DR MAHALINGAM MCET

COLLEGE OF ENGINEERING AND TECHNOLOGY

Enlightening Technical Minds

Dr. MAHALINGAM COLLEGE OF ENGINEERING AND TECHNOLOGY POLLACHI – 3

HYDRAULIC ENGINEERING - LABORATORY MANUAL -

NAME : ______________________________

ROLL NO. : ______________________________

REG. NO. : ______________________________

CLASS : ______________________________

PREFACE

This laboratory manual is prepared by the department of civil engineering, MCET for Hydraulic Engineering Laboratory. The purpose of this manual is to serve as an instruction book to the students, lab assistants and instructors to assist in performing and understanding the experiments. Currently, only the experiments as per the syllabus of Anna University, Coimbatore, are considered. In this revised version of the manual, experimental setup and procedure given for the experiments will match with the facilities available in the fluid mechanics laboratory. Additionally, model graphs are also given for each experiment.

This manual is divided into two sections each containing 6 experiments. The experiments are divided such a way to utilize the experimental facilities effectively in two cycles. This manual will be made available in the department pages of the college intranet in near future.

ACKNOWLEDGEMENT

This manual is prepared during odd semester, 2008-2009 by Dr. G. Jaisankar, Associate Professor and Mr. K. Balakrishnan, Lecturer under the guidance of Dr. R. Palaniswamy, HoD/CIVIL.

INSTRUCTIONS

Audience : Undergraduate Civil Engineering Students, MCET

Introduction

This laboratory manual is intended to guide you through several experiments in the hydraulic engineering. Because of the nature of the course and laboratory facilities, you may be required to perform some experiments not yet covered in the classroom. This requires an extra effort on your part to read the relevant sections of the textbook, as well as the lab manual, before you come to the lab. Being prepared will assist you in understanding the experimental work and allow you to finish in the allotted time.

The lab report is considered to be an engineering technical report. As such, you will be evaluated on your ability to correctly complete the experiment and analysis, as well as your ability to clearly communicate your methodology, results, and ideas to others. All charts, plots and drawings should be original (e.g. created by you, based on your experimental data).

Safety

Safety is our prime concern at all times and you will be asked to leave the lab if your conduct is deemed to compromise safety regulations. Do not perform unauthorized experiments by yourself. Never leave unattended an experiment that is in progress. Because of the nature of hydraulics, there is always a danger dealing with high pressures. There must be no fooling around in the lab. The students are strictly advised to wear shoes when they come to the laboratory as a measure of safety.

Books and Manuals

The primary text for this course is this manual.

Groups

The laboratory observation to be done by the team (group) of three and report writing should be done by an individual student. Team work is also an important aspect of this course and it will enhance your performance.

Lab cycle

The students must come prepared for their lab sessions with experiments in the given sequence.

Preparation for the laboratory session

Student will be allowed into the lab class only after submission of completed records of the previous experiment(s), if any. Before coming to the laboratory, students must have read carefully and understand the description of the experiment in the lab manual. You may go to the lab at an earlier date, with the permission of the instructor, to look at the experimental facility and understand it better. At the beginning of the class, if the instructor finds that a student is not adequately prepared, they will be given lower/zero marks for that experiment.

Laboratory Practice: Precautions To Be Observed In The Laboratory

Carelessness in personal conduct or in handling equipment may result in serious injury to the individual or the equipment. Do not run near moving machinery. Always be on the alert for strange sounds and find the cause of them. Adhere to lab dress code of the college and guard against entangling clothes in moving parts of machinery. Confine long hair and loose clothing when in the laboratory. No piece of equipment should be started or stopped except under the direct supervision of the instructors or upon specific instructions from them. Do not open or close any valve, switch, etc. without first learning its function and trying to determine what will happen when the operation is completed.

In particular observe the following:

1. Open and close all valves slowly.
2. While a piece of equipment is "warming up", see that proper lubrication is obtained, and that all gauges are reading normally.
3. Apply and remove loads slowly and uniformly.
4. Leave instruments and equipment in a clean and orderly condition upon completion of the experiment.

Every experiment should be completed, verified and evaluated in the same lab session.

Laboratory reports

You will submit a report for each experiment that you perform. All reports will be graded on the technical content as well as the writing and presentation. The deadline for submitting will be informed by the instructor. These deadlines are not changeable.

The principal goals of laboratory reports are to tell someone else (usually a teacher):

1. what you did in the lab.
2. why you did it.
3. what you thought would happen.
4. what really happened.
5. why you got the results you obtained.

All students are expected to produce their own work. Copying is not allowed and reference must be clearly stated at the end of report. If you use this manual as reference, convert the sentences into your own 'third person, past tense, passive voice' sentences and ensure the same. **ZERO** marks might be given if cases of plagiarism are found. Some of the experimental data observed as team are exception and the same can be used by all in that team. Use SI units throughout your report.

After the laboratory session

1. Clean up your work area.
2. Make sure you understand what kind of report is to be prepared and when it is due.
3. Check with the instructor or technician before you leave.

No Make-ups

Students must participate in all laboratory exercises as scheduled. We have absolutely no flexibility in our lab schedule. No repetition class will be given for forgone sessions.

Internal assessment Marks

Internal assessment will be performed as per the rules of the University.

SYLLABUS

HYDRAULIC ENGINEERING LAB 0 0 3 100

OBJECTIVE

Student should be able to verify the principles studied in theory by conducting the experiments.

LIST OF EXPERIMENTS

1. Determination of co-efficient of discharge for orifice
2. Determination of co-efficient of discharge for notches
3. Determination of co-efficient of discharge for venturimeter
4. Determination of co-efficient of discharge for orifice meter
5. Study of impact of jet on flat plate (normal / inclined)
6. Study of friction losses in pipes
7. Study of minor losses in pipes
8. Study on performance characteristics of Pelton turbine.
9. Study on performance characteristics of Francis turbine
10. Study on performance characteristics of Kaplan turbine
11. Study on performance characteristics of Centrifugal pumps (Constant speed / variable speed)
12. Study on performance characteristics of reciprocating pump.

LIST OF EQUIPMENTS AVAILABLE FOR THE EXPERIMENTS/IN LAB

1. Bernoulli's theorem – Verification Apparatus - 1 No.
2. Calculation of Metacentric height
   Water tank & Ship model with accessories - 1 No.
3. Measurement of velocity
   Pitot tube assembly - 1 No.
4. Flow measurement open channel flow
   (i) Channel with provision for fixing notches (rectangular, triangular & trapezoidal forms) -1 Unit
   (ii) Flume assembly with provisions for conducting experiments on Hydraulic jumps, generation of surges etc. -1 Unit

5. Flow measurement in pipes
   (i) Venturimeter, U tube manometer fixtures like Valves, collecting tank -1 Unit
   (ii) Orifice meter, U tube manometer fixtures like Valves, collecting tank -1 Unit
   (iii) Orifice tank with provisions for fixing orifices, internal and external mouth pieces of different shapes -1Unit

6. Losses in Pipes
   Major loss – Friction loss Pipe lengths (min. 3m) of different diameters with Valves and pressure rapping & collecting tank -1 Unit
   Minor Losses - Pipe line assembly with provisions for having Sudden contractions in diameter, Expansions Bends, elbow fitting, etc. -1 Unit

7. Pumps
   (i) Centrifugal pump assembly with accessories (single stage) -1 Unit
   (ii) Centrifugal pump assembly with accessories (multi stage) -1 Unit
   (iii) Reciprocating pump assembly with accessories -1 Unit
   (iv) Deep well pump assembly set with accessories -1 Unit

8. Turbine
   (i) Impulse (Pelton) turbine assembly with fittings & accessories -1 Unit
   (ii) Francis turbine assembly with fittings & accessories -1 Unit
   (iii) Kaplan turbine assembly with fittings & accessories -1 Unit

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EX.NO: DATE:

1. FLOW THROUGH ORIFICE

OBJECTIVES:

To determine the coefficients of discharge, contraction and velocity for the given orifice by constant head method.

To determine the time for emptying the tank when water drains through sharp edged orifice.

APPARATUS REQUIRED:

Orifice tank

Point gauge for measuring jet trajectory

Orifice/mouthpiece

Calibrated collecting tank

Stop watch

THEORY:

Orifice is a device which is used for discharging fluids in to the atmosphere from tanks. The tank is assumed to be sufficiently large for the velocity of flow in it to be negligibly small except close to the orifice. In the vicinity of the orifice, the fluid accelerates towards the centre of the hole, so that as the jet emerges it suffers a reduction of area due to the curvature of the streamlines. The reduction of area due to this local curvature may be taken to be complete at about half the orifice diameter downstream of the plane of the orifice. The reduced section is called the vena contracta..

For steady, frictionless flow of an incompressible fluid along a streamline, bernoulli's equation states:

$$z_1 + \frac{P_1}{g} + \frac{V_1^{\ 2}}{2g} = z_2 + \frac{P_2}{g} + \frac{V_2^{\ 2}}{2g}$$

. . . . (1)

In this equation $P_1 = P_2 = P$ atmospheric velocity v_1 is negligibly small and $z_1 - z_2 = H$. Hence we have

$$H = \frac{V_2^2}{2g}$$

. . . . (2)

Therefore velocity of fluid through the orifice

$$V_2 = \sqrt{2gH}$$

. . . . (3)

Velocity V_2 is the theoretical velocity in the plane of the vena contracta.

Because of the energy loss due to friction effects, the actual velocity V_{act} in the plane of the vena contracta will be less than V_2.

DESCRIPTION

Water enters the supply tank through a perforated diffuser placed below the water surface. The flow passes into the tank and leaves through a sharp-edged orifice set at the side of the tank. Water comes of the supply tank in the form of a jet is directed into the calibrated collection tank. The volumetric flow rate is measured by recording the time taken to collect a known volume of water in the tank.

A horizontal scale, with a hook gauge, mounted on to the inlet tank as shown in Fig. 1.1. Hook gauge can be moved horizontally as well as vertically and its corresponding movements can be read on the horizontal and vertical scales, respectively.

FORMULAE USED:

USING CONSTANT HEAD METHOD

(a) Coefficient of discharge

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

Where $Actual\ Discharge\ Q_{act} = \dfrac{Volume\ Collected}{Time\ Taken}$,

$Theoretical\ Discharge\ Q_{th} = a\sqrt{2\,g\,H}$,

a = Area of the orifice and H = head of water level above the orifice.

Use this formula to calculate Cd for each set of results obtained.

(b) Coefficient of velocity

Let x and y be the horizontal and vertical co-ordinates of the centre line of the jet in relation to the central point of the vena contracta, the actual velocity (v_{act}) of the jet can be calculated.

From the trajectory profile the horizontal coordinate of any point p on the jet is

$$t = \frac{x}{v}$$

$x = v_{act}\, t$ and hence

The vertical co-ordinate of P (Fig. 1.1) is

$$y = \frac{1}{2} g t^2 = \frac{1}{2} g \frac{x^2}{v^2}$$

$$\text{Hence} \quad v_{act}^2 = \frac{g x^2}{2y}$$

$$\text{or} \quad v_{act} = \left[\frac{gx^2}{2y}\right]^{1/2}$$

The coefficient of velocity Cv can then be calculated as

$$C_V = \frac{v_{act}}{v_{th}} = \left[\frac{\frac{gx^2}{2y}}{2gH}\right]^{1/2} = \frac{x}{2\sqrt{Hy}}$$

Use this equation to calculate Cv.

(c)Coefficient of contraction

$$C_c = \frac{C_d}{C_v} = \frac{a_{jet}}{a} = \frac{Q_{act} / \left(a\sqrt{2gH}\right)}{x / \left(2\sqrt{H\,y}\right)} = \frac{Q_{act}}{ax}\left[\frac{2y}{g}\right]^{1/2}$$

Use this formula to calculate Cc for each set of results.

The observations required for the calculation of coefficients Cd, Cc and Cv can be made simultaneously with the measurements taken. The jet trajectory is obtained by using the needle mounted on the vertical backboard to follow the profile of the jet. Release the securing screw for the needle and move the needle until its point is just behind the centre of the jet and re-tighten the screw. Now, measure the horizontal distance '*x*' between the vena contracta of the jet and the needle. Also note vertical distance '*y*' between the centre of vena contracta and the centre of jet below the needle. For the orifice, location of the vena contracta from the edge for the small orifice can be taken as 0.5 diameter of the orifice.

PRECAUTIONS

- Check that air is not trapped in the piezometric tube while taking reading.
- Ensure water level is constant in the supply tank before taking any reading for constant head method.

PROCEDURE (INSTRUCTIONAL MODE)

Determination of Cd, Cv and Cc using constant head method.

1. Fit the sharp edged circular orifice/mouthpiece of desired size to the opening in the side wall of the inlet tank, near its bottom.
2. Turn the pump on and adjust the flow rate using regulating valve so that the inlet tank is filled to the height of the overflow pipe and steady discharge is obtained.
3. Measure the head 'H' using the piezometric tube fixed to the inlet tank.
4. Once the jet is steady, use stopwatch for measuring discharge. Meanwhile measure the '*x*' and '*y*' distances. '*y*' may be measured from centre of the steady jets or may be measured relatively by keeping offset from centre.
5. Measure the discharge by volumetric method.

After entering the readings in the Tabulation 1.1, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

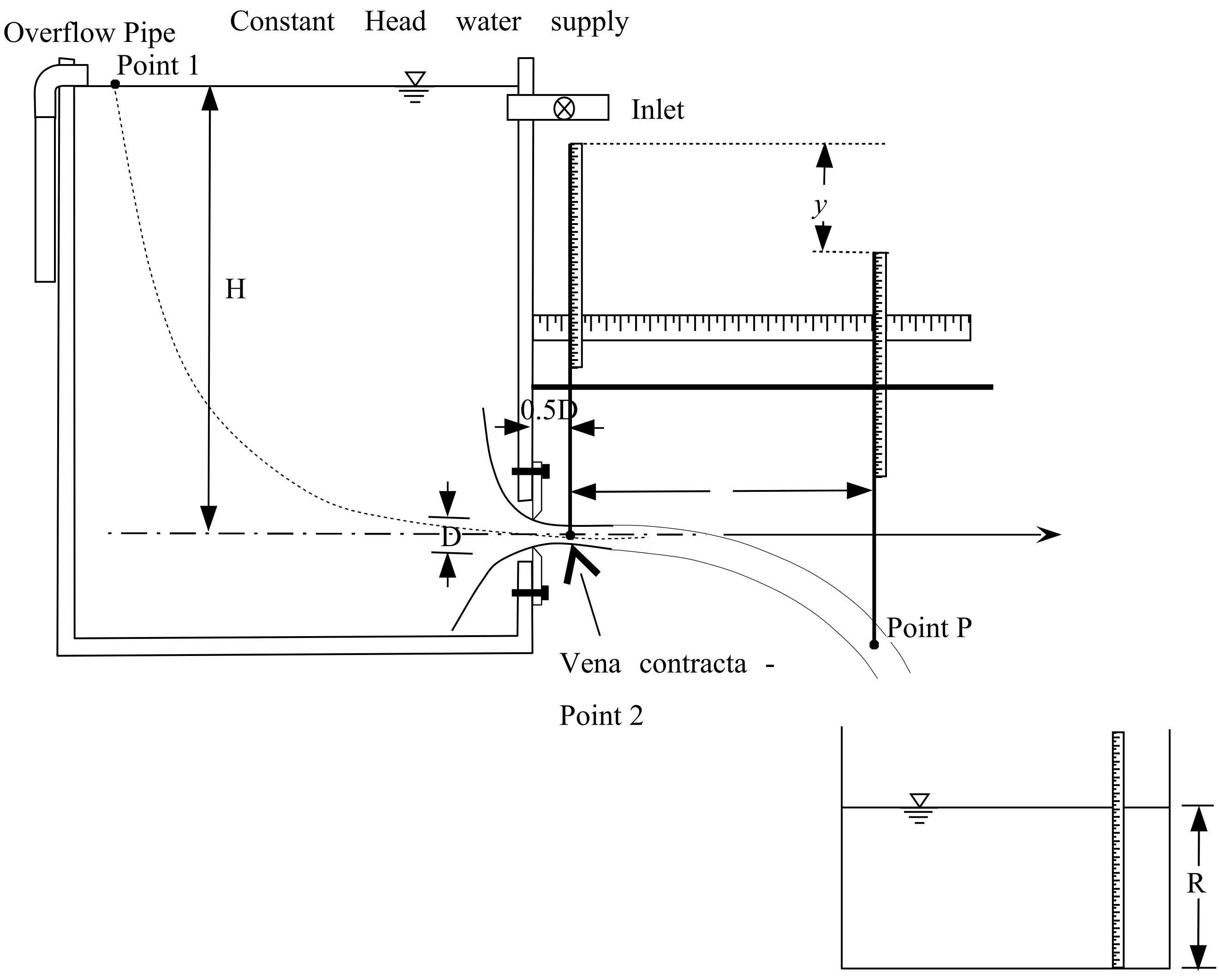


Fig 1.1 Experimental setup for determination of coefficients of orifice

OBSERVATION AND COMPUTATIONS (By constant Head Method)

Diameter of the orifice D = 30mm Area of the orifice 'a'= 7.0686×10^{-4} m^2

Area of collecting tank = 0.25 m^2

Tabulation 1.1 - Determination of the coefficient of discharge Cd.

Run No.↓	*Discharge Measurement*						$C_d = \dfrac{Q_{act}}{Q_{th}}$	*Jet data*			
	H (m)	Water rise in collecting tank 'R' (m)	Time Taken (sec)	Volume Colelcted (m^3)	Actual Discharge Q_{act}	Theoretical discharge $Q_{th} = a\sqrt{2gH}$		*x (m)*	*y (m)*	$C_v = \dfrac{x}{2\sqrt{Hy}}$	$C_c = \dfrac{Q_{act}}{ax}\left[\dfrac{2y}{g}\right]^{1/2}$
1											
2											
3											
4											
5											
6											
7											
8											

Average Value of Cd = …………………….

Average Value of Cv = ……………..….

Average value of Cc = …………………. Verification : Cc = Avg Cd/ Avg.Cv = …………………..

GRAPH:

Readings observed during the canstant head experiments were used in this graph.

1. Q_{th} , Q_{act} vs. $\sqrt{h}$ are drawn taking $\sqrt{h}$ on x -axis and Q_{th} , Q_{act} on y – axis.
2. C_d vs. Q_{act} is drawn taking Q_{act} on x -axis and Cd on y – axis.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. Did you observe distance at which the vena contracta occurred during the experiment? What is the relationship between Cd , Cc and Cv.

2. Can you use the same formula, if you fit a very large diameter of the orifice?

3. Write the equation of a waterjet trajectory which is coming out the orifice

4. Explain the volumetric method that you have used in this experiment?

EX.NO: DATE:

2. FLOW THROUGH NOTCHES

OBJECTIVES:

To determine the coefficients of discharge of the rectangular, triangular and trapezoidal notches.

APPARATUS REQUIRED:

Hydraulic bench

Notches – Rectangular, triangular, trapezoidal shape.

Hook and point gauge

Calibrated collecting tank

Stop watch

THEORY:

A notch is a sharp-edged device used for the measurement of discharge in free surface flows. A notch can be of different shapes – rectangular, triangular, trapezoidal etc. A triangular notch is particularly suited for measurement of small discharges. The discharge over a notch mainly depends on the head H, relative to the crest of the notch, measured upstream at a distance about 3 to 4 times H from the crest. General formula can be obtained for a symmetrical trapezoidal notch which is a combined shape of rectangular and triangular notches. By applying the Bernoulli Equation (conservation of energy equation) to a simplified flow model of a symmetric trapezoidal notch, theoretical discharge Q_{th} is obtained as:

$$Q_{th} = \frac{8}{15}\sqrt{2g}\ H^{5/2}\tan\frac{\theta}{2} + \frac{2}{3}\sqrt{2g}\ B\,H^{3/2} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where ‘H’ is the water head measured above the crest, ‘θ’ is the angle between the side edges and ‘B’ is the bottom width of the notch.

When θ=0, this equation is reduced and applicable for rectangular notch or when B=0 (no bottom width) it is applicable for triangular notch. Hence the same equation (1) can be also used for both rectangular and triangular notches by substituting corresponding values (ie θ=0 or B=0).

If Q_{act} actual discharge is known then coefficient of discharge Cd of the notch can be expressed as

$Cd = Q_{act}/Q_{th.}$

DESCRIPTION

In open channel hydraulics, weirs are commonly used to either regulate or to measure the volumetric flow rate. They are of particular use in large scale situations such as irrigation schemes, canals and rivers. For small scale applications, weirs are often referred to as notches and invariably are sharp edged and manufactured from thin plate material. Water enters the stilling baffles which calms the flow. Then, the flow passes into the channel and flows over a sharp-edged notch set at the other end of the channel. Water comes of the channel in the form of a nappe is then directed into the calibrated collection tank. The volumetric flow rate is measured by recording the time taken to collect a known volume of water in the tank.

A vertical hook and point gauge, mounted over the channel is used to measure the head of the flow above the crest of the notch as shown in Fig. 2.1. Hook gauge can be moved vertically to measure vertical movements.

FORMULAE USED:

A) RECTANGULAR NOTCH

Coefficient of discharge

$$Q_{th} = \frac{2}{3}\sqrt{2g}\,B\,H^{3/2}$$

$$Q_{act} = \frac{\text{Volume Collected}}{\text{Time Taken}}$$

$$C_d = \frac{Q_{act}}{Q_{th}}$$

B) TRIANGULAR NOTCH

Coefficient of discharge

$$Q_{th} = \frac{8}{15}\sqrt{2g}\,H^{5/2}\tan\frac{\theta}{2}$$

$$Q_{act} = \frac{\text{Volume Collected}}{\text{Time Taken}}$$

$$C_d = \frac{Q_{act}}{Q_{th}}$$

C) TRAPEZOIDAL NOTCH

Coefficient of discharge

$$Q_{th} = \frac{8}{15}\sqrt{2g}\ H^{5/2}\tan\frac{\theta}{2} + \frac{2}{3}\sqrt{2g}\ B\,H^{3/2}$$

$$Q_{act} = \frac{\text{Volume Collected}}{\text{Time Taken}}$$

$$C_d = \frac{Q_{act}}{Q_{th}}$$

PRECAUTIONS

- Ensure and read initial water level reading just above the crest.

PROCEDURE (INSTRUCTIONAL MODE)

Preparation for experiment:

1. Insert the given notch into the hydraulic bench and fit tightly by using bolts in order to prevent leakage.
2. Open the water supply and allow water till over flows over the notch. Stop water supply, let excess water drain through notch and note the initial reading of the water level 'h_0'using the hook and point gauge. Let water drain from collecting tank and shut the valve of collecting tank after emptying the collecting tank.

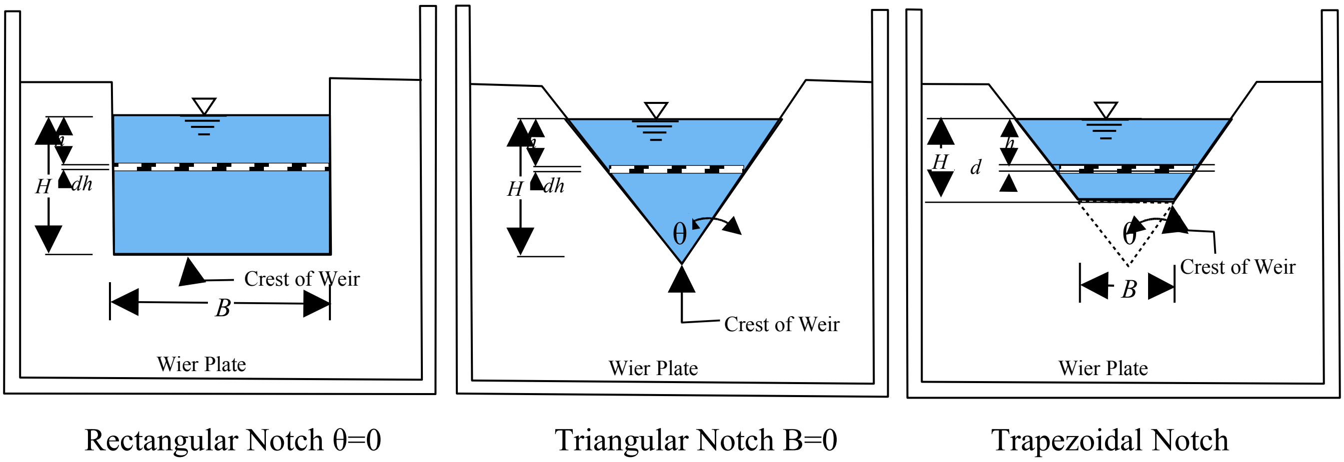
Experiment steps:

3. After initial preparation, open regulating valve to increase the flow and maintain water level over notch. Wait until flow is steady.
4. Move hook and point gauge vertically and measure the current water level 'h_1' to find the water head 'H' above the crest of the notch.
5. Note the piezometric reading 'z_0' in the collecting tank while switch on the stopwatch.
6. Record the time taken 'T' and the piezometric reading 'z_1' in the collecting tank after allowing sufficient water quantity of water in the collecting tank.

7. Repeat step 3 to step 6 by using different flow rate of water, which can be done by adjusting the water supply. Measure and record the H, the time and piezometric reading in the collecting tank until 5 sets of data have been taken. If collecting tank is full, just empty it before the step no 3.
8. To determine the coefficient of discharge for the other notch, repeat from step 1.

After entering the readings in the Tabulation 2.1 and Tabulation 2.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)



Cross Sectional view of different notches

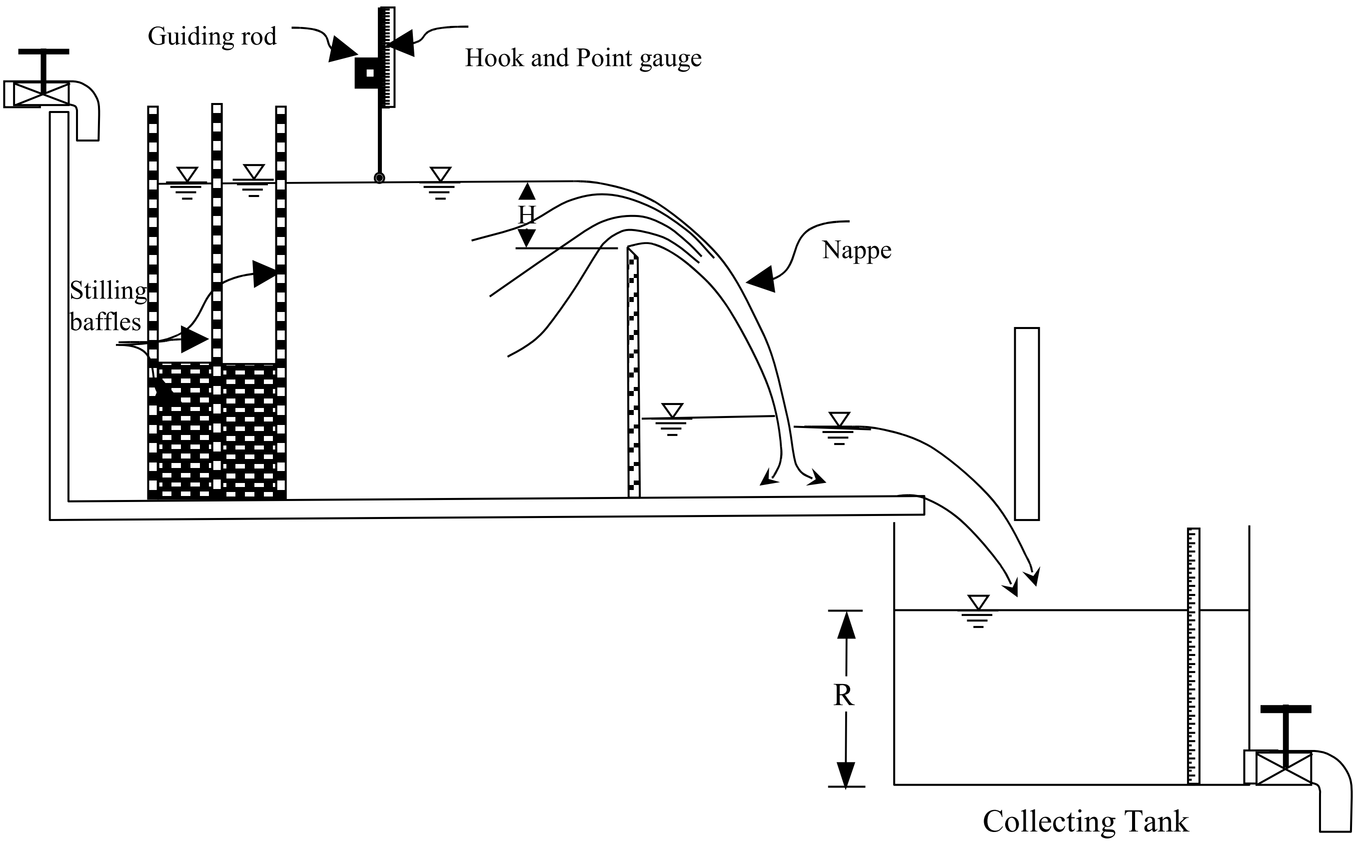


Fig 2.1 Longitudinal section of Experimental setup for notches

OBSERVATION AND COMPUTATIONS – I Date :_______________

A) For Rectangular notch

Notch width 'B' = 0.18m Initial reading of hook and point gauge h_0=

Area of collecting Tank A_{ct} = 0.80m x 0.80m = 0.64 m^2

Tabulation 2.1 – Determination of Cd of rectangular notch.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				*Cd*
	h_1 (m)	H (m)	Theoretical Discharge, $Q_{th} = \frac{2}{3}\sqrt{2g}\,B\,H^{3/2}$	Water Rise in Collecting Tank R (m)	Time Taken 'T' (sec)	Volume of water collected $(m^3)_{ct}$	Discharge, Q_{act}	$\frac{Q_{act}}{Q_{th}}$
1								
2								
3								
4								
5								
6								

Rectangular notch : Average Value of Cd = ……………..….

OBSERVATION AND COMPUTATIONS - II Date : _______________

B) For Triangular notch

Notch angle ‘θ’ = 90º or 60º Initial reading of hook and point gauge h_0=

Area of collecting Tank A_{ct} = 0.80m x 0.80m = 0.64 m^2

Tabulation 2.2 – Determination of Cd of triangular notch.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				*Cd*
	h_1 (m)	H (m)	Theoretical Discharge, $Q_{th} = \frac{8}{15}\sqrt{2g}\,H^{5/2}\tan\frac{\theta}{2}$	Water Rise in Collecting Tank R (m)	Time Taken ‘T’ (sec)	Volume of water collected $(m^3)_{ct}$	Discharge, Q_{act}	$\frac{Q_{act}}{Q_{th}}$
1								
2								
3								
4								
5								
6								

Triangular notch: Average Value of Cd = ……………...….

OBSERVATION AND COMPUTATIONS - III Date : _______________

For Trapezoidal notch

Notch Bottom Width ‘B’ = 0.12 m Notch angle ‘θ’ = 28º

Initial reading of hook and point gauge h_0= Area of collecting Tank A_{ct}= 0.80m x 0.80m = 0.64 m^2

Tabulation 2.3 – Determination of Cd of trapezoidal notch.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				*Cd*
	h_1 (m)	H (m)	Theoretical Discharge, $Q_{th} = \frac{8}{15}\sqrt{2g}\,H^{5/2}\tan\frac{\theta}{2} + \frac{2}{3}\sqrt{2g}\,B\,H^{3/2}$	Water Rise in Collecting Tank R (m)	Time Taken ‘T’ (sec)	Volume of water collected $(m^3)_{ct}$	Discharge, $\mathbf{Q_{act}}$	$\frac{\mathbf{Q_{act}}}{\mathbf{Q_{th}}}$
1								
2								
3								
4								
5								
6								

Trapezoidal notch: Average Value of Cd = ……………...….

GRAPH:

1- C_d versus Q_{act} curves are drawn taking Q_{act} on x -axis and Cd on y – axis in the same graph for all the notches.
2- Q_{act} versus H curves are drawn taking H on x -axis and Q_{act} on y – axis in the same graph for all the notches.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

- Discuss assumptions of the theory and possible experimental errors.
- What are the purposes of notch and weirs and where do you use them in the practical life.
- Compare the performance of the V-notch weir with that of the rectangular weir.

EX.NO: DATE:

3. FLOW THROUGH ORIFICE METER

OBJECTIVES:

- To determine the coefficient of discharge C_d for the two different orifice meters.

APPARATUS REQUIRED:

Pipe line setup with orificemeters including flow control devices.
Collecting tank
Stop watch

THEORY:

Orifice meter works based on the Bernoulli's principle that by reducing the cross-sectional area of the flow passage, a pressure difference is created between the inlet and throat and the measurement of the pressure enables the determination of the discharge through the pipe. Consider a cross section before the orifice throat as section (1) and a cross section at the orifice throat as section (2).

Assuming the flow to incompressible and inviscid between the section (1) and the Section (2), the continuity equation can be written as:

$Q = v_1 A_1 = v_2 A_2$ when v_1 and v_2 are the velocities, A_1 and A_2 are the in the section (1) and section (2)

and Bernoulli's equation can be written as:

$$\frac{p_1}{\rho g} + \frac{v_1}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2}{2g} + z_2$$

Substituting the values of v_1 in Bernoulli equation and rearranging the terms along with the manometer reading, discharge is obtained as:

$$Q_{th} = \frac{A_2\sqrt{2gH}}{\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}}.$$

Where H = $h_m * (\frac{\rho_m}{\rho} - 1)$ (h_m is differential level of Hg in manometer measured in meters, ρ_m and ρ are mass density of manometer fluid (usually mercury) and mass density of flowing fluid, respectively.)

For the known actual flow rate Q_{act} , orifice meter is calibrated and its

Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$

DESCRIPTION

An orifice meter is a simple device used for measuring the discharge through the pipes. 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. Construction of orifice meter is simplest amongst all the flow meters. It consists of a plate with a hole drilled in it. Even by creating the necessary differential pressure, flow rate relating to the differential pressure cannot be applied directly in practical applications. All the flow meters need calibration a priori where a known quantity of fluid is passed through the flow meter and the differential pressure across the flow meter related to the actual flow rate through a discharge coefficient given as the ratio of actual to theoretical flow rate. The apparatus consist of a flow bench that allows water flow to the orifice meter and venturi meter. A manometer is connected at two points, one at the let to the orifice meter and the other at the orifice throat. Manometer is filled with enough mercury to read the differential head 'h_m'. Water is colleted in the collecting tank for arriving actual discharge using stop watch and the piezometric level attached to the collecting tank.

FORMULAE USED:

Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$

Where $Q_{th} = \frac{A_2\sqrt{2gH}}{\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}}$. or $Q_{th} = K\sqrt{H}$

$$K = \frac{A_2\sqrt{2g}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}}.$$

A_1 and A_2 are area of cross section of the pipe and area of the throat respectively.

$H = h_m$ x ($\frac{\rho_m}{\rho}$ -1) (h_m is differential level of manometer fluid measured in meters)

Q_{act} = Actual discharge measured from volumetric technique.

PRECAUTIONS

- Since the apparatus is made for conducting many experiments, make sure only required valves are opened. Close all other valves which have to be in closed condition

PROCEDURE:

1. Note the inlet pipe diameter 'd_1' and inner throat diameter 'd_2' of the orifice meter.
2. Note the density of the manometer fluid 'ρ_m'and the flowing fluid 'ρ'. Mostly mercury is used as manometer fluid and water as flowing fluid in this lab. So ρ_m. =13600kg/m^3 and ρ = 1000kg/m^3
3. Start the pump and adjust the control valve in the line for maximum discharge. Wait for sometime so that flow is stabilized.
4. Measure the pressure difference 'h_m' across the orifice meter._
5. Note the piezometric reading 'z_0' in the collecting tank while switch on the stopwatch.
6. Record the time taken 'T' for 'R' m water level rise in the collecting tank.
7. Decrease the flow rate through the system by regulating the control valve and wait till flow is steady.
8. Repeat the steps 4 to 6 for 5 different flow rates.

After entering the readings in the Tabulation 4.1 and 4.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

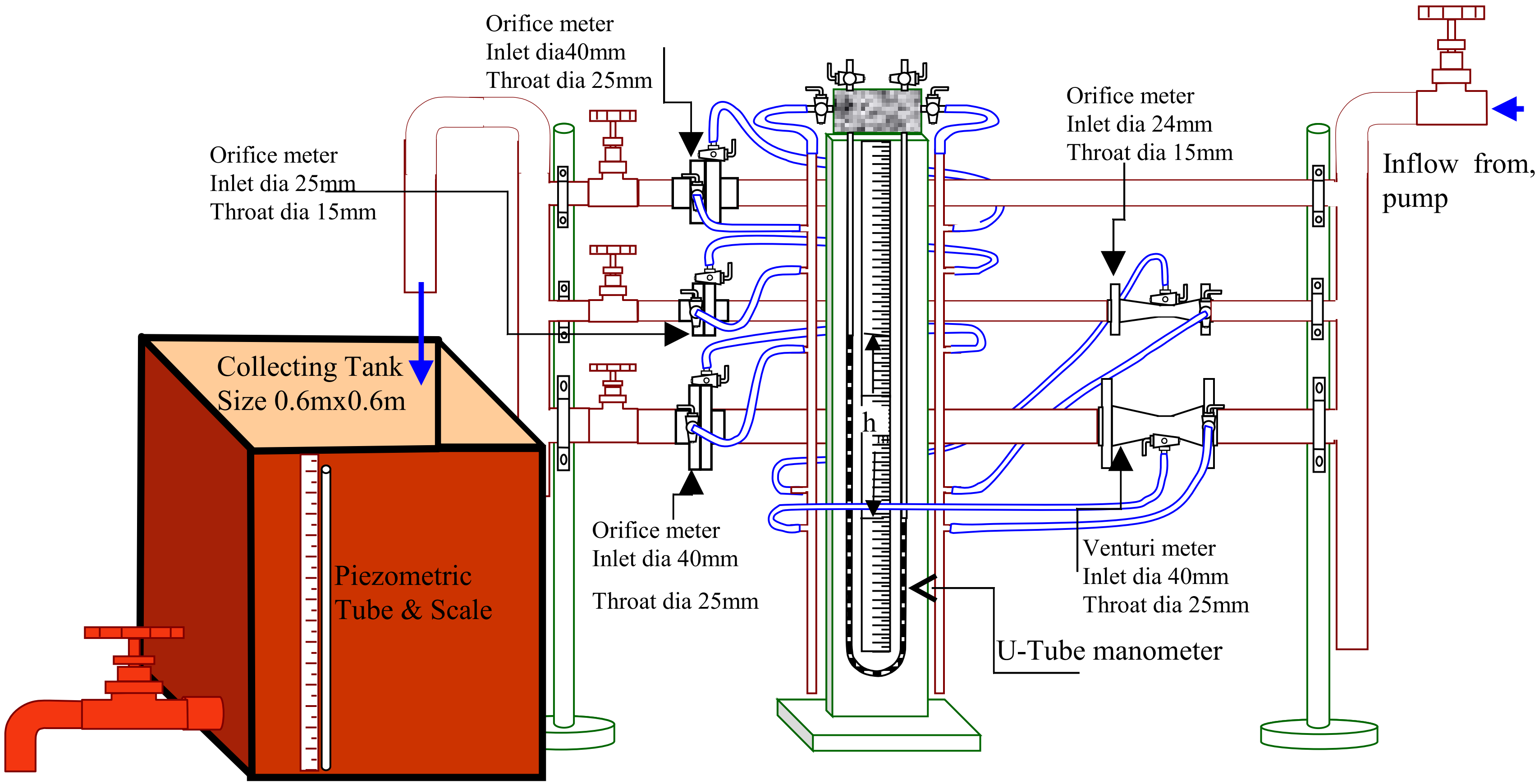


Fig 4.1 Orifice meters and Venturi meter test setup (MCET/BME/FM/E/006 setup)

OBSERVATION AND COMPUTATIONS – I Date : ______________

C) For orifice meter No. 1:

Diameter of of inlet pipe ‘d_1’ = 0.04 m

Diameter of of throat ‘d_2’ = 0.025m

Area of collecting Tank A_{ct} = 0.60m x 0.60m = 0.36 m^2

Density of the manometer liquid ρ_m = 13600 kg/m^3

Area of inlet ‘A_1’ = m^2

Area of inlet ‘A_2’ = m^2

K =

Density of the flowing fluid ρ = 1000 kg/m^3

Tabulation 4.1 – For orifice meter No. 1.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				Cd
	h_m (m)	H (m) $h_m * (\frac{\rho_m}{\rho} - 1)$	Theoretical Discharge, $Q_{th} = K\sqrt{H}$	Time T (sec)	Water rise in Collecting Tank R (m)	Volume collected (m^3) A_{ct} *R	Discharge, $\mathbf{Q}_{act}$	$C_d = \frac{Q_{act}}{Q_{th}}$
1								
2								
3								
4								
5								
6								

Average value of Cd for orifice No. 1. = ______________

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For orifice meter No. 2:

Diameter of of inlet pipe ‘d_1’ = 0.025 m Area of inlet ‘A_1’ = m^2

Diameter of of throat ‘d_2’ = 0.015 m Area of inlet ‘A_2’ = m^2

Area of collecting Tank A_{ct} = 0.60m x 0.60m = 0.36 m^2 K =

Density of the manometer liquid ρ_m = 13600 kg/m³ Density of the flowing fluid ρ = 1000 kg/m³

Tabulation 4.2 – For orifice meter No. 2.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				Cd
	h_m (m)	H (m) $h_m * (\frac{\rho_m}{\rho} - 1)$	Theoretical Discharge, $Q_{th} = K\sqrt{H}$	Time T (sec)	Water rise in Collecting Tank R (m)	Volume collected (m^3) A_{ct} *R	Discharge, $\mathbf{Q}_{act}$	$C_d = \frac{Q_{act}}{Q_{th}}$
1								
2								
3								
4								
5								
6								

Average value of Cd for orifice No. 2.=

GRAPH:

1- Q_{act} vs. $\sqrt{H}$ are drawn in the same graph for 2 orifice meters taking H on x -axis and Q_{act} on y – axis.

2- C_d versus Q_{act} curves are drawn taking Q_{act} on x -axis and Cd on y – axis in the same graph for both the orifice meters.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. Discuss assumptions of the theory and source of errors.

2. What is the purpose of finding Cd of orifice?

EX.NO: DATE:

4. IMPACT OF JET ON PLATES

OBJECTIVES:

To experimentally determine the force required to keep a flat plate at a datum level while it is subjected to the impact of a water jet.

To compare the experimentally measured force with the analytically calculated force from the control volume form of the linear momentum equation.

APPARATUS REQUIRED:

A hydraulic work bench setup containing nozzle for striking jet on plate.

Collecting tank

Stop watch

Weights

THEORY:

A fluid jet is a stream of fluid coming from a nozzle with a high velocity and hence a kinetic energy. When a jet strikes on a plate or a cup, it exerts a force on it. This force can be evaluated by using 'Impulse-momentum principle'. Fig 5.1 shows a fluid ket impinging a stationary flat plate held perpendicular or inclined to the direction of jet. After striking the plate with a force, jet direction is deflected. If 'ρ' is the density of the liquid, 'a' and 'v' are the cross-sectional area and velocity of the jet, respectively, then the mass of liquid per second striking the plate is (ρ . a . v). After striking the plate assuming the plate is smooth, jet leaves the plate with a velocity equal to the initial velocity.

Force exerted by the jet on the plate

F= Rate of change of momentum (in the direction of force)

= (Initial momentum – Final momentum) --- Impulse-momentum principle.

= (Mass/sec) * ([Velocity of jet before striking – velocity of jet after striking] in the direction of force.

A) ON THE NORMAL PLATE.

When plate is held normal to the vertically emerging jet with a velocity 'v', Force 'F_y' is equal to 'F_n' the only force to be measured which is normal to the plate and in the direction of jet.

By applying the impulse-momentum principle in the direction normal to the flat plate

So, $F_y = F_n = (\rho.\ a.\ v).\ (v-0) = \rho a v^2$

Which is also can be written as $\rho Q v$ or $\mathbf{F_y} = \rho \frac{Q^2}{a}$

B) ON THE INCLINED PLATE.

When plate is held inclined at θ° to the vertically emerging jet with a velocity 'v' as shown in fig. 5.1 (b), force 'F_n' which is normal to the plate is exerted on the plate by the jet.

By applying the impulse-momentum principle in the direction normal to the flat plate

So, $F_n = (\rho.\ a.\ v).\ (v.\sin\theta - 0) = \rho a v^2 \sin\theta$

This normal force can be resolved into two components;

$F_y = F_n \sin\theta = \rho a v^2 \sin^2\theta$ or $\mathbf{F_y} = \rho \frac{Q^2}{a} \sin^2\theta$

$F_x = F_n \cos\theta = \rho a v^2 \sin\theta \cos\theta$ or $\mathbf{F_x} = \rho \frac{Q^2}{a} \sin\theta \cos\theta$

DESCRIPTION

The apparatus consists of rectangular casing fabricated with transparent plexiglass on sides to see action of vertical jet coming from the nozzle at the bottom of the casing. Water discharged from a nozzle strikes a target that is attached to a lever which carries a weight. The lever is supported at fulcrum. Balancing weight is attached at one end of the lever for leveling the lever. On the other end, weights can be placed to measure the force exerted by the jet one the plate which may be held perpendicular or inclined to the jet. Impinged water falls down within the casing and immediately flows to the collecting tank.

FORMULAE USED:

A) THEORETICAL FORCE ON THE NORMAL PLATE.

$$\mathbf{F_y} = \rho \frac{Q^2}{a}$$

B) THEORETICAL FORCE ON THE INCLINED PLATE.

$$\mathbf{F}_y = \rho \frac{Q^2}{a} \sin^2\theta$$

PRECAUTIONS

- Make sure the fulcrum and the lever movement is friction free.
- Ensure the desired angle between jet and the plate.

PROCEDURE:

1- Measure the distance ‘x_a’from fulcrum and target link and the distance ‘x_b’from target link to the loading point on the lever.

2- Attach the plate at the target point at the desired inclination to the direction of jet.

3- Remove all weight and level the lever using the balancing weight.

4- Attach the desired mass ‘m’ and record it.

5- Open regulating valve and increase the flow till the lever is leveled by the jet. Wait until flow is steady.

6- After water level in the collecting tank reaches more than 30cm in the piezometric reading, switch on the stopwatch. This precautionary measure is to avoid fluctuation in initial reading.

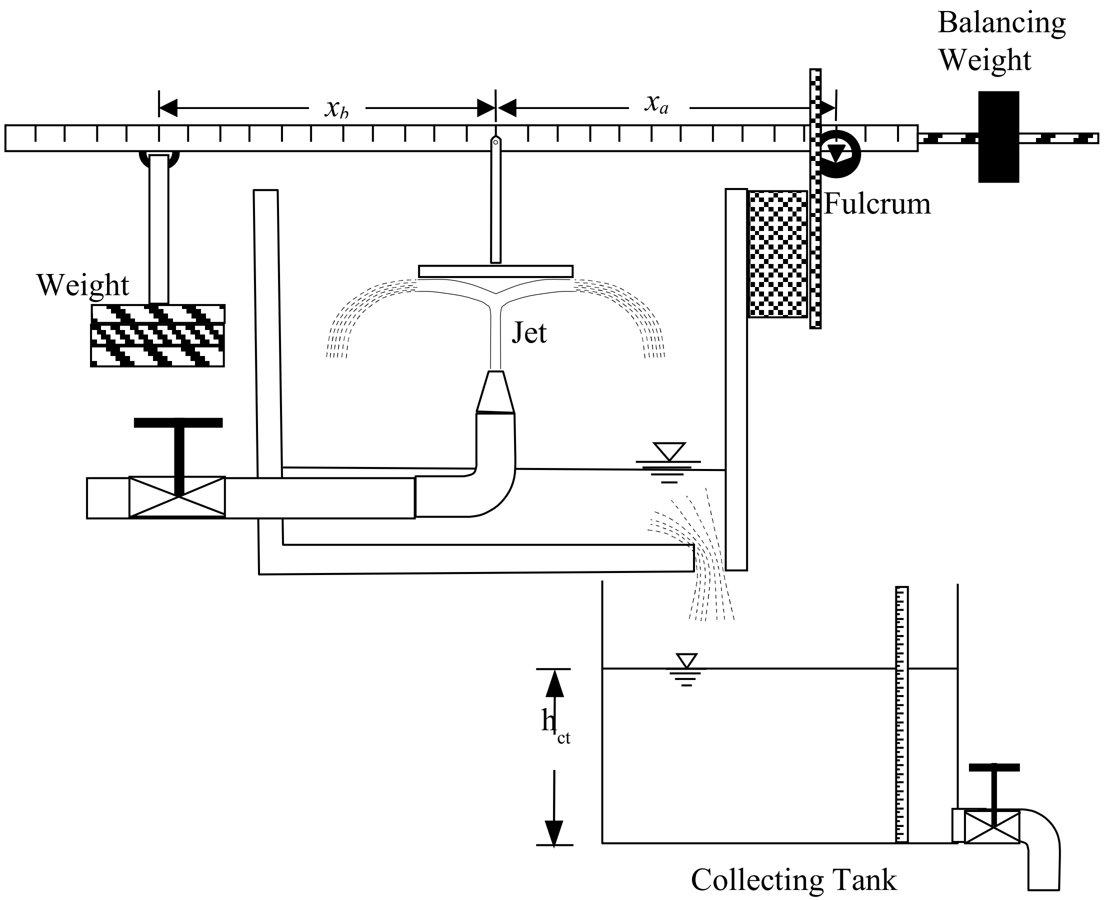
7- Record the time taken ‘T’ for rise in water level ‘R’ in the collecting tank after allowing sufficient water quantity of water in the collecting tank.

8- Repeat step 4 to step 7 by using different flow rate of water, which can be done by adjusting the water supply.

9- Record the mass ‘m’, the time and piezometric reading in the collecting tank until 5 sets of data have been taken. If collecting tank is full, just empty it before the step no 4.

After entering the readings in the Tabulation 5.1 and Tabulation 5.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)



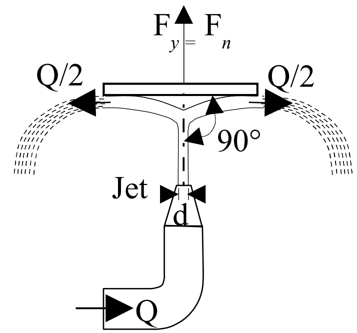


Fig. 5.1(a) Impact of Jet on normal plate

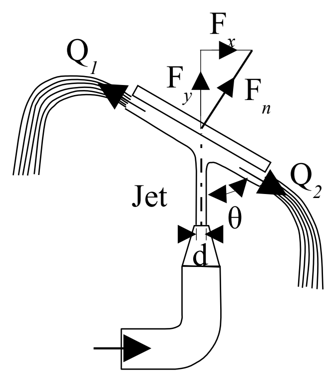


Fig. 3.1(b) Impact of Jet on inclined plate

Fig 5.1 Experimental setup for impact of jet

OBSERVATION AND COMPUTATIONS – I

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D) For normal plate

Diameter of nozzle 'd' = Area of jet 'a' = m^2 Area of collecting Tank = 0.5m x 0.5m = 0.25 m^2

X_a = m X_b = m

Density of the liquid $\rho = 1000\ kg/m^3$

Tabulation 5.1 – For Normal plate.

No.↓	*Experimental Force*		*Actual Discharge Measurement*				Theoretical Force	%Error
	Mass *m* (kg)	F $\frac{m\,g\,(x_a + x_b)}{x_a}$	Time T (sec)	Rise in water level in Collecting Tank R (m)	Volume (m^3)	Discharge, **Q**	$F_y = \rho \frac{Q^2}{a}$	100*(F-F_y)/F
1								
2								
3								
4								
5								

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For inclined plate

Diameter of nozzle 'd' = Area of jet 'a' = m^2

Diameter of nozzle 'd' = Area of jet 'a' = m^2 Angle between plate and jet θ = °

Area of collecting Tank = 0.5m x 0.5m = 0.25 m^2 X_a = m X_b = m

Tabulation 5.2 – For inclined plate.

No.↓	*Experimental Force*		*Actual Discharge Measurement*				Theoretical Force	%Error
	Mass *m* (kg)	F $\frac{m\,g\,(x_a + x_b)}{x_a}$	Time T (sec)	Rise in water level in Collecting Tank 'R' (m)	Volume (m^3)	Discharge, **Q**	$F_y = \rho \frac{Q^2}{a} \sin^2\theta$	$100*(F-F_y)/F$
1								
2								
3								
4								
5								

GRAPH:

A). For normal plate:

1- Experimental Force F versus Q and Theoretical force F_y versus Q are drawn in the same graph for the 5 set of values.

B). For inclined plate:

2- Experimental force F versus Q and Theoretical force F_y versus Q are drawn in the same graph for the 5 set of values.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. What is the relationship between force and volumetric flow rate?
2. Discuss assumptions of the theory and possible experimental errors.
3. When plate is too from the jet what factor(s) shoud be considered in the formulation?
4. Where this study can be applied in practical use?

EX.NO: DATE:

5. FRICTION (MAJOR) LOSSES IN PIPES

OBJECTIVES:

- To measure the friction factor for flow through different diameter of pipes over a wide range of Reynolds number (Laminar, transitional and turbulent flows) and compare with the corresponding theoretical value

APPARATUS REQUIRED:

"Flow losses in pipes" apparatus with flow control device and manometer.

Collecting tank

Stop watch

THEORY:

Various fluids are transported through pipes. When the fluids flow through pipes, energy losses occur due to various reasons. Predominant loss is due to the pipe roughness. To provide adequate pumping requirements, it is necessary to measure the friction factor of the pipe. Darcy–Weisbach equation relates the head loss due to frictional or turbulent through a pipe to the velocity of the fluid, friction factor and diameter of the pipe as:

$$h_f = \frac{fLV^2}{2gD}$$

where h_f = Loss of head due to friction,

L = Length of pipe between the sections used for measuring loss of head,

D = Diameter of the pipe,

f = Darcy coefficient of friction,

g = gravity due to acceleration.

DESCRIPTION

The experiment is performed by using a number of long horizontal pipes of different diameters connected to water supply using a regulator valve for achieving different constant flow rates. Pressure tappings are provided on each pipe at suitable distances apart and connected to U-tube differential manometer. Manometer is filled with enough mercury to read the differential head 'h_m'. Water is colleted in the collecting tank for arriving actual discharge using stop watch and the piezometric level attached to the collecting tank.

FORMULAE USED:

1). Darcy coefficient of friction (Friction factor) $f = \dfrac{2g.D.h_f}{LV^2}$

where f = Darcy coefficient of friction,

g = gravity due to acceleration.

D = Diameter of the pipe,

$h_f = h_m \times (\dfrac{\rho_m}{\rho} - 1)$ (h_m is differential level of manometer fluid measured in meters)

L = Length of pipe between the sections used for measuring loss of head,

Q_{act} = Actual discharge measured from volumetric technique.

2). Reynolds number $\mathrm{Re}_{D1} = \dfrac{\rho.V.D}{\mu}$

where μ is the coefficient of dyanamic viscosity of flowing fluid.

Viscosity of water at different temperatures is listed below (Ref: wikipedia.org).

Temperature [°C]	10	20	25	30	40	50	60	70
Viscosity μ [Pa·s] $\times 10^{-4}$	13.08	10.03	8.90	7.978	6.531	5.471	4.668	4.044

PRECAUTIONS

- Since the apparatus is made for conducting many experiments, make sure only required valves are opened. Close all other valves which have to be in closed condition

PROCEDURE: (Instructional mode)

1. Note the pipe diameter 'D', the density of the manometer fluid 'ρ_m'and the flowing fluid 'ρ'. Mostly mercury is used as manometer fluid and water as flowing fluid in this lab. So ρ_m. =13600 kg/m^3 and ρ = 1000 kg/m^3.
2. Make sure only required water regulator valves and required valves at tappings connected to manometer are opened.

3. Start the pump and adjust the control valve just enough to make fully developed flow (pipe full flow) but laminar flow. Wait for sometime so that flow is stabilized.
4. Measure the pressure difference ‘h_m’ across the orifice meter.
5. After water level in the collecting tank reaches more than 30cm in the piezometric reading, switch on the stopwatch. This precautionary measure is to avoid fluctuation in initial reading.
6. Record the time taken ‘T’ for rise in water level ‘R’ in the collecting tank after allowing sufficient water quantity of water in the collecting tank.
7. Increase the flow rate by regulating the control valve and wait till flow is steady.
8. Repeat the steps 4 to 6 for 8 different flow rates.

After entering the readings in the Tabulation 5.1 and 5.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

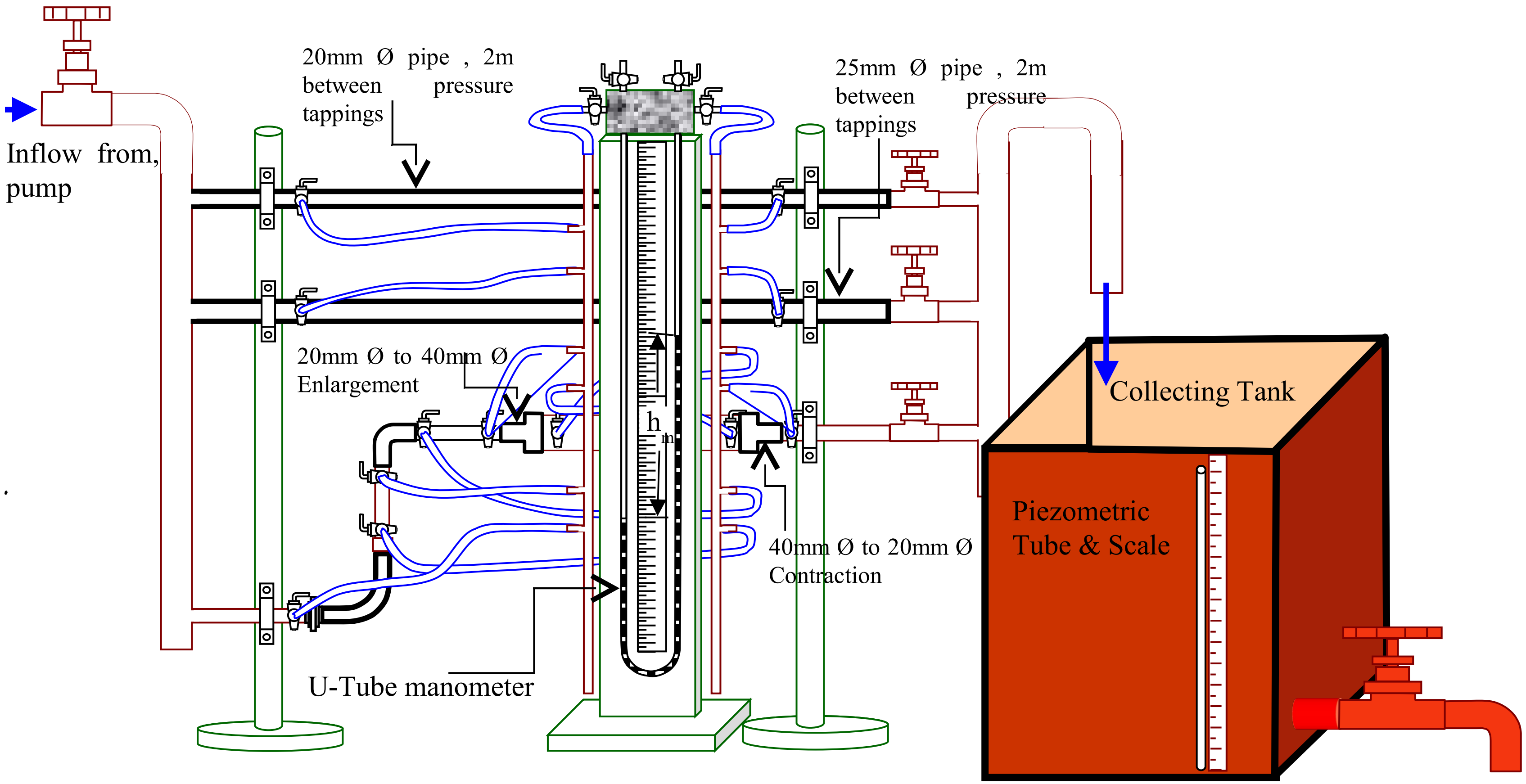

Fig 6.1 Experimental setup for finding friction losses (MCET/BME/FM/E/006 setup)

OBSERVATION AND COMPUTATIONS – I

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A) For pipe No. 1:

Diameter of pipe 'D' = 0.025 m Area of Pipe 'A' = m^2 Length of Pipe 'L' = 2.0m

Area of collecting Tank A_{ct} = 0.60mx 0.60m = 0.36 m^2 Coefficient of dynamic viscosity μ at °C = 7.91x 10^{-4} Pa.s.

Density of the manometer liquid ρ_m = 13600 kg/m^3 Density of the flowing fluid ρ = 1000 kg/m^3

Tabulation 5.1 – For pipe No. 1.

No.↓	*Actual Measurement*					*Calculated values*				*f*	Re No.
	z_1 (m)	z_0 (m)	h_m (m)	Time T (sec)	Rise of water level in Collecting Tank R (m)	Volume (m^3) A_{ct}* R	Discharge, Q_{act}	Velocity V =Q_{act}/A	h_f (m) $h_m * (\frac{\rho_m}{\rho} - 1)$	$f = \frac{2g.D.h_f}{LV^2}$	$\frac{\rho VD}{\mu}$
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

OBSERVATION AND COMPUTATIONS – II   Date :_______________

B) For pipe No. 2:

Diameter of pipe 'D' = 0.040 m   Area of Pipe 'A' = m^2 Length of Pipe 'L' = 2.0m

Area of collecting Tank A_{ct} = 0.60mx 0.60m = 0.36 m^2 Coefficient of dynamic viscosity μ at °C = 7.91x 10^{-4} Pa.s.

Density of the manometer liquid ρ_m = 13600 kg/m^3 Density of the flowing fluid ρ = 1000 kg/m^3

Tabulation 5.2 – For pipe No. 2.

No.↓	*Actual Measurement*					*Calculated values*				*f*	Re No.
	z_1 (m)	z_0 (m)	h_m (m)	Time T (sec)	Rise of water level in Collecting Tank R (m)	Volume (m^3) A_{ct}* R	Discharge, Q_{act}	Velocity V $=Q_{act}/A$	h_f (m) $h_m * (\frac{\rho_m}{\rho} - 1)$	$f = \frac{2g.D.h_f}{LV^2}$	$\frac{\rho VD}{\mu}$
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

GRAPH:

1- (SEMI-LOG Graph) Friction factor f vs. Reynolds number Re are drawn in the same graph for 2 pipes taking Re on x -axis and f on y – axis (Moody diagram). Laminar, transition, turbulent zone are identified on the graph and same have been marked on the graph.

2- Head loss h_f vs. Velocity V are plotted in the same graph for both the pipes. From the previous graph, velocities are identified and marked corresponding to zones.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. Comment on the importance of Reynolds number.

2. While flow is laminar in this experiment, which measure must be taken at most accuracy?

3. Where would do you apply the findings of this experiment?

EX.NO: DATE:

6. PELTON WHEEL TURBINE

OBJECTIVES:

To study the operation of Pelton wheel turbine and to measure the power output of a Pelton Wheel turbine.

To obtain the performance characteristics (Output, efficiency variation with speed) for different openings of the nozzle at a constant speed.

APPARATUS REQUIRED:

Pelton wheel unit inside a casing with a transparent window, supply pump, venturi meter with pressure gauge, tachometer, pressure gauge at the inlet to the turbine, rope brake drum with spring balance connected to the turbine.

THEORY:

The Pelton turbine used in this experiment is an impulse turbine. The total drop in pressure of the fluid takes place in stationary nozzles. A proportion of the kinetic energy of a high velocity jet is converted into mechanical work delivered to the shaft. The fluid transfers its momentum to buckets mounted on the circumference of a wheel. Pelton Wheel is used in hydroelectric scheme when the head available exceeds about 300m. The turbine is supplied with water under high head through a long conduit called *penstock*. The water is then accelerated through a nozzle and discharge at high-speed free jet at atmospheric pressure, which then impinges the cascade of impulse buckets. The impact thus produced causes the runner to rotate and hence produces the mechanical power at the shaft.

DESCRIPTION

Schematic of the Pelton turbine experimental setup is shown in Figure 8.1. The Pelton turbine consists of three basic components, a stationary inlet nozzle, a runner and a casing. The runner consists of multiple buckets mounted on a rotating wheel. The jet strikes the buckets and imparts momentum. The buckets are shaped manner to divide the flow in half and turn its relative velocity vector nearly 180°. Nozzle is controlled by the spear valve attached. A pressure gauge is attached to the water pipe entering the turbine for reading the available water head. The discharge to the setup is supplied by a pump and discharge is calculated from reading of pressure gauge that is attached to the venturi meter. Power is measured from the turbine using rope brake arrangement with spring balance system.

FORMULAE USED:

Assuming that the speed of the exiting jet is zero (all of the kinetic energy of the jet is expended in driving the buckets), negligible head loss at the nozzle and at the impact with the buckets (assuming that the entire available head is converted into jet velocity)

1). Power Available to the turbine $P_{input} = \rho.g.Q.H$

where

ρ is the density of water,
g is the acceleration due to gravity,
Q can be calculated using venurimeter pressure reading as:

$$Q_{th} = \frac{A_2\sqrt{2g\cdot(p_1 - p_2)\cdot 10}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}}. \quad \text{or } Q_{act} = K\sqrt{(p_1 - p_2)}$$

where Venturi meter constant $K = \frac{C_d \cdot A_2\sqrt{20g}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}}.$,

Cd is the coefficient of discharge venturi meter

p_1, p_2 are pressure readings at the inlet and the throat of venturi meter respectively

H is the available head which can be computed from the P_i .

H = 10 * Pi. (in m), if Pi is measured in kg/cm^2.

By applying the angular momentum equation (assuming negligible angular momentum for the exiting jet),

2). The power developed by the turbine on the shaft of brake drum can be written as:

$$P_{output} = T.\omega = (W + M_h - S).g.r.\frac{2\pi N}{60}$$

where

T is the torque on the rotor (shaft),

ω is the rotational speed of the rotor (shaft),

W is the mass in kg.

g is the acceleration due to gravity, (m/sec^2)

r is the radius of the brake drum + half thickness of rope.

N is rpm of the brake drum shaft.

PRECAUTIONS

- Ensure all the gauges read zero under no load, no flow conditions.
- Allow the cooling water to flow along the brake drum when the turbine runs under load.
- Keep the spear valve closed until the supply pump develops necessary head.
- Load the turbine gradually.
- Let the speed of the turbine stabilize after each change in the load before taking the readings.
- Remove the load on the brake drum before switching off the supply.

PROCEDURE: (Instructional mode)

1. Note the nozzle diameter, pipe diameter, veturimeter specifications. Measure brake drum diameter. Remove all the loads from the brake drum.
2. Keep the spear valve and inlet valve closed. Start the pump.
3. Increase the nozzle opening (increment by 2) with the help of spear valve.
4. Gradually open the delivery valve to obtain the desired head and let the turbine run no load.
5. Note the venturi meter pressure gauge readings P_1 and P_2 for measuring the discharge ‘Q’.
6. Note the turbine pressure gauge reading P_i.
7. Note the spring balance reading and measure the shaft speed (N) using Tachometer.
8. Increase the weight on brake drum and note the spring balance reading and weight on the drum (S and W). Measure the speed of the shaft (N) using tachometer.
9. Repeat step 8 for total of 10 times.
10. Close the control valve.
11. Repeat steps 3 to 10 for at least 4 different nozzle openings.
12. Finally shutdown the power and close all the valves.

After entering the readings in the Tabulation 6.1 to 68.4, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

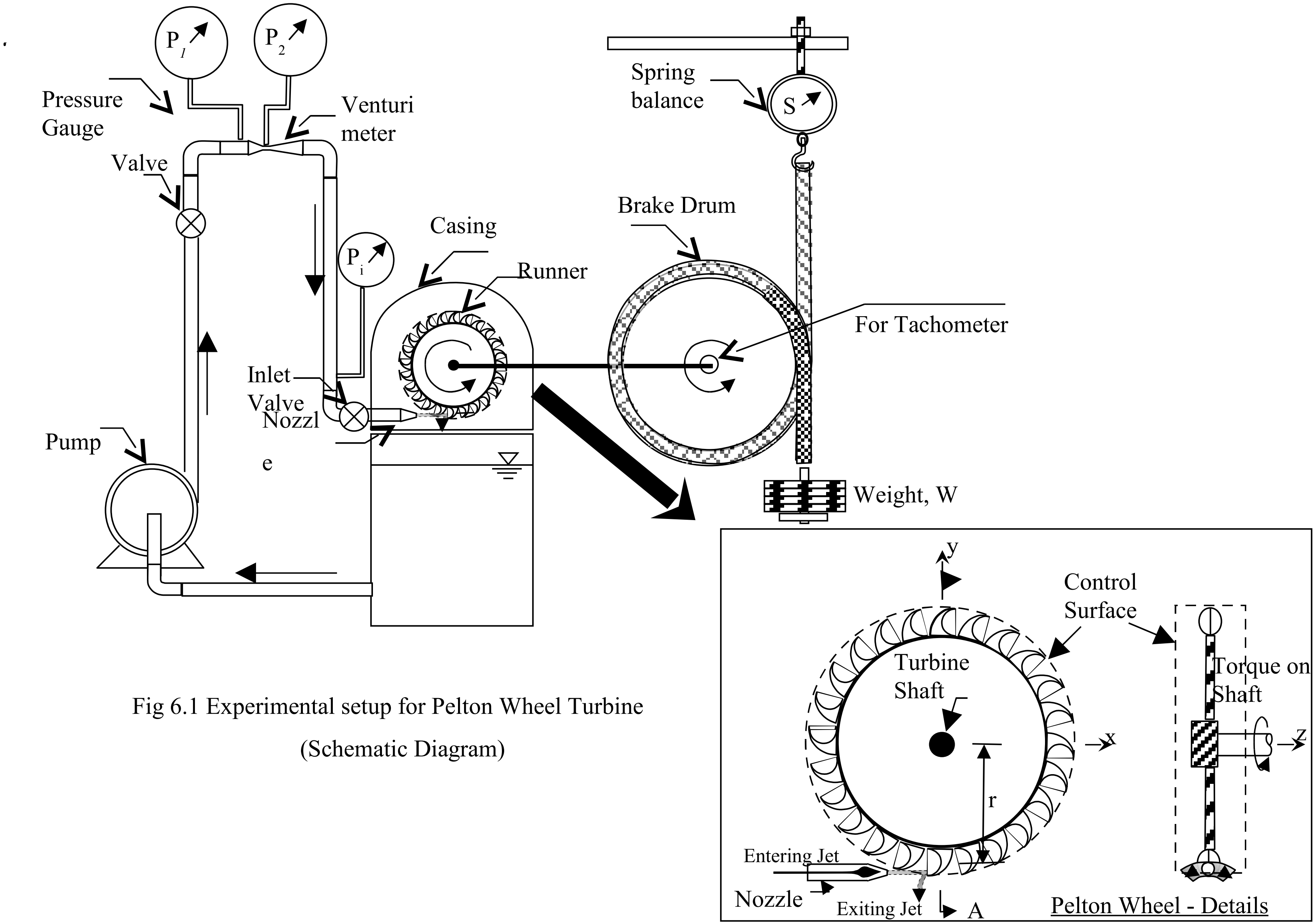

Fig 6.1 Experimental setup for Pelton Wheel Turbine

(Schematic Diagram)

OBSERVATION AND COMPUTATIONS – I

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Brake drum radius r1 = 0.2 m   Rope radius r2 = 0.0075 m   r=(r1+r2) = 0.2075 m   Mass of hanger M_h = 1 Kg

Venurimeter constants d_1 = m d_2 = m   Cd =0.98 A_1 = m^2 A_2 = m^2 K =

A) For 0.25% opening of spear valve.

Tabulation 6.1 – For 0.25% opening of spear valve

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure	Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i								
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

OBSERVATION AND COMPUTATIONS – II

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B) For 0.50% opening of spear valve.

Tabulation 6.2 – For 0.50% opening of spear valve

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure	Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i								
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

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C) For 0.75% opening of spear valve.

Tabulation 6.3 – For 0.75% opening of spear valve

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure	Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i								
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

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D) For full opening of spear valve.

Tabulation 6.4 – For full opening of spear valve

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure	Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i								
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

GRAPH:

1- Plotted unit Power P_u vs. unit speed N_u taking N_u on x -axis and unit Power P_u on y– axis for all cases in the same graph (4 curves)

2- Plotted efficiency η vs. unit speed N_u taking N_u on x -axis and η on y – axis for all the tables in the same graph(4 curves)

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. Why is splitter edge provided in the buckets?

2. Can the number of jet more than one? State the reason.

3. Give the reasons for all the points mentioned in the above section ‘precautions’. What happens if not followed.

4. What are the assumptions made in this experiment?

EX.NO: DATE:

7. FLOW THROUGH VENTURI METER

OBJECTIVES:

- To determine the coefficient of discharge C_d for the two different venturi meters.
- To study the variation of coefficient of discharge C_d with Reynolds Number

APPARATUS REQUIRED:

Pipe line setup with a venturi meter with flow control device.

Collecting tank

Stop watch

THEORY:

Venturi meter works based on the Bernoulli's principle that by reducing the cross-sectional area of the flow passage, a pressure difference is created between the inlet and throat and the measurement of the pressure enables the determination of the discharge through the pipe. Consider a cross section before the venturi throat as section (1) and a cross section at the venturi throat as section (2).

Assuming the flow to incompressible and inviscid between the section (1) and the Section (2), the continuity equation can be written as:

$Q = v_1 A_1 = v_2 A_2$ when v_1 and v_2 are the velocities, A_1 and A_2 are the in the section (1) and section (2)

and Bernoulli's equation can be written as:

$$\frac{p_1}{\rho g} + \frac{v_1}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2}{2g} + z_2$$

Substituting the values of v_1 in Bernoulli equation and rearranging the terms along with the manometer reading, discharge is obtained as:

$$Q_{th} = \frac{A_2\sqrt{2gH}}{\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}}.$$

Where H = $h_m * (\frac{\rho_m}{\rho} - 1)$ (h_m is differential level of Hg in manometer measured in meters, ρ_m and ρ are mass density of manometer fluid (usually mercury) and mass density of flowing fluid, respectively.)

For the known actual flow rate Q_{act} , venturi meter is calibrated and its

Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$

DESCRIPTION

A venturi meter is a device used for measuring the discharge through the pipes.

A Venturimeter consists of:

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

The inlet section of the Venturimeter is of the same diameter as that of the pipe, which is followed by a convergent cone. The convergent cone is a short pipe, which tapers from the original size of the pipe to that of the throat of the Venturimeter. The throat of the Venturimeter is a short parallel side tube having its cross-sectional area smaller than that of the pipe. The divergent cone of the Venturimeter is gradually diverging pipe with its cross-sectional area increasing from that of the throat to the original size of the pipe. All the flow meters need calibration a priori where a known quantity of fluid is passed through the flow meter and the differential pressure across the flow meter related to the actual flow rate through a discharge coefficient given as the ratio of actual to theoretical flow rate. The apparatus consist of a flow bench that allows water flow to the orifice meter and venturi meter. A manometer is connected at two points, one at the inlet of the venturi meter and the other at the venturi throat. Manometer is filled with enough mercury to read the differential head 'h_m'. Water is colleted in the collecting tank for arriving actual discharge using stop watch and the piezometric level attached to the collecting tank.

FORMULAE USED:

Coefficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$

Theortical discharge $Q_{th} = K\sqrt{H}$

Where Venturi meter constant $K = \dfrac{A_2\sqrt{2g}}{\sqrt{1-\left(\dfrac{A_2}{A_1}\right)^2}}$.

A_1 and A_2 are area of cross section of the pipe and area of the throat respectively.

$H = h_m \times (\frac{\rho_m}{\rho} - 1)$ (h_m is differential level of manometer fluid measured in meters)

Q_{act} = Actual discharge measured from volumetric technique.

PRECAUTIONS

- Since the apparatus is made for conducting many experiments, make sure only required valves are opened. Close all other valves which have to be in closed condition

PROCEDURE:

1. Note the inlet pipe diameter 'd_1' and inner throat diameter 'd_2' of the venturi meter.
2. Note the density of the manometer fluid 'ρ_m'and the flowing fluid 'ρ'. Mostly mercury is used as manometer fluid and water as flowing fluid in this lab. So ρ_m. =13.6 and ρ = 1.
3. Start the pump and adjust the control valve in the line for maximum discharge.
4. Measure the pressure difference 'h_m' across the venturi meter._
5. Note the piezometric reading 'z_0' in the collecting tank while switch on the stopwatch.
6. Record the time taken 'T' and the piezometric reading 'z_1' in the collecting tank after allowing sufficient water quantity of water in the collecting tank.
7. Decrease the flow rate through the system by regulating the control valve and wait till flow is steady.
8. Repeat the steps 4 to 6 for 5 different flow rates.

After entering the readings in the Tabulation 7.1 and 7.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

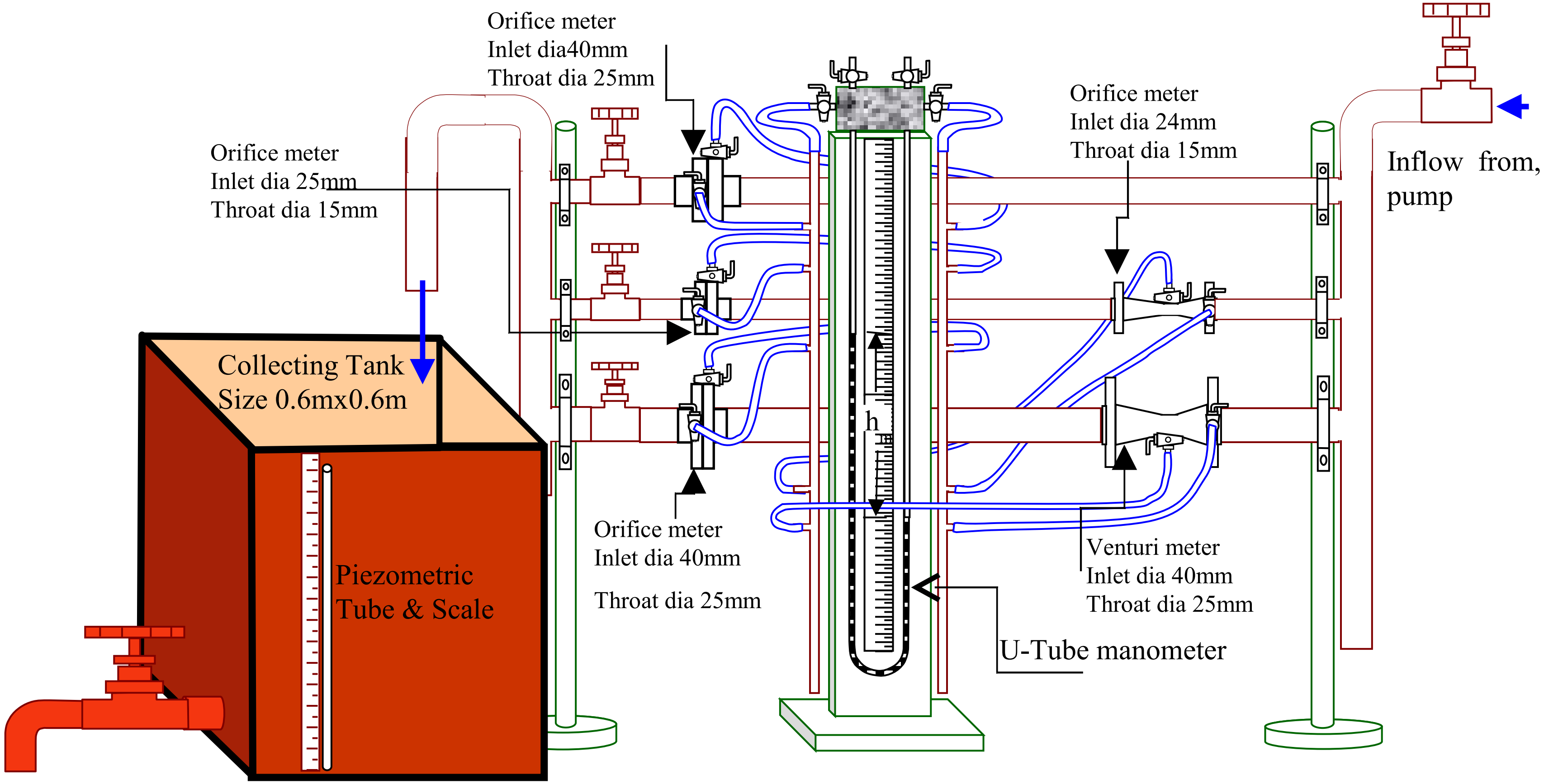

Fig 7.1 Orifice meters and Venturi meter test setup (MCET/BME/FM/E/006 setup)

OBSERVATION AND COMPUTATIONS – I

Date :________________

E) For venturi meter No. 1:

Diameter of inlet pipe 'd_1' = 0.04 m

Area of inlet 'A_1' = 1.2566×10^{-3} m^2

Diameter of throat 'd_2' = 0.025 m

Area of throat 'A_2' = 4.9087×10^{-4} m^2

Area of collecting Tank A_{ct} = 0.6m x 0.6m = 0.36 m^2

dynamic viscosity μ = 0.001 Pa.s

Density of the manometer liquid ρ_m = 13600 kg/m^3

Density of the flowing fluid ρ = 1000 kg/m^3

Hence, Venturi meter constant

$$K = \frac{A_2\sqrt{2g}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} = 0.002362$$

Tabulation 7.1 – For venturi meter No. 1.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				Cd	Reynolds no.
	h_m (m)	H (m) $(2)*(\frac{\rho_m}{\rho}-1)$	Theoretical Discharge, $Q_{th} = K\sqrt{H}$	Time T (sec)	Water Rise in Collecting Tank, R (m)	Volume (m^3) $A_{ct} * h_{ct}$	Discharge, Q_{act} (7)/(5)	$\frac{Q_{act}}{Q_{th}}$ (8)/(4)	$\frac{4\rho . Q_{act}}{\mu \, \pi \, . d_1}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
4									
5									
6									

Average value of Cd for venturi meter No. 1. = ________________

OBSERVATION AND COMPUTATIONS – II

Date : ________________

B) For venturi meter No. 2:

Diameter of inlet pipe 'd_1' = 0.024 m

Diameter of throat 'd_2' = 0.015 m

Area of collecting Tank A_{ct} = 0.6m x 0.6m = 0.36 m^2

Density of the manometer liquid ρ_m = 13600 kg/m^3

Area of inlet 'A_1' = 4.5239 x10^{-4} m^2

Area of throat 'A_2' = 1.7671x10^{-4} m^2

dynamic viscosity μ = 0.001 Pa.s

Density of the flowing fluid ρ = 1000 kg/m^3

Hence, Venturi meter constant

$$K = \frac{A_2\sqrt{2g}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} = 0.0008503$$

Tabulation 7.2 – For venturi meter No. 2.

No.↓	*Theoretical Discharge Measurement*			*Actual Discharge Measurement*				Cd	Reynolds no.
	h_m (m)	H (m) $(2) * (\frac{\rho_m}{\rho} - 1)$	Theoretical Discharge, $Q_{th} = K\sqrt{H}$	Time T (sec)	Water Rise in Collecting Tank, R (m)	Volume (m^3) $A_{ct} * h_{ct}$	Discharge, Q_{act} (7)/(5)	$\frac{Q_{act}}{Q_{th}}$ (8)/(4)	$\frac{4\rho . Q_{act}}{\mu \pi . d_1}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
4									
5									
6									

Average value of Cd for venturi meter No. 2.=

GRAPH:

1- C_d vs. Q_{act} are drawn in the same graph for both the venturi meters taking Q_{act} on x -axis and C_d on y – axis.

2- Q_{act} vs. $\sqrt{H}$ are drawn in the same graph for both the venturi meters taking H on x -axis and Q_{act} on y – axis.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. what is the venturi meter principle?.

2. What is your conclusion when you compare this results with those of orifice meter?

3. At what situation do you recommend orifice meter over venturi meter. Why?

EX.NO: DATE:

8. MINOR LOSSES IN PIPES

OBJECTIVES:

- To measure the head loss due to different pipe fittings at different flow rates and to determine the loss coefficient for sudden enlargement and sudden contraction of pipe fitting.

APPARATUS REQUIRED:

"Flow losses in pipes" apparatus with flow control device and manometer.

Collecting tank

Stop watch

THEORY:

Various fluids are transported through pipes. When the fluids flow through pipes, energy losses occur due to various reasons. Predominant loss is due to the pipe roughness. Also the additional components like inlet, outlet bends valves and etc. add to the overall head loss of the system. To provide adequate pumping requirements, it is necessary to add the head loss due to the pipe fittings in addition to the head loss due to friction of pipes.

A) The head loss due to sudden enlargement

Applying the Bernoulli's equation, momentum equation and continuity eqution, theretically, the head loss due to sudden enlargement has been calculated as:

$$h_e = \frac{\left(V_1 - V_2\right)^2}{2g}$$

where $h_e =$ Loss of head due to sudden enlargement,

Q = Discharge,

V_1 = Q/A_1 = Velocity at the inlet,

V_2 = Q/A_2 = Velocity at the enlarged section,

g = gravity due to acceleration.

However, using the measured the pressure head difference H, Bernoulli's equation can be written as

$$\frac{p_1 - p_2}{\rho g} = \frac{V_2^2 - V_1^2}{2g} + h_e \Rightarrow \quad - H = \frac{V_2^2 - V_1^2}{2g} + h_e$$

$$\Rightarrow \quad h_e = \frac{V_1^2 - V_2^2}{2g} - H \qquad \cdots \text{Eq (8.2)}$$

Then equating $h_e = K_e \dfrac{V_2^2}{2g}$ with equation (8.2) , loss coefficient K_e can be found as

$$K_e = \left(\frac{A_2^2}{A_1^2} - 1 \right) - \frac{2gH}{V_2^2} \quad \text{or} \quad K_e = \left(\frac{v_1^2}{v_2^2} - 1 \right) - \frac{2gH}{V_2^2}$$

B) The head loss due to sudden contraction

Expression for head loss due to the sudden enlargement is applicable for the sudden contraction condition. In this case loss is from the vena contracta section to the outlet section (contracted section).

So, $h_c = \dfrac{(V_c - V_2)^2}{2g} = \dfrac{V_2^2}{2g}\left(\dfrac{1}{C_c} - 1 \right)^2$ where Cc is coefficient of contraction.

When $k_c = \left(\dfrac{1}{C_c} - 1 \right)^2$, then

$$h_c = \frac{k_c V_2^2}{2g}$$

However, using the measured the pressure head difference H, Bernoulli's equation can be written as

$$\frac{p_1 - p_2}{\rho g} = \frac{V_2^2 - V_1^2}{2g} + h_c \Rightarrow \quad H = \frac{V_2^2 - V_1^2}{2g} + h_c$$

$$\Rightarrow \quad h_c = \frac{V_1^2 - V_2^2}{2g} + H \qquad \cdots \text{Eq (8.2)}$$

Then equating $h_c = K_c \dfrac{V_2^2}{2g}$ with equation (8.2) , loss coefficient K_e can be found as

$$K_e = \left(\frac{A_2^2}{A_1^2} - 1 \right) + \frac{2gH}{V_2^2}$$

DESCRIPTION

The experiment is performed by using a number of long horizontal pipes of different diameters connected to water supply using a regulator valve for achieving different constant flow rates. Pressure tappings are provided on each pipe at suitable distances apart and connected to U-tube differential manometer. Manometer is filled with enough mercury to read the differential head 'h_m'. Water is colleted in the collecting tank for arriving actual discharge using stop watch and the piezometric level attached to the collecting tank.

FORMULAE USED:

A). The head loss due to sudden enlargement can be calculated as:

$h_e = \dfrac{(V_1 - V_2)^2}{2g}$ and is to be compared with $h_e = \dfrac{V_2^2}{2g}\left(\dfrac{A_2^2}{A_1^2} - 1 \right) - H$

$$K_e = \left(\frac{A_2^2}{A_1^2} - 1 \right) - \frac{2gH}{V_2^2} \quad \text{or} \quad K_e = \left(\frac{v_1^2}{v_2^2} - 1 \right) - \frac{2gH}{V_2^2}$$

B) The head loss due to sudden contraction

$h_c = \dfrac{kV_2^2}{2g}$ and

$$K_e = \left(\frac{v_1^2}{v_2^2} - 1 \right) + \frac{2gH}{V_2^2}$$

where $h_e =$ Loss of head due to sudden enlargement,

$h_c =$ Loss of head due to sudden contraction,

Q_{act} = Actual Discharge,

$V_1 = Q_{act}/A_1$ = Velocity at the inlet,

$V_2 = Q_{act}/A_2$ = Velocity at the enlarged section,

g = gravity due to acceleration.

K_e = loss coefficient for sudden enlargement

K_c = loss coefficient for sudden contraction

Using interpolation, find out K from the following table.

A2/A1	0.1	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Cc	0.624	0.632	0.6375	0.643	0.659	0.681	0.712	0.755	0.813	0.892	1.0
K	0.365	0.340	0.324	0.308	0.266	0.219	0.164	0.106	0.055	0.015	0

PRECAUTIONS

- Since the apparatus is made for conducting many experiments, make sure only required valves are opened. Close all other valves which have to be in closed condition

PROCEDURE:

1. Note the inlet and outlet diameters of the test section.
2. Make sure only required water regulator valves and required valves at tappings connected to manometer are opened.
3. Start the pump and adjust the control valve just enough to make fully developed flow (pipe full flow).
4. Measure the pressure difference 'h_m' across the test section.
5. Record the time taken 'T' for the determined water level rise 'R' in the collecting tank.
6. Increase the flow rate by regulating the control valve and wait till flow is steady.
7. Repeat the steps 4 to 6 for 10 different flow rates.

After entering the readings in the respective tables and compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

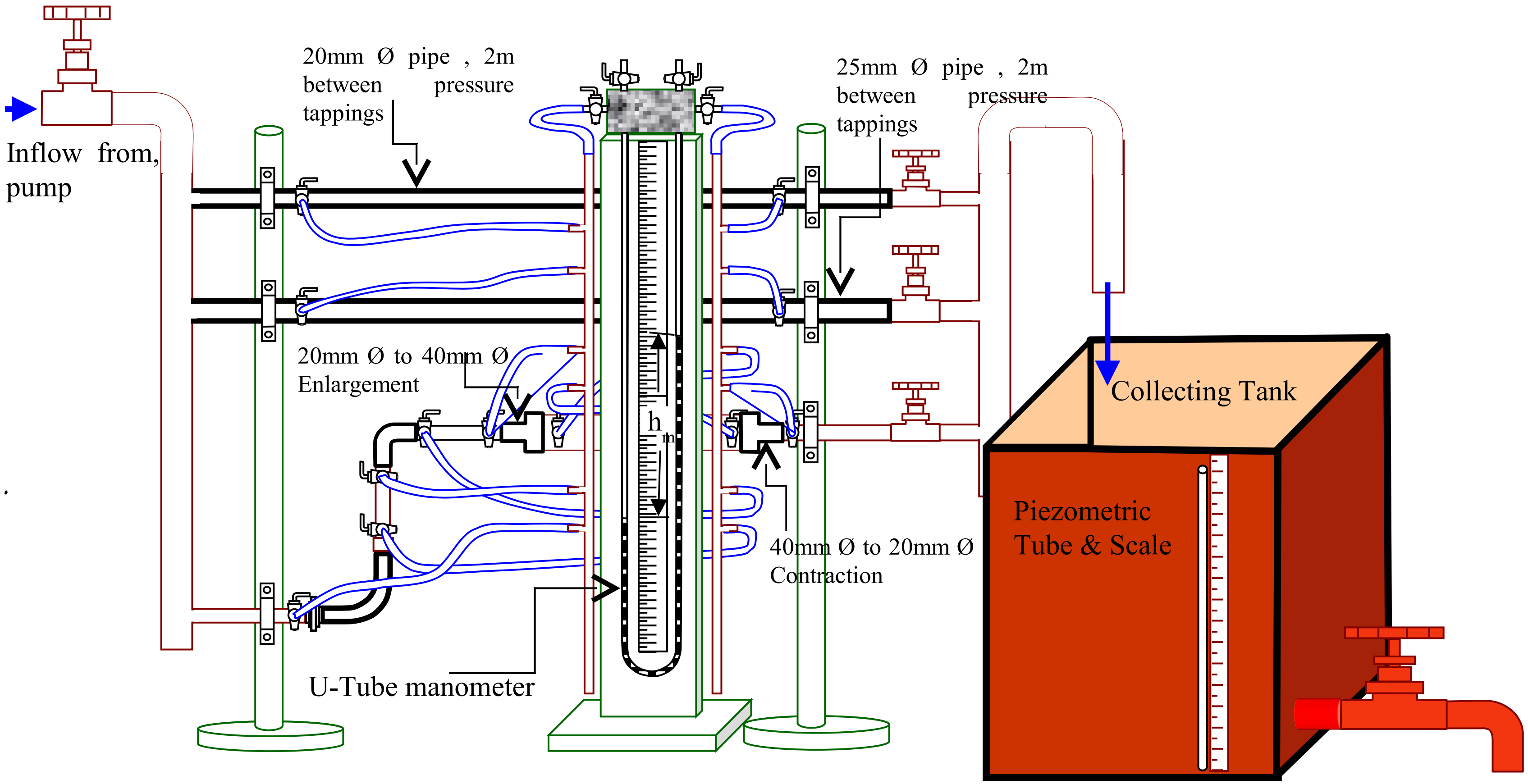

Fig 6.1 Experimental setup for finding friction losses (MCET/BME/FM/E/006 setup)

OBSERVATION AND COMPUTATIONS – I Date :________________

C) For sudden Enlargement:

Diameter of inlet ‘d_1’ = 0.02 m Area of inlet ‘A_1’ = 3.1416×10^{-4} m^2

Diameter of outlet ‘d_2’ = 0.04 m Area of outlet ‘A_2’ = 1.2566×10^{-3} m^2 Area of collecting Tank A_{ct} = 0.6 m x 0.6 m = 0.36 m^2

Density of the manometer liquid ρ_m = 13600 kg/m^3 Density of the flowing fluid ρ = 1000 kg/m^3

Tabulation 8.1 – For sudden Enlargement

No.↓	*Actual Measurement*			*Head loss obtained from discharge alone (Theoretical)*					*Head Loss obtained from manometer reading*		Loss coefficient $K_e = \left(\frac{v_1^2}{v_2^2} - 1\right) - \frac{2gH}{V_2^2}$
	Time T (sec)	Water Rise R (m)	h_m (m)	Volume colelcted (m^3)	Discharge $\mathbf{Q}_{act}$	V_1	V_2	h_e $\frac{(V_1 - V_2)^2}{2g}$	H (m) $h_m * (\frac{\rho_m}{\rho} - 1)$	$h_e = \frac{V_1^2 - V_2^2}{2g} - H$	
1											
2											
3											
4											
5											
6											
										TOTAL	

Average loss coefficient for the given enlargement K_e = ……………………………..

OBSERVATION AND COMPUTATIONS – II Date :______________

D) For sudden contraction:

Diameter of inlet ‘d_1’ = 0.04 m Area of inlet ‘A_1’ = 1.2566×10^{-3} m^2

Diameter of outnlet ‘d_2’ = 0.02 m Area of outlet ‘A_2’ = 3.1416×10^{-4} m^2 Area of collecting Tank A_{ct} = 0.6 m x 0.6 m = 0.36 m^2

Density of the manometer liquid ρ_m = 13600 kg/m^3 Density of the flowing fluid ρ = 1000 kg/m^3 K = 0.324 from interpolation.

Tabulation 8.2 – For sudden contraction

No.↓	*Actual Measurement*			*Head loss obtained from discharge alone (Theoretical)*					*Head Loss obtained from manometer reading*		Loss coefficient
	Time T (sec)	Water Rise R (m)	h_m (m)	Volume colelcted (m^3)	Discharge $\mathbf{Q}_{act}$	V_1	V_2	$h_c = \frac{kV_2^2}{2g}$	H= $h_m * (\frac{\rho_m}{\rho} - 1)$ (m)	$h_e = \frac{V_1^2 - V_2^2}{2g} + H$	$K_e = \left(\frac{v_1^2}{v_2^2} - 1\right) + \frac{2gH}{V_2^2}$
1											
2											
3											
4											
5											
6											
										TOTAL	

Average loss coefficient for the given sudden contraction K_c = ……………………………..

GRAPH:

1) Head loss h_e vs. Actual discharge Q_{act} for sudden enlargement, 2)Head loss h_c vs. Actual discharge Q_{act} for sudden contraction are plotted in the same graph. Actual Discharge Q_{act} is marked on the x-axis.
2) Loss coefficient K_e vs. Actual discharge Q_{act} for sudden enlargement, 2) Loss coefficient K_c vs. Actual discharge Q_{act} for sudden contraction are plotted in the same graph. Actual Discharge Q_{act} is marked on the x-axis.

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. if the same test section is used for sudden enlargement and sudden contraction, in which case head loss would be more?

2. What are basic equations required to solve the head loss due to sudden enlargement?

3. Which is experimental value out of h_e and h_L notations used in this experiment? Did you find the difference? Why?

EX.NO: DATE:

9. KAPLAN TURBINE

OBJECTIVES:

To study the operation of Kaplan turbine and to measure the power output of a Kaplan turbine.

To obtain the performance characteristics

APPARATUS REQUIRED:

Kaplan turbine unit

Water supply pump

Venturi meter with pressure gauges

Tachometer

Pressure gauge at the inlet to the turbine

Brake drum with spring balance and loading setup.

THEORY:

Hydraulic Turbines are machines which convert Hydro energy to mechanical energy. Kaplan Turbine is an axial flow reaction turbine with adjustable vanes. This turbine is suitable where large quantity of water at low head is available. Water under pressure from pump enters, through the volute casing and the guide vanes, into the runner. While passing through the spiral casing and guide vanes, a portion of the potential energy is converted into the kinetic energy. Water thus enters the runner at a high velocity and as it passes through the runner vanes, the remaining potential energy is converted into kinetic energy. Due to the curvature of the vanes, kinetic energy is transformed into the mechanical energy and hence the runner rotates. The water from the runner is then discharged into the draft tube.

The flow through the pipe is measured with the venturi meter fitted in the pipe line. Two pressure gauges are provided to measure the pressure difference between inlet and throat of the venturi meter. The net pressure difference across the turbine inlet and exit is measured with a pressure gauge and a vacuum gauge. These readings are sufficient to calculate the Power available to the turbine. The turbine output is determined with the brake drum setup and tachometer.

DESCRIPTION

Schematic of the Kaplan turbine experimental setup is shown in Figure 12.1. The apparatus consists of a casing with a runner. Guide vanes situated inside the casing directs the water to the Runner. Provision has been made such that the runner blades can be adjusted depending on the loading condition. The water exits through an elbow type horizontal draft tube placed in the collecting tank. Transparent window is provided on the casing for a clear view of the runner blades and its functioning. Pressure tappings at appropriate positions are provided to measure delivery and vacuum head. An extension shaft with housing is provided for connecting the Rotor to the loading arrangement. The setup includes a centrifugal pump of required capacity to deliver the water. Water from the sump tank is delivered through pipeline to the turbine casing. The discharge from the casing passes through the draft tube. Flow measurement is done by Venturi meter. Pressure gauges are fitted at the inlet and throat of the Venturi meter for flow measurement. The head is controlled by means of a delivery control valve. Power is measured from the turbine using rope brake arrangement with spring balance system.

FORMULAE USED:

1). Power Available to the turbine $P_{input} = \rho.g.Q.H$

where

ρ is the density of water,
g is the acceleration due to gravity,
Q can be calculated using venurimeter pressure reading as:

$$Q = C_d K \frac{\pi d_2^{\ 2}}{4} \sqrt{2(p_1 - p_2)g.10}$$

where Cd is the coefficient of discharge venturi meter

$$K = \sqrt{\frac{1}{1 - \left(\frac{d_2}{d_1}\right)^4}}$$

d_1, d_2 are inner diameters of the venturi inlet and the throat respectively

p_1, p_2 are pressure readings at the inlet and the throat of venturi meter respectively

H is the available head which can be computed from the pressure at inlet of the turbine P_i and vacuum gauge reading P_v .

$$H = 10 * [Pi + (P_v/760)]. \text{ (in m), if Pi and } P_v \text{ are measured in kg/cm}^2.$$

2). The power developed by the turbine on the shaft of brake drum can be written as:

$$P_{output} = T.\omega = (W + M_h - S).g.r.\frac{2\pi N}{60}$$

where

T is the torque on the rotor (shaft),

ω is the rotational speed of the rotor (shaft),

W is the mass in kg.

g is the acceleration due to gravity, (m/sec^2)

r is the radius of the brake drum + half thickness of rope.

N is rpm of the brake drum shaft.

PRECAUTIONS

- Ensure all the gauges read zero under no load, no flow conditions.
- Allow the cooling water to flow along the brake drum when the turbine runs under load.
- Load the turbine gradually.
- Let the speed of the turbine stabilize after each change in the load before taking the readings.
- Remove the load on the brake drum before switching off the supply.

PROCEDURE:

1. Note the venturi meter specifications. Measure brake drum diameter and the rope diameter.
2. Keep the rotor vanes in half opening position.
3. Close the delivery valve and start the pump.
4. Gradually open the delivery valve so that the turbine rotor picks up the speed to the maximum.
5. Load the turbine by adding weights on the brake drum weight hanger.
6. Note the venturi meter pressure gauge readings ‘p_1’ and ‘p_2’ for measuring the discharge ‘Q’.
7. Note the turbine inlet pressure gauge reading P_i and vacuum gauge reading P_v.

8. Note the spring balance reading and weight (S and W) and measure the shaft speed (N).
9. Take 8 readings of ‘N’, in the allowable range of speed by varying the load (S and W) on the brake drum.
10. Repeat steps 3 to 9 for other rotor position (for full opening angle).
11. For main characteristic curves, constant head is to be maintained. So the main valve has to be adjusted to keep the total head constant when vary the loads.

After entering the readings in the Tabulation 9.1 to 9.2, compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

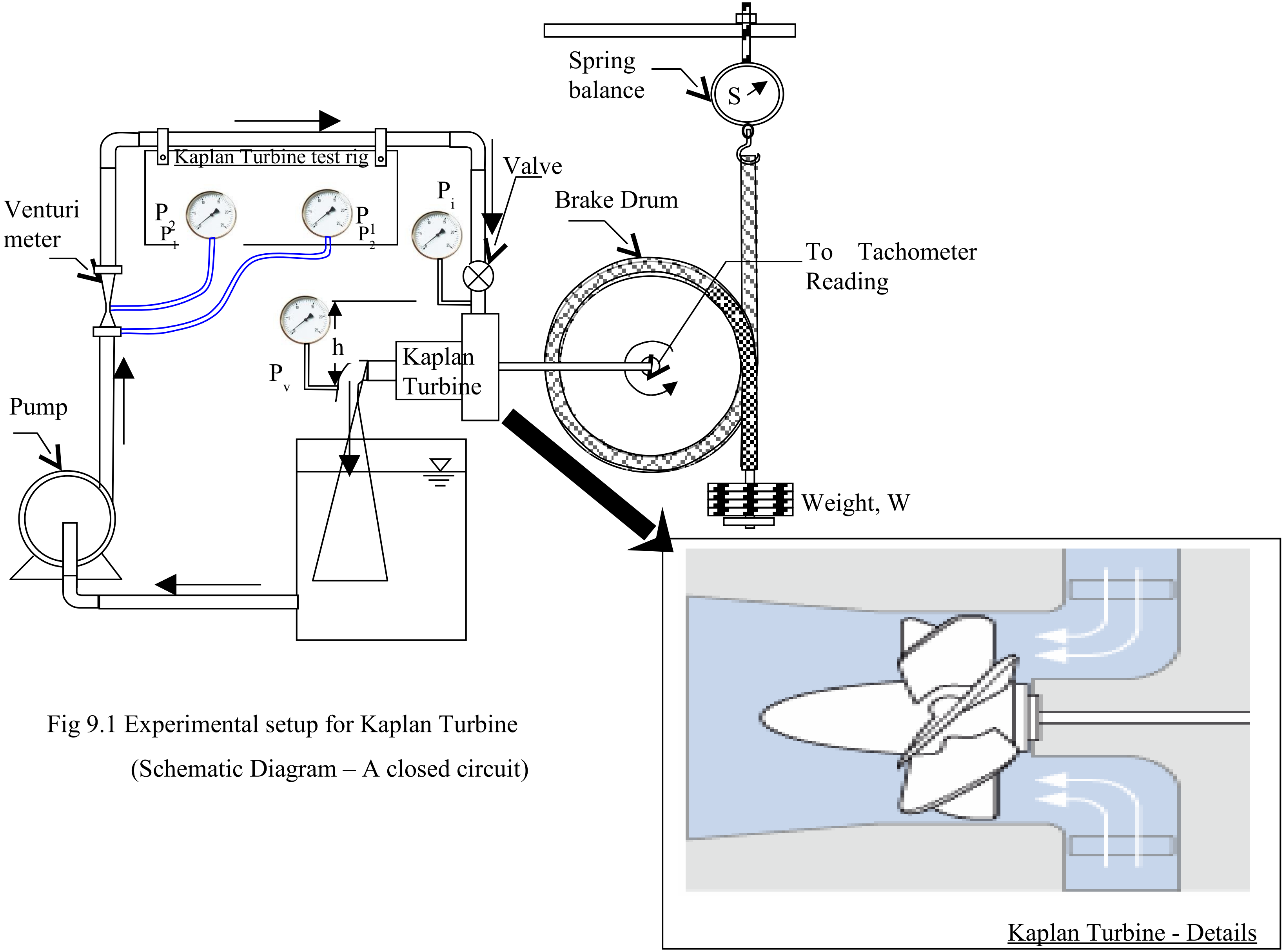

Fig 9.1 Experimental setup for Kaplan Turbine

(Schematic Diagram – A closed circuit)

OBSERVATION AND COMPUTATIONS – I   Date :________________

Density of water ρ = 1000 kg/m^3

Brake drum radius r1 = 0.1 m   Rope radius r2 = 0.0075 m   r=(r1+r2) = 0.1075 m   Mass of hanger M_h =   Kg

Venurimeter constants Cd = 0.98   d1=0.1 m   d2= 0.06 m   K = 1.072

A) For full gate opening - Tabulation 9.1

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure		Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i	P_v								
1															
2															
3															
4															
5															
6															
7															
8															

B) For half gate opening - Tabulation 9.2

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure		Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i	P_v								
1															
2															
3															
4															
5															
6															
7															
8															

C) For ¼ of gate opening - Tabulation 9.3

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure		Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i	P_v								
1															
2															
3															
4															
5															
6															
7															
8															

GRAPH:

1- Plotted unit Power P_u vs. unit speed N_u taking N_u on x -axis and unit Power P_u on y– axis for both the tables in the same graph (2 curves

2- Plotted efficiency η vs. unit speed N_u taking N_u on x -axis and η on y – axis for both the tables in the same graph(2 curves)

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. What is the difference between pelton wheel turbine and Kaplan turbine?
2. Differentiate the reaction, propeller, axial flow, radial flow turbines.
3. What is draft tube? Why is it used?
4. What are the assumptions made in this experiment?

EX.NO: DATE:

10. FRANCIS TURBINE

OBJECTIVES:

To study the operation of Francis turbine and to measure the power output of a Francis turbine.

To obtain the performance characteristic curves.

APPARATUS REQUIRED:

Francis turbine unit

Water supply pump

Venturi meter with pressure gauges

Tachometer

Pressure gauge at the inlet to the turbine

Brake drum with spring balance and loading setup.

THEORY:

Hydraulic Turbines are machines which convert hydro energy to mechanical energy. Francis Turbine is a radial flow reaction turbine with adjustable guiding vanes. Francis turbines are used for medium heads and medium flow rates. Water is delivered into a volute casing which completely surrounds the runner and is under pressure as well as velocity. The water is guided through both fixed and adjustable vanes in the casing and glides onto the runner blades at an angle. The water then turns in the runner to exit parallel with the axis of rotation. Finally the water from the runner is discharged into the draft tube.

The flow through the pipe is measured with the venturi meter fitted in the pipe line. Two pressure gauges are provided to measure the pressure difference between inlet and throat of the venturi meter. The net pressure difference across the turbine inlet and exit is measured with a pressure gauge and a vacuum gauge. These readings are sufficient to calculate the Power available to the turbine. The turbine output is determined with the brake drum setup and tachometer.

DESCRIPTION

Schematic of the Francis turbine experimental setup is shown in Figure 12.1. The turbine consists of a spiral casing, adjustable guide blade arrangement and break drum arrangement. Guide blades are controlled manually for which a hand wheel is provided.

The water exits through a elbow type horizontal draft tube placed in the collecting tank. Transparent window is provided on the casing for a clear view of the runner blades and its functioning. Pressure tappings at appropriate positions are provided to measure delivery and vacuum head. An extension shaft with housing is provided for connecting the rotor to the loading arrangement. The setup includes a centrifugal pump of required capacity to deliver the water. Water from the sump tank is delivered through pipeline to the turbine casing. The discharge from the casing passes through the draft tube. Flow measurement is done by Venturi meter. Pressure gauges are fitted at the inlet and throat of the Venturi meter for flow measurement. The head is controlled by means of a delivery control valve. Power is measured from the turbine using rope brake arrangement with spring balance system.

FORMULAE USED:

1). Power Available to the turbine $P_{input} = \rho.g.Q.H$

where

ρ is the density of water,
g is the acceleration due to gravity,
Q can be calculated using venurimeter pressure reading as:

$$Q = C_d K \frac{\pi d_2^{\,2}}{4} \sqrt{2(p_1 - p_2)g.10}$$

where Cd is the coefficient of discharge venturi meter

$$K = \sqrt{\frac{1}{1 - \left(\frac{d_2}{d_1}\right)^4}}$$

d_1, d_2 are inner diameters of the venturi inlet and the throat respectively

p_1, p_2 are pressure readings at the inlet and the throat of venturi meter respectively

H is the available head which can be computed from the pressure at inlet of the turbine P_i and vacuum gauge reading P_v .

H = 10 * [Pi+ (P_v/760)]. (in m), if Pi is measured in kg/cm^2 and Pv is in mm of Hg.

2). The power developed by the turbine on the shaft of brake drum can be written as:

$$P_{output} = T.\omega = (W + M_h - S).g.r.\frac{2\pi N}{60}$$

where

T is the torque on the rotor (shaft),

ω is the rotational speed of the rotor (shaft),

W is the mass in kg.

g is the acceleration due to gravity, (m/sec^2)

r is the radius of the brake drum + half thickness of rope.

N is rpm of the brake drum shaft.

PRECAUTIONS

- Ensure all the gauges read zero under no load, no flow conditions.
- Allow the cooling water to flow along the brake drum when the turbine runs under load.
- Load the turbine gradually.
- Let the speed of the turbine stabilize after each change in the load before taking the readings.
- Remove the load on the brake drum before switching off the supply.

PROCEDURE:

1. Note the venturi meter specifications. Measure brake drum diameter and the rope diameter.
2. Keep the guiding vane at suitable angle.
3. Close the delivery valve and start the pump.
4. Gradually open the delivery valve so that the turbine rotor picks up the speed to the maximum.
5. Load the turbine by adding weights on the brake drum weight hanger.
6. Note the venturi meter pressure gauge readings 'p_1' and 'p_2' for measuring the discharge 'Q'.

7. Note the turbine inlet pressure gauge reading P_i and vacuum gauge reading P_v.
8. Note the spring balance reading and weight (S and W) and measure the shaft speed (N).
9. Take 8 readings of 'N', in the allowable range of speed by varying the load (S and W) on the brake drum.
10. Repeat steps 3 to 9 for other rotor position (for full opening angle).
11. For main characteristic curves, constant head is to be maintained. So the main valve has to be adjusted to keep the total head constant when vary the loads.

After entering the readings in the respective tables and compute the necessary values.

PROCEDURE (Write down your own procedure in presentation mode)

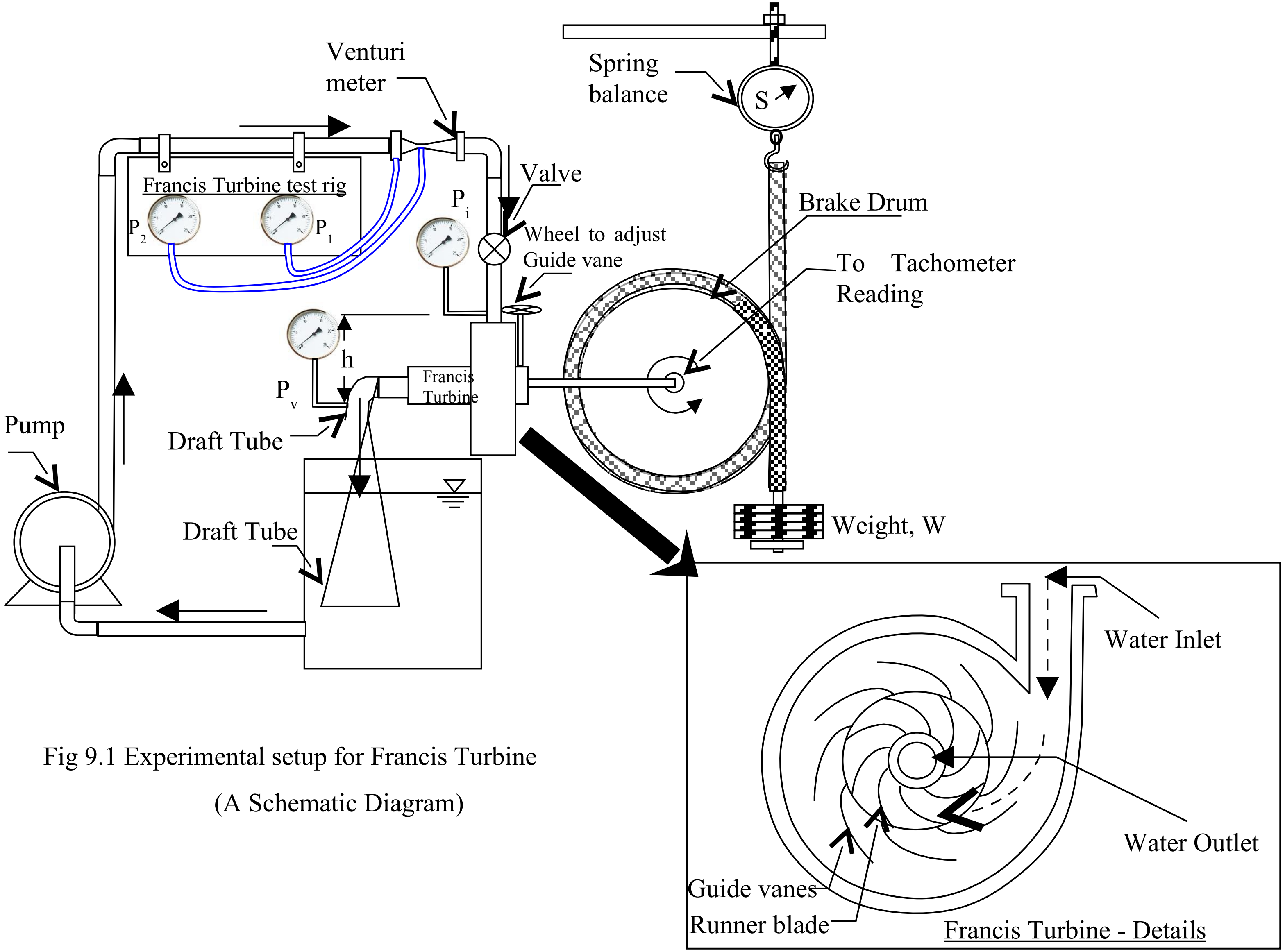

Fig 9.1 Experimental setup for Francis Turbine

(A Schematic Diagram)

OBSERVATION AND COMPUTATIONS – I   Date :________________

Density of water ρ = 1000 kg/m^3

Brake drum radius r1 = 0.15 m   Rope radius r2 = 0.0075 m   r=(r1+r2) = 0.1575 m   Mass of hanger M_h =   Kg

Venurimeter constants Cd = 0.98   d1= 0.1 m   d2= 0.06 m   K = 1.072

A) For half opened guide blade position. : Tabulation 10.1

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure		Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i	P_v								
1															
2															
3															
4															
5															
6															
7															
8															

OBSERVATION AND COMPUTATIONS – II

Date :_______________

B) For fully opened guide blade position : Tabulation 10.2

No	W (kg)	S (kg)	Speed N(rpm)	Venturimeter		Turbine Pressure		Q	H	Torque T	P_{input}	P_{output}	Unit Speed $N_u = \frac{N}{\sqrt{H}}$	Unit Power $P_u = \frac{P_{output}}{H^{3/2}}$	Efficiency η
				P_1	P_2	P_i	P_v								
1															
2															
3															
4															
5															
6															
7															
8															

GRAPH:

1- Plotted unit Power P_u vs. unit speed N_u taking N_u on x -axis and unit Power P_u on y– axis for both the tables in the same graph (2 curves

2- Plotted efficiency η vs. unit speed N_u taking N_u on x -axis and η on y – axis for both the tables in the same graph(2 curves)

RESULTS AND COMMENTS

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

1. What is the difference between Francis turbine and Kaplan turbine?

2. Differentiate the reaction, propeller, axial flow, radial flow turbines.

3. What is draft tube? Why is it used?

4. What are the assumptions made in this experiment?

EX.NO: DATE:

11. PERFORMANCE TEST ON CENTRIFUGAL PUMP

OBJECTIVES:

To study the operation of centrifugal pump and to obtain the performance characteristic curves.

APPARATUS REQUIRED:

Centrifugal pump with pressure gauge and vacuum gauge setup.

Stop Watch

Collecting tank

Scale

Tachometer

Energy meter

THEORY:

A centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the pressure of a fluid. The pump works by the conversion of the rotational kinetic energy, typically from an electric motor or turbine, to an increased static fluid pressure. This action is described by Bernoulli's principle. The rotation of the pump impeller imparts kinetic energy to the fluid as it is drawn in from the impeller eye and is forced outward through the impeller vanes to the periphery. As the fluid exits the impeller, the fluid kinetic energy is then converted to pressure due to the change in area the fluid experiences in the volute section. The energy conversion, results in an increased pressure on the delivery side of the pump, causes the flow.

DESCRIPTION

The test pump is a single stage centrifugal pump. It is coupled with an electric motor by means cone pulley belt drive system. An energy meter is permanently connected to measure the energy consumed by the electric motor for driving the pump. A stop watch is provided to measure the input power to the pump. A pressure gauge and a vacuum gauge are fitted it the delivery and suction pipes, respectively, to measure the pressure.

FORMULAE USED:

1) TOTAL HEAD $H = 10(p_d + \frac{p_v}{760}) + h$ m

Where p_d is the pressure gauge reading at delivery section in kg/cm^2

p_v is the vacuum gauge reading at suction section in mm of Hg

h is the vertical distance between the vacuum gauge and pressure gauge.

2) Discharge Q = $\frac{Volume\ collected}{Time\ Taken} = \frac{A_{ct} \times R}{T_C}$ m^3/s

Where A_{ct} is collecting tank area

R is the height of water rise in the collecting tank

Tc is the time taken

3) Power output of the pump $P_O = \rho g Q H$ N.m/s or Watt

4) Power input to the motor = $\frac{N_R \times 3600 \times 10^3}{N_e \times T}$ N.m/s or Watt

Where N_e is the energy meter constant ie. N_e revolution for 1KWh.

T is the time in sec for N_R revolution in energy meter

5) Power input to the pump $P_I = \frac{N_R \times 3600 \times 10^3}{N_e \times T} \times 0.8 \times 0.9$ N.m/s or Watt

Where N_e is the energy meter constant ie. N_e revolution for 1KWh.

T is the time in sec for N_R revolution in energy meter

0.8 and 0.9 are assumed values for the efficiency of the motor and the belt transmission efficiency, respectively

6) % Efficiency = $\eta = \frac{P_O}{P_I} \times 100$

PRECAUTIONS

- Ensure zero reading in pressure gauge and vacuum gauge before starting the experiment

PROCEDURE:

- Note the collecting tank measurements, energy meter constant N_e and vertical distance 'h' from the vacuum gauge and pressure gauge.
- Keep the delivery valve fully closed and suction valve fully open, after initially priming the pump.
- Start the motor
- Adjust the gate value for a required flow rate. For this flow note the following readings:
  - Pressure gauge reading p_d
  - Vacuum gauge reading p_v
  - Speed of the pump using tachometer reading (N) rpm
  - Time T in seconds for N_R revolutions in energy meter.
  - Time taken in seconds for determined height rise in the collecting tank.
- Repeat the step 4 for the 10 different flow rates.
- Repeat the same test by changing belt to the other pulley.

PROCEDURE (Write down your own procedure in presentation mode)

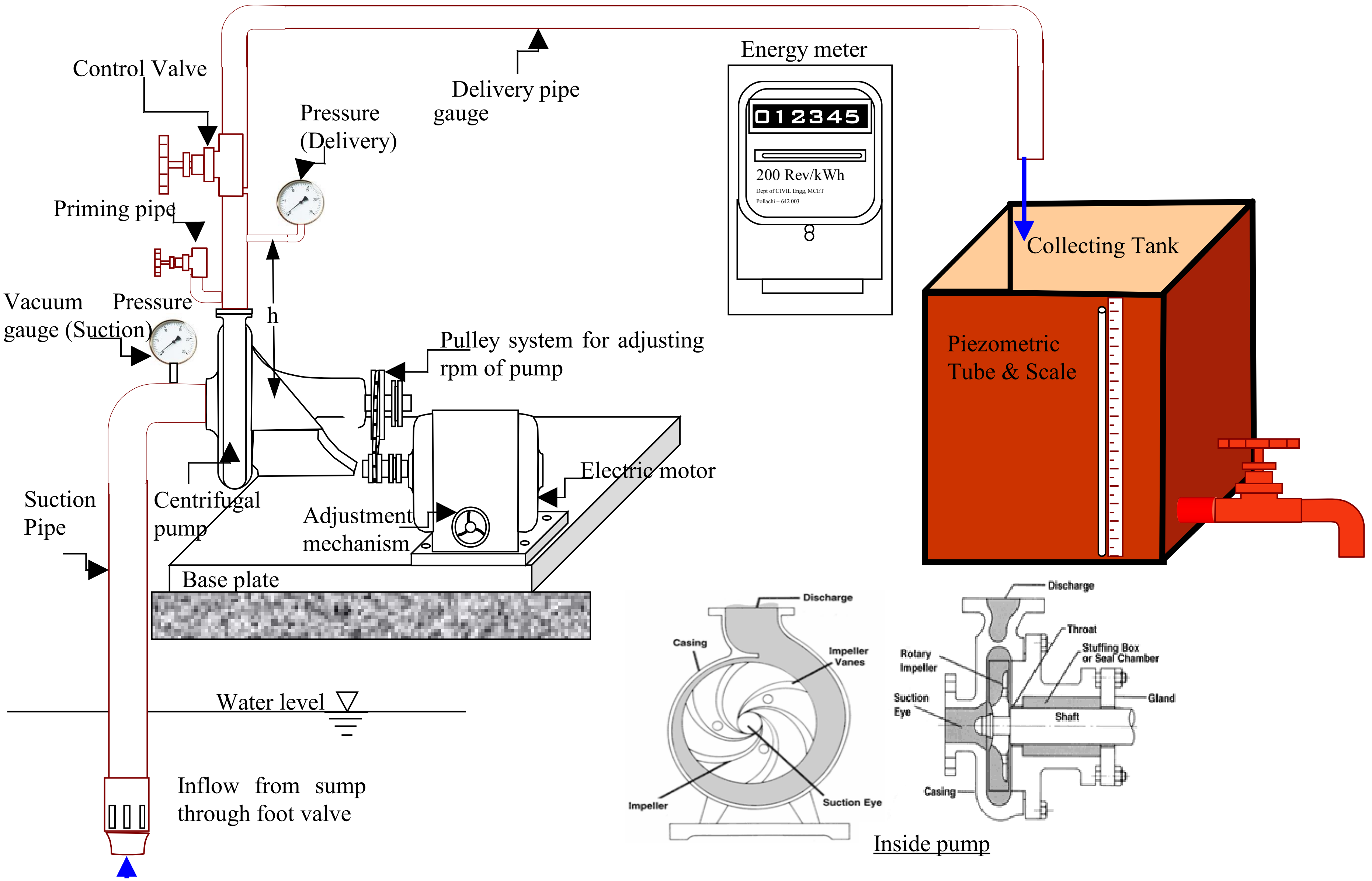

Fig. 11.1 Centrifugal pump test rig

OBSERVATION AND COMPUTATIONS – I   Date :_______________

Density of water $\rho = 1000$ kg/m^3 Acceleration due to gravity $g = 9.81$ m/s^2 m

Energy meter Constant N_e = ... Vertical height between pressure gauge and vacuum gauge 'h' = ... m

Area of collecting tank =

Table 11.1 For belt connected to the pulley No:

No	Pump Speed N	Pressure gauge P_d	Vacuum gauge P_v	Total Head H	R (m)	Tc (sec)	Q	N_R	T	Power input P_I	Power Output P_O	Efficiency η %
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Table 11.2 For belt connected to the pulley No:

No	Pump Speed N	Pressure gauge P_d	Vacuum gauge P_v	Total Head H	R (m)	Tc (sec)	Q	N_R	T	P_{input} P_I	P_{output} P_O	Efficiency η %
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

GRAPH:

Readings observed during the falling head experiments were used in this graph.

1. H vs Q , P_I vs. Q, P_O vs. Q and η vs. Q, drawn taking Q on x -axis and others on y – axis (Table 9.1 and Table 9.2) 2 curves in each graph. 4 graphs.

RESULTS AND COMMENTS

The performance test on centrifugal pump was conducted and the characteristic curves were drawn.

Maximum efficiency is found as % and

corresponding discharge is m^3/s

corresponding power output is KW

corresponding head is m

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

- What is priming? Why is it necessary?

- Where do you recommend centrifugal pumps over reciprocating pumps?

- What is cavitation? What is the effect of cavitation?

EX.NO: DATE:

12. PERFORMANCE TEST ON RECIPROCATING PUMP

OBJECTIVES:

To conduct the performance test and there by study the characteristics of the reciprocating pump.

APPARATUS REQUIRED:

Reciprocating pump with pressure gauge and vacuum gauge setup.

Stop Watch

Collecting tank

Scale

Tachometer

Energy meter

THEORY:

A reciprocating pump is a positive displacement type pump, because of the liquid is sucked and displaced due to the thrust exerted on it by a moving piston inside the cylinder. The cylinder has two one-way valves, one for allowing water into the cylinder from the suction pipe and the other for discharging water from the cylinder to the delivery pipe. The pump operates in two strokes. During suction stroke, the suction valve opens and delivery valve closes while the piston move away from the valve. This movement creates low pressure/partial vacuum inside the cylinder hence water enters through suction valve. During delivery stroke, the piston moves towards the valves. Due to this, the suction valve closes and the delivery valve opens, hence liquid is delivered through delivery valve to the delivery pipe.

DESCRIPTION

The reciprocating pipe consists of a pump cylinder, piston, piston rod, crank, connecting rod, suction pipe, delivery pipe, suction valve and delivery valve. It is coupled with an electric motor by means cone pulley belt drive system. An energy meter is permanently connected to measure the energy consumed by the electric motor for driving the pump. A stop watch is provided to measure the input power to the pump. A pressure gauge and a vacuum gauge are fitted it the delivery and suction pipes, respectively, to measure the pressure.

FORMULAE USED:

1) TOTAL HEAD $H = 10(p_d + \frac{p_v}{760}) + h$ m

Where p_d is the pressure gauge reading at delivery section in kg/cm^2

p_v is the vacuum gauge reading at suction section in kg/cm^2

h is the vertical distance between the vacuum gauge and pressure gauge.

2) Discharge Q = $\frac{Volume\ collected}{Time\ Taken} = \frac{A_{ct} \times R}{T_C}$ m^3/s

Where A_{ct} is collecting tank area

R is the height of water rise in the collecting tank

Tc is the time taken

3) Power output of the pump $P_O = \rho g Q H$ N.m/s or Watt

4) Power input to the motor = $\frac{N_R \times 3600 \times 10^3}{N_e \times T}$ N.m/s or Watt

Where N_e is the energy meter constant ie. N_e revolution for 1KWh.

T is the time in sec for N_R revolution in energy meter

5) Power input to the pump $P_I = \frac{N_R \times 3600 \times 10^3}{N_e \times T} \times 0.8 \times 0.9$ N.m/s or Watt

Where N_e is the energy meter constant ie. N_e revolution for 1KWh.

T is the time in sec for N_R revolution in energy meter

0.8 and 0.9 are assumed values for the efficiency of the motor and the belt transmission efficiency, respectively

6) % Efficiency = $\eta = \frac{P_O}{P_I} \times 100$

PRECAUTIONS

- Ensure zero reading in pressure gauge and vacuum gauge before starting the experiment

PROCEDURE:

- Note the collecting tank measurements, energy meter constant N_e and vertical distance 'h' from the vacuum gauge and pressure gauge.
- Keep the delivery valve fully closed and suction valve fully open, after initially priming the pump.
- Start the motor
- Adjust the gate value for a required flow rate. For this flow note the following readings:
    - Pressure gauge reading p_d
    - Vacuum gauge reading p_v
    - Speed of the pump using tachometer reading (N) rpm
    - Time T in seconds for N_R revolutions in energy meter.
    - Time taken in seconds for determined height rise in the collecting tank.
- Repeat the step 4 for the 10 different flow rates.
- Repeat the same test by changing belt to the other pulley.

PROCEDURE (Write down your own procedure in presentation mode)

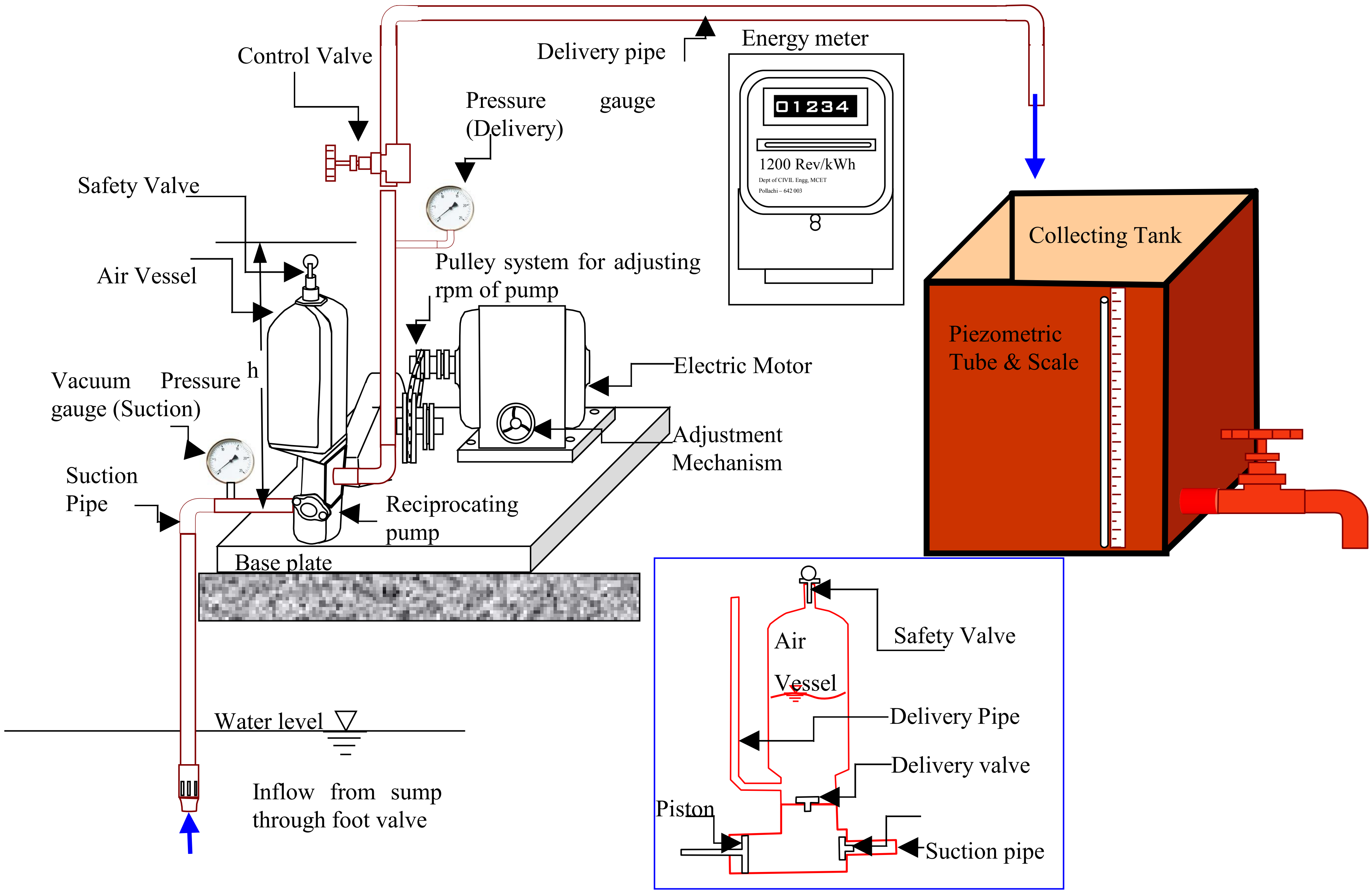

Fig. 11.1 Single acting reciprocating pump test rig

Inside pump

OBSERVATION AND COMPUTATIONS – I

Date :_______________

Density of water ρ = 1000 kg/m^3 Acceleration due to gravity g = 9.81 m/s^2 m

Energy meter Constant N_e = ... Vertical height between pressure gauge and vacuum gauge 'h' = ... m

Area of collecting tank =

Table 12.1 For belt connected to the pulley No:

No	Pump Speed N	Pressure gauge P_d	Vacuum gauge P_v	Total Head H	R (m)	Tc (sec)	Q	N_R	T	Power input P_I	Power Output P_O	Efficiency η %
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Table 12.2 For belt connected to the pulley No:

No	Pump Speed N	Pressure gauge P_d	Vacuum gauge P_v	Total Head H	R (m)	Tc (sec)	Q	N_R	T	P_{input} P_I	P_{output} P_O	Efficiency η %
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GRAPH:

Readings observed during the falling head experiments were used in this graph.

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RESULTS AND COMMENTS

The performance test on reciprocating pump was conducted and the characteristic curves were drawn.

Maximum efficiency is found as % and

corresponding discharge is m^3/s

corresponding power output is KW

corresponding head is m

POST EXPERIMENT ACTIVITIES

The apparatus should be drained and cleaned after use.

QUESTIONS FOR DISCUSSION

- What is an air vessel? Describe its functions.
- Where do you recommend reciprocating pumps over centrifugal pumps?
- What are the difficulties you had while taking measurements?