgf

$F_{th}=2\times1000\times0.01256\times(0.09952)^2=0.2487$ kgf

$F_{th}=2\times1000\times0.01256\times(0.01326)^2=0.04410$ kgf

2. **Co-efficient of impact, Ci**

$$Ci = F_a / F_{th}$$

Where,

'F_a' = Actual force developed as indicated by the digital force indicator.

'F_t' = Theoretical force acting parallel to the direction of the jet.

FLAT:

$F_a/F_{th}=0.042/0.0552$
=0.763

AVG=0.92

$F_a/F_{th}=0.113\ /0.124$
=0.911

$F_a/F_{th}=0.022/0.02083$
=1.10

INCLINED:

Fa/Fth=0.035/0.0478
=0.744

Fa/Fth=0.095/0.1072
=0.887 AVG=0.86

Fa/Fth=0.184/0.01912
=0.964

HEMISPHERICAL:

Fa/Fth=0.041/0.1105
=0.372

Fa/Fth=0.128/0.2487 AVG=0.48
=0.516

Fa/Fth=0.248/0.441
=0.563

v. <u>TABULAR COLUMN FOR CALCULATIONS</u>:

Sl. No.	Dia of Jet	Type of vane	Rotameter Reading 'Q' in lpm'	Actual Force F_a in Kgf	Theoretical Force F_{th} in Kgf	Coefficient of impact $C_i = F_a / F_{th}$
1	4mm	FLAT	5	0.042	0.0552	0.763
			7.5	0.113	0.1243	0.911
			10	0.022	0.02083	1.10
2	4mm	INLINED	5	0.035	0.0478	0.744
			7.5	0.095	0.1077	0.887
			10	0.184	0.01912	0.964
3	4mm	HEMISPHERICAL	5	0.041	0.1105	0.372
			7.5	0.128	0.2487	0.516
			10	0.248	0.4416	0.563

vi. RESULTS:

Thus,The experiment is conducted and the Coefficient of impact by comparing the momentum in a fluid jet with the force generated when it strikes a fixed surface of flat vane, inclined vane and Hemi-Sphere vane was determined as shown in below table

S.No	Type of vane	Actual Force F_a in Kgf	Theoretical Force F_{th} in Kgf	Coefficient of impact $C_i = F_a / F_{th}$
1	Flat	0.042	0.0552	0.763
2	Inclined	0.035	0.0478	0.744
3	Hemi-sphere	0.041	0.1105	0.372
Average				

4. PRECAUTIONS

- Do not run the pump dry.
- Clean the tanks regularly, say for every 15 days.
- Do not run the equipment if the voltage is below 180V.
- Check all the electrical connections before running.
- Before starting and after finishing the experiment the main control valve should be in close position.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

PERFORMANCE TEST ON PELTON WHEEL TURBINE

1. INTRODUCTION

Hydraulic (or Water) Turbines are the machines that use the Energy of water (Hydro – Power) and convert it into Mechanical Energy. Thus the Turbines become the Prime mover to run Electrical Generators to produce electricity, Viz., Hydro Electric Power.

Turbines are classified as Impulse and Reaction Types. In Impulse Turbine, the head of the water is completely converted into a jet, which impulse the force on the Turbine. In Reaction Turbine, it is the pressure of the flowing water, which rotates the runner of the Turbine. Of many types of Turbine, the Pelton Wheel, most commonly used, falls into this category of Impulse Turbine while the Francis & Kaplan fall into the category of Reaction Turbines. Normally, Pelton Wheel requires high Heads and Low Discharge while the Francis & Kaplan (Reaction Turbines) requires relatively low Heads and high Discharge. These corresponding Heads and Discharges are difficult to create in a laboratory size Turbine from the limitation of the pumps availability in the market. Nevertheless, at least the performance characteristics could be obtained within the limited facility available in the laboratories. Further, understating of various elements associated with any particular Turbine is possible with this kind of facility.

2. DESCRIPTION OF THE APPARATUS:

1. The apparatus consists of the following major parts
   i. **Monobloc Centifugal Pump of** Kirloskar Make.
   ii. **Turbine Unit**
   iii. **Sphere Rod Assembly**
   iv. **Sump Tank**
   v. **Venturimeter with pressure tappings.**

2. All are arranged in such a way that the whole unit works as a recirculating water system.

3. Centrifugal pump set supplies water from Sump Tank to the Turbine through control valve.

4. Water re - enters the Sump Tank after passing through the Turbine unit.

5. Loading of the Turbine is achieved by a rope brake drum connected to spring balance.

6. Provisions for measurement of Turbine speed (digital RPM indicator), Head on Turbine (Pressure gauge) are built in on the control panel.

7. The whole arrangement is mounted on an **Aesthetically designed sturdy frame** made of **MS angle** with all the provisions for holding the tanks and accessories.

3. OPERATION:

1. Connect the supply water pump – water unit to 3ph, 440 V, 30A electrical supply, with neutral and earth connections and ensure the correct direction of the pump motor unit.
2. Keep the Butterfly valve at closed Position.
3. Keep the loading at minimum.
4. Press the green button of the supply pump starter. Now the pump picks up the full speed and becomes operational.

4. EXPERIMENTATION:

i. AIM:

The experiment is conducted to:

a. Obtain Constant Head and Speed characteristics.

ii. PROCEDURE:

A. TO OBTAIN CONSTANT HEAD CHARACTERISTICS.

- Keep the Delivery valve open at Maximum.
- Set the head at required value.
- Now apply the load.
- Operating the Sphere Rod Assembly, maintain the head to the Set value.
- Repeat the steps 4 and 5 till the maximum load the turbine can take.
- In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

B. TO OBTAIN CONSTANT SPEED CHARACTERISTICS.

- Keep the Delivery valve open at Maximum.
- Now apply the load.
- Operating the Sphere Rod Assembly, maintain the speed to the Set value.
- Repeat the steps 4 and 5 till the maximum load the turbine can take.
- In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

C. PERFORMANCE UNDER UNIT HEAD – UNIT QUANTITIES.

In order to predict the behavior of a turbine working under varying conditions and to facilitate comparison between the performances of the turbines of the same type but having different outputs and speeds and working under different heads, it is often convenient to express the test results in terms of certain unit quantities. From the output of the turbine corresponding to different working heads (Tabular Column - 1), it is possible to compute the output, which would be developed if the head was reduced to unity (say 1 Meter): the speed being adjustable so that the efficiency remains unaffected.

a) **Unit Speed,**

$$N_u = \frac{N}{\sqrt{H}}$$

b) **Unit Power,**

$$P_u = \frac{P}{H^{3/2}}$$

c) **Unit Discharge,**

$$Q_u = \frac{Q}{\sqrt{H}}$$

d) **Specific Speed,**

The Specific Speed of any Turbine is the speed in rpm of a turbine geometrically similar to the actual turbine but of such a size that under corresponding conditions it will develop 1 metric horse power when working under unit head (i.e. 1 meter). The Specific Speed is usually computed for the operating conditions corresponding to the maximum efficiency.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

iii. **OBSERVATIONS**:

Constant Head/Speed

Sl. No	Turbine speed N rpm	Delivery Pressure` P' Kg/cm^2	Venturimeter Head		Load, Kg		
			P1 Kg/cm^2	P2 Kg/cm^2	F1	F2	F=F1~F2
1	1000	2.7	2.6	2	2	0.6	1.4
2	1000	3.2	3.1	2.5	4	1.4	2.6
3	1000	4	3.8	3.4	6	2	4

iv. CALCULATIONS:

- **Total Head of Turbine in meters of water, H**

$$H = \left(P + \frac{P_v}{760}\right) * 10 \qquad \text{m of water}$$

Where,

p = Pressure gauge readings in Kg/Cm²

p_v = vacuum Pressure gauge readings in mm of hg

$P_v = P_1 - P_2$

- $P_v = 2.6 - 2$

  $P_v = 0.6$

  H = (P+ ($\frac{P_v}{760}$)) × 10 m of water

  H = (2.7+ ($\frac{0.6}{760}$)) × 10 m of water

  H_1 = 27.00 m

- $P_v = P_1 - P_2$

  P_v =0.6

  H = (P+ ($\frac{P_v}{760}$)) × 10 m of water

  H = (3.2+ ($\frac{0.6}{760}$)) × 10 m of water

  H_2 = 32.00 m

- $P_v = P_1 - P_2$

  P_v = 0.4

  H = (P+ ($\frac{P_v}{760}$)) × 10 m of water

  H = (4+ ($\frac{0.4}{760}$)) × 10 m of water

  H_3 = 40.00 m

- **Discharge, Q**

$$Q = \frac{Cd * A1 * A2 * \sqrt{2gh}}{\left(\sqrt{A1^2 - A2^2}\right)} \ m\ /s$$

Where,

h = (P1 - P2) x 10

A1 = Area of the Venturimeter

$$A_1 = \frac{\pi\ x\ D_1{}^2}{4}\ m^2$$

Where, D1 = Venturimeter Inlet diameter = 50mm

A2 = Area of the throat of the Venturimeter

$$A_2 = \frac{\pi\ x\ D_2{}^2}{4}\ m^2$$

Where, D2 = Venturimeter Throat diameter = 26mm

C_d = 0.95 (Constant)

$$A_1 = \frac{\pi\ x\ D_1{}^2}{4}\ m^2 \qquad \text{(D1=50 mm)}$$

$A_1 = 1963.49\times10^{-6}$

$A_2 = 530.39\times10^{-6}$

$h = (P_1 - P_2) \times 10$

$h = (2.6-2) \times 10 = 6$ (C_d =0.95)

$$Q_1 = \left(\frac{0.95\times1963.4\times530.9\times10^{-6}\times\sqrt{2\times9.81\times6}}{\sqrt{(1963.49\times10^{-6})^2-(530.9\times10^{-6})^2}}\right)$$

$= 5.683\times10^{-3}\ m^3/s$

$$Q_2 = \left(\frac{0.95\times1963.4\times530.9\times10^{-6}\times\sqrt{2\times9.81\times6}}{\sqrt{(1963.49\times10^{-6})^2-(530.9\times10^{-6})^2}}\right)$$

$=5.683\times10^{-3}\ m^3/s$

$$Q_3 = \left(\frac{0.95\times1963.4\times530.9\times10^{-6}\times\sqrt{2\times9.81\times2}}{\sqrt{(1963.49\times10^{-6})^2-(530.9\times10^{-6})^2}}\right)$$

$=4.640\times10^{-3}\ m^3/s$

- **<u>Input to the turbine, IP(Hydraulic)</u>**

$$IP = \frac{WQH}{1000}\ kW$$

Where,

W = 9810 Kg/m³

Q =Discharge in m³/s

H =Total Head in m of water

$$IP = \frac{9810 \times 5.683\times10^{-3} X\ 27}{1000}\ kW \quad =1.505\ kW$$

$$IP = \frac{9810 \times 5.683\times10^{-3} X\ 32}{1000}\ kW \quad = 1.784\ kW$$

$$IP = \frac{9810 \times 4.640\times10^{-3} X\ 40}{1000}\ kW \quad = 1.821\ kW$$

- **Output from turbine, OP (Mechanial Workdone)**

$$OP = \frac{2\pi NT}{60 \text{ x } 1000} \text{ kW}$$

Where,

N = Speed of the Turbine

T = Torque

T = F x R x 9.81

Where, R = Radius of the brake drum= 0.125 m

T_1 = 1.4 x 0.125 x 9.81 = 1.717 N-m

T_2 = 2.6 x 0.125 x 9.81 = 3.188 N-m

T_3 = 4 x 0.125 x 9.81 = 4.905 N-m

$$OP = \frac{2\pi \times 1000 \times 1.717}{60 \text{ x } 1000} \text{ kW}$$

= 0.1798 kW

$$OP = \frac{2\pi \times 1000 \times 3.188}{60 \text{ x } 1000} \text{ kW}$$

= 0.3338 kW

$$OP = \frac{2\pi \times 1000 \times 4.905}{60 \text{ x } 1000} \text{ kW}$$

= 0.5136 kW

- **Turbine Efficiency**,

$$\eta\,\% = \frac{OP\ x\ 100}{IP}$$

$$\eta\,\% = \frac{0.1798\ x\ 100}{1.505}$$ =11.95

$$\eta\,\% = \frac{0.3338\ x\ 100}{1.784}$$ =18.71

$$\eta\,\% = \frac{0.5136\ x\ 100}{1.821}$$ =28.20

v. TABULAR COLUMN

Sl. No	Total Head H, m	Discharge Q, m^3/sec	IP, KW	OP, KW	Turbine efficiency %η
1	27	5.683×10	1.505	0.1798	11.95
2	32	5.683×10	1.784	0.3338	18.71
3	40	4.640×10	1.821	0.5136	28.20

vi. RESULT:

Thus performance test on Pelton turbine has been done and following results are observed.

a) For various speeds, efficiencies have been determined.

b) Graphs have been plotted for the constant head/speed characteristics of the turbine.

c) The unit head and other quantities are calculated from the knowledge of constant head characteristics.

d) An attempt has been made to provide the facility to understand the various components of the Francis turbine & present the characteristic curves.

REFERENCES:

a. Fluid Mechanics & Machinery by H.M RAGHUNATH

b. Hydraulics & Fluid Mechanics by Dr. P.N MODI & Dr. S.M. SETH

c. Flow Measurement Engineering Handbook by R.W.MILLER.

5. PRECAUTIONS:

1. Do not start Pump set if the supply voltage is less than 300V (Phase to Phase voltage)
2. Do not forget to give electrical earth and neutral connections correctly, otherwise the RPM indicator gets burnt.
3. Initially, fill in the tank with clean water free from foreign material, change the water every six months.
4. Frequently, at least once in three months, grease all visual moving parts.
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 positions 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 manufacturers and do not attempt to repair.

PERFORMANCE TEST ON FRANCIS TURBINE

1. INTRODUCTION

Hydraulic (or Water) Turbines are the machines that use the Energy of water (Hydro – Power) and convert it into Mechanical Energy. Thus the Turbines become the Prime mover to run Electrical Generators to produce electricity, Viz., Hydro Electric Power.

Turbines are classified as Impulse and Reaction Types. In Impulse Turbine, the head of the water is completely converted into a jet, which impulse the force on the Turbine. In Reaction Turbine, it is the pressure of the flowing water, which rotates the runner of the Turbine. Of many types of Turbine, the Pelton Wheel, most commonly used, falls into this category of Impulse Turbine while the Francis & Kaplan fall into the category of Reaction Turbines. Normally, Pelton Wheel requires high Heads and Low Discharge while the Francis & Kaplan (Reaction Turbines) requires relatively low Heads and high Discharge. These corresponding Heads and Discharges are difficult to create in a laboratory size Turbine from the limitation of the pumps availability in the market. Nevertheless, at least the performance characteristics could be obtained within the limited facility available in the laboratories. Further, understating of various elements associated with any particular Turbine is possible with this kind of facility.

2. DESCRIPTION OF THE APPARATUS:

- The apparatus consists of the following major parts
    i. **Monobloc Centifugal Pump of** Kirloskar Make.
    ii. **Turbine Unit**
    iii. **Sump Tank**
    iv. **Venturimeter/Orificemeter with pressure tappings.**

- All are arranged in such a way that the whole unit works as a recirculating water system.

- Centrifugal pump set supplies water from Sump Tank to the Turbine through control valve.

- Water re - enters the Sump Tank after passing through the Turbine unit.

- Loading of the Turbine is achieved by a rope brake drum connected to spring balance.

- Provisions for measurement of Turbine speed (digital RPM indicator), Head on Turbine (Pressure gauge) are built in on the control panel.

- The whole arrangement is mounted on an **Aesthetically designed sturdy frame** made of **MS angle** with all the provisions for holding the tanks and accessories.

3. OPERATION:

1. Connect the supply water pump – water unit to 3ph, 440 V, 20A electrical supply, with neutral and earth connections and ensure the correct direction of the pump motor unit.
2. Keep the Butterfly valve at closed Position.
3. Keep the loading at minimum.
4. Press the green button of the supply pump starter. Now the pump picks up the full speed and becomes operational.

4. EXPERIMENTATION:

i. AIM:

The experiment is conducted to:

- Obtain Constant Head and Speed characteristics.

ii. PROCEDURE:

A. TO OBTAIN CONSTANT HEAD CHARACTERISTICS.

- Set the Vane position.
- Keep the Delivery valve open at Maximum.
- Set the head at required value.
- Now apply the load.
- Operating the delivery valve, maintain the head to the Set value.
- Repeat the steps 4 and 5 till the maximum load the turbine can take.
- In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

B. TO OBTAIN CONSTANT SPEED CHARACTERISTICS.

- Set the Vane position.
- Keep the Delivery valve open at Maximum.
- Set the speed to the required value using the same delivery Valve.
- Now apply the load.
- Operating the delivery valve, maintain the speed to the Set value.
- Repeat the steps 4 and 5 till the maximum load the turbine can take.
- In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

C. PERFORMANCE UNDER UNIT HEAD – UNIT QUANTITIES.

In order to predict the behavior of a turbine working under varying conditions and to facilitate comparison between the performances of the turbines of the same type but having different outputs and speeds and working under different heads, it is often convenient to express the test results in terms of certain unit quantities. From the output of the turbine corresponding to different working heads (Tabular Column - 1), it is possible to compute the output, which would be developed if the head was reduced to unity (say 1 Meter): the speed being adjustable so that the efficiency remains unaffected.

a) Unit Speed,

$$N_u = \frac{N}{\sqrt{H}}$$

b) Unit Power,

$$P_u = \frac{P}{H^{3/2}}$$

c) Unit Discharge,

$$Q_u = \frac{Q}{\sqrt{H}}$$

d) Specific Speed,

The Specific Speed of any Turbine is the speed in rpm of a turbine geometrically similar to the actual turbine but of such a size that under corresponding conditions it will develop 1 metric horse power when working under unit head (i.e. 1 meter). The Specific Speed is usually computed for the operating conditions corresponding to the maximum efficiency.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

iii. OBSERVATIONS:

Constant Head/Speed

Sl. No	Turbine speed N rpm	Delivery Pressure `P' Kg/cm²	Vacuum pressure 'Pv' mm of Hg	Flow meter Head		Power Output	
				P1 Kg/cm²	P2 Kg/cm²	Voltage 'V' volts	Current 'I' amps
1	1260	0.6	20	1.5	0.25	128	0.33
2	1140	0.55	30	1.45	0.20	114	0.50
3	1010	0.5	40	1.4	0.15	160	0.63

iv. CALCULATIONS:

- **Total Head of Turbine in meters of water, H**

$$H = \left(P + \frac{P_v}{760}\right) * 10 \quad \text{m of water}$$

Where,

p = Pressure gauge readings in Kg/Cm²

p_v = vacuum Pressure gauge readings in mm of Hg

$h = (P_1 - P_2) \times 10$

Head=H= $(p+\frac{Pv}{760}) \times 10$

$h_1 = (1.35-0.20) \times 10 = 11.5$ m

$h_2 = (1.30-0.5) \times 10 = 1.5$ m

$h_3 = (1.25-0.16) \times 10 = 1.5$ m

H_1= $(0.45+\frac{20}{760})\times 10$=4.76 m

H_2= $(0.45+\frac{30}{760})\times 10$=4.89 m

H_3= $(0.40+\frac{40}{760})\times 10$=4.5 m

- **<u>Discharge, Q</u>**

$$Q = \frac{Cd * A1 * A2 * \sqrt{2gh}}{\left(\sqrt{A1^2 - A2^2}\right)}\ m^3/s$$

Where,

h = (P1 - P2) x 10

A1 = Area of the Venturimeter

$$A_1 = \frac{\pi\ x\ D_1{}^2}{4}\ m^2$$

Where, D1 = Flow meter Inlet diameter = 75mm

A2 = Area of the throat of the Venturimeter

$$A_2 = \frac{\pi\ x\ D_2{}^2}{4}\ m^2$$

Where, D2 = Flow meter Throat diameter = 38mm

C_d = 0.95 for Venturimeter C_d = 0.62 for Orificemeter

$$Q=\frac{0.95\times4\times10-3\times1.13\times10-3\times\sqrt{2\times9.81\times11.5}}{\sqrt{(4\times10-3)2-(1.13\times10-3)2)}}$$

=0.017

- **Input to the turbine, IP(Hydraulic)**

$$IP = \frac{WQH}{1000} \text{ kW}$$

Where,

W = 9810 Kg/m³

Q =Discharge in m³/s

H =Total Head in m of water

$$IP1=\frac{9810\times0.017\times4.76}{1000}=0.79$$

$$IP2=\frac{9810\times0.017\times4.89}{1000}=0.81$$

$$IP2=\frac{9810\times0.017\times4.52}{1000}=0.75$$

- **Output from turbine, OP (Mechanial Workdone)**

$$OP = \frac{V \times I}{\eta_T \times \eta_A \times 1000} \quad kW$$

Where,

n = No. of revolutions of energy meter,

K = Energy meter constant.

t = Time taken for 'n' revolutions of energy meter.

ηT = Transmission Efficiency (Belt Transmission) 0.75.

ηA = Alternator Efficiency = 0.65.

$$OP1=\frac{10.5\times0.30}{0.75\times0.05\times1000}=0.064\ KW$$

$$OP2=\frac{96\times0.45}{0.75\times0.65\times1000}=0.0888\ KW$$

$$OP3=\frac{86\times0.581}{1000\times0.75\times0.05}=0.1023\ KW$$

- **Turbine Efficiency**,

$$\eta\% = \frac{OP\ x\ 100}{IP}$$

$$\eta1\% = \frac{0.064x\ 100}{0.79} = 8.10$$

$$\eta2\% = \frac{0.88\ x\ 100}{0.81} = 10.86$$

$$\eta3\% = \frac{0.102x\ 100}{0.75} = 13.6$$

- **Unit Quantities – Under Unit Head,**

a) Unit Speed,

$$N_u = \frac{N}{\sqrt{H}}$$

$$N_u = \frac{1136.6}{\sqrt{4.72}}=523.16\ rpm$$

b) Unit Power,

$$P = \frac{P}{H^{3/2}}$$

$$P = \frac{0.034}{4.72^{3/2}}$$ =0.008 KW

c) Unit Discharge,

$$Q_u = \frac{Q}{\sqrt{H}}$$

$$Q_u = \frac{0.017}{\sqrt{4.72}}$$ = 0.007 m^3/

d) Specific Speed,

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_s = \frac{113.6\sqrt{0.014}}{4.72^{5/4}}$$ = 47.34 rpm

v. TABULAR COLUMN

Sl. No	Total Head H, m	Discharge Q, m^3/sec	IP, KW	OP, KW	Turbine efficiency %η
1	4.76	0.79	0.79	0.064	8.166
2	4.89	0.81	0.81	0.0886	10.89
3	4.52	0.75	0.75	0.1023	13.6

vi. RESULT:

Thus performance test on Francis turbine has been done and following results are observed.

b) For various speeds, efficiencies have been determined.

c) Graphs have been plotted for the constant head/speed characteristics of the turbine.

c) The unit head and other quantities are calculated from the knowledge of constant head characteristics.

d) An attempt has been made to provide the facility to understand the various components of the Francis turbine & present the characteristic curves.

REFERENCES:

a. Fluid Mechanics & Machinery by H.M RAGHUNATH

b. Hydraulics & Fluid Mechanics by Dr. P.N MODI & Dr. S.M. SETH

c. Flow Measurement Engineering Handbook by R.W.MILLER.

5. PRECAUTIONS TO REMEMBER:

1. Do not start Pump set if the supply voltage is less than 300V (Phase to Phase voltage)
2. Do not forget to give electrical earth and neutral connections correctly, otherwise the RPM indicator gets burnt.
3. Initially, fill in the tank with clean water free from foreign material, change the water every six months.
4. Frequently, at least once in three months, grease all visual moving parts.
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 positions 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 manufacturers and do not attempt to repair.

PERFORMANCE TEST ON KAPLAN TURBINE

1. INTRODUCTION

Hydraulic (or Water) Turbines are the machines that use the Energy of water (Hydro – Power) and convert it into Mechanical Energy. Thus the Turbines become the Prime mover to run Electrical Generators to produce electricity, Viz., Hydro Electric Power.

Turbines are classified as Impulse and Reaction Types. In Impulse Turbine, the head of the water is completely converted into a jet, which impulse the force on the Turbine. In Reaction Turbine, it is the pressure of the flowing water, which rotates the runner of the Turbine. Of many types of Turbine, the Pelton Wheel, most commonly used, falls into this category of Impulse Turbine while the Francis & Kaplan fall into the category of Reaction Turbines. Normally, Pelton Wheel requires high Heads and Low Discharge while the Francis & Kaplan (Reaction Turbines) requires relatively low Heads and high Discharge. These corresponding Heads and Discharges are difficult to create in a laboratory size Turbine from the limitation of the pumps availability in the market. Nevertheless, at least the performance characteristics could be obtained within the limited facility available in the laboratories. Further, understating of various elements associated with any particular Turbine is possible with this kind of facility.

2. DESCRIPTION OF THE APPARATUS:

1. The apparatus consists of the following major parts
   i. **Monobloc Centifugal Pump of** Kirloskar Make.
   ii. **Turbine Unit**
   iii. **Sump Tank**
   iv. **Venturimeter/Orificemeter with pressure tappings.**

2. All are arranged in such a way that the whole unit works as a recirculating water system.

3. Centrifugal pump set supplies water from Sump Tank to the Turbine through control valve.

4. Water re - enters the Sump Tank after passing through the Turbine unit.

6. Loading of the Turbine is achieved by a rope brake drum connected to spring balance.

7. Provisions for measurement of Turbine speed (digital RPM indicator), Head on Turbine (Pressure gauge) are built in on the control panel.

8. The whole arrangement is mounted on an **Aesthetically designed sturdy frame** made of **MS angle** with all the provisions for holding the tanks and accessories.

3. OPERATION:

1. Connect the supply water pump – water unit to 3ph, 440 V, 20A electrical supply, with neutral and earth connections and ensure the correct direction of the pump motor unit.
2. Keep the Butterfly valve at closed Position.
3. Keep the loading at minimum.
4. Press the green button of the supply pump starter. Now the Pump picks up the full speed and becomes operational.

4. EXPERIMENTATION:

i. AIM:

The experiment is conducted to:

a. Obtain Constant Head and Speed characteristics.

ii. PROCEDURE:

A. TO OBTAIN CONSTANT HEAD CHARACTERISTICS.

1. Set the Vane position.
2. Keep the Delivery valve open at Maximum.
5. Set the head at required value.
6. Now apply the load.
7. Operating the delivery valve, maintain the head to the Set value.(if required)
8. Repeat the steps 4 and 5 till the maximum load the turbine can take.
9. In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

B. TO OBTAIN CONSTANT SPEED CHARACTERISTICS.

1. Set the Vane position.
2. Keep the Delivery valve open at Maximum.
3. Set the speed to the required value using the same delivery Valve.
4. Now apply the load.
5. Operating the delivery valve, maintain the speed to the Set value.
6. Repeat the steps 4 and 5 till the maximum load the turbine can take.
7. In the meantime, Note down the turbine speed, vacuum head and Venturimeter readings for each loadings.

C. PERFORMANCE UNDER UNIT HEAD – UNIT QUANTITIES.

In order to predict the behavior of a turbine working under varying conditions and to facilitate comparison between the performances of the turbines of the same type but having different outputs and speeds and working under different heads, it is often convenient to express the test results in terms of certain unit quantities. From the output of the turbine corresponding to different working heads (Tabular Column - 1), it is possible to compute the output, which would be developed if the head was reduced to unity (say 1 Meter): the speed being adjustable so that the efficiency remains unaffected.

a) Unit Speed,

$$N_u = \frac{N}{\sqrt{H}}$$

b) Unit Power,

$$P_u = \frac{P}{H^{3/2}}$$

c) Unit Discharge,

$$Q_u = \frac{Q}{\sqrt{H}}$$

d) Specific Speed,

The Specific Speed of any Turbine is the speed in rpm of a turbine geometrically similar to the actual turbine but of such a size that under corresponding conditions it will develop 1 metric horse power when working under unit head (i.e. 1 meter). The Specific Speed is usually computed for the operating conditions corresponding to the maximum efficiency.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

iii. OBSERVATIONS:

Constant Head/Speed

Sl. No	Turbine speed N rpm	Delivery Pressure `P' Kg/cm²	Vacuum pressure 'Pv' mm of Hg	Venturi meter Head		Power Output	
				P1 Kg/cm²	P2 Kg/cm²	Voltage 'V' volts	Current 'I' amps
1	1000	0.8	15	0.9	0.25	98	0.51
2	1000	0.75	20	0.9	0.25	68	0.85
3	1000	0.75	20	0.9	0.25	49	1.12

iv. CALCULATIONS:

- **Total Head of Turbine in meters of water, H**

$$H = \left(P + \frac{P_v}{760}\right) * 10 \qquad \text{m of water}$$

Where,

p = Pressure gauge readings in Kg/Cm²

p_v = vacuum pressure gauge readings in mm of Hg

H_1= (0.8+ (15/760)) ×10=8.19 m

H_2= (0.75+ (20/760)) ×10=7.76 m

H_3= (0.75+ (20/760)) ×10=7.76 m

- **Discharge, Q**

$$Q = \frac{Cd * A1 * A2 * \sqrt{2gh}}{\left(\sqrt{A1^2 - A2^2}\right)} \; m^3/s$$

Where,

h = $(P_1 - P_2)$ x 10

A_1 = Area of the Venturimeter

$A_1 = \frac{\pi \ x \ {D_1}^2}{4} \ \ m^2$

Where, D1 = Venturi meter Inlet diameter = 100mm

A_2 = Area of the throat of the Venturimeter

$A_2 = \frac{\pi \ x \ {D_2}^2}{4} \ \ m^2$

Where, D2 = Venturi meter Throat diameter = 50mm

C_d = 0.95 for Venturimeter

C_d = 0.62 for Orificemeter

h=(0.9-0.25)*10=6.5

$A1 = \frac{\pi \ x \ 100^2}{4} = 7.85 \times 410^{-3} \ m^2$

$$A2 = \frac{\pi \ x 50^2}{4} = 1.96 \times 10^{-3} \ m^2$$

Q=$\frac{0.95 \times 7.85 \times 10-3 \times 1.96 \times 10-3 \times \sqrt{2 \times 9.81 \times 6.5}}{\sqrt{(7.85 \times 10-3)2-(1.96 \times 10-3)2)}}$ =0.021 m^3/s

- **<u>Input to the turbine, IP(Hydraulic)</u>**

$$IP \ = \frac{WQH}{1000} \ kW$$

Where,

W = 9810 Kg/m^3

Q =Discharge in m^3/s

H =Total Head in m of water

$$IP = \frac{9810 \times 0.021 \times 8.19}{1000} \text{ kW} = 1.68\text{KW}$$

$$IP = \frac{9810 \times 0.021 \times 7.76}{1000} \text{ kW} = 1.59\text{KW}$$

$$IP = \frac{9810 \times 0.021 \times 7.76}{1000} \text{ kW} = 1.59\text{KW}$$

- **Output from turbine, OP (Mechanial Workdone)**

$$OP = \frac{V \times I}{\eta_T \times \eta_A \times 1000} \text{ kW}$$

Where,

V = Voltmeter reading.

I = Ammeter reading.

ηT = Transmission Efficiency (Belt Transmission) 0.75.

ηA = Alternator Efficiency = 0.65.

$$OP = \frac{98 \times 0.51}{0.75 \times 0.65 \times 1000} \, kW = 0.102KW$$

$$OP = \frac{68 \times 0.85}{1000 \times 0.75 \times 0.65} \, kW = 0.118\text{KW}$$

$$OP = \frac{49 \times 1.12}{1000 \times 0.65 \times 0.75} \, kW = 0.112KW$$

- **<u>Turbine Efficiency</u>**,

$$\eta\% = \frac{OP\ x\ 100}{IP}$$

$$\eta\% = \frac{0.102\times 100}{1.68} = 6.17\ \%$$

$$\eta\% = \frac{0.118\times 100}{1.59} = 7.42\ \%$$

$$\eta\% = \frac{0.112\times 100}{1.59} = 7.04\ \%$$

- **<u>Unit Quantities – Under Unit Head,</u>**

a) <u>Unit Speed,</u>

$$N_u = \frac{N}{\sqrt{H}}$$

b) <u>Unit Power,</u>

$$P_u = \frac{P}{H^{3/2}}$$

c) <u>Unit Discharge,</u>

$$Q_u = \frac{Q}{\sqrt{H}}$$

d) <u>Specific Speed,</u>

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

v. TABULAR COLUMN

Sl. No	Total Head H, m	Discharge Q, m^3/sec	IP, KW	OP, KW	Turbine efficiency %η
1	8.19	0.021	1.68	0.102	6.17
2	7.16	0.021	1.59	0.118	7.42
3	7.16	0.021	1.59	0.112	7.04

vi. RESULT:

1) Graphs plotted show the constant head/speed characteristics of the KAPLAN turbine.
2) An attempt has been made to provide the facility to understand the various components of the KAPLAN turbine & present the characteristic curves.
3) The unit head and other quantities are calculated from the knowledge of constant head characteristics.
4) The numerical values in graphs and design calculations should be looked upon as qualitative figures rather than quantitative ones as some of the components available in the market for constructing the turbine are limited.

REFERENCES:

1. Fluid Mechanics & Machinery by H.M RAGHUNATH
2. Hydraulics & Fluid Mechanics by Dr. P.N MODI & Dr. S.M. SETH
3. Flow Measurement Engineering Handbook by R.W.MILLER.

1. PRECAUTIONS TO REMEMBER:

1. Do not start Pump set if the supply voltage is less than 300V (Phase to Phase voltage)
2. Do not forget to give electrical earth and neutral connections correctly, otherwise the RPM indicator gets burnt.
3. Initially, fill in the tank with clean water free from foreign material, change the water every six months.
4. Frequently, at least once in three months, grease all visual moving parts.
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 positions 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 manufacturers and do not attempt to repair.

PERFORMANCE TEST ON SINGLE – STAGE CENTRIFUGAL PUMP

1. INTRODUCTION

In general, a pump may be defined as mechanical device when connected in a pipe line, can convert the mechanical energy into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

Pumps are of major concern to most engineers and technicians. The types of pumps 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 are Centrifugal, reciprocating, axial flow (stage pumps), air jet, diaphragm and turbine pumps. Most of these pumps fall mainly into a class namely rotodynamic, reciprocating (positive displacement) and fluid operated pumps. In a Centrifugal pump, pressure head is developed by centrifugal action. The pump consists of an impeller, which rotates in a casing. Fluid enters through the eye of the pump and discharges radially outwards to the delivery pipe. Centrifugal Pumps also come based on the type of vanes: Backward curved blades, Radial Type and Forward Curved Type. Centrifugal pumps are commercially available as Single stage and Multi-stage pumps.

In this pump, the liquid is made to rotate in a closed chamber (volute casing), thus creating the centrifugal action, which gradually builds 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 (muddy), liquids can be directly coupled to high speed electric motors (without any speed reduction), 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. The present test rig allows the students to understand and draw the operating characteristics at various heads, flow rates and Stages.

2. DESCRIPTION OF APPARATUS

The Centrifugal Pump Test Rig comes with the following two versions along with the standard specifications:

a. DC Version.

This version has a Centrifugal pump coupled to a DC Motor with Thyrister control drive for desirable speed setting.

b. AC Version– YOUR EQUIPMENT.

This version has a Centrifugal pump coupled to an AC Motor with Stepped Cone Pulley arrangement for operating the pump at Three different speeds.

3. Standard Specifications:

1. The pump is of **KIRLOSKAR** make of 1hp capacity with the head of 11m head.
2. The Pump is coupled to **DC or AC motor** of suitable make and capacity with Thyristor control drive.
3. The above two are fitted on the Base frame.
4. Water from the sump tank is sucked by the pump and is delivered through the delivery pipe to the collecting tank.
5. **Overflow** arrangement is provided to the collecting tank.
6. **Butterfly valve** is provided in the measuring tank for instant close and release.
7. The suction and delivery can be controlled by means of **control valves**.
8. **Piezometer** with Vinyl sticker scale (For better readability) is provided to measure the height of the water collected in the measuring tank.
9. The apparatus comes with a separate **NOVAPAN** board control panel with standard accessories such as **Digital RPM Indicator**, Energy meter, Delivery and Vacuum gauges.
10. The equipment has been designed for closed circuit operation.
11. The whole arrangement is mounted on an aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories.

4. EXPERIMENTATION

i. AIM:

The experiment is conducted to:

a. Study the Performance Characteristics of the pump.

b. Draw Characteristics curves of the pump at different head.

c. Comparative analysis of the curves.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.
2. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.
3. Prime the pump.
4. Open the suction side valve and close the Discharge Valve.
5. Start the motor by pressing the green button switch on the panel.
6. Now, slowly set the speed of the pump using the drive and allow attaining steady flow of water.
7. Now slowly open to vary the discharge and note down the following:
    a. Vacuum gauge reading
    b. Delivery Pressure gauge reading.
    c. Time taken for 5 revolutions of energy meter disc
    d. Time taken for 10 cm rise in measuring tank
    e. Speed of the pump
8. Change the discharge using the discharge valve and repeat the above step.
9. Repeat the experiment for various speeds.

NOTE: Set the vacuum pressure initially such that the indicator reads 100mm of Hg. Also you can conduct the experiment by varying the suction valve and fully opening the discharge valve.

iii. OBSERVATIONS:

SL. No	**Delivery Pressure 'P' kg/cm²**	**Vacuum 'Pv'**	**Time taken for 10cm rise of water, t sec**	**Time taken for 5 rev of energy meter, T sec**	**Speed of the pump, N, rpm**
1	0.7	280	48.32	32.53	1380
2	0.5	350	49.02	33.31	1394
3	0.25	420	50.16	34.97	1405

CALCULATIONS:

1. TOTAL HEAD, H

$$H = \left(P + \frac{P_v}{760}\right) * 10\ m\ of\ Water$$

Where,

p = Delivery Pressure, kg/cm²

p_v = Vacuum Pressure, mm of Hg.

H_1 = (0.7 + (280/760))*10 = 10.68 m

H_2 = (0.5+ (350/760))*10 = 9.60 m

H_3 = (0.25+ (420/760))*10 = 8.02 m

2. DISCHARGE, Q

$$Q = \frac{A \, x \, R}{t \, x \, 100} \; m^3/s$$

Where,

A = Area of collecting tank = 0.09 m².

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

$$Q_1 = \frac{0.9*0.1}{48.32*100} = 1.86*10^{-4} \; m^3/sec$$

$$Q_2 = \frac{0.9*0.1}{49.02*100} = 1.83*10^{-4} \; m^3/sec$$

$$Q_3 = \frac{0.9*0.1}{50.16*100} = 1.79*10^{-4} \; m^3/sec$$

INPUT POWER, IP (Electrical)

$$IP = \frac{K \, x \, 3600 \, x \, \eta_T}{EMC \; x \, T} \; kW$$

Where,

η_m = transmission = 0.80

K = no of revolutions of energy meter

EMC = energy meter constant = 750rev/kW-hr

T = Time taken for 'K' revolutions of Energy meter

$$IP_1 = \frac{5*3600*0.80}{750*32.53} = 0.59 \text{ KW}$$

$$IP_2 = \frac{5*3600*0.80}{750*33.31} = 0.57 \text{ KW}$$

$$IP_3 = \frac{5*3600*0.80}{750*34.97} = 0.54 \text{ KW}$$

3. OUTPUT POWER, OP (Hydraulic)

$$OP = \frac{WQH}{1000} \; kW$$

Where,

W = 9810 N/m^3
Q = Discharge, m^3/sec
H = Total Head.

$$OP_1 = \frac{9810*1.86*10^{-4}*10.68}{1000} = 0.019 \text{ KW}$$

$$OP_2 = \frac{9810*1.83*10^{-4}*9.60}{1000} = 0.017 \text{ KW}$$

$$OP_3 = \frac{9810*1.79*10\text{-}4*8.02}{1000} = 0.014 \text{ KW}$$

4. **Efficiency of the pump, η%**

$$\eta\% = \frac{OP \ x \ 100}{IP}$$

η1 = $\frac{0.019*100}{0.57}$ = 2.98%

η2 = $\frac{0.017*100}{0.57}$ = 2.98%

η3 = $\frac{0.014*100}{0.54}$ = 2.59%

TABULAR COLUMN:

SL. No	Total Head 'H' m of water	Discharge. Q, m³/sec	Input power, IP, hp	Output Power, OP, hp	Efficiency	Speed of the pump, N, rpm
1	1.06	1.86	0.59	0.019	2.98	1380
2	0.96	1.79	0.57	0.017	2.98	1394
3	0.80	1.79	0.54	0.014	2.59	1405

Graphs

- Discharge Vs Head
- OP Vs Head
- Efficiency Vs Head

RESULTS:

Thus, the experiment is conducted on single – stage centrifugal pump test rig for various speeds, efficiencies has been determined for that speeds as show in below table, Performance Characteristics of the pump has been studied and Characteristics curves of the pump at different heads has been drawn and analyzed.

S.No	**Speed of the pump(rpm)**	**Efficiency of the pump(%)**
1	1380	2.98
2	1394	2.98
3	1405	2.59
Average Efficiency of the pump		2.85

5. PRECAUTIONS

- Don't start the pump if the voltage is less than 180 V.
- Don't forget to give Electrical neutral and earthing connections to the main plug.
- At least once in 3 months grease/oil the rotating parts.
- Initially put the clean water free from foreign material.
- Clean the tanks regularly, Say once in 15days.
- At least every week, operate the unit for five minutes to prevent clogging of moving parts

PERFORMANCE TEST ON MULTI- STAGE CENTRIFUGAL PUMP

1. INTRODUCTION

In general, a pump may be defined as mechanical device when connected in a pipe line, can convert the mechanical energy into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

Pumps are of major concern to most engineers and technicians. The types of pumps 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 are Centrifugal, reciprocating, axial flow (stage pumps), air jet, diaphragm and turbine pumps. Most of these pumps fall mainly into a class namely rotodynamic, reciprocating (positive displacement) and fluid operated pumps. In a Centrifugal pump, pressure head is developed by centrifugal action. The pump consists of an impeller, which rotates in a casing. Fluid enters through the eye of the pump and discharges radially outwards to the delivery pipe. Centrifugal Pumps also come based on the type of vanes: Backward curved blades, Radial Type and Forward Curved Type. Centrifugal pumps are commercially available as Single stage and Multi-stage pumps.

In this pump, the liquid is made to rotate in a closed chamber (volute casing), thus creating the centrifugal action, which gradually builds 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 (muddy), liquids can be directly coupled to high speed electric motors (without any speed reduction), 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. The present test rig allows the students to understand and draw the operating characteristics at various heads, flow rates and Stages.

2. DESCRIPTION OF APPARATUS

1. The pump is of **SUGUNA** make of 2hp capacity with the head of 72m and 32lpm delilvery.
2. The Motor coupled is of **KIRLOSKAR** make of same capacity of the motor and is coupled by Jaw coupling.
3. The above two are fitted on the Base frame.
4. Water from the sump tank is sucked by the pump and is delivered through the delivery pipe back from 3 lower stages to the collecting tank.
5. **Overflow** arrangement is provided to the collecting tank.
6. **Butterfly valve** is provided in the measuring tank for instant close and release.
7. The suction and delivery can be controlled by means of **control valves**.
8. **Piezometer** with Vinyl sticker scale (For better readability) is provided to measure the height of the water collected in the measuring tank.
9. The apparatus comes with a separate **NOVAPAN** board control panel with standard accessories such as **Digital RPM Indicator**, Energy meter, Delivery and Vacuum gauges.
10. The equipment has been designed for closed circuit operation.

11. The whole arrangement is mounted on an aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION

i. AIM:

The experiment is conducted to:

d. Study the Performance Characteristics of the pump.
e. Draw Characteristics curves of the pump at different head.
f. Comparative analysis of the curves.
g. To Study the Stage wise built in pressure of the pump.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.

2. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.

3. Prime the pump.

4. Close the discharge valve and start the motor by pressing the green button switch on the starter.

5. Now slowly open to vary the discharge and note down the following:

   a. Vacuum gauge reading
   b. Delivery Pressure gauge reading.
   c. Time taken for 10 revolutions of energy meter disc
   d. Time taken for 10 cm rise in measuring tank
   e. Speed of the pump

6. Change the discharge using the discharge valve and repeat the above step.

NOTE: Set the vacuum pressure initially such that the indicator reads 100mm of Hg. Also you can conduct the experiment by varying the suction valve and fully opening the discharge valve.

iii. OBSERVATIONS TABLE :

SL. No	Delivery Pressure 'P' kg/cm²	Vacuum 'Pv'	Time taken for 10cm rise of water, t sec	Time taken for 5 rev of energy meter, T sec	Speed of the pump, N, rpm
1	1	90	13.5	5.97	1419
2	2	80	14.35	5.84	1400
3	3	70	15.10	5.16	1390

iv. CALCULATIONS:

TOTAL HEAD, H

$$H = \left(P + \frac{P_v}{760}\right) * 10\ m\ of\ Water$$

Where,

p = Delivery Pressure, kg/cm²
p_v = vacuum pressure, kg/cm²

H_1 = (1+ (90/760))*10 = 111.84 m.

H_2 = (1+ (80/760))*10 =210.52 m

H_3 = (3+(70/760))*10 = 30.9 m

DISCHARGE, Q

$$Q = \frac{A\,x\,R}{t\,x\,100}\ m^3/s$$

Where,

A = Area of collecting tank = 0.16 m^2.

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

$$Q_1 = \frac{0.16*10}{13.6*100} = 1.79*10^{-3}\ m^3/sec$$

$$Q_2 = \frac{0.16*10}{14.35*100} = 1.11*10^{-3}\ m^3/sec$$

$$Q_3 = \frac{0.16*10}{15.10*100} = 1.059*10^{-3}\ m^3/sec$$

INPUT POWER, IP (Electrical)

$$IP = \frac{K\,x\,3600\,x\,\eta_T}{EMC\,\,x\,T}\ kW$$

Where,

η_m = transmission = 0.80 (0% assumed)

K = no of revolutions of energy meter

EMC = energy meter constant = 200rev/kW-hr

T = Time taken for 'K' revolutions of Energy meter

$$IP_1 = \frac{3*3600*0.8}{200*5.97} = 12.06\ KW$$

$$IP_2 = \frac{5*3600*0.8}{200*5.84} = 12.32KW$$

$IP_3 = \frac{5*3600*0.8}{200*5.16} = 13.9$ KW

OUTPUT POWER, OP (Hydraulic)

$$OP = \frac{WQH}{1000} kW$$

Where,

W = 9810 N/m^3
Q = Discharge, m^3/sec
H = Total Head.

$OP_1 = \frac{9810*1.17*10^{-3}*111.184}{1000} = 1.24$ KW

$OP_2 = \frac{9810*1.11*10^{-3}*201.52}{1000} = 2.3$ KW

$OP_3 = \frac{9810*1.05*10^{-3}*30.9}{1000} = 3.2$ KW

Efficiency of the pump, η%

$$\eta\% = \frac{OP \, x \, 100}{IP}$$

$\eta_1 = \frac{1.24}{12.06}*100 = 10.72\%$

$\eta_2 = \frac{2.3*100}{12.32} = 18.6\%$

$\eta_3 = \frac{3.2*100}{13.9} = 23.03\%$

v. TABULAR COLUMN:

SL. No	Total Head 'H' cm of water	Discharge. Q, m³/sec	Input power, IP, kw	Output Power, OP, kw	Efficiency	Speed of the pump, N, rpm
1	111.84	$1.79*10^{-3}$	12.06	1.24	10.72	1419
2	210.52	$1.11*10^{-3}$	12.32	2.3	18.6	1400
3	30.9	$1.059*10^{-3}$	13.9	3.2	23.03	1390

Graphs

- Discharge Vs Head
- OP Vs Head
- Efficiency Vs Head

vi. RESULTS:

Thus, the experiment is conducted on Multi – stage centrifugal pump test rig for various speeds, efficiencies has been determined for that speeds as show in below table, Performance Characteristics of the pump has been studied and Characteristics curves of the pump at different heads has been drawn and analyzed.

S.No	Speed of the pump(rpm)	Efficiency of the pump(%)
1	1419	10.72
2	1400	18.6
3	1390	23.03
Average Efficiency of the pump		17.45

4. PRECAUTIONS

- Don’t start the pump if the voltage is less than 380 V
- Don’t forget to give Electrical neutral and earthing connections to the main plug
- At least once in 3 months grease/oil the rotating parts
- Initially put the clean water free from foreign material, and change the water once in 3 months.
- At least every week, operate the unit for five minutes to prevent clogging of moving parts

Note: For any further clarifications on how to run the equipment or for up gradation, please contact us.

PERFORMANCE TEST ON RECIPROCATING PUMP

1. INTRODUCTION

In general, a pump may be defined as mechanical device when connected in a pipe line, can convert the mechanical energy into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

Pumps are of major concern to most engineers and technicians. The types of pumps 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 are Centrifugal, reciprocating, axial flow (stage pumps), air jet, diaphragm and turbine pumps. Most of these pumps fall mainly into a class namely rotodynamic, reciprocating (positive displacement) and fluid operated pumps.

Reciprocating pump is based purely on mechanical concepts, since the liquid is displaced by a piston (plunger) moving in a cylinder. They discharge a definite quantity of liquid irrespective of the head on the pump i.e., positive displacement. However, in a single acting pump, water is sucked into the cylinder in the suction stroke and delivered out of the cylinder in the delivery stroke that is the discharge only on alternate strokes, where as in double acting pump there is suction and delivery in each stroke that is the discharge is continuous.

2. DESCRIPTION OF APPARATUS

The Reciprocating Pump Test Rig comes with the following two versions along with the standard specifications:

a. DC Version.

This version has a Reciprocating pump coupled to a DC Motor with Thyrister control drive for desirable speed setting.

b. AC Version– YOUR EQUIPMENT.

This version has a Reciprocating pump coupled to an AC Motor with Stepped Cone Pulley arrangement for operating the pump at Three different speeds.

Standard Specifications:

1. The pump is of **SUGUNA** make with the head of 36m.
2. The PUMP is coupled to **CROMPTON GREAVES/UNIPRO/KIRLOSKAR** make motor of suitable capacity with **AC Drive** to conduct the experiment at different speeds
3. The above two are fitted on the Base frame.
4. Water from the sump tank is sucked by the pump and is delivered through the delivery pipe to the collecting tank.
5. **Overflow** arrangement is provided to the collecting tank.
6. **Valve** is provided in the measuring tank for instant close and release.
7. The suction and delivery can be controlled by means of **control valves**.
8. **Piezometer** with Vinyl sticker scale (For better readability) is provided to measure the height of the water collected in the measuring tank.

9. The apparatus comes with a separate **NOVAPAN** board control panel with standard accessories such as **Digital RPM Indicator**, Energy meter, Delivery and Vacuum gauges.
10. The equipment has been designed for closed circuit operation.
11. The whole arrangement is mounted on an aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION

i. AIM:

The experiment is conducted to:

a. Study the Performance Characteristics of the pump.
b. Draw Characteristics curves of the pump at different head.
c. Comparative analysis of the curves.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.

2. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.

3. Open the suction and Discharge Valves.

4. using the Motor and the AC Drive arrangement, fix for one of the speeds.

5. Start the motor by pressing the green button switch on the panel.

6. Now slowly open to vary the discharge and note down the following:

a. Vacuum gauge reading
b. Delivery Pressure gauge reading.
c. Time taken for 5 revolutions of energy meter disc
d. Time taken for 10 cm rise in measuring tank
e. Speed of the pump

7. Change the discharge using the discharge valve and repeat the above step.
8. Repeat the experiment for other speeds.

NOTE: Set the vacuum pressure initially such that the indicator reads 100mm of Hg. Also you can conduct the experiment by varying the suction valve and fully opening the discharge valve.

iii. OBSERVATIONS TABLE:

SL. No	Delivery Pressure 'P' kg/cm²	Vacuum 'P_v'	Time taken for 10cm rise of water, t sec	Time taken for 5 rev of energy meter, T sec	Speed of the pump, N, rpm
1	2	35	30.53	44.41	181
2	1.5	40	29.19	52.25	188
3	1	45	27.94	62.66	193

iv. CALCULATIONS:

TOTAL HEAD, H

$$H = \left(P + \frac{P_v}{760}\right) * 10\ m\ of\ Water$$

Where,

P = Delivery Pressure, kg/cm^2
Pv = Vacuum Pressure, mm of Hg.

H1= (2+(35/700))*10 =20.46 cm

H2=(1.5+(40/700))*10=15.52 cm

H3=(1+(15/700))*10=10.59 cm

DISCHARGE, Q

$$Q = \frac{A\,x\,R}{t\,x\,100}\ m^3/s$$

Where,

A = Area of collecting tank = 0.09 m².

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

$$Q1 = \frac{0.09*10}{30.53*100} = 2.94*10^{-4}\ m^3/sec$$

$$Q2 = \frac{0.09*10}{29.19*100} = 3.08*10^{-4}\ m^3/sec$$

$$Q3 = \frac{0.09*10}{27.94*100} = 3.22*10^{-4}\ m^3/sec$$

INPUT POWER, IP (Electrical)

$$IP = \frac{K \; x \; 3600 \; x \; \eta_T}{EMC \; x \; T} \; kW$$

Where,

η_m	=	transmission = 0.80
K	=	no of revolutions of energy meter
EMC	=	energy meter constant = 750rev/kW-hr
T	=	Time taken for 'K' revolutions of Energy meter

$$IP\,1 = \frac{5*3600*0.8}{750*44.44} = 0.43 \text{ kw}$$

$$IP2 = \frac{5*3600*0.80}{750*52.25} = 0.36 \text{ kw}$$

$$IP3 = \frac{5*3600*0.80}{750*62.66} = 0.30 \text{ kw}$$

OUTPUT POWER, OP (Hydraulic)

$$OP = \frac{WQH}{1000} \; kW$$

Where,

W	=	9810 N/m^3
Q	=	Discharge, m^3/sec
H	=	Total Head.

$$OP_1 = \frac{9810*2.94*10^{-4}*20.41}{1000} = 0.059 \text{ KW}$$

$$OP_2 = \frac{9810*3.08*10^{-4}*15.52}{1000} = 0.046\ KW$$

$$OP_3 = \frac{9810*3.22*10-4*10.59}{1000} = 0.033\ KW$$

Efficiency of the pump, η%

$$\eta\% = \frac{OP\ x\ 100}{IP}$$

$$\eta_1 = \frac{0.059*100}{0.43} = 13.72$$

$$\eta_2 = \frac{0.046*100}{0.43} = 12.77$$

$$\eta_3 = \frac{0.033*100}{0.30} = 11$$

vii. Graphs

- Discharge Vs Head
- OP Vs Head
- Efficiency Vs Head

v. RESULTS:

Thus, the experiment is conducted on reciprocating pump test rig for various speeds, efficiencies has been determined for that speeds as show in below table, Performance Characteristics of the pump has been studied and Characteristics curves of the pump at different heads has been drawn and analyzed.

S.No	**Speed of the pump(rpm)**	**Efficiency of the pump(%)**
1	181	13.72
2	188	12.77
3	193	11
Average Efficiency of the pump		12.49

4. PRECAUTIONS

- Don’t start the pump if the voltage is less than 180 V.
- Don’t forget to give Electrical neutral and earthing connections to the main plug.
- At least once in 3 months grease/oil the rotating parts.
- Initially put the clean water free from foreign material.
- Clean the tanks regularly, Say once in 15days.
- At least every week, operate the unit for five minutes to prevent clogging of moving parts

CALIBRATION OF VENTURIMETER

1. INTRODUCTION

A *Venturi Meter* is a device that is used for measuring the rate of flow of fluid through a pipeline. 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 & the measurement of the pressure difference enables the determination of the discharge through the pipe.

A Venturi Meter consists of,

1. An inlet section followed by a convergent cone,
2. A cylindrical throat,
3. A gradually divergent cone.

The inlet section of the Venturi Meter is of the same diameter as that of the pipe, which is followed by a convergent one. 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 side tube having its cross – sectional area smaller than that of the pipe. The divergent cone of the Venturi Meter is a gradually diverging pipe with its cross – sectional area increasing from that of the throat to the original size of the pipe. At the inlet and the throat, of the Venturi Meter, pressure taps are provided through pressure rings.

A Nozzle is a device used for increasing the velocity of a steadily flowing stream of fluid. The fluid enters the nozzle at low velocity and high pressure. As the fluid flows through the nozzle, it expands to a lower pressure. With the fall in pressure, velocity increases from the entrance to the exit of the nozzle.

2. DESCRIPTION OF THE APPARATUS:

- The apparatus consists of an **Orifice meter** and a **Venturi meter** made of **clear ACRYLIC** fitted to specially made separate pipelines which are interchangeable.

- The apparatus is also fitted with FLOWNOZZLE, ROTAMETER and WATERMETER for Callibration purpose.

- **Tappings** with **Ball Valves** are provided at appropriate positions which is connected to a **Manometer***.

*In case of Digital indications Manometer will not be provided.

- **ACRYLIC Piezometer** is provided to measure the height of the water collected in the **measuring tank**.

- **Mercury filled Manometer** made of Acrylic is provided to measure the pressure difference.

- **Valve** is provided in the measuring tank for instant close and release.

- **Overflow arrangement** is also provided to the tanks.

- A **supply pump (Kirloskar/Sharp make)** with starter is provided for supplying the water and a supply tank is provided to store the water.

- **Vinyl sticker scale** is provided for both Manometer and Piezometer for better readability.

- The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION:

i. AIM:

The experiment is conducted to

- Calibration of Venturimeter at different flow rate.
- Determination of Co-efficient of Discharge for Venturimeter.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.
2. Keep the delivery valve closed and manometer valve at open position.
3. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.
4. Switch on the pump & open the delivery valve.
5. Open the corresponding Ball valve of the pipeline in test.
6. Adjust the flow through the control valve of the pump.
7. Open the corresponding Ball valves fitted to meter tappings.
8. Note down the differential head reading in the Manometer. (Expel if any air is the by opening the drain cocks provided with the Manometer.)
9. 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.
10. Change the flow rate and repeat the experiment.

iii. OBSERVATIONS:

Sl. No	TYPE	MANOMETER READING ‘m’ H	Time for ‘R’ cm rise in water ‘T’ sec
1	Venturi Meter	0.212	67.69
2		0.245	33.41
3		0.420	21.41

iv. CALCULATIONS:

- **Pressure Head, H**

H = H x 13.6 m of water

Where, 13.6 = conversion factor from mercury to water head

H1= (0.212) ×12.6=2.6712 m

H2= (0.245) ×12.6=3.087 m

H3 = $(0.420) \times 12.6 = 5.292$ m

- **Theoretical discharge, QT**

$$Q_{TH} = \frac{Cd * A1 * A2 * \sqrt{2gH}}{\left(\sqrt{A1^2 - A2^2}\right)} \ m^3/s$$

Where,

A1	=	cross sectional area of pipe, m^2
A2	=	cross sectional area of throat, m^2
g	=	Acceleration due to gravity = 9.81 m/s^2
H	=	Total head(Digital Reading)
d1	=	diameter at the inlet
	=	0.025 for Venturimeter & Orifice meter
	=	0.020 for Nozzle
d2	=	throat/orifice
	=	0.0125 for Venturimeter & Orificemeter
	=	0.010 for Nozzle

$$Q=\frac{4.908\times10^{-4}\times1.227\times10^{-4}\times\sqrt{2\times9.81\times0.212}}{\sqrt{(4.908\times10^{-4})^2-(1.227\times10^{-4})^2}} = 2.584\times10^{-4}\ m^3/s$$

$$Q=\frac{4.908\times10-4\ \times1.227\times10-4\times\sqrt{2\times9.81\times0.245}}{\sqrt{(4.908\times10^{-4})^2-(1.227\times10^{-4})^2}}=2.778\times10^{-4}\ m^3/s$$

$$Q=\frac{4.908\times10-4\ \times1.227\times10-4\times\sqrt{2\times9.81\times0.420}}{\sqrt{(4.908\times10^{-4})^2-(1.227\times10^{-4})^2}}=3.687\times10^{-4}\ m^3/s$$

- **Actual Discharge, QA**

$$Q_A = \frac{A\ x\ R}{t\ x\ 100}\ m^3/s$$

Where, A = Area of collecting tank = 0.1 m^2.

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

$$Q_a = \frac{0.1\times10}{67.69\times100} = 1.4774\times10^{-4}\ m^3/s$$

$$Q_a = \frac{0.1\times10}{33.41\times100} = 2.993\times10^{-4}\ m^3/s$$

$$Q_a = \frac{0.1\times10}{21.41\times100} = 4.670\times10^{-4}\ m^3/s$$

- **Co – efficient of discharge, C_d**

$$C_d = \frac{Q_A}{Q_{TH}}$$

$C_d = \frac{1.477\times10^{-4}}{2.584\times10^{-4}}$

$C_d = \frac{2.993\times10^{-4}}{2.778\times10^{-4}}$

$= 1.0773$

$C_d = \frac{4.670\times10^{-4}}{3.637\times10^{-4}}$

$= 1.2840$

v. TABULAR COLUMNS AND GRAPHS:

A. For Venturimeter:

Loss of Head H (m)	Actual Discharge Q_A m³/sec	Theoretical Discharge Q_{TH} m³/sec	Coefficient Of Discharge 'C_d'	Average 'C_d'
2.8832	1.477×10^{-4}	2.584×10^{-4}	0.5714	0.9775
3.332	2.993×10^{-4}	2.778×10^{-4}	1.0773	
5.712	4.670×10^{-4}	3.637×10^{-4}	1.2840	

vi. RESULTS:

Thus the experiment is conducted on Venturimeter following results are determined and Graphs are plotted.

a. Actual Discharge, QA $=3.046\times10^{-4}$ m³/s

b. Theoretical Discharge, QT $= 2.999\times10^{-4}$ m³/s

c. Co – efficient of Discharge, Cd= 0.9775

4. PRECAUTIONS

- Do not run the pump dry.
- Clean the tanks regularly, say for every 15days.
- Do not run the equipment if the voltage is below 180V.
- Check all the electrical connections before running.
- Before starting and after finishing the experiment the main control valve should be in close position.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

CALIBRATION OF ORIFICEMETER

1. INTRODUCTION

An *ORIFICE METER* is a simple device used for measuring the discharge through pipes.

The basic principle on which an Orifice meter works is that 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 measure 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 with Venturi Meter. As such where the space is limited, the Orifice meter may be used for the measurement of discharge through pipes.

A Nozzle is a device used for increasing the velocity of a steadily flowing stream of fluid. The fluid enters the nozzle at low velocity and high pressure. As the fluid flows through the nozzle, it expands to a lower pressure. With the fall in pressure, velocity increases from the entrance to the exit of the nozzle.

2. DESCRIPTION OF THE APPARATUS:

- The apparatus consists of an **Orifice meter** and a **Venturi meter** made of **clear ACRYLIC** fitted to specially made separate pipelines which are interchangeable.

- The apparatus is also fitted with FLOWNOZZLE, ROTAMETER and WATERMETER for Calibration purpose.

- **Tappings** with **Ball Valves** are provided at appropriate positions which is connected to a **Manometer***.

*In case of Digital indications Manometer will not be provided.

- **ACRYLIC Piezometer** is provided to measure the height of the water collected in the **measuring tank**.

- **Mercury filled Manometer** made of Acrylic is provided to measure the pressure difference.

- **Valve** is provided in the measuring tank for instant close and release.

- **Overflow arrangement** is also provided to the tanks.

- A **supply pump (Kirloskar/Sharp make)** with starter is provided for supplying the water and a supply tank is provided to store the water.

- **Vinyl sticker scale** is provided for both Manometer and Piezometer for better readability.

- The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION:

i. AIM:

The experiment is conducted to

- Calibration of Orificemeter at different flow rate.
- Determination of Co-efficient of Discharge for orifice meter.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.

2. Keep the delivery valve closed and manometer valve at open position.

3. Connect the power cable to 1Ph, 220V, 10 Amps with earth Connection.

4. Switch on the pump & open the delivery valve.

5. Open the corresponding Ball valve of the pipeline in test.

6. Adjust the flow through the control valve of the pump.

7. Open the corresponding Ball valves fitted to meter tapings.

8. Note down the differential head reading in the Manometer. (Expel if any Air is the by opening the drain cocks provided with the Manometer.)

9. 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.

10. Change the flow rate and repeat the experiment.

iii. **OBSERVATIONS**:

Sl. No	TYPE	MANOMETER READING 'm' H	Time for 'R' cm rise in water 'T' sec
1	ORIFICE METER	0.362	63.66
2		0.711	29.97
3		1.388	19.87

CALCULATIONS:

a. Pressure Head, H

H = H x 13.6 m of water

Where, 13.6 = conversion factor from mercury to water head

- **Theoretical discharge, QT**

$$Q_{TH} = \frac{Cd * A1 * A2 * \sqrt{2gH}}{\left(\sqrt{A1^2 - A2^2}\right)} \; m^3/s$$

Where, A1 = cross sectional area of pipe, m^2

A2 = cross sectional area of throat, m^2

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

H = Total head(Digital Reading)

d1 = diameter at the inlet

= 0.025 for Venturimeter & Orifice meter

= 0.020 for Nozzle

d2 = throat/orifice

= 0.0125 for Venturimeter & Orificemeter

= 0.010 for Nozzle

$$Q_{TH} = \frac{Cd * A1 * A2 * \sqrt{2gH}}{\left(\sqrt{A1^2 - A2^2}\right)}\ m^3/s$$

$$Q_{TH} = \frac{4.90 \times 10^{-4}\sqrt{2 \times 9.81 \times 4.9232}}{\left(\sqrt{(4.90 \times 10^{-4})^2 - (1.22 \times 10^{-4})^2}\right)}\ m^3/s$$

$=1.24\times10^{-3}\ m^3/s$

$$Q_{TH} = \frac{4.90 \times 10^{-4} \times 1.22 \times 10^{-4}\sqrt{2 \times 9.81 \times 9.6696}}{\left(\sqrt{(4.90 \times 10^{-4})^2 - (1.22 \times 10^{-4})^2}\right)}\ m^3/s$$

$=1.73\times10^{-3}\ m^3/s$

$$Q_{TH} = \frac{4.90 \times 10^{-4} \times 1.22 \times 10^{-4}\sqrt{2 \times 9.81 \times 18.8996}}{\left(\sqrt{(4.90 \times 10^{-4})^2 - (1.22 \times 10^{-4})^2}\right)}\ m^3/s$$

$=2.4\times10^{-3}\ m^3/S$

- **Actual Discharge, QA**

$$Q_A = \frac{A\ x\ R}{t\ x\ 100}\ m^3/s$$

Where,A = Area of collecting tank = m².

R = Rise in water level of the collecting tank, cm.

t = time for ‘R’ cm rise of water, sec

100 = Conversion from cm to m.

$Q_{a1} = \frac{0.1\times10}{63.66\times100} = 1.57\times10^{-4} m^3/s$

$Q_{a1} = \frac{0.1\times10}{29.97\times100} = 3.33\times10^{-4} m^3/s$

$Q_{a1} = \frac{0.1\times10}{19.87\times100} = 5.08\times10^{-4} m^3/s$

Co – efficient of discharge, Cd:

$$C_d = \frac{Q_A}{Q_{TH}}$$

$$C_d = \frac{1.57\times10^{-4}}{1.24\times10^{-3}} = 0.12$$

$$C_d = \frac{3.33\times10^{-4}}{1.24\times10^{-3}} = 0.12$$

$$C_d = \frac{5.03\times10^{-4}}{2.14\times10^{-3}} = 0.21$$

iv. TABULAR COLUMNS AND GRAPHS

A. For Orificemeter:

Loss of Head H (m)	Actual Discharge Q_A m³/sec	Theoretical Discharge Q_{TH} m³/sec	Coefficient of Discharge 'CD'	Average 'CD'
4.9232	1.57×10^{-4}	1.24×10^{-3}	0.12	0.17
9.6696	3.33×10^{-4}	1.73×10^{-3}	0.19	
18.8496	5.03×10^{-4}	2.41×10^{-3}	0.21	

v. RESULTS:

Thus the experiment is conducted on Orificemeter following results are determined and Graphs are plotted.

a. Actual Discharge, QA = 3.31×10^{-4} m³/s
b. Theoretical Discharge, QT = 1.79×10^{-3} m³/s
c. Co – efficient of Discharge, Cd= 0.17

4. PRECAUTIONS

- Do not run the pump dry.
- Clean the tanks regularly, say for every 15days.
- Do not run the equipment if the voltage is below 180V.
- Check all the electrical connections before running.
- Before starting and after finishing the experiment the main control valve should be in close position.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

MAJOR AND MINOR LOSSES
(DETERMINATION OF FRICTION FACTOR AND HEAD LOSSES FOR A GIVEN PIPELINES)

1. INTRODUCTION

A pipe may be of various diameters and may have bends, valves, etc. When a liquid is flowing through such pipes, the velocity of the liquid layer adjacent to the pipe wall is zero. The velocity of the liquid goes on increasing from the wall and hence shear stresses are produced in the liquid due to viscosity. This viscous action causes loss of energy, which is usually known as Frictional loss.

Here, we are going to consider two important losses that occur during flow,

1. Major Losses.
2. Minor Losses.

Major losses occur due to friction. This friction may be due to viscosity or roughness in the pipe.

Minor losses can be due to various reasons such as Inlet and Outlet of the pipe, bends, gates, sudden expansions and contractions.

The apparatus is designed to study the friction losses that appear in long pipes and the obstructions that are encountered in the way of flow by various types of fittings.

2. DESCRIPTION OF THE APPARATUS:

1. The apparatus has 4 different **specially made pipelines** comprising of
   a. **1" G.I**
   b. **1/2" G.I**
   c. **1" PVC**
   b. **1"G.I** pipe with Reducing Collar, Enlarging collar, Union and Collar
   d. **1"G.I** pipe with 90° BENDS
2. All these are mounted on **interchangeable** lines for operation with necessary **Pressure tappings** at appropriate positions and **Ball valves** which is connected to a Manometer.
3. A measuring tank is provided to measure the flow rate.
4. **Piezometer** is provided to measure the height of the water Collected in the measuring tank.
5. **Mercury filled Manometer** made of **Acrylic** is provided to Measure the pressure difference.
6. **Ball valve** is provided in the measuring tank for instant Close and release.
7. **Overflow arrangement** is also provided to the tanks.
8. A **supply pump (Kirloskar/Sharp make)** with starter is provided for supplying the water.
9. A **supply tank** is provided to store the water.
10. **Vinyl sticker scale** is provided for both **Manometer** and **Piezometer** for better readability.
11. The whole arrangement is mounted on an **Aesthetically designed sturdy frame** made of **MS angle** with all the provisions for holding the tanks and accessories.

3. **EXPERIMENTATION:**

i. **AIM:**

The experiment is conducted to determine:

1. Determination of Pressure drop across different pipes.
2. Comparative analysis of different type of pipes.
3. Friction factor for different pipe fittings.
4. Comparative analysis of friction factor through different pipe fittings.

ii. **PROCEDURE:**

a. Fill in the sump tank with clean water.

b. Keep the delivery valve closed and manometer valve at open position.

c. Check and give necessary electrical connections to the system.

d. Switch on the pump & open the delivery valve.

e. Open the corresponding Ball valve of the pipeline.

f. Adjust the flow through the control valve of the pump.

g. Open the corresponding Ball valves of the Pipeline/Fitting in study.(Make sure that all valves of other fittings to be in closed position)

h. Note down the differential head reading in the Manometer. (Expel if any air is the by opening the drain cocks provided with the Manometer.)

i. Operate the Ball valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.

j. Change the flow rate and repeat the experiment.

NOTE: For digital Indication manometer will not be provided.

iii. OBSERVATIONS

Sl. No	TYPE OF PIPE / FITTINGS	MANOMETER READING, m H	Time for 'R' cm rise in water 'T' sec
1.	1'' GI PIPE	0.205	44.22
2.	1/2'' GI PIPE	0.184	45.59
3.	SUDDEN CONTRACTION	0.528	47.57
4.	SUDDEN EXPANSION	0.216	45.63
5.	LONG BEND	0.181	45.87
6.	90° BEND	0.234	47.06

iv. CALCULATIONS:

1. TOTAL HEAD, H

$$H = H \times 13.6 \text{ m of water}$$

Where,

13.6 = conversion factor from mercury to water head

$H1=0.205\times13.6=2.788$

$H2=0.184\times13.6=2.502$

$H3=0.528\times13.6=7.180$

$H4=0.216\times13.6=2.937$

$H5=0.181\times13.6=2.462$

$H6=0.234\times13.6=3.182$

2. **DISCHARGE, Q**

$$Q = \frac{A\ x\ R}{t\ x\ 100}\ m^3/s$$

Where,

A = Area of collecting tank = 0.125 m^2.

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

Q1=$\frac{0.125\times10}{44.22\times100}$ = 2.82×10^{-4}

Q2=$\frac{0.125\times10}{45.5\times100}$ = 2.74×10^{-4}

Q3=$\frac{0.125\times10}{47.57\times100}$ = 2.63×10^{-4}

Q4=$\frac{0.125\times10}{45.63\times100}$ = 2.73×10^{-4}

Q5=$\frac{0.125\times10}{45.87\times100}$ = 2.72×10^{-4}

Q6=$\frac{0.125\times10}{47.06\times100}$ = $2.66\times10^{-}$

.

3. **VELOCITY, V**

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

Where, $A' = \frac{\pi \ x \ D^2}{4}$

A' = area of the pipe/fitting in use=

V1 = $\frac{2.82\times10^{-4}}{\frac{\pi \ x \ 0.025^2}{4}}$ =0.57 m/s

V2 = $\frac{2.74\times10^{-4}}{\frac{\pi \ x \ 0.025^2}{4}}$ =0.56 m/s

V3 = $\frac{2.68\times10^{-4}}{\frac{\pi \ x \ 0.025^2}{4}}$ =2.14 m/s

V4 = $\frac{2.73\times10^{-4}}{\frac{\pi \ x \ 0.0125^2}{4}}$ =2.14 m/s

V5 = $\frac{2.72\times10^{-4}}{\frac{\pi \ x \ 0.025^2}{4}}$ =0.56 m/s

V6 = $\frac{2.66\times10^{-4}}{\frac{\pi \ x \ 0.025^2}{4}}$ =0.54 m/s

4. **FRICTION FACTOR,(MAJOR LOSSES) F:**

$$F = \frac{2gH}{4LV^2}$$

Where,

H = total head, m of water

V = velocity, m

g = acceleration due to gravity, 9.81m/s²

L = Distance b/w tapping = 1.5m

$$F1 = \frac{2\times9.81\times2.788\times0.025}{4\times1.5\times0.57}$$

$=0.70$

$$F2 = \frac{2\times9.81\times2.52\times0.025}{4\times1.5\times0.56}$$

$=0.65$

5. **HEAD LOSS DUE TO FITTINGS, (MINOR LOSSES) K**:

$$K = \frac{2gH}{V^2}$$

Where,

H = total head, m of water

V = velocity, m

g = acceleration due to gravity, $9.81 m/s^2$

$$K1=\frac{2\times9.81\times7.186\times0.025}{2.14^2} =0.76$$

$$K2=\frac{2\times9.81\times2.937\times0.025}{0.56^2} = 4.59$$

$$K3=\frac{2\times9.81\times2.462\times0.025}{0.55^2} =3.98$$

$$K4=\frac{2\times9.81\times3.18\times0.025}{0.54^2} =5.35$$

v. RESULTS:

a) Friction factor for 1'' GI PIPE is 0.70
b) Friction factor for 1/2'' GI PIPE is 0.65
c) Head loss for SUDDEN CONTRACTION is 0.76
d) Head loss for SUDDEN EXPANSION is 4.59
e) Head loss for LONG BEND is 3.98
f) Head loss for 90° BEND is 5.35

4. PRECAUTIONS

- Do not run the pump dry.
- Clean the tanks regularly, say for every 15days.
- Do not run the equipment if the voltage is below 180V.
- Check all the electrical connections before running.
- Before starting and after finishing the experiment the main control valve should be in close position.
- Do not attempt to alter the equipment as this may cause damage to the whole system

VERIFICATION OF BERNOULLI'S THEOREM

1. INTRODUCTION

Bernoulli's Theorem gives the relationship between pressure head, velocity head and the datum. Here the attempt has been made to study the relationship of the above said parameters using venturimeter.

2. DESCRIPTION OF THE APPARATUS:

1. The apparatus consists of a specially fabricated clear **ACRYLIC Venturimeter** with necessary tappings connected to a **Multibank Piezometer** also made of clear **ACRYLIC**.
2. The apparatus consists of two overhead tanks interconnected with the venturimeter, which is placed in between the tanks.
3. The overhead tanks are provided with the Head variation mechanism for conducting the experiments at various heads.
4. Water in the sump tank is pumped using a **Monobloc Centrifugal pump** (Kirloskar make) which passes through the control valve to the overhead tank.
5. The height of the water in the **collecting tank** is measured using the **acrylic Piezometer** to find the flowrate.
6. The whole arrangement is mounted on an **aesthetically** designed **sturdy frame** made of MS tubes and **NOVAPAN Board** with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION:

i. AIM:

The experiment is conducted to

1. Study of Pressure Gradient at different zones.
2. Verification of Bernoulli's Equation.
3. Comparative analysis under different flow rates.

ii. PROCEDURE:

1. Fill in the sump tank with clean water.

2. Keep the delivery valve closed.

3. Check and give necessary electrical connections to the system.

4. Switch on the pump & Slowly open the delivery valve.

5. Adjust the flow through the control valve of the pump.

6. Allow the system to attain the steady state. i.e., let the water pass from the second overhead tank to the collecting tank.

7. Note down the Pressure head at different points of the venture meter on the multi-tube piezometer. (Expel if any air is the by inserting the thin pin into the piezometer openings)

8. Close the ball valve of the collecting tank and measure the time for the known rise of water.

9. Change the flow rate and repeat the experiment.

iii. OBSERVATIONS:

Sl. No	Static Head Loss, h										Time for 'R' cm rise in water 'T' sec
	1	2	3	4	5	6	7	8	9	10	
1	36.8	36.8	36.5	35.7	34.5	35.4	35.7	35.7	35.8	35.9	30.75
2	36.4	36.4	36.2	35.7	35.3	35.4	35.5	35.7	35.7	35.7	39.12

iv. CALCULATIONS:

a. Discharge, QA

$$Q = \frac{A\,x\,R}{t\,x\,100}\ m^3/s$$

Where,

A = Area of collecting tank = 0.045 m^2.

R = Rise in water level of the collecting tank, cm.

t = time for 'R' cm rise of water, sec

100 = Conversion from cm to m.

b. Pressure Head,

$$Pressure\ Head = \frac{P}{\rho\,x\,g} = h \quad m\ of\ water$$

Where,

ρ = density of water.

g = gravitational constant

h = head measured, m of water column

c. Velocity Head,

$$Velocity\,Head = \frac{V^2}{2g} \quad m\,of\,water$$

Where,

V = **Q / a**

Where, a = Area at the particular section* of the venturimeter m².

***See annexure for area at different sections of venturimeter.**

Tabular Column for section 1:

S.No	Area(A) m^2	Discharge(Q) (m^3/s)	Velocity(Q/A) (m/s)	Velocity Head($V^2/2g$)
1	491			1.30×10^{-7}
2	357			2.46×10^{-7}
3	245			5.21×10^{-6}
4	153			1.35×10^{-6}
5	123			2.08×10^{-6}
6	153			1.35×10^{-6}
7	202			7.75×10^{-7}
8	279			4.05×10^{-7}
9	369			2.42×10^{-7}
10	471			1.42×10^{-7}

Tabular Column for section 2:

S.No	Area(A) m^2	Discharge(Q) (m^3/s)	Velocity(Q/A) (m/s)	Velocity Head($V^2/2g$)
1	491			
2	357			1.56×10^{-7}
3	245			3.18×10^{-7}
4	153			8.31×10^{-7}
5	1232			1.32×10^{-6}
6	153			8.52×10^{-7}
7	202			4.89×10^{-7}
8	279			2.98×10^{-7}
9	369			1.45×10^{-7}
10	471			9.01×10^{-8}

d. Verification of BERNOULLI'S EQUATION

Bernoulli's Equation is given as:

$$\frac{p}{\rho g} + \frac{V^2}{2g} + z = 0$$

After finding,

a. Pressure Head, h

b. Velocity head,

at different cross-section of the Venturimeter.

Put the same in the above equation for different points and verify whether all the values obtained are same.

NOTE: Consider the datum, z to be constant.

S.No	Total head at section 1	Total head at section 2
1	36.80	36.40
2	36.80	36.40
3	36.50	36.20
4	35.70	35.70
5	34.7	35.30
6	34.5	35.40
7	35.4	35.5
8	35.7	35.7
9	35.8	35.7
10	35.9	35.7

v. RESULTS:

Hence At any flow rate the total head is constant (i.e. total head =pressure head + kinetic head+ datum head), Hence Bernoulli's theorem is verified.

4. PRECAUTIONS

- Do not run the pump dry.
- Clean the tanks regularly, say for every 15days.
- Do not run the equipment if the voltage is below 180V.
- Check all the electrical connections before running.
- Before starting and after finishing the experiment the main
- Control valve should be in close position.
- Do not attempt to alter the equipment as this may cause Damage to the whole system.

ANNEXURE

AREA AT DIFFERENT CROSS-SECTION OF VENTURIMETER:

Cross – section from the inlet	Area, mm^2
1	491
2	357
3	245
4	153
5	123
6	153
7	202
8	279
9	369
10	471