SIR C.R.REDDY COLLEGE OF ENGINEERING
ELURU-534007

FLUID MECHANICS & MACHINERY LABORATORY MANUAL

III/IV B.TECH (Mechanical): II SEMESTER

DEPARTMENT OF MECHANICAL ENGINEERING

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FLUID MECHANICS & MACHINERY LAB

LIST OF EXPERIMENTS

1.VENTURIMETER

AIM: To calculate the co-efficient of discharge of Venturimeter and to find its variation with throat diameter.

APPARATUS: 1) Venturimeter Test Rig 2) Stopwatch 3) Scale

DESCRIPTION: The apparatus consists of 3 Venturimeters of different throat diameters provided with valves so that we can operate with one Venturimeter at one time and with the help of these, we can adjust the flow rate also. The apparatus is provided with a water tank and a collecting tank. Water in the main tank can be driven by means of a motor through the selected Venturimeter and collected in the collecting tank. Which is provided with same means to read the depth of water collected. Venturimeter is connected to a U-tube manometer by means of things, so that we can read the pressure difference.

THEORY: A Venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe. It consists of three parts

1) A short converging part 2) Throat 3) Diverging part.

It is based on the principle of Bernoulli's equation.
The discharge through Venturimeter under ideal condition i.e. theoretical flow rate is given by

$$Q_{th} = \frac{a_1\, a_2 \sqrt{2gh_w}}{\sqrt{a_1^2 - a_2^2}}$$

Where a_1 = Cross sectional area of the inlet
a_2 = Cross sectional area at the throat
g = Acceleration due to gravity
h_w = Net pressure head of water

But actual discharge will be less than theoretical discharge & is given by

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

Where C_d is coefficient of discharge of Venturimeter and its value is always less than 1.
So C_d can be calculated as for the following formula

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

PROCEDURE:

1. The main tank is filled in with water and the motor connected to Venturimeter tubes is switched on.
2. First the valve of Venturimeter corresponding to throat diameter 20mm is slightly opened so that flow through the Venturimeter takes place.
3. The pressure difference in the U-tube manometer is noted down.
4. Time for 5 cm rise of water level is noted down.
5. The valve is further opened in order to attain different flow rates and the above procedure is repeated for three times and totally four readings are tabulated.
6. The above procedure is repeated for the remaining two Venturimeters of throat diameters 25 mm and 40 mm respectively.

PRECAUTIONS:

1. While adjusting the mercury limbs in U-tube manometer care should be taken to avoid any expelling out of mercury.
2. While performing the experiment on the Venturimeter the two remaining valves corresponding to two Venturimeters should be closed.
3. Time taken for 5 cm rise in water level in the collecting tank should be noted carefully.

S.No	Time taken for 5 cm rise of water level	Manometer readings		$h_m = \frac{h_1-h_2}{100}$ meters	Q_{th}	Q_{act}	C_d
		h_1 cm	h_2 cm				

MODEL CALCULATIONS:

$$Q_{th} = \frac{a_1\, a_2 \sqrt{2gh_w}}{\sqrt{a_1^2 - a_2^2}}$$

$a_2 / a_1 = 0.35$

Where a_1 = Cross sectional area of the inlet = $\pi /4 \times d_1^2$

a_2 = Cross sectional area at the throat

d_1 = Dia of the inlet pipe

g = Acceleration due to gravity

h_w = Net pressure head of water in meters

$$h_w - h_m\left(\frac{\rho_m}{\rho_w} - 1\right)$$

h_m = Net pressure head of mercury manometer in meters
ρ_m = Density of mercury = 13,600 kg / m^3
ρ_w = Density of water = 1000 kg / m^3

Q_{act} = A x H / t
Where A = Area of the collecting tank = 0.1979 m^2
H = Rise of water in collecting tank with in the time 't' in meters
t = time taken for 10 cm rise of water in collecting tank (in seconds)

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

Where C_d = Coefficient of discharge of Venturimeter

GRAPHS: 1)$Q_{act} V_s \sqrt{H_w}$ 2)$Q_{act} Vs Q_{th}$ Take Q_{act} on Y-axis

RESULT:

Mean value of Cd of Venturimeter =

C_d of Venturimeter by Graph =

2.ORIFICEMETER

AIM: To calculate the co-efficient of discharge and find its variation with the orifice diameters

APPARATUS: 1) Orificemeter Test Rig 2) Stop Watch 3) Scale

DESCRIPTION: The apparatus consists of 3 orifice meters of different orifice diameters provided with valves so that we can operate with one Orificemeter at one time and with the help of these we can adjust the flow rate also. The apparatus is provided with a tank of water and a collecting tank. Water in the main tank can be driven by means of a motor through the selected Orificemeter and collected in the collecting tank which is provided with same means to read the depth of water collected. Orificemeter is connected to a tube manometer by means of tubings, so that we can read the pressure difference.

THEORY: Orifice meter is a device used for measuring the rate of flow of a fluid through a pipe. It also works on the same principle as that of Venturimeter. It consists of a flat circular plate which has a circular sharp edged hole called orifice, which is concentric with the pipe. The co-efficient of discharge for orifice meter is much smaller than that for a Venturimeter.

The discharge through Orificemeter under ideal condition i.e. theoretical flow rate is given by

$$Q_{th} = \frac{a_1 \, a_o \sqrt{2gh_w}}{\sqrt{a_1^2 - a_o^2}}$$

Where a_1 = Cross sectional area of the pipe
a_o = Cross sectional area of the orifice
g = Acceleration due to gravity
h_w = Net pressure head of water

But actual discharge will be less than theoretical discharge & is given by

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

Where C_d is coefficient of discharge of Orificemeter and its value is always less than 1.
So C_d can be calculated as for the following formula

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

PROCEDURE:

1. The main tank is filled in with water and the motor connected to Orificemeter tubes is switched on
2. First the valve of Orificemeter corresponding to throat diameter 20 mm is slightly opened so that flow through the Orificemeter tubes takes place.
3. The pressure difference in the U-tube manometer is noted down
4. Time for 5 cm rise of water in the U-tube manometer is noted down
5. The value is further opened in order to attain different flow rates and the above procedure is repeated for three times and totally your readings tabulated

6. The above procedure is repeated for the remaining two Orificemeters of throat diameters 25 mm and 40 mm respectively.

PRECAUTIONS:

1. While adjusting the mercury limbs in U-tube manometer care should be taken to avoid any expelling of mercury out.
2. While performing the experiment on the Orificemeter, the two measuring valves (remaining valves) corresponding to two Orificemeters should be closed.
3. Time taken for 5 cm rise in water level in the collecting tank should be noted carefully

OBSERVATIONS:

S.No	Time taken for 5 cm rise of water level	Manometer readings		$h_m = \frac{h_1-h_2}{100}$ meters	Q_{th}	Q_{act}	C_d
		h_1 cm	h_2 cm				

MODEL CALCULATIONS:

$$Q_{th} = \frac{a_1\, a_o \sqrt{2gh_w}}{\sqrt{a_1^2 - a_o^2}}$$

$a_0 / a_1 = 0.45$

Where a_1 = Cross sectional area of the pipe = $\pi /4 \times d_1^2$

a_o = Cross sectional area of the orifice

d_1 = Dia of the pipe

g = Acceleration due to gravity

h_w = Net pressure head of water

$$h_w = h_m \times \left(\frac{\rho_m}{\rho_w} - 1\right)$$

h_m = Net pressure head of mercury mano meter

ρ_m = Density of mercury = 13,600 kg / m^3

ρ_w = Density of water = 1000 kg / m^3

$Q_{act} = A \times H / t$

Where A = Area of the collecting tank = 0.1979 m^2
H = Rise of water in collecting tank with in the time 't' in meters
t = time taken for 10 cm rise of water in collecting tank (in seconds)

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

Where C_d = Coefficient of discharge of Orificemeter

<u>GRAPHS</u>: 1) Q_{act} Vs $\sqrt{H_w}$ 2) Q_{act} Vs Q_{th} Take Q_{act} on Y-axis

<u>RESULT</u>:

Mean value of Cd of Orificemeter =

Cd of Orificemeter by Graph =

3.MOUTH PIECE (FALLING HEAD METHOD)

AIM: To observe the variation in the coefficient of discharge of a mouth piece with that in the head above the mouth piece using a mouth piece apparatus by falling head method.

APPARATUS: 1) Mouth piece apparatus, 2) Stop watch, 3) Scale

DESCRIPTION: The apparatus consists of a mouthpiece fitted to one side of a vertical tank, main water tank and a collecting tank. Water in the main tank can be driven by means of a motor so that it flows in the mouthpiece fitted tank and there by into the collecting tank through the mouth piece. A valve is provided at the site of motor so that flow in the mouth piece fitted tank can be adjusted. The vertical tank is provided with some scale to measure the head of water above the mouth piece. The collecting tank is provided with some scale to read the water level in it and there by volume of water collected can be computed.

THEORY: Mouth piece is a short length pipe which is two or three times its diameter in length, fitted in a tank or vessel containing fluid. It is used to measure the rate of flow of fluid.

Mouth piece fitted external to the tank is called external mouthpiece (this is the present use with our experiment). The jet of liquid entering the mouth piece constructs to form a vena – contracta. Beyond this section jet again expands and fill the mouth piece completely.

Measurement of coefficient of discharge by falling head method

$$\text{Coefficient of discharge } = C_d = \frac{2A(\sqrt{H_1} - \sqrt{H_2})}{(a \times t \times \sqrt{2g})}$$

Where A = area of the over head tank

H = head of water above the mouth piece

a = area of mouth piece

t = time for water level to fall by 5 cm

PROCEDURE:

1) The mouthpiece fitted tank is completely filled with water.
2) Starting from say40 cm above the mouthpiece (i.e head) time taken for water level to drop by say 5cm is noted.
3) Now time for water level to drop from 35 to 40cm is noted
4) Similarly 5 to 6 readings are noted.
5) The readings are tabulated.

PRECAUTIONS:

1) Head above the mouthpiece should be noted carefully.
2) Time for rise in water level in collecting tank and that for fall in water level in mouth piece fitted tank should be correctly noted.

OBSERVATIONS:

S.No	Water head above the mouth piece		Time taken for 5 cm fall of water level	C_d
	Initial H_1	Final H_2		

MODEL CALCULATIONS:

$$\text{Coefficient of discharge} = C_d = \frac{2A(\sqrt{H_1} - \sqrt{H_2})}{(a \times t \times \sqrt{2g})}$$

Where A = area of the over head tank = 0.34 X 0.35 = 0.119 m^2
H_1 = Initial head of water above the mouth piece =
H_2 = Final head of water above the mouth piece =
a = area of mouth piece ($\pi/4\ d^2$)
d = Diameter of the mouth piece = 0.01 m
t = time for water level to fall by 5 cm

GRAPHS: t Vs $\sqrt{H_1} - \sqrt{H_2}$

RESULT: Mean value of C_d of mouth piece =

4.MOUTH PIECE (CONSTANT HEAD METHOD)

AIM: To observe the variation in the coefficient of discharge of a mouth piece with that in the head above the mouth piece using a mouth piece apparatus by constant head method.

APPARATUS: 1) Mouth piece apparatus, 2) Stop watch, 3) Scale

DESCRIPTION: The apparatus consists of a mouthpiece fitted to one side of a vertical tank, main water tank and a collecting tank. Water in the main tank can be driven by means of a motor so that it flows in the mouthpiece fitted tank and there by into the collecting tank through the mouth piece. A valve is provided at the site of motor so that flow in the mouth piece fitted tank can be adjusted. The vertical tank is provided with some scale to measure the head of water above the mouth piece. The collecting tank is provided with some scale to read the water level in it and there by volume of water collected can be computed.

THEORY: Mouth piece is a short length pipe which is two or three times its diameter in length, fitted in a tank or vessel containing fluid. It is used to measure the rate of flow of fluid.

Mouth piece fitted external to the tank is called external mouthpiece (this is the present use with our experiment). The jet of liquid entering the mouth piece constructs to form a vena – contracta. Beyond this section jet again expands and fill the mouth piece completely.

Measurement of coefficient of discharge by Constant head method

Theoretical discharge = $Q_{th} = a\sqrt{2gH}$

Where a – area of mouth piece
H – head of water above the mouth piece

Actual discharge = $Q_{act} = (A \times h) / t$

Where A – area of the collecting tank
h – rise in water level
And t – time for water level to rise by h

Coefficient of discharge is defined as the ratio of actual discharge to theoretical discharge

$$C_d = Q_{act} / Q_{th}$$

PROCEDURE:

6) The main tank is filled with water and the motor is switched on
7) Valve at the motor site is closed to transfer in to the vertical mouth piece fitted tank
8) Time is allowed for the water level to settle at some height above the mouth piece
9) The head of water above the mouthpiece is measured by means of the scale provided at the side of the tank.

10) Time for 5am rise in water level in the collecting tank is noted.
11) The valve at motor site is further closed to achieve another flow rate and the above procedure is adopted.
12) In this manner for 2 more times the similar procedure is repeated and the readings are noted.
13) Readings at 4 different heads are noted in a tabular form..

PRECAUTIONS:

1) Head above the mouth piece should be noted carefully.
2) Time for rise in water level in collecting tank and that for fall in water level in mouth piece fitted tank should be correctly noted.

OBSERVATIONS:

S.No	Time taken for 5 cm rise of water level	Head above mouth piece H cm	Q_{act}	Q_{th}	C_d

MODEL CALCULATIONS:

Theoritical discharge = $Q_{th} = a\sqrt{2gH}$

Where a – area of mouth piece = $\pi d^2/4$
d = dia of mouth piece = 0.01 m
H – head of water above the mouth piece in meters

Actual discharge = $Q_{act} = (A \times h) / t$

Where A – area of the collecting tank = .45x 0.55 = 0.2475 m^2
h – rise in water level (in meters)
t – time for water level to rise by h

$C_d = Q_{act} / Q_{th}$

GRAPHS: 1) Q_{act} Vs $\sqrt{H}$ 2) Q_{act} Vs Q_{th} Take Q_{act} on Y-axis

RESULT:

Mean value of Cd of mouth piece = Cd of mouth piece by Graph =

5.V– NOTCH

AIM: To observe the variation in co-efficient of discharge of a V-notch with that in the heights of V-notch using V-notch apparatus.

APPARATUS: 1) V-Notch Test rig, 2) Stop Watch, 3) Scale

DESCRIPTION: The apparatus consists of a V-notch fitted to inside of a channel in rectangular shape, another side of which is closed, main water tank and a collecting tank. Water in the main tank can be driven by means of a motor so that water flows in to the channel and there by in to the collecting tank through V-notch. A valve is provided at the motor site so that the flow rate through V-notch can be adjusted. The channel is provided with some means to read the V-notch height. The collecting tank is also provided with some means to read the rise in water level and there by volume of water collected can be measured.

THEORY: A notch is a device used for measuring the rate of flow through a small channel or a tank. It may be defined as an opening in the side of a tank or a small channel in such a way as liquid surface in the tank or channel is below the top edge of the opening.

Theoritical discharge through V-notch is given by

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

Where θ = V-notch angle
H = head of water above the notch

Actual discharge through V-notch is given by

$$Q_{act} = \frac{A \times h}{t}$$

Where A = area of the collecting tank
h = rise in water level in the collecting tank
And t = time for water level to rise by h

Co-efficient of discharge through V-notch is defined as the ratio of actual discharge to the theoritical discharge

$$C_d = Q_{act} / Q_{th}$$

PROCEDURE:

1. The main tank is filled with water and the motor is switched on
2. Value at the motor site is closed to transfer water rate in to the rectangular channel
3. The valve is opened completely to cease the water flow into the channel when the water level exceeds the notch bottom
4. Time is allowed for the water to flow through the notch till the level settles at the bottom level of notch

5. Scale provided at the rectangular tank (channel) is adjusted at zero for the present water level
6. Now the valve at the motor site is closed tightly so that water moves into the tank and some time is allowed for the water level to settle at constant height
7. The head of water above the notch is read by means of the scale provided
8. By means of a stop watch, time for 5 cm rise in water level in the collecting tank is measured
9. The valve at motor site is further closed so that water rises in the rectangular tank and the above described procedure is repeated and the readings are tabulated

PRECAUTIONS:

1. Initially water in the rectangular channel (tank) should be in plane with that of V-notch bottom
2. Head above the V-notch should carefully be noted
3. Time taken for 5 cm rise in water level should be read accurately

OBSERVATIONS:

S.No	Time taken for 5 cm rise of water level	Head above notch H cm	Q_{act}	Q_{th}	C_d

MODEL CALCULATIONS:

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

Where θ = V-notch angle = 60^o
H = head of water above the notch

$$Q_{act} = (A \times h)/t$$

Where A = area of the collecting tank = 0.54 x 0.44 = 0.2376 m^2
h = rise in water level in the collecting tank (in meters)
And t = time for water level to rise by h

$$C_d = Q_{act} / Q_{th}$$

GRAPHS: 1) Q_{act} Vs $H^{5/2}$ 2) Q_{act} Vs Q_{th} Take Q_{act} on Y-axis

RESULT:

Mean value of Cd of V- notch = Cd of V- notch by Graph =

6.RECIPROCATING PUMP

AIM: To draw the characteristic curves of a reciprocating pump

APPARATUS: Reciprocating pump test rig, tachometer and stopwatch

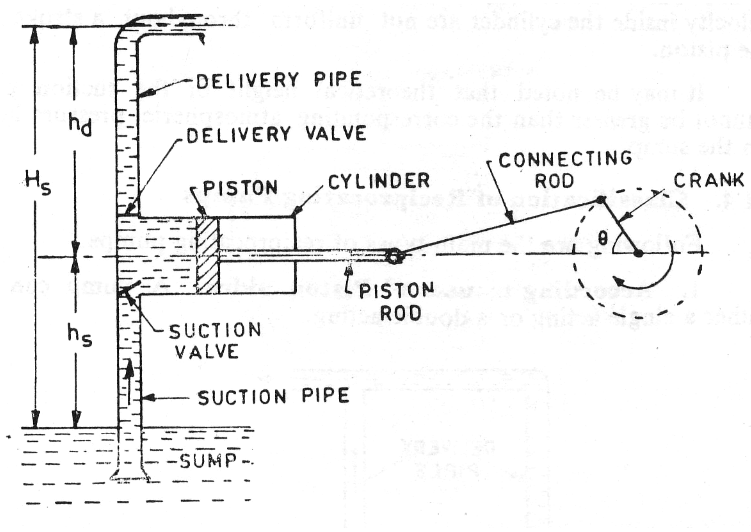
DESCRIPTION:

The experiment setup is a closed circuit type, it mainly consists of

1. Double acting reciprocating pump
2. A single speed 1 HP AC motor with rated speed of 1420 rpm.
3. A piping system and measuring tank .
4. A stepped pulley arrangement for changing of speed.
5. In put power measuring arrangement.
6. Sump.

The reciprocating pump is a double acting type. The suction and delivery pipes are 1” and ¾” in diameter. The pump is driven by a V-belt from the motor through the pulley arrangement, the measuring tank size is 0.3m x 0.3 m

THEORY: A reciprocating pump essentially consists of a piston or plunger which moves to and fro in a closed fitting cylinder. A typical double acting cylinder is connected to suction and delivery pipes, each of which is provided with a non return valve. The piston is connected to a crank by means of connecting rod. During the suction stroke, the crank rotates from 0 to 180 degrees and a partial vaccum is created in the cylinder, which enables the atmospheric pressure acting on the liquid surface in the sump below, force the liquid up the suction and fill the cylinder by opening the suction valve. During the delivery stroke the crank rotates 1800 to 3600 and the piston forces the water to go out of the cylinder through the delivery valve. The operating characteristic curves of a reciprocating pump are obtained by plotting the discharge Q power input P and overall efficiency η against the head developed by the pump H when it is operating at constant speed.



PROCEDURE :

1) The pump is filled with sufficient amount of water and the pump is primed if necessary.
2) The delivery valve is kept open and the pump is started and is run at a particular speed. The speed of the pump is measured with the help of a tachometer.
3) The actual discharge Q is measured by noting the time taken for a rise in height of water in the measuring tank.
4) The input power is calculated by noting the time taken for 5 revolutions of the energy meter disc.
5) Suction and delivery pressures are noted from the pressure gauges.
6) Position of delivery valve is slightly altered for different delivery pressures and another set of readings of suction pressure, delivery pressure and discharge are found.
7) Characteristic curves are plotted according to the values obtained.

PRECAUTIONS:

1. The delivery valve should be completely closed before starting and stopping of the pump
2. Priming is done for the pump before starting

OBSERVATIONS:

S. No	Speed (N) rpm	Time taken for 5 rev disc t	Time taken for 5cm rise of water T	Suction head P_s	Delivery Head P_d	H meters	Input power W	Out put power W	η = (Op/Ip) x 100	Discharge Q(m^3/sec)

MODEL CALCULATIONS:

1. Input power = $\dfrac{n \times 3600 \times 1000}{t \times E.C}$

n = no. of rev of the energy meter disc = 5 rev
t = time taken for 5 rev of the disc
E.C = Energy meter constant = 1200 rev/kwh

2. Output power = WQH

W = Specific weight of water = 9810 N/m^3

$$Q = \frac{A \times h}{T}$$

Q = Discharge of the pump

A = area of the collecting tank = 0.3 x 0.3

h = height of the water level in the tank

T = time taken for 5 cm rise of water level

$$H = \left[\frac{P_s}{760} + \frac{P_d}{1.033}\right] \times 10.33 \text{ m of water head}$$

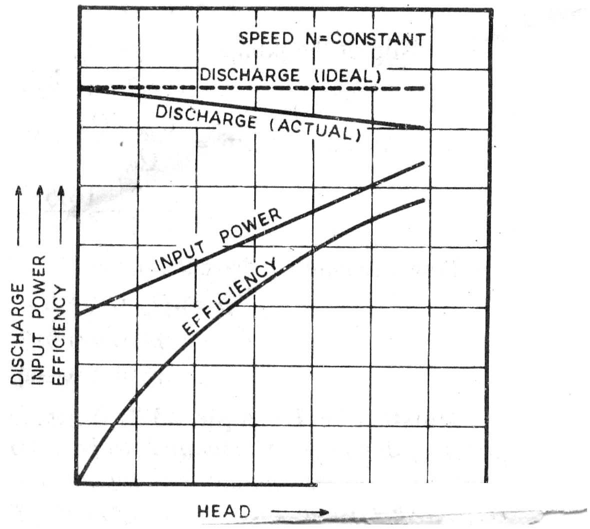
P_s = Vacuum pressure in mm of H_g

P_d = Delivery pressure in Kg/cm^2

3. Efficiency of pump $\eta = \dfrac{outputpower}{inputpower} \times 100$

GRAPHS:

1) Head Vs Discharge
2) Head Vs Efficiency
3) Head Vs Power



RESULT: The performance curves of the pump are obtained.

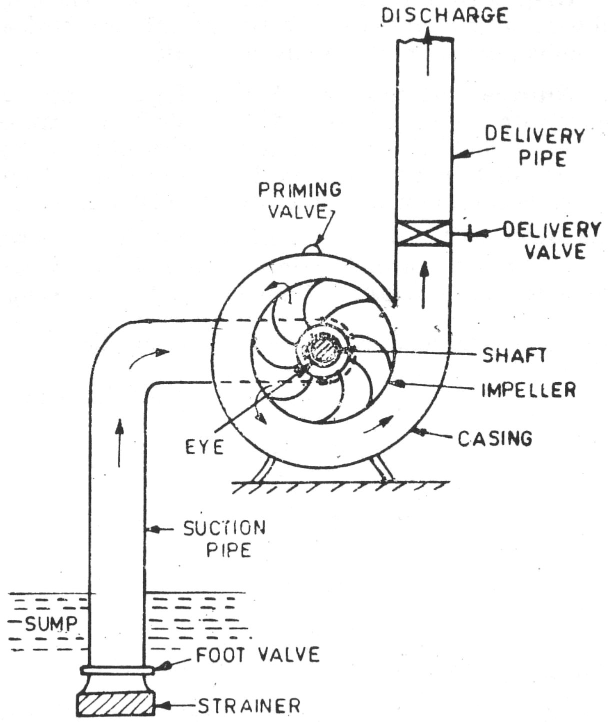
7.CENTRIFUGAL PUMP

AIM: To draw the performance curves of centrifugal pump

APPARATUS: Centrifugal test rig, Stop watch, Tachometer

THEORY: The hydraulic machine converts the mechanical energy into the pressure energy or hydraulic energy. The machine, which converts the mechanical energy to the hydraulic energy by means of centrifugal force, that hydraulic machine is known as centrifugal pump.

The centrifugal pump works on the principle of force vortex flow by means that when certain mass of fluid is rotated by means of any external force. There will be rise of pressure of the fluid at its centre of rotation takes place at the outlet of the impeller when the radius is more, the rise in head is more and the discharge is also high. Due to this rise in pressure head this pressure head can be used to rise the fluid



to a high level.

PROCEDURE:

1. The sump is filled with sufficient amount of water keeping the delivery valve fully closed, the pump is started
2. Priming is done for the pump before starting

3. Then the valve is slowly opened and the actual discharge is found by noting the time taken for 5 cm raise of water level.

4. The time taken for 5 revolutions of the energy meter disc is noted and by using this time the input power can be known

5. The suction and delivery pressure are known by the pressure gauges

6. The procedure is repeated for different set of readings

PRECAUTIONS:

3. The delivery valve should be completely closed before starting and stopping of the pump

4. Priming is done for the pump before starting

OBSERVATIONS:

S. No	Speed (N) rpm	Time taken for 5 rev disc t	Time taken for 5cm rise of water T	Suction head P_s	Delivery Head P_d	H meters	Input power W	Out put power W	η = (Op/Ip) x 100	Discharge Q(m^3/sec)

MODEL CALCULATIONS:

4. Input power = $\dfrac{n \times 3600 \times 1000}{t \times E.C}$

n = no. of rev of the energy meter disc = 5 rev
t = time taken for 5 rev of the disc
E.C = Energy meter constant = 150 rev/kWh

5. Output power = WQH

W = Specific weight of water = 9810 N/m^3

$$Q = \frac{A \times h}{T}$$

Q = Discharge of the pump in m^3/sec
A = area of the collecting tank = 1x 0.4 m^2
h = height of the water level in the tank in m

T = time taken for 5 cm rise of water level

$$H = \left[\frac{P_s}{760} + \frac{P_d}{1.033}\right] \times 10.33 \text{ m of water head}$$

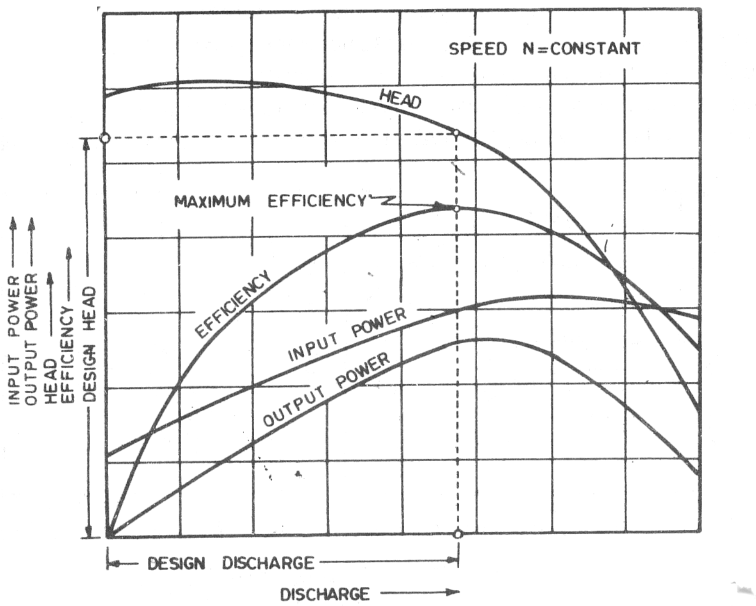
P_s = Vacuum pressure in mm of H_g

P_d = Delivery pressure in Kg/cm^2

6. Efficiency of pump $\eta = \dfrac{outputpower}{inputpower} \times 100$

GRAPHS:

4) Discharge Vs Head
5) Discharge Vs Efficiency
6) Discharge Vs Power



RESULT: The performance curves of the pump are obtained.

8.FRANCIS TURBINE

AIM: To draw the performance characteristic curves of Francis turbine

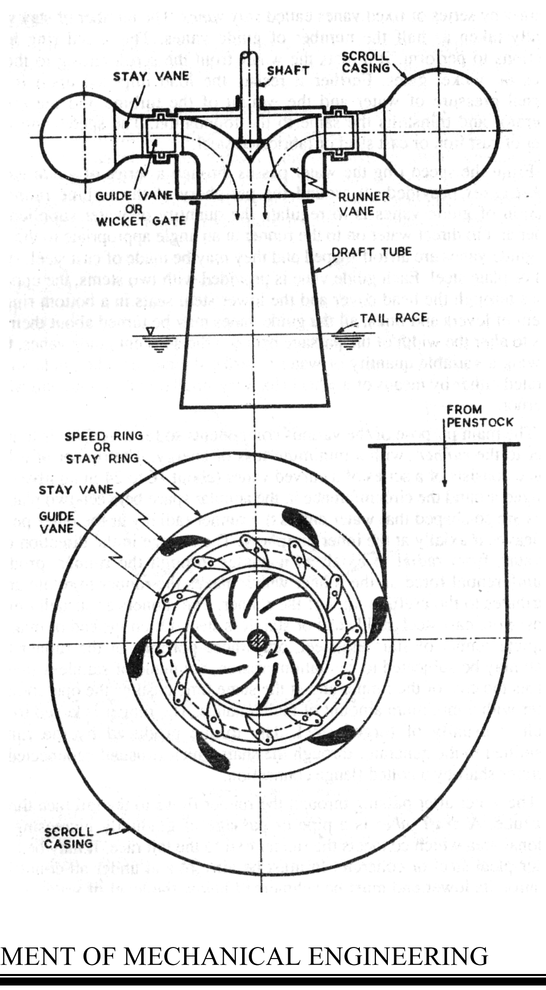
APPARATUS: Closed circuit experiment setup containing Francis turbine, tachometer, weights

THEORY: Radial flow turbines are those turbines in which the water flows in the radial direction. The water may flow radially from outwards to inwards or vice versa. If the water flows from outwards to inwards through the runner, the turbine is known as inward flow reaction turbine.

Reaction turbine means that the water at the inlet of the turbine possess kinetic energy as well as pressure energy. As the water flows through the runner, a part of pressure energy goes on changing into kinetic energy

The inward flow reaction turbine having radial discharge at outlet is known as Francis turbine. In the modern Francis turbine, the water enters the turbine in the radial direction at the outlet and leaves in the axial direction at the inlet of the runner. The main parts of the turbine are

1. Casing
2. Runner
3. Guide mechanism
4. Draft tube



PROCEDURE:

1. The pump is filled with sufficient amount of water and the pump is primed if necessary
2. The turbine is kept in the unloaded position. The gate valve and the manometer cocks are kept closed
3. The pump is started and the gate valve is slowly opened. The amount of water entering the casing is adjusted by turning the wheel connected to the guide valves
4. The speed of the turbine is measured and the manometer readings are noted. The head of the turbine is measured.
5. The turbine is gradually loaded from lower to higher weights and the speed, manometer readings, load applied are noted for each step of loading
6. The above procedure is repeated for ½, 3/4th, fully open conditions of the gate valve

PRECAUTIONS:

1. Before the experiment is started, it must be checked that the gate valve and the cocks of the manometer are closed.
2. The water used must be free from dust
3. The cocks of the manometer must be opened gently

OBSERVATIONS:

Gate opening	Speed N (rpm)	Pressure gauge reading P_1 Kg/cm^2	Head of the Water H meters	Manometer readings			Load applied W(kg)	Spring balance reading S(kg)	Net load (kg) W - S	WP	BP	η	Nu	Pu	Qu
				h1 Cm	h2 cm	h=(h1-h2)x 10 mm									
¼ ½ ¾ full															

MODEL CALCULATIONS:

$$\textbf{Input Power =Water power =} \frac{WQH}{1000} \textbf{ in Kw}$$

W = 9810 N/m^3

$$Q = \left(\frac{84.5 \times \sqrt{h}}{60000}\right) \text{ in m}^3\text{/sec}$$

84.5 = Venturimeter constant

h = Manometer reading in mm of Hg

$$H = \left(\frac{P_1 + 1.033}{1.033}\right) \times (10.33) \text{ in meters of water}$$

P_1 = Pressure gauge reading in Kg/cm^2

Brake power = Output Power $= \dfrac{2\pi NT}{60000}$ Kw

N = Speed of brake drum dynamometer in rpm

T = $(W - S) \times 9.81 \times 0.162$ N-m

Efficiency $\eta = \dfrac{output}{input} \times 100$

Unit speed $N_u = \dfrac{N}{\sqrt{H}}$

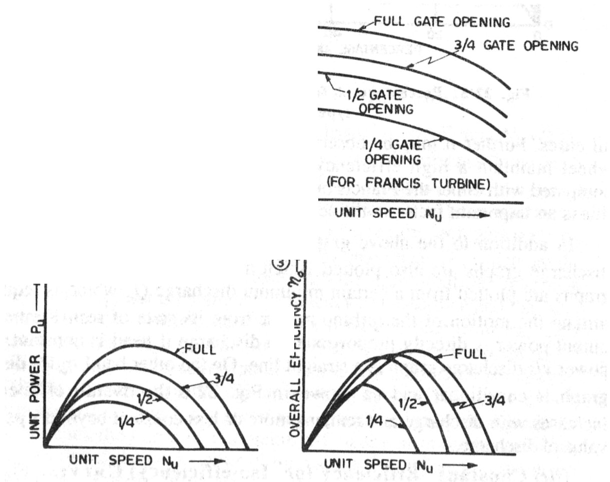
Unit discharge $Q_u = \dfrac{Q}{\sqrt{H}}$

Unit power $P_u = \dfrac{P}{H^{3/2}}$

P = Brake Power

GRAPHS:

1. Unit Speed Vs Unit Discharge
2. Unit Speed Vs Unit Power
3. Unit Speed Vs Efficiency



RESULT: The performance characteristic curves of Francis Turbine are obtained.

9.PELTON WHEEL

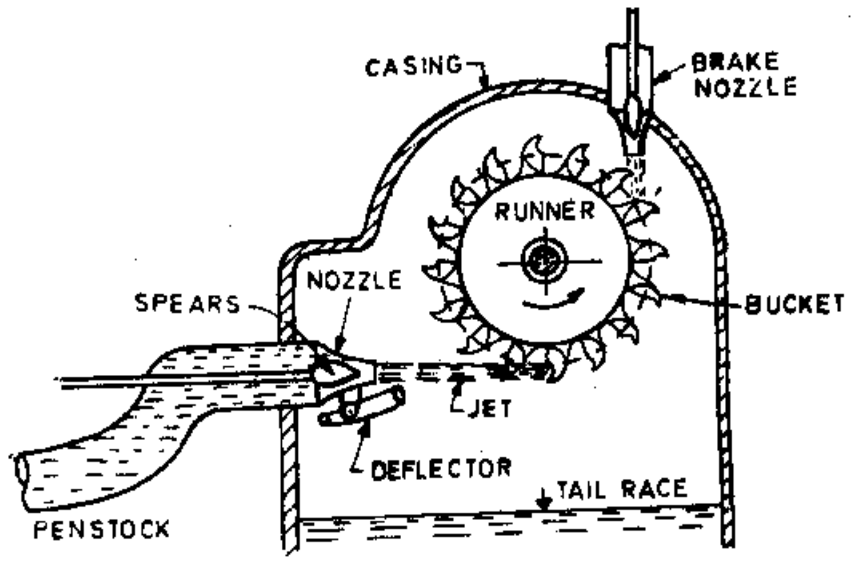
AIM: To draw the performance characteristic curves of Pelton wheel

APPARATUS: Closed circuit experimental setup containing Pelton wheel, tachometer, Weights

THEORY: The Pelton wheel or Pelton turbine is a tangential flow impulse turbine. The water strikes the bucket along the tangent of runner. The energy available at the runner is only kinetic energy. The pressure at the inlet and outlet of the turbine is atmospheric. This turbine is used for high heads

The water flows from the reservoir and flows through the penstock at the outlet of which a nozzle is fitted, the nozzle increases the kinetic energy of water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of a jet and strikes the buckets of the runner. The main parts of the Pelton wheel are

1. Nozzle and flow regulating arrangement
2. Runner and buckets
3. Casing and braking jet



Single-jet Pelton turbine

PROCEDURE:

1. The pump is fitted with sufficient amount of water and the pump is primed if necessary
2. The turbine is kept in the unloaded position, gate valve and cocks of the manometer are kept constant
3. The pump is started and the gate valve is slowly opened. The amount of water striking the wheel is adjusted by keeping the spear in $1/4^{th}$ open conditions
4. The speed of the turbine is measured and the manometer reading is noted. The head on the turbine is measured

5. The turbine is gradually loaded from lower to higher weights and the speed, manometer reading and the load applied are noted in each case
6. The above procedure is repeated for ½, ¾ th, fully open conditions.

PRECAUTIONS:

1. The gate valve and cocks of the manometer must be closed at the initial stage
2. Water used must be free from dust
3. Manometer readings are taken with out parallax error
4. Cocks of the manometer must be opened gently

OBSERVATIONS:

Gate opening	Speed N (rpm)	Pressure gauge reading P_1 Kg/cm^2	Head of the Water H meters	Manometer readings			Load applied W(kg)	Spring balance reading S(kg)	Net load (kg) W - S	WP	BP	η	Nu	Pu	Qu
				h1 Cm	h2 cm	h=(h1-h2)x 10 mm									
¼ ½ ¾ full															

MODEL CALCULATIONS:

$$\text{Input Power} = \text{Water power} = \frac{WQH}{1000} \quad \text{in Kw}$$

$W = 9810\ N/m^3$

$$Q = \left(\frac{35.7 \times \sqrt{h}}{60000}\right) \text{ in } m^3/sec$$

35.7 = Venturimeter constant

h = Manometer reading in mm of Hg

$$H = \left(\frac{P_1 + 1.033}{1.033}\right) \times (10.33) \text{ in meters of water}$$

P_1 = Pressure gauge reading in Kg/cm^2

$$\text{Brake power} = \text{Output Power} = \frac{2\pi NT}{60000} \quad Kw$$

N = Speed of brake drum dynamometer in rpm

T = $(W - S) \times 9.81 \times 0.162$ N-m

Efficiency $\eta = \dfrac{output}{input} \times 100$

Unit speed $N_u = \dfrac{N}{\sqrt{H}}$

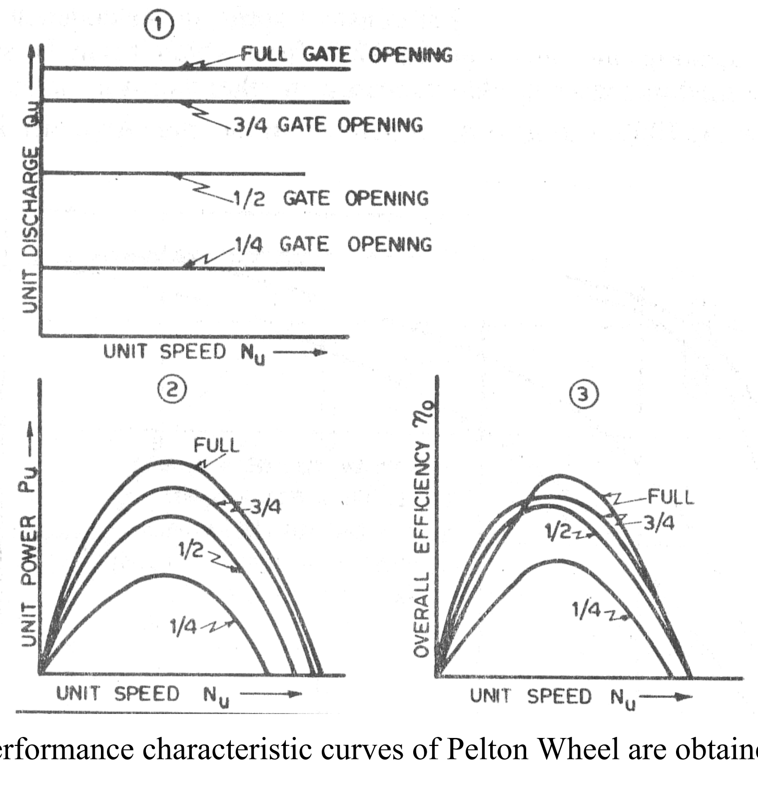
Unit discharge $Q_u = \dfrac{Q}{\sqrt{H}}$

Unit power $P_u = \dfrac{P}{H^{3/2}}$

P = Brake Power

GRAPHS:

4. Unit Speed Vs Unit Discharge
5. Unit Speed Vs Unit Power
6. Unit Speed Vs Efficiency



RESULT: The performance characteristic curves of Pelton Wheel are obtained.

10.LIFT AND DRAG COEFFICIENT FOR AN AEROFOIL

Aim:

To determine the lift and drag forces for the given aerofoil and hence to obtain co-efficient of lift and coefficient of drag.

Apparatus:

1. Wind tunnel test rig
2. NACA 0018 aerofoil of axial chord = 16 cm and Span = 25 cm
3. NACA 0018 aerofoil with a linkage mechanism and a digital component force measuring transducer to determine lift and drag forces.
4. A pitot - static tube with a U-tube water manometer

Description:

The wind tunnel is of suction type with an axial flow fan driven by a variable speed DC motor. It consists of an entrance section with a bell mouth inlet containing a flow straighter, screen and a straw honey combs. This section is followed by a nozzle section, test section, a diffuser section and a duct containing the axial flow fan. The whole unit is supported on steel frame. The complete wind tunnel except the test section is constructed of MS sheets for strength and rigidity. The test section is made of teak wood and has plexiglass window for visual observations of flow phenomena. The control of the DC motor is by a rectifier controlled variable speed drive.

Theory:

Wind tunnel is generally used for testing the models of various shapes like aerofoils, cylinders, cascade of blades etc. In a wind tunnel the important part is the test section. The aim is to obtain a truly rectilinear flow across the test section. The object to be tested are placed in the test section. The wind tunnel can be of suction type or blower type. The air enters in to the settling chamber on account of the large cross section area of the setting chamber. Its velocity is reduced, and the presence of wire gauges and honey comb straightens the flow before it is expanded in the contraction zone. The working or test section receives a uniform stream of air from the contraction zone.

Procedure:

1. The given aerofoil is rigidly fixed in the test section to the vertical rod extending from the transducer. The angle of incidence (α) is kept at zero initially.
2. The transducers are connected to the digital display device where the lift and drag forces can be read directly.
3. The motor is started and speed is increased gradually. So that manometer deflection from the pitot tube is at least 5 cm.
4. The lift force & drag force are noted from the display device
5. The angle of incidence is altered to different angles and the readings of lift and drag forces are noted.
6. Graphs are plotted for C_L C_D Versus incidence angle.

Observations:

S.No	Angle of incidence α (Deg)	Pitot tube reading q (cm)	Drag force F_D (kgf)	Lift force F_L (kgf)

Model Calculations:

Incidence angle (α) = 0^0

Pitot tube reading = q cm

Velocity (V) = 13 √q m/s

Drag Coefficient (C_D):

Drag coefficient (C_D) = $\dfrac{F_D}{\frac{1}{2}\rho V^2 \times A}$

Where A = Chord x span

Lift Coefficient (C_l):

Lift coefficient (C_L)= $\dfrac{F_L}{\frac{1}{2}\rho V^2 \times A}$

Results:

SNo	Angle of incidence α (Deg)	Velocity of Air V (m/sec)	Drag Coefficient (C_D)	Lift Coefficient (C_L)

Precautions:

1. When the power is turned with main switch, the speed control knob of the motor should be kept at minimum.
2. The DC motor should not be operated at low inlet voltages.
3. The aerofoi1 should be tight in its position while taking the readings for a particular incidence angle.

11.VERIFICATION OF BERNOULLI'S THEOREM

Aim:

To verify Bernoulli's theorem.

Theory:

The Bernoulli's theorem states that for steady, uniform & laminar flow of an incompressible fluid, the total energy per unit weight or total head of each particle remains same along a stream line provided no energy is gained or lost.

Most of the hydraulic studies are based on the principle of Bernoulli's theorem. Verification of the above principle experimentally helps in better understanding of the principles of hydraulics flow.

Mathematically, Bernoulli' s theorem can be expressed as Total head (or) Total energy per unit weight,

$$H_t = z + \frac{v^2}{2g} + \frac{p}{w} = \text{Constant}$$

Where, Z = datum head = position of center of conduit with respect to datum

$\frac{v^2}{2g}$ = Velocity Head

Q = Actual Discharge

V = Velocity of flow = $\frac{Q}{A}$ = ______________

A = Cross sectional area

g = Acceleration due to gravity

$\frac{p}{w}$ = Piezometric head or pressure head

w = Specific weight i.e., weight per unit volume = $\rho \times g$ = 9810 N/m^3

ρ = Mass density is the mass per unit volume for water

Apparatus:

Bernouli's Apparatus

Collecting tank with piezometer

Stopwatch to measure the time of collection

Meter scale to measure the internal dimensions of the collecting tank

Description Of The Equipment:

The experimental set up consists of a convergent- passage of rectangular cross section made out of clear transparent sheet to facilitate visual observation of the flow. The passage walls are so made that the top of the wall is horizontal and the sidewalls are vertical and mutually parallel to each other. The lower wall is so constructed that it gives the passage to the required convergence and divergence. The total length of test section of the passage divided in to a number of equal lengths, where piezometric tubes are fitted. Each of these piezometric tubes is provided with a scale to measure the pressure energy or pressure heads.

At both the ends of the passage tanks are provided, which help to stabilize the flow. The calibrated scale is provided to measure the volume of water in the measuring tank based on the water level in the gauge glass.

The setup is provided with an arrangement for injecting a dye (color) into the passage at its entrance a fine nozzle with the help of which usual observation of the flow can be made

Procedure:

1. The experiment is conducted with datum line taken at the center line of the rectangular channel of varying cross sections and is same at all sections and considered ‘zero’ as its value.
2. Open the inlet valve to allow the flow from the supply tank through the conduct. Also admit the dye into the passage.
3. Adjust the outlet valve of the apparatus, so that a constant head is maintained in the supply tank of the apparatus.
4. Remove air bubbles in the piezometer tubes. Measure the pressure heads at various sections of the conduit with the piezometers placed at each section.
5. Note the time ‘t’ for collection of water to the known rise ‘H’ of water level in the collecting tank.
6. Calculate velocity and hence velocity head.
7. Tabulate the observations and calculate the total heads.

Specimen Calculations:

(Reading No:)

Area of the collecting tank, A = L x B = 0.3 x 0.3 = 0.09 m^2

Discharge, $Q = \frac{AH}{t} = \frac{0.09x0.1}{t} = \frac{0.009}{t}\ m^3/s$

Velocity, $v = \frac{Q}{a} =$ m/s

Velocity head, $\frac{v^2}{2g} =$ m

Pressure head, $h = \frac{p}{w} =$ m

Cross section		Time for 'H' m rise 't' in sec		Avg time 't' in sec	Discharge $Q = \frac{AH}{t}$ in m^3/s	Velocity $v = \frac{Q}{a}$ in m^3/s	Velocity head, $\frac{v^2}{2g}$ in m/s	Pressure head, $h = \frac{p}{w}$ in m	Datum head Z in m	Total head $H_t = z + \frac{v^2}{2g} + \frac{p}{w}$ in m
No	Area 10^{-4} m^2	1	2							
1	a_1=1.8									
2	a_2=1.6									
3	a_3 = 1.4									
4	a_4=1.2									
5	a_5=1									
6	a_6=1.1									
7	a_7=1.2									
8	a_8=1.3									
9	a_9=1.4									
10	a_{10}=1.5									
11	a_{11}=1.6									
12	a_{12}=1.7									
13	a_{13}=1.8									
14	a_{14}=1.9									

Datum head, z = m

Therefore, total head at each station, $H_t = z + \frac{v^2}{2g} + \frac{p}{w} =$ m

$$\therefore H_t = z_1 + \frac{v_1^2}{2g} + \frac{p_1}{w} = H_t = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{w} = \text{Constant}$$

Graph:

The graphs of pressure head, velocity head and total head are drawn at various cross-sections, taking the cross section area on X-axis.

12.CO-EFFICIENT OF FRICTION IN PIPES

Aim:

To determine the Coefficient of Friction of a pipe

Theory:

When a liquid flows through a pipe it looses some of its energy in over coming the frictional resistance. Hence, the pressure applied at one end of the pipe does not reach the other end, due to the friction. This loss in pressure head is called the frictional loss and it depends upon the contact area, velocity of flow and length of pipe. Determination of Co-efficient of friction helps to determine the head loss in the flow as it flows from one point to other.

Apparatus:

- Test pipe with valves to control now
- Manometer or any pressure measuring device to measure the pressure difference between points of observation
- Collecting lank to collect the discharge through pipe
- Stop Watch to determine the time of collection of water to know raise of water level in the tank
- Scale to measure the plan dimensions of collecting tank

Description of apparatus:

The test rig consists of a pipe length with inlet and outlet control valves. Two pressure tapings are made at a length (1 meter) and connected to a U-tube mercury manometer or any pressure measuring devices to measure the pressure difference between the two points of observation. A collecting tank is provided at the out let end to collect the discharge and to find out the actual discharge.

Procedure:

1. Open the inlet valve and allow the liquid to flow through the pipe
2. Note the left limb and right limb readings in the manometer or pressure gauge readings at the point of observation.
3. Close the outlet valve in the collecting tank
4. Note the time taken for ‘H’ mm raise of water level in collecting lank
5. Increase the discharge by opening the inlet valve and repeat for at least five times

Observations & Tabulations:

Manometric readings in left limb of the manometer, $h_1 =$ m

Manometric readings in right limb of the manometer, $h_2 =$ m

Specific gravity of manometer liquid, (Mercury) $S_m = 13.6$

Specific gravity of flowing liquid, (water) $S_f = 1.0$

Co-efficient of friction, f =

Length of pipe between the points of observation, l = m

Velocity of flow in pipe, $v = \frac{Q}{a}$, v = m/sec

Cross sectional area of pipe, a = m^2

Diameter of pipe, d = m

Internal plan area of collecting tank, A = m^2

Rise of liquid level in the collecting tank, H = m

Time of collection for 'H' rise in the collecting tank, t = sec

Discharge through the pipe, $Q = \frac{AH}{t}$ Q = m^3/sec

S.No	Manometer readings			Loss of head	Time taken for 'H' mm of rise (sec)	Discharge	Velocity	Coefficient of friction,
	Left Limb h_1 (mm)	Right Limb h_2 (mm)	Difference, x = (h_1-h_2) (mm)	$h_f = x\left[\frac{S_m - S_f}{S_f}\right]$ = 12.6 x (mm)		$Q = \frac{AH}{t}$ (m^3/sec)	$V = \frac{Q}{a}$ m/sec	$f = \frac{h_f.2.g.d}{4.l.v^2}$
1								
2								
3								
4								
5								
6								

Specimen calculation:

Actual Discharge, $Q_{act} = \frac{AH}{t}$ = m^3/sec

Area of tank, A = m^2

Rise of water, H = m

Time taken for 'H' m rise of water, t = sec

Lose of head in terms of flowing liquid due to friction,

$$h_f = x\left(\frac{S_m - S_f}{S_f}\right) = \left(\frac{(13.6-1)(h_1 - h_2)}{1}\right)$$

Coefficient of friction, $$f = \frac{h_f.2.g.d}{4.l.v^2}$$

Graph: Draw the graph between h_f V_s $\frac{V^2}{2g}$ with h_f on y-axis

Result: The coefficient of friction for the given pipe, f =

13.HYDRAULIC RAM

Aim:

To determine Rankine's Efficiency and D'Aubuisson's Efficiency of Hydraulic Ram

Apparatus:

Closed circuit Hydraulic Ram Apparatus, Stop watch

Theory:

The Hydraulic Ram is a type of pump in which the energy of large quantity of water falling through small height is utilized to lift a small quantity of this water to a greater height No external power is therefore required to operate this pump. Hydraulic Ram consists of a valve chamber having a waste valve and delivery valve. The waste valve opens into an air vessel to which a delivery pipe is connected. This valve opens into an air vessel to which a delivery pipe is connected. This delivery pipe carries water to the delivery tank. The valve chamber is connected to a low level supply tank through a supply pipe.

The working of Hydraulic Ram is based on the principle of water hammer or inertia pressure developed in the supply pipe. When the waste valve is remains closed then the hydraulic ram does not function at all. When the waste valve kept open, then water in the pipe begins to run through waste valve and the flow is set up. The velocity of water in drive pipe increases under the supply head.

During this period the dynamic pressure of the water under side of valve will become greater than the dead weight of the waste valve at one stage, then the waste valve gets closed. Due to this the momentum of moving column of liquid in the pipe is destroyed. This change in momentum results in increased pressure in the valve chamber. If this pressure exceeds, the pressure in the topside of the delivery valve due to the column of water in the delivery pipeline and then the delivery valve opens. The cater from valve chamber rushes into air vessel and then flow through the delivery pipeline to delivery tank.

Procedure:

1) Fill the supply tank by water.
2) Select particular stroke of waste valve. Then start the priming in valve chamber by using waste valve. After some time valve starts moving by its own and water starts collecting in waste water tank and also starts delivering through delivery pipe.
3) Then start the pump.
4) Measure the water column height in waste water tank for particular number of strokes and time & note it down.
5) Then measure the water column height in the delivery tank for same number of strokes and note down time.
6) Take number of readings by varying the lift of waste valve.
7) Do the calculations as per given below and find out the Ram Efficiency.

Observations:

1) Delivery Tank size : 290 x 290 mm = 0.0841 m^2
2) Waste water tank size : 390 x 390 mm = 0.1521 m^2
3) Supply Head (H) : 1.4m
4) Delivery Head (h_d) : 2.8m

Observation Table :

Sr No	Waste valve lift in mm	No of stroke per min of waste valve	Waste water tank			Delivery tank			D'Aubuisson's Efficiency	Rankine's Efficiency
			Height of water column 'X' in glass tube	Time 'T in sec for 'X' mm height	Water discharge 'Q' in m^3/sec	Height of water column 'y' in glass tube	Time 't' in sec for 'y' mm height	Water discharge 'q' in m^3/sec		

Calculations:

1) D' Aubuisson's Efficiency = $\dfrac{q x h_d}{(Q+q)\times h}$

Where, q = Volume of water lifted by ram in m^3/sec

= $\frac{y}{t}$ X Cross sectional area of delivery tank

Where, y = Height of water column increase in delivery tank in m.

T = Time for collecting 'y' m of water column.

Q = Volume of water collecting in waste water tank.

Q = $\frac{x}{T}$ X Cross sectional area of waste water tank.

Where, x = Height of water column increase in waste water tank in m.

T = Time for collecting 'x' m of water column

2) Rankine's Efficiency = $\dfrac{q(h_d - H)}{Q \times H}$

Graph:

No of strokes per minute of waste valve Vs Rankine's Efficiency

No of strokes per minute of waste valve Vs D'aubuisson's Efficiency