FLUID MECHANICS AND MACHINERY LABORATORY MANUAL

MECHANICAL ENGINEERING DEPARTMENT

(ISO 9001:2008 Certified)

MES COLLEGE OF ENGINEERING, KUTTIPPURAM

Fluid Mechanics and Machinery Laboratory Manual

MECHANICAL ENGINEERING DEPARTMENT

MES
College Of Engineering

Revision	Date	Prepared by			Approved by		
		Name	Designation	Signature	Name	Designation	Signature
Rev1.0	01-11-2018	Muhammed Azeem V	Asst. Prof.& Lab in charge		Dr.Rahmathunza. I	Prof. & HoD ME Dept.	

VISION

To develop the Department into a premier destination of international level for advanced learning in Mechanical Engineering and to mould quality engineers to serve the society through creative solutions.

MISSION

- To mould engineers who would be able to apply the basic science and mathematics with confidence in professional activities for the benefit of all.
- To make our graduates experts in practical problem solving with abstract thinking skills.
- To make our students life-long learners capable of building their careers upon a solid foundation of knowledge and competent in communicating technical materials and concepts in individual group situations

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

After 3-4 years of graduation, our students will be able to

- Demonstrate their skills in technical profession and/or higher education by using the acquired knowledge in Mathematics, Science and Engineering fundamentals.
- Analyze the real life problems and propose sustainable design solutions for specific needs through applications of Engineering principles.
- Recognize the ethical responsibility as engineers and judiciously serve their peers, employers & society for the benefit of all.
- Practice life-long learning by continuing up gradation of possessed skills.

PROGRAM SPECIFIC OUTCOMES (PSOs)

At the end of four year programme the students (graduates) will be able to:

- Demonstrate basic knowledge in mathematics, science and engineering.
- Design, manufacture and analyze a Mechanical system using modern engineering software tools and measurement systems.
- Cognize concepts involved in thermal and fluid energy systems.
- Utilize self education to develop lifelong learning to appraise and adapt global and societal contexts to propose Engineering solutions.

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analy**sis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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Course Outcomes (CO's)

Course Outcomes (COs)

ME230 FLUID MECHANICS AND MACHINES LABORATORY (C 216)	
C216.1	Able to demonstrate physical basis of Bernoulli's equation, and apply it in different flow measurement devices
C216.2	Able to examine and infer the performance of different hydraulic pumps and turbines

CALIBRATION OF RECTANGULAR NOTCH

AIM

1. To calibrate the given rectangular notch and determine the coefficient of discharge for different flow rates

2. To plot the following graphs:

   a) Coefficient of discharge vs. head over notch

   b) Actual discharge vs. head over notch

   c) Calibration curve for actual discharge vs. head

APPARATUS REQUIRED

1. Test set up of the rectangular notch fitted on the open channel
2. A measuring tank with standard fitting for accessing the discharge
3. Stop watch
4. Meter scale to measure the measuring tank size.

SPECIFICATION

Width of notch, L = 10 cm

Depth of notch, D = 10 cm

PRINCIPLE

The test is conducted by varying the discharge in steps from full to near zero value. At each discharge suitable observations are made to determine the discharge and head over notch.

The calculations involved are given below:

a) Actual discharge, Qa

$$Q_a = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

t_m – mean time for rise of water in measuring tank through ‘h’ height, (s)

Observation data:

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 10cm = 0.1 m

Width of notch, L =

Depth of notch, D =

Initial sill level reading, h_i = (MSR+VS.Dx0.01) = …..cm.+ … x 0.01cm = …….cm

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

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Final hook gauge reading	Head	Actual discharge	Theoretical discharge	Coefficient of Discharge
	t_1	t_2	t_m	h_f = (MSR+VS.Dx0.01)	$H = (h_i - h_f)x10^{-2}$	Q_a	Q_{th}	C_d
	s	s	s	cm	m	m^3/s	m^3/s	--
1								
2								
3								
4								
5								
6								

b) Head over notch, H

$$H = (h_i - h_f) \times 10^{-2} \text{ (m)}$$

h_i – initial sill level reading, (cm)

h_f – final hook gauge reading, (cm)

c) Theoretical discharge, Q_{th}

$$Q_{th} = \frac{2}{3} L\sqrt{2g}\, H^{\frac{3}{2}} \text{ (m}^3\text{/s)}$$

L – width of notch (m)

d) Coefficient of discharge, C_d

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

e) Calibration constants, K & n

The actual discharge through the rectangular notch can be expressed as

$$Q_a = K H^n \quad \text{or}$$

$$\log Q_a = \log K + n \log H$$

The graph log Q_a Vs. log H will be a straight line plot. From this graph 'K' is determined by finding the antilog of y intercept and 'n' by taking the slope.

PRECAUTIONS

Before taking observations, steady state conditions are to be ascertained. The drain valve of the measuring tank is to be closed before noting the time for level rise of water in it. It may be opened after noting the time.

PROCEDURE

The cross sectional dimensions of the measuring tank and notch were noted. Water was filled in the notch tank till it tends to over flow. Then the initial sill level reading of the notch was noted.

Table 2: Data and result for calibration curve

Sl No	Logarithmic values		Head over notch	Actual discharge (calibrated)
	log H	log Q_a	H	$Q_a = K H^n$
	--	--	m	m^3/s
1				
2				
3				
4				
5				
6				

<u>Graphs:</u>

1. Calculated actual discharge vs. head over notch
2. Coefficient of discharge vs. head over notch
3. log Q_a vs. log H
4. Calibrated actual discharge vs. head over notch

<u>Sample calculation steps (Set No:)</u>

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \qquad (m^3/s)$$

2. Head over notch, H

$$H = (h_i - h_f) \times 10^{-2} \qquad (m)$$

3. Theoretical discharge, Q_{th}

$$Q_{th} = \frac{2}{3} L\sqrt{2g}\, H^{\frac{3}{2}} \quad (m^3/s)$$

4. Coefficient of discharge, C_d

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

5. Calibration constants, K & n

log Q_a =

log H =

log K = y intercept =

Therefore K = antilog (y intercept) =

Slope, n =

$Q_a = K H^n$ =

After observing the precautions, water was allowed to flow over the notch to the maximum possible level by regulating the inlet valve. The reading in the hook gauge and the average time to collect a certain quantity of water in the measuring tank were noted down.

The process was repeated by reducing the discharge in steps to near zero value, by regulating the inlet valve and the observations were taken as before. At the end of the observation process, the inlet valve was closed and the drain valve kept in open position.

RESULT

Calibrated the given rectangular notch and determined the coefficient of discharge for different flow rates and plotted the required graphs

1. C_d vs. H
2. Q_a (observed) vs. H
3. log Q_a vs. log H
4. Q_a (calibrated) vs. H

Average coefficient of discharge from graph, C_d = …………….

Calibration constants, K = …………….; n = …………..

INFERENCE

CALIBRATION OF VENTURIMETER

AIM

1. To calibrate the given Venturimeter and determine the coefficient of discharge for different flow rates
2. To plot the following graphs:

   a) Coefficient of discharge vs. Head in meter of water

   b) Actual discharge vs. Head in meter of water

   b) Calibration curve for actual discharge vs. head

APPARATUS REQUIRED

1. Experimental set up of Venturimeter mounted on a horizontal pipe with pressure tapping at fixed distance which is connected to a differential mercury manometer
2. A measuring tank with standard fitting for accessing the discharge
3. Stop watch
4. Meter scale to measure the measuring tank size.

SPECIFICATION

Inlet diameter of Venturimeter, d_1 = 25 mm

Throat diameter of Venturimeter, d_2 = 17.5 mm

PRINCIPLE

Water is allowed to flow through the Venturimeter at different flow rates ranging from zero to maximum value and the corresponding pressure difference shown in the manometer were noted. The actual discharge is determined using tank and stop watch. The calculations involved are given below:

a) Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \ (\text{m}^3/\text{s})$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

t_m – mean time for rise of water in measuring tank through ‘h’ height, (s)

Observation data:

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 10cm = 0.1 m

Inlet diameter of venturimeter, d_1 =

Throat diameter of venturimeter, d_2 =

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

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Manometer reading			Head in terms of water column	Actual discharge	Theoretical discharge	Coefficient of Discharge
	t_1	t_2	t_m	h_L	h_R	$H_{Hg} = h_L - h_R$	$H_w = H_{Hg} \times 12.6 \times 10^{-2}$	Q_a	Q_{th}	C_d
	s	s	s	cm	cm	cm	m	m^3/s	m^3/s	--
1										
2										
3										
4										
5										
6										

b) Head difference, H_{hg}

$H_{Hg} = (h_R - h_L)$ (cm)

h_R – level of Hg in right limb of manometer, (cm)

h_L – level of Hg in left limb of manometer, (cm)

c) Head of water, H_w

$$H_w = \frac{H_{Hg}(\rho_{Hg} - \rho_w) \text{ x } 10^{-2}}{\rho_w} \quad \text{(m)}$$

ρ_{Hg} – density of mercury, 13.6g/cc

ρ_w – density water, 1g/cc

d) Theoretical discharge, Q_{th}

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gH_w}}{\sqrt{{a_1}^2 - {a_2}^2}} \quad (\text{m}^3/\text{s})$$

a_1 – cross sectional area of inlet, (m^2)

a_2 – cross sectional area of throat, (m^2)

$$a_1 = \frac{\pi {d_1}^2}{4}; \quad a_2 = \frac{\pi {d_2}^2}{4}$$

e) Coefficient of discharge, C_d

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

Calibration constants, K & n

The actual discharge through the Venturimeter can be expressed as

$Q_a = K\, {H_w}^n$

$\log Q_a = \log K + n \log H_w$

The graph log Q_a Vs. log H_w will be a straight line plot. From this graph ‘K’ is determined by finding the antilog of y intercept and ‘n’ by taking the slope.

Table 2: Data and result for calibration curve

Sl No	logarithmic values		Head difference	Actual discharge (calibrated)
	log H_w	log Q_a	H_w	$Q_a = K H_w^n$
	--	--	m	m^3/s
1				
2				
3				
4				
5				
6				

Graphs:

1. Calculated actual discharge vs. head in meter of water
2. Coefficient of discharge vs. head in meter of water
3. log Q_a vs. log H_w
4. Calibrated actual discharge vs. head in meter of water

Sample calculation steps (Set No:)

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \; (m^3/s)$$

2. Head difference, H_{Hg}

$$H_{Hg} = (h_R - h_L) \; (cm)$$

3. Head of water, Hw

$$H_w = \frac{H_{Hg}(\rho_{Hg} - \rho_w) \text{ x } 10^{-2}}{\rho_w} \quad \text{(m)}$$

4. Theoretical discharge, Q_{th}

$$a_1 = \frac{\pi {d_1}^2}{4} \ (\text{m}^2)$$

$$a_2 = \frac{\pi {d_2}^2}{4} \ (\text{m}^2)$$

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gH_w}}{\sqrt{{a_1}^2 - {a_2}^2}} \ (\text{m}^3/\text{s})$$

5. Coefficient of discharge, C_d

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

6. Calibration constants, K & n

log Q_a =

log H_w =

log K = y intercept =

Therefore K = antilog (y intercept) =

Slope, n =

$Q_a = K H_w^n$ =

PRECAUTIONS

There should not be any air bubbles in the connecting tubes of the mercury manometer. The Venturimeter should run full. The drain valve of the measuring tank is to be closed before noting the time for the level rise of water in it. It may be opened after noting the time. Before taking observations steady state conditions are to be ascertained.

PROCEDURE

The cross sectional dimensions of the measuring tank was noted. After observing the precautions, the supply valve was fully opened. The outlet valve was opened full to get the maximum difference in the manometer. The manometer reading and average time for collecting a certain quantity of water in the measuring tank were noted.

The experiment was repeated by varying the discharge in steps and the observations were taken as before. The observations were entered in the table. At the end of the observation process, the inlet valve was closed and the drain valve kept in open position.

RESULT

Calibrated the given venturimeter and determined the coefficient of discharge for different flow rates and plotted the required graphs

1. C_d vs. H_w
2. Q_a (observed) vs. H_w
3. log Q_a vs. log H_w
4. Q_a (calibrated) vs. H_w

Average coefficient of discharge from graph, C_d = …………….

Calibration constants, K = …………….; n = …………..

INFERENCE

TEST ON PIPE FRICTION APPARATUS

AIM

1. To conduct a test on pipe friction apparatus for different discharges to determine:

   a) Darcy's coefficient

   b) Chezy's constant

2. To plot the following graphs:

   a) Darcy's coefficient vs. pipe Reynold's number

   b) Chezy's coefficient vs. pipe Reynold's number

APPARATUS REQUIRED

1. Experimental set up consisting of pipe lines fitted with differential manometer
2. A measuring tank with standard fitting for accessing the discharge
3. Stop watch
4. Meter scale to measure the measuring tank size.

SPECIFICATION

Length of pipe, L = 3m

Diameter of pipe, d = 30mm

PRINCIPLE

The test is conducted by varying the discharge in steps from full to near zero value. At each discharge suitable observations are made to determine the Darcy's coefficient and Chezy's constant. The calculations involved are:

a) Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \ (\text{m}^3/\text{s})$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

Observation data:

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 10cm = 0.1 m

Length of pipe, L =

Diameter of pipe, d =

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

Density of water, ρ = 1000 kg/m^3

Viscosity of water, μ = 0.00089 Pa.s

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Manometer reading			Actual discharge	Velocity of flow	Darcy's coefficient	Hydraulic gradient	Chezy's constant	Reynold's number
	t_1	t_2	t_m	h_L	h_R	$H_f = (h_L - h_R) \times 10^{-2}$	Q_a	v	f	i	C	Re
	s	s	s	cm	cm	m	m^3/s	m/s	--	--	$m^{1/2} s^{-1}$	--
1												
2												
3												
4												
5												
6												

Graphs:

1. Darcy's coefficient vs. Pipe Reynold's number
2. Chezy's coefficient vs. Pipe Reynold's number

t_m – mean time for rise of water in measuring tank through ‘h’ height, (s)

b) Velocity of water inside pipe, v

$$v = \frac{Q_a}{\left(\frac{\pi d^2}{4}\right)} \qquad \text{(m/s)}$$

d – diameter of pipe, (m)

c) Head loss due to friction, H_f

$H_f = (h_L - h_R) \times 10^{-2}$ (m)

h_R – level of water in right limb of manometer, (cm)

h_L – level of water in left limb of manometer, (cm)

d) Darcy’s coefficient, f

$$f = \frac{2H_f dg}{4Lv^2}$$

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

e) Chezy’s constant, C

$$C = \frac{v}{\sqrt{mi}} \quad \left(\sqrt{m}/_s\right)$$

m – cross sectional area of pipe / wetted perimeter

$$m = \frac{\pi d^2/4}{\pi d} = \frac{d}{4} \quad \text{(m)}$$

i – the hydraulic gradient

$$i = \frac{H_f}{L}$$

<u>Sample calculation steps (Set No:)</u>

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \quad (m^3/s)$$

2. Velocity of water inside pipe, v

$$v = \frac{Q_a}{\left(\frac{\pi d^2}{4}\right)} \quad (m/s)$$

3. Head loss due to friction, H_f

$$H_f = (h_R - h_L) \times 10^{-2} \quad (m)$$

4. Darcy's coefficient, f

$$f = \frac{2H_f dg}{4Lv^2}$$

5. Chezy's constant, C

Hydraulic mean depth, $m = \frac{\pi d^2/4}{\pi d} = \frac{d}{4}$ (m)

Hydraulic gradient, $i = \frac{H_f}{L}$

$$C = \frac{v}{\sqrt{mi}} \quad \left(\sqrt{m}/_{s}\right)$$

6. Reynold's number, Re

$$Re = \frac{\rho v d}{\mu}$$

f) Reynold's number, Re

$$Re = \frac{\rho v d}{\mu}$$

ρ – density of water, 1000 kg/m^3

μ – viscosity of water, μ = 0.89 mPa.s

PRECAUTIONS

Before starting the experiment water is allowed to flow through pipe line. The valves of two limbs of manometer are opened. The drain valve of measuring tank is to be closed before noting the time taken for level rise of water. It may be opened after noting the time. Before taking the observations steady state condition are to be ascertained.

PROCEDURE

The cross sectional dimensions of measuring tank and the diameter of pipe line were noted. After observing the precaution the inlet valve to the pipe line was opened fully. The average time to collect a certain quantity of water in the measuring tank and the level difference in the two limbs of manometer were noted down. The test was repeated by closing the outlet valve to reduce discharge to near zero value in steps and observations were taken as before. The test was stopped by closing of the inlet valve to pipeline while keeping the drain valve in open position.

RESULT

The friction head loss in the pipe for various flow values were calculated and plotted the following graphs;

1. f vs. Re
2. C vs. Re

Average value of Darcy's coefficient from graph, f = …………………

Average value of Chezy's constant from graph, C = …………………$\left(\sqrt{m}/_{s}\right)$

INFERENCE

LOAD TEST ON PELTON TURBINE

AIM

1. To conduct a load test on Pelton turbine at constant head and constant speed and to plot:

   a) Input power vs. Output power
   b) Overall efficiency vs. Output power
   c) Discharge vs. Output power
   d) Overall efficiency vs. Discharge

2. To calculate the specific speed of turbine

APPARATUS REQUIRED

1. The experimental set up of the turbine fitted with loading arrangement.

2. A motor pump set to supply water at the required level

3. Venturimeter to measure the discharge

4. Pressure gauge at the inlet to the nozzle to measure the total head of the turbine.

5. Tachometer to measure the speed of the turbine

SPECIFICATIONS

Turbine:

Head – 45m
Speed – 1000 rpm
Power – 3750 W

Loading arrangement:

Brake drum radius – 300mm
Rope radius – 16mm

PRINCIPLE

The test is conducted at constant head and constant speed. The output of the turbine is varied in steps from zero to the rated value and at each output; the speed and head are made constant by adjusting the

Observation data:

Rated speed of turbine, N = 1000 rpm

Rated supply head of turbine, H_R = 45m

Rated power of turbine, P_T = 3750 W

Venturimeter constant, K = 0.595

Brake drum diameter, D = 300mm

Diameter of rope, d = 16mm

Brake drum radius, $R = D/2 \times 10^{-3}$ = …………..m

Radius of rope, $r = d/2 \times 10^{-3}$ = …………..m

Hanger weight, w_H = 2kg

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

Density of water, ρ = 1000 kg/m^3

Table 1: Data and result of experiment

Sl No	Reading of weight			Manometer reading			Discharge	Input power	Output power	Overall efficiency
	F	S	F-S	h_L	h_R	$H = (h_L - h_R) \times 10$	Q	P_i	P_o	η
	kgf	kgf	kgf	cm	cm	mm	m^3/s	W	W	%
1										
2										
3										
4										
5										
6										

inlet valve of turbine (delivery valve of the pump) and the spear valve. The applied load, the level difference of the manometer of the venturimeter and the constant values of the speed and the head are noted. The calculations involved are:

a) Discharge, Q

$$Q = K\sqrt{H} \text{ x } 10^{-3} \quad (m^3/s)$$

K – venturimeter constant, 0.595

H – Level difference in manometer, (mm of Hg)

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

b) Input power, P_i

$$P_i = \rho g Q H_R \quad (W)$$

H_R – Rated head of turbine, (m)

ρ – density of water, 1000 kg/m^3

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

c) Output power, P_o

$$P_o = (F-S)\,(R+r)\,g\,2\pi N/60 \quad (W)$$

F – weight placed on hanger, (kgf)

S – spring balance reading, (kgf)

R – radius of brake drum, (m)

r – radius of rope, (m)

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

Graphs:

1) Input power vs. Output power
2) Overall efficiency vs. Output power
3) Discharge vs. Output power
4) Overall efficiency vs. Discharge

Sample calculation steps (Set No:)

i. Maximum load, F-S

$$F - S = \frac{P_T}{(R + r)\, g\, 2\pi N/60} \quad \text{(kgf)}$$

ii. Discharge, Q

$$Q = K\sqrt{H} \quad \text{(lps)}$$

$$Q = K\sqrt{H} \times 10^{-3} \quad (m^3/s)$$

H – Level difference in manometer, (mm of Hg)

iii. Input power, P_i

$$P_i = \rho g Q H_R \quad (W)$$

iv. Output power, P_o

$$P_o = (F-S)\,(R+r)\,g\,2\pi N/60 \quad (W)$$

d) Overall Efficiency of turbine, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

e) Specific speed, Ns

$$N_s = \frac{N\sqrt{P_m}}{H_R^{\frac{5}{4}}}$$

P_m – Output power at maximum efficiency, (kW)

N - Rotational speed of turbine, (rpm)

H_R – Rated head of turbine, (m)

PRECAUTIONS

Wherever necessary the pump supplying water to the turbine is to be primed so that it is never allowed to run dry, as the pump running dry will be detrimental to the motor. In case the pump is primed, the air vent on the casing and the valve fitted to the priming line is to be closed after priming. The delivery valve is to be closed before starting as well as stopping the pump to avoid unnecessary development of acceleration heads in the pipes. The plug cocks of the pressure gauge and the manometer are to be in the opened position. The turbine is to be on 'no load' while starting (this is ensured by checking the flywheel of the turbine for free rotation). After taking observations, the load on the brake drum is to be released (the speed should not shoot up while doing so) gradually. Care is to be taken not to overload the turbine. Before switching off the motor pump set the delivery valve of the pump is to be closed. Before taking observations, steady state conditions are to be ascertained.

PROCEDURE

The maximum load that can be applied on the brake drum of the turbine was calculated substituting rated power for P_o in the equation for the output of the turbine. After observing precautions, the motor-pump set was switched ON. The spear valve was opened a little and the delivery valve of the pump was opened to run the turbine at slow speed. By adjusting the spear valve and the delivery valve of the

v. Efficiency, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

vi. Specific speed, N_s

$$N_s = \frac{N\sqrt{P_m}}{H_R^{\frac{5}{4}}}$$

centrifugal pump simultaneously, the speed and the head of the turbine was made constant at the rated values. The turbine was made to run for a few minutes to attain steady state condition. The speed and the head of the turbine were noted. The level difference in the manometer of the venturimeter was also noted.

A weight was placed on the hanger of the rope and the hand wheel of the spring balance was rotated clockwise to load the turbine. At the same time, the speed and head of the turbine were adjusted to the rated values as done before while on ‘no load’ condition. The turbine was made to run for a few minutes to attain steady state condition. The weight placed on the hanger, the spring balance reading, the level difference of the manometer, the speed and the head were noted.

The experiment was repeated by varying the load in steps to the maximum load on the brake drum and observations were taken as before. The observations were entered in the table. The turbine was stopped, by gradually removing the weight placed on the hanger and at the same time adjusting the spear valve and the delivery valve of the pump so as not to allow the speed to shoot up. After removing all the weights, the delivery valve of the pump was closed and the motor-pump set was switched off.

RESULT

The load test was conducted on Pelton turbine at constant speed and constant head. The following graphs are plotted:

a) Input power vs. Output power

b) Overall efficiency vs. Output power

c) Discharge vs. Output power

d) Overall efficiency vs. Discharge

The specific speed of turbine, N_s = …………………

INFERENCE

CONSTANT SPEED CHARACTERISTICS OF RECIPROCATING PUMP

AIM

1. To test the pump at constant rated speed for determining its characteristics and to plot following graphs:

   a) Input power vs. Total head

   b) Actual discharge vs. Total head

   c) Overall efficiency vs. Total head

   d) % slip vs. Total head

2. To determine the maximum efficiency of pump

3. To determine the total head and discharge corresponding to maximum efficiency of pump

APPARATUS REQUIRED

1. The experimental setup of reciprocating pump motor set fitted with pressure and vacuum gauges to delivery and suction line
2. A measuring tank with standard fittings for assessing the discharge
3. Energy meter connected in the electric motor input line to measure the input power to electric motor
4. Tachometer to measure the rotational speed of pump
5. Stop watch
6. A meter scale to measure the measuring tank size and level difference between the center points of pressure gauge and vacuum gauge.

SPECIFICATION

Reciprocating pump:

Type - single cylinder, double acting
Bore – 42mm
Stroke – 72 mm
Speed – 170 rpm
Lubricating oil – SAE 40
Maximum safe delivery pressure – 4 kgf/cm^2

Observation data:

Energy meter constant, k	= ……………rev/kWh
Length of measuring tank, l	=
Breadth of measuring tank, b	=
Height of water level rise, h	= 10cm = 0.1 m
Bore of piston, D	=
Stroke length of piston, L	=
Height difference between gauges, l_d	=
Rotating speed of pump, N	= …………… rpm
Efficiency of motor, η_m	= 60%
Acceleration due to gravity,g	= 9.81 m/s^2
Density of water, ρ_w	= 1000 kg/m^3
Density of mercury, ρ_{Hg}	= 13600 kg/m^3
Number of revolutions of energy meter disc, n_e	= 5

Motor:

Supply – 230V,AC, 50Hz, 1ϕ
Speed – 1440 rpm
Efficiency of motor – 60%

PRINCIPLE

The test is conducted at the constant speed of the driving electric motor, which is same as that of the pump. The discharge of the pump is varied in steps from full to near zero value and at each discharge; suitable observations are made to determine the discharge, the corresponding total head, the input power to the electric motor and the speed of the pump. The calculations involved are:

a) Actual Discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \quad (m^3/s)$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

t_m – mean time for rise of water in measuring tank through 'h' height, (s)

b) Total head, H

$$H = H_d + H_s + l_d \quad (m)$$

$$H = \frac{h_d}{\rho_{water} \times 10^{-4}} + \frac{h_s \times 25.4 \times 10^{-3} \times \rho_{mercury}}{\rho_{water}} + l_d \quad (m)$$

H_d – Delivery pressure head, (m H_2O)

H_s – Suction pressure head, (m H_2O)

l_d – Level difference between delivery and suction pressure heads, (m)

h_d – Delivery pressure head, (kgf/cm^2)

h_s – Suction pressure head, (inches of Hg)

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Time for 5 revolutions of energy meter disc			Delivery pressure	Suction pressure	Total head	Actual discharge	Input power	Output power	Overall efficiency	Theoretical discharge	% slip
	t_1	t_2	t_m	t_1	t_2	t_e	h_d	h_s	H	Q_a	P_i	P_o	η	Q_{th}	s
	s	s	s	s	s	s	kgf/cm^2	Inches of Hg	m	m^3/s	W	W	%	m^3/s	%
1							0								
2							0.5								
3							1								
4							1.5								
5							2								
6							2.5								

<u>Graphs:</u>

a) Input power vs. Total head

b) Actual discharge vs. Total head

c) Overall efficiency vs. Total head

d) % slip vs. Total head

<u>Sample calculation steps (Set No:)</u>

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \ (m^3/s)$$

2. Total head, H

$$H = H_d + H_s + l_d$$

$$H = \frac{h_d}{\rho_w \text{ x } 10^{-4}} + \frac{h_s \text{ x } 25.4 \text{ x } 10^{-3} \text{ x } \rho_{Hg}}{\rho_w} + l_d \ (m)$$

c) Output power of pump, P_o

$$P_o = \rho g Q_a H \quad (W)$$

ρ – density of water, 1000 kg/m^3

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

d) Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{ x } \eta_m}{t_e \text{ x k}} \quad (W)$$

n_e – number of revolutions of energy meter disc

η_m – efficiency of motor, 60%

t_e – average time for n_e revolution of energy meter disc (s)

k – Energy meter constant, 1200 rev/kWh

e) Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

f) Theoretical discharge, Q_{th}

$$Q_{th} = \frac{\pi D^2 \, LN \, x \, 2}{4 \, x \, 60} \quad (m^3/s)$$

D – the bore diameter of the piston (m)

L – the stroke length of the piston (m)

N – the rotational speed of pump (rpm)

g) % Slip, S

$$S = \frac{Q_{th} - Q_a}{Q_{th}} \times 100 \ (\%)$$

PRECAUTIONS

Since this is a positive displacement pump, priming is not necessary. The lubricating oil level is checked by returning through the sight glass. The level of the oil is to be made up, if needed at the

3. Output power of pump, P_o

$$P_o = \rho_w g Q_a H \quad (W)$$

4. Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{ x } \eta_m}{t_e \text{ x k}} \quad (W)$$

5. Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

6. Theoretical discharge, Q_{th}

$$Q_{th} = \frac{\pi D^2 \text{ LN x } 2}{4 \text{ x } 60} \quad (m^3/s)$$

7. % Slip, S

$$S = \frac{Q_{th} - Q_a}{Q_{th}} \times 100 \ (\%)$$

required level. The delivery valve of the pump is to be opened before starting the pump as well as stopping the pump to avoid unsafe pressure rise in the pump and pipe line. The drain valve of measuring tank is to be closed before noting the time for the level rise of water in it. The plug cock of the pressure and vacuum gauges are to be in the opened position before taking the observations, steady state condition are to be ascertained.

PROCEDURE

The cross sectional dimensions of the measuring tank, the level difference between gauges and the energy meter constant were noted. After observing the precautions, the electric motor was switched ON and the pump was made to run for a few minutes to ascertain steady state condition. The speed of the pump was noted using a tachometer. The average time for collecting a certain quantity water in the measuring tank, the suction gauge and pressure gauge readings and average time for certain number of revolutions of energy meter disc were noted.

The experiment was repeated by varying the discharge in steps and the observations were taken as before. The observations were entered in the table. After opening the delivery valve fully and keeping the drain valve in the opened position, the pump was stopped by switching OFF the electric motor.

RESULT

The pump was tested at constant speed and following characteristics are plotted;

1. Input power vs. Total head
2. Actual discharge vs. Total head
3. Overall efficiency vs. Total head
4. % slip vs. Total head

Maximum efficiency of pump obtained, η_{max} =

Total head corresponding to maximum efficiency =

Total discharge corresponding to maximum efficiency =

Slip corresponding to maximum efficiency =

INFERENCE

CONSTANT SPEED CHARACTERISTICS OF GEAR PUMP

AIM

1. To test the gear pump at constant rated speed for determining its characteristics and to plot the following graphs:

   a) Input power vs. Total head

   b) Discharge vs. Total head

   c) Overall efficiency vs. Total head

2. To determine the maximum efficiency of pump

3. To determine the total head and discharge corresponding to maximum efficiency of pump

APPARATUS REQUIRED

1. The experimental setup of gear pump-motor set fitted with pressure and vacuum gauges fitted to the delivery and suction line
2. A measuring tank with standard fittings for accessing the discharge
3. Energy meter connected in the electric motor input line to measure the input power to electric motor
4. Stop watch
5. A meter scale to measure the measuring tank size and level difference between the center points of pressure gauge and vacuum gauge.

SPECIFICATION

Gear pump:

Size – 20 mm
Speed – 1440 rpm
Discharge – 25 lpm
Maximum safe delivery pressure – 5 kgf/cm^2

Observation data:

Energy meter constant, k = ……………rev/kWh

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of oil level rise, h = 10cm = 0.1 m

Height difference between gauges, l_d =

Efficiency of motor, η_m = 60%

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

Density of oil, ρ_o = 830 kg/m^3

Density of mercury, ρ_{Hg} = 13600 kg/m^3

Number of revolutions of energy meter disc, n_e = 5

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Time for 5 revolutions of energy meter disc			Delivery pressure	Suction pressure	Total head	Actual discharge	Input power	Output power	Overall efficiency
	t_1	t_2	t_m	t_1	t_2	t_e	h_d	h_s	H	Q_a	P_i	P_o	η
	s	s	s	s	s	s	kgf/cm^2	mm of Hg	m	m^3/s	W	W	%
1													
2													
3													
4													
5													
6													

Graphs:

a) Input power vs. Total head

b) Discharge vs. Total head

c) Overall efficiency vs. Total head

Motor:

Supply – 230V,AC, 50Hz, 1Ø
Speed – 1440 rpm
Power – 1 Hp (746 W)
Efficiency of motor – 60%

PRINCIPLE

The test is conducted at constant speed of the driving electric motor which is same as that of the pump. The discharge of pump is varied in steps from full to near zero value and at each discharge, suitable observations are made to determine the discharge and the corresponding total head and the input power to the electric motor. The calculations involved are:

a) Discharge, Q

$$Q = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of oil level for time observed with stopwatch, (m)

t_m – mean time for rise of oil in measuring tank through 'h' height, (s)

b) Total head, H

$$H = H_d + H_s + l_d \quad \text{(m)}$$

$$H = \frac{h_d}{\rho_o \text{ x } 10^{-4}} + \frac{h_s \text{ x } 10^{-3} \text{ x } \rho_{mercury}}{\rho_o} + l_d \text{ (m)}$$

H_d – Delivery pressure head, (m of Oil)

H_s – Suction pressure head, (m of Oil)

l_d – Level difference between delivery and suction pressure heads, (m)

h_d – Delivery pressure head, (kgf/cm^2)

h_s – Suction pressure head, (mm of Hg)

ρ_o – Density of oil, 830 kg/m^3

Sample calculation steps (Set No:)

1. Discharge, Q

$$Q = \frac{lbh}{t_m} \; (m^3/s)$$

2. Total head, H

$$H = H_d + H_s + l_d$$

$$H = \frac{h_d}{\rho_o \text{ x } 10^{-4}} + \frac{h_s \text{ x } 10^{-3} \text{ x } \rho_{Hg}}{\rho_o} + l_d \; (m)$$

3. Output power of pump, P_o

$$P_o = \rho_o gQH \quad (W)$$

4. Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{ x } \eta_m}{t_e \text{ x } k} \; (W)$$

5. Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \; (\%)$$

c) Output power of pump, P_o

$$P_o = \rho_o g Q H \quad (W)$$

ρ_o – density of oil, 830 kg/m^3

d) Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{ x } \eta_m}{t_e \text{ x k}} \quad (W)$$

n_e – number of revolutions of energy meter disc

t_e – average time for Ne revolution of energy meter (s)

η_m – efficiency of motor, 60%

k – Energy meter constant, 200 rev/kWh

e) Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

PRECAUTIONS

Since this is a positive displacement pump, priming is not necessary. The delivery valve is to be opened before starting and stopping the pump to avoid unsafe pressure rises inside the pump and the pipeline. The drain valve of the measuring tank is to be closed before noting the time for the level rise of oil in it. The plug cocks of the pressure and vacuum gauges are to be in the opened position. Before taking the observations, steady state conditions are to be ascertained.

PROCEDURE

The cross sectional dimensions of the measuring tank, the level difference between the gauges and the energy meter constant were noted. After observing the precautions, the electric motor was switched ON and the pump was made to run for a few minute to asertain steady state condition. The average time for collecting certain quantity of oil in the measuring tank, the suction gauge and pressure gauge readings and average time for certain numbers of revolutions of energy meter disc were noted.

The experiment was repeated by varying the discharge in steps and observations were taken as before. The observations were entered in the table. After opening the delivery valve fully and keeping the drain valve in the opened position, the pump was stopped by switching OFF the electric motor.

RESULT

The pump was tested at constant speed and following characteristics are plotted;

1. Input power vs. Total head
2. Discharge vs. Total head
3. Overall efficiency vs. Total head

Maximum efficiency of pump obtained, η_{max} =

Total head corresponding to maximum efficiency =

Total discharge corresponding to maximum efficiency =

INFERENCE

DETERMINATION OF REYNOLD'S NUMBER

AIM

To determine the type of flow through a circular pipe by using the Reynold's apparatus.

APPARATUS REQUIRED

1. Experimental set up of Reynold's apparatus
2. A measuring tank with standard fitting for accessing the discharge

ACCESSORIES REQUIRED

1. Stop watch
2. Meter scale to measure the measuring tank size.

SPECIFICATION

Diameter of pipe, d = 22 mm

PRINCIPLE

A fluid flow can be said to be laminar, if the Reynold's number, Re < 2000. The flow is turbulent if Re > 4000. The transition condition is when 2000 < Re < 4000. Critical velocity is the velocity at which the flow of fluid changes from laminar to turbulent.

The calculations involved are given below:

a) Actual discharge, Q

$$Q = \frac{V}{t} \text{ (m}^3\text{/s)}$$

V – volume of water collected in the measuring tank, (m^3)

t – time for collection of 'V' volume of water in the measuring tank, (s)

b) Velocity of water inside pipe, v

$$v = \frac{Q}{\left(\frac{\pi d^2}{4}\right)} \text{ (m/s)}$$

d – diameter of pipe, m

c) Reynold's number, Re

Observation data:

Diameter of pipe, d =

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

Viscosity of water, μ = 0.00089 Pa.s

Table 1: Data and result of experiment

Sl No	Volume of water collected	Time taken	Actual discharge	Velocityof flow	Reynold's number	Flow pattern
	V	t	Q_a	v	Re	--
	m^3	s	m^3/s	m/s	--	--
1						
2						
3						
4						
5						
6						

Sample calculation steps (Set No:)

1. Actual discharge, Q

$$Q = \frac{V}{t} \text{ (m}^3\text{/s)}$$

2. Velocity of water inside pipe, v

$$v = \frac{Q}{\left(\frac{\pi d^2}{4}\right)} \text{ (m/s)}$$

3. Reynold's number, Re

$$Re = \frac{\rho v d}{\mu}$$

$$Re = \frac{\rho v d}{\mu}$$

ρ – density of water, 1000 kg/m^3

μ – viscosity of water, μ = 0.89 mPa.s

PRECAUTIONS

The water in the reservoir should be kept at constant head. The dye should enter the centre of the pipe. The variation in the discharge should be done very slowly. Steady state conditions should be ascertained before taking the observations.

PROCEDURE

The water from the tank was allowed to flow through the pipe. The liquid dye having the same specific weight as that of water was introduced as a narrow filament into the centre of the pipe. The time to collect a certain volume of water in the tank was noted.

The experiment was repeated by varying the discharge and hence the velocity of flow by regulating the valve. The observations were tabulated and for each velocity of flow, the Reynold's number was calculated. The flow pattern was determined from Reynold's number values obtained.

RESULT

Conducted experiment on the Reynold's number apparatus.

Reynold's number, Re =

Type of flow =

INFERENCE

CALIBRATION OF ORIFICEMETER

AIM

1. To calibrate the given Orificemeter and determine the coefficient of discharge for different flow rates
2. To plot the following graphs:

   a) Coefficient of discharge vs. Head in meter of water

   b) Actual discharge vs. Head in meter of water

   b) Calibration curve for actual discharge vs. head

APPARATUS REQUIRED

1. Experimental set up of orificemeter mounted on a horizontal pipe with pressure tapping at fixed distance which is connected to a differential mercury manometer
2. A measuring tank with standard fitting for accessing the discharge
3. Stop watch
4. Meter scale to measure the measuring tank size.

SPECIFICATION

Pipe diameter, d_1 = 25 mm

Diameter of orifice, d_2 = 15 mm

Axis - Horizontal

PRINCIPLE

Water is allowed to flow through the Orificemeter at different flow rates ranging from zero to maximum value and the corresponding pressure difference shown in the manometer were noted. The actual discharge is determined using tank and stop watch. The calculations involved are given below:

a) Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \quad (m^3/s)$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

Observation data:

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 10cm = 0.1 m

Pipe diameter, d_1 =

Diameter of orifice, d_2 =

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

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Manometer reading			Head in terms of water column	Actual discharge	Theoretical discharge	Coefficient of Discharge
	t_1	t_2	t_m	h_L	h_R	$H_{Hg} = h_L - h_R$	$H_w = H_{Hg} \times 12.6 \times 10^{-2}$	Q_a	Q_{th}	C_d
	s	s	s	cm	cm	cm	m	m^3/s	m^3/s	--
1										
2										
3										
4										
5										
6										

t_m – mean time for rise of water in measuring tank through 'h' height, (s)

b) Head difference, H_{Hg}

$H_{Hg} = (h_R - h_L)$ (cm)

h_R – level of Hg in right limb of manometer, (cm)

h_L – level of Hg in left limb of manometer, (cm)

c) Head of water, H_w

$$H_w = \frac{H_{Hg}(\rho_{Hg} - \rho_w) \times 10^{-2}}{\rho_w} \quad \text{(m)}$$

ρ_{hg} – density of mercury, 13.6g/cc

ρ_w – density water, 1g/cc

d) Theoretical discharge, Q_{th}

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gH_w}}{\sqrt{{a_1}^2 - {a_2}^2}} \text{ (m}^3\text{/s)}$$

a_1 – cross sectional area of inlet pipe, (m^2)

a_2 – cross sectional area of orifice, (m^2)

$$a_1 = \frac{\pi {d_1}^2}{4}; \quad a_2 = \frac{\pi {d_2}^2}{4}$$

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

e) Coefficient of discharge, C_d

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

f) Calibration constants, K & n

The actual discharge through the Orificemeter can be expressed as

$Q_a = K H_w^n$

$\log Q_a = \log K + n \log H_w$

Table 2: Data and result for calibration curve

Sl No	logarithmic values		Head difference	Actual discharge (calibrated)
	log H_w	log Q_a	H_w	$Q_a = K H_w^n$
	--	--	m	m^3/s
1				
2				
3				
4				
5				
6				

Graphs:

1. Calculated actual discharge vs head in meter of water
2. Coefficient of discharge vs head in meter of water
3. log Q_a vs log H_w
4. Calibrated actual discharge vs head in meter of water

Sample calculation steps (Set No:)

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \quad (m^3/s)$$

2. Head difference, H_{Hg}

$$H_{Hg} = (h_R - h_L) \text{ (cm)}$$

3. Head of water, H_w

$$H_w = \frac{H_{Hg}(\rho_{Hg} - \rho_w) \text{ x } 10^{-2}}{\rho_w} \quad \text{(m)}$$

4. Theoretical discharge, Q_{th}

$$a_1 = \frac{\pi {d_1}^2}{4} \ (m^2)$$

$$a_2 = \frac{\pi {d_2}^2}{4} \ (m^2)$$

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gH_w}}{\sqrt{{a_1}^2 - {a_2}^2}} \ (m^3/s)$$

5. Coefficient of discharge, C_d

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

6. Calibration constants, K & n

log Q_a =

log H_w =

log K = y intercept =

Therefore K = antilog (y intercept) =

Slope, n =

$Q_a = K\ H_w^n$ =

The graph log Q_a Vs. log H_w will be a straight line plot. From this graph 'K' is determined by finding the antilog of y intercept and 'n' by taking the slope.

PRECAUTIONS

There should not be any air bubbles in the connecting tubes of the mercury manometer. The Orificemeter should run full. The drain valve of the measuring tank is to be closed before noting the time for the level rise of water in it. It may be opened after noting the time. Before taking observations steady state conditions are to be ascertained.

PROCEDURE

The cross sectional dimensions of the measuring tank was noted. After observing the precautions, the supply valve was fully opened. The outlet valve was opened full to get the maximum difference in the manometer. The manometer reading and average time for collecting a certain quantity of water in the measuring tank were noted.

The experiment was repeated by varying the discharge in steps and the observations were taken as before. The observations were entered in the table. At the end of the observation process, the inlet valve was closed and the drain valve kept in open position.

RESULT

Calibrated the given Orificemeter and determined the coefficient of discharge for different flow rates and plotted the required graphs

5. Cd vs. H_w
6. Q_a (observed) vs. H_w
7. log Qact vs. log H_w
8. Q_a (calibrated) vs. H_w

Average coefficient of discharge from graph, C_d = …………….

Calibration constants, K = …………….; n = …………..

INFERENCE

DETERMINATION OF THE HYDRAULIC COEFFICIENTS OF A CIRCULAR ORIFICE

AIM

To conduct a test on given Orifice apparatus to determine its:

a) Coefficient of discharge

b) Coefficient of velocity

c) Coefficient of contraction

APPARATUS REQUIRED

1. Experimental set up consists of the Orifice tank with orifice plate located on one of its walls near the bottom.
2. A hook gauge with horizontal scale mounted on it is fixed to the tank just above the opening. The hook gauge can slide on the horizontal scale to measure the horizontal movement (x- coordinate) with reference to the section of vena contracta. The corresponding vertical movement (y- coordinate) can also be measured.
3. A measuring tank with standard fitting for accessing the discharge
4. Stop watch
5. Meter scale to measure the measuring tank size.

SPECIFICATION

Diameter of orifice, d = 20 mm

PRINCIPLE

An orifice is an opening, usually circular, in the wall of a tank or in a plate, normal to the axis of the pipe. An orifice is characterized by the fact that the thickness of the wall or plate is very small relative to the size of the opening. Orifice apparatus is used for the measurement of discharges, for which its various coefficients have to be known.

The velocity that would be attained by the jet of the fluid, provided, if friction did not exist, may be termed as the theoretical velocity. Owing to surface tension and frictional effects, actual average velocity at the vena contracta of the jet is less than its theoretical velocity. The ratio of actual velocity to theoretical velocity of flow is termed as the Coefficient of velocity of the orifice, C_v

Observation data:

Length of collecting tank, l =

Breadth of collecting tank, b =

Height of water level drawn, h = 10 cm = 0.1 m

Diameter of orifice, d =

Horizontal coordinate w.r.t vena contracta, x_1 =

Vertical coordinate w.r.t vena contracta, y_1 =

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

Table 1: Data and result of experiment

Sl No	Time for 10cm drawing of water			Head of water over the centre of orifice	Actual discharge	Theoretical discharge	Cordinates w.r.t orifice		Horizontal and vertical distances		Coefficient of velocity	Coefficient of discharge	Coefficient of contraction
	t_1	t_2	t_m	H	Q_a	Q_{th}	x_2	y_2	x	y	C_v	C_d	C_c
	s	s	s	m	m^3/s	m/s	--	--	--	--	--	--	--
1													
2													
3													
4													
5													
6													
	Mean												

Sample calculation steps (Set No:)

1. Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

The streamlines in approaching the orifice converge. They continue to converge beyond the downstream section of orifice until a short length of about 0.5d (d is the diameter of the orifice). The jet has minimum area at this section. The section of the jet, where its area is the minimum, is called its vena contracta. Beyond the vena contracta, the streamlines commonly diverge because of frictional effects. The ratio of the area of jet at vena contracta to the area of orifice is called as the Coefficient of contraction, C_c.

The ratio of the actual rate to the theoretical rate of discharge through the orifice, is defined as the Coefficient of discharge, C_d, The calculations involved are:

a) Actual discharge, Q_a

$$Q_a = \frac{lbh}{t_m} \quad (m^3/s)$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

t_m – mean time for rise of water in measuring tank through 'h' height, (s)

b) Theoretical discharge, Q_{th}

$$Q_{th} = a_o\sqrt{2gH} \quad (m^3/s)$$

a_o – area of orifice, (m^2)

$$a_o = \frac{\pi d^2}{4} \ (m^2)$$

d – diameter of orifice, (m)

H - head of water over the centre of orifice, (m)

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

c) Coefficient of velocity, C_v

$$C_v = \sqrt{\frac{x^2}{(4yH)}}$$

2. Theoretical discharge, Q_{th}

$$a_o = \frac{\pi d^2}{4} \text{ (m}^2\text{)}$$

$$Q_{th} = a_o\sqrt{2gH} \text{ (m}^3\text{/s)}$$

3. Coefficient of velocity, C_v

$$x = x_2 - x_1 \text{ (m)}$$

$$y = y_2 - y_1 \text{ (m)}$$

$$C_v = \sqrt{\frac{x^2}{(4yH)}}$$

4. Coefficient of discharge, C_d

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

5. Coefficient of contraction, C_c

$$C_c = \frac{C_d}{C_v}$$

x, y – horizontal and vertical coordinates respectively of a point in the jet with respect to vena contracta, (m)

$x = x_2 - x_1$ (m)

$y = y_2 - y_1$ (m)

x_2, y_2 – horizontal and vertical coordinates to a point in the centerline of the jet, measured with respect to orifice as origin, (m)

x_1, y_1 – horizontal and vertical coordinates with respect to venacontracta, (m)

d) Coefficient of discharge, C_d

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

e) Coefficient of contraction, C_c

$$C_c = \frac{a_v}{a_o}$$

a_v – area of cross section of the jet at vena contracta, (m^2)

Also,

$$C_c = \frac{C_d}{C_v}$$

PRECAUTIONS

It is to be ensured that the head of water over the orifice remains constant when the readings are taken. The drain valve of measuring tank is to be closed before noting the time taken for level rise of water. It may be opened after noting the time. Before taking the observations steady state condition are to be ascertained.

PROCEDURE

The orifice tank was filled with water up to a particular head. The steady head of water over the orifice is maintained by regulating the inlet valve to the tank by trial and error. The horizontal coordinate

x_1 and vertical coordinate y_1 of the centre line of the jet at the section of vena contracta was measured with respect to the origin of the jet, by means of the hook gauge.

The hook gauge was slide away from the origin to any other transverse plane on the jet and the corresponding coordinates x_2 and y_2, of a point on the centre line of the jet was measured.

The experiment was repeated for different sets of head over orifice, and in each case different values of horizontal and vertical coordinates of the jet were selected, the inlet valve was closed and the readings were tabulated. The test was stopped by closing of the inlet valve to pipeline while keeping the drain valve in open position.

RESULT

The Coefficient of velocity, C_v =

The Coefficient of contraction, C_c =

The Coefficient of discharge, C_d =

INFERENCE

LOAD TEST ON FRANCIS TURBINE

AIM

1. To conduct a load test on Francis turbine at constant head and constant speed and to plot:

   a) Input power vs. Output power
   b) Overall efficiency vs. Output power
   c) Discharge vs. Output power
   d) Overall efficiency vs. Discharge

2. To calculate the specific speed of turbine

APPARATUS REQUIRED

1. The experimental set up of the turbine fitted with loading arrangement.
2. A motor pump set to supply water at the required level
3. Venturimeter to measure the discharge
4. Pressure gauge at the inlet of the turbine and vacuum gauge at the inlet of the draft tube.
5. Tachometer to measure the speed of the turbine

SPECIFICATIONS

Turbine:

Head – 15m
Speed – 1250 rpm
Power – 3750 W

Loading arrangement:

Brake drum diameter – 300mm
Rope diameter – 16mm

PRINCIPLE

The test is conducted at constant head and constant speed. The output of the turbine is varied in steps from zero to the rated value and at each output; the speed and head are made constant by adjusting the inlet valve of turbine (delivery valve of the pump) and the guide vane opening. The applied load, the

Observation data:

Rated speed of turbine, N = 1250 rpm

Rated supply head of turbine, H_R = 15m

Rated power of turbine, P_T = 3750 W

Venturimeter constant, K = 14.083×10^{-4}

Brake drum diameter, D = 300mm

Diameter of rope, d = 16mm

Brake drum radius, $R = D/2 \times 10^{-3}$ = …………..m

Radius of rope, $r = d/2 \times 10^{-3}$ = …………..m

Hanger weight, w_H = 2kg

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

Density of water, ρ = 1000 kg/m^3

Table 1: Data and result of experiment

Sl No	Reading of weight			Manometer reading			Discharge	Input power	Output power	Overall efficiency
	F	S	F-S	h_L	h_R	$H = (h_L - h_R) \times 10$	Q	P_i	P_o	η
	kgf	kgf	kgf	cm	cm	mm	m^3/s	W	W	%
1										
2										
3										
4										
5										
6										

level difference of the manometer of the venturimeter and the constant values of the speed and the head are noted. The calculations involved are:

a) Discharge, Q

$$Q = K\sqrt{H} \times 10^{-3} \ (m^3/s)$$

K – Venturimeter constant, 14.083×10^{-4}

H – Level difference in manometer, (mm of Hg)

b) Input power, P_i

$$P_i = \rho g Q H_R \quad (W)$$

H_R – Rated head of turbine, (m)

ρ – density of water, 1000 kg/m^3

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

c) Output power, P_o

$$P_o = (F-S)(R+r)\, g\, 2\pi N/60 \quad (W)$$

F – weight placed on hanger, (kgf)

S – spring balance reading, (kgf)

R – radius of brake drum, (m)

r – radius of rope, (m)

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

d) Overall Efficiency of turbine, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

Graphs:

1) Input power vs. Output power
2) Overall efficiency vs. Output power
3) Discharge vs. Output power
4) Overall efficiency vs. Discharge

Sample calculation steps (Set No:)

i. Maximum load, F-S

$$F - S = \frac{P_T}{(\mathrm{R}+\mathrm{r})\ \mathrm{g}\ 2\pi\mathrm{N}/60} \quad \text{(kgf)}$$

ii. Discharge, Q

$$Q = K\sqrt{H} \times 10^3 \quad \text{(lps)}$$

$$Q = K\sqrt{H} \quad (\mathrm{m}^3/\mathrm{s})$$

H – Level difference in manometer, (mm of Hg)

iii. Input power, P_i

$$P_i = \rho g Q H_R \quad \text{(W)}$$

iv. Output power, P_o

$$P_o = (\mathrm{F-S})\ (\mathrm{R}+\mathrm{r})\ \mathrm{g}\ 2\pi\mathrm{N}/60 \quad \text{(W)}$$

e) Specific speed, N_s

$$N_s = \frac{N\sqrt{P_m}}{H_R^{\frac{5}{4}}}$$

P_m – Output power at maximum efficiency, (kW)

N – Rotational speed of turbine, (rpm)

H_R – Rated head of turbine, (m)

PRECAUTIONS

Wherever necessary the pump supplying water to the turbine is to be primed so that it is never allowed to run dry, as the pump running dry will be detrimental to the motor. In case the pump is primed, the air vent on the casing and the valve fitted to the priming line is to be closed after priming. The delivery valve is to be closed before starting as well as stopping the pump to avoid unnecessary development of acceleration heads in the pipes. The plug cocks of the pressure gauge and the manometer are to be in the opened position. The turbine is to be on 'no load' while starting (this is ensured by checking the flywheel of the turbine for free rotation). After taking observations, the load on the brake drum is to be released (the speed should not shoot up while doing so) gradually. Care is to be taken not to overload the turbine. Before switching off the motor pump set the delivery valve of the pump is to be closed. Before taking observations, steady state conditions are to be ascertained.

PROCEDURE

The maximum load that can be applied on the brake drum of the turbine was calculated substituting rated power for P_o in the equation for the output of the turbine. After observing precautions, the motor-pump set was switched ON. The spear valve was opened a little and the delivery valve of the pump was opened to run the turbine at slow speed. By adjusting the guide vane and the delivery valve of the centrifugal pump simultaneously, the speed and the head of the turbine was made constant at the rated values. The turbine was made to run for a few minutes to attain steady state condition. The speed and the head of the turbine were noted. The level difference in the manometer of the venturimeter was also noted.

v. Efficiency, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

vi. Specific speed, N_s

$$N_s = \frac{N\sqrt{P_m}}{H_R^{\frac{5}{4}}}$$

A weight was placed on the hanger of the rope and the hand wheel of the spring balance was rotated clockwise to load the turbine. At the same time, the speed and head of the turbine were adjusted to the rated values as done before while on ‘no load’ condition. The turbine was made to run for a few minutes to attain steady state condition. The weight placed on the hanger, the spring balance reading, the level difference of the manometer, the speed and the head were noted.

The experiment was repeated by varying the load in steps to the maximum load on the brake drum and observations were taken as before. The observations were entered in the table. The turbine was stopped, by gradually removing the weight placed on the hanger and at the same time adjusting the spear valve and the delivery valve of the pump so as not to allow the speed to shoot up. After removing all the weights, the delivery valve of the pump was closed and the motor-pump set was switched off.

RESULT

The load test was conducted on Francis turbine at constant speed and constant head. The following graphs are plotted:

a) Input power vs. Output power

b) Overall efficiency vs. Output power

c) Discharge vs. Output power

d) Overall efficiency vs. Discharge

The specific speed of turbine, N_s = ………………….

INFERENCE

CONSTANT SPEED CHARACTERISTICS OF CENTRIFUGAL PUMP

AIM

1. To test the pump at constant rated speed for determining its characteristics and to plot following graphs:

   a) Input power vs. Discharge

   b) Discharge vs. Discharge

   c) Overall efficiency vs. Discharge

2. To determine the specific speed of pump

3. To determine the maximum efficiency of pump

4. To determine the total head and discharge corresponding to maximum efficiency of pump

APPARATUS REQUIRED

1. The experimental setup of the centrifugal pump motor set fitted with pressure and vacuum gauges to the delivery and suction line
2. A measuring tank with standard fittings for assessing the discharge
3. Energy meter connected in the electric motor input line to measure the input power to electric motor
4. Tachometer to measure the rotational speed of pump
5. Stop watch
6. A meter scale to measure the measuring tank size and level difference between the center points of pressure gauge and vacuum gauge.

SPECIFICATION

Centrifugal pump:

Minimum discharge – 2 lps

Maximum head – 25m

Motor:

Supply – 230V,AC, 50Hz, 3ϕ

Speed – 2880 rpm

Efficiency of motor – 60%

Observation data:

Energy meter constant, k = ……………rev/kWh

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 10cm = 0.1 m

Height difference between gauges, l_d =

Rated speed of pump, N = 2880 rpm

Efficiency of motor, η_m = 80%

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

Density of water, ρ_w = 1000 kg/m^3

Density of mercury, ρ_{Hg} = 13600 kg/m^3

Number of revolutions of energy meter disc, n_e = 5

Table 1: Data and result of experiment

Sl No	Time for 10cm rise of water			Time for 5 revolutions of energy meter disc			Delivery pressure	Suction pressure	Total head	Actual discharge	Input power	Output power	Overall efficiency
	t_1	t_2	t_m	t_1	t_2	t_e	h_d	h_s	H	Q_a	P_i	P_o	η
	s	s	s	s	s	s	kgf/cm^2	Inches of Hg	m	m^3/s	W	W	%
1							0						
2							0.6						
3							1.2						
4							1.8						
5							2.4						
6							3.0						

PRINCIPLE

The test is conducted at the constant speed of the driving electric motor, which is same as that of the pump. The discharge of the pump is varied in steps from zero to full value and at each discharge; suitable observations are made to determine the discharge, the corresponding total head, the input power to the electric motor and the speed of the pump. The calculations involved are:

a) Discharge, Q

$$Q = \frac{lbh}{t_m} \quad (m^3/s)$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of water level for time observed with stopwatch, (m)

t_m – mean time for rise of water in measuring tank through ‘h’ height, (s)

b) Total head, H

$$H = H_d + H_s + l_d \quad (m)$$

$$H = \frac{h_d}{\rho_{water} \times 10^{-4}} + \frac{h_s \times 25.4 \times 10^{-3} \times \rho_{mercury}}{\rho_{water}} + l_d \quad (m)$$

H_d – Delivery pressure head, (m H_2O)

H_s – Suction pressure head, (m H_2O)

l_d – Level difference between delivery and suction pressure heads, (m)

h_d – Delivery pressure head, (kgf/cm^2)

h_s – Suction pressure head, (inches of Hg)

c) Output power of pump, P_o

$$P_o = \rho g Q H \quad (W)$$

ρ – density of water, 1000 kg/m^3

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

Graphs:

a) Input power vs. Total head
b) Discharge vs. Total head
c) Overall efficiency vs. Total head

Sample calculation steps (Set No:)

1. Discharge, Q

$$Q = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

2. Total head, H

$$H = H_d + H_s + l_d \quad \text{(m)}$$

$$H = \frac{h_d}{\rho_{water} \text{ x } 10^{-4}} + \frac{h_s \text{ x } 25.4 \text{ x } 10^{-3} \text{ x } \rho_{mercury}}{\rho_{water}} + l_d \text{ (m)}$$

3. Output power of pump, P_o

$$P_o = \rho gQH \quad \text{(W)}$$

4. Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{ x } \eta_m}{t_e \text{ x k}} \text{ (W)}$$

d) Input power of pump, P_i

$$P_i = \frac{n_e \text{ x } 3.6 \text{ x } 10^6 \text{x } \eta_m}{t_e \text{ x k}} \text{ (W)}$$

n_e – number of revolutions of energy meter disc

η_m – efficiency of motor, 80%

t_e – average time for n_e revolution of energy meter disc (s)

k – Energy meter constant, 200 rev/kWh

e) Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \text{ (\%)}$$

f) Specific speed, N_s

$$N_s = \frac{N\sqrt{Q_m}}{H_m^{\frac{3}{4}}}$$

Q_m – Discharge at maximum efficiency, (m^3/s)

H_m – Head at maximum efficiency, (m)

N – Rotational speed of pump, (rpm)

PRECAUTIONS

Wherever necessary the pump is to be primed so that it is never allowed to run dry, as the pump running dry will be detrimental to the motor. In case the pump is primed the air vent on the casing and the valve fitted to the priming line is to be closed after priming. The delivery valve is to be closed before starting as well as stopping the pump to avoid unnecessary development of acceleration heads in the pipes. The drain valve of the measuring tank is to be closed before noting the time for the level rise of water in it. The plug cocks of the pressure and vacuum gauges are to be in the opened position. Before taking the observations, steady state conditions are to be ascertained.

5. Overall efficiency of pump, η

$$\eta = \frac{P_o}{P_i} \times 100 \ (\%)$$

6. Specific speed, N_s

$$N_s = \frac{N\sqrt{Q_m}}{H_m^{\frac{3}{4}}}$$

PROCEDURE

The cross sectional dimensions of the measuring tank, the level difference between gauges and the energy meter constant were noted. After observing the precautions, the electric motor was switched ON and the pump was made to run for a few minutes to ascertain steady state condition. The suction gauge and pressure gauge readings and average time for certain number of revolutions of energy meter disc were noted.

The delivery valve was opened a little to obtain a small discharge and after ensuring steady state, the average time for collecting certain quantity of water in the measuring tank, the average time for certain number of revolutions of energy meter disc, the suction gauge and pressure gauge readings were noted.

The experiment was repeated by varying the discharge in steps and the observations were taken as before. The observations were entered in the table. After closing the delivery valve fully and keeping the drain valve in the opened position, the pump was stopped by switching OFF the electric motor.

RESULT

The pump was tested at constant speed and following characteristics are plotted;

a) Input power vs. Discharge
b) Discharge vs. Discharge
c) Overall efficiency vs. Discharge

Maximum efficiency of pump obtained, η_{max} =

Total head corresponding to maximum efficiency =

Total discharge corresponding to maximum efficiency =

The specific speed of pump, N_s = ………………..

INFERENCE

IMPACT OF WATER JET ON VANE

AIM

1. To determine the coefficient of impact for the force exerted by water jet striking on stationary flat plates and curved vanes for the following configurations:

   a) Water jet striking flat plate kept perpendicular to the axis of jet.

   b) Water jet striking on a stationary flat plate kept inclined at an angle to the axis of the jet

   c) Water jet striking on the centre of a symmetrically curved stationary vane.

2. To draw the graph, Coefficient of impact vs velocity of jet, for the above conditions.

APPARATUS REQUIRED

1. The jet on vane apparatus consisting of a free water jet, and lever arrangement for measuring the impact of the jet.
2. The flat plate and symmetrically curved vanes.
3. A measuring tank with standard fittings for assessing the discharge.
4. Stop watch
5. A meter scale to measure the measuring tank size.

SPECIFICATION

Jet diameter – 15 mm
Distance between fulcrum of lever and weight applied – 500 mm
Distance between fulcrum of lever and axis of jet – 100 mm
Angle of inclination of flat plate – 60°
Angle of turn of symmetrically curved vane – 45°

PRINCIPLE

The impact of a jet on a stationary plate or a stationary curved vane is measured by a lever mechanism in the setup. The theoretical force that is exerted by the water jet is calculated from the first principle of

Observation data:

Length of measuring tank, l =

Breadth of measuring tank, b =

Height of water level rise, h = 5cm = 0.05 m

Distance between fulcrum of lever and weight applied = 500 mm

Distance between fulcrum of lever and axis of jet = 100 mm

Coefficient of contraction, Cc = 0.97

Coefficient of velocity, Cv = 0.98

Nozzle inlet diameter = 20 mm

Diameter of jet (throat), d = 15mm = ……… (m)

Angle of inclination of the plate to the axis of the jet, θ = 60°

Angle of turn of the symmetrically curved vane, ϕ = 45°

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

Table 1: Data and result of experiment

Sl No	Type of vane	Time for 5cm rise of water			Actual discharge	Velocity of discharge	Theoretical Impact of jet	Distance between the fulcrum of the lever and the fulcrum of the stirrup	Distance between the fulcrum of the lever and the axis of the jet	Weight of the stirrup	Actual impact of jet	Coefficient of impact
		t_1	t_2	t_m	Q_a	v	F_t	L	l	W	F_o	K
		s	s	s	m^3/s	m/s	N	m	m	kgf	N	--
1	Flat											
2												
3	Inclined θ = 60°											
4												
5	Curved ϕ = 45°											
6												

motion which states force is equal to the rate of change in momentum. The coefficient of impact is the ration of the actual impact of jet to the theoretical value. The calculations involved are:

a) Discharge, Q

$$Q = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

l, b – dimensions of cross section of measuring tank, (m)

h – rise of oil level for time observed with stopwatch, (m)

t_m – mean time for rise of oil in measuring tank through 'h' height, (s)

b) Velocity of the jet, v

$$v = c_c c_v \frac{Q}{\left(\frac{\pi d^2}{4}\right)} \quad \text{(m/s)}$$

C_c – Coefficient of contraction, 0.97

C_v – Coefficient of velocity, 0.98

d – diameter of jet (throat), (m)

c) Theoretical impact of jet, F_t

i) Stationary flat plate kept perpendicular to the axis of the jet

$F_{tp} = \rho Qv$ (N)

ρ – density of water, 1000 kg/m^3

ii) Stationary flat plate kept inclined at an angle to the axis of the jet

$F_{tip} = \rho Qv \text{Sin}\theta$ (N)

θ – angle of inclination of the plate to the axis of the jet, (°)

iii) Symmetrically curved stationary vane

$F_{tcv} = \rho Qv(1+\text{Cos}\phi)$ (N)

ϕ – angle of turn of the curved vane, (°)

Graphs:

a) Coefficient of impact vs. velocity of jet for all three conditions.

Sample calculation steps (Set No:)

1. Discharge, Q

$$Q = \frac{lbh}{t_m} \text{ (m}^3\text{/s)}$$

2. Velocity of the jet, v

$$v = c_c c_v \frac{Q}{\left(\frac{\pi d^2}{4}\right)} \quad \text{(m/s)}$$

3. Theoretical impact of jet, F_t

i) Stationary flat plate kept perpendicular to the axis of the jet

$$F_{tp} = \rho Q v \qquad \text{(N)}$$

ii) Stationary flat plate kept inclined at an angle to the axis of the jet

$$F_{tip} = \rho Q v \text{Sin}\theta \qquad \text{(N)}$$

iii) Symmetrically curved stationary vane

$$F_{tcv} = \rho Q v (1+\text{Cos}\phi) \qquad \text{(N)}$$

d) The actual impact of jet, F_a

$$F_a = \frac{WgL}{l} \quad \text{(N)}$$

W – weight of the stirrup, (kgf)

L – distance between the fulcrum of the lever and the fulcrum of the stirrup, measured along the length of the lever, (m)

l – distance between the fulcrum of the lever and the axis of the jet, measured along the length of the lever, (m)

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

e) The coefficient of impact, K

i) Stationary flat plate kept perpendicular to the axis of the jet

$$K_p = \frac{F_a}{F_{tp}}$$

ii) Stationary flat plate kept inclined at an angle to the axis of the jet

$$K_{ip} = \frac{F_a}{F_{tip}}$$

iii) Symmetrically curved stationary vane

$$K_{cv} = \frac{F_a}{F_{tcv}}$$

PRECAUTIONS

The fulcrums of the lever are to be well lubricated. The flat plates/symmetrical curved vanes are to be fixed firmly in its holder. The jet has to strike exactly at the centre of the flat plate/curved vane. Before starting the experiment and while noting down the observations the lever is to be made horizontal by adjusting the counter weight. Before taking observations, steady state conditions are to be ascertained. The drain valve of the measuring tank is to be closed before noting the time for the level rise of water in it.

4. The actual impact of jet, Fa

$$F_a = \frac{WgL}{I} \quad \text{(N)}$$

5. The coefficient of impact, K

i) Stationary flat plate kept perpendicular to the axis of the jet

$$K_p = \frac{F_a}{F_{tp}}$$

ii) Stationary flat plate kept inclined at an angle to the axis of the jet

$$K_{ip} = \frac{F_a}{F_{tip}}$$

iii) Symmetrically curved stationary vane

$$K_{cv} = \frac{F_a}{F_{tcv}}$$

PROCEDURE

The cross sectional dimensions of the measuring tank, the distance between the fulcrum of the lever and the fulcrum of the stirrup (measured along the length of the lever), the distance between the fulcrum of the lever and the axis of the jet (measured along the length of the lever) were measured. The size of the nozzle, the angle of inclination of the flat plate and the angle of turn of the symmetrical vane were also measured. After observing the precautions, a weight was placed on the stirrup of the lever. The inlet water valve was opened and the water jet was made to strike the flat plate/curved vane. The quantity of water issuing out of the jet was controlled by adjusting the inlet valve to make the lever horizontal. After ensuring the steady state conditions, the weight placed on the stirrup and the average time for collecting a certain quantity of water in the measuring tank was also noted.

The experiment was repeated for different weights placed on the stirrup and the observations were taken as before. The observations were entered in the table. At the end of the test, the inlet valve was closed and drain valve kept in open position. The weights and the flat plates/symmetrically curved vanes were removed.

RESULT

The impact test of water jet on vane was conducted for the following conditions:

a) Water jet striking flat plate kept perpendicular to the axis of jet.

Plotted the graph Coefficient of impact vs velocity of jet

Coefficient of impact, K_p = ……………..

b) Water jet striking on a stationary flat plate kept inclined at an angle to the axis of the jet

Plotted the graph Coefficient of impact vs velocity of jet

Coefficient of impact, K_{ip} = ……………..

c) Water jet striking on the centre of a symmetrically curved stationary vane.

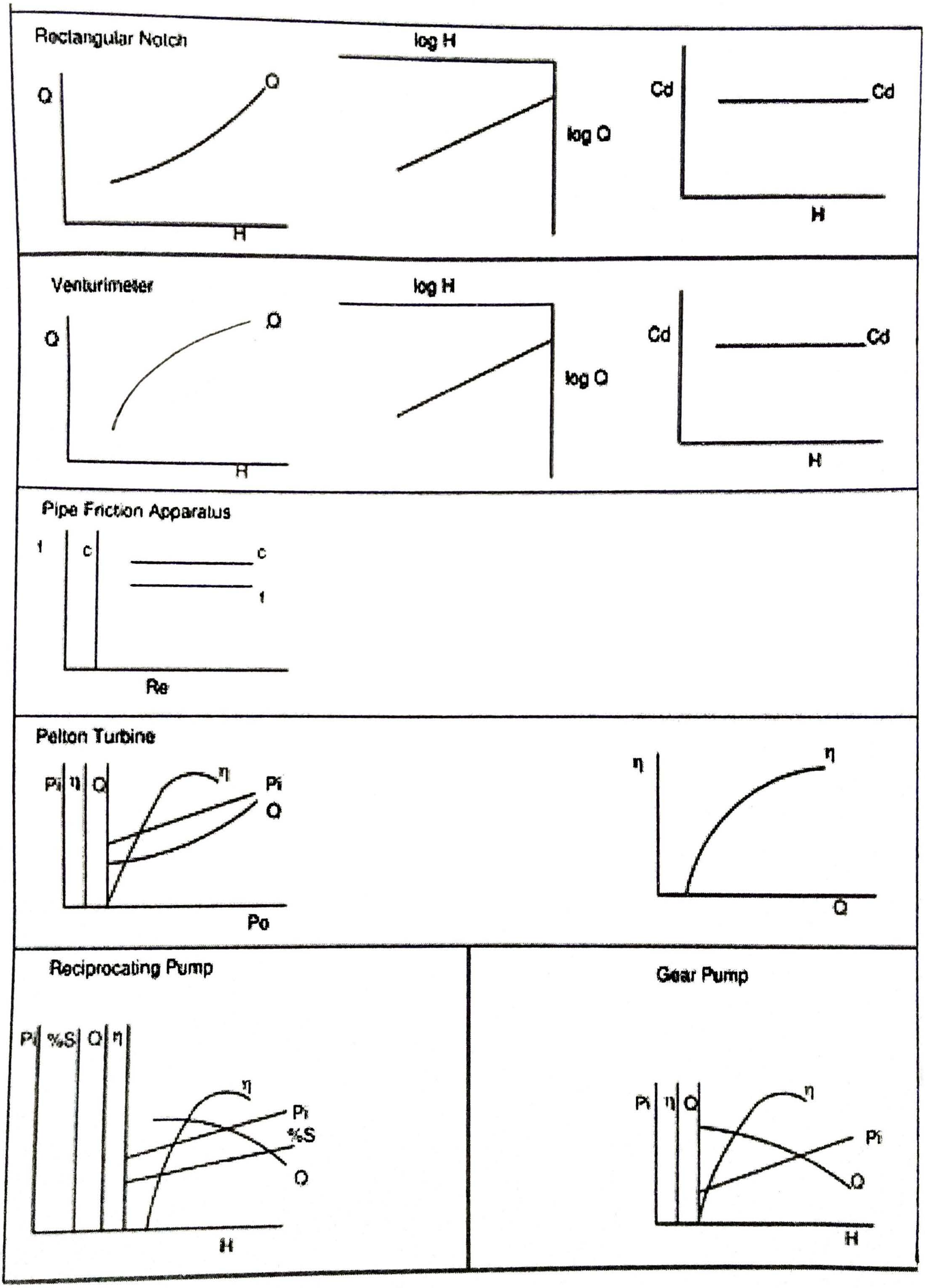
Plotted the graph Coefficient of impact vs velocity of jet

Coefficient of impact, K_{cv} = ……………..

INFERENCE

APPENDIX

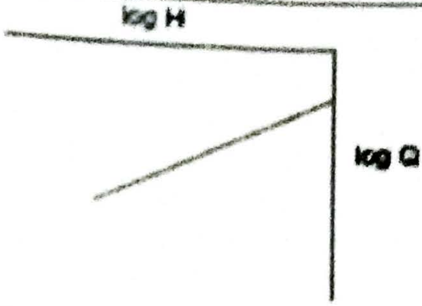
EXPECTED TREND CURVES

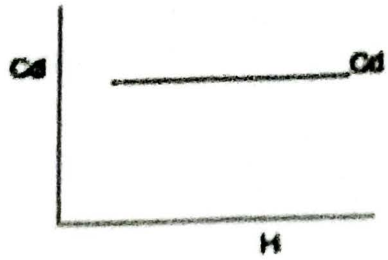


APPENDIX

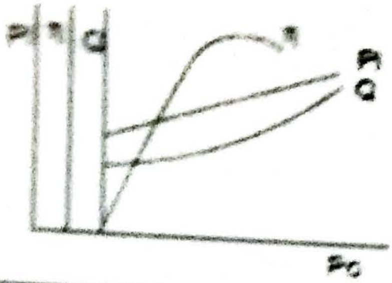
EXPECTED TREND CURVES

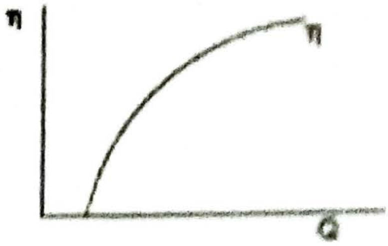
Orificemeter





Francis Turbine





Centrifugal Pump