1. CALIBRATION OF VENTURI METER

AIM: To determine the Coefficient of Discharge of Venturimeter

APPARATUS REQUIRED:

1. Venturimeter
2. Measuring Tank
3. Sump Tank
4. Differential Manometer
5. Piping System
6. Supply Pump Set 7. Stop Watch.

SPECIFICATIONS:

1.	Sump tank size	: 0.3 m x 0.45 m x 0.94 m S.S. Tank
2.	Measuring tank size	: 0.3 m x 0.3 m x 0.5 m S.S. Tank
3.	Differential Manometer	: 1.0 m range with 1mm scale graduations
4.	Pipe size	: 25 mm
5.	Venturimeterinlet diameter (d_1)	: 25 mm
6.	Venturimeter throat diameter (d_2)	: 14 mm
7.	Area ratio (a_2/a_1) m	: 0.3136
8.	Supply pump set	: Pump is 25 x 25 mm^2 size, Centrifugal Monoset pump with single phase, 2 Pole, 220V, 50Hz, ½ HP, 2780 RPM, AC Supply

DESCRIPTION OF APPARATUS: It is a closed circuit water re-circulation system consisting of sump tank, measuring tank, centrifugal monoset pump, one pipeline fitted with Venturimeter

1. **VENTURI METER**:Venturimeteris a device which is used for measuring the rate of flow of fluid through a pipe which consists of hose collars. Venturimeterconsists of

a. An inlet section followed by a convergent cone
b. A cylindrical throat
c. A gradually divergent cone

a. Inlet Section: It is of the same diameter as that of the pipe which is followed by a convergent cone.

Convergent cone : It is a short pipe which tapers from the original size of the pipe to that of the throat of the venturi meter

b. Throat: It is a short parallel sided tube having its cross-sectional area smaller than that of the pipe

c. Divergent Cone: It is a gradually diverging pipe with its cross-sectional area increasing from that of the throat to the original size of the pipe.

At the Inlet section and throat, pressure taps are provided through pressure rings.

1. Total included angle of convergent cone : $21^0 \pm 1^0$
2. Length parallel to the axis of convergent cone : 2.7 (D-d)
    i. D = Diameter of the inlet section
    ii. d = Diameter of the throat
3. Length of throat : d
4. Total included angle of divergent cone : 5^0 to 15^0 (preferably about 6^0)

Diameter of throat may very from $\frac{1}{3}$ to $\frac{3}{4}$ of the pipe diameter and more commonly the diameter of the thoat is kept equal to $\frac{1}{2}$ of pipe diameter

2.PIPING SYSTEM: Consist of a pipe of size 25mm with separate control valve and mountedon a suitable strong iron stand. Separate upstream and downstream pressure feed pipes are provided. There are pressure taping valves which are ball valves and there are four manometer ball valves.

3.MEASURING TANK: It is a stainless steel (S.S) Tank with gauge glass, a scale arrangement for quick and easy measurements. A ball valve which is outlet valve of measuring tank is provided to empty the tank.

4.SUMP TANK: It is also a S.S. tank to store sufficient fluid for experimentation and arrange within the floor space of main unit. The sump should be filled with fresh water leaving 25 mm space at the top.

5.DIFFERENTIAL MANOMETER: It is used to measure the differential head produced by venturimeter.

6.PUMPSET: It is used to pump water from sump tank to measuring tank through pipe.

THEORY: A Venturi meter is a device which is used for measuring the rate of flow or discharge of fluid through a pipe. The principle of the venturi meter was first demonstrated in 1797 by Italian Physicist G.B.Venturi(1746 - 1822), but the principle was first applied by C. Hershel(1842 - 1930) in 1887.

The basic principle on which a venturi works is that by reducing the cross sectional area of the flow passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through the pipe. To avoid the possibility of flow separation and the consequent energy loss, the divergent cone of the venturi meter is made longer with a gradual divergence. Since the separation of flow may occur in the divergent cone of the venturi meter, this portion is not used for discharge measurement.

Since the cross sectional area of the throat is smaller than the cross-sectional area of the inlet section, the velocity of flow at the throat will become greater than that at the inlet section, according to continuity equation. The increase in the velocity of flow at the throat results in the decrease in the pressure at this section. As such a pressure difference is developed between the inlet section and the throat of the venturi meter. The pressure difference between these sections can be determined by connecting a differential manometer. The formation of vapour and air pockets in the liquid results in a phenomenon called cavitation which is not desirable. In order to avoid cavitation to occur, the diameter of the throat can be reduced only up to a certain limited value.

PROCEDURE:

1. Before starting the experiment, do priming of pump to remove air bubbles by pouring water in the priming device.
2. Then open the inlet valve of the piping system of pump and Venturi meter pipe outlet valve and close orifice meter pipe outlet valve.
3. Start the motor and open the pressure feed pipes valves to remove the air bubbles if any.
4. Close all the valves, except upstream and downstream ball valves of pipes connected with Venturi meter.
5. Note the readings in differential manometer

6. Close the outlet valve of measuring tank and note the 10 cm raise of water using stop watch.
7. Repeat the process 3 to 4 times and note the values for different flow rates of water.
8. After conducting experiment close all the pressure feed pipe valves and switch off the power supply.

FORMULAE:

***Actual discharge*:**

Actual discharge (Q_{act}) = $\frac{A.R}{t}$ m^3/s

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise 'R' in 't' seconds

The actual discharge is measured with the help of measuring tank and by noting the time for definite raise of water level in the tank.

***Theoretical discharge*:** Theoretical discharge (Q_{th}) = $\frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$ m^3/s

Where H = $\left[(h_1 - h_2)\frac{(S_1 - S_2)}{S_2}\right]$ / 100 m of water

h_1-h_2 = Difference in Manometric liquid in cm

S_1 = Specific gravity of Manometric liquid

S_2 = Specific gravity of flowing liquid

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

a_1 = Inlet area of Venturi meter in m^2

a_2 = Area of throat in m^2

***Coefficient of discharge*:**

Coefficient of discharge(C_d) = $\frac{Q_{act}}{Q_{th}}$ = $\frac{Actual Discharge}{Theoritical Discharge}$

<u>TABLE OF READINGS</u>:

S.NO	Manometer readingcm of hg		Time for (10 cm) rise of water level

	h_1	h_2	h_m	Manometer head h (cm)	't' in Sec.

SAMPLE CALCULATIONS:

Area of inlet (a_1) = $\frac{(\pi d_1^2)}{4}$ in m^2 =

Where

d_1 = Venturi inlet diameter = 25 mm = $25x10^{-3}$ m

Area of throat (a_2) = $\frac{(\pi d_2^2)}{4}$ in m^2 =

Where

d_2 = Throat diameter = 14 mm = $14x10^{-3}$ m

Manometer head h in m =

Theoretical discharge of Venturi meter (Q_{th}) in $\frac{m^3}{s}$ =

Time for 100 mm rise in sec (t) =

Actual discharge of Venturi meter (Q_{act}) in $\frac{m^3}{s}$ =

Coefficient of discharge of Venturi meter (C_d) = $\frac{Q_{act}}{Q_{th}}$ =

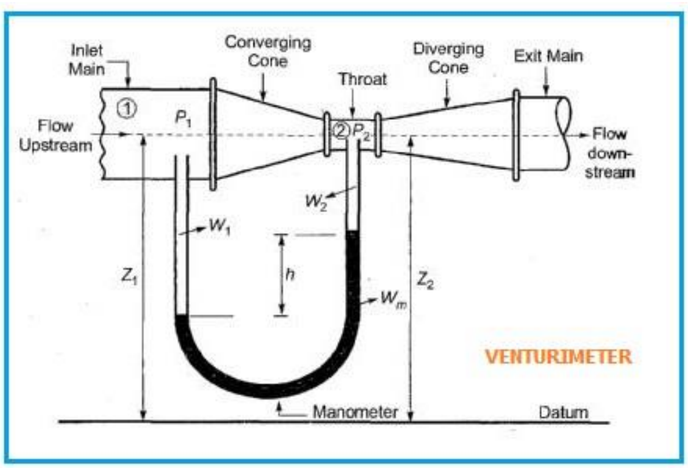
<u>TABLE OF CALCULATIONS</u>:

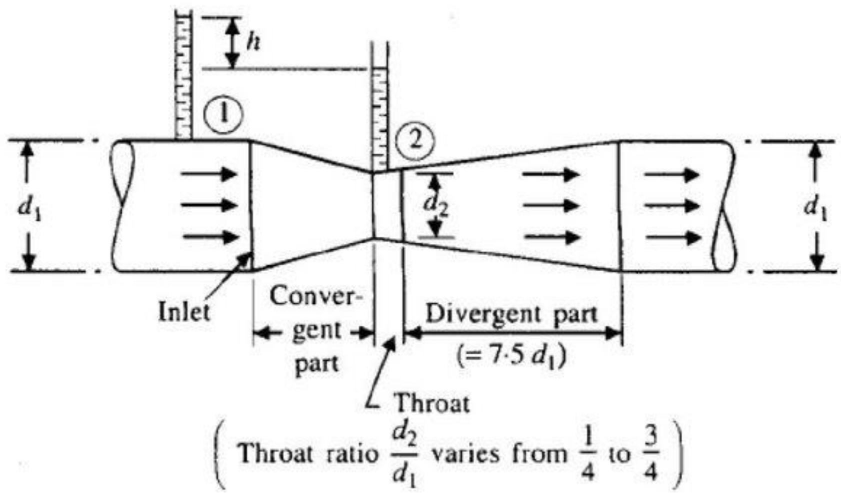
S.NO	**Actual Discharge** Q_{act} m^3/sec	**Theoretical Discharge** Q_{th} m^3/sec	**Coefficient of Discharge** $C_d = Q_{act} / Q_{th}$

Precautions:

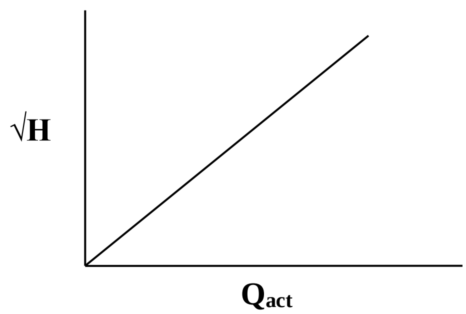
1. All the joints should be leak proof and water tight
2. Manometer should be filled to about half the height with mercury
3. All valves on the pressure feed pipes and manometer should be closed to prevent damage and over loading of the manometer before starting the motor.
4. Ensure that gauge glass and meter scale assembly of the measuring tank is fixed vertically and water tight
5. Ensure that the pump is primed before starting the motor
6. Remove the air bubbles in differential manometer by opening air release valves
7. Take the differential manometer readings without parallax error
8. Ensure that the electric switch does not come in contact with water
9. The water filled in the sump tank should be 2 inches below the upper end.

FIGURE:





MODEL GRAPH: A graph between Q_{act} vs √H



RESULTS:

VIVA QUESTIONS:

1. What are the applications of Bernoulli's equation?

A. Venturi meter, Orifice meter, Pitot tube, Nozzle meter

2. What is Venturi meter? And what is its use?

A. Venturi meter is a device which is used for measuring the rate of flow of fluid through a pipe

3. Who demonstrated the principle of Venturi meter first?

A. The Principle of Venturi meter was first demonstrated in 1797 by Italian Physicist G.B. Venturi (1746 - 1822).

4. Who applied Venturi meter principle?

A. C. Herschel (1842-1930) applied Venturi meter principle in 1887.

5. What is the basic principle of venturi meter?

A. The basic principle on which a venturi meter works is that by reducing the cross-sectional area of the flow passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through the pipe.

6. What are the parts of Venturi meter?

A. a. An inlet section followed by a convergent cone
b. A Cylindrical throat

c. A gradually divergent cone

7. What is convergent cone?
A. It is a short pipe which tapers from the original size of the pipe to that of the throat of the venturi meter

8. What is throat of Venturi meter?
A. The throat of the Venturi meter is a short parallel sided tube having its cross-sectional area smaller than that of the pipe.

9. What is divergent cone?
A. It is a gradually diverging pipe with its cross-sectional area increasing from that of the throat to the original size of the pipe.

10. Where pressure taps are provided?
A. At the inlet section and throat.

11. What is the total included angle of convergent cone of Venturi meter?
A. $21^0 \pm 1^0$

12. What is the length of the convergent cone?
A. 2.7 (D-d)

D = Diameter of the inlet section

d = Diameter of the throat

13. What is the included angle of divergent cone?
A. 5^0 to 15^0 (preferably about 6^0)

14. Which part is smaller, convergent cone or divergent cone? Why?
A. Convergent cone is smaller. To avoid the possibility of flow separation and the consequent energy loss, the divergent cone of the venturi meter is made longer with a gradual divergence.

15. Where separation of flow occurs?
A. In Divergent cone of Venturi meter

16. Which portion is not used for discharge measurement?
A. Divergent cone

17. Which cross-sectional area is smaller than cross sectional area of inlet section?
A. Throat

18. Where velocity of flow greater?
A. Throat

19. Where pressure is low in Venturi meter?
A. Throat

20. How pressure difference is determined?
A. By connecting a differential manometer

21. Between which sections the pressure difference can be determined?

A. Inlet section and Throat

22. What we should do for getting greater accuracy in the measurement of the pressure difference?
A. The cross sectional area of the throat should be reduced so that the pressure at throat is very much reduced.
23. What is cavitation?
A. The formation of the vapour and air pockets in the liquid ultimately results in a phenomenon called Cavitation.
24. What is value of diameter of throat?
A. The diameter of throat may very from 1/3 to ¾ of the pipe diameter and more

commonly the diameter of the throat is kept equal to ½ of the pipe diameter.

25. What should be done to avoid cavitation?
A. The diameter of throat should be reduced only up to a certain limited value

26. Write the formula for actual discharge.

A. $Q_{act} = \frac{AR}{t}$

27. Write the formula for theoretical discharge.

A. $Q_{th} = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

28. Write the co-efficient discharge

A. Coefficient of discharge (C_d) = $\frac{Q_{act}}{Q_{th}}$

29. Venturi meter based on which principles?
A. Bemoulli's equation.

30. What is the value of C_d for Venturi meter?
A. It is less than 1 and it may be between 0.95 and 0.99.

NEWLLY ADDED 2020-2021

1. What is the working principle of a venturimeter?
2. What are the sections of a venturimeter?
3. What are the losses on account of flow through a venturimeter?
4. What is the co-efficient of discharge in a venturimeter?
5. What are the precautions to be taken while performing the experiment?
6. The air of velocity 15 m/s and of density 1.3 kg/m^3 is entering the Venturi tube (placed in the horizontal position) from the left. The radius of the wide part of the tube is 1.0 cm; the radius of the thin part of the tube is 0.5 cm. The tube of shape U connecting wide and thin part of the main tube (see the picture) is filled with the mercury of the density 13 600 kg/m^3. Determine the height difference that stabilizes between the surfaces of the mercury in U-tube.

2. CALIBRATION OF ORIFICE METER

AIM: To determine the Coefficient of Discharge of Orifice meter.

APPARATUS REQUIRED:

1. Orifice Meter
2. Measuring Tank
3. Sump Tank
4. Differential Manometer
5. Piping System
6. Supply Pump set and
7. Stop Watch.

SPECIFICATIONS:

1. Sump tank size : 0.3 m x 0.45 m x 0.95 m S.S. Tank
2. Measuring tank size : 0.3 m x 0.3 m x 0.5 m S.S. Tank
3. Differential Manometer : 1.0 m range with 1mm scale graduations
4. Supply pump set : Pump is 25 x 25 mm^2 size, Centrifugal monoset pump with single phase, 2 pole, 220V, 50Hz, ½ HP, 2780 RPM, AC supply
5. Pipe size : 25 mm
6. Orifice meter inlet diameter(d_1) : 25 mm
7. Orifice meter diameter(d_2) : 13 mm
8. Area ratio (a_2/a_1) m : 0.45

DESCRIPTION OF APPARATUS: It is a closed circuit water re-circulation system consisting of Sump tank, Measuring tank, Centrifugal Monoset pump, one pipeline fitted with Orifice meter.

1. ORIFICE METER: It is a cheaper arrangement for discharge measurement through pipes and its installations requires a smaller length as compared with venturi meter .It consistsof a flat circular plate with a circular hole called orifice which is concentric with the pipe axis. The thickness of the plate t is less than or equal to 0.05 times the diameter of the pipe From the upstream face of the plate the edge of the orifice is made flat for a thickness $t_1$less than or equal to 0.02 times the diameter of the pipe and for the remaining thickness of the plate it is bevelled with the bevel angel lying between $30^0$to 45^0. If the plate thickness t is equal to t_1, then no bevelling is done for the edge of the orifice. The diameter of the orifice may vary from 0.2 to 0.85 times the pipe diameter, but generally the orifice diameter is kept as 0.5 times the pipe diameter. Two pressure taps are provided, one on upstream side of the orifice plate, and the other on the downstream side of the orifice plate. The upstream pressure tap is located at a distance of 0.9 to 1.1 times the pipe diameter from the orifice plate .The position of the downstream pressure tap, depends on the ratio of the orifice diameter and pipe diameter.

2. PIPING SYSTEM:Consist of a pipe of size 25mm with separate control valve and mounted on a suitable strong iron stand. Separate upstream and downstream pressure feed pipes are provided. There are pressure taping valves which are ball valves and there are four manometer ball valves.

3. MEASURING TANK:It is a stainless steel (S.S) Tank with gauge glass, a scale arrangement for quick and easy measurements. A ball valve which is outlet valve of measuring tank is provided to empty the tank.

4. SUMP TANK:It is also S.S. tank to store sufficient fluid for experimentation and Arranged within the floor space of main unit. The sump should be filled with fresh Water leaving 25 mm space at the top.

5. DIFFERENTIAL MANOMETER: It is used to measure the differential head produced by Orifice meter.

6. **PUMP SET**:It is used to pump water from sump tank to measuring tank through pipe.

THEORY:

An orifice meter is another simple device used for measuring the discharge through pipes. Orifice meter also works on the same principle as that of venturi meter i.e, by reducing the cross sectional area of the flow passage a pressure difference between the two sections is developed and the measurement of the pressure difference enables the determination of the discharge through the pipe. On the downstream side the pressure tap is provided quite close to the orifice plate at the section where the converging jet of the fluid has almost the smallest cross sectional area(which is known as ***vena contracta***) resulting in almost the maximum velocity of the flow and consequently minimum pressure at this section. Therefore the maximum possible pressure difference exists between the sections 1 and 2, which is measured by connecting a differential manometer. The jet of the fluid coming out of the orifice meter gradually expands from the *vena contracta* to again fill the pipe. Since in the case an orifice meter an abrupt change in the cross sectional area of the flow passage is provided and there being no gradual change in the cross sectional area of the flow passage as in the case of a venturi meter, there is a greater loss of energy in an orifice meter than in a venturi meter .

PROCEDURE:

1. Before starting the experiment, do priming of pump to remove air bubbles by pouring water in the priming device.
2. Then open the inlet valve of the piping system of pump and orifice meter outlet valve and close venturimeter pipe outlet valve.
3. Start the motor and open the pressure feed pipe valves to remove the air bubbles if any.
4. Close all the valves, except upstream and downstream ball valves of pipes connected with orifice meter
5. Note the readings in differential manometer
6. Close the outlet valve of measuring tank and note the 100 mm raise of water using stop watch.
7. Repeat the process 3 to 4 times and note the values for different flow rates of water.
8. After conducting experiment close all the pressure feed pipe valves and switch off the power supply.

FORMULAE:

***Actualdischarge*:**

Actual discharge (Q_{act}) = $\frac{AR}{t}$ m^3/s

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise 'R' in 't' seconds

The actual discharge is measured with the help of measuring tank and by noting the time for definite rise of water level in the tank

Theoreticaldischarge:

Theoretical discharge (Q_{th}) = $\dfrac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

$$h = \left[(h_1 - h_2)\frac{(S_1 - S_2)}{S_2} \right] \; / \; 100 \quad \text{m of water}$$

$h_1 - h_2$ = Difference in manometric liquid in cm
S_1 = Specific gravity of manometric liquid
S_2 = Specific gravity of flowing liquid
g = Acceleration due to gravity (9.81 m/s^2)
a_1 = Area of inlet diameter of orifice meter in m^2
a_2 = Area of orifice meter in m^2

Coefficientof discharge:

Coefficient of discharge(C_d) = $\dfrac{Q_{act}}{Q_{th}} = \dfrac{Actual Discharge}{Theoritical Discharge}$

<u>TABLE OF READINGS</u>:

S.NO	Manometer reading cm of hg			Manometer head h (m)	Time for (10 cm) rise of water level t in Sec.
	h_1	h_2	h_m		

SAMPLE CALCULATIONS:

Area of inlet diameter of orificemeter (a_1) = $\dfrac{(\pi d_1^2)}{4}$ in m^2 =

Where

d_1 = orifice inlet diameter = 25 mm = 25×10^{-3} m

Area of orifice meter (a_2) = $\frac{(\pi d_2^2)}{4}$ in m^2 =

d_2 = orifice diameter = 13.0 mm = 13×10^{-3} m

Manometer head h in m =

Theoretical discharge of Orifice meter (Q_{th}) in $\frac{m^3}{s}$ =

Time for 100 mm rise t in sec =

Actual discharge of Orifice meter (Q_{act}) in $\frac{m^3}{s}$ =

Coefficient of discharge of Orifice meter (C_d) = $\frac{Q_{act}}{Q_{th}}$ =

TABLE OF CALCULATIONS:

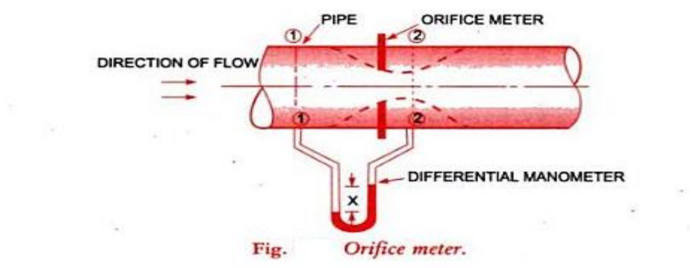
S.NO	**Actual Discharge** **Q_{act}** **m^3/sec**	**Theoretical Discharge** **Q_{th}** **m^3/sec**	**Coefficient of Discharge** **$C_d = Q_{act} / Q_{th}$**

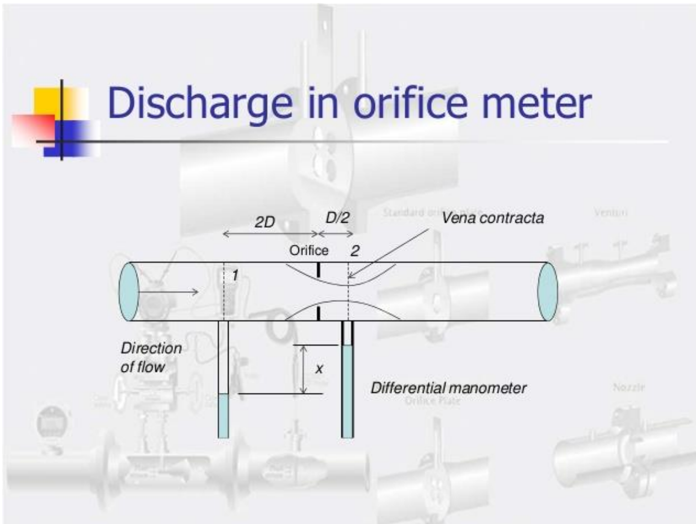
Precautions:

1. All the joints should be leak proof and water tight
2. Manometer should be filled to about half the height with mercury
3. All valves on the pressure feed pipes and manometer should be closed to prevent damage and over loading of the manometer before starting the motor.
4. Ensure that gauge glass and meter scale assembly of the measuring tank is fixed vertically and water tight
5. Ensure that the pump is primed before starting the motor
6. Remove the air bubbles in differential manometer by opening air release valve
7. Take the differential manometer readings without parallax error
8. Ensure that the electric switch does not come in contact with water
9. The water filled in the sump tank should be 2 inches below the upper end.

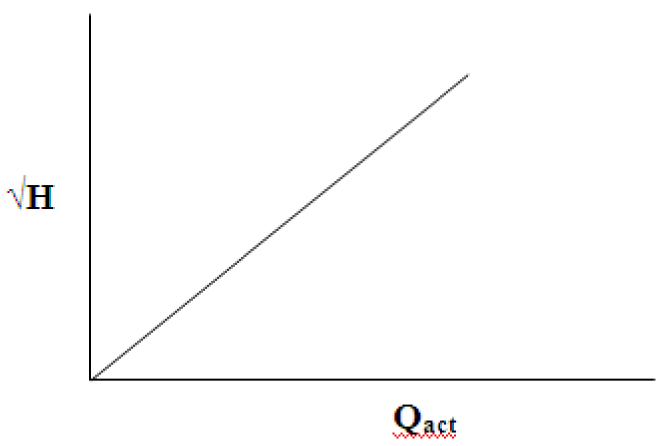
Graph: A graph between Q_{act} vs $\sqrt{H}$

FIGURE:





Model Graph:



Results:

VIVA QUESTIONS:

1. For which one, the coefficient of discharge is smaller, venturimeter or Orificemeter?

A. Orifice meter

2. What is the reason for smaller value of C_d ?

A. There are no gradual converging and diverging flow passages as in the case of venturimeter which results in a greater loss of energy and consequent reduction of the coefficient of discharge for an orifice meter

3. What is Orifice meter?

A. An orifice meter is another simple device used for measuring the discharge through pipes.

4. What is the principle of Orifice meter?

A. Orifice meter also works on the same principle as that of venturi meter i.e, by reducing the cross sectional area of the flow passage a pressure difference between the two sections is developed and the measurement of the pressure difference enables the determination of the discharge through the pipe.

5. For discharge measurement through pipes which is having cheaper arrangement and whose installation requires a smaller length?

A. Orifice meter

6. What are the parts of Orifice meter?

A. Flat circular plate with a circular hole

7. What is the thickness of the plate t?

A. $t \leq 0.05d$

d= diameter of the pipe

8. What is the range of bevel angle in orifice meter?

A. 30^0 to 45^0 (preferably 45^0)

9. What is the diameter of the orifice?

A. It may vary from 0.2 to 0.85 times the pipe diameter, but generally the orifice diameter is kept as 0.5 times pipe diameter

10. Where two pressure taps are provided?

A. One on upstream side of the orifice plate and the other on downstream side of the orifice plate.

11. Where upstream pressure tap is located?

A. It is located at a distance of 0.9 to 1.1 times the pipe diameter from the orifice plate.

12. Which diameter is less, orifice or pipe?

A. Orifice meter

13. What is vena contracta?

A. Smallest cross sectional area

14. At which section on the downstream side the pressure tap is provided quite close to orifice plate?

A. At the section where the converging jet of fluid has almost the smallest cross sectional area (which is known as vena contracta)

15. Where the velocity of flow is maximum and pressure is minimum?

A. At vena contracta

16. Maximum possible pressure difference that exists between upstream side of the orifice plate and downstream side of the orifice plate is measured by means of what?

A. Differential manometer

17. Where there is a greater loss of energy, whether in venturi meter or in orifice meter?

A. In orifice meter

18. Why there is a greater loss of energy in orifice meter?

A. Because there is an abrupt change in the cross-sectional area of flow passage

19. What is value of c_d?

A. It is the range of 0.6 to 0.68

20. What is the manometer liquid?

A. Mercury

21. When an orifice is called large orifice?

A. When head of liquid from the center of the orifice is less than 5 times the depth of orifice

22. On what the position of downstream pressure tap depends?

A. It depends on the ratio of the orifice diameter and the pipe diameter.

NEWLLY ADDED 2020-2021

Questions:

1. What is the working principle of an orificemeter?

2. What are the sections of an orificemeter?
3. What are the losses on account of flow through an orificemeter?
4. What is the co-efficient of discharge in an orificemeter?
5. What are the precautions to be taken while performing the experiment?
6. What are the different types of orifices?

3. DETERMINATION OF FRICTION FACTOR FOR A GIVEN PIPE LINES

AIM: To measure the frictional losses in pipes of different sizes.

APPARATUS REQUIRED:

1. Piping system

2.Sump Tank
3.Measuring Tank
4.Differential Manometer
5.Pump Set.
6. Stop Watch

SPECIFICATIONS:

1.	Sump tank size	: 0.95 m x 0.45 m x 0.3 m S.S. tank
2.	Measuring Tank Size	: 0.3 m x 0.3m x 0.5 m S.S. Tank
3.	Differential Manometer	: 1 m range with 1mm scale of graduation
4.	No. of pipes	: 1S.S, 2 Galvanized Iron(GI) pipes
5.	Piping system sizes	: 20 mm, 20mm, 12.7mm
6.	Pressure taping distance	: 0.1 m
7.	Pump set	: Pump is 25x25mm^2 size, centrifugal, moonset pump with single phase, 2pole, 220V, 1/2HP, 50 Hz, 2880 rpm, AC supply.

DESCRIPTION OF APPARATUS:

1**. PIPING SYSTEM**: Consists of a set of 2G.I pipes and 1 S.S pipes of size 20mm, 12.7mm and 20mm and length 1 m between pressure tapings with separate flow control valves. Separate upstream and downstream pressure feed pipes are provided for the measurement of pressure heads with control situated at common place for easy operation.

2**.SUMP TANK**: It is S.S. tank to store sufficient fluid for experimentation and arranged within the floor space of main unit. The sump should be filled with fresh water having 25 mm space at the top.

3**.MEASURING TANK**: It is also a S.S tank with gauge glass, a scale arrangement for quick and easy measurements. A ball valve which is outlet valve of measuring tank is provided to empty the tank.

4**.DIFFERENTIAL MANOMETER**: It is used to measure the differential head produced by piping system.

5**.PUMP SET**: It is used to pump water from sump tank to measuring tank through pipe.

THEORY:

A pipe is a closed conduit which is used for carrying fluids under pressure. Pipes are commonly circular section. As the pipes carry fluids under pressure, the pipes always run full.

The fluid flowing in a pipe is always subjected to resistance due to shear forces between fluid particles and the boundary walls of the pipe and between the fluid particles themselves resulting from the viscosity of the fluid. The resistance to the flow of fluid is, in general known as frictional resistance. Since certain amount of energy possessed by the flowing fluid will be consumed in overcoming this resistance to the flow, there will always be some loss of energy in the direction of flow, which however depends on the type of flow, W.froude conducted a series of experiments to investigate frictional resistance offered to the flowing water by different surfaces $h_f = \frac{fLV^2}{2gD}$ is Darcy Weisbach equation Which is commonly used for computing the loss of head due to friction of pipes. Here is f friction factor. In order to determine the loss of head due to friction correctly, it is essential to estimate the value of the factor f correctly when a fluid flows through a pipe, certain resistance is offered to the flowing fluid, which results in causing a loss of energy. The various energy losses in pipes may be classified as

i) major losses

ii) minor losses

The major loss of energy, as a fluid of flows through a pipe, is caused by friction. It may be computed by Darcy-Weisbach equation. The loss of energy due to friction is classified as a major loss because in the case of long pipelines it is usually much more than the loss of energy Incurred by other causes.

PROCEDURE:

1. Before starting the experiment, do priming of the pump to remove air bubbles by pouring water into the priming device.
2. Open the inlet valve in the piping systems of the pump and outlet valve of one of the 3 pipes and remaining 2 valves will be in closed condition
3. Start the motor and open the upstream pressure feed pipe valves and downstream pressure feed pipe valves of the concerned pipe
4. Remove the air bubbles by opening the pressure feed pipe valves if any.
5. Note down the manometer reading
6. Close the outlet valve of measuring tank and measure the time taken for 10 cm raise in water level by measuring tank.
7. Repeat the procedure 2 to 3 times for various flow rates of water
8. Same procedure is adopted for 2 other pipes by opening the concerned valves and remaining valves in closed condition.
9. Note the values and do the calculation to find out the frictional loss.

FORMULAE:

The actual loss of head is determined from the manometer readings. The frictional loss of head pipes is given by the following formula

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

f = Coefficient of friction for the pipe (frictional factor)
L= Distance between two sections from which loss of head is measured (3 m)

V = Average velocity of flow = $\frac{Q}{a}$

Q = Discharge in $\frac{m^3}{s}$

a=Area of the pipe

a= $\frac{\pi d^2}{4}$

g = acceleration due to gravity
D = Pipe diameter in meters

$$h_f = \left(\frac{S_m - S_f}{S_f}\right) * \left(\frac{h_m}{100}\right)$$

S_m = specific gravity of manometric liquid

S_f = specific gravity of flowing liquid

$h_m = h_1 - h_2$ cm of Hg

TABLE OF READINGS:

Type of Pipe	**Diameter of the Pipe 'd'**		**Area of Pipe A m^2**	**Manometer reading**			**Time for (10 cm) rise of water level t in Sec.**
				h_1	**h_2**	**h_m**	
	Mm	**m**		**cm of Hg**			**Sec**

SAMPLE CALCULATIONS:

Actual discharge in m^3/s =

Area of the pipe = $\frac{\pi d^2}{4}$ = m^2

Average velocity of water in the pipe v = $\frac{Qact}{a}$ = m/sec

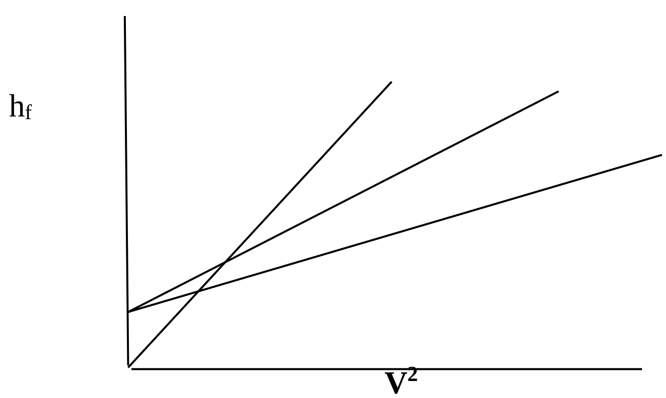
Frictional loss of head in pipe h_f =
Frictional factor f =

TABLE OF CALCULATIONS:

Loss Of Head $\frac{(12.6 \times h_m)}{100}$ 'h_f'	Actual Discharge Q_{act} = A R/t	TheoreticalVelocity $V = \frac{Qact}{a}$	V^2	Friction Factor f
M	m^3/sec	m^3/sec		

GRAPH: A graph between V^2 on X-axis and h_f on Y-axis is drawn

MODEL GRAPH:



PRECAUTIONS:

1. Ensure that the pump is primed before starting the motor
2. While doing the experiment on a particular pipe keep the other pipe line closed
3. Take the differential manometer readings without parallax error
4. Ensure that the electric switch does not come in contact with water

5. Remove air bubbles in differential manometer by opening air release valve
6. Ensure that opening and closing of manometer valves should be done carefully to avoid leakage of mercury
7. Check that gauge glass and meter scale assembly of the measuring tank is fixed vertically and water tight
8. Manometer should be filled to about half the height with mercury
9. Ensure that all valves on the pressure feed pipes and manometer should be closed to prevent damage and over loading of the manometer
10. All the joints should be leak proof and water tight.
11. The water filled in the sump tank should be 2” below the upper end

RESULTS:

VIVA QUESTIONS:

1. What is pipe?

A. A pipe is a closed circuit which is used for carrying fluids under pressure

2. The fluid flowing by a pie is always subjected to what?

A. It is subjected to resistance due to shear forces between fluid particles and the boundary walls of the pipe and between the fluid articles themselves resulting from the viscosity of the fluid

3. What is frictional resistance?

A. The resistance to the flow of fluid is frictional resistance.

4. In overcoming the frictional resistance what is consumed?

A. Certain amount of energy possessed by the flowing fluid will be consumed

5. What will be there in the direction of flow and it depends on what?

A. There will be some loss of energy in the direction of flow and depends on the type of flow.

6. What are the types of flow of fluid in a pipe?

A. Laminar, turbulent

7. On what the frictional resistance offered to the flow depends on?

A. Type of flow

8. What is Darcy-Weisbach equation?

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

9. What is the use of Darcy-Weisbach equation?

A. It is used for computing the loss of head due to friction in pipes

10. On what friction factor f depends upon?

A. f is not a constant, but its value depends on the roughness condition of the pipe surface and the Reynolds number of flow

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11. Which is essential to determine the loss of head due to friction correctly?

A. Correct estimation of the value of the factor

12. In addition to Darcy-Weisbach equation what are the other formulae for head loss due to friction in pipes?

A. Chezy's formula, Manning's formula, Hazen-Williams formula

13. What is the reason behind the major head losses?

Major head losses are due to friction.

14. Write down Darcy -weisbach's equation used for finding major head losses.

-Darcy -weisback's equation = $4FLV^2$ /d*2g Where f is coefficient of friction, L is length of pipe , V is velocity through pipe , d is diameter of the pipe and g is acceleration due to gravity.

15. What is the formula for darcy weisbech?

16. Define viscosity and its units?

17. What are the units for kinematic viscosity?

18. What is the reason for eddies?

19. Define specific weight?

20. Define vapor pressure?

21. Define absolute pressure?

22. Difference between simple manometer and differential manometer?

23. What do you mean by single column manometer?

24. What do you mean by vacuum pressure?
25. Define pressure?
26. What is a manometer?
27. What are different types of mechanical gauges?
28. What is hydrostatic pressure distribution?
29. Define density and its units?
30. Define surface tension and its units.

4. DETERMINATION OF MINOR LOSSES OF HEAD DUE TO SUDDEN CONTRACTION IN A PIPE LINE

AIM: To determine the coefficient of Minor losses of head due to sudden contraction

APPARATUS REQUIRED:

1. Piping system
2. Sump Tank
3. Measuring Tank
4. Differential Manometer
5. Pump Set.
6. Stop Watch

SPECIFICATIONS:

1.	Sump tank size	: 0.9 m x 0.45 m x 0.3 m S.S. tank
2.	Measuring Tank Size	: 0.6 m x 0.3m x 0.3 m S.S. Tank
3.	Differential Manometer	: 1 m range with 1mm scale of graduation
4.	No. of pipes	: 2 Galvanized Iron(GI)
5.	Piping system sizes	: 25 mm,12.5mm
6.	Pressure taping distance	: 0.5 m
7.	Pump set	: Pump is 25x25mm^2 size, centrifugal, moonset pump with single phase, 2pole, 220V, 1/2HP, 50 Hz, 2880 rpm, AC supply.

DESCRIPTION OF APPARATUS:

1.PIPING SYSTEM:piping system of size 25 mm diameter and 12.5 mm with a flow control valve.

2.SUMP TANK:It is S.S. tank to store sufficient fluid for experimentation and arranged within the floor space of main unit. The sump should be filled with fresh water having 25 mm space at the top.

3.MEASURING TANK:It is also a S.S tank with gauge glass, a scale arrangement for quick and easy measurements. A ball valve which is outlet valve of measuring tank is provided to empty the tank.

4.DIFFERENTIAL MANOMETER:It is used to measure the differential head produced by piping system.

5.PUMP SET:It is used to pump water from sump tank to measuring tank through pipe.

PROCEDURE:

1. Start the motor keeping the delivery valve close. Make sure that the ball valve is fully open which is at the collecting tank
2. Slowly open the cocks which are fitted at sudden contraction end and make sure that manometer is free from air bubbles
3. Make sure while taking the readings, that the manometer is properly primed. Priming is the operation of removing the air bubbles from the pipes. Note down the loss of head "h_c" from the manometer scale.
4. Note down the time required for the rise of 10 cm (i.e 0.1 m) water in the collecting tank by using stopwatch.
5. Repeat the steps 2 to 5 for different sets of readings by regulating the discharge valve

CALCULATION:

Discharge: The time taken to collect some 'X' cm of water in the collecting tank in m^3/sec

$$Q = \frac{AR}{t}$$

Where

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise 'R' in't' seconds

Calculate the velocity of the jet by following formula

V = Discharge / Area of pipe = Q / A m/sec

Where

A = Cross sectional area of the pipe = $\Pi / 4 * d^2$

d = diameter of the pipe

Calculate the coefficient of contraction for the given pipe by

$$h_c = v^2 / 2g * K$$

Where

h_c = loss of head due to sudden contraction = $(h_1 - h_2) * 12.6/100$ m

K = co-efficient for loss of head in contraction

$= [1/C_c - 1]^2$

V = Average Velocity of flow in m/sec.

TABLE OF READINGS:

Type of Pipe	**Diameter of the Pipe 'd'**		**Area of Pipe A m^2**	**Manometer reading**			**Time for (10 cm) rise of water level t in Sec.**
				h_1	**h_2**	**h_m**	
	mm	**m**		**cm of Hg**			**Sec**

TABLE OF CALCULATIONS:

Actual Discharge $Q_{act} = A R/t$	**Theoretical Velocity $V = \frac{Q}{a}$**	**h_c**	**Coefficient of contraction C_c**
m^3/sec	**m/sec**	m	

PRECAUTIONS:

1. Ensure that the pump is primed before starting the motor
2. While doing the experiment on a particular pipe keep the other pipe line closed
3. Take the differential manometer readings without parallax error
4. Ensure that the electric switch does not come in contact with water
5. Remove air bubbles in differential manometer by opening air release valve
6. Ensure that opening and closing of manometer valves should be done carefully to avoid leakage of mercury
7. Check that gauge glass and meter scale assembly of the measuring tank is fixed vertically and water tight
8. Manometer should be filled to about half the height with mercury
9. Ensure that all valves on the pressure feed pipes and manometer should be closed to prevent damage and over loading of the manometer
10. All the joints should be leak proof and water tight.
11. The water filled in the sump tank should be 2” below the upper end

RESULTS:

VIVA QUESTIONS:

1. Write the classification of various energy losses.

A. Major losses, minor losses

2. What causes major loss of energy?

A. Friction

3. Major loss of energy computed by which equation?

A. Darcy-Weisbach equation

4. What is the reason for the classification of loss of energy due to friction as major loss?

A. In the case of long pipelines it is usually much more than the loss of energy incurred by other causes.

5. Due to what the minor losses of energy are caused?

A. Due to change in the velocity of flowing fluid (either by magnitude or direction)

6. Why these are called minor losses?

A. In case of long pipes these losses are usually quite small as compared with the loss of energy due to friction and hence these are termed. Minor losses which may be neglected without serious error.

7. In where minor losses outweigh the friction loss?

A. In Short pipes

8. Write some minor losses which may be caused due to the change of velocity.

   i. Loss of energy due to sudden enlargement
   ii. Loss of energy due to sudden contraction
   iii. Loss of energy at entrance to a pipe
   iv. Loss of energy at the exit from a pipe
   v. Loss of energy due to gradual contraction or enlargement
   vi. Loss of energy in bends
   vii. Loss of energy in various pipe fit

9. what is differential manometer?

10. what is piping system?

11.what is the use of sump tank?

12.what is the use of pump set ?

13.write the coefficient of contraction of the pipe?

14.define discharge?

15.write the coefficient of contraction?

16.what is the use of ball valve?

17.Define priming?

18.Define pressure taping distance ?

19.What are minor losses ?

20.what are losses of energies in bends?

21. Define absolute pressure?

22. Difference between simple manometer and differential manometer?

23. What do you mean by single column manometer?

24. What do you mean by vacuum pressure?

25. Define pressure?

26. What is a manometer?

27. What are different types of mechanical gauges?

28. What is hydrostatic pressure distribution?

29. Define density and its units?

30. Define surface tension and its units

5. VERIFICATION OF BERNOULLIS EQUATION

AIM: To prove that the total head at any point along the flow is same i.e, datum head + pressure head + velocity head is constant along the flow

Or

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

APPARATUS REQUIRED:

1. Bernoullis apparatus which consists of supply and receiving chambers with scales and glass tubes
2. Piezometer glass tubes
3. Sump tank
4. Measuring tank (collecting tank)
5. Supply pump set
6. Stop Watch

SPECIFICATIONS:

1. Sump tank size : 1.25 m x 0.3m x 0.3m S.S. tank
2. Measuring Tank size : 0.3 m x 0.5 m
3. Pump size : 25mm x 25 mm
4. Supply pump set : Pump is centrifugal manometer pump with single phase, 2 pole, 220V, 50 Hz, ½ Hp, 2880 RPM, AC supply

DESCRIPTION OF APPARATUS:

There are supply and receiving chambers and interlinking experimental sides made out of perspex sheets for the purpose of observing the flow. The interlinking duct is smoothly varying in cross section so that the velocity of flow changes gradually for the purpose of experiments with minimum friction loss and loss due to turbulence. Piezometer glass tubes are provided at suitable intervals along the duct for the measurement of pressure head at various points. A flow control valve is provided at the exit of the receiving chamber for adjusting and keeping different flow rates through the apparatus. A collecting tank (receiving chamber) is provided for the measurement of rate of flow. The apparatus is kept in the spirit level position horizontally by means of adjusting the screw arrangement provided at the bottom of the sump.

MEASURING TANK: It is a stainless steel (S.S) Tank with gauge glass, a scale arrangement for quick and easy measurements. A ball valve which is outlet valve of measuring tank is provided to empty the tank.

SUMP TANK: It is also S.S. tank to store sufficient fluid for experimentation and arranged within the floor space of main unit. The sump should be filled with fresh water leaving 25 mm space at the top.

PUMP SET: It is used to pump water from sump tank to measuring tank through pipe.

THEORY:

The Bernoullis equation is

$$\frac{p}{w} + \frac{v^2}{2g} + z = c$$

Which is applicable for steady, irrotational flow of incompressible fluids

P= pressure

W= ρ g=specificweight

V= velocity at any point

g=gravitational acceleration

ρ = mass density

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

$\frac{v^2}{2g}$ = velocity head or kinetic head

Z = potential head or datum head

C= arbitrary constant

The sum of pressure head, velocity head and the potential head is known as the total head or the total energy per unit weight of the fluid. Bernoullis equation states that in a steady irrotational flow of an incompressible fluid the total energy at any point is constant.

If Bernoulli's equation is applied between any two points in a steady irrotational flow of an incompressible fluid, then we get

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

Where the different terms with subscripts and 2 correspond to the two points considered. The sum of the pressure head and the potential head ($\frac{p}{w}$ + z) is termed as piezometric head. Each term represent the energy permit weight of the flowing fluid. The energy per unit weight of the fluid is expressed as N.m/N that is, it has a dimension of length and therefore it is known as head.

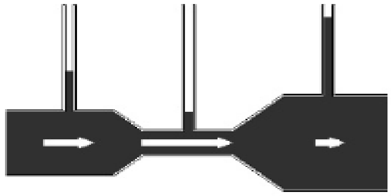

Figure : Pressure head increases with decrease in velocity head.

PROCEDURE:

1. Before starting the experiment, do priming of the pump to remove the air bubbles.
2. Open the inlet valve of the piping system of the pump.
3. Open the outlet valve of the piezometer tube.
4. Start the motor and keep the water level constant in the supply tank by operating various valves.
5. Then note down the pressure head from the piezometer scale directly
6. Close the outlet valve of the mercury tank and note down the time for 100 mm raise of water level note down the valves for pressure head, velocity head for different areas of piezometer and calculate the total head.

FORMULAE:

Actual discharge: Actual discharge (m^3/s) = $Q_{act} = \frac{AR}{t}$ m^3/S

A= Area of measuring tank = 0.3 x 0.3m^2

R = Difference in levels of water in measuring tank in m

T = time in seconds

Velocity = Q/a

a= cross sectional area of duct at various intervals

Total Head:

$$\frac{p}{w} + \frac{V^2}{2g} + z = c$$

$\frac{p}{w}$ = Piezometer reading pressure head

$\frac{V^2}{2g}$ = velocity head

Z = datum head

OBSERVATIONS TABLE:

Cross sectional area (a)	Time for R= 10 cm rise	Actual discharge = Q_{act} = $\frac{AR}{t}$	Velocity V= $\frac{Q}{a}$	Velocity head $\frac{V^2}{2g}$	Piozometer reading pressure head $\frac{p}{w}$	Datum Head z	Total head $\frac{V^2}{2g}+\frac{p}{w}$ + +z = c	
m^2	Sec	m^3/s	m/s	m	M	m	m	

SAMPLE CALCULATIONS:

Time for 100 mm raise (t) in sec =

Actual discharge (Q) in m^3/s = $\frac{AR}{t}$

a= cross sectional area =

Velocity (v) = $\frac{Q}{a}$

Velocity head = $\frac{V^2}{2g}$ =

Piezometer reading pressure head $\frac{p}{w}$ =

Datum head (z) =

Total head = $\frac{p}{w} + \frac{V^2}{2g}$ + z = c

PRECAUTIONS:

1. Be careful to avoid leakage of the piezometer tubes
2. The water filled in the sump tank should be 2 inches below the upper end
3. Ensure that the electric switch does not come in contact with water
4. Ensure that the water level is constant in the supply tank during the experiment
5. Check that the gauge glass and meter scale assembly of the measuring tank is fixed vertically and water tight.
6. Ensure that the pump is primed before starting the motor.
7. All joints should be leak proof and water tight

RESULT:

VIVA QUESTIONS:

1. What is Bernoulli's equation?

A. $\frac{p}{w} + \frac{v^2}{2g}$ +z = Constant

2. What is $\frac{p}{w}$?

A. Pressure energy per unit weight of fluid or pressure head or static head.

3. What is $\frac{v^2}{2g}$?

A. Kinetic energy per unit weight or kinetic head or velocity head

4. What is z?

A. Potential energy per unit weight or potential head or datum head

5. What are the assumptions of Bernoulli's equation?

A. 1) The fluid is ideal (i.e, viscosity is zero)

2) The flow is steady

3) The flow is incompressible

4) The flow is irrotational

6. What Bernoulli's equation states?

A. It states that in a steady, ideal, irrotational flow of an incompressible fluid, the total energy at any point of the fluid in constant

7. For which type of fluids Bernoulli's equation is applicable?

A. For steady, irrotational flow of incompressible fluids

8. What is total head?

A. Sum of pressure head, velocity head, and potential head is known as total head

9. If Bernoulli's equation is applicable between two points what is the equation of Bernoulli?

A. $\frac{p_1}{w} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{v_2^2}{2g} + z_2$

10. What is Piezometric head?

A. Sum of pressure head and potential head

11. In Bernoulli's equation each term represents what?

A. The energy per unit weight of the flowing fluid.

12. Why each term is called head?

A. The energy per unit weight of the fluid is expressed as N.m/N that is it has a dimension of length and therefore it is known as head

13. What is viscosity?

A. It is the property of fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of fluid.

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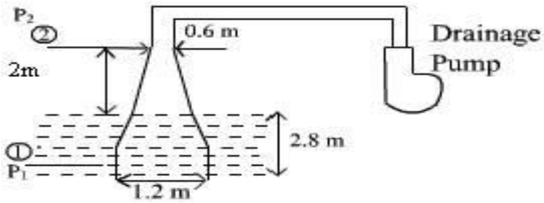
1. What is meant by the term pressure head?
2. State the law of conservation of energy.
3. Write down Bernoulli's equation and explain the meaning of each term involved in it.
4. Write down the Bernoulli's equation for real fluids.
5. State Bernoulli's theorem and write down its assumption.
6. Write down three heads used in Bernoulli's theorem.
7. A pipe having diameters 20cm and 10cm at two sections A and B, carries water that flows at a rate 40Lts/s. Section A is 5m above datum and section 'B' is 2m above datum. If the pressure at section A is 4 bar, find the pressure at section 2.
8. A drainage pump has inlet as a vertical pipe with a tapered section, which is filled with water as shown in the following figure. Diameters at ends of the tapered inlet are 1.2m and .06m respectively. The pipe is running full of water. The free water surface is 2.8 m above the

center at the inlet and center at upper end is 2m above the top at the free surface. The pressure at the upper end of the pipe is 28cm of Hg and the head loss between two sections is 1/10 of the velocity head at top section. Find the discharge of water in the pipe.



9. what is the use of sump tank?

10.what is the use of pump set ?

11.write the coefficient of contraction of the pipe?

12.define discharge?

13.write the coefficient of contraction?

14.what is the use of ball valve?

15..Define priming?

16.Define pressure taping distance

6. IMPACT OF JETS ON VANES

AIM: To find the coefficient of impact of jet on a flat vane.

THEORY: A jet of water issuing from a nozzle has some velocity and hence it possesses a certain amount of kinetic energy. If this jet strikes an obstruction (plate) plated in its path, it will exert a force on the obstruction. This impressed force is known as impact of the jet and it is designated as hydrodynamic force. This force is due to the change in the momentum of the jet as a consequence of the impact. This force is equal to the rate of change of momentum i.e.; the force is equal to (mass striking the plate per second) x (change in velocity)

The amount of force exerted depends on the diameter of jet, shape of vane, fluid density, and flow rate of water. More importantly, it also depends on whether the vane is moving or stationary. In our case, we are concerned about the force exerted on the stationary vanes.

DESCRIPTION: It is a closed circuit water re- circulation system consisting of sump tank, mono block centrifugal pump set, jet/vane chamber, digital force indicator. The water is drawn from the sump tank by mono block centrifugal pump and delivers it vertically to the nozzle. The flow control valve is also provided for controlling the water into the nozzle. The water is issued out of nozzle as jet. The jet is made to strike the vane, the force of which is transferred directly to the force indicator. The force is read in Kgf or N. The provision is made to change the size of nozzle / jet and the vane of different shapes.

PROCEDURE*:*

1) Fix the required diameter jet, and the vane of required shape in position.
2) Set the force indicator to zero.
3) Keep the delivery valve closed and switch on the pump.
4) Close the front transparent cover tightly.
5) Open the delivery valve and adjust the flow rate of water as read on the rotameter.
6) Observe the force as indicated on force indicator.
7) Note down the diameter of jet, shape of vane, flow rate and force and tabulate the readings for five different flow rates.
8) Repeat the experiment for the other vanes.
9) Switch off the pump after the experiment is over and close the delivery valve.

CALCULATTION:

Discharge: - The time taken to collect some ‘x’ cm of water in the collecting tank in m^3/sec.

$$Q = A \times R / t$$

Where:

A = area of the collecting tank in m^2 (0.3m X 0.3m)

R = rise of water level taken in meters (say 0.1m or 10cm)

t = time taken for rise of water level to rise ‘r’ in‘t‘seconds.

Calculate the velocity of the jet by following formula

$$V = \frac{\text{Discharge}}{\text{Co.eff. Of contraction X Area of the jet}} = Q/C_c \times A \text{ m/sec}$$

a = cross sectional area of the jet = $\pi d^2/4$, Cc =coefficient of contraction=0.67

d =diameter of the nozzle =8mm= 0.008m

Calculate the theoretical force by the momentum equation

$$F_{th} = \rho a V^2$$

ρ = Density of water =1000 kg/m^3

Ø = angle made by the velocity of the jet with outlet tangent of the vane which is zero in our case.

For flat vane $F_{th} = \rho a V^2$.

For hemispherical vane $F_{th} = 2\rho a V^2$.

F_{act}= (observed reading in gm+ 250 gm) x 9.81 **N**ewton

Flat Plate,

Theoretical force, F_t

$F_t = \rho AV^2$ N

Where,

ρ = Density of Water = 1000 Kg/m^3

A = Area of Jet = $\frac{\pi d^2}{4}$ = m^2

D = diameter of jet = m

V = Velocity = m/sec

Actual force, F_a

F_a = Actual force developed as indicated by the digital Indicator

Co-efficient of Impact = $\frac{F_a}{F_t}$ = **N**

TABLE OF READINGS

Diameter of jet		**Vane type**	**Discharge ‘Q’**	**Force Indicator Reading F_a**	**Time for rise in water level**
Mm	**m**		**m^3/sec**	**Kg X9.81 N**	**Sec**

TABLE OF CALCULATIONS

Velocity V	**Actual Force F_a**	**Theoretical Force F_t**	**Percent of error $\frac{F_t - F_a}{F_t}$ x 100**	**Coefficient of Impact**
m/sec	**N**	**N**		

GRAPH: Draw the graph F_a vs V^2. From this compute the value of the co-efficient of impact

RESULT:

VIVA QUESTIONS:

1. Define Impact of jet?
2. Write the formula for force exerted by a jet of water on a stationary & moving plate.
3. Write the formula for force exerted by a jet of water on a curved plate at center & at one of the tips of the jet.
4. The three plates which one has the maximum force of impact?
5. Even though the hemispherical vanes have the maximum force of impact, why they are not used in Pelton wheel?
6. What is the effect of density of fluid on force of impact?
7. What is the relationship between Newton force and kg. force?
8. What is the conversion factor for l.p.m. to m3/s?
9. What is mass momentum principle
10. What is impulse momentum principle
11. What is fore excreted by jet on unsymmetrical rough surface fixed curve vane
12. A jet of oil of specific gravity strikes a fixed curved symmetrical plate at its center and leaves at the outlet tips. The diameter of the jet is 62 mm and the velocity of the jet is 45 m/sec. If the jet is deflected by 100 degrees, calculate the force exerted on the curved plate.b) How do you estimate the impact of a jet striking a moving normal plate in the direction of the jet.
13. A jet of water strikes with a velocity of 50 m/sec a flat fixed plate inclined at 30 degrees with the axis of the jet. The cross sectional area of the plate is 100 cm2 . Find the force exerted by the jet on the plate and the ratio in which the jet gets divided after striking. b) Derive the equation for the impact of jet striking a curved plate at the centre when the plate is stationary
14. Write the formulae for curved radial vane ,work done per second?
15. Write the formulae for work done per second per kg of fluid?

16. Write the angle of swing about the hinge?
17. For a series of vanes ,write the force and work done ?
18. Write the efficiency of a series of vanes ?
19. Write the efficiency for a curved radial vane ?
20. What is jet propulsion?
21. What is the formula for darcy weisbech?
22. Define viscosity and its units?
23. What are the units for kinematic viscosity?
24. What is the reason for eddies?
25. Define specific weight?
26. Define vapor pressure?
27. Define absolute pressure?
28. Difference between simple manometer and differential manometer?
29. What do you mean by single column manometer?
30. What do you mean by vacuum pressure?

7. PERFORMANCE TEST ON PELTON WHEEL

AIM: To determine the performance characteristics of Pelton wheel turbine under constant head and constant speed.

APPARATUS REQUIRED:

Pelton wheel turbine test rig.

THEORY:

Hydro -power is one of major cheap source of power available on earth, and hence it is widely used for generation of electric power world wide. Water stored in the dam contains potential energy. The water flows through the turbine, so that power is generated by impact of water or reaction of water flow. The turbine drives a generator Which delivers electrical power. Thus, turbines are of great importance.

Turbines are basically of two types, viz. impulse turbines and reaction turbines. In impulse turbines, water coming from high head acquires high velocity. The high velocity water jet strikes the buckets of the turbine runner and cause it to rotate by impact. In reaction turbine, total head of water is partly converted into velocity head as it approaches turbine runner and it fills the runner and pressure of water gradually changes as it flows through runner. In impulse turbine, the only turbine used now-a-days is Pelton Wheel Turbine. In reaction turbines, Francis Turbine and Kaplan Turbine are the examples.

The Pelton wheel turbine consists of runner mounted over the main shaft. Runner consists of buckets fitted to the disc. The buckets have a shape of double ellipsoidal cups. The runner is encased in a casing provided with a Perspex window for visualization. A nozzle fitted in the side of casing directs the water jet over the 'Splitter' or center ridge of the buckets. A spear operates inside the nozzle to control the water flow. On the other side of the shaft, a rope brake is mounted for loading the turbine.

Impulse turbines change the velocity of a water jet. The jet impinges on the turbine's curved blades which reverse the flow. The resulting change in momentum (impulse) causes a force on the turbine blades. Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy.

Prior to hitting the turbine blades, the water's pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine. No pressure change occurs at the turbine blades, and the turbine doesn't require a housing for operation.Newton's second law describes the transfer of energy for impulse turbines.Impulse turbines are most often used in very high head applications.

PROCEDURE:

1. Connect the supply water pump – motor unit to 3 ph, 440V, 30A, electrical supply, with neutral and earth connections and ensure the correct direction of pump-motor unit.
2. Keep the Butterfly valve and spear valve closed.
3. Keep the Brake Drum loading at minimum.
4. Press the green button of the supply pump starter. Now the pump picks-up the full speed and becomes operational.
5. Slowly, open the spear valve so that the turbine rotor picks up the speed and attains maximum at full opening of the valve.

OBSERVATION TABLE:

Speed **'N'** in rpm	Pressure at inlet of turbine	Supply Head (H)	PressureGauge readings across venturimeter **'P'** in kg/cm^2			Load on Brake drum dynamo meter (kg)		
			P1	P2	P1-P2	W1	W2	W1-W2

FORMULAE:

1. Head on the Turbine

   'H' in meters of water = 10 P

   Where P is the pressure gauge reading in kg / cm^2.

2. INPUT POWER = $\frac{WQH}{100}$

Where, W = 9810N/m^3

Q = Flow rate of water in m^3/sec

H = Head on Turbine in m.

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

a_1 = Inlet area of Venturi meter in m^2

a_2 = Area of throat in m^2

4. OUTPUT POWER = 2π N T/6000 KW

N=RPM of the turbine

T=Torque of turbine shaft

T= (W1-W2)xRx9.81

W= load applied on turbine

R= Radiusof the brake drum with rope in meters=0.12m

5. Efficiency = $\frac{\text{OUTPUT POWER}}{\text{INPUT POWER X FRICTIONAL EFFICIENCY}} \text{X} 100$

FRICTIONAL EFFICIENCY =85% =0.85

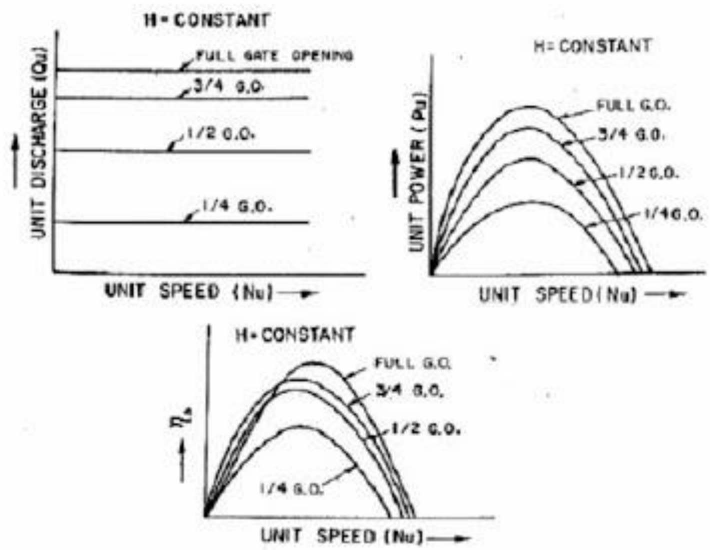
TABLE OF CALCULATIONS:

DISCHARGE m^3/s	INPUT POWER (KW)	OUTPUT POWER (KW)	SPECIFIC SPEED $N_S=N\sqrt{P}/H^{5/4}$	UNIT DISCHARGE $Q_U=Q/\sqrt{H}$	UNIT POWER $P_U=P/H^{3/2}$	UNIT SPEED $N_U=N/\sqrt{H}$	EFFICIENCY

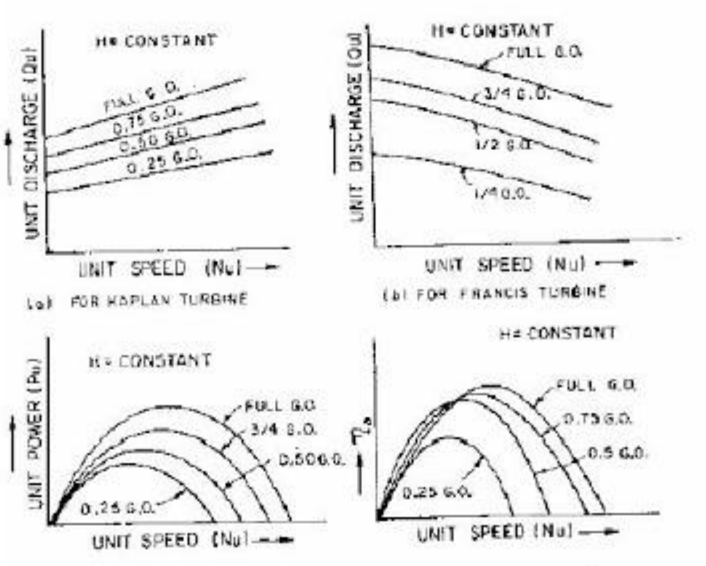
GRAPH:

1. **Speed Vs Discharge**

2. **SpeedVsPower**
3. **Speed vs efficiency**
4. **Unitspeedvsunitdischarge**
5. **Unit Speed Vs Unit Power**
6. **Unitspeedvsunitefficiency**



. Main characteristic curves for a Pelton wheel.



Main characteristic curves for reaction turbine.

PRECAUTIONS:

1. Do not start pump set if the supply voltage is less than 300 V (phase to phase voltage).
2. Do not forget to give electrical earth and neutral connections correctly. Otherwise, the RPM indicator gets burnt if connections are wrong.

3. Frequently, at least once in three months, grease all visual moving parts.
4. Initially, fill-in the tank with clean water free from foreign material. Change the water every six months.
5. At least every week, operate the unit for five minutes to prevent any clogging of the moving parts.
6. To start and stop the supply pump, always keep gate valve closed.
7. It is recommended to keep spear rod setting at close position before starting the turbine. This is to prevent racing of the propeller shaft without load.
8. In case of any major faults, please write to manufacturer, and do not attempt to repair.

RESULT :

VIVA QUESTIONS:

1. On what principle the Pelton wheel turbine works?
2. What is the shape of buckets in Pelton wheel turbine?
3. What is the clearance angle of the buckets? State why it is not 180^0?
4. Define unit quantities and specific speed.
5. Why multiple jets are used in Pelton wheel turbine?
6. What is specific speed of pelton turbine?
7. Define specific speed?

8. Difference between impulse turbine and reaction turbine?
9. What is shaft power?
10. Define overall efficiency?
11. Define volumetric efficiency?
12. Define mechanical efficiency?
13. Define jet ratio?
14. How do you estimate the number of buckets on a pelton wheel?
15. Define effective head?
16. Define gross head?
17. A Pelton wheel is working under a head of 50 m and the discharge is 0.85 m3 /sec. The mean bucket speed is 15m/sec. Find the power produced if the jet is deflected by the blades through an angle of 1550 . The coefficient of velocity is 0.98.
18. Define reaction in Kaplan turbine?
19. Define reaction in francis turbine?
20. Define Speciffic speed?
21. What is the formula for darcy weisbech?
22. Define viscosity and its units?
23. What are the units for kinematic viscosity?
24. What is the reason for eddies?
25. Define specific weight?
26. Define vapor pressure?
27. Define absolute pressure?
28. Difference between simple manometer and differential manometer?
29. What do you mean by single column manometer?
30. What do you mean by vacuum pressure?

8. PERFORMANCE TEST ON FRANCIS TURBINE

AIM: To determine the performance characteristics of Francis turbine under constant head and constant speed.

Apparatus Required: Francis turbine Experimental setup

THEORY:

Hydraulic (or Water) turbines are the machines which use the energy of water (Hydro – Power) and convert it into mechanical energy. Thus the turbine becomes the prime mover to run the electrical generators to produce the electricity, Viz., Hydro-Electric Power.

The turbines are classified as Impulse & Reaction types. In impulse turbine, the head of water is completely converted into a jet, which impulses the forces on the turbine. In reaction turbine, it is the pressure of the flowing water, which rotates the runner of the turbine. Of many types of turbine, the Pelton wheel, most commonly used, falls into the category of turbines. While Francis & Kaplan falls in category of impulse reaction turbines.

The **Francis turbine** is a mixed flow **reaction turbine**, which means that the working fluid changes pressure as it moves through the turbine, giving up its energy. A casement is needed to contain the water flow. The turbine is located between the high pressure water source and the low pressure water exit, usually at the base of a dam.

The inlet is spiral shaped. Guide vanes direct the water tangentially to the runner. This radial flow acts on the runner vanes, causing the runner to spin. The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions. As the water moves through the runner its spinning radius decreases, further acting on the runner. Imagine swinging a ball on a string around in a circle. If the string is pulled short, the ball spins faster. This property, in addition to the water's pressure, helps inward flow turbines harness water energy. At the exit, water acts on cup shaped runner features, leaving with no swirl and very little kinetic or potential energy. The turbine's exit tube is specially shaped, called Draft tube, to help decelerate the water flow and recover pressure energy.

Normally, Pelton wheel (impulse turbine) requires high heads and low discharge, while the Francis & Kaplan (reaction turbines) require relatively low heads and high discharge. These corresponding heads and discharges are difficult to create in laboratory size turbine from the limitation of the pumps availability in the market. Nevertheless, at least the performance characteristics could be obtained within the limited facility available in the laboratories. Further, understanding various elements associated with any particular turbine is possible with this kind of facility.

PHOTOGRAPH OF THE SETUP:


Guide vanes at full flow setting (cut-away view) Guide vanes at minimum flow setting

PROCEDURE:

1. Connect the supply pump – motor unit to 3 ph, 440V, 30A, electrical supply, with neutral and earth connections and ensure the correct direction of pump-motor unit.
2. Keep the gate closed.
3. Keep the spring load at zero, by operating the spring balance hand wheel.
4. Press the green button of the supply pump starter & then release.
5. a) Slowly, open the gate so that the turbine rotor picks up the speed and attains maximum at full opening of the gate.

   b) Keep the guide vane angles at maximum and see that the speed does not exceed 1500 rpm at any load.

6. a) Note down spring balance reading (F1 & F2), speed, pressure ,vacuum on the control panel, head over the notch, and tabulate the results.

   b) Change the position of the guide vane angles and repeat the readings. If necessary, the gate valve (butterfly valve) also can be used for speed control.

7. Close the gate and then switch OFF the supply water pump set.
8. **8.** Follow the procedure described below for taking down the reading for evaluating the performance characteristics of the Francis turbine.

OBSERVATION TABLE:

Speed **'N'** in rpm	Pressure at inlet	Head at inlet of turbine	PressureGauge readings across venturemeter **'P'** in kg/cm^2	Load on Brake drum dynamo meter (kg)

	of turbine	(H)	P1	P2	P1-P2	W1	W2	W1-W2

FORMULAE:

1. Discharge (Q_{th}) = $\dfrac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$ m^3/s

a_1 = Inlet area of Venturi meter in m^2

a_2 = Area of throat in m^2

2. Head on the Turbine = pressure head – vacuum head

Pressure head 'H' in meters of water = 10 P

Vacuum head in meters of water = h*13.6/1000

Where P is the pressure gauge reading in kg / cm^2.

3. INPUT POWER = $\dfrac{\rho \times Q \times H \times g}{100}$

Where, ρ = 1000 kg/m^3

Q = Flow rate of water in m^3/sec

H = Head on Turbine in m.

4. OUTPUT POWER = 2π N T/6000

N=RPM of the turbine

T=Torque of turbine shaft

T= (W1-W2)xRx9.81

W= load applied on turbine

R= Radiusof the brake drum with rope in meters=0.12m

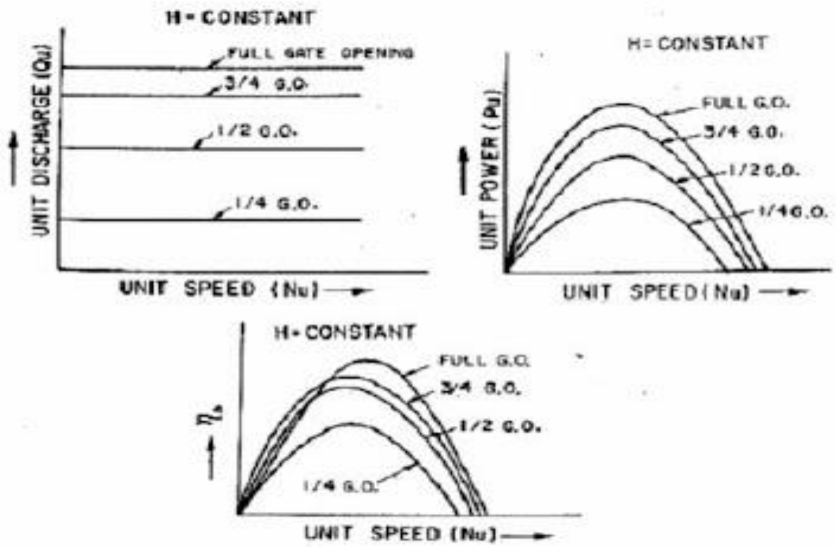
5. Efficiency = $\frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} \times 100$

TABLE OF CALCULATIONS:

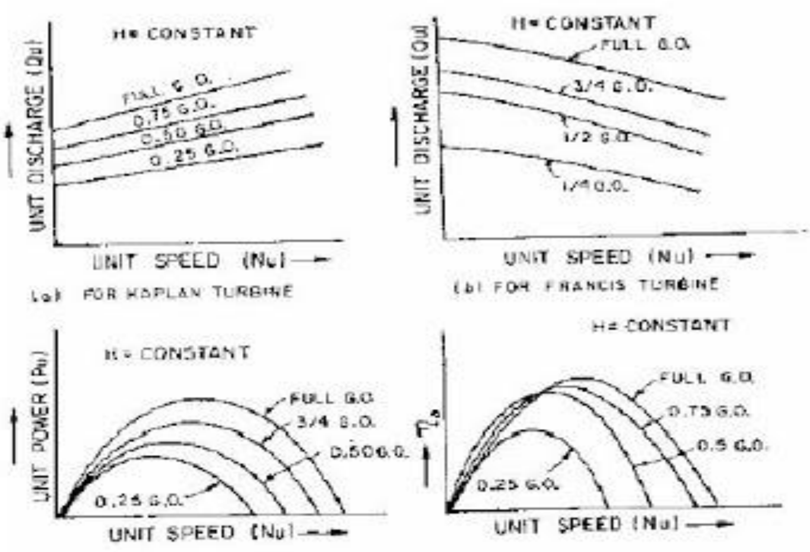
DISCHARGE m^3/s	INPUT POWER (KW)	OUTPUT POWER (KW)	SPECIFIC SPEED $N_S = N\sqrt{P}/H^{5/4}$	UNIT DISCHARGE $Q_U = Q/\sqrt{H}$	UNIT POWER $P_U = P/H^{3/2}$	UNIT SPEED $N_U = N/\sqrt{H}$	EFFICIENCY

GRAPH:

1. **Speed Vs Discharge**
2. **Speed Vs Input Power**
3. **Speed Vs Efficiency**
4. **Unit Speed Vs Unit Discharge**
5. **Unit Speed VsUnit Power**
6. **Unit Speed VsEfficiency**



. Main characteristic curves for a Pelton wheel.



Main characteristic curves for reaction turbine.

PRECAUTIONS:

1. Do not start pump set if the supply voltage is less than 300 V (phase to phase voltage).

2. Do not forget to give electrical earth and neutral connections correctly. Otherwise, the RPM indicator gets burnt if connections are wrong.

3. Frequently, at least once in three months, grease all visual moving parts.

4. Initially, fill-in the tank with clean water free from foreign material. Change the water every six months.

5. At least every week, operate the unit for five minutes to prevent any clogging of the moving parts.

6. To start and stop the supply pump, always keep gate valve closed.

7. It is recommended to keep spear rod setting at close position before starting the turbine. This is to prevent racing of the propeller shaft without load.

8. In case of any major faults, please write to manufacturer, and do not attempt to repair.

RESULT:

VIVA QUESTIONS:

1. On what principle the Francis turbine works?
2. What is the shape and function of draft tube in Francis turbine?
3. What is the purpose of guide vanes?
4. Define unit quantities and specific speed.
5. What type of flow occurs in Francis turbine?
6. What is specific speed of turbine?
7. What type of turbine is Francis turbine?
8. Define flow ratio?
9. Define speed ratio?
10. What is the formula for discharge of francs turbine?
11. What are the disadvantages of Francis turbine?

12. What is draft tube?
13. Why the draft tube is used in Francis turbine?
14. What is reaction turbine?
15. Define specific speed?
16. Difference between impulse turbine and reaction turbine?
17. What is shaft power?
18. Define overall efficiency?
19. Define volumetric efficiency?
20. Define mechanical efficiency?
21. Define jet ratio?
22. How do you estimate the number of buckets on a pelton wheel?
23. Define effective head?
24. Define gross head?
25. What are the units for kinematic viscosity?
26. What is the reason for eddies?
27. Define specific weight?
28. Define vapor pressure?
29. Define absolute pressure?
30. Different types of draft tube?

9. KAPLAN TURBINE

Aim: To determine the performance characteristics of Kaplan turbine under constant head and constant speed.

Apparatus Required: Kaplan turbine test rig. Tacho meter,

Specifications:

The actual experimental set-up consists of a centrifugal pump set turbine unit, sump tank, notch tank arranged in such a way that the whole unit works on re-circulating water system. The centrifugal pump set supplies the water from the sump tank to the turbine through gate valve which has the marking to meter the known quantity of water. The water after passing through the turbine unit enters the collecting tank through the draft tube. The water then flows back to the sump tank through the notch tank with rectangular notch for the measurement of flow rate.

The loading of the turbine is achieved by electrical AC generator connected to lamp bank. The provisions for; measurement of electrical energy AC voltmeter and ammeter turbine speed (digital RPM indicator), Head on the turbine (pressure gauge), are built-in on the control panel.

Supply Pump / motor Capacity : 12 hp, 3 ph, 440V, 50 Hz AC.

Turbine	:	150 mm dia. Propeller with four blades.
	:	Propeller blade angles adjustable from maximum to minimum.
	:	Run-away speed – 2500 rpm (approx.).
	:	Max. flow of water – 2500 lpm (approx.).
	:	Max. Head – 10 m. (approx.).
Loading	:	AC generator.
Provisions	:	a. Flow rate by notch, Cd = 0.6 (assumed).
		b. Head on turbine by pressure gauge of range "0.2kg / cm2 and vacuum gauge :1 – 760 mm of Hg
		c. Electrical load change by toggle switch (maximum connected load : 2000 watts).
		d. Electrical load measurement by energy meter.
		e. Voltage & current of generator by analog meters.
		f. Propeller speed by digital rpm indicator
		g. Supply water control by gate valve.
Electrical Supply	:	3ph, 440V, AC, 30A, with neutral & earth.

Note: Volume of water required for operation unit : 3000 lt. (approx.).

Theory:

Hydraulic (or Water) turbines are the machines which use the energy of water (Hydro – Power) and convert it into mechanical energy. Thus the turbine becomes the prime-mover to run the electrical generators to produce the electricity, Viz., Hydro-Electric Power.

The turbines are classified as Impulse & Reaction types. In impulse turbine, the head of water is completely converted into a jet, which impulses the forces on the turbine. In reaction turbine, it is the pressure of the flowing water, which rotates the runner of the turbine. Of many types of turbine, the Pelton wheel, most commonly used, falls into the category of turbines. While Francis & Kaplan falls in category of impulse reaction turbines.

The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The design combines radial and axial features.

The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate. Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin. Between the scroll casing and the runner, the water turns through right angle into the axial direction and passes through the runner and thus rotating the runner shaft. The runner has four blades which can be turned about their own axis so that the angle of inclination may be adjusted while the turbine is in motion. When runner blade angles are varied, high efficiency can be maintained over wide range of operating conditions. In other words even at part loads, when a low discharge is flowing through the runner, a high efficiency can be attained in case of Kaplan turbine, whereas this provision does not exist in Francis & Propeller turbines where, the runner blade angles are fixed and integral with hub.

The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy. The turbine does not need to be at the lowest point of water flow, as long as the draft tube remains full of water. A higher turbine location, however, increases the suction that is imparted on the turbine blades by the draft tube. The resulting pressure drop may lead to cavitation..

Normally, Pelton wheel (impulse turbine) requires high heads and low discharge, while the Francis & Kaplan (reaction turbines) require relatively low heads and high discharge. These corresponding he1ds and discharge are difficult to create in laboratory size turbine from the limitation of the pumps availability in the market. Nevertheless, at least the performance characteristics could be obtained within the limited facility available in the laboratories. Further, understanding various elements associated with any particular turbine is possible with this kind of facility.

Line diagram of the setup:

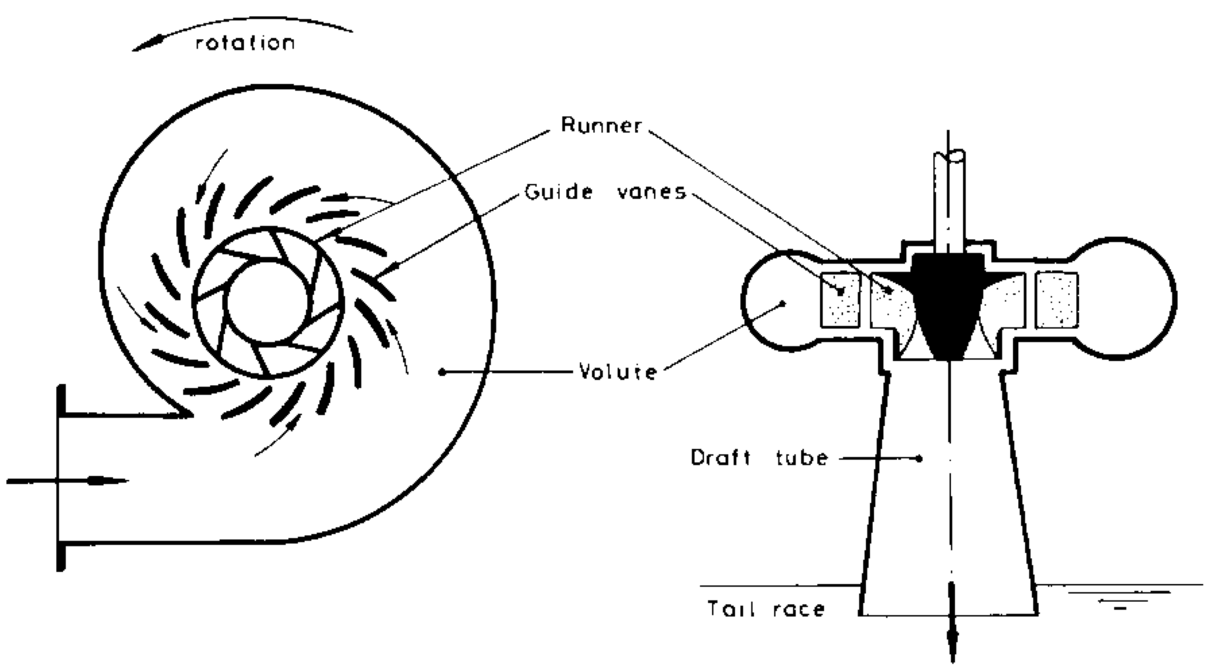


FIGURE B. 6 :
Sectional Views of a Francis Turbine

Procedure:

1. Connect the supply pump – motor unit to 3 ph, 440V, 30A, electrical supply, with neutral and earth connections and ensure the correct direction of pump-motor unit.
2. Keep the gate closed.
3. Keep the electrical load at maximum, by keeping the all switches at ON position.
4. Press the green button of the supply pump starter & then release.
5. Slowly, open the gate so that the turbine rotor picks up the speed and attains maximum at full opening of the gate.

1. Note down the voltage and current, speed, pressure vacuum on the control panel, head over the notch, and tabulate the results.
2. Close the gate and then switch OFF the supply water pump set.
3. Follow the procedure described below for taking down the reading for evaluating the performance characteristics of the Kaplan turbine.

To obtain constant speed characteristics: (operating characteristics)

1. Keep the gate opening at maximum
2. For different electrical loads on the turbine / generator, change the gate position, so that the speed is held constant; say at 1500 rpm. See that the voltage does not exceed 250 V to avoid excess voltage on Bulbs.
3. Reduce the gate opening setting to different position and repeat (2) for different speeds 1500 rpm, 1000 rpm and tabulate the results.
4. The above readings will be utilized for drawing constant speed characteristics Viz.,
   a. Percentage of full load V/s efficiency.
   b. Efficiency and BHP V/s discharge characteristics.

To obtain constant head characteristics: (main characteristics)

1. Select the propeller vane angle position.

2. Keep the gate closed, and start the pump.
3. Slowly open the gate and set the pressure on the gauge.
4. For different electrical load, change the rotor pitch position and maintain the constant head and tabulate the results as given in Table – II.

To obtain Run – Away speed characteristics:

1. Switch OFF the entire load on the turbine and the voltmeter.
2. Keep propeller vane angle at optimum position (Head, h = 0.75 Kg / cm2).
3. Slowly open the gate to maximum and note down the turbine speed. This is the runaway speed which is maximum.

Note:

Run-away speed is also influenced by the tightening in gland packing of the turbine shaft. More is the tightness, less is the run-away speed.

Performance under unit head – unit quantities:

In order to predict the behavior of a turbine working under varying conditions and to facilitate comparison between the performances of the turbines of the same type but having different outputs and speeds and working under different heads, it is often convenient to express the test results in terms of certain unit quantities.

From the output of a turbine corresponding to different working heads (Table of Calculations – II) it is possible to compute the output which would be developed if the head was reduced to unit (say 1mt); the speed being adjustable so that the efficiency remains unaffected.

a. Unit Speed, $N_u = N/\sqrt{H}$
b. Unit power, $P_u = P/H^{3/2}$
c. Unit Discharge, $Q_u = Q/\sqrt{H}$

Specific Speed:

The specific speed of any turbine is the speed in rpm of a turbine geometrically similar to the actual turbine but of such a size that under corresponding conditions it will develop 1 metric horse power when working under unit head (i.e., 1 meter.).

The specific speed is usually computed for the operating conditions corresponding to the maximum efficiency.

$$N_u = \frac{N\sqrt{P}}{H^{5/4}}$$

Observation Table:

Speed **'N'** in rpm	Pressure at inlet of turbine	Head at inlet of turbine (H)	PressureGauge readings across orifice meter **'P'** in kg/cm^2			Load on Brake drum dynamo meter (kg)		
			P1	P2	P1-P2	W1	W2	W1-W2

1. Head on the Turbine
2. Discharge (Flow rate) of water through the Turbine = Flow Rate over the orifice

Q =Flow rate of water in m3/sec

$$= \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

3. Input power to the Turbine, $= \frac{WQH}{1000}$ kw W = ρg = 9810 N/m^3

Where, ρ = 1000kg/m3

Q =Flow rate of water in m3/sec

H = Head on Turbine in m from Formula

4. Unit quantities – under unit head,
   a. Unit Speed, $N_u = N/\sqrt{H}$
   b. Unit power, $P_u = P/H^{3/2}$
   c. Unit Discharge, $Q_u = Q/\sqrt{H}$
5. Specific speed,

$$N_u = \frac{N\sqrt{P}}{H^{5/4}}$$

Table II

DISCHARGE m^3/s	INPUT POWER (KW)	OUTPUT POWER (KW)	SPECIFIC SPEED $N_S=N\sqrt{P}/H^{5/4}$	UNIT DISCHARGE $Q_U=Q/\sqrt{H}$	UNIT POWER $P_U=P/H^{3/2}$	UNIT SPEED $N_U= N/\sqrt{H}$	EFFICIENCY

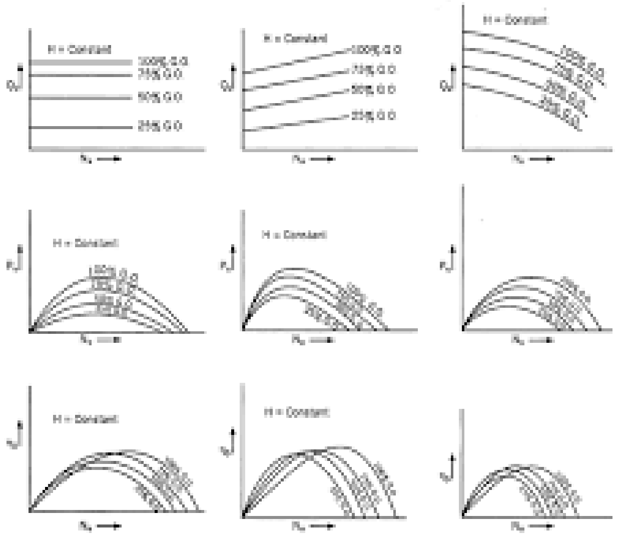
Graph:Constant head characteristics

1. **Speed Vs Discharge**
2. **Speed Vs Input Power**

3. **Speed Vs Efficiency**
4. **Unit Speed Vs Unit Discharge**
5. **Unit Speed VsUnit Power**
6. **Unit Speed Vs Efficiency**

Constant speed characteristics

1. Percentage efficiency (η) vs. percentage full load.



(a) Main characteristics of a pelton wheel. (b) Main characteristics of a Kaplan turbine. (c) Shows the main characteristic curves of a Francis turbine.

Fig. 23.1. (a), (b) and (c).

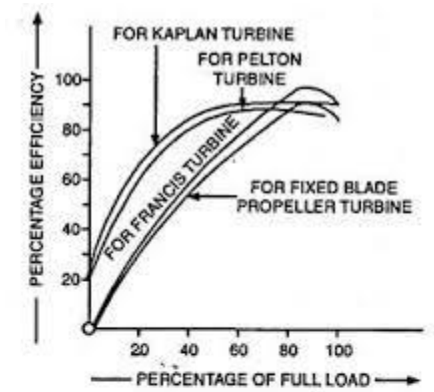


Fig. 2.21. ***Efficiency Curve of Reaction Turbines***

Precautions:

1. Do not start pump set if the supply voltage is less than 300 V (phase to phase voltage).
2. Do not forget to give electrical earth and neutral connections correctly. Otherwise, the RPM indicator gets burnt if connections are wrong.
3. Frequently, alteast once in three months, grease all visual moving parts.
4. Initially, fill-in the tank with clean water free from foreign material. Change the water every six months.
5. Atleast every week, operate the unit for five minutes to prevent any clogging of the moving parts.
6. To start and stop the supply pump, always keep gate closed.
7. Gradual opening and closing of the gate is recommended for smooth operation.
8. In case of any major faults, please write to manufacturer, and do not attempt to repair.
9. Fill the water enough so that the pump does not choke.

Note on the design of Kaplan turbine

Data:

Maximum Head available on Turbine,	'H'	= 10 Mts
Maximum Flow Rate available through Runner,	'Q'	= 2500 lpm. (approx).
Propeller Diameter,	'D'	= 150 mm
Number of Blades,		= 4
Hub Diameter,	'd'	= 60 mm

Propeller Vane angle adjustable from zero to maximum to change the head on turbine.

Energy meter constant = 1500 rev / kWh

Calculations:

Data:

N = 1790 rpm

P = 1.6

H = 5.52 m

Q = 0.0436 m3/Sec

Speed Ratio $= \frac{u}{\sqrt{2gH}}$

Where, u = $\frac{\pi DN}{60}$ = Peripheral Speed

and H = Head on Turbine

Flow Ratio $= \frac{V}{\sqrt{2gH}}$

Where, V = Q / A

In which Q is Discharge; A is rotor annular area = $\frac{\pi\left(D^2 - d^2\right)}{4}$

Specific Speed, = $N_s - \frac{N\sqrt{p}}{H^{5/4}}$

Where,

'N' is the Propeller Speed at Head (H)

when developing power 'P'

'H' is in Meter

'N' is in RPM

'P' is in KW

On substitution of the values from the above Data, we obtain the following:

Speed Ratio = 1.35

Flow Ratio = 0.28

Specific Speed, Ns = 2.63

Hub to propeller Diameter Ratio = n = d / D = 60 / 150 = 0.4

Applications

Kaplan turbines are widely used throughout the world for electrical power production. They cover the lowest head hydro sites and are especially suited for high flow conditions. Inexpensive micro turbines are manufactured for individual power production with as little as two feet of head.Large Kaplan turbines are individually designed for each site to operate at the highest possible efficiency, typically over 90%. They are very expensive to design, manufacture and install, but operate for decades.

VIVA QUESTIONS:

1. On what principle the Kaplan turbine works?
2. What is the shape and function of draft tube?
3. Why V notch is not used in Kaplan turbine?
4. Define unit quantities and specific speed.
5. What is the nature of flow in Kaplan turbine?
6. What is specific speed Kaplan turbine
7. What is the difference between Kaplan turbine and propeller turbine
8. What is mean by degree of reaction
9. What is flow ratio
10. Define speed ratio
11. What is use of governor
12. Write the formula for discharge of Kaplan turbine
13. A Kaplan turbine has the following details about its draft tube. Find the pressure at inlet of the draft tube. Inlet diameter of draft tube = 2m Out let diameter of draft tube = 3m Velocity of water at outlet = 4.2 m /sec Atmosphere pressure = 10.1 m of water Height of draft tube above tail race = 3.5m Loss of head in draft tube = 0.2 times the velocity head at outlet.
14. A Kaplan turbine working under a head of 15 m develops 7357.5 kW shaft power. The outer diameter of the runner is 4 m and hub diameter 2 m. The guide blade angle at the extreme edge of the runner is 30°. The hydraulic and overall efficiencies of the turbine are 90% and 85% respectively. If the velocity of whirl is zero at outlet, determine: (i) runner vane angles at inlet and outlet at the extreme edge of the runner and (ii) speed of the turbine
15. What is cavitation?
16. What are the units for kinematic viscosity?
17. What is the reason for eddies?
18. Define specific weight?
19. Define vapor pressure?
20. Define absolute pressure?
21. Define specific speed?
22. Difference between impulse turbine and reaction turbine?
23. What is shaft power?
24. Define overall efficiency?
25. Define volumetric efficiency?
26. Define mechanical efficiency?
27. Define jet ratio?
28. How do you estimate the number of buckets on a pelton wheel?
29. Define effective head?
30. Define gross head?

10. PERFORMANCE TEST ON A SINGLE STAGE CENTRIFUGAL PUMP

AIM: To conduct a performance test ona single stage centrifugal pump. and draw the performance characteristic curves.

APPARATUS REQUIRED: Centrifugal pump test rig, stop watch.

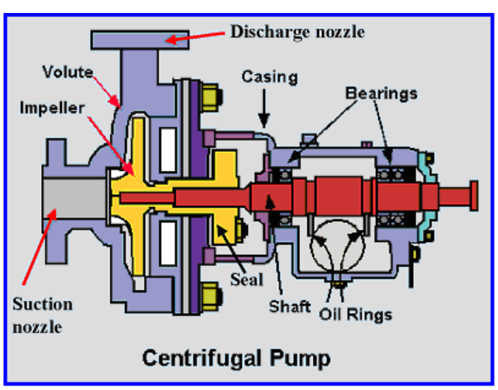
THEORY:

In general, a pump may be defined as a mechanical device which, when interposed in a pipe line, converts the mechanical energy supplied to it from some external source into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

The pumps are of major concern to most Engineers and Technicians. The types of pump vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial purposes are; Centrifugal, Piston, Axial Flow (Stage pumps), Air Jet, Diaphragm and Turbine pumps. Most of these pumps fall into the main class, namely, Rotodynamic, Reciprocating (Positive Displacement), Fluid (Air) operated pumps.

In centrifugal pump the liquid is made to rotate in a closed chamber (Volute Casing), thus resulting in the continuous flow. These pumps compared to Reciprocating Pumps are simple in construction, more suitable for handling viscous, turbid (muddy) liquids. But, their hydraulic heads per stage at low flow rates is limited, and hence not suitable for very high heads compared to Reciprocating Pumps of same capacity. But, still in most cases, this is the only type of pump which is being widely used for agricultural purposes.

PHOTOGRAPH OF THE SETUP:



PROCEDURE:

1. Fill in the Sump Tank with clean water.
2. Keep the delivery valve closed and suction valve open, after initially priming the pump.
3. Connect the power cable to 1 Ph, 230V, 15A with earth connection.
4. Confirm the belt is put to the lowest speed position.
5. Switch ON the Mains, so that the Mains On Indicator glows. Now, switch-ON the starter.
6. Now you will find the water starts flowing to the Measuring Tank.
7. Close the delivery valve slightly, so that the delivery pressure is readable
8. Operate the Butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.
9. Note down the Pressure Gauges, Vacuum Gauges, and time for number of revolutions of Energy Meter Disc.
10. Note down the other readings as indicated in the tabular column.
11. Repeat the experiment for different openings of the Delivery Valve and Suction Valve.
12. Change the belt to different speed positions and repeat the experiment.
13. After the experiment is over, keep all the delivery and suction valves open.

OBSERVATION TABLE:

Sr.No.	Pressure Gauge Reading 'P' kg / cm^2	Vacuum Gauge Reading in mm of Hg	Time taken for 5 rev. of Energy meter in sec.	Time taken for 10 cm rise of water in Sec

CALCULATIONS:

1. **Discharge Rate "Q" in m^3 / Sec.**

$$Q = \frac{A \times R}{t} m^3/sec$$

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise ‘R’ in ‘t’ seconds

2. Total Head ‘H’ in meter.:

Pressure head in meters of water = 10 P

Vacuum head in meters of water = h*13.6/1000

Where P is the pressure gauge reading in kg / cm^2.

Total Head ‘H’= Pressure head+ Vacuum head +Datum head

2. INPUT POWER = X*3600*0.60/C*T

X= No. of revolutions of energy meter disk

0.6= combined motor (0.75) and transmission losses (0.8)

T= time taken for X revolutions of energy meter disk

C= Energy constant

3. OUTPOWER = $\frac{WQH}{100}$

Where, W = 9810N/m^3

Q = Flow rate of water in m^3/sec

H = Total Head

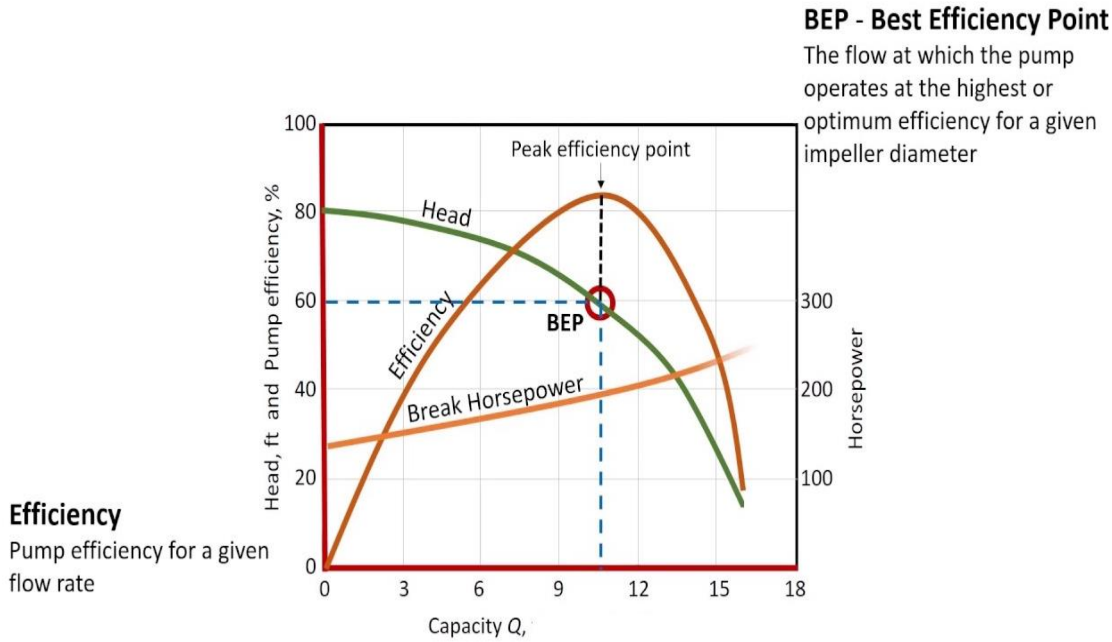
5. **EFFICIENCY** = $\frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} \text{X} \, 100$

TABLE OF CALCULATIONS:

Sr. No	Specific speed $N_S=N\sqrt{Q}/H^{3/4}$	Discharge m3/sec	Net Head (H) in m	Input Power (KW)	Output Power (KW)	Efficiency

GRAPH:

1. Discharge Vs Head
2. Discharge Vs Input Power
3. Discharge Vs Efficiency
4. Speed Vs Head



PRECAUTIONS:

1. Do not start the pump if the voltage is less than 180 V.
2. Frequently (at least once in three months) grease / oil the rotating parts.
3. Initially, put clean water free from foreign material, and change once in three months.
4. At least every week, operate the unit for five minutes to prevent clogging of the moving parts.
5. Don't exceed 5 kg / cm^2 on pressure gauge reading and never fully close the delivery valve.

RESULT:

VIVA QUESTIONS:

1. What is meant by a Roto-dynamic machine?
2. What is meant by priming of a pump?
3. What energy is converted in a pump?
4. What types of fluids are pumped by centrifugal pumps?
5. What are the pumping characteristics of a centrifugal pump?
6. What is meant by efficiency of a pump?
7. Write the formula for work done by centrifugal pump per sec unit weight of liquid?

8. Write euler momentum equation for centrifugal pump?
9. What is suction head?
10. What is delivery head?
11. What is manomatric head?
12. What do you by minimum speed for starting a centrifugal pump?
13. What are the losses in pump ?
14. Define mechanical efficiency pump?
15. Define manomatic efficiency?
16. What is static head?
17. What is euler head?
18. What is the formula for work done by reciprocating pump per sec?
19. Define slip?
20. What is mean by negative slip?
21. What is indicator diagram?
22. Define volumetric efficiency?
23. What is the use of air vessel?
24. What is cavitation?
25. How to avoid capitation in pumps?
26. Disadvantages of cavitations?
27. Define specific speed?
28. Define density and its units?
29. What are the units for viscosity?
30. Define pressure and its units?

11. PERFORMANCE TEST ONA TWO STAGE CENTRIFUGAL PUMP

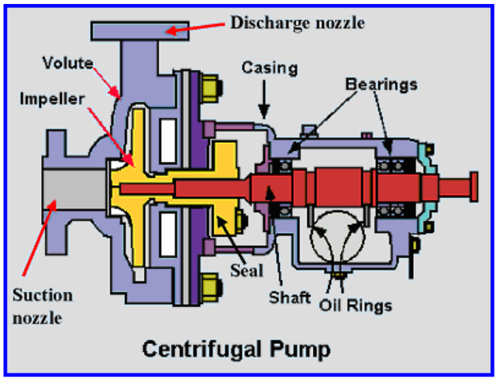
AIM: To conduct a performance test on a two stage centrifugal pump. and draw the performance characteristic curves.

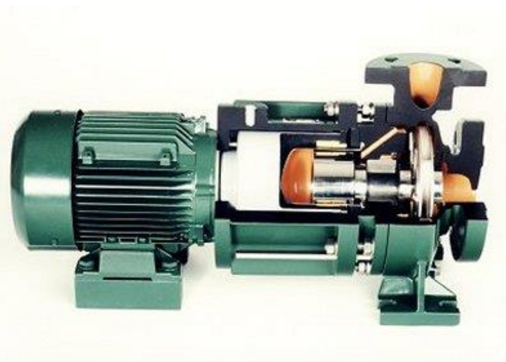
APPARATUS REQUIRED: Centrifugal pump test rig, stop watch.

THEORY:

In general, a pump may be defined as a mechanical device which, when interposed in a pipe line, converts the mechanical energy supplied to it from some external source into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.The pumps are of major concern to most Engineers and Technicians. The types of pump vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial purposes are; Centrifugal, Piston, Axial Flow (Stage pumps), Air Jet, Diaphragm and Turbine pumps. Most of these pumps fall into the main class, namely, Rotodynamic, Reciprocating (Positive Displacement), Fluid (Air) operated pumps.In centrifugal pump the liquid is made to rotate in a closed chamber (Volute Casing), thus resulting in the continuous flow. These pumps compared to Reciprocating Pumps are simple in construction, more suitable for handling viscous, turbid (muddy) liquids. But, their hydraulic heads per stage at low flow rates is limited, and hence not suitable for very high heads compared to Reciprocating Pumps of same capacity. But, still in most cases, this is the only type of pump which is being widely used for agricultural purposes.

PHOTOGRAPH OF THE SETUP:





PROCEDURE:

1. Fill in the Sump Tank with clean water.
2. Keep the delivery valve closed and suction valve open, after initially priming the pump.
3. Connect the power cable to 1 Ph, 230V, 15A with earth connection.
4. Confirm the belt is put to the lowest speed position.
5. Switch ON the Mains, so that the Mains On Indicator glows. Now, switch-ON the starter.
6. Now you will find the water starts flowing to the Measuring Tank.
7. Close the delivery valve slightly, so that the delivery pressure is readable
8. Operate the Butterfly valve to note down the collecting tank reading against the known time and keep it open when the readings are not taken.
9. Note down the Pressure Gauges, Vacuum Gauges, and time for number of revolutions of Energy Meter Disc.

10. Note down the other readings as indicated in the tabular column.
11. Repeat the experiment for different openings of the Delivery Valve and Suction Valve.
12. Change the belt to different speed positions and repeat the experiment.
13. After the experiment is over, keep all the delivery and suction valves open.

OBSERVATION TABLE:

Sr.No.	Pressure Gauge Reading 'P' kg / cm^2	Vacuum Gauge Reading in mm of Hg	Time taken for 5 rev. of Energy meter in sec.	Time taken for 10 cm rise of water in Sec

CALCULATIONS:

1. **Discharge Rate "Q" in m^3 / Sec.**

$$Q = \frac{A \times R}{t} m^3/sec$$

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise 'R' in 't' seconds

2. **Total Head 'H' in mtr.:**

Pressure head in meters of water = 10 P

Vacuum head in meters of water = h*13.6/1000

Where P is the pressure gauge reading in kg / cm^2.

Total Head 'H'= Pressure head+ Vacuum head +Datum head

4. INPUT POWER = X*3600*0.60/C*T

X= No. of revolutions of energy meter disk

0.6= combined motor (0.75) and transmission losses (0.8)

T= time taken for X revolutions of energy meter disk

C= Energy constant

5. **OUTPOWER** = $\frac{WQH}{100}$

Where, W = 9810N/m^3

Q = Flow rate of water in m^3/sec

H = Total Head

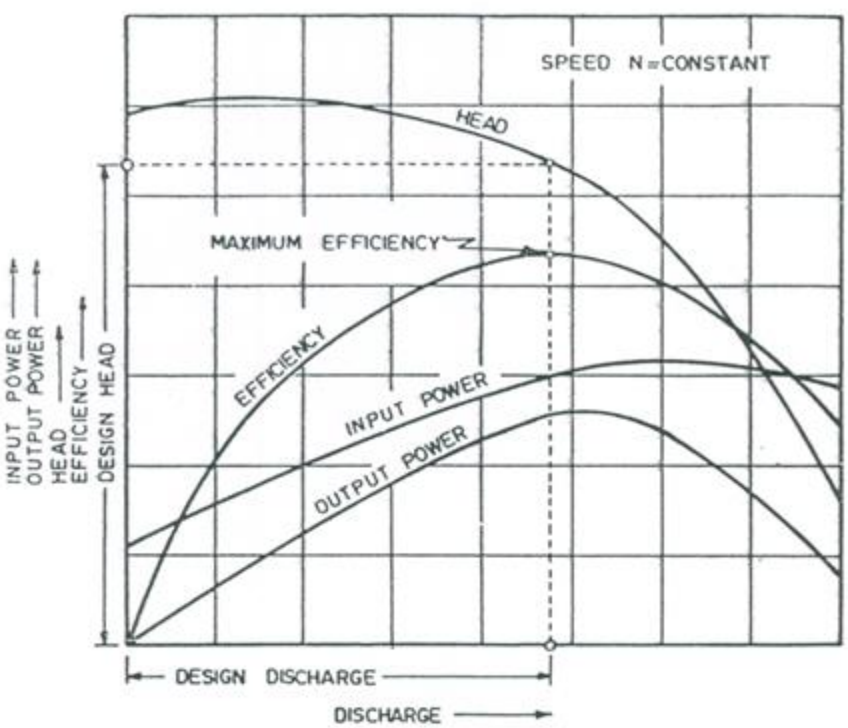
5. **EFFICIENCY** = $\frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} \text{X} 100$

TABLE OF CALCULATIONS:

Sr. No	DISCHARGE m3/sec	NET HEAD (H) in m	INPUT POWER (KW)	OUTPUT POWER (KW)	EFFICIENCY

GRAPH:

1. Discharge Vs Head
2. Discharge Vs Input Power
3. Discharge Vs Efficiency



PRECAUTIONS:

1. Do not start the pump if the voltage is less than 180 V.

2. Frequently (at least once in three months) grease / oil the rotating parts.
3. Initially, put clean water free from foreign material, and change once in three months.
4. At least every week, operate the unit for five minutes to prevent clogging of the moving parts.
5. Don't exceed 5 kg / cm^2 on pressure gauge reading and never fully close the delivery valve.

RESULT :

VIVA QUESTIONS:

1. What is meant by a Roto-dynamic machine?
2. What is meant by priming of a pump?
3. What energy is converted in a pump?
4. What types of fluids are pumped by centrifugal pumps?
5. What are the pumping characteristics of a centrifugal pump?
6. What is meant by efficiency of a pump?
7. Write the formula for work done by centrifugal pump per sec unit weight of liquid?
8. Write euler momentum equation for centrifugal pump?
9. What is suction head?
10. What is delivery head?
11. What is manomatric head?
12. What do you by minimum speed for starting a centrifugal pump?
13. What are the losses in pump ?
14. Define mechanical efficiency pump?
15. Define manomatic efficiency?
16. What is static head?
17. What is euler head?
18. What is meant by a Roto-dynamic machine?

19. What is meant by priming of a pump?
20. What energy is converted in a pump?
21. What type of fluids are pumped by centrifugal pumps?
22. What are the pumping characteristics of a centrifugal pump?
23. What is meant by efficiency of a pump?
24. What is the formula for work done by reciprocating pump per sec?
25. Define slip?
26. What is mean by negative slip?
27. What is indicator diagram?
28. Define volumetric efficiency?
29. What is the use of air vessel?
30. What is cavitation?

12. PERFORMANCE TEST ON A RECIPROCATING PUMP

AIM: To conduct a performance test on a reciprocating pump. And draw the performance characteristic curves

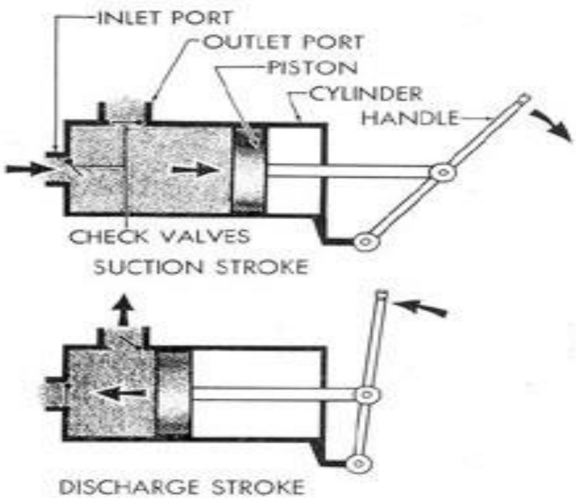
APPARATUS REQUIRED: Reciprocating pump test rig, **Stop** watch.

THEORY:

In general, a pump may be defined as a mechanical device which, when interposed in a pipe line, converts the mechanical energy supplied to it from some external source into hydraulic energy, thus resulting in the flow of liquid from lower potential to higher potential.

The pumps are of major concern to most Engineers and Technicians. The types of pump vary in principle and design. The selection of the pump for any particular application is to be done by understanding their characteristics. The most commonly used pumps for domestic, agricultural and industrial purposes are: Centrifugal, Piston, Axial Flow (Stage pumps), Air Jet, Diaphragm and Turbine pumps. Most of these pumps fall into the main class, namely, Rotodynamic, Reciprocating (Positive Displacement), Fluid (Air) operated pumps.

PHOTOGRAPH OF THE SETUP:



RECIPROCATING ACTION OF THE PISTON

PROCEDURE:

1. Fill in the sump tank with clean water.
2. Keep the delivery and suction valves open.
3. Connect the power cable to 1 ph, 220 V, 15 Amps.
4. Select the required speed using stepped cone pulley arrangement.
5. Switch ON the mains so that the mains ON indicator glows. Now, switch on the motor.
6. Note down the speed from digital rpm indicator.
7. Note down the Pressure Gauge, Vacuum Gauge and time for number of revolutions of energy meter disc at full opening of delivery and suction valve.
8. Operate the butterfly valve to note down the collecting tank reading against the known time, and keep it open when the readings are not taken.
9. Repeat the experiment for different openings of the delivery valve (Pressure & Flow Rate). Note down the readings as indicated in tabular column.
10. Repeat the experiment for different speeds and repeat the steps (4 & 9).
11. After the experiment is over, keep the delivery valve open and switch OFF the mains.

OBSERVATION TABLE:

Sl.No.	Pressure Gauge Reading 'P' kg / cm^2	Vacuum Gauge Reading in mm of Hg	Time taken for 5 rev. of Energy meter in sec.	Time taken for 10 cm rise of water in Sec

CALCULATIONS:

1. Discharge Rate "Q" in m^3 / Sec.

$$Q = \frac{A \times R}{t} m^3/sec$$

A = Area of measuring (or) collecting tank = 0.3 x 0.3 m^2

R = Rise of water level taken in meters (say 0.1 m or 10 cm)

t = time taken for rise of water level to rise 'R' in 't' seconds

2.Total Head 'H' in m.:

Pressure head in meters of water = 10 P

Vacuum head in meters of water = h*13.6/1000

Where P is the pressure gauge reading in kg / cm^2.

Total Head 'H'= Pressure head+ Vacuum head + Datum head

3. **INPUT POWER** = X*3600*0.70*0.80/C*T

X= No. of revolutions of energy meter disk

0.7= combined motor (0.75) and transmission losses (0.8)

T= time taken for X revolutions of energy meter disk

C= Energy constant

4. OUTPOWER = $\frac{WQH}{100}$

Where, W = 9810N/m^3

Q = Flow rate of water in m^3/sec

H = Total Head

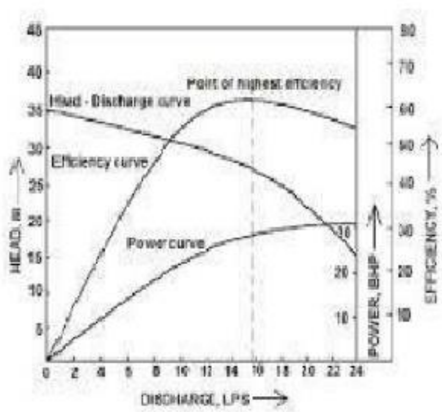
5. **Efficiency** = $\frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} X 100$

TABLE OF CALCULATIONS:

Sr. No	DISCHARGE m3/sec	NET HEAD (H) in m	INPUT POWER (KW)	OUTPUT POWER (KW)	EFFICIENCY

GRAPH:

1. Efficiency Vs Head



PRECAUTIONS:

1. Do not start the pump if the voltage is less than 180 V.
2. Frequently (at least once in three months) grease / oil the rotating parts.
3. Initially, put clean water free from foreign material, and change once in three months.
4. At least every week, operate the unit for five minutes to prevent clogging of the moving parts.
5. Don’t exceed 5 kg / cm^2 on pressure gauge reading and never fully close the delivery valve.

RESULT

VIVA QUESTIONS:

1. What is the main aim of the experiment?
2. What is meant by a positive displacement pump?
3. What types of fluids are pumped by Reciprocating pumps?
4. What are the pumping characteristics of a Reciprocating pump?
5. What is the normal efficiency of a Reciprocating pump?
6. What are the normal precautions to be taken when operating a pump?
7. What is the function of air vessel?
8. What is the formula for work done by reciprocating pump per sec?
9. Define slip?
10. What is mean by negative slip?
11. What is indicator diagram?
12. Define volumetric efficiency?
13. What is the use of air vessel?
14. What is cavitation?
15. How to avoid capitation in pumps?
16. Disadvantages of cavitations?
17. Define specific speed?

18. Difference between impulse turbine and reaction turbine?
19. What is shaft power?
20. Define overall efficiency?
21. Define volumetric efficiency?
22. Define mechanical efficiency?
23. Define jet ratio?
24. How do you estimate the number of buckets on a pelton wheel?
25. Define effective head?
26. Define gross head?
27. What is meant by efficiency of a pump?
28. Write the formula for work done by centrifugal pump per sec unit weight of liquid?
29. Write euler momentum equation for centrifugal pump?
30. What is suction head?

MODIFCATIONS:

Experiment object and outcomes

Newly added viva questions

Diagrams

Theory

Problems added related to experiments