

## CALIBRATION OF NOTCHES

A notch may be defined as an overflow opening provided in the side of a tank or a small channel such that the liquid surface in the tank or channel is below the top edge of the Opening. Notches are usually used in narrow channels in order to measure the small charges accurately.

Notches are classified according to the shape of the opening as rectangular notch, triangular notch (or v-notch), trapezoidal notch, parabolic notch, stepped notch etc. Notches may also be classified according to the effect of the nappe emerging from a notch, as a notch with end contractions and a notch without end contractions or suppressed notch.

A Triangular notch may be further classified as  $90^\circ$  V-notch and  $60^\circ$  V-notch depending upon the angle between the two sloping sides.

Cipolletti notch is a specific type of Trapezoidal notch, with side slopes of 1 horizontal to

4 vertical i.e.  $n/2 = 1/4$ .

The discharge equations for triangular, rectangular and trapezoidal (cipolletti) notches can be written as:

### 1. Triangular notch;

$$Q_{actual} = \frac{8}{15} C_d \sqrt{2gH^{\frac{5}{2}}} \tan \frac{\theta}{2} \dots \dots eq.(1)$$

### 2. Rectangular notch (Suppressed):

$$Q_{actual} = \frac{2}{3} C_d \sqrt{2gH^{\frac{3}{2}}} L \dots \dots eq.(2)$$

where:

$C_d$  is the coefficient of discharge.

H is the head over the notch.

L is the length of the notch at crest level.

In general, the above equations can be written as:

$$Q_{actual} = KH^N \dots \dots \dots eq.(3)$$

Where:

K is the constant for the given notch & N is the index.

The purpose of calibration of the notches is to find the constant K and the index N. In the laboratory it is necessary to measure  $Q_{actual}$  and the head over the notches H to calculate K and N.

After measuring  $Q_{actual}$  and H, we have to draw a curve of  $Q_{actual}$  v/s H. But this curve will be non linear. Because of non linearity, interpolation or extrapolation of discharge Q for a given head H becomes difficult. In order to overcome this difficulty the eq.(4) can be expressed in terms of logarithmic functions as:

$$\text{Log } Q = N \text{ log } H + \text{log } K \text{ Eq(4), Which represents a straight line.}$$

The slope of the curve is

$$N = \frac{\text{Log } Q - \text{log } K}{\text{Log } H} \dots \dots \dots eq.(5)$$

For H=1, log Q= log K, Which represents the interception of log Q v/s log H curve on y-axis.

If we express the above equation in terms of anti logarithm function, then

$$Q = K \dots \dots \dots$$

From the above equation the value of C for the given notch can be found out.

## Experiment No. 1

### Calibration of 90° V-Notch

**Aim of the experiment:** To determine the coefficient of discharge  $C_d$ , constant  $K$  & the index  $N$  for the given notch.

**Apparatus required:** Hook gauge, a 90° V-notch, scale & a stop watch.

**Experimental procedure:**

1. Note down the least count of the hook gauge.
2. Measure the dimensions of the measuring tank.
3. Maintain the water level just at the sill of the notch and note down the no-flow head over the notch (initial level of hook gauge) by using the hook gauge.
4. By operating the control valve at the upstream side of the notch slowly increase the head over the notch & when flow becomes steady note down the final reading of the hook gauge.
5. Note down the time in seconds required to collect 5 cm of water, in the measuring tank
6. Repeat the steps 4 & 5 for 5 or 6 times.
7. Tabulate the readings as shown in the table.
8. Draw a curve of  $Q$  v/s  $H$  on a log-log graph.
9. Determine the value of  $C_d$  &  $N$ .

**Specimen Calculations: For Trial No 1**

Head over the notch ( $H$ ) = Final hook gauge reading - Initial hook gauge reading

$$H = \dots\dots\text{cm.}$$

Time taken for 5cm ( $h$ ) rise of water in collecting tank,  $t = \text{sec}$

$$Q_{\text{actual}} = \frac{LxBxh}{t} \text{m}^3 / \text{sec}$$

Draw a graph of  $Q$  vs  $H$  on log-log graph.

From the graph the slope of the line,  $N =$

$$Q = K H^N \quad \text{for } H=1$$

Where,  $\theta = 90^\circ$

$$K = \frac{8}{15} C_d \sqrt{2g} \tan^{\frac{N}{2}} =$$

$$C_d = \frac{15K}{8\sqrt{2g} \tan^{\frac{N}{2}}} =$$

**Conclusions:**

**TABLE -1**

**Calibration of 90° V-Notch**

**Dimensions of measuring tank:** Length, L = cm  
 Breadth, B = cm  
 Depth of water collected =  
 Least count of hook gauge = mm

Sl No	Head over 90° V-notch			Time taken for 5 cm rise of water in the measuring tank 't' sec	$Q_{\text{actual}} = LxBxh/t$ m <sup>3</sup> /sec
	Final hook gauge readings (cm)	Initial hook gauge readings (cm)	H= Difference of hook gauge readings (metres of water)		
1					
2					
3					
4					
5					

## Experiment No. 2

### Calibration of Broad Crested Weir

**Aim of the experiment:** To determine the coefficient of discharge  $C_d$ , constant  $K$  & the index  $N$  for the given weir.

**Apparatus required:** Hook gauges,  $90^\circ$  V-notch, broad crested weir.

#### Experimental procedure:

1. Note down the least counts of the hook gauges near  $90^\circ$  v-notch & broad crested weir.
2. Maintain the water level just at the sill of the notch and the weir and note down the no flow head over the notch and the weir (initial level of hook gauge) by using the hook gauges.
3. By operating the control valve at the upstream side of the notches slowly increase the head over the notch and the weir & when flow becomes steady note down the final readings of the hook gauges.
4. Repeat the step 3 for 5 or 6 times.
5. Tabulate the readings as shown in the table.
6. Draw a curve of  $Q$  v/s  $H$  on a log-log graph.
7. Determine the value of  $C_d$  &  $N$ .

#### Specimen Calculations: For trial No.1

Head over the  $90^\circ$  v-notch ( $H$ ) = Final hook gauge reading - Initial hook gauge reading

=..... m.

$$Q_{actual} = \frac{8}{15} C_d \sqrt{2gH^{\frac{5}{2}}} \tan \frac{\theta}{2} \dots m^3 / Sec$$

where  $C_d = 0.62$  (assumed),  $\theta = 90^\circ$

Head over the broad crested weir ( $H_1$ ) = Final hook gauge reading — initial hook gauge reading

=..... m.

Draw a graph of  $Q$  vs  $H_1$  on a log-log scale

From the graph the slope of the curve,  $N =$

$$Q = K H_1^N$$

Where  $K = 17 C_d L$

Where  $L =$  length of the broad crested weir

$$C_d = \frac{K}{17L}$$

## Experiment No. 3

### Calibration of Venturimeter

Venturimeter is a metering device used for the measurement of rate of flow in a pipe line. The principle on which the venturimeter works is that a pressure difference is created by gradually reducing the cross sectional area of flow from inlet to the throat.

The main parts of the venturimeter are: inlet section, convergent cone, throat and divergent cone. The inlet section is of the same diameter as that of the pipe. The convergent cone is a short pipe, which tapers from inlet section to the throat. Divergent section is relatively a large cone, whose cross sectional area is gradually increases from throat to the original size of the pipe. In the convergent cone the velocity gradually increases from inlet section to the throat and the pressure decreases from inlet to the throat, in order to satisfy Bernoulli's theorem, This pressure difference is made use for the measurement of discharge. It is to be noted that only the inlet section and the throat is used for metering purpose and not the throat and the divergent cone.

#### Observation.

Sl.No	Manometer reading			Head of water $H=h \times 12.6$ (m)	Time taken to collect 'R' m rise of water in secs	Actual discharge $Q_a$ (m <sup>3</sup> /sce)	Theoretical discharge (Qt) (m <sup>3</sup> /sec)	Cd
	h <sub>1</sub> (cm)	h <sub>2</sub> (cm)	h=h <sub>1</sub> +h <sub>2</sub> (cm)					

The discharge equation for the venturimeter is:

$$Q = \frac{C_d A_1 A_2 \sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}}$$

Where  $A_1$  is the cross sectional area of flow at the inlet

$A_2$  is the cross sectional area of flow at the throat

H is the venturimeter head

$C_d$  is the coefficient of discharge

the above equation can be written as:

in general  $Q = K\sqrt{H}$ , where

$$K = \frac{C_d A_1 A_2 \sqrt{2g}}{\sqrt{A_1^2 - A_2^2}}$$

And therefore,  $C_d = \frac{K\sqrt{A_1^2 - A_2^2}}{A_1 A_2 \sqrt{2g}}$

**Aim of the experiment:** To determine the coefficient of discharge  $C_d$  constant K & the index N.

**Apparatus required:** Venturimeter experimental setup, stop watch, measuring tank and scale vernier-caliper.

**Experimental procedure:**

1. Note down the dimensions of the measuring tank.
2. Measure the diameter of the section and throat by using a vernier-caliper.
3. By operating the inlet valve adjust the flow through the venturimeter
4. Note down the differences in levels of mercury column in the two limbs of the differential manometer.
5. By using a stop watch, register the time taken in seconds to collect 5 cm rise of water in the measuring tank.
6. Repeat the steps 4 & 5 for 5 or 6 times by increasing the discharge through the venturimeter each time.
7. Draw a graph of Q v/s H on a log-log scale.
8. Calculate the values of  $C_d$  & N.

**Specimen Calculations: For Trail No. I**

$$\text{Area of the inlet, } A_1 = \frac{fd_1^2}{4} = \quad m^2 =$$

$$\text{Area of the inlet, } A_2 = \frac{fd_2^2}{4} = \quad m^2 =$$

$$\text{Venturimeter head, } H = X \left( \frac{S_2}{S_1} - 1 \right) = \text{ meter of water}$$

Where,

$S_1$  = Specific gravity of water = 1

$S_2$  = Specific gravity of mercury = 13.6

$D_1$  = Diameter of inlet section

$D_2$  = Diameter of throat section

X = Deflection of mercury column in the two limbs of differential manometer in m

$$Q = \frac{LxBxh}{t} = \quad m^3 / \text{Sec}$$

Where,

L = Length of the collecting tank in m

B = Breadth of the collecting tank in m

H = Rise in water level in time t sec = 5 cm

Plot Q vs H on a log-log graph

From the graph, the slope of the line, N=

$$\text{When } H=1, Q = K, \text{ and therefore, } Cd = \frac{K\sqrt{A_1^2 - A_2^2}}{A_1 A_2 \sqrt{2g}}$$

**TABLE -4****Calibration of Venturimeter****Dimensions of measuring tank:**

Length, L = m  
 Breadth, B = m  
 Height of water, h =

Diameter of inlet,  $d_1 =$  m

Diameter of throat,  $d_2 =$  m

Sl. No.	Deflection of differential manometer, x (cm of Hg)	Venturimeter head, $H=x(S_2/S_1-1)$ (meter of water)	Time taken to collect 5 cm rise of water in the measuring tank, t (seconds)	$Q(LxBxh)/t$ ( $m^3/Sec$ )
1.				
2.				
3.				
4.				
5.				

**Conclusions:**

## Experiment No. 4

### Calibration of Venturiflume

Venturiflume is a metering device used for the measurement of rate of flow in open channel. The basic principle on which the venturiflume works is same as that of an venturimeter.

The main parts of the venturiflume are: inlet section, convergent section, throat and divergent section. The inlet section is same as that of the approach channel. The convergent section tapers from inlet section to the throat. Divergent section is relatively large, whose cross sectional area is gradually increases from throat to the original size of the channel. In the convergent section the velocity gradually increases from inlet section to the throat and the pressure head decreases from inlet to the throat, in order to satisfy Bernoulli's theorem. The pressure head difference is made use for the measurement of discharges. It is to be noted that only the inlet section and the throat is used for metering purpose and not the throat and the divergent section.

The discharge equation for the venturiflume is:.

$$Q = \frac{C_d A_1 A_2 \sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}}$$

Where

$A_1$  is the cross sectional area of the approach channel

$A_2$  is the cross sectional area of flow at the throat

H is the venturiflume head

$C_d$  is the coefficient of discharge

the above equation can be written as:

In general,  $Q = K \sqrt{H}$ , where

$$K = \frac{C_d A_1 A_2 \sqrt{2g}}{\sqrt{A_1^2 - A_2^2}}$$

And therefore,  $C_d = \frac{K \sqrt{A_1^2 - A_2^2}}{A_1 A_2 \sqrt{2g}}$

**Aim of the experiment:** To determine the coefficient of discharge  $C_d$  constant  $K$  & the index  $N$ .

**Apparatus required:** Venturiflume experimental setup, stop watch, measuring tank and scale

**Experimental procedure:**

1. Note down the dimensions of the measuring tank.
2. Measure the width of the approach channel and throat by using a scale.
3. By operating the inlet valve adjust the flow through the venturiflume.
4. Note down the head differences at the approach channel and the throat by using hook gauges.
5. By using a stop watch, register the time taken in seconds to collect 5 cm rise of water in the measuring tank.
6. Repeat the steps 4 & 5 for 5 or 6 times by increasing the discharge through the venturiflume each time.
7. Draw a graph of  $Q$  v/s  $H$  or a log scale.
8. Calculate the values of  $C_d$  &  $N$ .

**Specimen Calculations: For Trail No. I**

Area of the inlet,  $A_1 = B$  (width of approach channel) x  $H_1$  (Head difference at the approach channel)  
=  $\text{m}^2$

Area of the throat,  $A_2 = B$  (width of the throat) x  $H_2$  (Head difference at the throat) =  $\text{m}^2$

Venturiflume head,  $H = H_1 - H_2 =$  metre of water

$$Q = \frac{LxBxh}{t} = \text{m}^3 / \text{Sec}$$

Where,

$L$  = length of the collecting tank in m

$B$  = breadth of the collecting tank in m

$h$  = rise in water level in time  $t$  sec = 5 cm

Plot  $Q$  vs  $H$  on a log-log graph

From the graph, the slope of the line,  $N =$

When  $H=1$ ,  $Q = K$ , and therefore,  $C_d = \frac{K \sqrt{A_1^2 - A_2^2}}{A_1 A_2 \sqrt{2g}}$

**TABLE -5****Calibration of Venturiflume****Dimensions of measuring tank:**

Length, L = m

Breadth, B m = m

Height of water, h = 5cm

Least count of hook gauge = mm

Sl No	Head at approach channel			Head at the throat			$Q_{\text{actual}}$ (m <sup>3</sup> /sec)
	Final hook gauge readings (cm)	Initial hook gauge readings (cm)	Difference H (m)	Final hook gauge readings (cm)	Initial hook gauge readings (cm)	Difference H <sub>1</sub> (m)	
1							
2							
3							
4							
5							
6							

**Conclusions:**

## Experiment No. 5

### Determination of Hydraulic Coefficients for an Orifice or A Mouthpiece

**Aim of the experiment:** To determine the hydraulic coefficients  $C_d$ ,  $C_v$ ,  $C_c$ , and  $C_r$  for a given orifice or a mouthpiece.

**Apparatus required:** Experimental setup of orifices, points gauge, stop watch, measuring tank, scale and vernier calipers.

#### Experimental procedure:

1. By using slide caliper, find out the diameter of the given orifice or a mouthpiece.
2. Note down the dimensions of the measuring tank.
3. By operating the inlet valve, maintain a constant head(h) over the orifice.
4. Note down the required to collect 5 cm rise of water in the collecting tank.
5. By using point gauge measure the x and y co-ordinates from vena-contracta section.
6. Repeat the steps 4 & 5 by varying the head over the orifice or a mouthpiece.

#### Specimen Calculations: For Sl. No. 1

##### A. Orifice

Area of orifice,

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

Theoretical discharge,  $Q_{th} = a \sqrt{2gh} = \quad \quad \quad m^3 / Sec$

Actual discharge,  $Q_{act} = \frac{LxBxH}{t} = \quad \quad \quad m^3 / Sec$

Coefficient of discharge,  $C_d = \frac{Q_{act}}{Q_{th}} =$

Coefficient of velocity,  $C_v = \sqrt{\frac{x^2}{4yh}}$

Coefficient of contraction,  $C_r = \left( \frac{1}{C_v^2} - 1 \right)$

Where,

d = diameter of Orifice

H = head over the orifice

L = Length of the collection tank

B = breath of the collecting tank

H= rise in water level in time t Sec

X,Y are the horizontal and vertical co-ordinates of any point on the jet measured from vena-contracta section.

Conclusions:

**TABLE -8**

**Determination of Hydraulic Coefficients for an Orifice or A Mouthpiece**

Diameter of the orifice, d =                      cm

Dimensions of measuring tank:

Length, L    =                      m

Breadth, B    =                      m

Height of water, H                                =                      m

Sl. No	Head over the orifice h(m)	Actual discharge $Q_{act}=(LBH) / t$ (m <sup>3</sup> / sec)	Theoretical discharge $Q_{th}=a \sqrt{2gh}$ (m <sup>3</sup> /sec)	Horizontal co-ordinate x (cm)	Vertical co-ordinate y(cm)	Coeff. of discharge $C_d$	Coeff. of velocity $C_v$	Coeff. of contraction $C_c$	Coeff. of resista $C_r$
1									
2									
3									
4									
5									
6									

**Specimen Calculations: For Sl.No.1****B. Standard Cylindrical Mouthpiece**

Area of mouth piece,

$$a = \frac{f}{4} d^2 = \quad m^2$$

$$\text{Theoretical discharge, } Q_{th} = a\sqrt{2gh} = \quad m^3 / \text{sec}$$

$$\text{Actual discharge, } Q_{act} = \frac{LxBxH}{t} = \quad m^3 / \text{sec}$$

$$\text{Coefficient of discharge, } C_d = \frac{Q_{act}}{Q_{th}} =$$

$$\text{Coefficient of velocity, } C_v = C_d$$

$$\text{Coefficient of contraction, } C_c = 1 (\because C_d = C_v \times C_c)$$

$$\text{Coefficient of resistance, } C_r = \left( \frac{1}{C_v^2} - 1 \right)$$

Where, d = diameter of mouthpiece

H = head over the mouthpiece

L = length of the collecting tank

B = breadth of the collecting tank

H = rise in water level in time t sec

**Conclusions:**

**TABLE -8 (B)**

**DETERMINATION OF HYDRAULIC COEFFICIENTS FOR MOUTH PIECE**

Diameter of the mouth piece, d=            cm

Dimensions of measuring tank:

Length, L                                    =                    m  
 Breadth, B                                 =                    m  
 Height of water, H                       =                    m

Sl. No	Head over the mouth piece H (m)	Actual discharge $Q_{act}(LxBxH)/t$ (m <sup>3</sup> /sec)	Theoretical discharge $Q_{th}=a \sqrt{2gh}$ (m <sup>3</sup> /sec)	Coefficient of discharge $C_d$	Horizontal Coordinate(x)	Vertical Co-ordinate (y)	Coefficient of velocity $C_v$	Coefficient of resistance $C_r$
1.								
2.								
3.								
4.								
5.								
6.								

Conclusions:

## Experiment No. 9

### Impact of Jet on Vanes

A jet of fluid issuing from a nozzle possesses kinetic energy. If the jet strikes an obstruction placed in its path, it will exert a force on the obstruction and this impressed force is known as impact force or hydrodynamic force. The general equation for the theoretical force exerted on the surface of the vane is given by:

$$F_{th} = \frac{\gamma a_j v^2 (1 + \cos \theta)}{g}$$

Where:

- $\gamma$  - unit weight of water
- $a_j$  - area of the Jet.
- $v$  - is the actual impact velocity;
- $\theta$  - is the angle of the vane.

(For flat vane,  $\theta = 90^\circ$ , For curved vane  $\theta = 45^\circ$ , For hemispherical vane  $\theta = 0$ )

**Aim of the experiment:** To determine the coefficient of impact ( $C_i$ ) of the jet on the following vanes:

- i) Flat vane;
- ii) Curved vane
- iii) Hemispherical Vane

**Apparatus required:** Experimental setup, Stop watch, Set of vanes, weight box, scale, etc.

Experimental procedure:

- 1) Fix the given vane to the fulcrum lever properly.
- 2) Measure the distance between:
  - i) Center line of the jet and the fulcrum point (a)
  - ii) Center line of the jet and the line of application of load (b)
- 3) Balance the lever arm system by using counter weight for zero load
- 4) Place a small weight in the pan, Then the lever arm tilts
- 5) Open the water inlet valve and adjust the velocity of the jet so that the lever arm is balanced.
- 6) Collect the discharge of water from the jet in a collecting tank for a known period of time.
- 7) Repeat the steps (4) through (6) for different pan weights.

**Specimen calculations For Sl. No.1****Flat Vane:**

T = time in sec to collect 5 cm rise in water level  
 L = length of the collecting tank in metres  
 B = Breadth of the collecting tank in metres;  
 H = Rise of water level (5Cm) in the collecting tank in time T Sec.  
 $Q_{act} = L \cdot B \cdot H / T$  Cu.m /sec  
 Pan Weight added = W = .....gms  
 Pan Weight added = W = .....N

$$F_{act} = \frac{W(a+b)}{a}$$

Where,

a = Distance between centre line of the jet and the fulcrum point (m)  
 b = Distance between centre line of the jet and the line of application of load (m)

Velocity of the Jet =  $V = Q / a_j$

Where,

$a_j$  = Area of the jet in sq.m;  
 =  $C_c \cdot \text{area of the nozzle } (a_n)$ ; where  $a_n = \frac{f}{4} d^2 (m^2)$

$C_c$  = coefficient of contraction for the jet = 0.65,

$$F_{th} = \frac{\chi a_j v^2}{g} (1 + \cos \theta);$$

Where:

$\chi$  = Specific weight of water = 9.81 KN/m<sup>3</sup>

Where,

d = diameter of the nozzle (m);  
 v = actual impact velocity of the jet (m/sec);  
 $\theta$  = angle of the vane;

$C_i = F_{act} / F_{th}$

Results: The coefficient of impact for

- (i) Flat vane
- (ii) For curved vane
- (iii) Hemispherical vane

**TABLE - 9**

**Impact of Jet on Vanes**

Dia. Of nozzle (m) =  
 Length of measuring tank (m) =  
 Breadth of measuring tank (m) =  
 Lever arms constants: a = b=

Sl. No	Type of vane	Time in sec(t)	Pan wt. in gms	Pan wt. in N	Discharge Q (m <sup>3</sup> / sec)	velocity V (m <sup>3</sup> / sec)	F <sub>th</sub> (N)	F <sub>act</sub> (N)	C <sub>i</sub>
1.	Flat vane								
2.									
3.									
4.									
1.	Curved Vane								
2.									
3.									
4.									
1.	Hemispherical vane								
2.									
3.									
4.									

## PUMPS

A pump is a mechanical device, which converts the mechanical energy, applied to it from an external source, into hydraulic energy and transfers the same to the liquid thereby increasing the energy of the flowing liquid.

The pumps may be classified as;

1. Positive — displacement pumps and
2. Roto-dynamic pumps

In positive displacement pumps, the liquid is sucked and then it is actually pushed or displaced due to the thrust exerted on it by a moving member, which results in lifting the liquid to the required height.  
Ex. Reciprocating pump.

In Roto dynamic pump, there is a rotating element, called impeller, while the liquid passes over the impeller, its angular momentum changes, due to which the pressure energy of the liquid is increased.  
Ex. Centrifugal pump.

The Centrifugal pump has greater discharging capacity than a reciprocating pump.

### Specific speed of a centrifugal pump

It is defined as the speed of a geometrically similar pump, which delivers one litre of liquid per second against a head of one metre and is denoted by “ $N_s$ ”.

$$\text{The specific speed } N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

Where:

$N$  = speed of the pump in r.p.m;

$Q$  = discharge of the pump in l.p.s;

$H_m$  = manometric head in metres of water.

## Experiment No. 10

### Single Stage Centrifugal Pump

Centrifugal pump is so named because it works on the principle of centrifugal action. It consists of an impeller rotating within a casing. The impeller is made up of a number of curved vanes which are enclosed on both the sides by plates known as shrouds. Fluid enters the central portion of the impeller called the eye, flows radially outwards and is discharged around the entire circumference of the casing. During the flow over the rotating impeller and the volute casing, the fluid receives energy, resulting in an increase of dynamic pressure.

Centrifugal pumps are classified as follows:

- 1) Single stage centrifugal pump
- 2) Multi-stage centrifugal pump.

In case of single stage centrifugal pump, there will be only one impeller on the pump shaft and it can be used to lift water upto a head of 30 metres

If there are more than one impellers on the pump shaft then it is known as multistage centrifugal pump.

**Aim of the experiment:** To study the performance of pump under varying conditions of speed, head, and to determine the efficiency of the “ip.

**Apparatus required:** Stop watch, Tachometer, centrifugal pump test rig., etc.

#### Experimental procedure:

1. Close the delivery valve completely and prime the pump;
2. Start the pump at a constant speed;
3. Open the delivery valve gradually to get the required head of water.
4. Note down the following:
  - a) Speed of the pump (N) in rpm
  - b) Suction head (H<sub>3</sub>);
  - c) Delivery head (H<sub>d</sub>);
  - d) Watt meter reading W<sub>i</sub> and w<sub>2</sub>;
  - e) Hook gauge reading (h); for measuring actual discharge
5. Experiment is repeated for different valve positions and for different speeds.

**Specimen Calculations: For SLNo.1**

Speed in rpm =  
 Suction head = H<sub>s</sub> = x cm of Hg = x \* 0.136 m of water  
 Delivery head = H<sub>d</sub> = ..... Ksc  
 = ..... \*10 m of water  
 Total head = H = H<sub>s</sub> + H<sub>d</sub> + x  
 Where, x is the distance between the pressure gauges  
 Wattmeter readings, W1 = , W2=.....

$$1) \text{ Input} = \frac{w_1 + w_2}{1000} \times y_m \text{ (kw)};$$

Where,  $y_m$  is the efficiency of the motor = 0.85

Head over 90° V-notch = h = .....m  
 80

$$2). Q_{act} = \frac{8}{15} c_d \sqrt{2g} h^{\frac{5}{2}} \tan \frac{\theta}{2} m^3 / \text{sec}$$

where,

$Q_{act}$  is the actual discharge  
 $C_d$  is the coefficient of discharge = 0.62;  
 $\theta$  is the angle of the notch = 90°

$$2) \text{ Output} = \gamma Q_{act} H \text{ (KW)};$$

Where:

$$\gamma = \text{Sp. Wt. of water} = 10 \text{ KN/m}^3$$

$$3) \gamma, \% \text{ Efficiency} = \frac{\text{output}}{\text{input}} \times 100$$

$$4) N_s = \frac{N \sqrt{Q}}{H_m^{3/4}} \text{ Where, Q is the discharge in lit/sec}$$

Graphs:

1. QVsH;
2. Q Vs input
3. Q VS% y l

**TABLE -10**

**Single Stage Centrifugal Pump**

Sl. No	Speed (rpm)	Suction head		Delivery pressure (Kg/cm <sup>2</sup> )	Delivery head in m. of water (H <sub>d</sub> )	Total head in m. of water (H <sub>m</sub> )	Watt meter reading		Hook gauge reading			Discharge Q (m <sup>3</sup> /s)	Input (Kw)	Output (KW)	η <sub>0</sub> (%)	Specific speed (N <sub>s</sub> )	
		Cm of Hg	m. of water (H <sub>s</sub> )				W1	W2	Fin	In	Diff						

## HYDRAULIC TURBINES

Hydraulic turbines are the machines used to convert hydraulic energy of water into mechanical energy. The mechanical energy so developed will be used to generate electrical power by directly coupling generator with the shaft of the turbine.

**Hydraulic Turbines are classified as:**

- i) Impulse turbine
- ii) Reaction turbine or pressure turbine.

Every turbine, whether Impulse/Reaction has the following parts:

A wheel commonly known as a runner having vanes around its circumference which rotates under the action of water gliding on the vanes. The guiding mechanism guides the water to the vanes of the runner. From the source of supply, water enters the turbine through a conduit known as penstock. The water after gliding over the moving vanes ultimately falls into the tailrace.

In impulse turbine, the Jet of water issuing from the nozzle directly strikes the vanes of the runner. The hydraulic energy of water gets directly converted to Kinetic energy, which will run the blades of the turbine. Therefore, the water leaving the turbine is at atmospheric pressure.

In the case of reaction turh.s the wt& enters the wheel, glides over the vanes of the runner and flows through the draft tuoe before leaving the turbine. The pressure energy of water gets converted into Kinetic energy gradually. The pressure of water leaving the turbine is below the atmospheric pressure. Therefore a draft tube is necessary to lead the water from the outlet of the turbine to the tailrace.

Example: Francis turbine, Kaplan turbine.

**Unit Characteristics:**

**i) Unit power ( $P_u$ ):** is defined as the power (P) developed theoretically by a given turbine when working under one metre head, while the overall efficiency of the turbine remains constant.

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

**ii) Unit Speed ( $N_u$ ):** is defined as the theoretical speed (N) of a given turbine, when working under one metre head, while the overall efficiency remains constant.

$$N_u = \frac{N}{\sqrt{H}}$$

**iii) Unit discharge ( $Q_u$ ):** is defined as the discharge (Q) of turbine when working under a net head of one metre.

$$Q_u = \frac{Q}{\sqrt{H}}$$

**iv) Specific speed ( $N_s$ ):** The specific speed of a turbine may be defined as the speed (N) of a geometrically similar turbine which develops a unit power when working under a head of 1m

$$N_s = \frac{Q}{\sqrt{H^{5/4}}}$$

These characteristics are used in classifying the turbines.

## Experiment No. 11

### Pelton Wheel Turbine

Pelton wheel is a tangential flow impulse turbine. The powerful jet issued from the nozzle impinges on the buckets provided on the periphery of the wheel. The buckets have the shape of a double semi-ellipsoidal cups. Each bucket is divided into two symmetrical parts by a sharp edged ridge known as splitter.

**Aim of the experiment:** To study the performance of pelton wheel under varying condition of head, speed and gate opening.

**Apparatus required:** Stop watch. Tachometre, Pelton wheel etc.,

#### Experimental procedure:

- 1) Prime the centrifugal pump provided to supply the required head of water to the turbine and start it with the gate valve closed. The spear head in the turbine should also be in the closed position.
- 2) Gradually open the discharge valve by rotating the hand wheel until the turbine attains the normal head / speed.

#### Constant speed characteristics:

- 1) Gradually open the spear head valve, and set it at the required gate opening (1/4, 1/2, 3/4, 1) and run the turbine at required speed (say 800 rpm).
- 2) Note down the following for no load condition:
  - a) Pressure gauge reading (supply head);
  - b) Load on the brake drum;
  - c) Spring balance reading;
  - d) Manometer reading;
- 3) Load the turbine by keeping dead weight on the brake drum and bring back the speed to 800 rpm by throttling the discharge valve, and note down the above set of readings as in step 2.

#### Constant head characteristics:

1. Set the spearhead at a required gate opening (1/4, 1/2, 3/4, 1), and run the turbine at the required head (say 2 Ksc)
2. Note down the following for no load condition;
  - a) Pressure gauge reading (supply head);
  - b) Speed of the turbine;
  - c) Load on the brake drum;
  - d) Spring balance reading;
  - e) Manometer reading;

3. Repeat the experiment for loads of 2 kgs, 4 kgs, 6 kgs, and 8 kgs on the brake drum and tabulate the reading as in step 4. Repeat the experiment for different gate settings.

### Specimen Calculations: For SLNo.1

Diameter at inlet,  $d_1 = 63.8$  mm

Throat diameter,  $d_2 = 38.1$  mm

$$\text{Area at inlet, } A_1 = \frac{\pi d_1^2}{4} =$$

$$\text{Area at throat, } A_2 = \frac{\pi d_2^2}{4} =$$

$$\text{Supply head} = H_s = \dots\dots \text{Ksc}$$

$$= \dots\dots \text{m of water}$$

$$\text{Speed (N)} = \dots\dots \text{r.p.m}$$

$$\text{Venturimeter head} = \dots\dots \text{m of water}$$

$$1. \text{ Actual Discharge, } Q = \frac{C_d A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}} \frac{m^3}{\text{Sec}}$$

Where:

$C_d$  = Coefficient of discharge for venturi meter (0.98)

$h$  = Venturimeter head in meter of water.

$$2. \text{ Input} = \gamma Q H \text{ kw}$$

Where:

$\gamma$  is the specific weight of water = 10 KN/m<sup>3</sup>

$H = H_s$  = total head on the turbine in m of water

$Q$  is the discharge of the turbine m<sup>3</sup>/sec

$$3. \text{ Output } P = \frac{2fN(W - S)(R + r)}{60} \text{ (kw)}$$

Where:

$N$  is speed in rpm

$W$  is the load on the brake drum in KN

$R$  is radius of brake drum in m

$r$  is radius of rope in

$$4. \text{ Overall efficiency, } \eta_0 = \frac{\text{output}}{\text{input}} \times 100$$

$$5. \text{ Unit Power, } P_u = \frac{P}{H^{\frac{3}{2}}}$$

$$6. \text{ Unit speed, } (N_u) = \frac{N}{\sqrt{H}}$$

7. Unit discharge,  $(Q_u) = \frac{Q}{\sqrt{H}}$

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

Graphs to be drawn:

1.  $N_u \text{ Vs } P_u$

2.  $N_u, \text{ Vs } Q_u,$

3.  $N_u \text{ Vs } y$

**TABLE – 11(A)**

**PELTON WHEEL TURBINE**

**CONSTANT HEAD**

Gate Setting	Sl. No	Supply head, (Hs) (kg/cm <sub>2</sub> )	Supply head (Hs) (m. of water)(H)	Speed (rpm)	Venturi meter head (h)		Load (KN)		Q (m <sup>3</sup> / sec)	Input(Kw)	Output(Kw)	y <sub>0</sub> (%)	Unit speed (N <sub>u</sub> )	Unit Power (P <sub>u</sub> )	Unit discharge (Q <sub>u</sub> )	Specific speed (N <sub>s</sub> )
					Cm of Hg	m. of water (h)	Dead load W	Spring Load S								

**TABLE – 11(B)**

**PELTON WHEEL TURBINE**

**CONSTANT HEAD**

Gate Setting	Sl. No	Supply head, (Hs) (kg/cm <sub>2</sub> )	Supply head (Hs) (m. of water)(H)	Speed (rpm)	Venturi meter head (h)		Load (KN)		Q (m <sup>3</sup> / sec)	Input(Kw)	Output(Kw)	y <sub>0</sub> (%)	Unit speed (N <sub>u</sub> )	Unit Power (P <sub>u</sub> )	Unit discharge (Q <sub>u</sub> )	Specific speed (N <sub>s</sub> )
					Cm of Hg	m. of water (h)	Dead load W	Spring Load S								

## Experiment No. 12

### Francis Turbine

Francis turbine is a mixed flow reaction turbine in which, water enters the runner radially at its outer periphery and leaves axially at its center. Before water leaves the turbine, it is made to flow through the draft tube into the tailrace. This type of turbine is suitable for medium heads and discharges.

**Aim of the experiment:** To study the performance of the turbine under varying conditions of head, load and gate openings.

**Apparatus required :** Stop watch, Tachometer, Francis Turbine test rig, etc.

#### Experimental procedure:

1. Prime the centrifugal pump provided to supply the desired head of water to the turbine and start it with gate valve closed.
2. Slowly open the gate valve by rotating the hand wheel until the turbine attains the normal rated speed/head

#### Constant speed:

1. Set the spearhead at the required gate opening (1/4, Y2, %, 1) and run the turbine at required speed (say 800 rpm) by operating the gate valve.
2. Note down the following for no load condition;
  - a) Pressure gauge reading (both at supply and delivery sides);
  - b) Load on the brake drum;
  - c) Spring balance reading;
  - d) Manometer reading.
3. Load the turbine by keeping dead weight on the brake drum and bring back the speed to 800 rpm by adjusting the discharge valve, and note down the above set of readings as in step 2.
4. Repeat the experiment for different loads and different gate settings.

#### Constant Head:

1. Set the Spear head at the required opening (1/4, Y2, %, 1). Gradually open the gate valve and maintain the required head( say 2 Ksc)
2. Note down the following for no load condition;
  - a) Pressure gauge readings, (both supply and delivery sides)
  - b) Speed of the turbine;
  - c) Load on brake drum;
  - d) Spring balance reading;
  - e) Manometer reading.
- 3) Repeat the experiment for loads of 2 kgs, 4 kgs, 6 kgs, etc., on the brake drum and tabulate the readings.

4) Repeat the experiment for different gate settings.

**Observations:**

1. Inlet dia. of venturimeter = d1 101.60 mm
2. Throat dia of venturimeter d2 = 60.96 mm
3. Inlet area of venturimeter = A1 = 8.1 X 10<sup>2</sup> sqm.
4. Throat area of venturimeter = A2 2.91 X 10<sup>2</sup> sqm.

**Specimen calculations: For SLN0.1**

**Constant Head:**

Supply head H<sub>s</sub> = .....Ksc  
 H<sub>s</sub>= .....m of water  
 Vacuum Pressure=H<sub>d</sub> = .... mm of Hg  
 H<sub>d</sub> = .....m of water

Total Head= H=H<sub>s</sub>+H<sub>d</sub>+X =.....:m of water  
 Where, X is the distance between pressure gauges

Venturimeter head=h=.....m of water

1. Actual Discharge,  $Q_{act} = \frac{C_d A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}} \frac{m^3}{sec}$

Where:  
 C<sub>d</sub> = Coefficient of discharge for venturimeter (0.98)

2. Input x QH (kw)

Where:  
 x is the specific weight of water =10 KN/m<sup>3</sup>

3. Output power,  $P = \frac{2fN(W - S)(R + r)}{60} kw$

Where:  
 N is speed in rpm  
 W is the load on the brake drum in KN.  
 R is radius of brake drum in metres  
 r is radius of rope in metres

## Experiment No. 13

### Bernoullis Theorem

**Aim:** To verify Bernoullis Theorem.

**Apparatus:** Bernoullis experimental set up, stop clock.

**Theory:** The Bernoullis Theorem states that for a perfect incompressible liquid flowing in a pipe line the total energy of a particle remains constant while the particle moves from one point to another, assuming that there are no frictional losses in the pipe line.

Mathematically Bernoullis theorem states,

$$Z + V^2/2g + P/W = \text{Constant}$$

**Procedure:**

1. Switch on the pump.
2. Partially close the “by pass” valve, water flows into the supply tank.
3. As the water level rises in the supply tank water starts flowing into the reservoir tank through the venture test section and the water level in the receiving tank also rises.
4. When the water level in both the tanks reaches their respective over flow level, control the “by pass” valve.
5. Allow the water flow to become steady.
6. Record the readings of piezometer and the flow rate from the receiving tank against time by closing the outlet valve of measuring tank for 5cm rise of water level.
7. Repeat the experiment for different discharge.
8. Tabulate all the readings and calculate to verify the Bernoullis theorem.

**Tabular column**

**Cross section area of collecting tank = 0.104 m<sup>2</sup>**

SI. No.	Head in tank 1 (mm)	Head in tank 2 (mm)	Time for 5 cm rise in t sec	Piezometer (static head) in mm											Q <sub>act</sub> m <sup>3</sup> /sec
				Pa	Pb	Pc	Pd	Pe	Pf	Pg	Ph	Pi	Pj	Pk	
1															
2															
3															

**Observations & calculations:**

1. Q<sub>act</sub> = (A×h)/t
2. Diameter of test section from d<sub>a</sub> to d<sub>k</sub>  
d<sub>a</sub> = 25 mm

$$d_b = 22.7 \text{ mm}$$

$$d_c = 20.4 \text{ mm}$$

$$d_d = 18.4 \text{ mm}$$

$$d_e = 15.8 \text{ mm}$$

$$d_f = 13.5 \text{ mm}$$

$$d_g = 15.8 \text{ mm}$$

$$d_h = 18.4 \text{ mm}$$

$$d_i = 20.4 \text{ mm}$$

$$d_j = 22.7 \text{ mm}$$

$$d_k = 25 \text{ mm}$$

3. Area of test section at various pressure ports from a to k

$$A_a = (d_a)^2/4 \quad \text{m}^2$$

Similarly calculate areas from  $A_a$  to  $A_k$

4. Velocity of flow for at different cross sections

$$V = Q/A \quad \text{m/sec}$$

Similarly calculate areas from  $V_a$  to  $V_k$

5. Velocity head

$$V_h = V^2/2g \quad \text{m}$$

6. Pressure head  $Ph$  (from tabular column)

7. Total head (Total Energy)  $E$

$$E = Ph + Vh$$

## Result

## **VIVA QUESTIONS**

1. What do you mean by gauge and absolute pressure?
2. What do you mean by vacuum pressure?
3. What is a manometer? Describe the different types of manometer?
4. Distinguish between a simple & differential manometer?
5. What do you understand by the term hydrostatic pressure?
6. What is the difference between the specific weight of a substance & its specific gravity?
7. Explain the principle of floatation.
8. Restate Archimede 's principle.
9. Define the term centre of buoyancy & metacentre.
10. Restate the equation for continuity of flow.
11. Distinguish clearly between stream lines & streak lines.
12. State Bernoulli's theorem. Mention its limitations & applications.
13. What do you understand by the term viscosity? What is the relation between the absolute viscosity & kinematic viscosity?
14. What is meant by Newtonian & non-Newtonian?
15. What are the various instruments used to measure discharge through a pipe, based on the principle of Bernoulli's theorem?
16. Define vena-contracta.
17. Define coefficient of contraction, coefficient of velocity & coefficient of discharge for a sharp edged orifice. What is the relation between them?
18. Distinguish between small & large orifices. What do mean by drowned orifice?
19. What do you mean by venturi head?
20. Can you employ a venturi meter in a vertical position?
21. in a venturi meter usually the length of the divergent outlet part is made longer than that of the converging inlet part. Why?
22. What are the relative advantages of venturi & orifice meters?
23. Define velocity of approach.
24. What is a notch?
25. Why a V-notch is preferred to a rectangular notch for measuring discharge?
26. What is weir? How is it different from a notch?
27. Describe a hook gauge.
28. Differentiate between laminar & turbulent flow? How is the type of flow related to Reynold's number?
29. Why there is loss of head when a fluid passes through a pipe line? On what factors it depend?

30. State the Darcy's & Chezy's formula for the determination of loss of head due to friction in pipe.
31. What is an open channel? What are the various types of open channels?
32. What is a hydraulic jump?
33. What is the principle involved in the design of Hydraulic machines?
34. How do you classify turbines?
35. Differentiate between reaction and impulse turbines.
36. How do you select turbines?
37. Why the splitter is provided in the buckets of Pelton wheel?
38. Why the shape of bucket is made hemispherical in Pelton wheel?
39. Why the lower lip of the bucket is notched in Pelton wheel?
40. What is the difference between speed ratio and velocity ratio applicable to turbines?
41. What is the necessity of spiral casing in reaction
42. Why guide blades are provided in Turbines?
43. Why draft tube is provided in reaction turbines? Explain different types of draft tubes.
44. How does cavitation occur in turbines?
45. What is the difference between an impeller and a rotor?
46. How to avoid Water Hammer in turbines?
47. What are the different types of surge tanks used in turbines?
48. What do you understand by governing of turbines?
49. Explain runaway speed of turbines?
50. What is the difference between Kaplan and Propeller Turbines?
51. Explain unit quantities of turbines. What is the Specific speed of a turbine? What is its significance?
52. Explain performance characteristic curves of turbines?
53. What are the different types of efficiencies of turbines?
54. How do you classify pumps?
55. What is the difference between rotodynamic and positive displacement pumps?
56. Explain slip of a reciprocating pump?
57. When does negative slip occurs in reciprocating pump?
58. Explain indicator diagram.
59. What is the necessity of providing Air Vessels in reciprocating pumps?
60. Why reciprocating pump cannot be run at very high speed.
61. What is the difference between Free and Forced Vortex?
62. What is the principle involved in design of centrifugal pumps?
63. Why priming needed in centrifugal pump?
64. What are parts of a centrifugal pump?
65. Why Volute Casing and Vortex Casing are needed in centrifugal pump?

66. What are the different types of impellers?
67. How do you increase the efficiency of a centrifugal pump?
68. Explain Manometric Head. Write down different types of expressions for manometric head.
69. What are the losses of centrifugal pump?
70. Write short notes on Efficiencies of centrifugal pump.
71. Why centrifugal pump should be started with minimum speed?
72. Explain the specific speed of a centrifugal pump.
73. What are Multi-Stage Centrifugal pumps?
74. What type of pump you suggest in the following instances:
  - a) Multistoried building;
  - b) Irrigation purpose;
  - c) Lifting muddy water.
75. What are the characteristic curves of a centrifugal pump?
76. Explain positive suction head of a centrifugal pump.
77. Why does Cavitation occur in centrifugal pump?
78. Explain Thomas' Cavitation factor.
79. What is suction specific speed of a centrifugal pump?
80. What are the priming devices used in centrifugal pumps?
81. What is the principle on which Hydraulic Ram is designed?
82. What is the significance of beats in Hydraulic Ram?