FLUID MECHANICS AND HYDRAULIC MACHINES LABORATORY

Sub Code : 18CVL48
Semester : 4th

IA Marks : 40
Exam Hours : 03
Exam Marks : 100

EXPERIMENTS

1.	Verification of Bernoulli's equation.
2.	Determination of Cd for Venturimeter and Orifice meter.
3.	Determination of hydraulic coefficients of small vertical orifice.
4.	Determination of Cd for Rectangular and Triangular notch
5.	Determination of Cd for Ogee and Broad crested weir
6.	Determination of Cd for Venturiflume
7.	Determination of force exerted by a jet on flat and curved vanes.
8.	Determination of efficiency of Pelton wheel turbine
9.	Determination of efficiency of Francis turbine, Kaplan Turbine,
10.	Determination of efficiency of centrifugal pump
11.	Determination of Major Loss in Pipes
12.	Determination of Minor losses in pipe due to sudden enlargement, sudden contraction and bend.

CONTENTS

1. MAJOR HEAD LOSS IN PIPE

Aim : Estimation of friction factor of a given pipe.

Apparatus:

1) Three pipes of different diameter with supply value and outlet values.
1) Measuring tank with peizometer and scale.
2) Differential U-tube mercury manometer with scale
3) Stop watch.

Theory: Pipes are used to transmit liquid from one place to other under pressure. During transmission of liquid there will be loss of pressure head in pipe due to friction. Experimental observations on the flow of water in a long, straight and uniform diameter pipe indicated that the head loss due to friction 'h_f' between two sections of the pipe varied (i) in direct proportion with the velocity head $\frac{v^2}{2g}$, (ii) the distance between two sections 'L' and (iii) inversely with the pipe diameter 'D'. Introducing a coefficient of proportionality 'f', called as friction factor. It is given by the Darcy Weisbach formula.

$$h_f = \frac{fLv^2}{2gD}.$$

where,

h_f = loss of head in cm of water obtained from the manometer reading

h = differential head in cm of mercury as obtained from Manometer

L = length of the pipe in cm

v = velocity of flow obtained from the actual discharge Q_a ($v = \frac{Q_a}{a}$)

Q_a = actual discharge

a = cross sectional (C/S) area of pipe in cm^2

D = Diameter of pipe in cm

f = friction factor. It is different for different commercial pipes available in market. Ex: G.I Pipe, P.V.C pipe, Cast iron pipe etc. To calculate the loss of head between two ends of pipe friction factor of the pipe should be obtained from experimentation in the laboratory. The laboratory set up is as shown in Fig. 1.

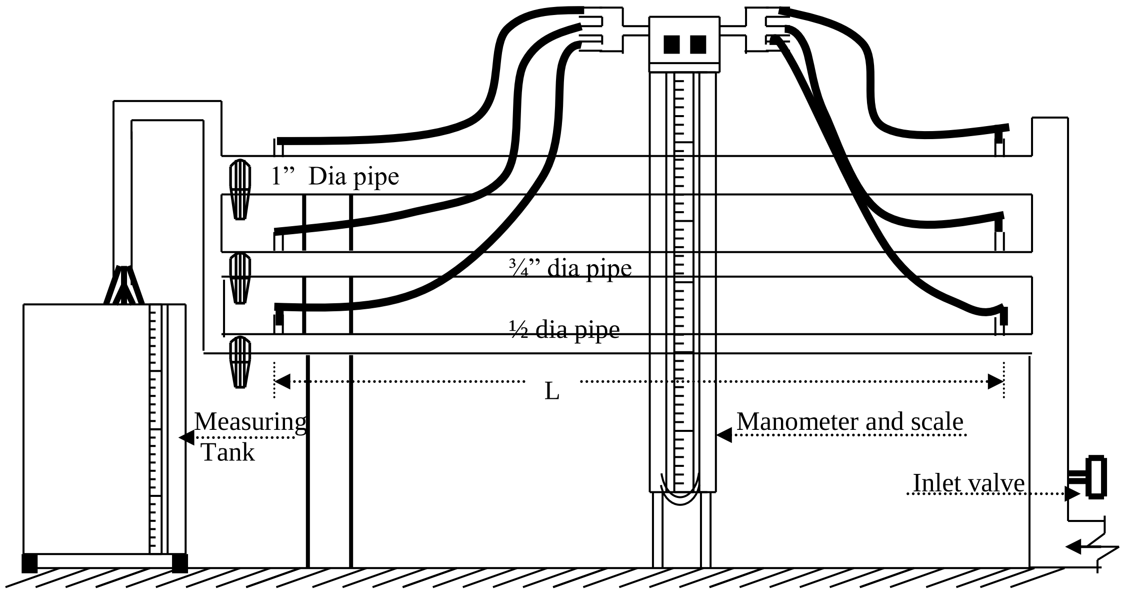


Fig.1 Friction loss experiment

Observation:

1) Measuring tank dimensions

- Length of tank (l) = cm
- Width of tank (b) = cm
- Area of tank (A=l × b) = cm^2

2) Pipe dimensions

Pipe No	Diameter of pipe, D in cm	C/S Area of pipe, a in cm^2	Length of pipe L, in cm
1			
2			
3			

Procedure:

1. Open the valves of the nipples at the ends of a pipe for which the friction factor is to be estimated. Also close the values of the nipples of other two pipes. By doing so, the manometer will be connected to the end of the pipe under consideration.
2. Open the inlet ball-valve fully on supply pipe and close the outlet valve at the discharging end of all three pipes.
3. Remove the air bubbles present in manometer and flexible connecting pipe with the help of air vent valve provided at the head of manometer.
4. Open the outlet of first pipe to some percentage (say 100%) and wait for some time for the stabilisation of flow. (same valve position should be maintained until step 8)
5. Take the readings of the mercury levels on both the limbs of the manometer, say h_1 and h_2.
6. Close the outlet valve of the measuring tank and note down the level of water (d_1) with the help of peizometer.
7. Tilt the hopper towards the tank and simultaneously start the stop-
8. After a particular duration of time 't' seconds reverse the hopper and take the peizometer reading, d_2 ('t' may be any convenient time around 60 sec).
9. Repeat steps No. 4 to 8 for the different percentage of outlet valve openings, say 75%, 50% and 25%.
10. Repeat the whole procedure for the other two pipes.

Observations and Calculations:

Pipe No and diameter	Manometer reading			Head Difference $h_f = h*12.6$ cm of water	Measuring tank reading			Actual Discharge $Q_a = \frac{Ad}{t}$ cm^3.	Actual velocity $v = \frac{Q_a}{a}$ cm / sec	Friction factor $f = \frac{2h_f gD}{Lv^2}$	Average friction factor 'f'
	Left limb Level h_1 cm	Right limb Level h_2 cm	Difference in level $h=h_2$ -		Initial Water Level d_1 cm	Final water level d_2 cm	Depth of water $D=d_2-d_1$				
1inch											
¾ inch											
½ inch											

Conclusion and remarks on results:

2. MINOR HEAD LOSSES IN PIPE

Aim : Estimation of coefficients of minor losses for various fittings.

Apparatus:

1) Pipes of three different diameters fitted with bend, elbow, sudden-expansion, sudden-contraction, supply-value and outlet values.
2) Measuring tank with peizometer and scale.
3) Differential U-tube manometer filled with carbon tetrachloride
4) Stop watch.

Theory:- Losses due to change of section, bends, elbows, valves and fittings of all types fall into the category which contribute minor head losses in pipe lines. In long pipe lines, the friction losses are much larger than these minor losses and hence the later are often neglected. But, in shorter pipe lines, it is necessary to consider the minor head losses.

From the experimental observations with water at high Reynolds number the following general equation was proposed for the minor losses in pipes.

$$h_L = k\left[\frac{v^2}{2g}\right],$$

However, for abrupt enlargement of section, the simultaneous application of the continuity equation, Bernoulli's equation and the momentum equation shows that

$$h_L = k\left[\frac{(v - v_2)^2}{2g}\right]$$

Nomenclature

h = differential head in cm of mercury as obtained from Manometer

h_L = loss of head in cm of water obtained from the manometer reading (h_L=12.6h) in cm of water.

v = velocity of flow obtained from the actual discharge Qa ($v = \frac{Q_a}{a}$)

Q_a = actual discharge cm^3/sec

D = Diameter of pipe in cm

a = C/S area of pipe in cm^2

D_2 = Diameter of enlarged part of pipe in cm

a_2 = C/S area enlarged part of pipe in cm^2

k = Coefficient of minor loss. It is different for different types of fittings such as bend, elbow, sudden-expansion and sudden-contraction

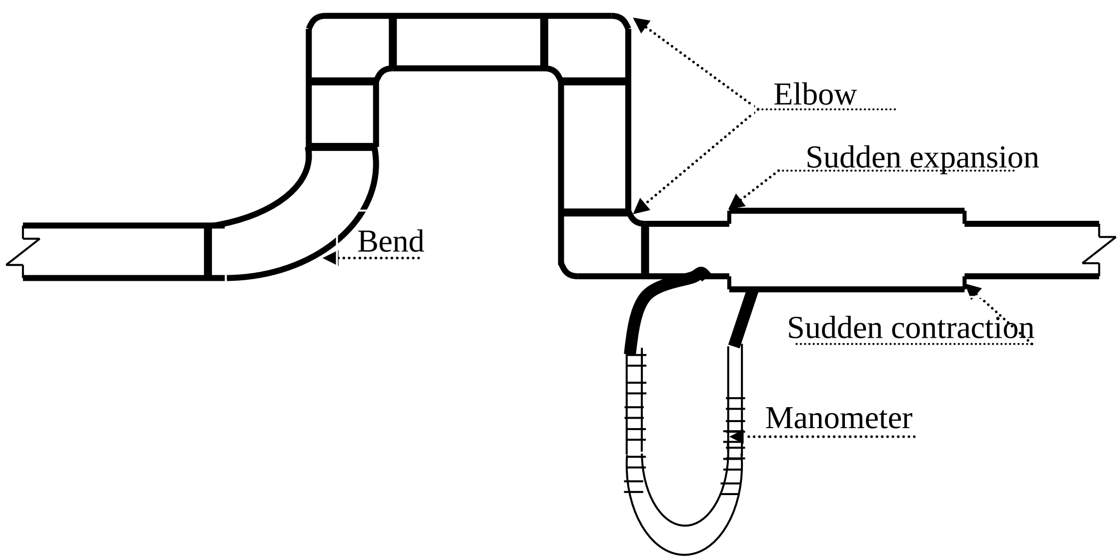
Observation:

1) Measuring tank dimensions

- Length of tank (l) = cm
- Width of tank (b) = cm
- Area of tank (A = l × b) = cm^2

2) Pipe dimensions

Pipe No	Diameter of pipe, D in cm	C/S area of pipe, a in cm^2	C/S area of enlarged part of the pipe, a_1 in cm^2
1			
2			
3			



Experimental Set-up for minor losses in pipe

Procedure:

1. Open the nipple valves at both sides of a particular fitting (say elbow) for which the minor loss coefficient, k is to be estimated. Also close all other nipple valves. By doing so, the manometer will be connected to measure the head loss in that particular fitting.
2. Open the inlet ball-valve fully on supply pipe and close the outlet valve at the discharging end of all five pipes.
3. Remove the air bubbles present in manometer and flexible connecting pipe with the help of air vent valve provided at the head of manometer.
4. Open the outlet of a pipe (in which the minor head loss of the fitting under consideration) to some percentage (say 100%) and wait for some time for the stabilisation of flow. (same valve position should be maintained until step 8)
5. Take the readings of the carbon tetra-chloride levels on both the limbs of the manometer, say h_1 and h_2.
6. Close the outlet valve of the measuring tank and note down the level of water (d_1) with the help of peizometer.
7. Tilt the hopper towards the tank and simultaneously start the stop-
8. After a particular duration of time 't' seconds reverse the hopper and take the peizometer reading, d_2 ('t' may be any convenient time around 60 sec).
9. Repeat steps No. 4 to 8 for the different percentage of outlet valve openings, say 75%, 50% and 25%.
10. Repeat the whole procedure for all the fittings.

Observations and Calculations:

Pipe No And Diameter	Name of the fitting (Example)	Manometer reading: Left limb Level h_1 cm	Manometer reading: Right limb level h_2 cm	Manometer reading: Difference in level $h=h_2-h_2$ cm	Head Difference $h_f = h*12.6$ cm of water	Measuring tank reading: Initial water level d_1 cm	Measuring tank reading: Final water level d_2 cm	Measuring tank reading: Depth of water $D=d_2-d_1$ cm	Actual Discharge $Q_a = \frac{Ad}{t}$ cm^3	Actual velocity $v = \frac{Q_a}{a}$ cm / sec	Actual velocity $v_2 = \frac{Q_a}{a_1}$ cm / sec	Friction factor $k = \frac{2gh_L}{v^2}$ or $k = \frac{2gh_L}{(v-v_2)^2}$	Average friction factor 'k'
For ex. 1" Pipe	Bend												
For ex. 1.5"	Elbow												
For ex. 2" Pipe	Sudden Expan												

Conclusion and remarks on results:

3. VENTURI METER

Aim: Calibration of the Venturimeter.

Apparatus:

1) Venturimeter of three sizes fitted to the three different diameter pipes with supply value and outlet values.
2) Measuring tank with peizometer and scale.
3) Differential U-tube mercuric manometer with scale
4) Stop watch.

Theory: Venturimeter is a simple devise fitted as part of a pipe used to measure the discharge in pipe flow. It is consisting of three component parts, namely convergent cone, throat and divergent cone. Diameter gradually decreases in convergent part and reaches minimum at throat and the same c/s area continues for a small length and further it gradually increases and reaches the original diameter of pipe. Length of the divergent cone is comparably higher then the convergent cone for the smooth transition of flow.

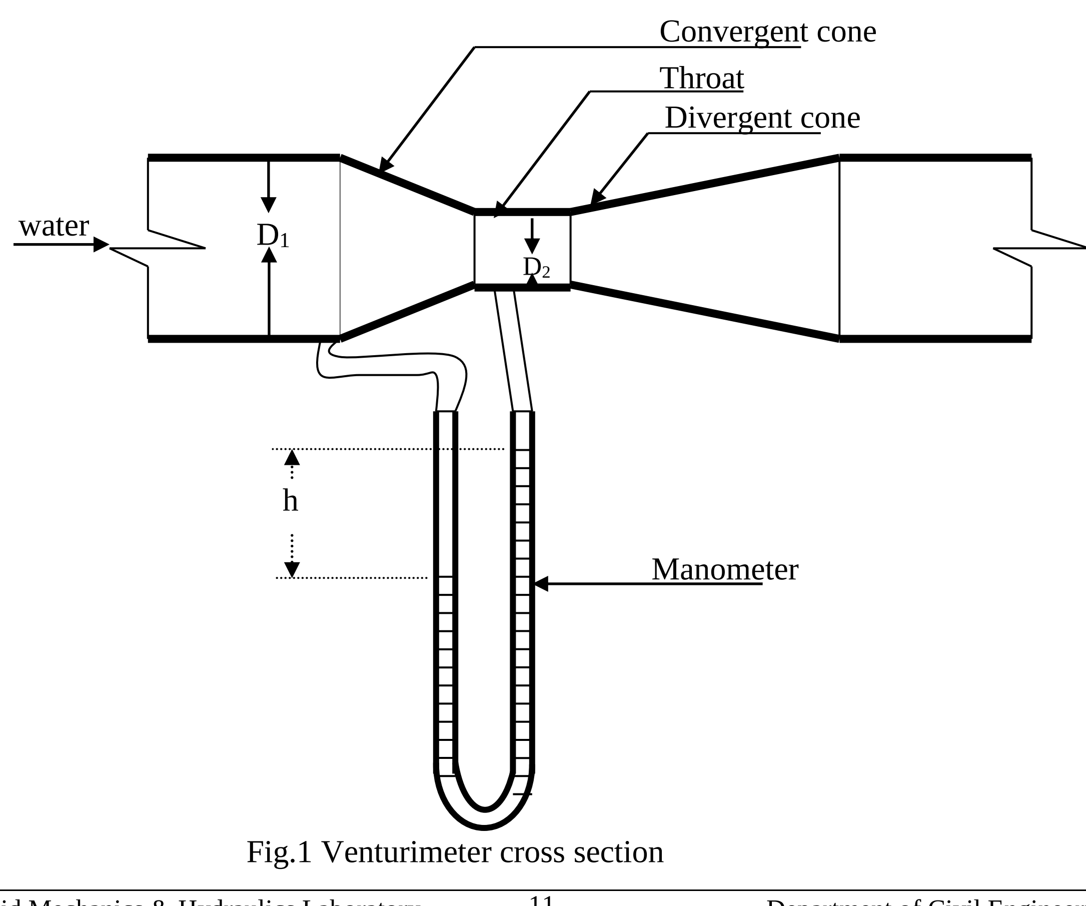


Fig.1 Venturimeter cross section

As the c/s area of pipe is minimum at the throat, the velocity of flow will be maximum and hence pressure at the throat will be minimum. This leads to the pressure difference between the entrance and the throat of the Venturimeter. The pressure difference can be read by the manometer by connecting each of its limb to the entrance and the throat of the Venturimeter. The longitudinal section of Venturimeter is as shown in Fig.1.

Coefficient of discharge is given by

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

The theoretical and actual discharges are given by

$$Q_{th} = \frac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}} \qquad \text{Put} \qquad K = \frac{a_1 a_2 \sqrt{2g}}{\sqrt{a_1^2 - a_2^2}}$$

$$Q_a = c_d \frac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}}$$

$$Q_a = C_d K H^{1/2} \quad \text{or} \quad Q_a = C_d K H^{n}$$

Taking logarithms on both the sides of equation, we get

$$\text{Log } Q = \text{Log } C_d K + n \text{ Log } H$$

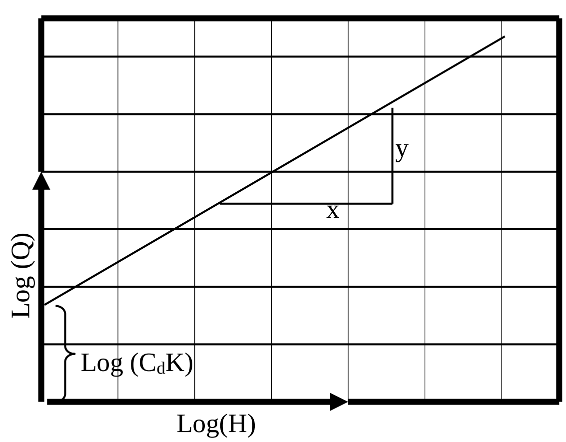


Fig. 2 Plot of Logarithmic values of H and Q

$$C_d = \frac{\text{antilog}\,[\log(C_d K)]}{K}$$

$$n = \frac{\log(Q) - \log(C_d K)}{\log(H)} \qquad \text{OR} \qquad \tan\theta = n = \frac{y}{x}$$

where:-

C_d	=	Coefficient of discharge
Q_d	=	Actual discharge obtained from the measuring tank.
Q_{th}	=	Theoretical discharge in cm^3/sec
a_1	=	C/S area of pipe in cm^2
a_2	=	C/S area of Venturimeter throat in cm^2.
h	=	differential head in cm of mercury as obtained from Manometer
H	=	differential head between the inlet and throat of Venturimeter in cm of water (H =12.6*h)

Observations:

1) Measuring tank dimensions

- Length of tank (l) = cm
- Width of tank (b) = cm
- Area of tank ($A = l \times b$) = cm^2

2) Pipe and Venturimeter dimension

Pipe Dia	Venturimeter entrance		Venturimeter throat		$K = \frac{a_1 a_2 \sqrt{2g}}{\sqrt{a_1^2 - a_2^2}}$
	Dia D_1 cm	C/S area a_1 cm^2	Dia D_2 cm	C/S area a_2 cm^2	
2.0"					
1.5"					
1.0"					

Procedure:

1. Open the nipple valves at the entrance and throat of a Venturimeter for which the calibration is to be carried out. Also close all other nipple valves. By doing so, the manometer will be connected to the Venturimeter under consideration.
2. Open the inlet ball-valve fully on supply pipe and close the outlet valve at the discharging end of all three pipes.
3. Remove the air bubbles present in manometer and flexible connecting pipe with the help of air vent valve provided at the head of manometer.
4. Open the outlet of first pipe to some percentage (say 100%) and wait for some time for the stabilisation of flow. (same valve position should be maintained until step 8)
5. Take the readings of the mercury levels on both the limbs of the manometer, say h_1 and h_2.
6. Close the outlet valve of the measuring tank and note down the level of water (d_1) with the help of peizometer.
7. Tilt the hopper towards the tank and simultaneously start the stop-
8. After a particular duration of time 't' seconds reverse the hopper and take the peizometer reading, d_2 ('t' may be any convenient time around 60 sec).
9. Repeat steps No. 4 to 8 for the different percentage of outlet valve openings, say 75%, 50% and 25%.
10. Repeat the whole procedure for the other two Venturimeters.

Tabulation and Calculations:

Pipe No and diameter	Manometer reading			Head Difference H = h*12.6 cm of water	Measuring tank reading			Actual Discharge $Q_a = \frac{Ad}{t}$ cm^3.	log Q_a	log H	Log C_dK	n
	Left limb Level h_1 cm	Right limb Level h_2 cm	Difference in level $h=h_2$ -		Initial Water Level d_1 cm	Final water level d_2 cm	Depth of water $D=d_2-d_1$					
2inch												
1.5 inch												
1 inch												

Conclusion and remarks on results:- Coefficient of discharge of a Venturimeter should be between 0 to 1. Normally it is around 0.9 and theoretical valve of n is 0.5

4. ORIFICE & MOUTH PIECES

Aim: Calibration of orifices & mouth pieces i.e. estimation of Coefficient of discharge (C_d), Coefficient of velocity(C_v) and Coefficient of contraction(C_c).

Apparatus: 1) Tank with controlled in-flow from top & circular opening on side-wall.

2) Orifices and mouth pieces.

3) Measuring tank with scale and peizometer.

4) Stop watch.

Theory: -An orifice is an opening in the wall of a tank or in a plate which may be fitted in a pipe such that the plate is normal to the pipe axis. Usually an orifice has a sharp edge.

Mouthpieces are the simple devices fitted at the side of tank. A mouthpiece is a short pipe whose length does not exceed two to three times the diameter. It may be of uniform section or may have varying section.

Orifices and mouthpieces are used for discharge measurement (Refer Fig.1). The jet approaching the orifice or mouthpiece continues to converge beyond the entrance till the streamlines are parallel. This section of the jet is, then, a section of minimum area and is known as vena-contracta. Discharge is a function of the height of water above the center of opening and cross sectional area of flow. Discharge from the orifice & mouthpieces are given by equation

$$Q_a = C_d a\sqrt{2gH}$$

where, Q_a = Actual discharge as obtained from the measuring tank in cm^3/sec

$Q_{th} = a\sqrt{2gH}$ =Theoretical discharge in cm^3/sec

a = Cross section of orifices & mouthpieces in in cm^2/sec.

H = Height of water above the opening in cm and

$C_d = \dfrac{Q_a}{Q_{th}}$, Coefficient of discharge.

Theoretical velocity of flow is given by equation $V_{th} = \sqrt{2gH}$

Let x = horizontal distance to the point on the jet from the vana-contracta.

($x = x_1 - x_0$)

x_1 = Reading on horizontal scale after fixing the tip of vertical scale to a point on the jet coming out of orifice or mouth piece

x_0 = Reading on horizontal scale after fixing the tip of vertical scale to a vena-contracta on the jet coming out of orifice or mouth piece

y = vertical distance to the point on the jet from the vana-contracta.

($y = y_1 - y_0$)

y_1 = Reading on vertical scale after fixing the tip of vertical scale to a point on the jet coming out of orifice or mouth piece (corresponding to the reading x_1)

y_0 = Reading on vertical scale after fixing the tip of vertical scale to a vena-contracta on the jet coming out of orifice or mouth piece

We have $x = vt \Rightarrow t^2 = x^2/v^2$ ----------(1)

$y = ut + ½ gt^2$ (but u=0)

$y = ½ gt^2$ ------------(2)

Substituting (1) in (2) we get

Actual velocity, $v_a = \sqrt{\frac{gx^2}{2y}}$

Coefficient of velocity, $C_v = \frac{v_a}{v_{th}}$

The coefficient of contraction can be estimated using the relation

Coefficient of contraction, $C_c = \frac{C_d}{C_V}$

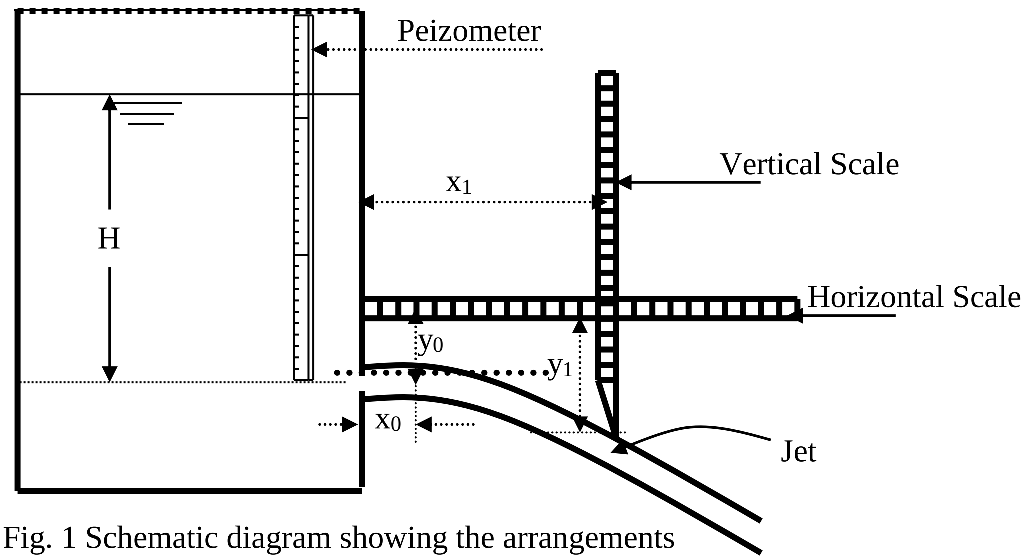


Fig. 1 Schematic diagram showing the arrangements for orifice and mouthpiece Experiment.

Observations:

1) Measuring tank dimensions

Length of tank (l) = cm

Width of tank (b) = cm

Area of tank (A=l*b) = cm^2

2) Orifice and mouth piece dimension

Type of opening	Diameter of pipe, D cm	C/S Area of Pipe, a cm^2
Orifice plate		
Divergent mouth piece		
Convergent and divergent mouth piece		
Uniform C/S area mouth piece		

Procedure:

1. Fix the given orifice plate to the position on the side-wall at the bottom of tank using washer, nuts and bolts.
2. Open the inlet valve to some % (say 25%) and wait for stabilization i.e the level of water in the tank should be stationary to certain head, H over the center of the orifice/mouthpiece. Then take the reading 'H' from the peizometric scale attached to the same tank.
3. Close the outlet valve of the measuring tank and note down the level of water (d_1) with the help of peizometer.
4. Tilt the hopper towards the tank and simultaneously start the stop-watch.
5. After a particular duration of time 't' seconds reverse the hopper and take the peizometer reading, d_2 ('t' may be any convenient time around 60 sec).
6. Locate the veena-contracta (minimum C/S area) of the jet and fix the tip of vertical scale to the top surface of the jet and take the horizontal scale reading x_0 and vertical scale reading y_0.
7. Divide the horizontal length of jet into three equal intervals. At the end of each interval adjust the tip of vertical scale to the top surface of the jet, then take the readings x_1 and y_1 on horizontal scale and vertical scale respectively (totally three sets of reading to the each constant head 'H').
8. Repeat step no 2 to 7 for different height of water 'H' in the tank (at least for three head).
9. Repeat the whole procedure for the mouth pieces.

Observation and calculation table:

Type of Device	Head In Tank H cm	Measuring tank readings					Theoretical discharge in cm^3/sec $Q_{th} = a\sqrt{2gH}$	$C_d=Q_a/Q_{th}$	Sl No of readings taken at different x ordinates	Jet measurement with gauge						Coefficient of velocity $C_v = \sqrt{\frac{x^2}{4Hy}}$	Average of each jet C_v	Average C_v	Average C_d	Avera
		Time (t) sec	Initial d_1 cm	Final d_2 cm	Depth, $d = d_2 - d_1$ cm	Actual discharge in cm^3/sec $Q_{ac} = \frac{A*d}{t}$				x_0 cm	x_1 cm	$x = x_1 - x_0$ cm	y_0 cm	y_1 cm	$y = y_1 - y_0$ cm					
Orifice									1											
									2											
									3											
									1											
									2											
									3											
									1											
									2											
									3											

5. NOTCHES

Aim :- Calibration of the Notches.

Apparatus: -

1) Artificial open canal with inlet and outlet.
2) Rectangular and V-notches
3) Measuring tank with peizometer and scale.
4) Measuring gauge over the canal (sliding vertical scale)
5) Stop watch.

Theory:- A weir has been in use since long time for the measurement of discharge in free surface flows (i.e such flows in which there is a free surface in contact with the atmosphere). A weir can be said to be an orifice across the direction of flow so that the head on its upper edge is zero. Hence, upper edge can be eliminated, leaving only the sides and lower edge (named as weir crest). A weir can be of different shapes-rectangular, triangular, trapezoidal, cippoletti etc. A triangular weir is particularly suited for measurement of small discharges.

Notches are the structural construction component in an open channel, which facilitates the measurement of discharge. It may be constructed with concrete or made of steel. The rate of flow over a given notch or weir depends on the head H, and the geometry of the notch. The head over the notch is to be measured at a distance of about 3 to 4 times H from the crest along the U/S side.

The coefficient of discharge is defined as

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

Theoretical discharge in rectangular notch given by

$$Q_{th} = \frac{2}{3}\sqrt{2g}LH^{\frac{3}{2}} \qquad \text{Put} \quad K = \frac{2}{3}\sqrt{2g}L$$

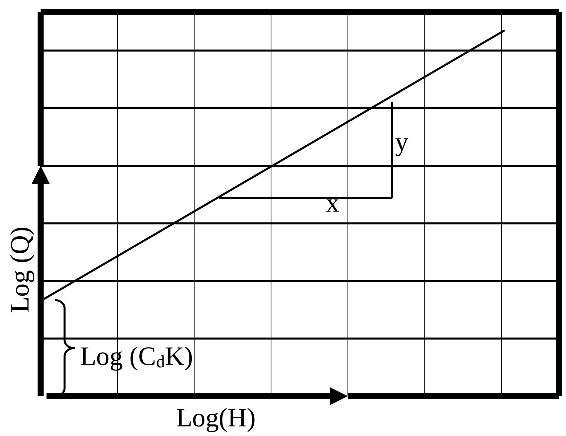
$$Q_{th} = KH^{n} \qquad \text{Then} \quad Q_a = C_d KH^{n}$$

Theoretical discharge in triangular notch given by

$$Q_{th} = \frac{8}{15}\sqrt{2g}H^{\frac{5}{2}}\tan \theta/2 \qquad \text{Put} \qquad K = \frac{8}{15}\sqrt{2g}\tan \theta/2$$

$$Q_{th} = KH^{n} \qquad \text{then} \qquad Q_{a} = C_{d}KH^{n}$$

$$\text{Log } Q = \text{Log } C_dK + n \text{ Log } H$$



$$C_d = \frac{\text{antilog}\left[\log(C_d K)\right]}{K}$$

$$n = \frac{\text{Log}(Q) - \text{Log}(c_d K)}{\text{LogH}} \qquad \text{OR}$$

$$\tan\theta = n = \frac{y}{x}$$

Where:

C_d = Coefficient of discharge

Q_d = Actual discharge obtained from the measuring tank.

Q_{th} = Theoretical discharge

L = Width of rectangular notch.

θ = Angle of triangular notch.

H = Depth of flow above the crest of notch towards its upstream ($H_1 - H_2$).

H_1 = Initial reading in vertical scale to the free surface of the static water.

H_2 = Final reading in vertical scale to the free surface of the flowing water for some % inlet valve opening.

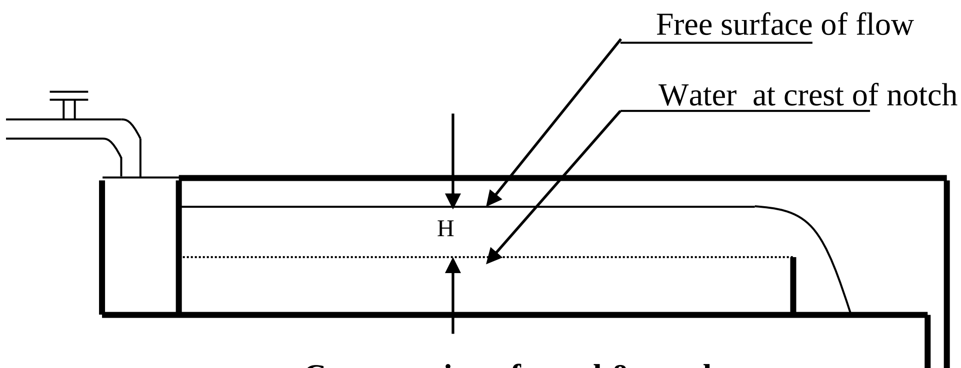
Observation:

1) Measuring tank dimension

- Length of tank (l) = cm
- Width of tank (b) = cm
- Area of tank ($A = l \times b$) = cm^2
- Width of rectangular notch (L) = cm
- Half the angle of triangular notch (θ) = degree

2) Dimensions of notches.

Type of notch	Width of notch crest in cm	Angle of notch In degree	Constants of notch
Triangular Notch	------		$K = \frac{8}{15}\sqrt{2g}\tan \theta/2$
Rectangular Notch		------	$K = \frac{2}{3}\sqrt{2g}L$



Cross-section of canal & notch

Procedure:

1. Fix the given rectangular-notch to the artificial canal with the help of net-bolt and water tight washer.
2. Open the inlet ball-valve fully and wait for some time until gets overflow over the notch, then close the inlet valve and wait until the discharging of surplus water (water stands up to crest level of weir).
3. Adjust the vertical scale tip to the free surface of static water towards the upstream of notch and take the reading H_1
4. Open the inlet ball valve for some % (say for 100%) and wait for the steady state of flow. (valve position should be maintained until step 7)
5. Adjust the vertical scale tip to the free surface of flowing water towards the upstream at distance two to three times the depth of flow (for horizontal free surface) of notch and take the reading H_2
6. Close the outlet valve of the measuring tank and note down the level of water in tank d_1 with the help of peizometer and scale, also at the same instant start the stopwatch.
7. Observe the time in stopwatch, at the instant of completion of 't' seconds ('t' may be any convenient time around 60 sec) note down the level of water in the measuring tank d_2 with the help of same scale and peizometer.
8. Repeat steps No. 4 to 7 for the different percentage of inlet valve opening, say 90%, 80%, 70%, 60%, 50% and 30%.
9. Repeat the whole procedure for the triangular notch

Observations and Calculations:

Type of notch	Vertical scale reading			Measuring tank reading			Actual Discharge $Qa=d*A/t$ cm^3	Log(H)	Log(Qa)	Log(KC_d)	C_d	n
	Initial reading H_1 cm	Final reading H_2 cm	Difference in level $H= H_1 - H_2$ cm	Initial Water Level d_1 cm	Final water level d_2 cm	Depth of water $d=d_2-d_1$						
Rectangular Notch												
Triangular notch												

Conclusion and remarks on results:

6. BROAD CRESTED WEIR

Aim : Calibration the Broad crested weir

Apparatus:

1) U-tube mercuric Manometer.
2) Tilting flume with Pointer gauge
3) Broad crested weir with net bolts and watertight washer.
4) Venturimeter and differential

Theory:-

Same as explained for notches, but for the thickness of the crest of weir, which is considerably broad. Depending on the cross section of the weir, the weirs are classified as (i) Broad crested weir and (ii) Ogee spillway. Both the weir and spillway are the over flow parts of dam or small bund, constructed with concrete as a material. Broad crested weir and spillway are used to discharge surplus water and also can be used for measuring discharges.

The rate of flow per unit length over a given weir depends on the head H, which is the difference in elevation to the surface of water in the upstream side and the elevation of water surface just over the weir. The longitudinal section with the details are shown in Fig.1

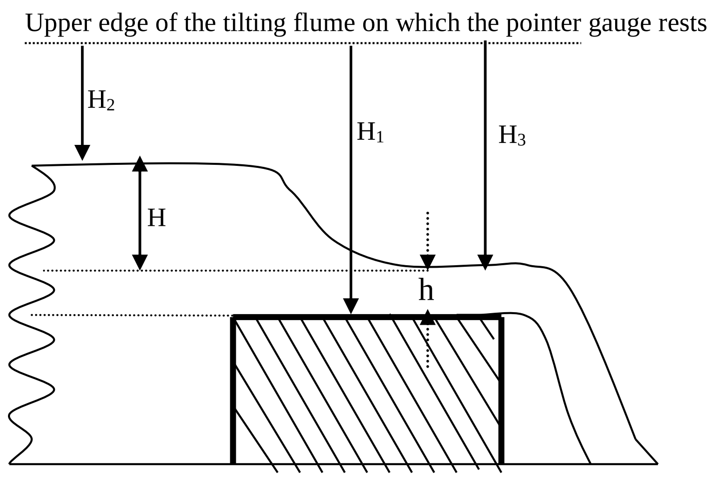


Fig.1 Cross section of Broad crested weir

H_1 = Pointer gauge reading to the crest of the weir in cm.

H_2 = Pointer gauge reading to the surface of water in the u/s side in cm, which is to be

taken atleast at distance of 3 to 4 times the value of H.

H_3 = Pointer gauge reading to the surface of water just over the crest in cm.

H = H_2 -H_3, Head causing the flow in cm.

h = head over the crest in cm.

Coefficient of discharge is given by:

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

The theoretical and actual discharges are given by

$$Q_{th} = Lh\sqrt{2gH}$$

$$Q_a = C_d Lh\sqrt{2gH}$$

where

C_d = Coefficient of discharge

Q_a =Actual discharge in ltres per minute obtained from the chart corresponding to the differential head h_d in mercury manometer fitted to Venturimeter (connected to the supply pipe) in mm of mercury. This shall be converted to cm^3/sec.

Q_{th} = Theoretical discharge cm^3/sec.

L = Length of broad crested weir (usually equal to width of tilting flume)

Observation:

- Length of Broad crested weir along the width of channel (L)= cm.

Procedure:

1. Open the inlet gate-valve fully and wait for some time until water overflows over the weir. Then close the inlet valve and wait until the discharge of surplus water (water stands up to crest level of weir).
2. Adjust the vertical pointer gauge's tip to the free surface of static water in the upstream side of notch and take the reading H_1.
3. Open the inlet ball valve for some % (say for 100%) and wait for stabilsation of steady state of flow. (same valve position should be maintained until step 5)
4. Using the rack and pinion screw of the pointer gauge, take the reading H_2 and H_3 on the free surfaces of flow in the upstream and over the crest respectively..
5. Take the manometer reading fitted to the supply pipe and using the calibrated chart of the manometer, determine the actual discharge.
6. Repeat steps No. 3 to 5 for different percentage of inlet valve opening, say 90%, 80%, 70%, 60%, 50%,30% etc (at least 8 to 10 times)

Tabulation and Calculations:

	Pointer gauge readings					Manometer readings			Actual discharge Qa=d*A/t Cm^3/s	Theoretical discharge Q_{th} in cm^3/s	Coefficient of discharge $C_d = \frac{Q_a}{Q_{th}}$	Average C_d
		Final To Free surface water										
Percentage of inlet valve opening	Initial reading H_1 cm	At u/s H_2 cm	Over the crest H_3 cm	Difference in level at u/s $H= H_1- H_2$ cm	Difference in level at u/s $h= H_1- H_3$ cm	Left limb (Hg) level d_1 cm	Left limb (Hg) level d_2 cm	Head difference $d=d_2-d_1$ cm				
Broad crested weir $Q_{th} = Lh\sqrt{2gH}$												

7. OGEE WEIR (SPILLWAY)

Aim : Calibration the Ogee weir

Apparatus:

1) Tilting flume.
2) Ogee weir nets bolts and watertight washer.
3) Venturimeter and differential U-tube mercuric Manometer.
4) Pointer gauge

Theory:-

Same as explained for broad crested weir, but for the cross sectional shape of the weir. The rate of flow per unit length over a given weir depends on the head H, which is the difference in elevation to the surface of water in the upstream side and the elevation of water surface just over the weir. The longitudinal section with the details are shown in Fig.1

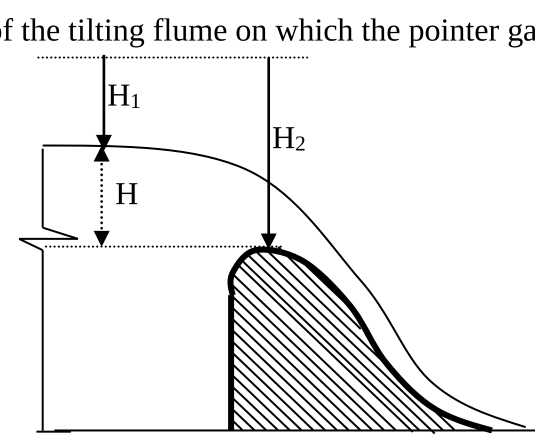


Fig.1 Cross section of Ogee weir

H_1 = Pointer gauge reading to the surface of water in the u/s side in cm, which is to be taken atleast at distance of 3 to 4 times the value of H.

H_2 = Pointer gauge reading to the crest of the weir in cm.

$H = H_1 - H_2$, Head causing the flow in cm.

Coefficient of discharge is given by:

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

The theoretical and actual discharges are given by

$$Q_{th} = L\sqrt{2g}H^{\frac{3}{2}}$$

$$Q_a = C_d L\sqrt{2g}H^{\frac{3}{2}}$$

Put $K = L\sqrt{2g}$

Therefore a general expression for the actual discharge can be written as

$$Q_a = C_d K H^n$$

where

C_d = Coefficient of discharge

n = Constant and nearly equal to 1.5

Q_a =Actual discharge in ltres per minute obtained from the chart corresponding to the differential head h_d in mercury manometer fitted to Venturimeter (connected to the supply pipe) in mm of mercury. This shall be converted to cm^3/sec.

Q_{th} = Theoretical discharge cm^3/sec.

L = Length of broad crested weir (usually equal to width of tilting flume)

Taking logarithms on both the sides of Eq. (1), we get

$$\text{Log } Q = \text{Log } C_d K + n \text{ Log } H$$

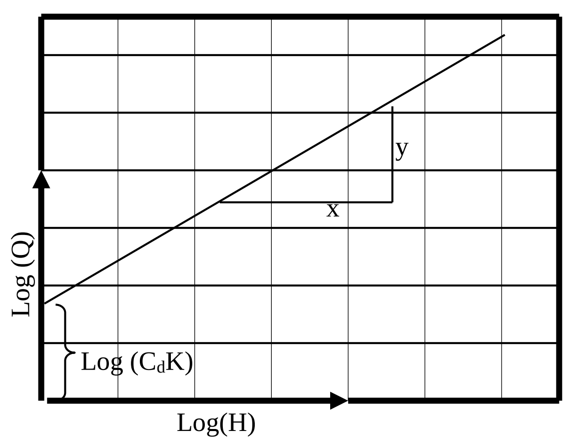


Fig.2 Typical graph of logarithmic discharge vs. Logarithmic Head

$$C_d = \frac{\text{Antilog}[\log(C_d K)]}{K}$$

$$n = \frac{\text{Log}(Q) - \text{Log}(C_d K)}{\text{Log}(H)} \qquad \text{OR}$$

$$\tan\theta = n = \frac{y}{x}$$

Observation:

- Length of Broad crested weir along the width of channel (L)=   cm.

Procedure:

1. Open the inlet gate-valve fully and wait for some time until water overflows over the weir. Then close the inlet valve and wait until the discharge of surplus water (water stands up to crest level of weir).
2. Adjust the vertical pointer gauge's tip to the free surface of static water in the upstream side of notch and take the reading H_2.
3. Open the inlet ball valve for some % (say for 100%) and wait for stabilsation of steady state of flow. (same valve position should be maintained until step 5)
4. Using the rack and pinion screw of the pointer gauge, take the reading H_1 on the free surface of flow in the upstream side.
5. Take the manometer reading fitted to the supply pipe and using the calibrated chart of the manometer, determine the actual discharge.
6. Repeat steps No. 3 to 5 for different percentage of inlet valve opening, say 90%, 80%, 70%, 60%, 50%,30%   etc (at least 8 to 10 times)

Observations and Calculations:

Percentage of inlet valve opening (Ogee spillway)	Vertical scale readings			Manometer readings			Actual Discharge From chart Corresponding to d $Qa = d*A/t$ cm^3/s	Log(H)	Log(Qa)	$Log(C_dK)$	Coefficient of discharge C_d	Slope of line, n
	Initial reading H_1 cm	Final reading H_2 cm	Difference in level $H= H_1 - H_2$ cm	Left limb (Hg) level d_1 cm	Left limb (Hg) Level d_2 cm	Head difference $d=d_2-d_1$ cm						

Conclusion and remarks on results:

8. VENTURI FLUME

Aim : Calibration the Venturi-flume.

Apparatus:

1) Tilting flume.
2) Venturi-flume with net bolts and watertight washer.
3) Venturimeter and differential U-tube mercuric Manometer.
4) Pointer gauge

Theory:-

Venturiflume is a structure in a channel which has a contracted section called throat, downstream of which follows a splayed transition section designed to restore the stream to its original width. It is an open channel counterpart of a Venturimeter, which is used for measuring discharge in open channels. The velocity of flow at the throat is always less than critical velocity and hence the discharge passing through it will be a function of the difference between the depth of flow at the upstream of the entrance section and at the throat. The Plan and longitudinal section of the venturi flume is shown in Fig.1.

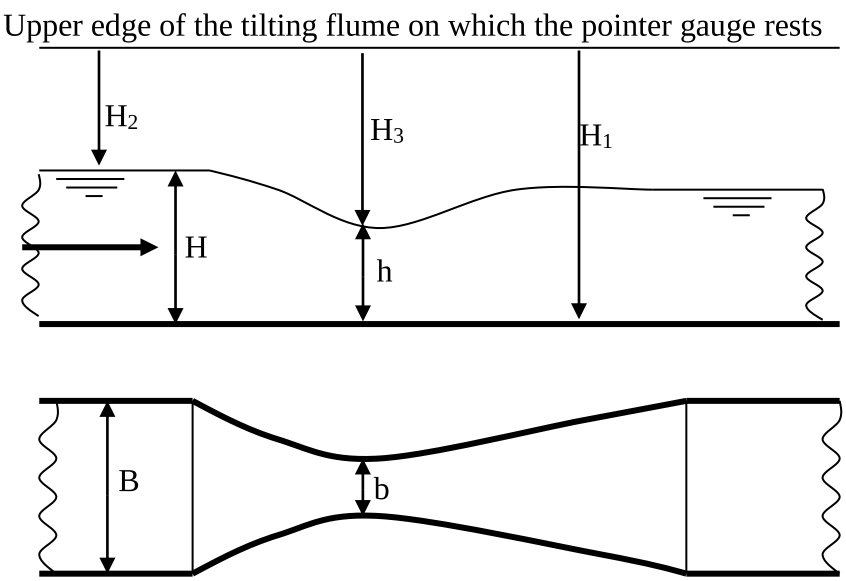


Fig. 1. Plan and Longitudinal section of Venturiflume

B = Width of channel in cm,

b = Width of throat in cm,

H_1 = Pointer gauge reading to the bed of the canal in cm

H_2 = Pointer gauge reading to the free surface of water in the u/s side in cm

H_3 = Pointer gauge reading to the free surface of water at the throat in cm

H = $H_1 - H_2$ = Depth of water in the u/s side in cm.

h = $H_1 - H_3$ = Depth of water at the throat in cm.

The theoretical and actual discharges are given by

$$Q_{th} = \frac{(BH)x(bh)\sqrt{2g(H - h)}}{\sqrt{(BH)^2 - (bh)^2}}$$

$$Q_a = C_d \frac{(BH)x(bh)\sqrt{2g(H - h)}}{\sqrt{(BH)^2 - (bh)^2}}$$

where,

C_d = Coefficient of discharge

Q_a = Actual discharge obtained from the chart corresponding to the differential head in cm^3/sec.

Q_{th} = Theoretical discharge in cm^3/sec.

h_d = Manometeric head in mercury fitted to Venturimeter (connected to the supply pipe).

Observation:

- Width of tilting flume (canal) B= in cm
- Width of throat b = in cm

Procedure:

1. Open the inlet ball-valve fully and wait for some time until water overflows over the notch. Then close the inlet valve and wait until the discharge of surplus water (water stands up to crest level of weir).

2. Adjust the vertical pointer gauge's tip to the free surface of static water in the upstream side of notch and take the reading H_1.
3. Open the inlet ball valve for some % (say for 100%) and wait for stabilsation of steady state of flow. (same valve position should be maintained until step 7)
4. Using the rack and pinion screw of the pointer gauge, take the reading H_1 to the bed of flume, H_2 and H_3 to the free surfaces of flow at the normal section in the u/s and at the throat section.
5. Take the manometer reading fitted to the supply pipe and using the calibrated chart of the manometer, determine the actual discharge.
6. Repeat steps No. 3 to 5 for different percentage of inlet valve opening, say 90%, 80%, 70%, 60%, 50%,30% etc (at least 8 to 10 times)

Tabulation and Calculations:

Percentage of inlet valve opening	Pointer gauge readings					Manometer readings			Actual discharge Qa=d*A/t cm^3 /sec	Theoretical discharge Q_{th} in cm^3/sec	Coefficient of discharge $C_d = \frac{Q_a}{Q_{th}}$	Average C_d
	Initial reading H_1 cm	Final To Free surface water		Difference in level at u/s $H = H_1 - H_2$ cm	Difference in level at throat $h = H_1 - H_3$ cm	Left limb (Hg) level d_1 cm	Left limb (Hg) level d_2 cm	Head difference $d = d_2 - d_1$ cm				
		At u/s H_2 cm	At throat H_3 cm									
Venturi flume $Q_{th} = \frac{(BH)x(bh)\sqrt{2g}}{\sqrt{(BH)^2 - (bh)^2}}(\sqrt{(H-h)}$												

9. IMPACT OF JET

Aim : Calibration of different types of vanes.

Apparatus:

1) Conical vane, flat vane, hemispherical vane.
2) Measuring tank with peizometer and scale.
3) Loading and balancing arrangement frame with scale.
4) Stopwatch etc.

Theory: A jet of fluid emerging from a nozzle has some velocity and hence it possesses a certain amount of kinetic energy. If this jet strikes an obstruction placed 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, in order to distinguish it from the forces due to hydrostatic pressure. Since a dynamic force is exerted by virtue of fluid motion, it always involves a change of momentum, unlike a force due to hydrostatic pressure that implies no motion. Hence the impulse-momentum principle may be utilised to evaluate the hydrodynamic force exerted on a body by a fluid jet.

Theoretical expression for the force exerted by the jet for different types of vanes are as fallow:

a) Flat vane:- $$F_{th} = \frac{wav^2}{g}$$

b) Conical vane :- $$F_{th} = \frac{wav^2[1 + \cos\theta]}{g}$$

c) Hemispherical vane :- $$F_{th} = \frac{2wav^2}{g}$$

Experimental measurment of Force(F_a):

Before jet striking the vane net moment about the pivot is balanced by desplacing the balancing load, keeping movable weight on zero position of scale. Then by taking moment for jet force (F_a) and movable weight (W) about pivot.

$$F_a \times l = W \times x$$

$$F_a = W\frac{x}{l}$$

where

W = weight of moveable load in Newton.

l = Distance between the pivot and vane position in m.

x = Distance in m through which moveable load is displaced to balance the force exerted by jet and to make net moment about the pivot zero.

F_{th} = force exerted by jet on vane in Newton.

w = specific weight of water N/m^3

a = cross section area of jet m^2.

V = velocity of jet in m/sec. θ = vane angle in degree

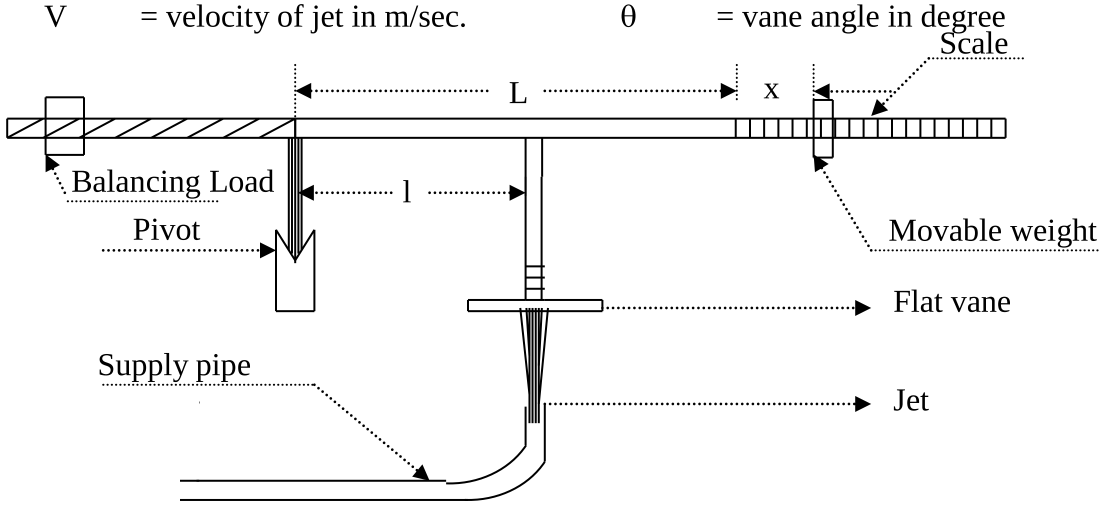


Fig. 1 Schematic diagram showing the arrangements for the measurement of force on vanes .

Observation:

1) Measuring tank dimension

- Length of tank (l) = m
- Width of tank (b) = m
- Area of tank (A = l× b)= m^2

2) Nozzle and other constants of experimental set-up

- Angle of the conical vane (θ) = degree
- Nozzle diameter (d) = m
- C/s area of the jet (a) = m^2
- Distance between pivot and vane position (l) = m

Procedure:

1. Connect the flat vane to the vane-fixing knob.
2. Move the moveable load to the zero position of the scale.
3. Now turn the balancing load in such a way that loading arm should be horizontal so that net moment about pivot became zero.
4. Open the inlet ball-valve to some percentage (say 20%) and same valve position should be maintained until step 8.
5. Jet strikes the vane and force Fa acts on it so that loading arm get deflects, then bring the arm to horizontal position (i.e zero moment about pivot) by moving moveable load on the scale through the distance (x) and note down the same.
6. Close the outlet valve of the measuring tank and note down the level of water (d_1) with the help of peizometer.
7. Tilt the hopper towards the tank and simultaneously start the stop-watch.
8. After a particular duration of time ‘t’ seconds reverse the hopper and take the peizometer reading, d_2 (‘t’ may be any convenient time around 60 sec).
9. Repeat steps No. 4 to 8 for the different percentage of outlet valve opening, say 75%, 50% and 25%.(for four sets of readings).
10. Repeat the whole procedure for the conical vane and hemispherical vane.

Observation and calculation:-

Inlet valve %	Reading in scale ‘x’ cm	Measuring tank reading			Actual Discharge $Q_a = \frac{Ad}{t}$ cm³/sec.	Velocity Of jet $v = \frac{Q}{a}$ cm/sec	Actual force $F_A = w\frac{x}{l}$ N	Theoretical Force F_{th}	Coefficient of force $K = \frac{F_a}{F_{th}}$	Average ‘K’
		Initial Water Level d_1 cm	Final water level d_2 cm	Depth of water $D=d_2-d_1$ cm						
Theoretical force of flat vane given by:- $F_{th} = \frac{wav^2}{g}$										
Theoretical force of conical vane given by:- $F_{th} = \frac{wav^2[1+\cos\theta]}{g}$										
Theoretical force of Hemispherical vane given by:- $F_{th} = \frac{2wav^2}{g}$										

Conclusion and remarks on results:

10. PELTON WHEEL

**Aim : ** To study the performance of Pelton-wheel and to plot the characteristic curves.

Apparatus:

1) Pelton wheel with adjustable supply valve.
2) Centrifugal pump and a motor, for artificial supply of water to the turbine.
3) Loading drum mounted on the shaft of Pelton-wheel and loading arrangements.
4) Pressure gauge to measure the supply head.
5) Calibrated Venturimeter and differential u-tube mercuric manometer (to get actual discharge from chart).
6) Tachometer to measure the speed of Pelton wheel.

Theory: Pelton wheel is an impulse type of turbine with tangential jet striking runner. It works under high head with low specific speed. It is named after Lester A. Pelton in 1880. Runner consists of a circular disc with a number of buckets evenly spaced round its periphery. The buckets have a shape of double semi-ellipsoidal cups. Each bucket is divided into two symmetrical parts by a sharp-edged ridge known as splitter. One or more nozzles are mounted so that each directs a jet along a tangent to the circle through the centres of the buckets called the pitch circle. The jet of water striking on the splitter and divides the jet into two equal portions. Then it flows round the smooth inner surface of the bucket and leaves it at its outer edge. The buckets are so shaped that the angle at the outlet tip varies from 10^0 to 20^0. So that the jet of water gets deflected through 170^0 to 160^0 to its initial jet direction.

Input to the Pelton wheel is measured in terms of discharge (Q) and supply head (H). Discharge to the Pelton wheel is obtained from a chart corresponding to the manometer reading. Head is measured using a pressure gauge. .

In-put power (I/P) = wQH Watts.

Output from the Pelton wheel is measured in terms of Torque, corresponding to the loading on the drum.

$$\text{Output (O/P)} = \frac{2\pi NT}{60} \text{ Watts}$$

$$\text{Overall efficiency, } \eta = \frac{\text{O/P}}{\text{I/P}}(100)\ \%$$

$$\text{Unit speed, } N_u = \frac{N}{\sqrt{H}}$$

$$\text{Unit power, } P_u = \frac{P}{H^{3/2}}$$

$$\text{Unit discharge, } Q_u = \frac{Q}{\sqrt{H}}$$

$$\text{Specific speed, } N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

where

N = Speed of turbine in rpm.

T = Torque applied on the loading drum in N-m

= (W1+W2)(R+r)

W1 = Load on drum in Newton

W2 = Spring scale reading Newton

R = Radius of loading drum in m

r = Radius of rope which transmit the load to the drum in m

Nu = Unit Speed.

Pu = Unit power.

Qu = Unit discharge.

Ns = Specific speed.

Observation: -

Radius of Loading drum and rope.:- Measure the circumferential length of loading drum (x) , then $R = \frac{x}{2\pi}$. For the radius of rope measure the diameter of rope with the help of slide-calliper (d),

- Radius of rope, $r = \frac{d}{2} =$ m
- Radius of drum, R = m

Procedure:

1. Prime the centrifugal pump, by filling water into suction pipe, casing and up-to delivery pipe. Forced water from the air vent indicates the completion of priming. Then close the air-vent, priming inlet and delivery pipe valve.
2. Start the motor and wait while until the pump pickup speed, then open the delivery valve gradually in order the avoid sudden initial torque.
3. Connect the manometer to the Venturimeter and remove the air bubbles, then keep the manometer in read position.

Steps for constant Speed method:

a) Turn the spear valve wheel to adjust the opening of nozzle to some percentage (say 50%).

b) Apply the load on loading drum say one kgf (1 kgf = 9.81 N).

c) Now observe the speed of the shaft with the help of tachometer, then turn the supply valve (speed of the shaft changes, speed increases with increase in discharge and speed decreases with decrease in discharge) and adjust the speed say for 1000rpm.

d) Note down the readings of manometer (h_1-h_2=h), load on the loading platform (W_1), spring scale reading (W_2), speed of shaft with the help of tachometer (N) rpm and pressure gauge reading (p) in kgf/cm^2.

e) Repeat the steps b) to d) with different loads in step b) say for 3kgf, 5kgf, 7kgf, 9kgf, 11kgf, 13kgf and 15kgf.

f) Repeat the steps a) to e) for another spear valve position. in step a) say for 75%.

Steps for constant Head method:

a) Turn the spear valve wheel to adjust the opening of nozzle to some percentage (say 25%).
b) Apply the load on loading drum say one kgf.
c) Now observe the pressure gauge reading (p)kgf/cm^2, then turn the supply valve (pressure head changes, head increases with increase in discharge and head decreases with decrease in discharge) and adjust the head say for 2.5 kgf/cm^2.
d) Note down the readings of manometer(h_1-h_2=h), Load on loading platform(W_1), Spring scale reading (W_2), Speed of shaft with the help of tachometer(N)rpm and pressure gauge reading(p)kgf/sqcm.
e) Repeat the steps b) to d) with different loads in step b) say for 3kgf, 5kgf, 7kgf, 9kgf, 11kgf, 13kgf and 15kgf.
f) Repeat the whole procedure with different spear valve position in step a) say for 100%.

Observation and calculation table for constant Speed method:

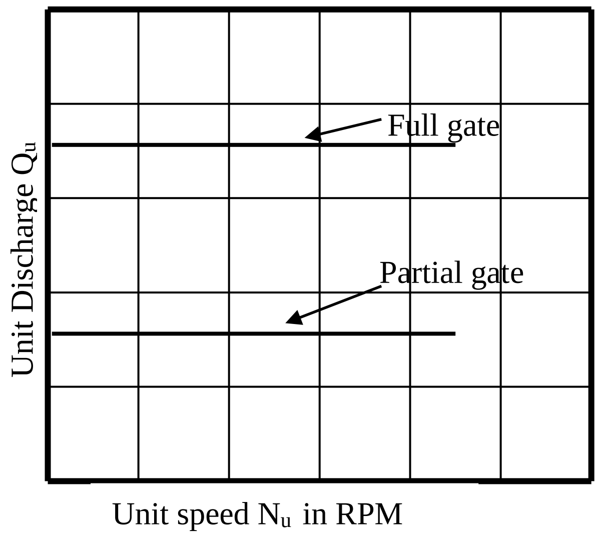
Gate Valve opened in %	Pressure Head in kgf/cm^2	Head In m of water (H) m	Load on Loading drum		Speed N in rpm	Manometer reading 'h' in mm of Hg	Discharge (Q) from chart		Torque (T) N-m	I/P watt	O/P watt	Efficiency η%	N_u	P_u	Q_u	N_s
			W_1	W_2			LPM	m^3/sec								

Observation and calculation table for constant Head method:

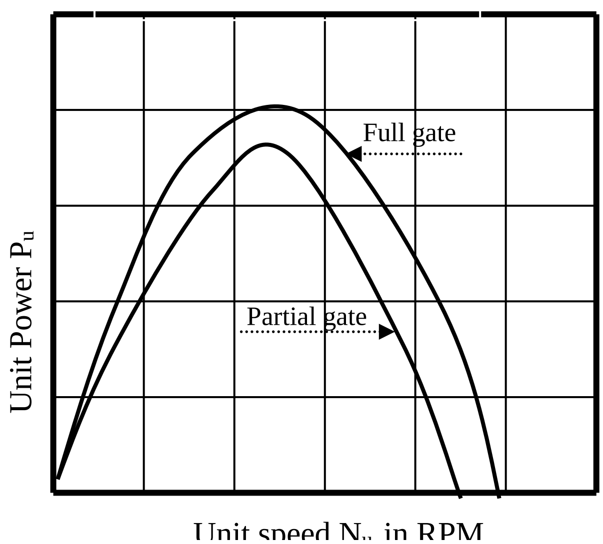
Gate Valve opened in %	Pressure Head in kg/cm^2	Head In m of water (H)	Load on Loading drum		Speed N in rpm	Manometer reading 'h' in mm of Hg	Discharge (Q) from chart		Torque (T)	I/P watt	O/P watt	Efficiency η%	N_u	P_u	Q_u	N_s
			W_1	W_2			LPM	m^3/sec								

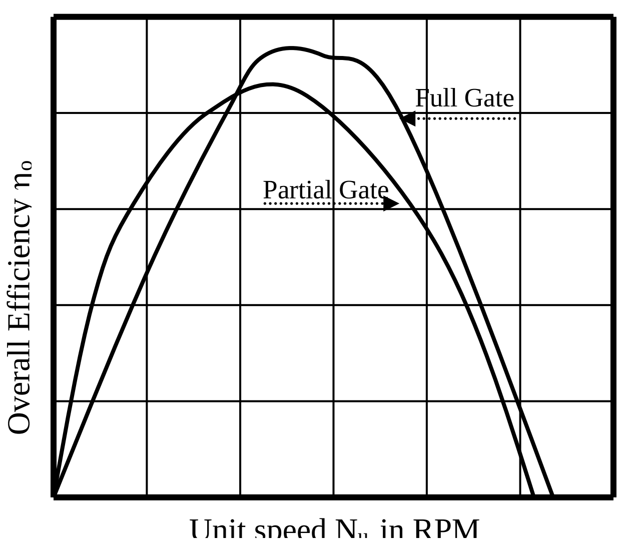
Conclusion and remarks with reference to the characteristics curves:

Typical Characteristics curves:



In each graph two characteristic curve are given for full spear gate valve opening and other for partial spear gate valve opening.





11. FRANCIS TURBINE

Aim : To study the performance of Francis turbine and to plot the characteristic curve.

Apparatus:

1) Francis turbine with adjustable supply valve.
2) Centrifugal pump and a motor, for the artificial supply of water to the turbine.
3) Loading drum mounted on the shaft of Francis turbine and loading arrangement.
4) Two Pressure gauges to measure supply and suction head.
5) Calibrated Venturimeter and differential u-tube mercuric manometer (to get actual discharge from chart).
6) Tachometer to measure the speed of Francis turbine.

Theory: Francis turbine is a reaction type of turbine in which the water enters the turbine in radial direction and leaves in an axial direction. It works under medium head with medium specific speed. It is named after James B. Francis in 1849. Scroll casing, stay ring, stay vane, guide vane, runner (series of curved vanes mounted on circular disc), shaft and draft tube. From penstock water enters the scroll casing which maintains the velocity of flow and pressure. From casing water enters stay vanes through stay ring. Number of stay vanes is usually taken as half the number of guide vanes. Stay vane directs water to guide vane and also acts as a support to turbine by transmitting load to foundation. From stay vane water enters guide vane, which directs the water to the runner in radial direction of which is of adjustable angle. In runner, water flow direction changes from radial to axial. From the runner water passes to the tailrace through draft tube.

Input to the Francis turbine is measured in terms of discharge (Q) and working head (H). Discharge to wheel is obtained from chart corresponding to the manometer reading. Head is measured with pressure gauge reading, there are two pressure gauge one is suction head pressure gauge(p_1) and another is supply head pressure gauge(p_2), difference of elevation between two pressure gauge is considered as the correction head(h_c). Net head on the turbine given by the sum of all three heads(H) in meters of water.

In-put power (I/P) = wQH.Watts

Output from the Francis turbine is measured in terms of Torque, corresponding to the loading on drum.

$$\text{Output(O/P)} = \frac{2\pi NT}{60} \text{ Watts}$$

$$\text{Overall efficiency, } \eta = \frac{O/P}{I/P}(100)\ \%$$

$$\text{Unit speed, } N_u = \frac{N}{\sqrt{H}}$$

$$\text{Unit power, } P_u = \frac{P}{H^{3/2}}$$

$$\text{Unit discharge, } Q_u = \frac{Q}{\sqrt{H}}$$

$$\text{Specific speed, } N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

where

N = Speed of turbine in rpm

T = Torque applied on the loading drum in N-m

= (W1+W2)(R+r)

W1 = Load on drum in Kgf.

W2 = Spring scale reading in Kgf

R = Radius of loading drum in m

r = Half the thickness of belt in m, which transmit the load to the drum.

Nu = Unit Speed.

Pu = Unit power.

Qu = Unit discharge.

Ns = Specific speed.

Observation: -Radius of Loading drum and rope.:- Measure the circumferential length of loading drum(x) , then $R = \frac{x}{2\pi}$. Thickness of the belt is measure with the help of slide-calliper(t), the $r = \frac{t}{2}$

- Radius of the loading drum(R) = m
- Half the thickness of belt (r) = m
- Head correction (h_c) = m

Procedure:

1. Prime the centrifugal pump, by filling water into suction pipe, casing and up-to delivery pipe. Forced water from the air vent indicates the completion of priming. Then close the air-vent, priming inlet and delivery pipe valve.
2. Start the motor and wait while until the pump pickup speed, then open the delivery valve gradually in order the avoid sudden initial torque.
3. Connect the manometer to the Venturimeter and remove the air bubbles, then keep the manometer in read position.

Steps for constant Speed method:

a) Turn the spear valve wheel to adjust the opening of nozzle to some percentage (say 50%).

b) Apply the load on loading drum say one kgf.

c) Now observe the speed of the shaft with the help of tachometer, then turn the supply valve (speed of the shaft changes, speed increases with increase in discharge and speed decreases with decrease in discharge) and adjust the speed say for 1000rpm.

d) Note down the readings of manometer (h_1-h_2=h), Load on loading platform (W_1), spring scale reading (W_2), speed of shaft with the help of tachometer (N) rpm and pressure gauge reading (p) kgf/cm^2.

e) Repeat the steps b) to d) with different loads in step b) say for 3kgf, 5kgf, 7kgf, 9kgf, 11kgf, 13kgf and 15kgf.

f) Repeat the whole procedure with different spear valve position in step a) say for 75%.

Steps for constant Head method:

a) Turn the spear valve wheel to adjust the opening of nozzle to some percentage (say 25%).

b) Apply the load on loading drum say one kgf.

c) Now observe the pressure gauge reading (p) kgf/cm^2, then turn the supply valve (supply pressure head changes: head increases with increase in discharge and head decreases with decrease in discharge) and adjust the head say for 2.5 kgf/cm^2.

d) Note down the readings of manometer (h_1-h_2=h), Load on loading platform (W_1), Spring scale reading (W_2), Speed of shaft with the help of tachometer (N) rpm and pressure gauge reading(p) kgf/cm^2.

e) Repeat the steps b) to d) with different loads in step b) say for 3kgf, 5kgf, 7kgf, 9kgf, 11kgf, 13kgf and 15kgf.

f) Repeat the whole procedure with different spear valve position in step a) say for 100%.

Observation and calculation table for constant Speed method:

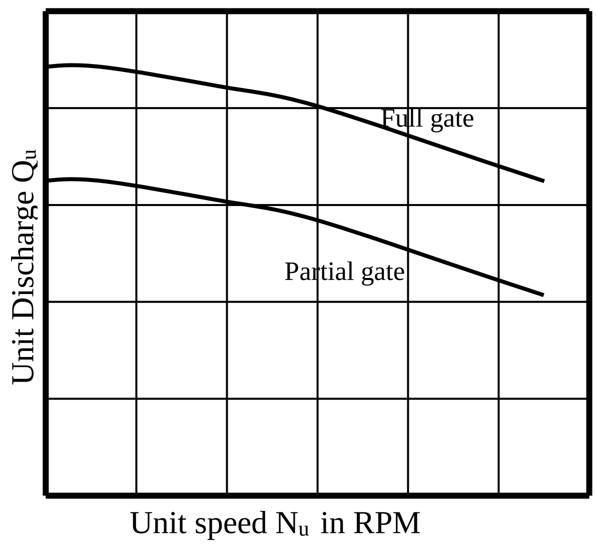
Spear Valve opening in %	Supply Pressure Head in (p_s) kg/cm^2	Suction Pressure Head in (p_d) kg/cm^2	Head in meters of water (H) m	Load on Loading drum		Speed N in rpm	Manometer reading ‘h’ in mm of Hg	Discharge (Q) from chart		Torque (T) N-m	I/P watt	O/P watt	Efficiency η%	N_u	P_u	Q_u	N_s
				W_1	W_2			LPM	m^3/sec								

Observation and calculation table for constant Head method:

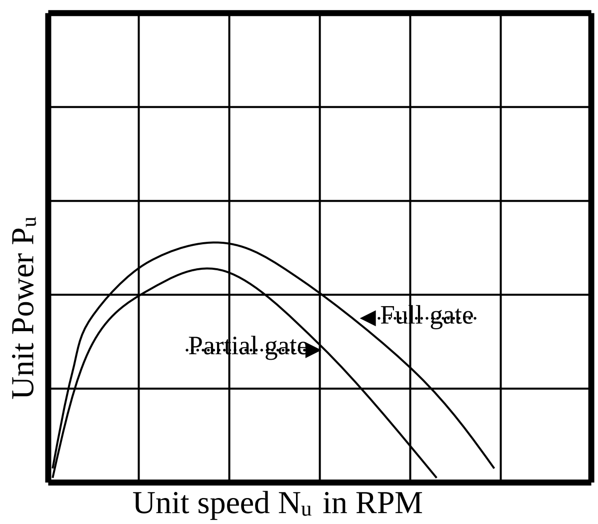
Gate Valve opened	Supply Pressure Head in (p_s) kg/cm^2	Suction Pressure Head in (p_d) kg/cm^2	Head In meters of water (H) m	Load on Loading drum		Speed N in rpm	Manometer reading 'h' in mm of Hg	Discharge (Q) from chart		Torque (T)	I/P watt	O/P watt	Efficiency η%	N_u	P_u	Q_u	N_s
				W_1	W_2			LPM	m^3/sec								

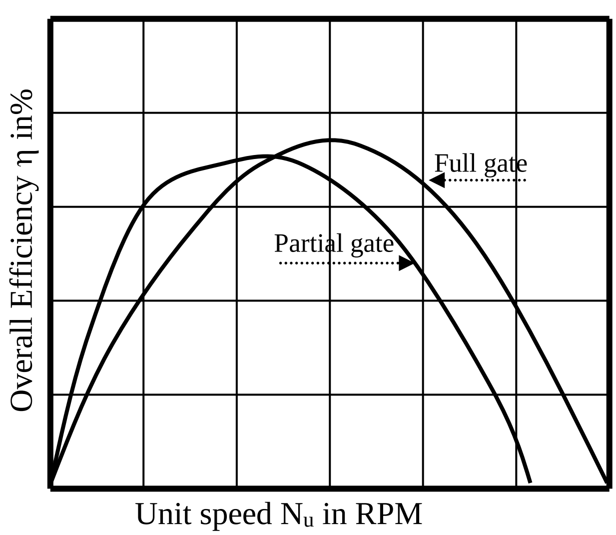
Conclusion and remarks with reference to the characteristics curves:

Typical Characteristics curves:-



In each graph two characteristic curves are given for full spear gate valve opening (Full gate) and other for partial spear gate valve opening (Partial gate).





12. CENTRIFUGAL PUMP

Aim : To study the performance of centrifugal pump and to plot the characteristic curves.

Apparatus:

1) Centrifugal pump with adjustable speed.
2) 3-Phase Watt meter to measure the input power to Centrifugal pump in kW
3) Two Pressure gauges to measure suction head and delivery head.
4) Calibrated Venturimeter and differential u-tube mercuric manometer (to get actual discharge from chart).
5) Tachometer to measure the speed of centrifugal pump.

Theory: Centrifugal pumps are classified under rotodynamic type of pump in which a dynamic pressure is developed which enables the lifting of liquids from a lower to a higher level. The basic principle on which a centrifugal pump works is that when a certain mass of liquid is made to rotate by an external force, it is thrown away from the central axis of rotation and a centrifugal head is impressed which enables it to rise to a higher level. Now if more liquid is constantly made available at the centre of rotation, then continuously water rises to the higher level through the delivery pipe.

Input to the centrifugal pump is electric power and it is measured with watt-meter in kilo-watt (P)

Out-put from the centrifugal pump is measured in terms of discharge (Q) and Net head (H). Discharge from pump is obtained from chart corresponding to the manometer reading. Head is measured with pressure gauge readings, there are two pressure gauges, one is suction head pressure gauge (p_s) and another is delivery head pressure gauge (p_d). Difference of elevation between two pressure gauges is considered as the correction head (h_c). Net head on the turbine is the sum of all three heads (H) in meters of water.

Out-put power (I/P) = wQH.

Overall efficiency(η) = $\frac{O/P}{I/P}(100)$ %

Unit speed, $N_u = \frac{N}{\sqrt{H}}$

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

Unit discharge, $Q_u = \frac{O}{\sqrt{H}}$

Specific speed, $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

where

N	= Speed of the shaft in rpm
H	= total head in meter of water
P	=Power in Watt
Q	=Discharge in m^3/sec
Nu	= Unit Speed.
Pu	= Unit power.
Qu	= Unit discharge.
Ns	= Specific speed.

Observation: -

- Head correction (h_c) = m

Procedure:-

1. Prime the centrifugal pump, by filling water into suction pipe, casing and up-to delivery pipe. Forced water from the air vent indicates the completion of priming. Then close the air-vent, priming inlet and delivery pipe valve.
2. Start the motor and wait till the pump pickups speed, then open the delivery valve gradually in order the avoid sudden initial torque.
3. Connect the manometer to the Venturimeter and remove the air bubbles, then keep the manometer in read position.

Steps for constant Speed method:

a) With the help of speed adjusting knob of motor fix the running speed of centrifugal pump say 900 rpm.

b) Now turn the delivery valve to control the discharge and open the valve to some percentage say for 100% opening.

c) Note down the readings of manometer (h_1-h_2=h), wattmeter. Measure the speed of shaft (N) with the help of tachometer in rpm, suction head pressure gauge reading (p_s) in kgf/cm^2 and delivery head pressure gauge reading (p_d) in kgf/cm^2

d) Repeat the steps b) and c) with different percentage delivery valve opening say 80%, 60%, 40%, and 20%.

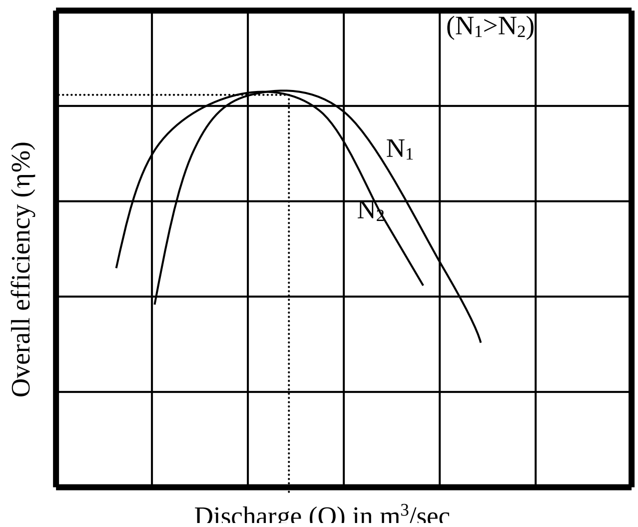
e) Repeat the whole procedure with different speed of centrifugal pump say 1000rpm and 1200rpm in step a)

Observation and calculation table with constant speed:-

Speed N in rpm	Percentage of valve opening	Section Pressure head in (p_s) kg/cm^2	Delivery Pressure head in (p_d) kg/cm^2	Net head in m of water (H)	Manometer reading 'h' in mm of Hg			Discharge (Q) from chart		I/P Power in watt	O/P power (wQH) in watt	Efficiency η%	N_u	P_u	Q_u	N_s
					Left limb reading h_1 in mm	Right limb reading h_2 in mm	Head difference $h=h_1-h_2$ in mm of Hg	LPM	m^3/sec							

Conclusion and remarks with reference to the characteristics curves:

Typical Characteristics curves:-



In each graph two characteristics curves are given for two different constant speeds N_1 and N_2