LABORATORY MANUAL

FLUID MACHINERY LABORATORY

Department of Mechanical Engineering

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SI No.	Name of the Experiment	Remark
1	Impact of Jet on Vanes	
2	Pelton Wheel Water Turbine	
3	Centrifugal Pump Test Rig	
4	Reciprocating Pump Test Rig	

OFFICE USE
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Experiment 1: Impact of Jet on Vanes

1.1 INTRODUCTION

Water turbines are widely used throughout the world to generate power. In the type of water turbine referred to as a Pelton wheel, one or more water jets are directed tangentially on to vanes or buckets that are fastened to the rim of the turbine disc. The impact of the water on the vanes generates a torque on the wheel, causing it to rotate and to develop power. Although the concept is essentially simple, such turbines can generate considerable output at high efficiency. Powers in excess of 100MW, and hydraulic efficiencies greater than 95%, are not uncommon. It may be noted that the Pelton wheel is best suited to conditions where the available head of water is great, and the flow rate is comparatively small.

1.2 OBJECTIVE

a) To measure the force generated by a jet of water striking a flat plate or a hemispherical cup and b) To compare the results are with the computed momentum flow rate in the jet.

1.3 THEORY

Figure 1 shows a jet of fluid impinging on a symmetrical vane.

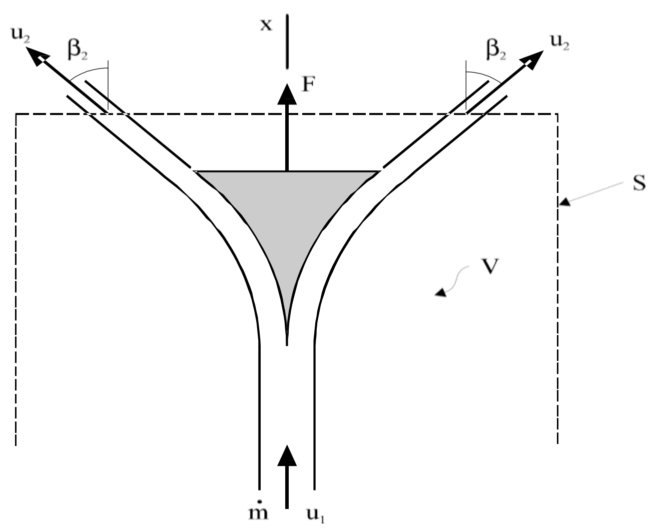

Figure 1: Sketch of jet impinging on a vane

Let the mass flow rate in the jet be m''. Imagine a control volume V, bounded by a control surface S which encloses the vane as shown. The velocity with which the jet enters the control volume is u_1, in the x-direction. The jet is deflected by its impingement on the vane, so that it leaves the control volume with velocity u_2, inclined at an angle β_2 to the x-direction. Now the pressure over the whole surface of the jet, apart from that part where it flows over the surface of the vane, is atmospheric. Therefore, neglecting the effect of gravity, the changed direction of the jet is due solely the force generated by pressure and shear stress at the vane's surface. If this force on the jet in the direction of x be denoted by F_j,

The momentum equation in the x-direction is $F_j = \ddot{m} \left(u_2 \cos \beta_2 - u_1\right)$

The force F **on the vane** is equal and opposite to this, namely $F = \ddot{m} \left(u_1 - u_2 \cos\beta_2\right)$

For the case of a flat plate, $\beta_2 = 90°$, so that $\cos \beta_2 = 0$.

It follows that $F = \ddot{m} u_1$ is the force on the flat plate, irrespective of the value of u_2.

For the case of a hemispherical cup, we assume that $\beta_2 = 180°$,so that $\cos \beta_2 = -1$,

And $F = \ddot{m}(u_1 + u_2)$

If we neglect the effect of change of elevation on jet speed, and the loss of speed due to friction over the surface of the vane, then $u_1 = u_2$,

So, $F = 2 \ddot{m} u_1$ is the maximum possible value of force on the hemispherical cup. This is just twice the force on the flat plate.

The rate at which momentum is entering the control volume is $\ddot{m} u_1$. We may think of this as a rate of flow of momentum in the jet, and denote this by the symbol J, where $J = \ddot{m} u_1$

For the flat plate, therefore $F = J$

And for the hemispherical cup the maximum possible value of force is $F = 2J$

1.4 DESCRIPTION OF THE APPAPATUS

Figure 2 shows the arrangement, in which water supplied from the Hydraulic Bench is fed to a vertical pipe terminating in a tapered nozzle. This produces a jet of water which impinges on a vane, in the form of a flat plate or a hemispherical cup.

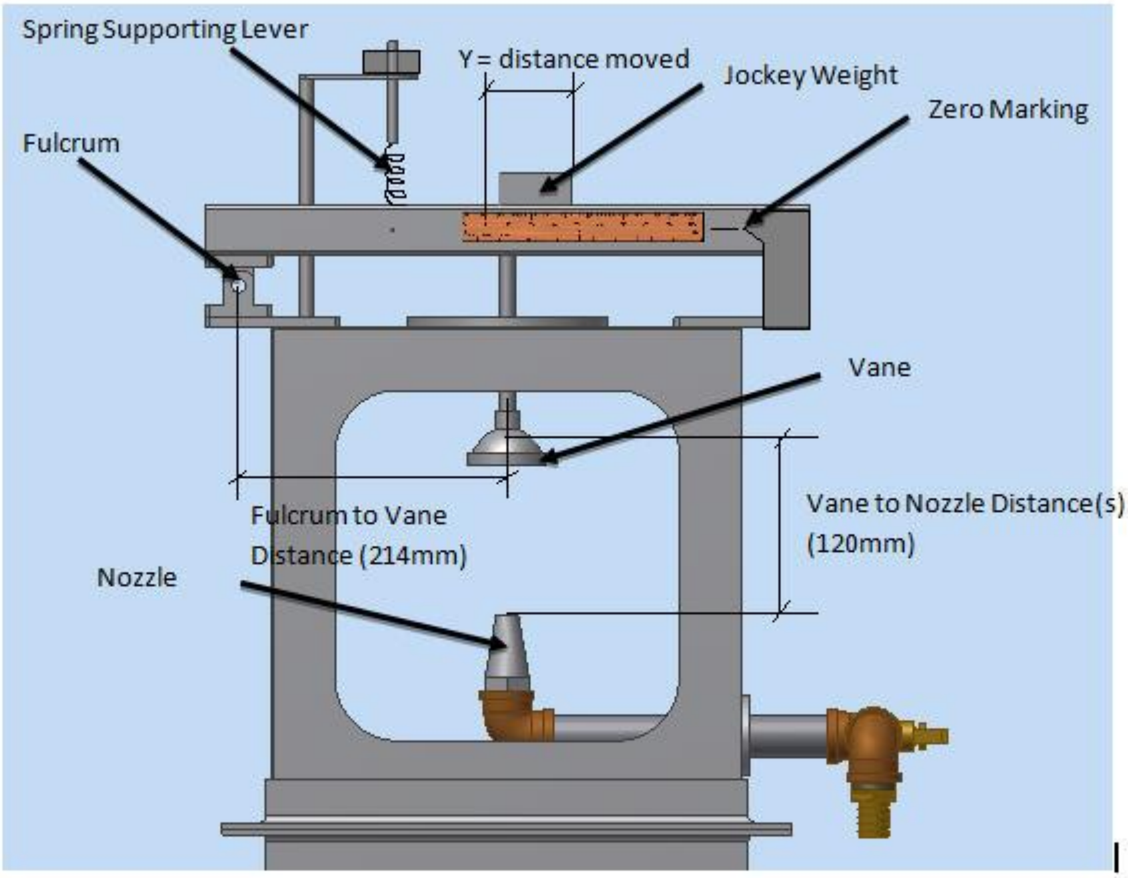

Figure 2 : Apparatus for impact of jet on vanes

The nozzle and vane are contained within a transparent cylinder, and at the base of the cylinder there is an out let from which the flow is directed to the measuring tank of the bench. As indicated in Fig 2 , the vane is supported by a lever which carries a jockey weight, and which is restrained by a light spring. The lever may be set to a balanced position (as indicated by a zero marking supported from it) by placing the jockey weight at its zero position, and then adjusting the knurled nut above the spring. Any force generated by impact of the jet on the vane may now be measured by moving the jockey weight along the lever until the zero marking intersects, shows that it has been restored to its original balanced position.

1.5 EXPERIMENTAL PROCEDURE

The apparatus is first leveled and the lever brought to the balanced position (as indicated by the zero position), with the jockey weight at its zero setting. Note the weight of the jockey, and the following dimensions: diameter of the nozzle, height of the vane above the tip of the nozzle when the lever is balanced, and distance from the pivot of the lever to the centre of the vane.

Water is then admitted through the bench supply valve, and the flow rate increased to the maximum. The force on the vane displaces the lever, which is then restored to its balanced position by sliding the jockey weight along the lever. The mass flow rate is established by collection of water over a timed interval. Further observations are then made at a number reducing flow rates. About eight readings should suffice.

The best way to set the conditions for reduced flow rate is to place the jockey weight exactly at the desired position, and then to adjust the flow control valve to bring the lever to the balanced position. The condition of balance is thereby found without touching the lever, which is much easier than finding the point of balance by sliding the jockey weight. Moreover, the range of settings of the jockey position may be divided neatly into equal steps.

The experiment should be run three times, first with the flat plate, inclined and then with the hemispherical cup.

1.6 ABBREVIATION & SYMBOLS

Diameter of nozzle, D	=10.2 mm		
Cross sectional area of nozzle, $A= \pi D^2/4$	$=78.5mm^2$	=	$7.85\times 10^{-5}\ m^2$
Height of vane above nozzle tip, s	=120 mm	=	0.12 m
Distance from Centre of vane to pivot of lever L	= 214 mm	=	0.21 m
Mass of jockey weight, M	=0.600 kg		
Jockey weight, W= Mg	$= 0.600 \times 9.81$	=	5.89 N
Density of Water, ρ	$= 997.13\ kg/m^3$		
Width of Collecting Tank, W	= 0.38 m		
Length of Collecting Tank, LC	= 0.38 m		
Area of Collecting Tank , AT	$= 0.1444\ m^2$		
Inclined vane, β	$= 60^0$		

When the jockey weight is moved a distance y mm from its zero position, the force F on the vane which is required to restore balance is given by: F×150 = W× y

Inserting the value of W, namely 5.89 N, gives

$$F = \frac{5.89\times y}{214} \quad \text{or} \quad F = 0.02752 \times y \text{ N}$$

The mass flow rate m" in the jet is found by timing the collection of a known mass of water. The velocity u_1 of the jet as it leaves the nozzle is found from the volumetric flow rate Q and the cross sectional area A of the nozzle. The velocity u_0 with which the jet strikes the vane is slightly less than u_1 because of the deceleration due to gravity. This effect maybe calculated from the expression $u_0^2 = u_1^2 - 2gs$

Inserting the value s = 0.12 m leads to the result $u0 = \sqrt{u_1^2 - 2.354}\ m/s$

1.7 READINGS

Sl No	Description	Measured value
1	jockey distance moved , y mm	
2	Difference in Tank Reading D_f m	
3	Mass flow rate m" kg/sec	
4	Volumetric flow rate Q, m^3/sec	

1.8 CALCULATIONS AND RESULT

Sl No	Description	Formula	Result
1	velocity at the nozzle, U1 m/sec	$U_1 = Q/A$	
2	velocity at the vane, U0 m/sec	$U_2 = \sqrt{u1^2} - 2gs$	
3	Discharge in mass, m″ kgs/sec	$Q = (AT \times Df)$	
4	Force measured in Newton F	F= 0.02752 × y	
5	Force predicted in Newton J	J = m" × u0	

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Date of Experiment :	Date :
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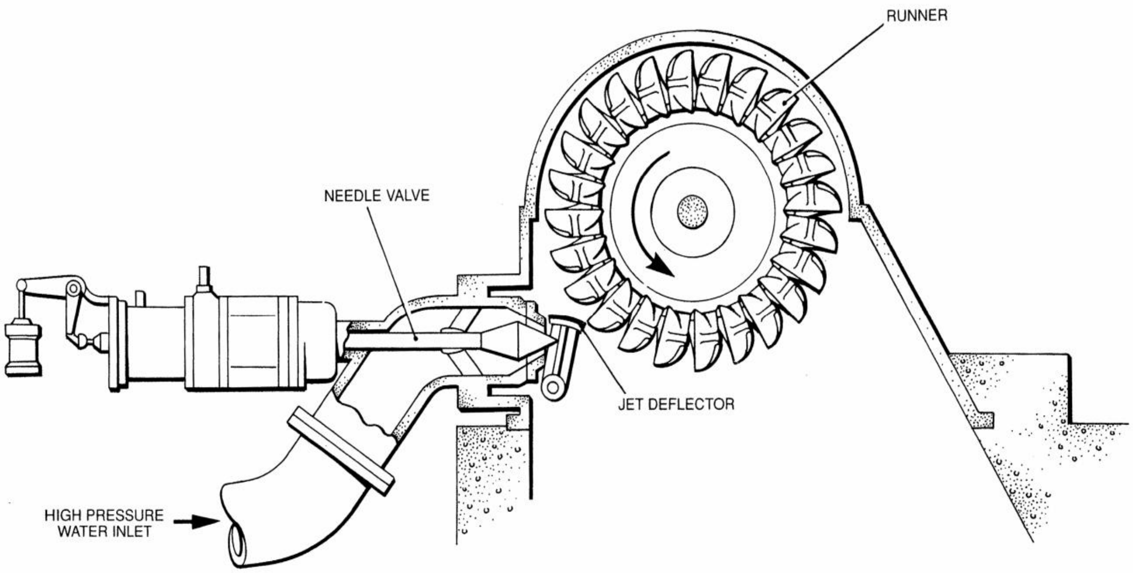
Experiment 2: Pelton Wheel Water Turbine

2.1 INTRODUCTION

Pelton Wheel Turbine is an IMPULSE type of turbine which is used to utilize high head for generation of electricity. All the energy is transferred by means of Nozzle & Spear arrangement. The water leaves the nozzle in a jet formation. The jet of water then strikes on the buckets of Pelton Wheel Runner. The buckets are in the shape of double cups joined together at the middle portion. The jet strikes the knife edge of the bucket with least resistance and shock. Then the jet glides along the path of the cup & jet is deflected through more than 160 – 170 degrees. While passing through along the buckets, the velocity of water is reduced & hence impulse force is applied to the cups which are moved & hence shaft is rotated.



2.2 CONSTRUCTION DETAILS OF PELTON TURBINE

Components of the Pelton turbine:-

- Nozzle: – the amount of water striking the vanes (buckets) of the runner is controlled by providing a spear (flow regulating arrangement) in the nozzle.

- Spear: – the spear is a conical needle which is operated either by a hand wheel
- Runner with bucket: – runner of Pelton wheel consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed.
- Casing: – casing is to prevent the splashing of the water and to discharge water to tail race. It is made up of cast iron or steel plate.
- Breaking jet: – when the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner reduce to zero.

But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is providing which directs the jet of water on the back of vanes. This jet of water is called breaking jet.

2.3 WORKING OF PELTON TURBINE

The amount of water striking the vanes (buckets) of the runner is controlled by providing a spear (flow regulating arrangement) in the nozzle. Then the nozzle converts the hydraulic energy into a high speed jet. The turbine rotor is called runner. The impact jet of water is striking on the runner and runner revolves at constant with the help of governing mechanism. The runner shaft is connected with the generator; thus the electricity is produce with the help of generator.

2.4 EXPERIMENT PROCEDURE:

- Keep the nozzle opening at the required position.
- Do the priming & start the pump.
- Allow the water in the turbine to rotate it.
- Note down the speed of the turbine, using tachometer.
- Take the respective readings in the respective pressure gauges.
- Load the turbine by putting the weights and adjust the spear wheel to get max speed.
- Note down the dead weights.
- Also note down the Head level.

2.5 ABBREVIATION & SYMBOLS

Sl No	Description	Symbol	Value	Unit
1	Density of Water	ρ	1000	kg/m^3
2	Diameter of the Brake drum	D	340	mm
3	Diameter of the rope	d	15	mm
4	Turbine speed	N		RPM
5	Pan Weight	P	1	Kg
6	Dead weight load	w		kg

2.6 READINGS

Sl No	Pressure Gauge kg/cm2 (P1)	Pressure Gauge kg/cm2 (P2)	Pelton Wheel Turbine Speed RPM	Dead Weight Load Kg
1				
2				
3				
4				
5				

2.7 CALCULATIONS AND RESULT

Total Head H in meter , H = (P1-P2) X 10

Discharge , $Q = 0.0055 \times \sqrt{H}$

Brake Horse Power in HP, $BHP = (\pi \times (D + d) \times N \times (W + P)/(60 \times 75)$

Indicated Horse Power in HP , $IHP = (1000 \times Q \times H)/75$

Efficiency in % $= \left(\frac{BHP}{IHP}\right) \times 100$

Sl No	Total Head H in m	Discharge Q	Brake Horse Power, BHP	Indicated Horse Power, IHP	Percentage Efficiency
1					
2					
3					
4					
5					

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Date of Experiment :	Date :
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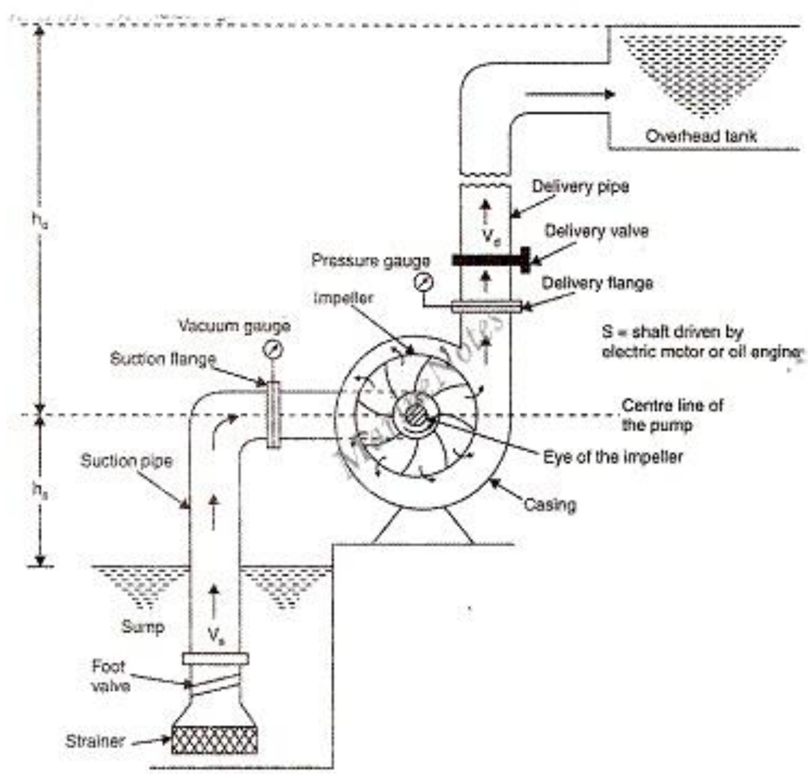
Experiment 3: Centrifugal Pump Test Rig

3.1 INTRODUCTION

A rotodynamic pump is a device where mechanical energy is transferred from the rotor to the fluid by the principle of fluid motion through it. The energy of the fluid can be sensed from the pressure and velocity of the fluid at the delivery end of the pump. Therefore, it is essentially a turbine in reverse. Pumps are classified according to the main direction of fluid path through them like (i) radial flow or centrifugal, (ii) axial flow and (iii) mixed flow types.

3.2 THEORY

An increase in the fluid pressure from the pump inlet to its outlet is created when the pump is in operation. This pressure difference drives the fluid through the system or plant. The centrifugal pump creates an increase in pressure by transferring mechanical energy from the motor to the fluid through the rotating impeller. The fluid flows from the inlet to the impeller centre and out along its blades. The centrifugal force hereby increases the fluid velocity and consequently also the kinetic energy is transformed to pressure.



3.3 OBJECTIVE

To study the performance characteristics of a centrifugal pump and to determine the characteristic with maximum efficiency.

3.4 PROCEDURE:

- Prime the pump, close the delivery valve and switch on the unit
- Open the delivery valve and maintain the required delivery head
- Note down the reading and note the corresponding suction head reading
- Close the drain valve and note down the time taken for 10 cm rise of water level in collecting tank
- Measure the area of collecting tank
- For different delivery tubes, repeat the experiment
- For every set reading note down the time taken for 5 revolutions of energy meter disc.

3.5 ABBREVIATION & SYMBOLS

Sl No	Description	Symbols	Value	Units
1	Pump Capacity	HP	1	HP
2	Speed	RPM	2800	RPM
3	Pump Head	PH	26	m
5	Width of Collecting Tank	W	0.4	meter
6	Length of Collecting Tank	LC	0.4	meter
7	Area of Collecting Tank	AT	0.16	m^2
8	Acceleration due to gravity	g	9.81	m/sec^2
9	Energy meter Constant	C	1200	kW/h
10	Density of Water	ρ	1000	kg/m^3
11	Diameter of the Delivery pipe	Dd	28	mm
12	Area of the Delivery Pipe	Ad	0.000615752	m^2
13	Diameter of the Section pipe	Ds	38	mm
14	Area of the Section Pipe	As	0.001134115	m^2

3.6 READINGS

Sl No	Initial Tank Reading in cm	Final Tank Reading in cm	Difference in Tank Reading in Meters , Df	Time Taken in Sec t	Pressure Gauge Reading in kgs/cm^2 P	Vacuum Gauge reading in mm of Hg Pv	Time taken for 5 Rev of Energy meter in sec , Te
1							
2							

3.7 CALCULATIONS AND RESULT

Electrical Power as indicated by Energy Meter $HP_{elect} = \frac{No\ of\ Rev \times 1000 \times 3600}{C \times 736 \times Te}$ HP

Actual Discharge Q_a in m^3/sec $Q_a = \frac{AT \times Df}{t}$ m^3/sec

Total Head in Meters $H = 10 \times (P - (Pv/760))$

Hydraulic Horse Power $HP_{pump} = \frac{\rho \times Qa \times H}{75}$ HP

Sl No	Electrical Power as indicated by Energy Meter HP_{elect}	Actual Discharge Q_a in m^3/sec	Total Head in Meters H	Hydraulic Horse Power HP pump	Overall Efficiency % $\frac{HP\ Pump}{HP\ elec}$ %
1					
2					

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Date of Experiment :	Date :
Seal	

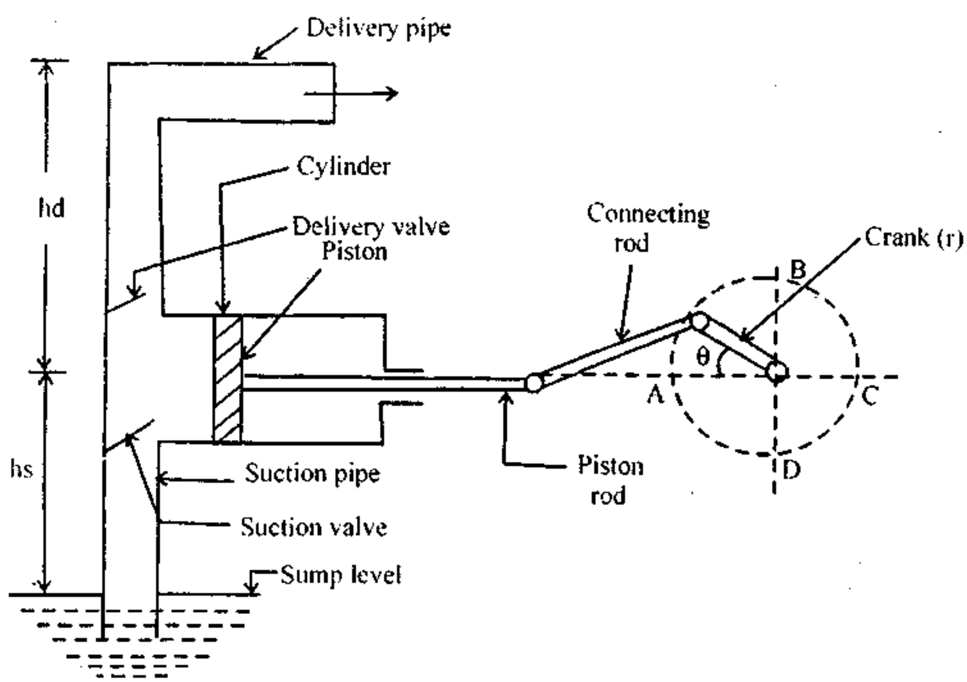
EXPERIMENT 4: RECIPROCATING PUMP TEST RIG

4.1 INTRODUCTION

A positive displacement hydraulic pump is a device used for converting mechanical energy into hydraulic energy. It is driven by a prime mover such as an electric motor. It basically performs two functions. First, it creates a partial vacuum at the pump inlet port. This vacuum enables atmospheric pressure to force the fluid from the reservoir into the pump. Second, the mechanical action of the pump traps this fluid within the pumping cavities, transports it through the pump and forces it into the hydraulic system. It is important to note that pumps create flow not pressure. Pressure is created by the resistance to flow.

4.2 THEORY

Operation of reciprocating motion is done by the power source (i.e. electric motor or i.c engine, etc). Power source gives rotary motion to crank; with the help of connecting rod reciprocating motion is transmitted to piston in the cylinder (i.e. intermediate link between connecting rod and piston). When crank moves from inner dead centre to outer dead centre vacuum will create in the cylinder. When piston moves outer dead centre to inner dead centre, the piston forces the water through outlet or delivery valve.



4.3 OBJECTIVE

To study the performance characteristics of a reciprocating pump and to determine the characteristic with maximum efficiency.

4.4 PROCEDURE:

- Prime the pump close the delivery valve and switch on the unit
- Open the delivery valve and maintain the required delivery head
- Note down the reading and note the corresponding suction head reading
- Close the drain valve and note down the time taken for 10 cm rise of water level in collecting tank
- Measure the area of collecting tank
- For different delivery tubes, repeat the experiment
- For every set reading note down the time taken for 5 revolutions of energy meter disc.

4.5 ABBREVIATION & SYMBOLS

Sl No	Description	Symbols	Value	Units
1	Pump Capacity	HP	1	HP
2	Speed	RPM	2800	RPM
3	Pump Head	PH	26	m
5	Width of Collecting Tank	W	0.4	meter
6	Length of Collecting Tank	LC	0.4	meter
7	Area of Collecting Tank	AT	0.16	m^2
8	Acceleration due to gravity	g	9.81	m/sec^2
9	Energy meter Constant	C	60	kW/h
10	Density of Water	ρ	1000	kg/m^3
11	Diameter of the Delivery pipe	Dd	28	mm
12	Area of the Delivery Pipe	Ad	0.000615752	m^2
13	Diameter of the Section pipe	Ds	38	mm
14	Area of the Section Pipe	As	0.001134115	m^2

4.6 READINGS

Sl No	Initial Tank Reading in cm	Final Tank Reading in cm	Difference in Tank Reading in Meters , Df	Time Taken in Sec t	Pressure Gauge Reading in kgs/cm^2 P	Vacuum Gauge reading in mm of Hg Pv	Time taken for 5 Rev of Energy meter in sec , Te
1							
2							

4.7 CALCULATION AND RESULT

Electrical Power as indicated by Energy Meter $HP_{elect} = \frac{No\ of\ Rev \times 1000 \times 3600}{C \times 736 \times Te}$ HP

Actual Discharge Q_a in m^3/sec $Q_a = \frac{AT \times Df}{t}$ m^3/sec

Total Head in Meters $H = 10 \times (P - (Pv/760))$

Hydraulic Horse Power $HP_{pump} = \frac{\rho \times Qa \times H}{75}$ HP

Sl No	Electrical Power as indicated by Energy Meter HP_{elect}	Actual Discharge Q_a in m^3/sec	Total Head in Meters H	Hydraulic Horse Power HP pump	Overall Efficiency % $\frac{HP\ Pump}{HP\ elec}$ %
1					
2					

Name :	Checked by :
Roll No. :	Signature :
Date of Experiment :	Date :
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