1. CONSTANT SPEED CENTRIFUGAL PUMP

AIM: To draw the pre-performance curves of the pump keeping speed constant.

APPARATUS: Centrifugal pump fitted with vacuum and pressure gauge the inlet and outlet ends. Electric motor coupled to the pump with energy meter. How measuring tank.

DESCRIPTION AND THEORY: A centrifugal pump essentially consists of an impeller and a casing surrounding it. Depending upon the type of casting, CF pumps are (1) volute pump and (2) turbine pumps. In volute type pumps the impeller is surrounded by a spiral casing whose area of cross section gradually increases form the tongue to the delivery pipe. In case of turbine pumps, the casing is replaced by guide blades an is termed as diffuser. The casing are provided to the pumps to increase the efficiency by utilizing the high velocity of the leaving water.

In principle a centrifugal pump is a reverse of an inward flow reaction turbine. All the centrifugal pumps are outward flow type since the centrifugal head impressed on water increases the discharge. The impeller full of water is rotated by an external device using an electric motor. A centrifugal force is then impressed on the water leaves the impeller with high velocity and pressure and the pressure energy is utilized in lifting the water to the required height. This cause a partial vacuum at the centre, technically known as the eve, and water flow from the pump.

SPECIFICATION OF THE MOTOR: The electric motor is a 3 phase AC 400/44 volts 50c/s. the motor is standard 5 HP rating 1440 RPM. Suction and delivery pipe sizes 50 mm diameter.

PROCEDURE: The delivery valve is closed, the pump is primed and the pump is started. Then slowly open the delivery valve and adjust to the required total head. The readings on the suction, delivery gauges are noted. The total head is measured with the help of the pressure and vacuum gauges. Total head is the sum of the pressure head, velocity head and the datum head. Discharge is the amount of liquid the pump delivers over a definite period of time. It is usually expressed in meter 3/s. The actual discharge is measured with the help of 0.7 * 0.8 m^2 area measuring tank. In this case the power input into the tank cannot be measured directly. Hence the power input of the AC motor is measured with the help of the energy meter, connected in the line. Efficiently is the relation between the power input to the pump and the power output from the pump. The power output from the pump is directly proportional to the total head and discharge. Power input into the pump is taker equal to power input to the motor.

If the total head (H) is measured and the discharge (Q) is in m^3/s / minute, then $\frac{pgQH}{1000}$ gives the output in kW. The kW input of the motor is measured with the help of energy meter. Then the efficiency is calculated by dividing the output by the input. For a particular desired speed of the pump and repeat the experiment. Thus the complete characteristics can be studied.

Figure 1: Constant Speed Centrifugal Pump

CONSTANT SPEED CENTRIFUGAL PUMP

FORMULAE:

Suction Head HS

Mm of Hg

$\frac{13.6}{1000}$ Xx meter of water

Delivery Head Hd = x kgf/cm^2

1 kgfcm^2 = 10 m of water

X kgf/cm^2 = P m of water

Total head = Suction Head + Delivery Head
= V + P

Discharge rate 'Q' in m^3/ sec

$$Q = \frac{AXh}{T}$$

Where A = 0.56 m^2 is the area of collecting tank
h = The height of water collected in collecting tank 30 cm = 0.3 m
T = The time taken in seconds for collecting water

Where 'w' = ρg
= 1000 X 9.81 N / m3

Output Power = $\frac{\rho g Q H}{1000}$ kW

Input Power = $\frac{60\ X\ 60\ X\ 5}{t\ x\ \ 2400}$ kW

Where Meter constant = 200 rev/KWH

Overall Efficiency = $\frac{Output}{Input}$ x100

GRAPHS:

4. Discharge Vs Power input
5. Discharge Vs Total head
6. Discharge Vs Efficiency

A typical tabular form is given below:

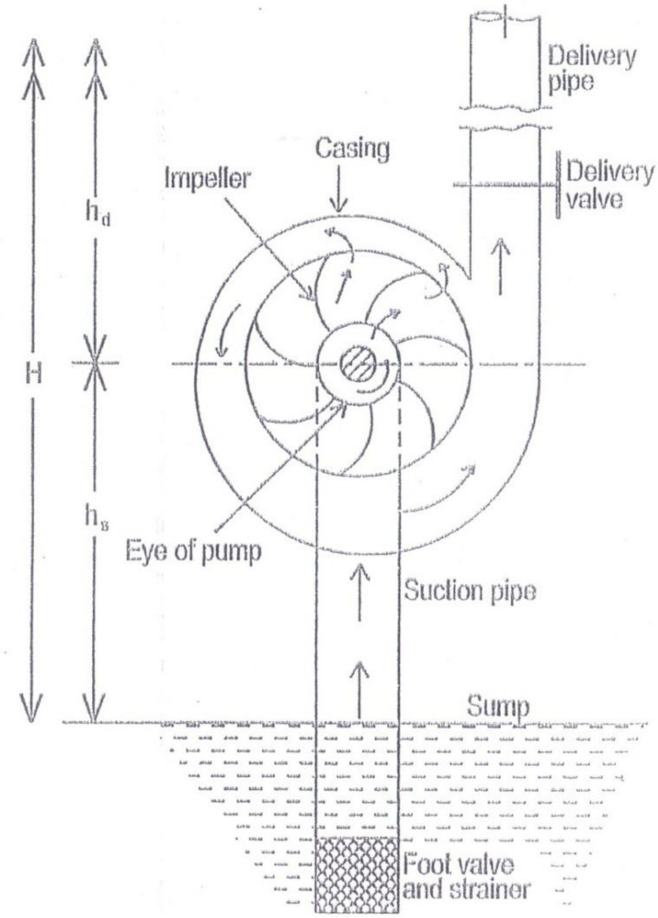


Figure : Constant Speed Centrifugal Pump

1. CONSTANT SPEED CENTRIFUGAL PUMP

OBSERVATIONS:

SPEED (rpm)	Hs (Suction) Head		Hd (Delivery) Head		Total Head in m	T (sec) Time for 30cm rise in tank	Discharge m^3/S	t(sec) Time for 5 rev of meter	Input Power (kW) $\frac{3600\,x\,5}{t\,x\,200}$	Output Power (kW) $\frac{\rho g Q H}{1000}$	Efficiency(%) $\frac{Output}{Input}$ x100
	Mm of Hg		Kgf/cm^2								

2. RECIPROCATING PUMP

AIM: Take the performance test on reciprocating pump.

Draw graphs between

1. Head V/s Discharge
2. Head V/s Power input
3. Head V/s Overall Efficiency

Figure2: Reciprocating pump

Description:- The working of the reciprocating pump is very simple and just like an I.C engine. First of all the piston has the function of providing the suction force, so that the liquid can be lift up or can be sucked in with great force. After that comes the compression part which will impart the required pressure energy to the fluids. In this part of the phase the piston have to do a great work so that the liquid can be compressed properly and its pressure can increased to the desired level. The inlet and the outlet valve open at a certain pressure which is set by the manufacturer.

If the piston is of single acting type which means it can suck from one side and transmit to the same side only. But we can have the double reciprocating pump too which have the function of the giving suction and discharge simultaneously in each stroke. This pump can be used as the compressor also but for that we have to have a good valve arrangement which can operate with goodfrequency.

Note: It is to be noted that the reciprocating pump is a positive displacements pump which means that the fluid can only move in one direction and can never reverse back. So due to this the pump is always started with outlet valve open otherwise the pressure will keep on building and this will lead to rupturing of the pipeline or even the pump itself. But if relief valve is fitted then this pressure will come down.

PROCEDURE: Prime the pump before starting. Start the motor keeping the delivery valve in fully open position. Open the gauge cock and see the pressure developed by pump. Delivery control valve may be closed upto 30m of water head on the delivery side. Under no circumstances the valve be closed beyond 40m head on the delivery side. If the pressure exceeds this value 4 Kg/cm^2, the cylinder head gasket joints can be damaged. To stop the pump set, first close the gauge cock. Do not close the delivery valve. Then switch off the motor.

After starting the pump, note the head. The speed of the pump is noted with a tachometer. The discharge is calculated from readings taken from collecting tank. The input is measured from the reading of the energy meter reading. The pump can be run a constant speed and head may be varied say from 10m to 30m. The discharge will be more or less same. Five to six reading may be taken and speed may be varied by changing the V-belt, to another groove.

RECIPROCATING PUMP

FORMULAE:

Given, Suction Head H_S in (mm of Hg)

H_s (mts) = H_s (mm of H_g) $\frac{13.6}{1000}$ Xx

Delivery Head Hd = x kgf/cm^2

1 kgfcm^2 = 10 m of water

X kgf/cm^2 = P m of water

Total head = Suction Head + Delivery Head
= V + P

Discharge rate 'Q' in m^3/ sec

$$Q = \frac{Axh}{T}$$

Where A = 0.04 m^2 is the area of collecting tank

h = The height of water collected in collecting tank 10 cm = 0.1 m

T = The time taken in seconds for collecting water

Where 'w' = ρg

= 1000 X 9.81 N / m3

Output Power = $\frac{\rho g Q H}{1000}$ kW

Input Power = $\frac{60\ X\ 60\ X\ 5}{t\ x\ 2400}$ kW

Where Meter constant = 2400 rev/KWH

Overall Efficiency = $\frac{Output}{Input}$ x 100

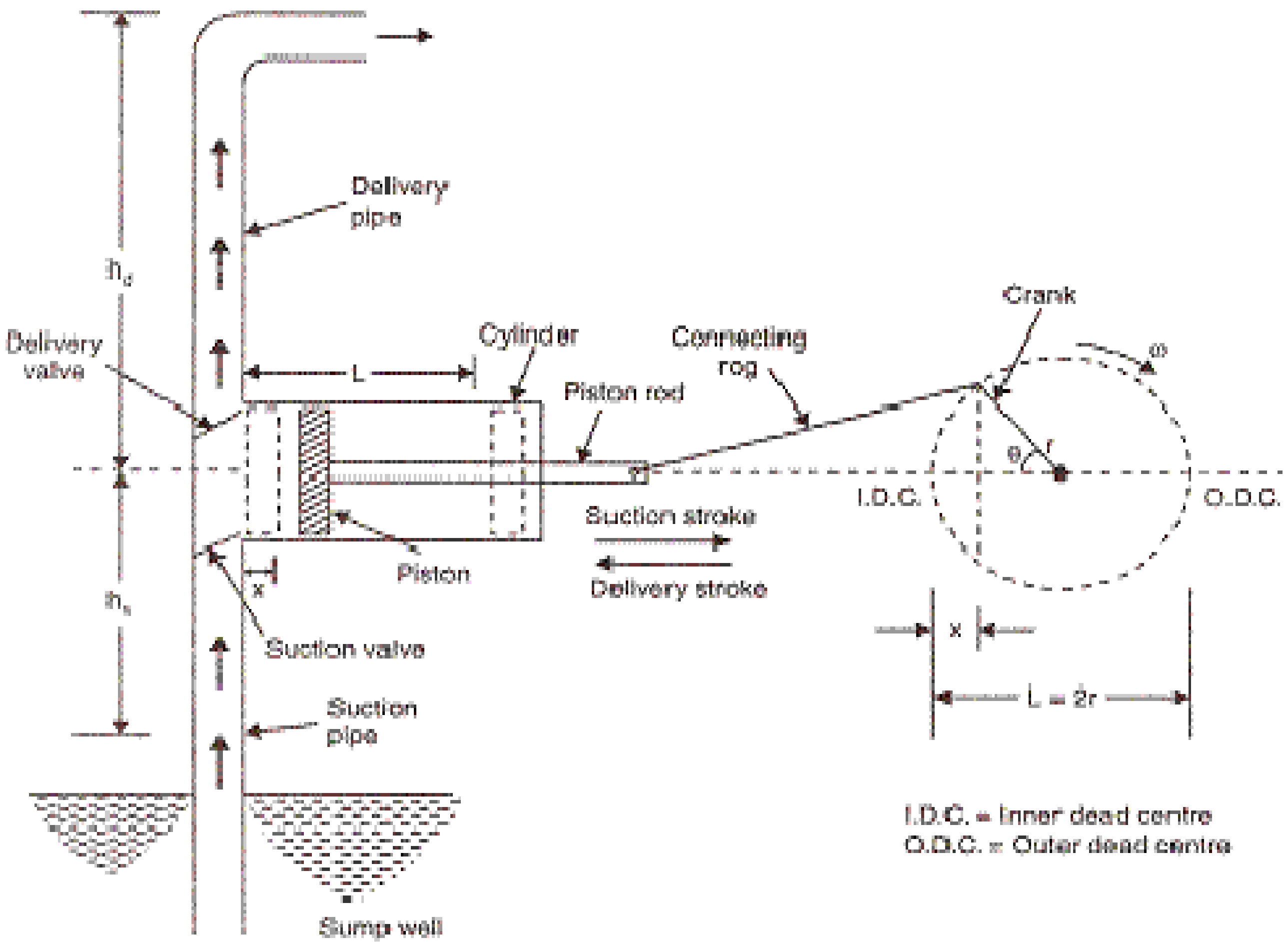


Figure :- Reciprocating pump

2. RECIPROCATING PUMP

OBSERVATIONS:

SPEED (rpm)	Hs (Suction) Head		Hd (Delivery) Head		Total Head in m	T (sec) Time for 10cm rise in tank	Discharge m^3/s	t(sec) Time for 5 rev of meter	Input Power (kW) $\frac{60\,x\,60\,x\,5}{t\,x\,2400}$	Output Power (kW) $\frac{\rho g Q H}{1000}$	Efficiency(%) $\frac{Output}{Input}$x 100
	mm of Hg	mts	Kgf/cm^2	mts							

3. JET PUMP

AIM: To Draw the Constant Speed Characteristics curves for jet pump

SPECIFICATIONS

Measuring tank Area : 0.12 sq metres

Description of Jet Pump:

The basic principle of jet pump is the transfer of energy and momentum from one stream of fluid to another through a process of turbulent mixing inside the mixing tube. The high pressure primary driving stream enters the suction chamber through nozzle with a high velocity. The increase of velocity and the resulting reduction in pressure at the nozzle exit causes the secondary driven fluid to flow into the mixing chamber. In the mixing chamber the transfer of momentum from the supply stream to secondary stream takes place. The mixed fluid then passes through the diffuser in which a portion of velocity energy is converted into pressure energy.

The working of the jet pump depends on the efficient turbulent mixing. At the entry to the mixing tube the velocity of the primary stream and the velocity of the secondary stream are different and non-uniform. The mixing tube will play the role of eliminating or at least minimizing the difference in velocity and the non-uniform distribution before the combined flow leaves the mixing tube. The length of mixing tube and its diameter decide the effectiveness of the mixing tube. These dimensions have a direct bearing on the performance of the jet pump. The mixing is very effective at high velocities. This is achieved by a smaller mixing tube diameter. This velocity energy is being converted to pressure energy to reduce the loss of energy during subsequent flow i.e. in the diffuser which is located at the exit of the mixing tube. The velocity distribution at the mixing tube entry depends on the primary nozzle and secondary nozzle geometry. All these parameters are having an influence on the jet pump performance.

The graphical representation of the efficiency and head w.r.t. the discharge is called the performance characteristics of the jet pump. The slope of the head vs discharge curve depends on the area of the jet pump. In case of efficiency vs discharge, the efficiency curve increases till a maximum and then it decreases.

PROCEDURE

- Keep the Delivery valve closed.
- Switch on the pump.
- Set the let jet line valve and outlet jet line valve to optimum
- Position by seeing the smooth discharge
- For different delivery pressure readings note down the
- Time taken for ‘h’ cm rise of water in the collecting tank
- Operate the Butterfly valve to empty (or) retain the water
- In the collecting tank
- Repeat the experiment for different opening of delivery valve
- And suction valve. Tabulate the Readings

SPECIMEN CALCULATIONS

GRAPHS:

1. % Efficiency vs ‘Q’ 2. ‘H’ vs ‘Q’ 3. O/P Power vs ‘Q’

JET PUMP

1. Basic Data/Constant

1 hp	=	746 Watts
1 Kgf / Cm^2	=	10 m of water
Density of Water, ‘ ρ ’	=	1000 Kg/m^3

2. Discharge Rate ‘Q’ in m^3 / Sec

$$Q = \frac{Axh}{T}$$

Where ‘A’ = 0.12 m^2 in the area of Collecting Tank

‘h’ = the height of water collected in collecting tank 5 cm = 0.05 m

‘T’ = the time taken in seconds for collecting water

3. Delivery Head ‘H’ in m

H = 10 x Delivery Pressure

= 10 x P

Where ‘P’ is the pressure in Kg/Cm2

- No vaccum exists in this type of Pump

Input HP Electrical = $\frac{VxIx0.75}{746} HP$

Output Power HP = $\frac{\rho gQH}{75} HP$

Where ‘W’ = ρ g

= 1000 X 9.81 N/m^3

Where efficiency of motor = 0.75 is the Efficiency of Electrical Motor

Efficiency of Pump = $\frac{Output}{Input} x100$

Figure 3 : Jet pump test rig.

3. JET PUMP

DELIVERY HEAD Kgf/cm^2		Time Taken for 'h' cm RISE (T)	DISCHARGE 'Q' m^3/s	ELECTRICAL I/P POWER			O/P POWER	%Efficencicy
				V	I	VxI		

4. PELTON WHEEL

AIM: To draw the performance curves of the pelton wheel

1. by keeping the head constant
2. by keeping the speed constant
3. by varying the spear opening keeping the load constant

SPECIFICATIONS:

1. Rated supply head	- 45 m
2. Discharge	- 630 LPM
3. Normal speed	- 1000 rpm
4. Power output	- 3.75 KW
5. Brake drum diameter	- 300 mm (D)
6. Rope brake diameter	- 16 mm (D)

Flow Measuring Unit :

$$Q = K\sqrt{h}$$

Where Q = discharge in m^3/S

K = 35.7 (meter constant)

h = difference in manometric columns in cm

Description of Pelton Turbine:-

In a Pelton Turbine or Pelton Wheel water jets impact on the blades of the turbine making the wheel rotate, producing torque and power. Learn more about design, analysis, working principle and applications of Pelton Wheel Turbine.

Hydraulic Turbines are being used from very ancient times to harness the energy stored in flowing streams, rivers and lakes. The oldest and the simplest form of a Hydraulic Turbine was the Waterwheel used for grinding grains. Different types of Hydraulic Turbines were developed with the increasing need for power. Three major types are Pelton Wheel, Francis and Kaplan Turbine.

Design of Pelton Wheel Turbine

The Pelton Turbine has a circular disk mounted on the rotating shaft or rotor. This circular disk has cup shaped blades, called as buckets, placed at equal spacing around its circumference. Nozzles are arranged around the wheel such that the water jet emerging from a nozzle is tangential to the circumference of the wheel of Pelton Turbine. According to the available water head (pressure of water) and the operating requirements the shape and number of nozzles placed around the Pelton Wheel can vary.

Working Principle of Pelton Turbine

The high speed water jets emerging form the nozzles strike the buckets at splitters, placed at the middle of a bucket, from where jets are divided into two equal streams. These stream flow along the inner curve of the bucket and leave it in the direction opposite to that of incoming jet. The high speed water jets running the Pelton Wheel Turbine are obtained by expanding the high pressure water through nozzles to the atmospheric pressure. The high pressure water can be obtained from any water body situated at some height or streams of water flowing down the hills.

The change in momentum (direction as well as speed) of water stream produces an impulse on the blades of the wheel of Pelton Turbine. This impulse generates the torque and rotation in the shaft of Pelton Turbine. To obtain the optimum output from the Pelton Turbine the impulse received by the blades should be maximum. For that, change in momentum of the water stream should be maximum possible. That is obtained when the water stream is deflected in the direction opposite to which it strikes the buckets and with the same speed relative to the buckets.

PROCEDURE:

Initially, to run the turbine, prime the pump and start the motor by keeping the delivery valve in closed position and also the spear. Then slowly open the delivery valve and open the cock fitted to the pressure gauge and see that the pump develops the rate head of 45m. Then note the different headings.

PELTON WHEEL

Varying load, speed keeping the constant. Take 5 or 6 set of readings, second time keep the speed constant vary the load and the gate opening. Again take a set of 5 to 6 readings. Thirdly by varying the gate opening and keeping load constant take 5 to 6 set of readings.

FORMULAE:

$$Q = \frac{k\sqrt{h_m}\, x 12.6}{1000\, x\, 60}$$

Where Q = discharge in m^3 / s

K = 35.7 (meter constant)

h_m= difference in manometric columns in cm

H = head of water in meters

Input Power = $\frac{\rho g Q H}{1000}$ kW

Output Power = $\frac{2\pi N m 9.81(R+r)}{1000\, x 60}$ kW

R = 0.15 m, r = 0.008 m

Where N = rpm

m = mass, Kg

R = Brake drum radius m

r = Rope radius m

Efficiency (n) = $\frac{Output}{Input}$ X 100

Specific Speed (N s) = $\frac{N\sqrt{p}}{H^{5/4}}$

Unit Speed (N u) = $\frac{N}{\sqrt{H}}$

Unit power (P u) = $\frac{P}{H^{3/2}}$

Unit discharge (Q u) = $\frac{Q}{\sqrt{H}}$

PELTON WHEEL

Graphs to be drawn:

Main characteristics

Speed V/s B P

Speed V/s efficiency

Speed V/s Q

I-Set:

Head Constant = 45m

Spear opening = 50%

Vary loading – Find speed

II- Set:

1. Q V/s Output
2. Q V/s Head

Figure 4: Pelton Turbine

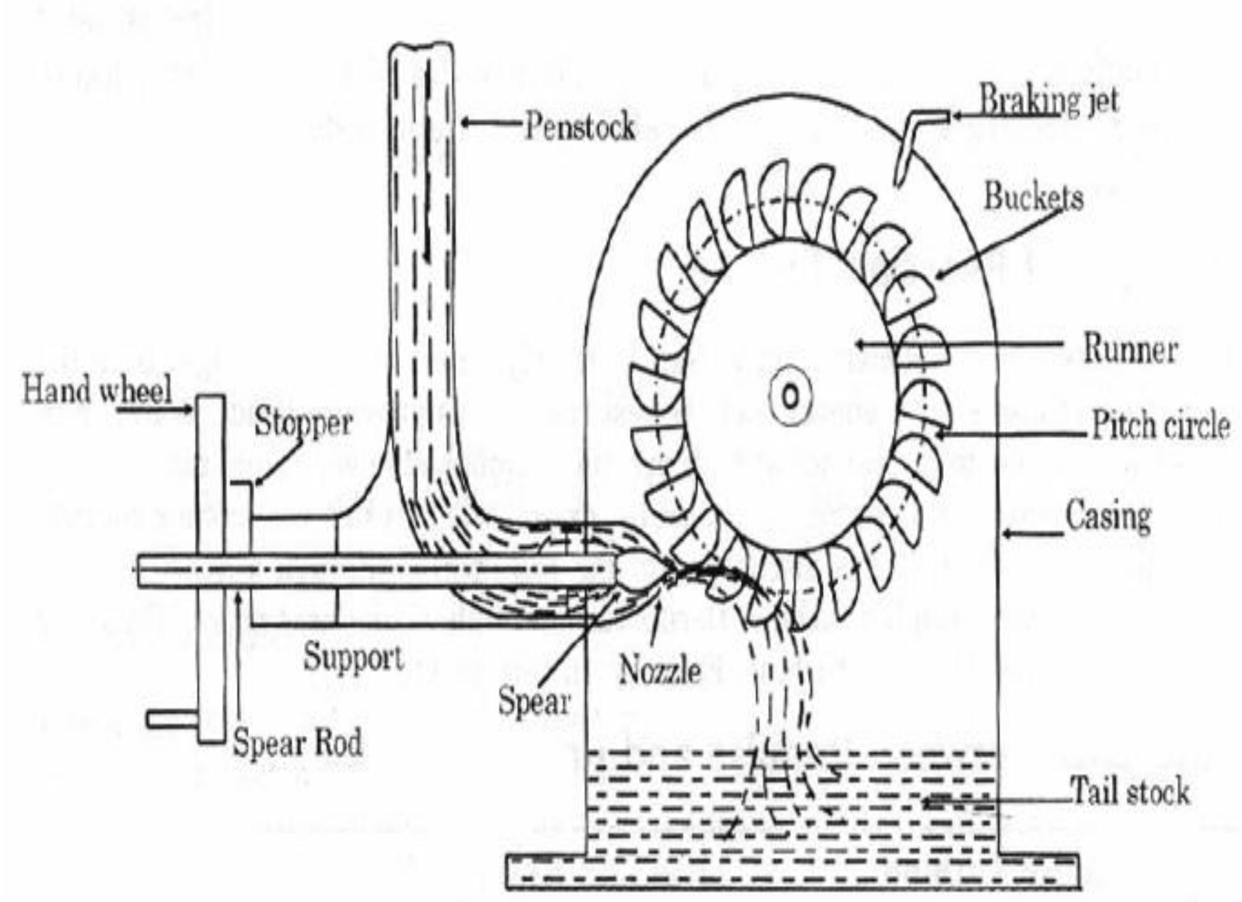


Figure : Pelton Turbine

4. PELTON WHEEL

OBSERVATIONS:

Sl. No	Net Supply Head $(H_1)_2$ Kgf/cm^2	mts	Spear Opening	Discharge $Q=k\sqrt{h\,x12.6}$ m^3/s	Input Power $\frac{\rho gQH}{1000}$ kW	Net load W_1-W_2	Total head H	Speed N	Manometric readings			Output KW	Efficiency(n)
									h1	h2	h1-h2		

5. FRANCIS TURBINE

AIM: To study the performance characteristics of Francis turbine.

SPECIFICATIONS:

1. Rated supply head	= 15 m
2. Discharge	= 2000 lit/min
3. Rated Speed	= 1250 rpm
4. Power output	= 3.75 KW
5. Brake drum diameter	= 300 mm
6. Brake rope diameter	= 16 mm

Description of Francis Turbine:-

In Francis Turbine water flow is radial into the turbine and exits the Turbine axially. Water pressure decreases as it passes through the turbine imparting reaction on the turbine blades making the turbine rotate. Read more about design and working principle of Francis Turbine in this article.

Francis Turbine is the first hydraulic turbine with radial inflow. It was designed by American scientist James Francis. Francis Turbine is a reaction turbine. Reaction Turbines have some primary features which differentiate them from Impulse Turbines. The major part of pressure drop occurs in the turbine itself, unlike the impulse turbine where complete pressure drop takes place up to the entry point and the turbine passage is completely filled by the water flow during the operation.

Design of Francis Turbine

Francis Turbine has a circular plate fixed to the rotating shaft perpendicular to its surface and passing through its center. This circular plate has curved channels on it; the plate with channels is collectively called as runner. The runner is encircled by a ring of stationary channels called as guide vanes. Guide vanes are housed in a spiral casing called as volute. The exit of the Francis turbine is at the center of the runner plate. There is a draft tube attached to the central exit of the runner. The design parameters such as, radius of the runner, curvature of channel, angle of vanes and the size of the turbine as whole depend on the available head and type of application altogether.

Working of Francis Turbine

Francis Turbines are generally installed with their axis vertical. Water with high head (pressure) enters the turbine through the spiral casing surrounding the guide vanes. The water looses a part of its pressure in the volute (spiral casing) to maintain its speed. Then water passes through guide vanes where it is directed to strike the blades on the runner at optimum angles. As the water flows through the runner its pressure and angular momentum reduces. This reduction imparts reaction on the runner and power is transferred to the turbine shaft.

If the turbine is operating at the design conditions the water leaves the runner in axial direction. Water exits the turbine through the draft tube, which acts as a diffuser and reduces the exit velocity of the flow to recover maximum energy from the flowing water.

PROCEDURE:

Initially to run the turbine, prime the pump and start the motor. The gate valves in turbine should also be closed then slowly open the gate valve situate above the turbine and open the cock fitted to the pressure gauge and see the pump develops the rated head. Slowly open the turbine guide vanes by rotating the hand wheel until the turbine attains the normal rated speed. Load the turbine slowly by the dead weights provided. The turbines first tested at constant supply head by varying load, speed and guide vane setting.

The output power from the turbines is calculated from the readings taken on the brake of speed of the shaft. The input power supplied to the turbines calculated from the net supply head and turbine discharge through turbine.

Efficiency is output by input measured by 100 mm veturimeter and note manometer fitted with calibrated scale. Supply head is measured with the help of pressure gauge. The speed is measured by a tachometer.

FRANCIS TURBINE

Graphs to be drawn:

Main characteristics

- Unit Speed V/s Unit B P
- Unit Speed V/s Efficiency
- Unit speed V/s Unit discharge

1-Set

- Supply head Constant = 0.8m
- Guide Vane setting constant = 50%
- Vary the load – Find speed

Figure 5: Francis Turbine

FRANCIS TURBINE

FORMULAE:

$$Q = \frac{k\sqrt{h_m \, x 12.6}}{1000 \, x 60}$$

Where Q = discharge in m^3/s

K = 84.5 (meter constant)

h = difference in manometric columns in cm
H = head of water in meters

Input Power = $\frac{\rho g Q H}{1000}$ kW

Output Power = $\frac{2\pi Nm 9.81(R+r)}{1000 \, x 60}$ kW

R = 0.15 m, r = 0.008 m

Where N = rpm
m = mass, Kg
R = Brake drum radius m
r = Rope radius m

Efficiency (n) = $\frac{Output}{Input}$ x 100

Specific Speed (N s) = $\frac{N\sqrt{p}}{H^{5/4}}$

Unit Speed (N u) = $\frac{N}{\sqrt{H}}$

Unit power (P u) = $\frac{P}{H^{3/2}}$

Unit discharge (Q u) = $\frac{Q}{\sqrt{H}}$

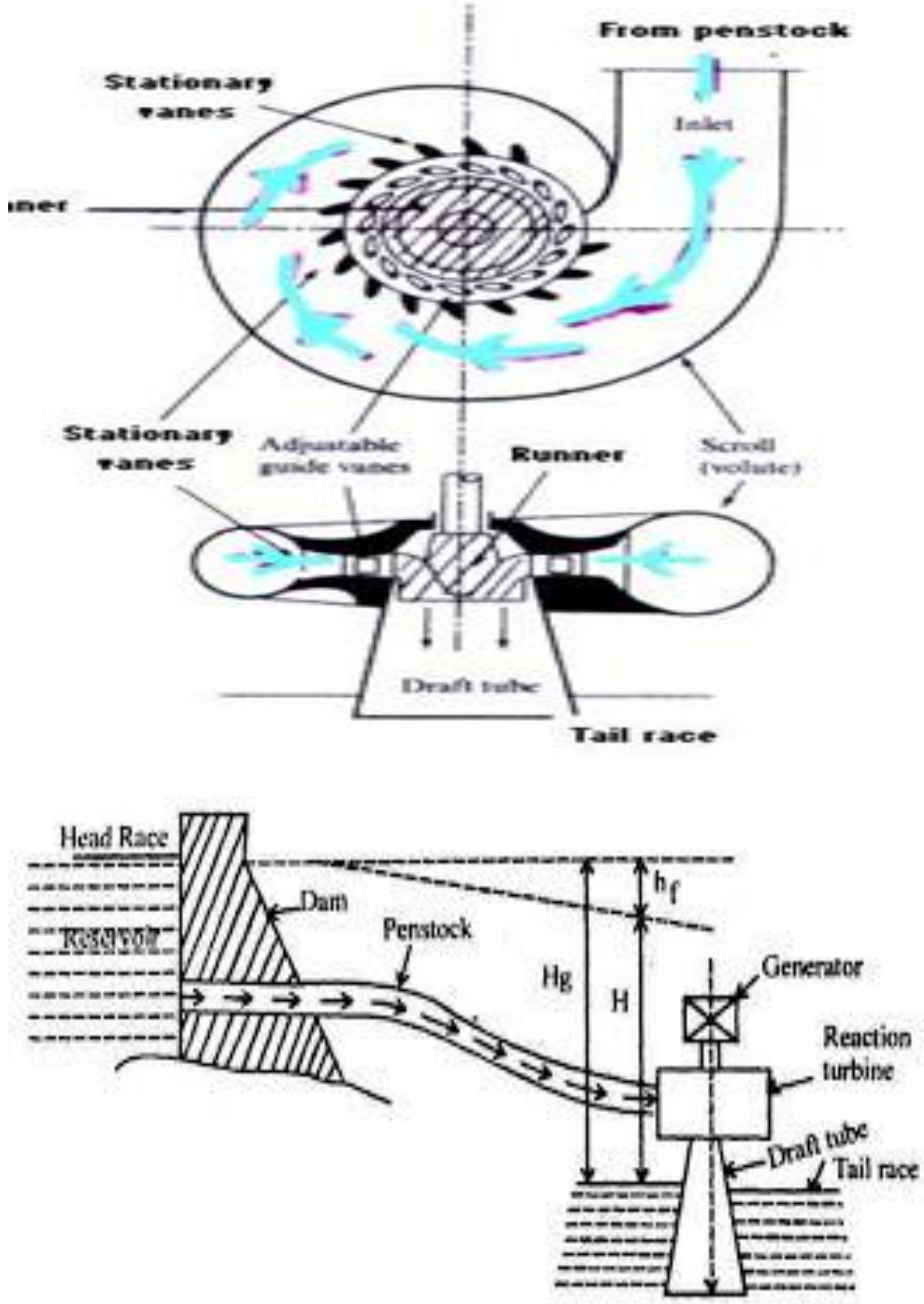


Figure : Francis Turbine

5. FRANCIS TURBINE

OBSERVATIONS:

Net Supply Head Kgf/cm^2	Guide Vane Setting	Discharge Q= $\frac{k\sqrt{h x 12.6}}{1000 x 60}$ m^3/s	Input $\frac{\rho g Q H}{1000}$ kW	Net load W_1-W_2	Total head H=Hs+H_d	Speed N	Manometric readings			Output KW	Efficiency(n)
							h1	h2	h1-h2		

6. KAPLAN TURBINE:

AIM: To draw the characteristics curves of Kaplan Turbine.

SPECIFICATION:

Max Flow of water = 2500 lpm

Max Head = 10 metres

Cd = 0.623

Description of Kaplan Turbine:-

Kaplan Turbine is designed for low water head applications. Kaplan Turbine has propeller like blades but works just reverse. Instead of displacing the water axially using shaft power and creating axial thrust, the axial force of water acts on the blades of Kaplan Turbine and generating shaft power.

Most of the turbines developed earlier were suitable for large heads of water. With increasing demand of power need was felt to harness power from sources of low head water, such as, rivers flowing at low heights. For such low head applications Viktor Kaplan designed a turbine similar to the propellers of ships. Its working is just reverse to that of propellers. The Kaplan Turbine is also called as Propeller Turbine.

Design of Kaplan Turbine

To generate substantial amount of power from small heads of water using Kaplan Turbine it is necessary to have large flow rates through the turbine. Kaplan Turbine is designed to accommodate the required large flow rates. Except the alignment of the blades the construction of the Kaplan Turbine is very much similar to that of the Francis Turbine. The overall path of flow of water through the Kaplan Turbine is from radial at the entrance to axial at the exit. Similar to the Francis Turbine, Kaplan Turbine also has a ring of fixed guide vanes at the inlet to the turbine. Unlike the Francis Turbine which has guide vanes at the periphery of the turbine rotor (called as runner in the case of Francis Turbine), there is a passage between the guide vanes and the rotor of the Kaplan Turbine. The shape of the passage is such that the flow which enters the passage in the radial direction is forced to flow in axial direction. The rotor of the Kaplan Turbine is similar to the propeller of a ship. The rotor blades are attached to the central shaft of the turbine. The blades are connected to the shaft with moveable joints such that the blades can be swiveled according to the flow rate and water head available.

The blades of the Kaplan Turbine are not planer as any other axial flow turbine; instead they are designed with twist along the length so as to allow swirling flow at entry and axial flow at exit.

The working head of water is low so large flow rates are allowed in the Kaplan Turbine. The water enters the turbine through the guide vanes which are aligned such as to give the flow a suitable degree of swirl determined according to the rotor of the turbine. The flow from guide vanes pass through the curved passage which forces the radial flow to axial direction with the initial swirl imparted by the inlet guide vanes which is now in the form of free vortex.

The axial flow of water with a component of swirl applies force on the blades of the rotor and looses its momentum, both linear and angular, producing torque and rotation (their product is power) in the shaft. The scheme for production of hydroelectricity by Kaplan Turbine is same as that for Francis Turbine.

OPERATION:

- Keep the gate valve closed.
- Keep the Electrical Load at Maximum by keeping all Switches at ON position.
- Press the Green button of the supply pump starter and then release.
- Slowly open the gate so that the Turbine Rotor picks up the Speed.
- And attains Maximum at full opening of the gate valve.

(i) Constant speed.

For different Electrical Loads on the Turbine change the Gate valve position, so that the speed is held constant; say at 1400 rpm. See that the voltage does not exceed 250 volts to avoid excess voltage on bulbs.

(ii) Constant head characteristics

Select the Propeller Vane angle position.

By slowly opening the Gate set the head on the gauge.

For different Electrical Loads change the Guide vane opening and Maintain the Head constant and Tabulate the readings.

PRECAUTIONS:

To start and Stop the supply pump always keep gate valve closed. Gradual opening and closing of the gate valve is Recommended.

SPECIMEN CALCULATIONS:

GRAPHS

(I) Constant speed:

Efficiency Vs ‘Q’

O / P power Vs ‘Q’

(II) Constant Head:

Efficiency vs ‘N’

‘Q’ Vs ‘N’

O / P power Vs ‘N’

Figure 6: Kaplan Turbine

FORMULAE FOR CALCULATIONS

1. Head on the Turbine

'H' in meters of water = P + Pv

Where P = Pressure gauge reading in Kg/Cm^2
= 10 X P mts

And Pv = vacuum gauge reading in mm of Hg
= 13.6/1000 x Pv

2. Discharge (Flow rate)

Of water through the Turbine = Flow rate over the rectangular Notch

Q = $2.95 L h^{3/2}$
Where L = crest width in mts
= 0.5 m

And h is in cms, convert it into mts.

Q = $1.48 h^{3/2}$

3. Hydraulic input to the Turbine = $\frac{W\,Q\,H}{75}$ HP

Where, W = $1000\ kg/m^3$
Q = Flow rate of water in m^3/sec
H = Head on Turbine in mts

4. Break horse Power of the Turbine,

$$BHP = \frac{Electrical\ Input}{Efficiency\ of\ Generator}$$

Where Efficiency of generator = 0.75

$$BHP = \frac{VxI}{736\,x\,0.75}$$

5. Turbine efficiency = $\frac{Output}{Input} x100$

6. Unit quantities –Under Unit Head

a) Unit Speed, Nu = $N/\sqrt{H}$

b) Unit power, Pu = $N/\sqrt{H}^{2/3}$

c) Unit discharge, Qu = $Q/\sqrt{H}$

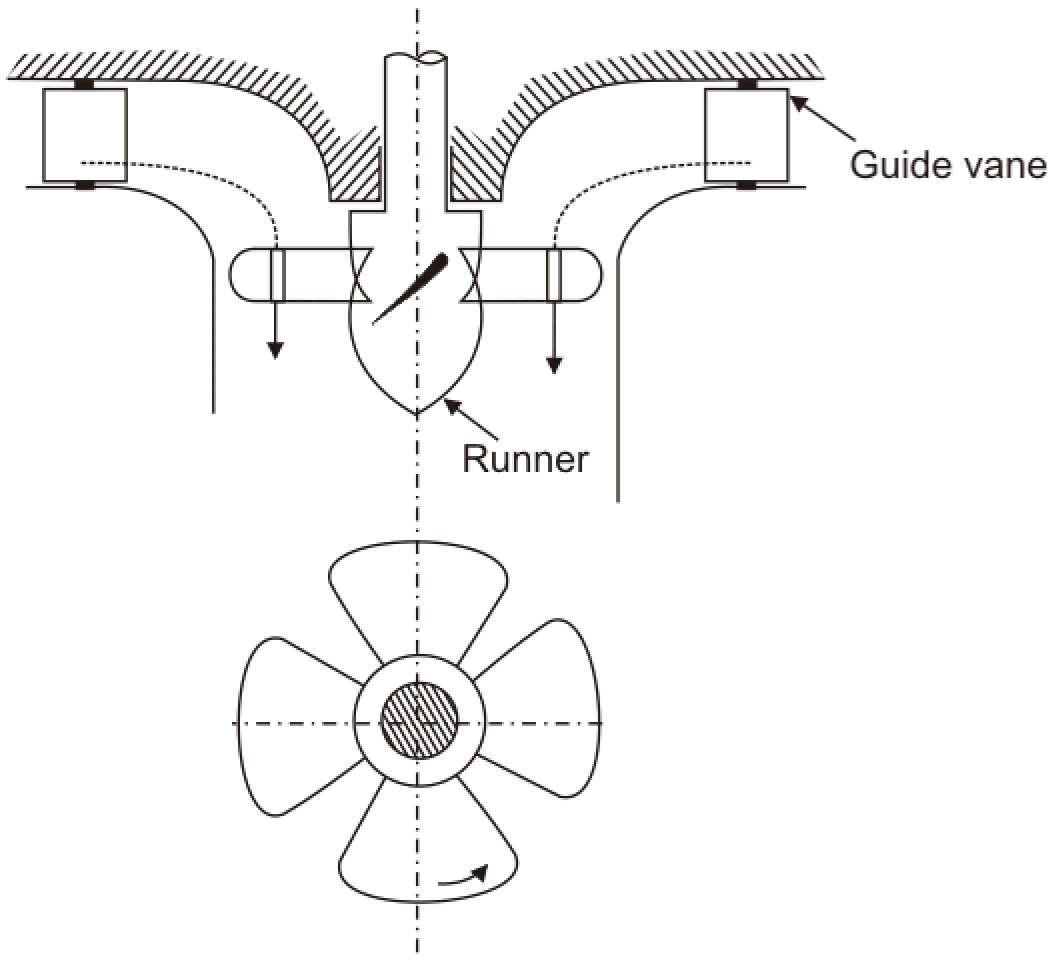


Figure: propeller of Kaplan turbine

6. KAPLAN TURBINE

TABULAR COLUMN

OBSERVATIONS:

Speed (RPM)	Net Supply Head Kgf/cm^2		Delivery Head (mm of Hg)	Total Head	Head over V Notch (cm)	Discharge Q	Bulbs (W)	Volts (V)	Current (I)	Input Power (HP)	Output (HP)	Efficiency (%)

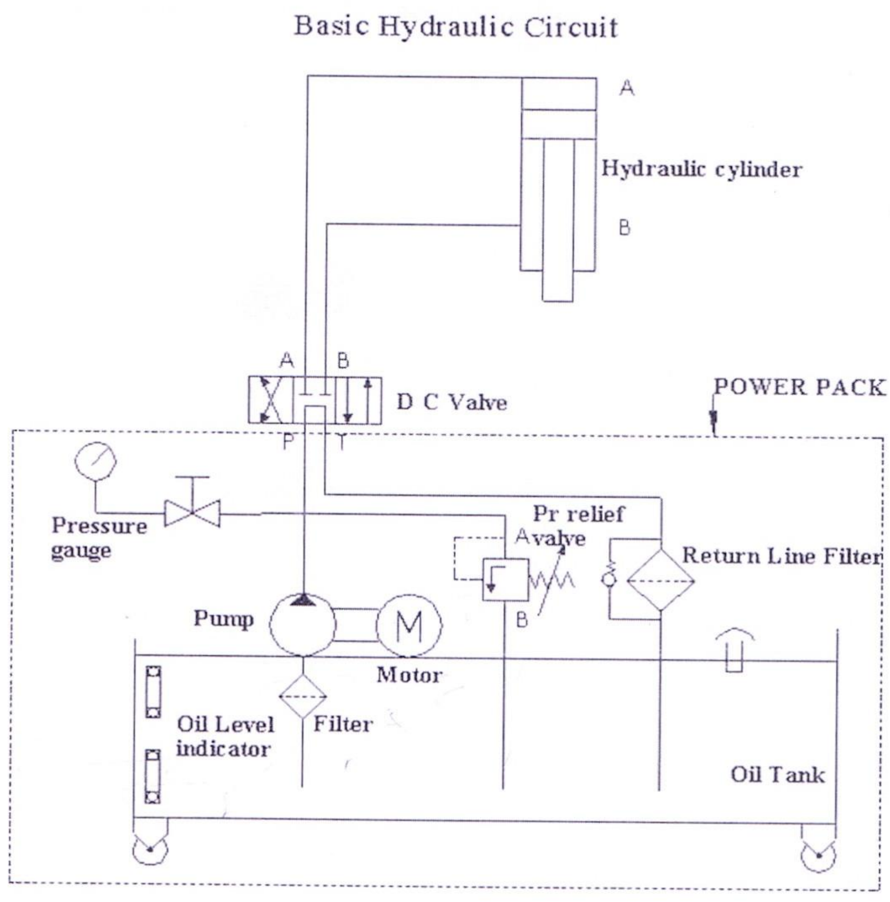
Experiment 7

Experiment 7(a)

BASIC HYDRAULIC CIRCUIT

AIM: To control the movement of a double acting cylinder using a 4 way type lever control directional Control valve.

CIRCUIT DIAGRAM:



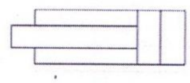
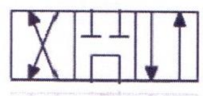
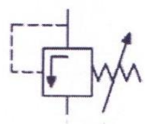
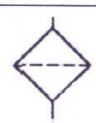
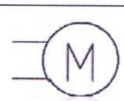
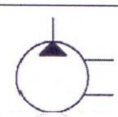
PROCEDURE:

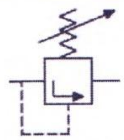
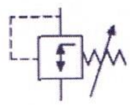
- Connect Port A of D C Valve to Port A of the hydraulic cylinder.
- Connect Port B of D C Valve to Port B of the hydraulic cylinder.

The connection and the components of the power pack will remain same for all circuits

- Use Suitable T joints if necessary and Hoses for obtaining the above connection.
- Start the Motor.
- Adjust the relief valve to set the required pressure, if any.
- Use the D C valve lever to see the piston movement.

LIST OF HYDRAULIC SYMBOLS USED

	Hydraulic Cylinder
	Direction Control Valve 4 way
	Relief Valve
	Check Valve
	Level indicator
	Filter or Strainer
	Motor
	Pump
	Spring loaded check valve

	Sequence Valve
	Flow control valve
	Pressure reducing valve
	Pressure gauge

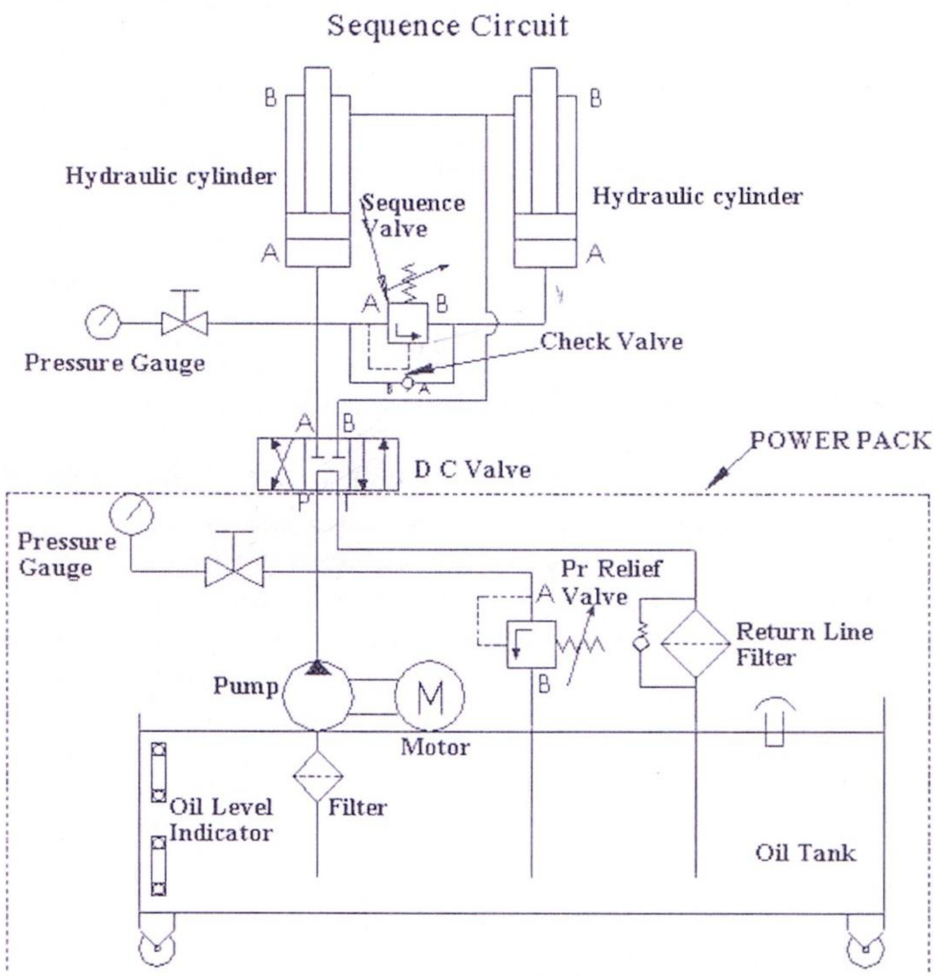
Experiment 7

Experiment 7(b)

SEQUENCING CIRCUIT

AIM: To Sequence the two double acting hydraulic cylinders using a sequence valve.

CIRCUIT DIAGRAM:



PROCEDURE:

- Connect the port A of the D C valve to the following components
  1) Port A of the hydraulic cylinder (any one).
  2) Pressure Gauge
  3) Port A of Sequence Valve
  4) Port B of check valve
- Connect the port A of the other cylinder to the following components
  a. Port B of Sequence valve
  b. Port A of check valve
- Connect the port B of the two cylinders with each other and direct it to the port B of the D C valve using a T joint.

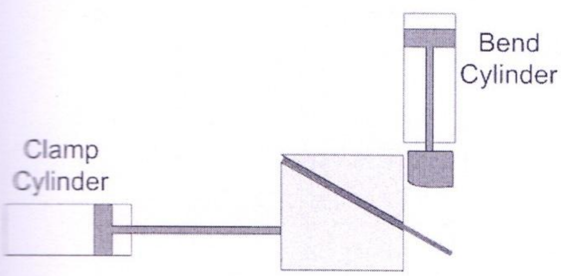
The connection and the components of the power pack will remain same for all circuits

- Use Suitable T joints if necessary and Hoses for obtaining the above connection.
- Start the Motor.
- Adjust the relief valve to set the required pressure, if any.
- Use the D C valve lever to see the piston movement.
- Adjust the Sequence Valve to obtain desired sequencing of the cylinders.

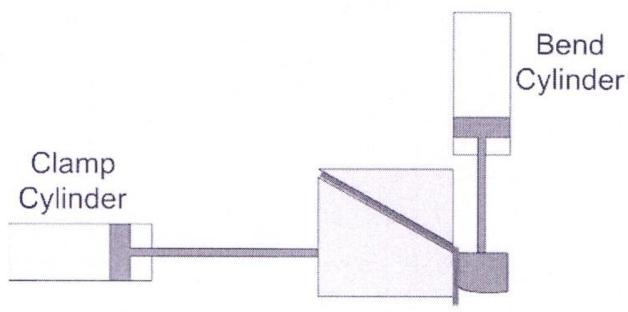
PRACTICAL APPLICATION:

Sequences valve, as the name implies are used when two operations are performs in sequence, that is, one operation ends before the other begins.

A practical example of the sequence valve is the operation of the clamp and bend machine. The clamp cylinder holds the work piece in place, and then a second cylinder bends it to a desired angle.



Stage 1) Clamp cylinder actuated



Stage 2) Bend cylinder sequenced

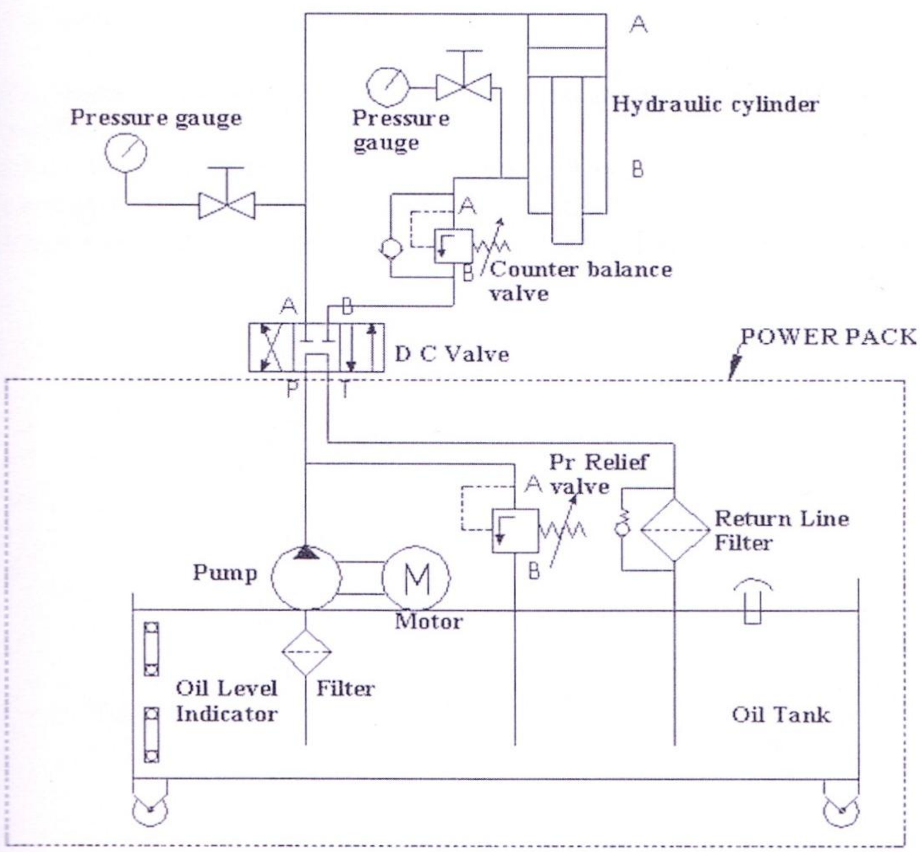
Experiment 7(c)

COUNTER BALANCE CIRCUIT

AIM: To obtain a counterbalance circuit using a counterbalance valve.

CIRCUIT DIAGRAM:

Counter Balance Circuit



PROCEDURE:

- Connect the port A of the D C valve to the port A of the cylinder by bypassing the pressure gauge.
- Connect the port B of the D C valve to the port A of the counter balance valve.
- Connect the port B of the counter balance valve to the port B of the cylinder by bypassing the second pressure gauge.

  The check valves shown in the circuit diagram parallel to the counterbalance valve is an integral part of the counter balance valve only, and no additional check valves are required in the circuit.

The connection and the components of the power pack will remain same for all circuits

- Use Suitable T joints if necessary and Hoses for obtaining the above connection.
- Start the Motor.
- Adjust the relief valve to set the required pressure, if any.
- Use the D C valve lever to see the piston movement.
- Adjust the counterbalance valve to obtain desired the desired pressure in the return stroke.

Merits and Demerits of Hydraulic systems:-

The advantages of hydraulic system over other methods of power transmission are:

1. Freedom of location of input and output power converters such as prime movers, pumps & actuators. This ensures flexibility.

2. Infinitely variable control of output force, output torque, output speed and actuator position. This provides control of speed & forces over wide range.
   Actuators (linear or rotary) of a hydraulic system can be driven at infinitely variable speed by either varying the pump delivery or by using a flow control valve.
   A pressure adjusting / regulating valve can be used to vary the operating pressure to adjust the output force or output torque.

3. Extremely high output forces and force multiplication is possible by means of the "hydraulic lever".

4. Drive system in hydraulics is reversible.
   A hydraulic actuator can be reversed instantly while in full motion without damage. A 4 way direction control valve or a reversible pump provides the reversing control.
   A pressure relief valve protects the system components from excess pressure occurring during instantaneous reversible.
   (Other types of drives like electric motor or I.C. Engine etc., have to be slowed down, stopped completely before reversing)

5. Safety and overload protection of the system components can be achieved by automatic valves, to prevent system breakdown.

6. Low inertia and ease of shock absorption during actuator motion start and stop operation is smooth & quiet. Vibration is kept to minimum.

7. Emergency power can be stored in an accumulator.

8. Greater efficiency and economy due to low friction losses and high system reliability (efficiency is approx. 70% -80%).

9. Design of system is simpler. In most cases few pre-engineered components will replace complicated mechanical linkages.

10. Small packages – The system has high power to weight ratio, ensuring compactness.

11. The hydraulic drive system can be stalled without damage when overloaded and will startup immediately when the load is reduced. During stall, the relief valve simply diverts pump delivery to tank which results only in loss of Horsepower.
12. Hydraulic systems are self lubricating and power can be diverted to alternative actuators.

Demerits / limitations of a hydraulic system :

1. Precision parts are necessary in fluid power system.

2. Precision parts are exposed to unsympathetic climates and dirty atmospheres and hence call for very cautious and regular system maintenance.

3. Initial system cost is high. But high efficiency, minimum frictional losses keeps the cost of power transmission at minimum. This offsets the disadvantage of high initial cost.

4. Contamination of hydraulic fluid is inevitable & is the most serious disadvantage of using fluid power. To prevent clogging of precision clearances in the fluid actuators and valves requires extensive filtering systems to maintain cleanliness in oil.

5. Leaking problems, both internal and external, are sure to occur. Special provisions must be made to accommodate such leakages.
   Line ruptures and bursts can cause hazard due to high velocity oil jets. Oil might also be flammable posing fire hazards.

6. Controllability of hydraulic systems is not as easy as electrical systems.

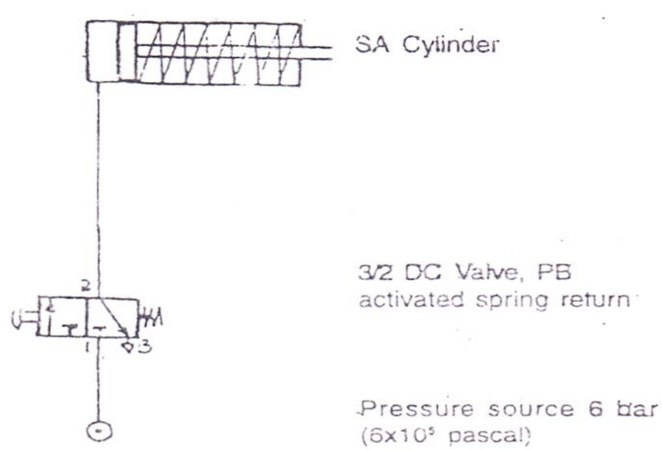
Experiment 8

Exercises for pneumatic trainer kit

Experiment 8(a)

(1) To control the movement of a single acting cylinder using a 3/2 D.C. valve push Button actuated, spring return (N.C. Type)

(2) Circuit Diagram



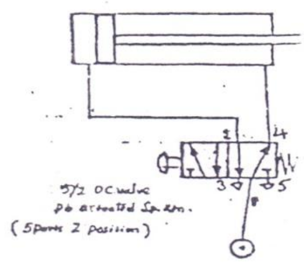
(3) List of Components

(i) Single acting Cylinder
(ii) Spring return Push Button type 3/2 D.C. valve

Experiment 8(b)

(1) Aim : Build pneumatic circuit for a STAMPING device, in which components are to be stamped. This is control the movement of a double acting cylinder using 4/2 OR A 5/2 D.C. Valve push button actuated spring return.

(2) Circuit Diagram



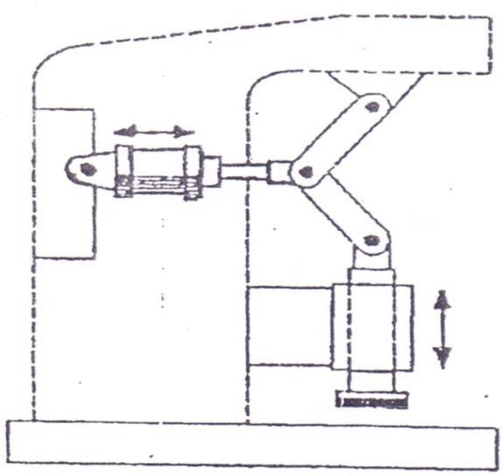
(3) List of Components
- i) Double acting cylinder
- ii) Spring return, Push Button type 4/2 or 5/2 D.C. valve.

(4) Observations

Components are to be stamped with a stamping device.

By pressing a push button switch the die is pushed down and the component is stamped. When the push button is released the die is returned to its start position.

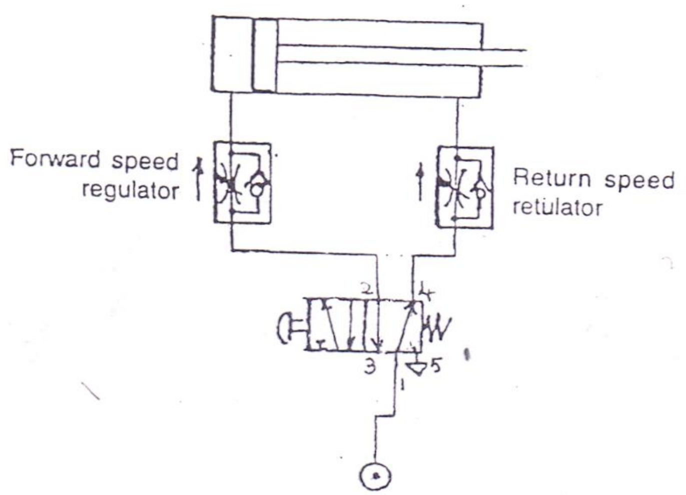
(5) Positional Sketch



Experiment 8(b)

(1) Aim : Build pneumatic circuit for opening and closing the value of a pipe line with speed regulation that is to regulate the movement of a D.A. cylinder differentially for forward and return motions (Supply throttling)

(2) Circuit Diagram



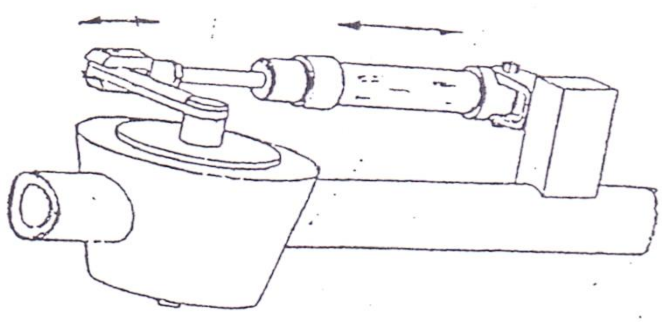
(3) List of Components

i) Double Acting Cylinder
ii) Throttle valves for speed regulation
iii) 5/2 D.C. valve push button type with spring return.

(4) Observations :

The valve of a pipe line is to be opened and closed. The valve is opened by pressing the pushbutton switch. When the pushbutton is released the valve is closed. The speed of opening and closing is to be regulated.

(5) Positional Sketch :



Merits and Demerits of Pneumatic systems:-

Merits :-

• Infinite availability of the source

Air is the most important thing in the pneumatic system, and as we all know, air is available in the world around us in unlimited quantities at all times and places.

• Easy channeled

Air is a substance that is easily passed or move from one place to another through a small pipe, the long and winding.

• Temperature is flexible

Air can be used flexibly at various temperatures are required, through equipment designed for specific circumstances, even in quite extreme conditions, the air was still able to work.

• **Safe**

The air can be loaded more safely than it is not flammable and does not short circuit occurs (konsleting) or explode, so protection against both of these things pretty easily, unlike the electrical system that could lead to fires *konsleting*.

• **Clean**

The air around us are tend to clean without chemicals that are harmful, and also, it can be minimized or cleaned with some processes, so it is safe to use pneumatic systems to the pharmaceutical industry, food and beverages and textiles.

• The transfer of power and the speed is very easy to set up

Air could move at speeds that can be adjusted from low to high or vice versa. When using a pneumatic cylinder actuator, the piston speed can reach 3 m / s. For pneumatic motors can spins at 30,000 rpm, while the turbine engine systems can reach 450,000 rpm.

• Can be stored

The air can be stored through the seat tube fed excess air pressure. Moreover, it can be installed so that the pressure boundary or the safety of the system to be safe.

• Easy utilized

Easy air either directly utilized to clean surfaces such as metal and machinery, or indirectly, ie through pneumatic equipment to produce certain movements.

Demerits :

• Requires installation of air-producing equipment.

Compressed air should be well prepared to meet the requirements. Meet certain criteria, such as dry, clean, and contain the necessary lubricant for pneumatic equipment. Therefore require installation of pneumatic systems are relatively expensive equipment, such as compressors, air filter, lube tube, dryer, regulators, etc.

• Easy to leak

One of the properties of pressurized air is like to always occupy the empty space and the air pressure is maintained in hard work. Therefore we need a seal so that air does not leak. Seal leakage can cause energy loss. Pneumatic equipment should be equipped with airtight equipment that compressed air leaks in the system can be minimized.

• Potential noise

Pneumatic using open system, meaning that the air that has been used will be thrown out of the system, the air comes out pretty loud and noisy so will cause noise, especially on the exhaust tract. The fix is to put a silencer on each dump line.

• Easy condenses

Pressurized air is easily condensed, so before entering the system must be processed first in order to meet certain requirements, such as dry, have enough pressure, and contains a small amount of lubricant to reduce friction in the valves and actuators.

Expected after knowing the advantages and disadvantages of the use of compressed air we can make the anticipation that these losses can be avoided.

9. Impact of Jet on Vanes

INTRODUCTION

Impact of jets apparatus enables experiments to be carried out on the reaction force produced on vanes when a jet of water impacts on to the vane. The study of these reaction forces is an essential step in the subject of mechanics of fluids which can be applied to hydraulic machinery such as the Peltron wheel and the impulse turbine.

AIM

The aim of this experiment is to demonstrate the impulse momentum theorem as it applies to the impact of a water jet on vanes with different geometrical shapes. This impulse Momentum theorem is the underlying physics behind the operation of the pelton wheel.

THEORY

When a jet of water flowing with a steady velocity strikes a solid surface the water is deflected to flow along the surface. If friction is neglected by assuming an inviscid fluid and it is also assumed that there are no losses due to shocks then the magnitude of the water velocity is unchanged. The pressure exerted by the water on the solid surface will everywhere be at right angles to the surface. Consider a jet of water which impacts on to a target surface causing the direction of the jet to be changed through an angle as shown in figure below. In the absence of friction the magnitude of the velocity across the surface is equal to the incident velocity Vi. The impulse force exerted on the target will be equal and opposite to the force which acts on the water to impart the change in direction.

Applying Newton's second law in the direction of the incident jet.

Force = mass x accerlation

= mass flow rate x change in velocity

$F = m (v_2 - v_1)$

$F = \rho Q (v_2 - v_1)$

The force exerted by the fluid on the solid body touching the control volume is equal and opposite of F. So the reaction force R is given by:

$R = -F$

$R = \rho Q (v_2 - v_1)$

$R = \rho Q (v_1 - v_1 \cos\theta)$

$R = \rho Q v_1 (1 - \cos\theta)$

APPLICATION TO IMPACT OF JET APPARATUS

In each case it is assumed that there is no splashing or rebound of the water from the surface so that the exist angle is parallel to the exit angle of the target.

The jet velocity can be calculated from the measured flow rate and the nozzle exit area.

$$v = \frac{Q}{A}$$

However, as the nozzle is below the target the impact velocity will be less than the nozzle velocity due to interchanges between potential energy and kinetic energy so that:

$$v_1 = \sqrt{v^2 - 2gh}$$

v = exit velocity at nozzle exit area

v_1 = velocity at entry near vane

h = is the height of target above the nozzle exit.

Produces a jet of water which impinges on a vane, in the form of a flat plate or a hemispherical cup or a inclined vane. The nozzle and vane are contained within a transparent cylinder, and at the base of the cylinder there is an outlet from which the flow is directed to the collecting tank of the bench. As indicated in Fig, the vane is supported by a sliding rod and a stopper plate which has a provision to carry counter weight, and which is restrained by a light spring. The stopper plate may be set to a balanced position by placing the pointer pointing on the line of the stopper plate. Any force generated by impact of the jet on the vane may now be measured by placing the counter weight on the stopper plate until it comes back to its original balanced position. The setup also has a pressure gauge and a Rota meter to measure to flow rate connected at the inlet. The system has two major lines the main line and the bypass line which are both consisted of flow control valves to adjust the flow equally in both lines to prevent excessive back pressure on the self-primping pump. The entire system is powered by a 1 HP self-primping pump which draws water from a 90 liter capacity SS tank and delivers in a 60 liter capacity collecting tank.

1. impact on Flat vane

For the Normal plane target $\theta = 90^o$

Therefore cos $\theta = 0$

R = ρ Q v_i

2. Impact on inclined vane (Angle of inclination 10^o)

For the inclined plane target ? = 100o

Therefore cos $\theta = 0.8623$

R = ρ Q Vi x 0.8623

3. Impact on Curved vane (Angle of inclination 135^o)

For the Curved plane target $\theta = 135^o$

R = ρ Q v_i x 2

OBSERVATIONS AND CALCULATIONS

Data used and recorded:

Density of water ρ = 1000 kg /m3

Diameter of nozzle d = 10/6.5/5/3.5 mm

Area of cross section of the nozzle $A = \frac{\pi d^2}{4} m^2$

Area of collecting tank = 0.16 m^2

Weight of the sliding rod + stopper = 280 gms

Weight of the flat vane = 280 gms

Weight of the inclined vane = 225 gms

Weight of the curved vane = 280 gms

Height of the target above the nozzle h = 50mm

EXPERIMENTAL PROCEDURE

1. Sump tank is cleaned and filled with water (Ensure water is free from foreign bodies)
2. Drain valves is closed and desired vane and nozzle is placed in the cylinder.
3. Main power supply is switched on.
4. Pump is switched on and the stopper plate and the pointer is set on a suitable position.

5. Flow rate of water is controlled using the two flow control vales in the main line and the bypass line.

6. Flow rate is measured is either using the Rota meter or by using the collecting tank and the stop watch.

7. Counter weight is then placed on the stopper plate and the flow rate is adjusted to bring it back to the original balanced position.

8. All reading are noted down.

9. The experiment is repeated with various combination of the vanes and nozzles.

Graph: Experimental force Vs Theoretical reaction force

Figure 9. Impact of Jet on Vanes

9. IMPACT OF JET ON VANES

Target Vane Type	Nozzle Dia (mm)	Height of the vane above the nozzle h(mm)	Additional weights (gms)	Total Weights (gms)	Experimental force (F') (N)= Total Weight x g	Flow rate Q (lpm)	Flow rate Q (m^3/s) =Q(lpm)x1.67 x10^{-5}	Nozzle exit velocity v(m/s)=Q/A A= πr^2	Velocity at vane entry v1(m/s) = v=(v2-2gh)	Theoritical reaction force R (N) = pQv_1X2	Error % (R - F^1)/R	Slope	1-cos θ
Curved vane	5	50	200										
			250										
			300										
			350										

10. SELF PRIMPING PUMP

AIM:

To study the performance of a self-priming pump and draw the characteristic curves.

DESCRIPTION OF THE APPARATUS

The apparatus consist of a hydraulic bench setup powered by a 1 HP self-priming pump whose characteristics study is to be carried out. The pump draws water from a 90L SS sum tank and delivers in collecting tank, the tanks are provided with a level gauge to measure the level of water. At the delivery of the pump, the flow can be adjusted by using a flow control valve and the same can be noted using a 50 LPH Rota meter. For the measurement of the output pressure head of the pumps, a pressure gauge arrangement is provided. For the purpose of measurement of the power consumption by the pump motor a voltmeter and an ammeter arrangement is also provided on the control panel.

OPERATION OF SELF-PRIMING PUMP:

During the priming cycle, air enters the pump and mixes with water at the impeller. Water and air are discharged together by centrifugal action of the impeller into the water reservoir. The air naturally tends to rise, while the water tends to sink. Air-free water, now heavier then air laden water, flows by gravity back down into the impeller chamber, ready to mix with more air coming in the suction line. Once all air has been evacuated and a vacuum created in the suction line, atmospheric pressure force water up into the suction line towards the impeller, and pumping begins.Recirculation of water within the pump stops when pumping begins. The next time the pump is started, it will “self-prime” – that is, it will be able to once again mix the water and air in the casing to create a pumpable fluid until the pump is fully primed again.

This type of pump differs from a standard centrifugal pump in that it has a water reservoir built into the unit which enables it to rid pump and suction line of air by recirculating water within the pump on priming cycle. This water reservoir may be above the impeller or in front of the impeller. In either case, the “self-priming” capability of the pump comes from the pump’s ability to retain water after the very first prime.

EXPERIMENTAL PROCEDURE

1. Sump tank is created and filled with water (Ensure water is free from foreign bodies)
2. Drain valves is closed and desired vane and nozzle is placed in the cylinder.
3. Main power supply is switched on.
4. Pump is switched on
5. By controlling the output discharge various reading are noted down.
6. Output flow rate can be measured either directly from the rotatmeter or by calculating the volume of water contained in a particular time.
7. Do not run the pump below 15 LPH to avoid excessive back pressure on the pump.

Figure 10: Self priming Pump

OBSERVATIONS AND CALCULATIONS:

$$P_h = \frac{Qgh}{36\,x10^6}(Kw)$$

$$P_s = \frac{V\,x\,I}{10^3}(Kw)$$

$$n = \frac{P_h}{P_s}x100$$

P_h = Output Power (KW)

Q = Flow rate (m^3/h)

P = density of the fluid $(\frac{Kg}{m^3})$

g= gravity (98.1 m/s^2)

h = Output head (m)

P_3 = Motor Power consumption (kw)

V = Input current (amp)

n = efficiency

GRAPHS:

Flow rate Vs Head

Flow rate Vs Power

Flow rate Vs Efficiency

RESULTS & CONCLUSIONS:

1. Record the results on a copy of the results sheet provided.

2. Calculate for each result the efficiency of the pump.

3. Plot the Head-flow, Power-flow & Efficiency-flow curves.

10. CHARACTERISTICS OF A SELF PRIMING PUMP

S.No	Flow rate Q(LPM)	Flow rate Q(m3/h)= Q(lpm)X 0.06	Delivery Pressure P (Kg/cm^2)	Output head h(m)=PX10	Volts(V)	Input current I (amps)	Output power P_h= $(\rho g Q H)$ /(3.6 X 10^6) (kw)	Input power P_s= Vx1/10^3(kw)	Efficiency= P_h/P_sx100
1									
2									
3									
4									
5									